TECHNOLOGIE, AFFAIRES INTERNATIONALES ET INSTITUT DE RECHERCHE D'HYDRO-QUÉBEC

REPORT OF ACTIVITIES 1990

TAI

Hydro-Québec

Hydro-Québec's *Groupe Technologie, Affaires internationales et IREQ* has a mandate to conduct research, testing, development and demonstration work in the areas of generation, transmission and distribution, together with applications of electricity.

Its activities cover electrical apparatus, cables, overhead lines, internal and external insulation, mechanical engineering, electronics, materials chemistry and technology, power system simulation and analysis, industrial electrotechnologies and energy savings. Alone or with outside partners, TAI markets some of the products developed at its laboratories or in other departments. It is also responsible for technology planning at Hydro-Québec. The utility has a number of subsidiaries which extend the scope of TAI' s activities: Hydro-Québec International, for instance, has taken the utility's expertise to some 30 countries, while an entire group of subsidiaries under the management of Nouveler has been created to market technological products. Other examples of partnerships include the Centre d'innovation en transport du Québec (CITEQ), founded jointly with ASEA Brown Boveri, and the new joint venture ACEP Inc., which was set up under an agreement with Yuasa Battery Co. of Japan.

TAI has a staff of 586 permanent employees and about 100 temporary employees. The budget allocated for its activities in 1990 amounted to $109 million. TAI operates major research and testing facilities: a high-voltage and a high-power laboratory for testing high-voltage systems and equipment; a power system study and simulation centre; electrochemical and electrical technology laboratories; and some 60 small specialized laboratories.

In addition to work for Hydro-Québec, TAI undertakes research and testing for many external clients.

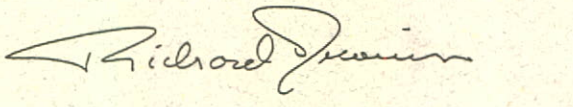
MESSAGE FROM THE CHAIRMAN OF THE BOARD AND CHIEF EXECUTIVE OFFICER, HYDRO-QUÉBEC

For many years now, technology has played a vital role at Hydro-Québec and contributed to the utility's success in operating and expanding its power system. Technological development has always been central to Hydro-Québec's mission, from service quality to balancing supply and demand, from the environment to ensuring the financial soundness of the corporation.

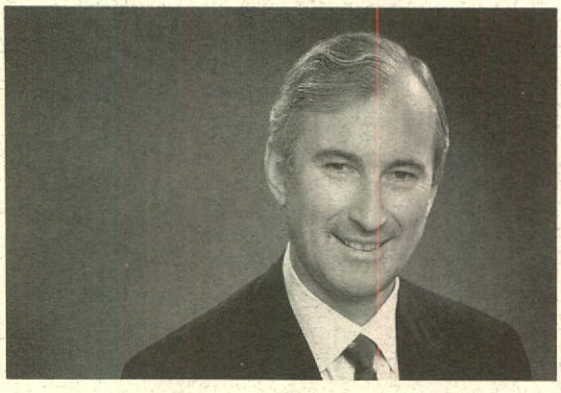
What is true today also held true 20 years ago, when Hydro-Québec created its research institute, IREQ. This year, IREQ celebrated its twentieth anniversary, and I am proud to underscore its achievements and congratulate its staff, a group of remarkable men and women dedicated to research and testing related to electric power generation, transmission and distribution and the search for new forms and applications of energy.

I have had many opportunities this year to see for myself how Hydro-Québec's scientific and technical people have made their mark both within the company and outside. The impact has taken different forms: an agreement with the Japanese firm Yuasa Battery to manufacture the new ACEP battery, the sale of software to the City of Los Angeles, participation in the international magnetic fusion project ITER, installation of new low-temperature circuit breakers, testing of underground cables and cable incorporating optical fibres, development of generation planning software, contributions to Canada's Superconductor Technology Consortium, etc.

Hydro-Québec earmarks 2.2 percent of its total revenue for research and development. Between now and 1996, this is expected to reach approximately $880 million. Hydro-Québec is therefore confident that, with its skilled scientific and technical personnel and well equipped laboratories, it is fully able to meet the technological challenge ahead.



Richard Drouin, Q.C.
Chairman of the Board
and Chief Executive Officer



MESSAGE FROM THE EXECUTIVE VICE PRESIDENT, TAI

Before I present the highlights of TAI's achievements over the past 12 months, I would first like to say a word about the men and women responsible for those achievements, for whom technogical development is part of daily life. Naturally I wish to thank and congratulate them but, above all, I would like to tell them how greatly their effort contributes to Hydro-Québec's productivity. Moreover, their skills will continue to be needed in the coming years to face the many technological challenges that still lie ahead.

The work performed during the year testifies to TAI's success in setting up first-rate technological partnerships. Examples include its relations with Hydro-Québec's technical departments, with which it carefully plans requirements and objectives and for which it undertakes research and testing. It also establishes partnerships with industry, cooperating with different firms to develop new equipment and technologies as well as manufacturing new products. Joint projects with Yuasa Battery, ABB, GEC Alsthom Énergie, Joslyn Canada, Canada Wire and Cable, and M3I Systems Inc., among others, speak eloquently of the dynamic relationships TAI maintains with industry. Lastly, TAI has created scientific links with various government agencies, universities and organizations, such as the Université de Montréal, Institut national de la recherche scientifique, Atomic Energy of Canada Limited and the Hydrogen Industry Council.

The year 1990 marked the twentieth anniversary of Hydro-Québec's research institute. Over the last two decades, IREQ has more than proven its salt and has built up a solid reputation both within the utility and outside. I can only echo our Chairman of the Board and Chief Executive Officer, Richard Drouin, and express my pride in the many achievements that have contributed to the enhanced efficiency of Hydro-Québec's power system over the years. In closing, I wish to pay tribute to two members of senior management who have recently left TAI. Toby Gilsig, Vice President, Technological Development and Marketing, is now President and Chief Executive Officer of M3I Systems Inc. and Louis Masson, Vice President, Laboratories, has become Vice President, Power System Planning. I thank them both for their excellent work and offer very best wishes for their success.

Maurice Huppé

Maurice Huppé
Executive Vice President

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Early in September, TAI personnel proudly celebrated the twentieth anniversary of Hydro-Québec's research institute. Over the last 20 years, IREQ has firmly established itself as a research centre of international renown and helped to place Québec among the world leaders in power engineering.

The idea of creating an electric power research centre dates back to the mid 1960s, when Québec launched its major hydroelectric development projects. With a power system of unprecedented size and complexity, and expansion in full swing, Hydro-Québec had no alternative but to innovate, to apply tailor-made solutions to problems as they arose. University professor and engineer, Lionel Boulet, the founding director of IREQ, was one of the first to claim that Québecers could and should take their scientific and technological development into their own hands. And, accordingly, on February 7, 1967, Québec Premier Daniel Johnson took advantage of the opening of Québec's Electricity Week to announce the creation of a research centre at Varennes.

Some three and a half years later, on September 29, 1970 to be precise, a group of researchers, engineers, technicians and support staff officially took possession of the new centre. They immediately set about defining the scientific program, establishing links with other research centres and universities, etc. Their efforts paid off and now, two decades later, IREQ is a going concern employing some 360 researchers and technicians.

RESEARCH AND DEVELOPMENT FOR HYDRO-QUÉBEC

From the outset, IREQ's primary mandate has been to fulfill Hydro-Québec's research needs. In fact 75% of all work undertaken at the institute is aimed at solving practical problems related to power system design, planning and operation. The major sphere of research therefore reflects the utility's basic activities, namely the generation, transmission and distribution of electricity.

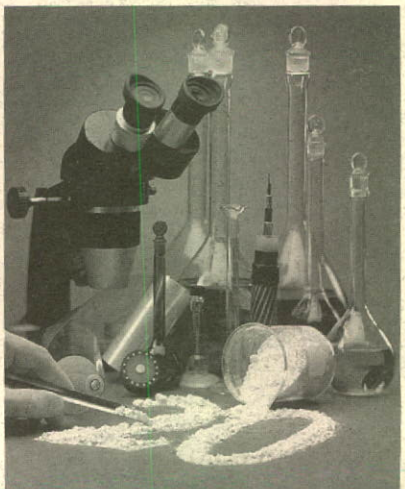
IREQ has continued to progress: research projects have multiplied, areas of activity have expanded, facilities are constantly improving. Thus, IREQ today operates some of the most modern facilities in the world. Its high-power and high-voltage laboratories, power system simulator and numerous laboratories with ultramodern equipment permit in-depth research in a wide range of areas, from materials chemistry and technology, electronics and data processing to power lines, insulation, electrical apparatus and mechanical engineering.

The institute's scientific and technical staff has many achievements to its credit, some of which have involved collaboration with various technological partners and industry. Among others, mention might be made of the compact robot designed for repairing turbines, Hydroloy steel, air-gap and power line proximity measuring devices, expert systems, the SUPER turbine monitoring system, the GFX low-temperature circuit breaker, the nonfragmenting polymer-concrete surge arrester, the spacer-damper, the dosimeter, power system analysis software, polymer-electrolyte batteries, HVDC studies and research into cables.

FUTURE RESEARCH AVENUES

In addition to meeting Hydro-Québec's needs, IREQ's researchers are engaged in another sphere of activity, just as important as the first: their participation in advanced studies on leading-edge topics such as superconductivity and nuclear fusion is helping to push back the boundaries of our knowledge and lay the groundwork for tomorrow's technology. Many of their research projects have been conducted with outside firms or universities.

Over the years, IREQ has also worked in conjunction with national and international organizations to draw up standards for electrical equipment. Meanwhile, many joint research contracts or projects have allowed the institute to promote its expertise throughout the world, with the result that its reputation now extends well beyond the Québec and Canadian borders.



(Seated) Paul-A. Léger, Advisor to the Vice President, Power Systems, Alain Brosseau, Vice President, Research, Yves Filion, Vice President, Generating Facilities and Buildings, Maurice Huppé, Executive Vice President, TAI (Standing, from l. to r.) Hugues Saint-Onge, Director, Technology Planning, Gérald Soulière, Technical Director, Customers and Distribution, Raymond Elsliger, Director, Transmission (Power System Planning), Louis Masson, Vice President, Laboratories (IREQ), Dominique Gastineau, Vice President, Corporate Planning, Claude de Grandmont, Vice President, Transmission Facilities, André Lavoie, Vice President, Maisonneuve Region, Claude Dumas, Manager, Commercial Development Bureau, José Salgado, Manager, Plans and Follow-up, Paul Lavoie, Manager, Planning and Development (Industrial Markets)

The primary objective of technology planning is to study Hydro-Québec's technological options that will prepare it for the challenges ahead. The related activities affect all aspects of research, development, demonstration and testing as well as long-term projects, the development of products and facilities, and the marketing of new products.

The planning process set up three years ago covers the strategic fields of generation, transmission, distribution and utilization of electricity. It has the following clear goals:

— promote a corporate view of technology;
— first meet Hydro-Québec's needs;
— incorporate technology planning into every activity in the utility's management cycle;
— encourage company-wide dialogue.

The cornerstone of the planning process is a forum for technological exchange which brings together some 150 representatives — middle management, experts, researchers, engineers and specialists — from the various sectors of activity at Hydro-Québec.

This forum provides an opportunity for departments throughout the utility, whether suppliers or beneficiaries of technological services, to participate on a continuing basis in the preparation of the Technology Plan. Their achievements in 1990 enabled Hydro-Québec to publish its second Technology Plan for the years 1990-1992.

The document is part of the Proposed Hydro-Québec Development Plan 1990-1992 — Horizon 1999, which was ratified by the Québec government this year. It reviews all the R&D, demonstration and testing activities mentioned in the 1989-1991 plan. Like the latter, it is not limited to describing the future activities of TAI but establishes a comprehensive plan covering all Hydro-Québec's technological activities in keeping with the orientations developed jointly with the beneficiaries.

As in the past, the technology planning activities marking 1990 focused on consolidating the three-year plan in terms of the utility's ever-evolving needs and priorities on the one hand and reinforcing the professional consultant-client approach on the other. A document entitled Programmation 1991-1993 now exists which covers all the products associated with the various research avenues explored within TAI. The document structure takes account of the utility's major objectives but, unlike previous plans, presents them with respect to the mandates of the client departments rather than by areas of technology, thus contributing to the utility's aim to give individual managers more responsibility.

The work assignment procedure, which has been in place for several years now, allowed most of last year's budget-decentralization objectives drawn up by TAI to be achieved. This approach is fully in keeping with the recommendations in the utility's new Défi Performance (performance challenge) program and furthermore is a key component of the professional consultant-client approach being promoted on a company-wide scale.

In addition, this year has seen the start of a profound reflection on the main orientations of technological development. The technology steering committee and sectorial committees are responsible for this task. So far, a set of long-term technological objectives has been established which is now serving as a basis for the 1991-1993 plan. This reflection will be the springboard for publication of a technology plan covering the next ten years' major orientations related to technology development and the marketing of products and services, together with the strategies needed to implement them.

In marketing activities, the focus was again on strategic planning aimed at exploring the full potential of Hydro-Québec's technological products. Twelve teams composed of more than 60 representatives from middle management and top-level specialists from the departments concerned are taking part in this activity. An inventory of techological products, system operation by-products and other products has been drawn up and major marketing orientations have been defined.

The technology development summary emphasizes the increasing responsibility of the different operating groups with respect to needs and priorities, and management of the associated budgets. TAI's leadership and professional-consultant role have also come under analysis.

As in the past, links have been strengthened with various outside organizations. Mention should be made of the creation of a standing committee to promote dialogue between Hydro-Québec and the Québec Ministry of Energy and Resources in order to coordinate the development of technology with the government's energy and R&D policies.

TAI also presented an important report to the Standing Committee on Industry, Science and Technology and Regional and Northern Development with a view to setting up partnerships between industry and the federal government for projects of national interest. During the year, Hydro-Québec and the Québec industrial research centre, CRIQ, signed a draft agreement to promote and develop the most promising technologies in their respective areas of interest. This five-year agreement covers financial contributions to long-term projects, support for research into emergent technologies, support for the marketing of technologies, promotion of applications of electricity and the use of testing facilities.

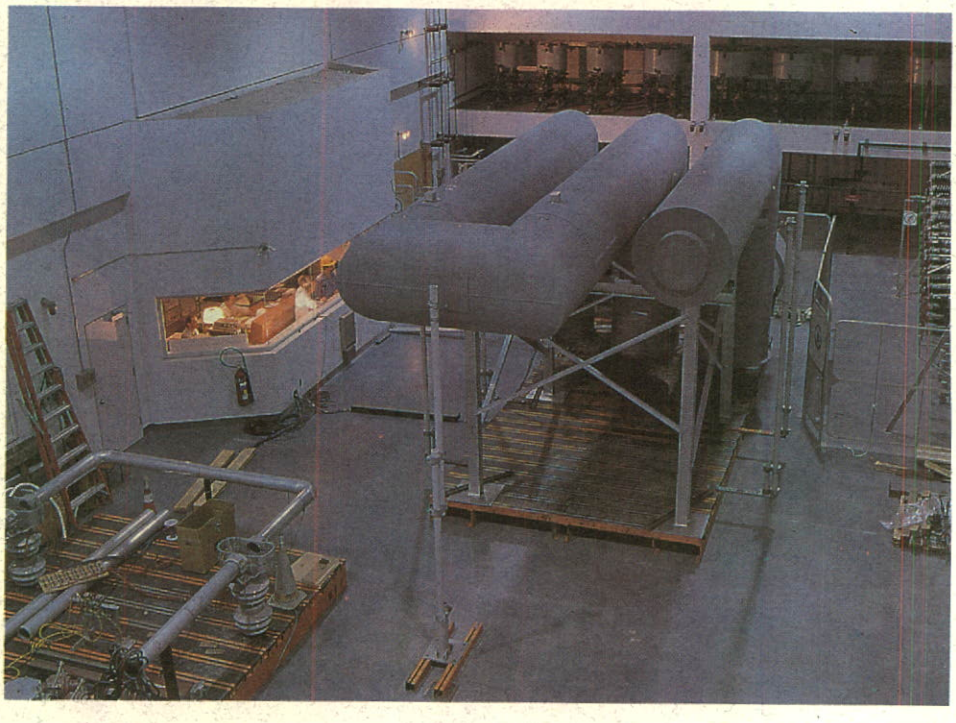
Lastly, the Hydro-Québec chair in technology management research created at the Université du Québec in Montréal with the help of the federal government will provide a forum where researchers and managers can find ways to promote innovation and foster initiative in the development of leading-edge technologies.

All TAI projects related to power generation have a common technological objective: to increase Hydro-Québec's room for manoeuvre so that the utility can meet the power and energy demand at all times.

With this aim in view, the High-Power Laboratory personnel carried out major tests on various types of generating plant. As far as hydroelectric facilities are concerned, the researchers have developed numerical models for turbine analysis and pursued their work on a computerized continuous monitoring system (SUPER) for turbine generators by developing a diagnostic function. Data acquisition systems for the vibratory detection of erosive cavitation, based on the acoustic signature, have also been developed and are now installed in different generating stations together with various prototypes of electrode devices for the measurement of electrical resistance to ensure quality control of joints on AC generators.

Concrete repair materials were the focus of several projects aimed at studying grouts and injection techniques, mortars, joints and seals. In other projects, research teams have put the finishing touches to different methods of using Hydroloy steel for turbine repair and begun to develop a digital stabilizer for generators together with a highly compact robot for repairing cavitation damage. A new generation scheduling model, SAPHYR, has been designed as well as new software, PERESE, which can be used to establish an optimal long-term reservoir management policy.

With regard to nuclear energy, a study was conducted of the thermal decomposition of trihalomethanes in the secondary cycle of nuclear generating stations, and a test method for characterizing the fracture resistance of irradiated pressure tubes was developed. Lastly, in the field of wind energy, work on the wind-diesel combination continued and draft-design studies for a 3- to 5-MW wind farm began during the year.



Testing of a naturally cooled isolated-phase bus at the high-power laboratory.

HIGH-POWER LABORATORY TESTS ON LA GRANDE 4 EQUIPMENT

Overexcitation tests were performed during the year on a 400-MVA, 422 kV/2 X 13.8 kV single-phase transformer damaged as a result of a 60-Hz overvoltage at La Grande 4 generating station. These tests were conducted to determine whether the unit could withstand a 150% increase in the 60-Hz rated voltage. In addition, measurements were made of the partial discharges on the capacitive tap of the H1 bushing, the wall tank vibration and the noise generated by core saturation. To complete the test program, the transformer's impedance and oil quality were compared before and after each test.

Tests were conducted for the utility's generating station rehabilitation department on 15-kV sacrificial arresters to be installed at the terminals of the 13.8-kV windings of 400-MVA transformers. The aim of these tests was to determine whether the 15-kV units would trigger before the physical integrity of other, 18-kV arresters at the generator terminals altered. This involved applying discharge currents from precharged capacitors at different current slopes di/dt. The ultimate objective of all these tests was to ensure suitable protection for personnel and 13.8-kV equipment at LG 4 generating station in the event of a breakdown between the 735-kV and 13.8-kV windings of the transformer.

Lastly, tests on the mechanical resistance of a shielded cabinet were undertaken at the manufacturer's request to study the risk of explosion caused by the operation of a 15-kV sacrificial arrester. The 140-kA_{rms} symmetrical power arc of 0.2 s was initiated by a fuse wire short-circuiting the metal-oxide disks of the arrester.

Laboratoire Grande puissance
(High-Power Laboratory)

TESTING OF GENERATION AND COMPENSATION EQUIPMENT

In conformity with ANSI standard C37.23, a 9.5-h temperature-rise test at 18 kA was performed for a Canadian manufacturer on a naturally cooled isolated-phase bus intended for La Grande 2A generating station.

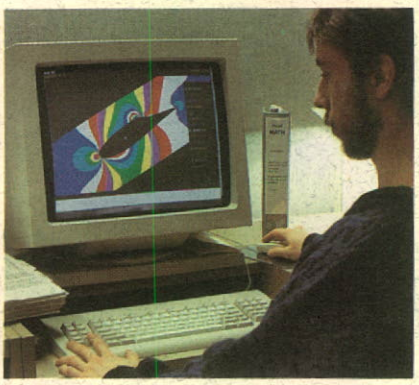
Testing was also performed for Hydro-Québec's Maisonneuve Region, which had requested accelerated-aging tests on the stator windings of generating units at Beauharnois. The tests consisted in heating the insulation of these windings to 90°C while at the same time applying a 35-kV overvoltage at 60 Hz for 250 h or up to breakdown. In addition, partial-discharge measurements were taken to assess the quality of the insulation.

Partial discharges were also measured on the stator windings of a synchronous compensator from Manicouagan substation. Two methods were used: delta Q in picocoulombs and N as a function of delta Q. This work was performed for the Cables and Insulation group at IREQ.

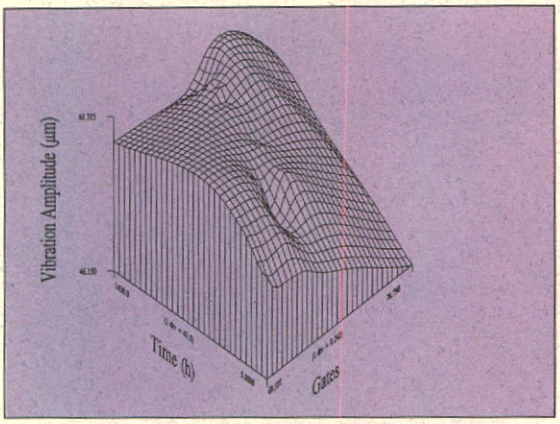
Laboratoire Grande puissance
(High-Power Laboratory)

HYDROELECTRIC GENERATION

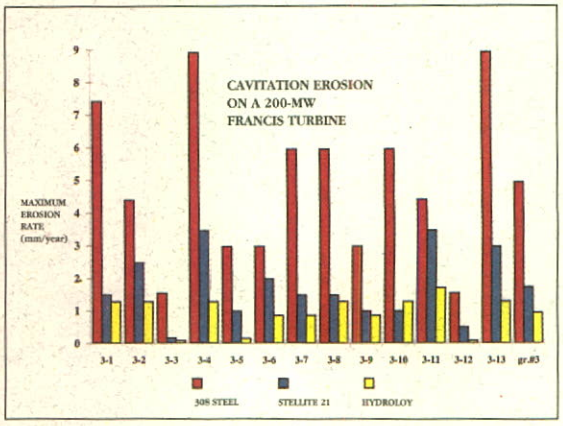
Research in hydroelectric generation is geared to meet the the needs expressed by Hydro-Québec specialists in various fields: generation, transmission and distribution; generating facilities and buildings; and regional operations. One of the studies related to hydro generation in the last 12 months consisted in developing numerical models for turbine analysis as part of the so-called MATH project. The applications for these new calculation tools range from the study of problems related to hydraulic machines, assessment of the margin of manoeuvre of in-service turbines and correction of design flaws to the validation of concepts and technical assistance for planners, designers and operators. Development activities involved a calculation module for measuring inter-blade fluid flow and another module, not yet completed, for calculating the meridional flow. Meanwhile, a series of tests aimed at measuring the pressure applied to turbine blades came to an end; the results of these tests will serve to validate the mathematical models.



Numerical modeling of inter-blade fluid flow in a turbine-generator at Rapide-Blanc generating station is an important part of the MATH project.



Vibration of the shaft at the guide bearing on unit 35 at Beauharnois generating station.



Hydroloy HQ 913, a new welding wire made of IRECA steel, allows a sixfold reduction in the maximum cavitation erosion rate measured after 20,000 hours' operation. This alloy, developed at IREQ laboratories, has replaced stainless steel 308 and Stellite 21, a cobalt-based alloy.

Development of a computerized continuous monitoring system (SUPER) for turbine-generators, a prototype of which had been installed at Rapide Blanc generating station in 1989, has produced a diagnostic function intended to inform power station operators of the cause of anomalies detected by SUPER and the remedial measures to be taken. So far, the research team has built a model of the diagnostic system, developed the cognitive cycle for turbine-generator maintenance, and selected an expert-system as the development tool. In the second stage of the work, now under way, a prototype of the diagnostic system will be developed.

Also in the monitoring field, research continued on vibratory detection of erosive cavitation based on the acoustic signature. The last 12 months saw the creation and field installation of stand-alone data acquisition systems.

In another area, a long-term study of wedging systems for stator windings is still in progress. A laboratory test bench was installed for this project during the year.

Lastly, in relation to dam monitoring and maintenance, a joint project with the Manicouagan Region has resulted in the laboratory development of various injection grouting techniques for repairing cracks in concrete. Initial tests have yielded very encouraging results.

Mécanique
(Mechanical Engineering)

DIGITAL STABILIZER

In an attempt to improve the efficiency of stabilizers during disturbances resulting from local operations or events occurring on the power system itself, IREQ researchers are currently developing a new stabilizer for AC generators. This work is for the system planning department. Rather than taking the acceleration power as its input signal, the new unit will use the rotor speed, which will be evaluated from the voltages and currents produced at the generator terminals. No external sensing device is therefore required. The digital-type stabilizer will be equipped with two redundant microcomputers, which will compute the rotor speed and evaluate the stability signal at the rate of 100 times per second.

Another advantage of this new design is that the digitally implemented lead-lag filters will result in greater accuracy of the transfer functions and, hence, better adjustment of the gains and phases of the damping loops. Its greater flexibility will make the new stabilizer compatible with any power generator in the system. Irregularities occurring in any of the microcomputers can be detected by comparing intermediate calculations. The new digital stabilizer's high degree of safety and reliability belies the simplicity of its design.

A prototype should be developed early in 1991 and is expected to be installed in one of the generating stations of the Manic-Outardes complex in spring to validate the new concepts and assess the stabilizer's reliability in a real operating environment.

Méthodes numériques
(Numerical Methods)

USE OF HYDROLOY STEEL (IRECA) TO REPAIR CAVITATION DAMAGE

A project has been undertaken for the generation facilities department with a view to ensuring or, if necessary, improving the efficiency of Hydroloy-based methods for repairing cavitation damage on hydraulic turbines. Because of the strong wear resistance of Hydroloy stainless steel, IRECA, these methods, all recent developments, have to be applied with the utmost caution. This steel is at least 25 times more resistant than the low-carbon steel usually employed to repair turbine blades, with the result that a poor-quality repair (insufficient thickness, welding error, etc.) can substantially curtail the expected service life of the turbine blade.

To eliminate this risk, tools are now being developed to make it easier to apply quality control methods for such repairs, improve inspection techniques and follow up erosion and repairs appropriately. For example, the quality of each batch of Hydroloy delivered is now controlled by means of tests performed at IREQ. In addition, the maximum thickness of the welded layer of Hydroloy has been modified, together with the composition and thickness of the steel underlayer required for deeper repairs. Another aspect of this work has been to assess simple application techniques for identifying the metals used and measuring their thickness. Some of these techniques seem quite promising and will later be tested in the field. To facilitate erosion follow-up and repair scheduling, a first microcomputer-based databank has been designed for collection and storage of useful data: machine characteristics, station operating history, erosion and repair details. Lastly, once cavitating-jet laboratory tests have been completed, slight alteration of the Hydroloy composition is planned to improve its behavior in a generating-station environment.

Technologie des matériaux
(Materials Technology)

RESISTANCE MEASUREMENTS FOR QUALITY CONTROL OF ELECTRICAL JOINTS

A project dealing with nondestructive test techniques for electrical joints on AC generators has involved the design and development of various prototype devices for the measurement of electrical resistance.

The new electrode devices and resistance-measurement technique proved to be particularly useful tools for quality control during recent rehabilitation work on a generator at Bersimis 1. The technique revealed a number of assembly flaws in the brazed joints of Roebel-transposed bars and in the circular joints of the generators. This success led Hydro-Québec to include the new testing and quality control method in its specification for generators to be installed at Manic 5 and to explore the possibility of including it also in the specifications for units intended for the new James Bay generating stations.

Another successful application of the resistance measuring technique has been for the detection of assembly flaws in the shielded buses at Bersimis 1 and in the joints of generating units at Tracy thermal plant.

The measuring instrumentation was developed for the Vice-présidence Réseaux and will be marketed by the Boucherville company, Ultra-Optec.

Chimie des matériaux
(Materials Chemistry)

DEVELOPMENT OF A PROTOTYPE SUPERCOMPACT ROBOT

Last year saw the development of a prototype compact robot for repairing hydraulic turbine blades damaged by cavitation. Hydrobot, as this tool is known, has been installed at Hydro-Québec's Carillon generating station where it has proved that robotized on-site repair is feasible. Albeit compact, Hydrobot is nevertheless too thick to reach all the damaged parts of blades in Francis turbines less than 5 m in diameter and cannot repair surfaces with a large radius of curvature, such as the groove of the turbine shaft. IREQ's robotics experts are therefore engaged in developing an even more compact robot, for the Vice-présidence Réseaux.

The new six-axis robot is not only slimmer and lighter than its predecessor but is equipped with a laser beam sensor enabling it to "see". Its self-programming functions will also make it easier to program. Work on the prototype is in its final phase and the first laboratory tests on the robot and computer vision system are scheduled for February 1991.

Technologie des matériaux
(Materials Technology)

Laboratory prototype of a supercompact robot for repairing Francis turbine blades damaged by cavitation. Equipped with a laser vision system, the robot is only 23 cm high.

CHEMISTRY OF NUCLEAR POWER PLANTS

A study for Gentilly 2 nuclear power station on the thermal decomposition of trihalogenated compounds of methane is nearing completion. These compounds are found in the secondary cycle of the generating station following chlorination of the make-up water supplied by the St. Lawrence River. There they decompose under the effect of heat to produce chlorides or bromides, both of which are very corrosive for the metallic components of the cycle. This study has allowed the research team to establish the concentration of trihalomethanes in water, in the order of parts per billion or per trillion. It also revealed an extremely rapid decomposition rate at the high temperatures prevailing in the secondary cycle.

A series of tests was performed to determine whether the molecular sieve used to trap the moisture in the ambient air at Gentilly 2 could be regenerated. The results confirmed the operators were right to replace this adsorbant and, in addition, gave them an opportunity to develop a quality follow-up procedure for this type of equipment.

Chimie des matériaux
(Materials Chemistry)

CHARACTERIZATION OF NUCLEAR REACTOR PRESSURE TUBES

To ensure the integrity of pressure tubes and prolong the service life of nuclear reactors, utilities need to periodically replace zirconium-2.5% niobium alloy tubes embrittled by irradiation. The first step in the costly retubing operation is to establish the characteristics of the irradiated pressure tubes in order to determine their residual properties. The only way to do this is at a distance, from shielded test chambers, which partially explains the high cost of the operation.

IREQ, at the request of the CANDU Owners' Group, has therefore begun work on developing a simple and economical method for characterizing fracture resistance based on the modified Charpy impact test. This project, which is being conducted jointly with Atomic Energy of Canada Limited (AECL), reached a turning point this year. Tests were performed on irradiated materials and yielded very conclusive results, proving that the method can be used to reliably characterize irradiated materials at a far lower cost than with traditional methods.

The Technical Committee of the CANDU Owners' Group has analyzed the joint IREQ-AECL report and acknowledged the validity of the method. Moreover, it considers that, since the new approach reveals significant differences in the resistance of the pressure tube material, it can also be used for initial quality control.

This work has led to the initiation of two other projects to be conducted over the next two years. In addition, the group has been invited by AECL to contribute to an international testing program involving eleven world laboratories. This program, whose aim is to validate a test method developed at AECL, has the full support of Hydro-Québec's nuclear management department.

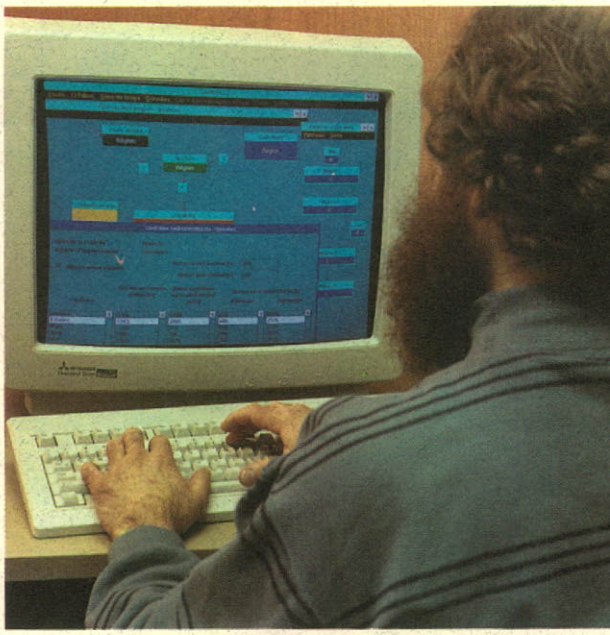
Technologie des matériaux
(Materials Technology)

GENERATION PLANNING SOFTWARE

The operations research team has developed a new deterministic generation planning model for a hydroelectric power system. The model runs on a microcomputer with an OS/2 operating system and has now been linked to a database and user-friendly graphic interfaces. In 1991, the resulting integrated software SAPHYR is due to replace the MODEX and NUMA programs used respectively by Hydro-Québec's generation expansion planning and operations planning departments hitherto. The central model of SAPHYR is also intended to serve as a basis for implementing an optimization tool for generation scheduling at the operations control department.

From the conceptual point of view, SAPHYR represents a synthesis of the models underlying MODEX and NUMA. The solution method gives the user adequate control over the optimization effort. Moreover, the method was designed to be easily adaptable to meet new users' modeling requirements. Use of the model at different levels of the utility will help increase consistency in the results of generation planning and scheduling.

Méthodes numériques
(Numerical Methods)



The SAPHYR generation planning system runs on a microcomputer.

LONG-TERM GENERATION PLANNING

Work has begun on the design of new software which will allow Hydro-Québec's operations planning department to establish an optimal long-term reservoir management policy. PERESE, as this software is known, will replace the EGERIE model whose use dates back to the early 1970s.

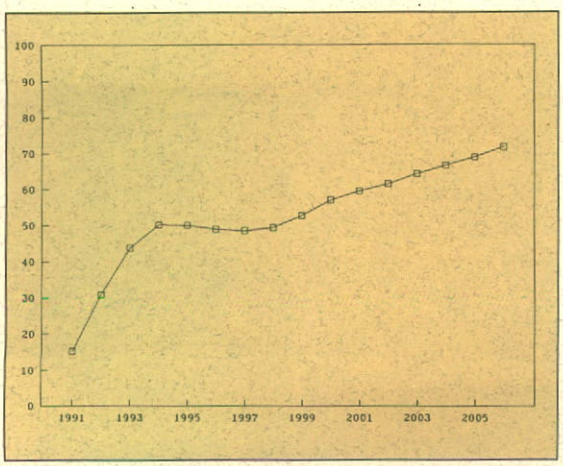
The first stage of the project was to aggregate the utility's hydroelectric facilities so that the mathematical model can easily be solved by means of stochastic dynamic programming. Furthermore, since the model has to provide an immediate response to a multitude of questions concerning the construction program (use of non-hydro generating facilities, surplus-energy sales, power system reliability, etc.), it was decided to divide the year into two periods of six months rather than into months or weeks, as is usually the case.

PERESE was implemented at the beginning of September on the computers (IBM 3090s) at Hydro-Québec's processing centre, where it has already served to draw up an optimal management policy for the aggregated system covering a 20-year period in less than one minute of CPU time.

The software includes a module for simulating the management policy selected by the optimization module, from synthetically generated water inflows. However, PERESE is not just an optimization program; it is also an excellent decision-making tool in that it allows the user to set the conditions to be fulfilled before starting up Tracy thermal generating station, buying energy on the import markets, interrupting dual-energy or surplus-energy sales, etc.

The second stage of the project will consist in disaggregating the results obtained for the aggregated model in terms of time and space. First, the six months' results will be distributed among the months, then according to the rivers in the generation system and, lastly, among the power stations in each valley. Regardless of the study under way, the user will always be able to stop the process at the aggregated reservoir or at the river level, or even continue and in this way establish the best management policy for each generating station in the system.

Méthodes numériques
(Numerical Methods)



Probabilities of surplus-electricity sales to neighboring utilities during the summer semester, as determined by the long-term planning program, PERESE.

WIND POWER

The last 12 months saw marked progress in the research under way on the wind turbine-diesel generator combination. The greatest achievement of these studies was to prove that a wind turbine, without any help from a diesel, can in fact generate electricity equal if not superior in quality to that produced by the diesel generator alone. With the frequency regulator developed at IREQ, the wind turbine can thus meet full energy demand unassisted.

In an attempt to reduce the operating costs of systems not connected to the main power grid, the research team also focused on developing the calculation and design tools needed for coupling wind turbines to the diesel generating units used to supply these remote systems. According to the most economical scenario, which involves a combination with no storage and with a high penetration level (ratio of wind power to load), the wind turbine's installed capacity can equal or even exceed the system peak demand.

This means that in sufficiently strong winds the diesel units could be shut down, leaving the wind machines to supply the entire load. A simulation model has been developed for assessing the fuel savings this represents for a specific diesel-based power system. In the mean time, a Norwegian group is helping to assess a scenario involving energy storage in batteries.

Work continued on the Kuujjuaq project, which is aimed at demonstrating the reliability of a wind turbine for Québec's northern regions. So far, this 65-kW machine has produced over 260 MWh in an operating time of almost 15,000 h. It maintained a 96% availability level throughout the year and continues to operate very successfully.

A draft-design study on a 3- to 5-MW wind farm, which is being conducted jointly with power system installations experts, is under way in the Îles-de-la-Madeleine. Scheduled for completion in 1991, this study comprises a wind analysis, selection of wind machines and sites, a study of the environment and dialogue with the local community.

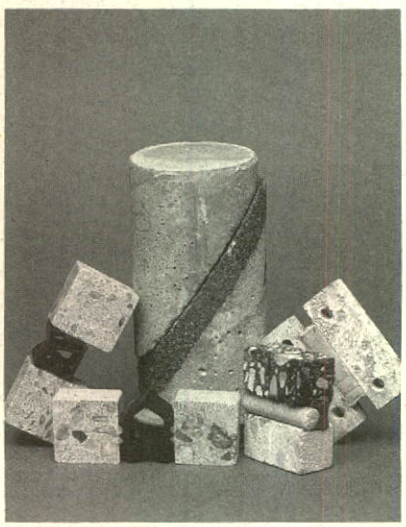
Lastly, work was undertaken with Hydro-Québec's power system planning experts to review the evaluation parameters for wind turbines as an extension to the main grid. The economic viability of wind power will be estimated in terms of the situation of the main power system. Account will therefore be taken of the rainfall, the need to add hydro facilities and the availability of dual-energy equipment which allows wind energy to be absorbed even in heavy rain conditions.

Mécanique
(Mechanical Engineering)

CONCRETE REPAIR MATERIALS

Three projects on concrete repair materials for northern climates are currently under way. The first, which deals with injection grouts (epoxy, polyurethane, polyester, cement slurry) used in the Manicouagan Region, involved analyzing the properties of the various products (bond strength, viscosity, setting time, compressive strength and ultimate tensile strength, at low temperatures; cement granulometry, porosity; microscopic examination) as well as the injection techniques themselves. The tests consisted in introducing artificial cracks in huge concrete slabs and injecting the various grouts at low temperatures. The study will continue in 1991 with a detailed analysis of the behavior of commercially available products as well as products formulated in-house.

Various studies are under way on concrete repair materials such as grouts, mortars, joints and seals.

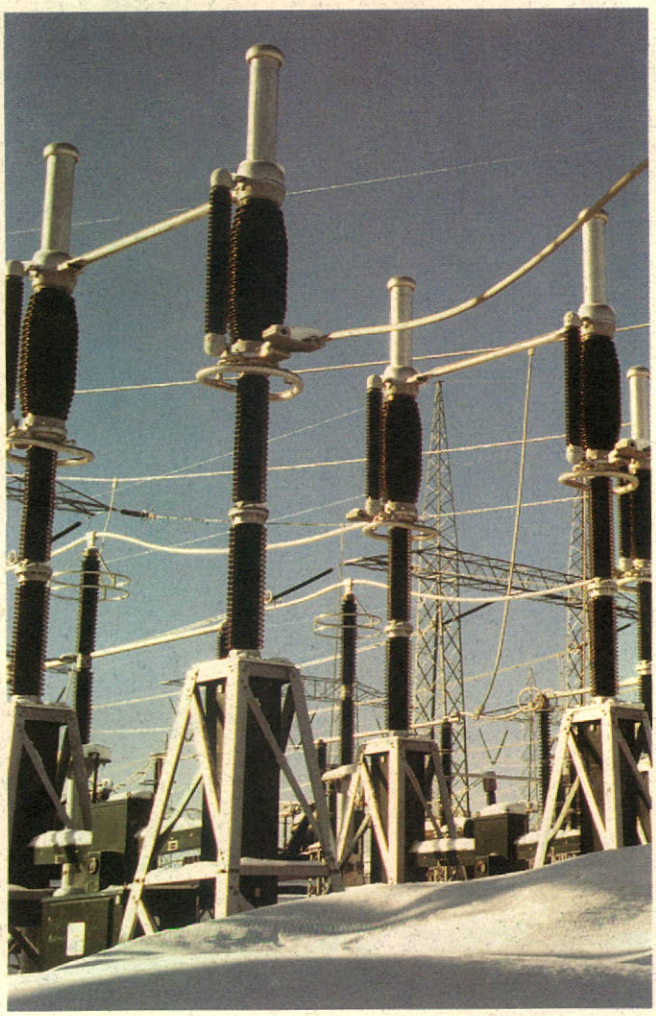


The second study is a joint project with the Canadian Electrical Association (CEA) on repair mortars for concrete surfaces damaged by erosion. The last year was devoted entirely to selecting the best commercially available mortars. Some 30 products including epoxy mortars, cementitious grouts and latex mortars were subjected to chemical analyses as well as compression, drying/shrinkage, bond strength and erosion tests. The better products, selected from the two pre-screening tests (bond strength and erosion resistance) will then be tested for thermal compatibility (freeze-thaw) with concrete, thermal expansion coefficient and permeability. Thus a good selection of products can be made, ready for the next stage of the study which is scheduled to take place in the field in summer 1991.

Another project undertaken with the CEA focuses on joint sealants for hydraulic structures in northern climates. A total of 21 sealants specifically recommended for concrete structures were evaluated in the laboratory and 15 were selected for field tests on concrete-concrete and steel-steel joints. Eight of the eleven premoulded sealants and four field-cured products yielded satisfactory results. The final report on this study will describe the selection criteria and classify the sealants according to their applications.

Technologie des matériaux
(Materials Technology)

Three main aims dominated the work related to power transmission in 1990: to increase sales to neighboring utilities, to enhance safety and service reliability, and to improve environmental protection. A new range of low-temperature circuit breakers was certified and installed in the field. The mechanical, electrical and optical aspects of optical fibres incorporated into the overhead ground wire on transmission lines were the focus of further research and testing. The program of tests on 500-kV DC cables continued during the year, as did research on HVDC wall bushings. An electrothermal model of station-type surge arresters was developed and compensation equipment for transient-stability studies was successfully modeled. The past year also saw work begin on adapting various digital protection systems for subtransmission stations. Many tests were performed at the high-power and high-voltage laboratories on electrical apparatus and power system phenomena. Meanwhile, work continued on a study of the effects of frost on substation foundations and an investigation into the deterioration of aluminum-copper connectors. A mobile unit for testing substation equipment has been developed. The study of new protection relays for series-compensated lines drew to an end as work continued on the HVDC multiterminal system studies. With regard to overhead transmission lines, the eolian vibrations of low-sag conductor bundles and triple bundles for the ±450-kV DC lines were evaluated on site. A detector for faulty insulators, a prototype control system for herbicide spraying by helicopter and quality control devices for the assembly of transmission line sleeves were among the many developments realized in 1990. Research continues on the biological effects of electric and magnetic fields and a number of new projects on this topic were launched.



The new 315-kV low-temperature SF_6 circuit breaker (GFX) installed at Manicouagan substation (Photo: GEC Alsthom Énergie)

CERTIFICATION OF THE NEW GFX LOW-TEMPERATURE CIRCUIT BREAKER

The GFX circuit breaker, which operates on a mixture of sulphur hexafluoride (SF_6) and nitrogen (N_2), is the outcome of a joint Hydro-Québec — GEC Alsthom Énergie project initiated in 1985. This year, the breaker was certified for voltage levels ranging from 145 kV to 765 kV, a short-circuit current of 50 kA and a minimum temperature of -50°C. In other words, it has been validated as a line or bus circuit breaker as well as for transformer and capacitor bank switching. It has also been validated as a shunt circuit breaker for the series compensation of transmission lines, which is now being implemented on the Hydro-Québec power system.

Following a meticulous inspection of the breaker construction and stringent testing both at IREQ's high-power laboratory and at the GEC Alsthom research and testing facilities in France, the circuit breaker has been duly certified. It has successfully passed terminal-fault breaking tests, short-line fault breaking tests and line-charging current breaking tests as well as dielectric tests on a complete pole. It has also met all the requirements of the mechanical and gas pressure tests at -50°C, which is the minimum operating temperature for circuit breakers on Hydro-Québec's power system.

Compared to air-blast and low-volume-oil equipment, SF_6 puffer circuit breakers offer many advantages. Moreover the simplicity of the mechanical design of the GFX breaker, which comprises a reduced number of vertically mounted interrupting chambers, guarantees greater reliability.

Hydro-Québec plans to put two of these GFX breakers into service for shunt reactor switching in spring 1991. One, rated 330 kV, will be installed at Manicouagan substation, the other, rated 765 kV, at Micoua substation.

The certification program was performed in close collaboration with Hydro-Québec's equipment standardization specialists in the Vice-présidence Équipements de transport.

Appareillage électrique
(Electrical Apparatus)

TRANSFORMER FAILURE AT LA GRANDE 4

Serious failures have hit six transformers at La Grande 4 generating station during power system disturbances in the last few years. However, although they have occurred several times, these failures have affected only one type of transformer and similar disturbances have not had any effect at La Grande 2 and 3. The consequences of the problem cannot be dismissed lightly: not only do they reduce station availability but they represent a safety risk for personnel and could damage the facilities.

Power system planning specialists at Hydro-Québec therefore requested IREQ to identify the cause of these failures and establish palliative measures for the same type of apparatus still in service. The research team therefore focused on the effect of microparticles of aluminum detected in the oil following an anomaly in the cooling system.

Different concentrations of contaminants were tested on models and on oil samples. It was concluded that particles could induce deterioration of the dielectric strength of the oil. The design of the transformers affected was then analyzed to determine the characteristics that make this equipment so vulnerable. Full-scale tests on a rewound unit show that the transformer design is perfectly adequate as long as no contaminants are present. Modeling of the transformer windings also helped the team to detect whether the unit produces high-frequency oscillations when subjected to steep-front overvoltages.

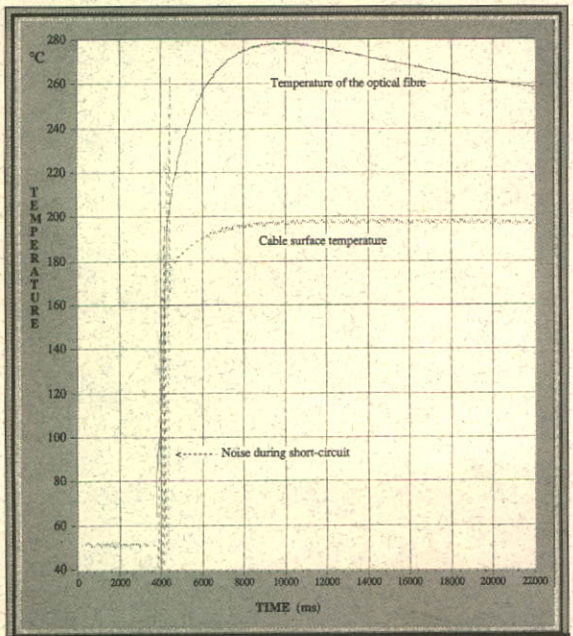
Complementary tests on a model and full-scale tests on a transformer withdrawn from service must now be performed to confirm the correlation between the contamination level and failures. Recommendations will then be made to improve the reliability of La Grande 4 generating station.

Appareillage électrique
(Electrical Apparatus)

RESEARCH AND TESTING ON SKY WIRES INCORPORATING OPTICAL FIBRES

Since the fall 1989 and throughout the year that followed, various teams of researchers and engineers from the electronics and mechanical engineering departments and the high-power laboratory carried out a wide range of studies on overhead ground wires incorporating fibre optic bundles. This new type of cable interests Hydro-Québec for two reasons: it protects the transmission line and at the same time, meets various telecommunications needs, especially with respect to control and protection of the power system and equipment.

Variations in the temperature of the optical fibre and the surface of an overhead ground wire following a 30-cycle 18,000-A fault.



High-Power Laboratory: Mechanical Engineering and Testing Division

As Hydro-Québec is planning to install this type of cable on its main telecommunications network, it needs to better understand the long-term behavior of the cable and the optical fibres subjected to mechanical and thermal stress under severe eolian vibration and fault conditions. A study was therefore undertaken in cooperation with the clients (Direction Télécommunications, Service Ingénierie de lignes and Service Études de normalisation) with participation by teams from the Maisonneuve and Matapédia Regions.

Overhead ground wires incorporating optical fibres have been subjected to electrical and mechanical tests at the high-power laboratory.

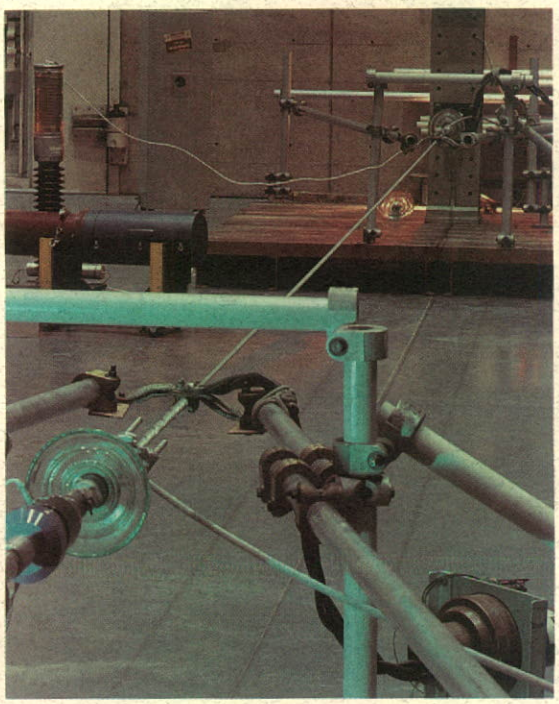
Two types of cable were tested at the Îles-de-la-Madeleine site to study their performance from two points of view: mechanical and optical. The aim of the mechanical tests was to assess the cable performance under eolian vibration, in particular the bending strain near the support points. The data gathered provided a basis for evaluating the cable lifetime and developing a laboratory test protocol for determining the fatigue resistance.

The optical tests consisted in measuring the impact of mechanical stress on the transmission quality of the cable. A special testing procedure and data acquisition system were developed for this purpose. A 6.4-km fibre-optic link was created by looping the fibres between the two ends of the sky wire, which covers 1.6 km of the test line. The data were collected by computer every 12 min for seven months in the case of the first cable type, two months for the second. The test team was therefore able to analyze the mean stresses and attenuation in terms of the temperature and wind-induced vibrations.

The two types of cable tested at the Îles-de-la-Madeleine site, together with a third, all from different manufacturers, also underwent tests at IREQ's high-power laboratory. These consisted in simulating line-to-ground lightning faults on the power system. Faults such as these cause a sharp increase in the temperature of both the cable and the optical fibre, creating a thermal and mechanical stress whose impact on the materials and transmission quality must be known before the maximum operating constraints are determined.

Each cable tested was 12.6 m long and contained 100-m and 50-m lengths of fibre-optic loops. After pre-heating to 50°C, the cables were individually subjected to ten successive faults applied as soon as the temperature returned to its original value. To determine the temperature of the fibres inside the cable, which is very difficult by conventional methods, the phase shift between the input and output optical signals was measured, since the two phenomena are directly proportional. The same measuring technique was used for the mechanical tests at the Îles-de-la-Madeleine site.

Électronique
(Electronics)
Mécanique
(Mechanical Engineering)
Laboratoire Grande puissance
(High-Power Laboratory)



UNDER-RIVER CROSSING

Testing continued throughout the year on the ±500-kV DC cable prototypes for the section of the transmission line carrying power from James Bay to New England, which is due to cross under the St. Lawrence River. This test program for Hydro-Québec's transmission facilities department brings together experts from many other areas: high-voltage and high-power testing, overhead lines, and measurement and data processing.

The cable prototypes were subjected to type tests, special demonstration tests and pollution tests. The aim of the tests performed in the high-voltage laboratory was to check that the prototypes and accessories supplied by the cable manufacturers meet the various standards in effect. The test protocol used for this work conforms to the recommendations of CIGRÉ (International Conference on Large High-Voltage Electric Systems). The special tests were aimed at validating the design of the DC cables by subjecting them to disturbances never applied before, such as lightning impulses followed by 10-kHz oscillations, and 60-Hz and 120-Hz alternating currents superposed on the direct current.

The demonstration tests consisted in exposing the cables to accelerated aging equivalent to 30 years' service with temperature cycling and polarity reversal. Most of the type tests and special tests will then be repeated to check the characteristics of the aged cables. Upon completion of all these tests, the cables will be subjected to lightning impulses up to insulation breakdown.

The pollution tests will verify the behavior of the cable ends under heavy rain and clean fog conditions, with uniform and nonuniform contamination of the porcelains.

Each cable prototype, some 130 m long, was installed in one of the reinforced-concrete troughs provided at the outdoor cable-testing facility. A number of thermocouples were then installed at strategic points both inside the conductor and on the surface and the troughs were filled with weak-mix concrete. The set-up is designed to simulate as closely as possible the thermal and mechanical environment of the actual under-river tunnel.

Other tests were conducted at the high-power laboratory to assess the mechanical resistance of the troughs and the fire hazards involved. This work led to the design of a mechanically functional trough model which not only holds the cable firmly in postion but ensures the environment is totally safe for maintenance employees. A video of these tests has been shown at the Grondines construction site.

Most of the type and demonstration tests have been successfully completed and the test program should draw to a close early in 1991.

Extra-high-voltage cables were also the focus of attention of specialists taking part in the preliminary studies, preparation of the technical specifications and evaluation of the tenders submitted by cable manufacturers in readiness for tests at IREQ on an 800-kV AC cable prototype for future Hydro-Québec under-river crossings. A test protocol covering the tests to be performed on this cable was drafted for this work, which is scheduled to start in 1991. A synthetic-paper-insulated cable will be the first to be tested.

Câbles et Isolants
(Cables and Insulation)

The high-voltage laboratory's underground-cable testing facility is now being used to assess 500-kV DC cables for the under-river crossing.

COMPARISON OF STANDARDS FOR STATION-TYPE SURGE ARRESTERS

Three different standards apply to the new ZnO station-type surge arrester at the present time, those of the IEC (International Electrotechnical Commission), ANSI (American National Standards Institute) and CSA (Canadian Standards Association). Since each organization recommends its own testing procedures, the question arises as to which best simulates the most severe conditions affecting the Hydro-Québec power system and at the same time offers the best durability margin.

Example of a delayed current zero during a fault on the series-compensated Churchill-Montagnais lines.

The research team at IREQ has therefore developed an electrothermal model of a surge arrester which simulates the various test procedures and evaluates the stresses imposed on the arrester together with its limit capacities. It also takes into account the designs used by the different manufacturers. The work covered the three types of durability test recommended in each standard and three designs of station-type surge arrester.

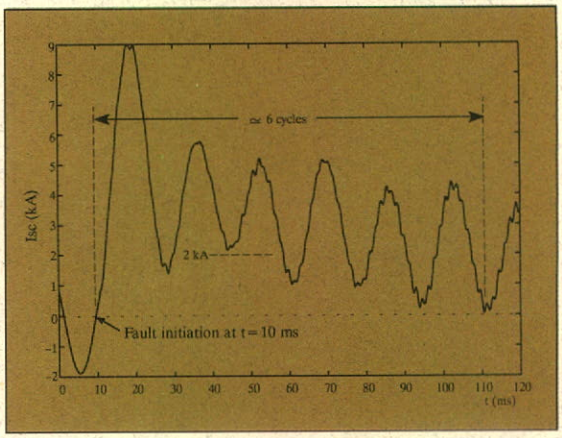
As far as the energy absorption capacity and thermal stability of the arresters are concerned, the IEC standard proved the most rigorous: its line discharge test was the most severe in terms of energy absorption capability and its operating duty test in terms of thermal stability. The severity of this IEC standard is due to the test circuit recommended for line discharges, a circuit that imposes almost three times the energy on the arrester specified by ANSI.

Two conventional arresters with a porcelain housing and another, hypothetical, thin-walled unit were modeled. It was generally observed that the maximum temperature stresses reached on the ZnO arresters subjected to the IEC tests were 30°C to 60°C higher than those obtained with the American and Canadian standards. Meanwhile, the hypothetical ideal arrester fulfilled all expectations with regard to energy absorption and its thermal stability was twice that of arresters with a porcelain housing.

Appareillage électrique
(Electrical Apparatus)

DELAYED CURRENT ZERO IN SHORT-CIRCUIT-CURRENT INTERRUPTION

Series compensation is currently being considered as a means of increasing the stability of Hydro-Québec's transmission system. Implementation calls for the installation of capacitor banks in series with the high-voltage lines but simulator studies have revealed that, when a short circuit occurs near a capacitor bank, some line circuit breakers have to interrupt a delayed fault current which does not pass through zero for five cycles. This phenomenon is due to a transient fault-impedance variation, which occurs when a metal-oxide surge arrester in parallel with the capacitor bank is in conduction.

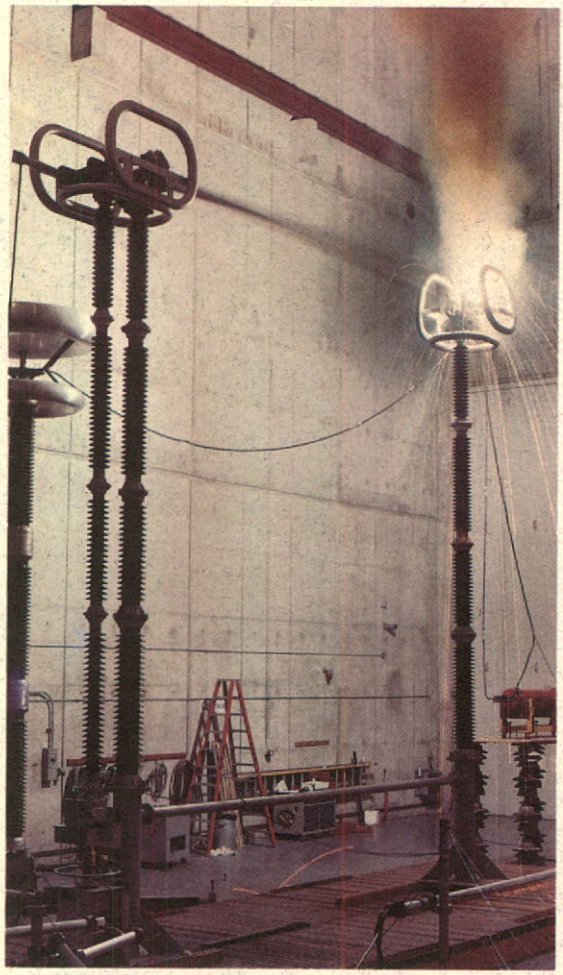


If the current does not pass through zero, circuit breakers with a low arc voltage have difficulty interrupting it. A circuit-breaker arcing model developed at IREQ was therefore used to simulate short-circuit-current interruptions for the Churchill-Montagnais, Radisson-Némiskau and Lemoyne-Albanel lines on a representation of the entire 765-kV system. The study showed that in the most severe case (Churchill-Montagnais line) SF_6 circuit breakers would be unable to interrupt the current because of its excessively low arc voltage. The simulations also revealed that at this same voltage of 765 kV, air-blast breakers would force the current to cross zero so that they would be able to interrupt the current without any problem, because their arc voltage is some 20 times that of the SF_6 units.

Appareillage électrique
(Electrical Apparatus)

TRANSMISSION EQUIPMENT TESTS AT THE HIGH-POWER LABORATORY

Several types of test were performed this year for manufacturers and for different departments of Hydro-Québec. For the Vice-présidence Réseaux, for example, a series of performance tests was conducted on the auxiliary opening chamber of a 735-kV air-blast circuit breaker in which some seals and springs had been replaced. The test program consisted of 1000 interruptions of an inductive 260-A current at 110 kV by the breaker, whose auxiliary opening chamber has a 500-ohm resistor designed to interrupt a 100-A current.



Tests on a 735-kV disconnecting switch at the high-power laboratory.

Measurements at the moment of short-circuit-current interruption were performed in an aim to identify the characteristics of the noise impact of a 735-kV air-blast circuit breaker on human hearing and to determine the effectiveness of earmuffs and earplugs in attenuating this type of noise. Undertaken at the request of the same Hydro-Québec department and the health and safety group, this program was conducted in cooperation with the Université de Montréal.

Meanwhile, certification tests comprising short-line-fault breaking tests and and back-to-back and isolated capacitor bank capacitance-current switching tests in conformity with ANSI Standard C37.09 were performed on one interrupting chamber of a two-break 245-kV GFX-type circuit breaker. Capacitive test currents of 189 and 630 A, with a crest TRV of 325 kV at 115 kV with an inrush current of 20 kA peak at 4250 Hz were produced in this program of back-to-back capacitor switching tests for a manufacturer and IREQ's electrical apparatus group.

Lastly, for the utility's line engineering specialists, mechanical tests were conducted on toughened-glass cap-and-pin insulators rated 25 to 230 kV. This test program included residual-resistance tests at high and low temperature (IEC 797), low- and high-temperature thermal-mechanical performance tests (IEC 575), impact tests (ANSI C29.2), mechanical failure tests and electromechanical failing load tests (IEC 383).

Laboratoire Grande puissance
(High-Power Laboratory)

STUDY OF ADFREEZE HEAVING OF AUGERED CAISSON FOOTINGS

Augered caisson footings of reinforced concrete offer an original mode of defence against the effects of frost. More economical and much faster to build than previous models, these footings are intended for the lightweight equipment to be installed in future substations. However, the design cannot be optimized before an experimental study is made of the risk of adfreeze heaving. This task has therefore been undertaken for Hydro-Québec's transmission facilities and standardization specialists.

The latest phase of this study involved a second series of tests during winter 1989-90 at Beaupré and Lévis substations, both of which are located on highly frost-susceptible soil. Preliminary analysis of the results allowed the research team to determine the factors likely to cause adheave and compare different types of caisson footings. A new concept in the form of a deep tube surrounded by sand proved especially effective in providing mechanical protection.

A third and last series of tests will be performed in winter 1990-91 to confirm these results. Additional footings have been built at Beaupré substation for this purpose.

Mécanique
(Mechanical Engineering)

ALUMINUM-COPPER ELECTRIC CONNECTORS

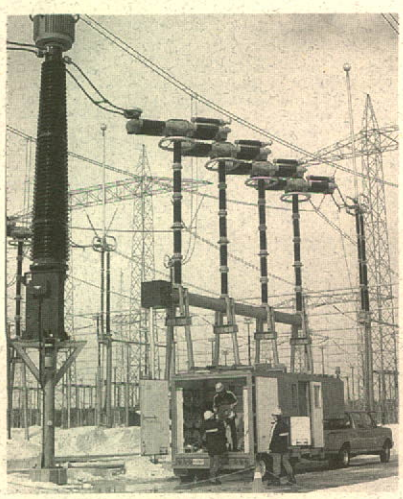
A study has been undertaken of the factors influencing the degradation of Al-Cu connectors used on power lines for standardization specialists in Hydro-Québec's transmission facilities department. The research also covered palliative measures that could reduce the deleterious effect of these factors. The work includes a review of international experience in this field and laboratory tests in dry and corrosive environments. It has been shown that reliable operation of an electrical connector can be secured by maintaining good joint elasticity and utilizing certain greases and platings. On the other hand, the use of bimetallic Al-Cu plates and tin-plating (Cu-Sn) is not efficient, since the formation of intermetallic phases caused by overheating of a joint leads to an irreversible increase in the contact resistance and ultimately to contact failure.

Greases, especially in polluted environments, have proven the best means of countering deterioration in connectors. A study was therefore conducted to determine the most efficient greases and recommend which to use with certain joint configurations. These two measures, combined with good connector design, should minimize failures and prolong connector service life.

Technologie des matériaux
(Materials Technology)

MOBILE TESTING UNIT

A project has been initiated for Hydro-Québec's apparatus department to provide personnel responsible for testing nonenergized electrical equipment with multi-purpose instrumentation which incorporates the work method, the measuring technique, results processing and the analysis criteria.



The new mobile testing unit is now in use at Nicolet substation.

With this newly developed instrumentation and software, a regional test team can keep control over all stages of the testing procedure. The focus throughout this project was on user-friendliness, to make work easier for the electricians and the technical personnel responsible for test programming.

The mobile testing unit put into service at Nicolet substation bears witness to a good coordination of the quality, accuracy, and methodology, which substantially reduces the risks of human error and promises to curtail by up to 30% the time spent on testing apparatus. Electricians are now familiarizing themselves with the mode of operation.

This instrumentation-software concept will favor the exchange of know-how between Hydro-Québec's regions and make it possible to link the unit to expert systems and central databanks. All the information and expertise needed for maintenance work can therefore be made available at the site itself.

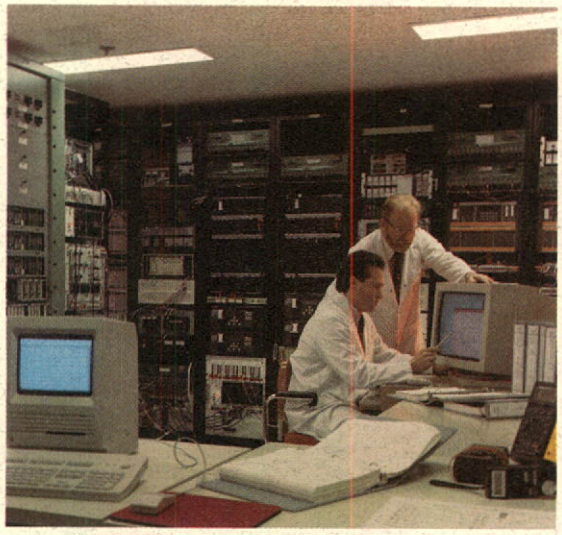
The next 12 months will be largely devoted to completing other units and transferring the technology to Hydro-Québec's nine administrative regions, all of which have contributed to this research. Short-term plans include an assessment of the tests currently under way and the introduction of new tests designed to check the condition of electrical equipment.

Électronique
(Electronics)

PROTECTION RELAY STUDY

Hydro-Québec's study of the protection relays to be used on series-compensated lines drew to a close this year after 17 months of testing during which some 120,000 faults were simulated on the power system simulator at IREQ. An interesting spinoff from this study is a waveform playback device allowing tests to be performed on new relays without mobilizing the entire simulator for long periods of time.

Implementation of series compensation on Hydro-Québec's extra-high-voltage transmission lines calls for new protection relays because those in place do not meet the requirements of the new technology. The utility's protection engineers consequently asked IREQ to test the behavior of eight new protection systems from five manufacturers. The relays operate on different principles: impedance measurement, traveling wave, current differential and phase comparison. The most appropriate relays have now been chosen on the basis of the test results.



The study of protection relays for series-compensated lines was completed this year.

The simulation work consisted in representing the winter 1993 configuration of the entire series-compensated system with network equivalents for voltages below 308 kV. All simulated faults were stored on optical disk creating a databank of 120,000 faults on 20 different transmission lines; these faults can be used again at a later date to test modified or new relays. The data bank and the playback system will make it possible to perform many tests by simply connecting the relays into the playback device using appropriate interfaces and rereading the optically stored test data. A new dynamic-test bench for protection relays is now available for all Hydro-Québec departments interested.

The results of this study have allowed the utility to select a number of relays, on the basis of their reliability and security for the two primary protection systems, and the backup required for the series-compensated lines.

Simulation de réseaux
(Power System Simulation)

STATIC COMPENSATORS AT CHAMOUCHOUANE SUBSTATION

At the request of the manufacturer, ASEA Brown Boveri, the static compensators to be installed at Chamouchouane substation underwent performance tests on the simulator, as stipulated in Hydro-Québec's purchase order. The first series of tests provided an opportunity to make a number of adjustments and improvements to the controller used with these compensators. For example:

— adjustments to the firing circuits on the IREQ simulator;
— enhancement of the dynamic performance of the antiresonance filters during system frequency swings;
— modification of the connection of the auxiliary voltage transformer to avoid zero-sequence;
— determining the settings of the DC balance circuit in the thyristor-controlled reactor;
— study of how to add a proportional gain to the integral gain of the controller's voltage regulator.

A second series of tests was conducted with technical experts from various Hydro-Québec departments to assess the behavior and level of tolerance of the controller and the compensator's main protection relays in the presence of harmonics. One of the studies concerned the generation of harmonics by direct current flowing in the transformer neutral, the results of which have added substantially to the team's understanding of the behavior of protection relays and their limits during geomagnetic storms.

Other tests focused on the sensitivity to harmonic voltages of some of the controller's inherent functions (voltage measurement, synchronization, etc.). The control of direct current in the thyristor-controlled reactor of the compensator was analyzed in an aim to establish the TCR's maximum capabilities and assess its attenuation potential in the event of compensator transformer saturation during geomagnetic storms.

Simulation de réseaux
(Power System Simulation)

DC MULTITERMINAL TRANSMISSION SYSTEM

Studies are presently under way for Hydro-Québec's transmission system and interconnection department. The objective is to ensure satisfactory operation of each of the many configurations of the multiterminal DC network necessary for power transmission from La Grande 2A generating station to southern Québec and for export to the United States. The following services are provided:

— supporting the commissioning and system acceptance tests by performing these tests first on the simulator;
— solving specific problems as they arise in the field;
— performing complementary commissioning and operating tests;
— control optimization.

The focus is primarily on the HVDC converter control and protection systems.

These studies alone were sufficiently important to justify the construction of a new network simulation facility at IREQ, where the study is being carried out. All Hydro-Québec's 1990 network is simulated with network equivalents for voltages below 315 kV. The modeling also includes part of the New England system, several static compensators and new dynamic machine models. Also, the AC/DC converter station equipment is represented in detail, including AC and DC filters, circuit breakers and disconnecting switches, and the neutral networks with station and remote ground electrodes.

In 1990, the work of the study team included validating the simulator's DC controls for Radisson and Sandy Pond, commissioning detailed models of the Hydro-Québec and New England power systems, and installing and commissioning the Nicolet, Des Cantons and Comerford substation models. In addition, commissioning and operating tests were performed in synchronous, monopolar and bipolar modes for the Radisson and Sandy Pond terminals.

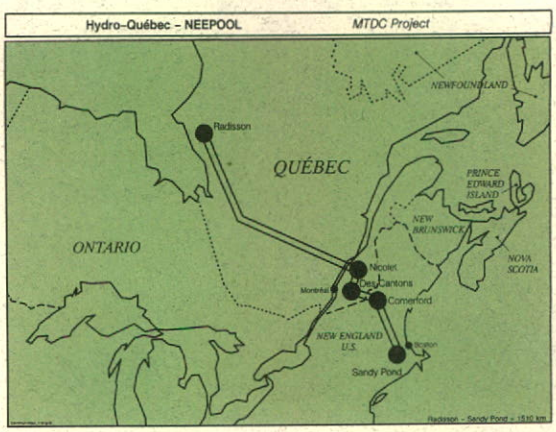
In 1991, the simulator model of the DC line will be commissioned in multiterminal operation. Commissioning studies will be undertaken for the Radisson-Sandy Pond line in synchronous and islanded modes, followed by the Radisson-Nicolet line in monopolar mode.

The EMTP transient-analysis program is an additional tool that will be used to analyze phenomena detected during simulation or commissioning tests. To this end, work continued on the development of a model of the multiterminal system in EMTP. This model will be validated for the AC as well as the DC system by comparison of the test results with those from the simulator. The emphasis of this development is on the detail and accuracy of the representation of the HVDC converter control and protection systems.

The first two stages of the project have already been completed: detailed modeling of the converter bridge control with the simplified AC power system, and perfecting of the Radisson-Sandy Pond two-terminal model, including additional functions such as the DC line protection needed to study system performance.

Modeling of the multiterminal transmission system complete with all the central control functions will be completed next year.

Simulation de réseaux
(Power System Simulation)



Route of the eleventh line (DC) from James Bay to New England.

DETECTION OF FAULTY INSULATORS

One of Hydro-Québec's major objectives is to increase equipment reliability. In view of this goal, the transmission facilities experts of the Vice-présidence Réseaux turned to IREQ to develop a detector for faulty insulators.

Most insulators affected by an occasional fault usually undergo some physical modification such as shattering of the porcelain housing, which makes the cause easy to identify. However, in the case of power supplies that tap the overhead ground wire to feed Hydro-Québec's repeater stations, little or no trace of the fault can be found. It is consequently very difficult to detect the faulty insulator. In addition, this type of power supply is used in remote areas that are not readily accessible. Fault detection therefore has to be done by helicopter in contact with ground crews, which is a very costly procedure.

The aim of this project, then, was to design a fault-indicating device specially for overhead ground-wire type insulators, which would operate without an external power supply and be easy to install at most sites without specialist assistance. So far, a thermo-resistive device with visual indications has been developed. According to laboratory test results, it seems to meet all Hydro-Québec's needs and will shortly be installed at a pilot site for validation tests.

Other work is in now progress to adapt this type of detector to synthetic insulators. The latter are exposed to intermittent failures which are not easy to detect and can easily trip a transmission line. The new detector would be most useful for pinpointing faulty units and would thus reduce system restoration times on the lines affected.

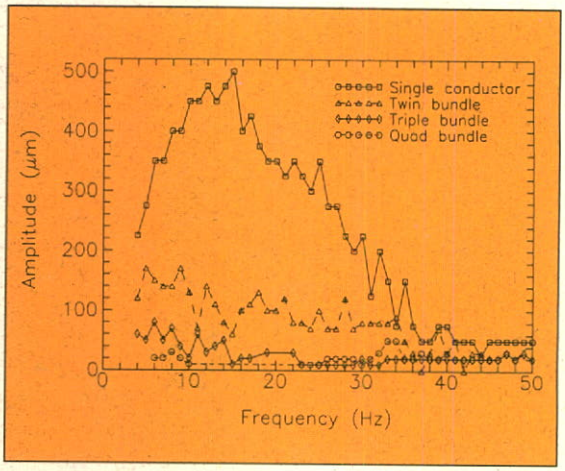
Électronique
(Electronics)

Detection device for locating faulty insulators.

LINE MECHANICS RESEARCH

One noteworthy example of the many studies completed in transmission line mechanics research this year is the field evaluation of eolian vibrations on low-sag ACSR (aluminum conductor steel-reinforced) conductor bundles. Initiated in 1986 for the Canadian Electrical Association, this study has provided an opportunity to establish the economic advantage and technical feasibility of using bundled conductors at higher everyday tensions.

Comparison of the behavior of single and bundled conductors.



Another field study brought to a successful close is one conducted for the transmission facilities department on the vibration behavior of triple-bundled all-alloy conductors for use on ±450-kV DC lines. The study's findings showed that these conductor systems represent a safe and viable technology. The last 12 months also saw completion of the development of the VIBEOL software, which is designed to improve the computation of eolian vibrations on bundled conductors. The first stage of a project related to the dynamic loading of transmission line towers under the effect of wind pressure on the conductors likewise came to an end. This project allowed experimental measurements to be compared to International Electrotechnical Commission requirements.

Meanwhile several studies are under way for Hydro-Québec's standardization experts. The main examples include a wind tunnel study at the Université de Sherbrooke on wind energy imparted to conductors exhibiting nonorthogonal vibration with respect to the direction of flow; modeling of cable self-damping based on the micro-slip of the strands, with Université Laval; field evaluation of fibre-optic cable vibrations and their effect on signal transmission; and, lastly, field and laboratory studies of aircraft warning systems for overhead lines.

After 17 years' uninterrupted operation, the Îles-de-la-Madeleine test line built for research on conductor dynamics was removed from use this year. In future, it will serve for line hardware aging studies.

Lastly, a word should be said about the completion of PAVICA, the overhead-conductor vibration measuring device now marketed by Roctest Ltd. of St. Lambert, Québec. This device was developed for the Service Équipements de transport.

Mécanique
(Mechanical Engineering)

QUALITY CONTROL OF TRANSMISSION LINE SLEEVES

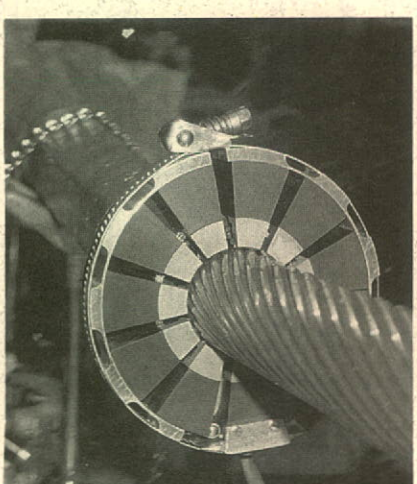
The last 12 months saw the successful completion of a project involving the design, development and testing of multi-electrode devices for ascertaining the quality of transmission line sleeve assembly. These new devices can be used to measure the contact resistance between the multi-strand aluminum cables and the sleeves on overhead 735-kV transmission lines.

A series of laboratory tests was performed at different compression values. However, the resistance measurements did not allow the quality of new joints to be determined, apart from their degree of misalignment. On the other hand, when the resistance method was used to examine 120-kV line sleeves removed from the power system in an industrial area east of Montréal, the method revealed that the facilities had deteriorated.

The new electrodes were specially designed for easy field application. This and other advantages of the quality control method for sleeve assembly will be assessed next year by the Service Études et Normalisation, which requested the study.

Chimie des matériaux
(Materials Chemistry)

Multi-electrode device for measuring the electrical resistance of 735-kV line sleeves.



DIGITAL PROTECTION FOR SUBSTATIONS

A study has been conducted for the transmission facilities department to adapt the digital protection systems developed for generating stations (DIGLO and RUPA) to the subtransmission level. Three protection systems were examined in particular: those for feeders, transformers and 120-kV lines. A detailed digital model with corresponding flowcharts was built for each. Various implementation scenarios were then established for the different functions for the hardware developed for generator protection.

The study revealed that a single one of these units could accommodate any of the three following combinations of functions: a maximum of four feeder protections, or two full protections for two transformers, or one full line protection. Each unit required will be connected from the outset to the ALCID unit by a RS-485 link. Furthermore, its microprocessors and analog-to-digital boards will be substantially upgraded in order to improve their performance and meet the requirements of the newly developed protection systems.

Électronique
(Electronics)

Modeling of overhead conductor behavior (Columbine) - Experimental and calculated curves.

LONG-TERM MATERIALS RESEARCH PROJECTS

The past year was marked by many activities and projects in the area of power transmission. Eight long-term projects were initiated for the Vice-présidence Équipement de transport, most of which combine research and expertise. Four in particular are worthy of note.

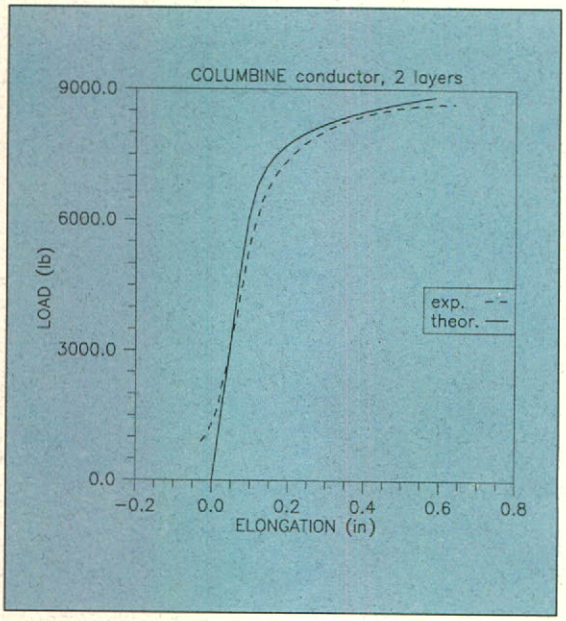
The first involved participation in work and technical studies related to the planning and engineering of ground electrodes. This project is of the utmost importance not only for the protection of facilities and personnel and public safety, but also for the enhancement of service quality and environmental protection. The activities included analysis of the corrosion hazards caused by the use of ground electrodes to oil pipelines and transmission lines, and development of ground resistance calculation methods for hydroelectric power complexes, substations and transmission lines that take account of combined resistances.

The aim of the second project was to design an entirely new model for calculating mechanical resistance in overhead conductors. The calculations performed in the course of this joint study financed by the Canadian Electrical Association were compared to the test results produced by Power Tech Lab and proved highly conclusive. This model is of great interest to transmission line design engineers at Hydro-Québec and could be incorporated into the Technology Plan under a a joint project with the line design department as early as 1991.

In addition, a new technique was developed for line hardware design together with dedicated failure diagrams based on the principles of Linear Elastic Fracture Mechanics. This novel approach was used successfully to alter the design of cast aluminum suspension clamps and anchoring systems and will now be presented for standardization.

Lastly, a task force comprising engineers from across the utility has been formed in connection with Hydro-Québec's power system design, quality, maintenance and research program to upgrade line and substation components and establish guidelines for medium- and long-term technological activities in this area.

Technologie des matériaux (Materials Technology)



INSULATING OILS FOR TRANSFORMERS AND CIRCUIT BREAKERS

A series of major problems in power transformers at La Grande 4 led Hydro-Québec's La Grande Region and apparatus specialists to call upon IREQ's expertise in the characterization of insulating oils in an attempt to assess the insulation of these transformers. An analysis was therefore made of the particles contained in the insulating oils, and the results of dissolved-gas analyses (DGA) were interpreted.

Ferrographic analysis revealed the presence of fine particles of aluminum caused by mechanical abrasion in the oil coolers. Interpretation of the DGA results revealed a number of hot spots, which later inspection proved due to overheating of low-voltage connectors.

Another study, for apparatus experts, dealt with various oils that could be used in Merlin-Gérin circuit breakers. The oil currently employed ages rapidly and needs changing every three years. One of the oils subjected to the accelerated-aging tests showed equivalent qualities but an estimated service life of at least nine years. Considerable savings would stand to be gained from the reduction in maintenance requirements and increased equipment availability if this oil was used in the Merlin-Gérin breakers on the Hydro-Québec system.

Câbles et Isolants (Cables and Insulation)

HV LABORATORY TESTS

The past 12 months were marked by intense activity consisting largely of design tests on high-voltage equipment for manufacturers and the utility. Over 40 power transformers and shunt reactors were tested together with 60 550- and 735-kV current transformers built at ASEA Brown Boveri's plant in Varennes. Several of these units are to be installed at strategic points on the power system: for example, an HVDC transformer at Nicolet substation, transformers for La Grande 2 and 4 generating stations, and a 735-kV, 225-MVA three-phase transformer for the synchronous compensator at Abitibi substation.

In the mean time, an extensive program of aging tests on distribution insulators from various manufacturers has been completed in a Canadian Electrical Association project.

With regard to the ±500-kV DC cables to be used for the James Bay line due to pass under the St. Lawrence River, type tests on the STK and Pirelli cables have been completed. In addition, since the new HVDC underground cable testing facility was commissioned last year, a full series of demonstration tests has been performed on three approximately 125-m loops of ±500-kV cable, together with the bushings and related hardware, from three different manufacturers. The main purpose of these tests was to check the components of the under-river link and assess their long-term behavior. The cables and insulation group at IREQ is in charge of this program, which has been undertaken for the utility's transmission facilities experts. (See also the article on page 20.)

The apparatus department requested validation tests on the new voltage detectors to be installed on the 735-kV transmission system. Out of a concern for personnel safety, several tests were performed on system maintenance equipment.

Tests on 500-kV DC cables in the main hall of the high-voltage laboratory.

Following a recent increase in the switching-impulse withstand of 735-kV system equipment, from 1425 to 1550 kV, switching-impulse tests were performed on a number of major items including disconnectors, power and current transformers and insulators.

Some of the laboratory facilities were modified during the year to conduct applied-voltage tests on 765-kV shunt reactors in keeping with the utility's new reliability criteria. These tests will now be performed at 750 kV_{rms} instead of 660 kV and the partial-discharge level should drop to below 500 pC.

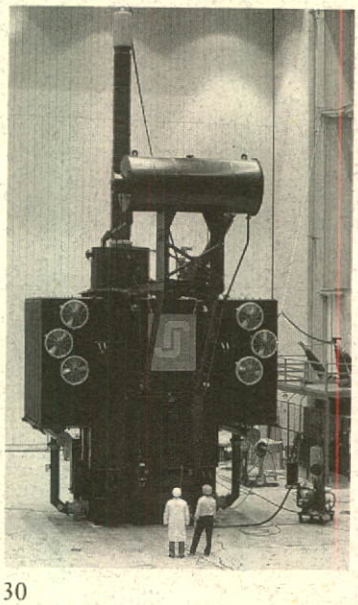
The following major modifications were made:

— Improvement of the insulation of the 122-MVA transformer to meet the 750-kV_{rms} requirement. So far, tests and partial-discharge measurements have yielded very satisfactory results.
— A new 80-kV, 80-Mvar capacitor bank was added.
— Installations adjacent to the capacitor banks have been modified so as to minimize the ambient level of partial discharges.

The commissioning tests on the new laboratory installations are scheduled for completion by March 1, 1991.

Laboratoire Haute tension
(High-Voltage Laboratory)

A Jeumont-Schneider transformer under test in the high-voltage laboratory.



ELECTROMAGNETIC INTERFERENCE

A research project has been undertaken for the Canadian Electrical Association in an aim to create a database on very-high-frequency electromagnetic noise generated by high-voltage transmission lines and substations. The database will be used by the Canadian Standards Association whose Technical Committee on the Electromagnetic Compatibility of High-Voltage Transmission Systems will soon be drafting a standard on acceptable interference levels and developing methods of measuring noise for frequencies between 30 Hz and 300 MHz. Communications Canada plans to use this standard to draw up its regulations in this area.

Several organizations have contributed to this project: Manitoba HVDC Centre, Saskatchewan Power, BC Hydro, Ontario Hydro Research and IREQ. The latter's role has consisted largely in measuring the noise emission from power lines at two sites over a 12-month period and drafting the final version of the joint report.

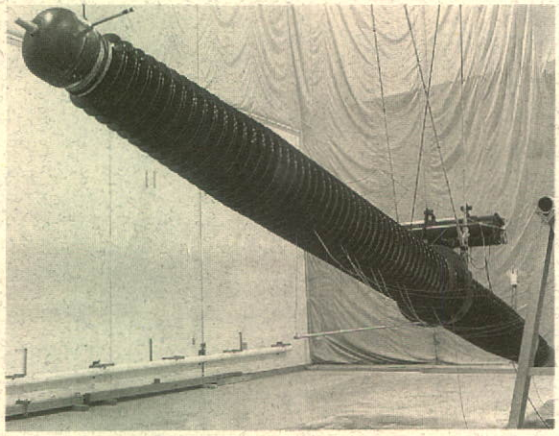
By now, all the required measurements have been taken and analysis is well under way. The report, too, is nearing completion and the project is expected to draw to a close early next year.

Lignes aériennes
(Overhead Lines)

IMPROVING THE PERFORMANCE OF HVDC WALL BUSHINGS

In 1989, Hydro-Québec's Maisonneuve Region built a scale model of a wall bushing to IREQ specifications. Over the last 12 months, the resistance and capacitance between the internal metal screens of this bushing were measured together with the voltage distribution on these screens under DC, AC and impulse voltage. In addition, uniform and nonuniform rain tests were performed on a real 600-kV HVDC wall bushing in the large pollution chamber in the high-voltage laboratory.

The purpose of these tests was to measure the surface resistance of the porcelain housing of this bushing at different precipitation rates and conductivity levels in an attempt to better understand the flashover mechanism of HVDC wall bushings, even at voltages below the service voltage. The



An HVDC wall bushing is tested in the large pollution chamber at the high-voltage laboratory.

research team was also able to determine the environmental conditions that will be used to simulate flashover by means of a mathematical model developed at IREQ and upgraded during the year.

Also in 1990, a paper on the modeling of a wall bushing under nonuniform rain was drafted and submitted to IEEE, and a two-year program of scientific exchanges on research activities was initiated with the U.S. Electric Power Research Institute.

Lignes aériennes
(Overhead Lines)

Among the on-going projects, work was completed on the development of power supply systems (three high-voltage sources), and measurement and control systems for an exposure chamber at IREQ to be used for examining the human perception of electric fields and ion currents. Volunteers will be recruited among the general public to take part in the tests scheduled to begin early in the new year.

In the environment characterization project, the campaign of taking electric and magnetic field measurements in different industrial and residential areas has ended. Work has now started on the analysis of the results and a report will be published in the first few months of 1991.

Meanwhile the team continues to lend technical assistance with the dosimetry aspect of the epidemiological study undertaken jointly by Hydro-Québec and Électricité de France. One of its main contributions is the development of a calibration and verification method for high-frequency transient measurement.

Électrium, an electric and magnetic field interpretation centre, opened its doors in the fall.

Lignes aériennes
(Overhead Lines)

BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS

As activities under way marked progress, new projects were initiated this last year to further explore the biological effects of electric and magnetic fields. A major undertaking with Ontario Hydro and Health and Welfare Canada was launched at the immunology research centre of the Armand-Frappier Institute in Montréal to determine whether exposure to 60-Hz magnetic fields increases the risk of cancer in rats. IREQ's contribution consisted mainly in offering its expertise for calibrating the field exposure and performing periodic checks.

A similar project on cows has begun at McGill University's McDonald College, where an exposure chamber simulating the influence of electric and magnetic fields produced by high-voltage lines is now being built. This facility will be used to analyze the milk production and quality, hormone activity and metabolic behavior of exposed cows.

SERVICE-AGED COMPOSITE INSULATOR ASSESSMENT

As early as 1975, Hydro-Québec began installing hundreds of composite insulators on sections of its 230-, 315- and 735-kV transmission lines. These insulators consist of a fibreglass rod with different weathersheds and various types of end fittings. On the whole, their field performance has been satisfactory but a few units have shown signs of weakness or had to be replaced. Now, almost 15 years later, the utility has decided to replace most of these insulators by new models manufactured according to the latest technologies.

The units removed from service have been subjected to a series of diagnostic tests, the results of which will be used to determine the different effects of aging. For example, surface degradation of the weathersheds due to electrical or environmental stresses is now being analyzed and an evaluation of the flashover voltage is under way using conventional methods as well as a new method better suited to the properties of composite insulators. Also, measurement of the mean failing load under tensile loads and time-load curves is under way.

Initial results show that as far as the ultimate tensile strength is concerned, the mechanical characteristics of insulators exposed to static tension loads do not degrade even after 12 years in service. It even appears that the changes occurring over that period could have a beneficial impact.

Lignes aériennes
(Overhead Lines)

NEW COMPUTER ENVIRONMENT FOR IREQ'S DIGITAL SIMULATION SOFTWARE

A new computer environment comprising SUN workstations and a CRAY supercomputer has been created by Hydro-Québec's power system planning department to enable it to perform more sophisticated simulation studies. The aim of these studies is to improve system reliability, analyze export contracts with neighboring utilities and examine the behavior of ever larger, increasingly complex systems.

IREQ's numerical methods group, which has already designed a substantial amount of this type of simulation software, was accordingly mandated to install it in the new environment. The first stage consisted in installing the software in the SUN workstations.

The next task was to implement the more powerful software — the transient-stability study program (ST600) and Electromagnetic Transients Program (EMTP) — in the CRAY supercomputer. Since the internal representation of the two systems was different, the CRAY software input-outputs had to be adjusted to be able to receive and transmit data according to the SUN representation system. A batch entry procedure is used to ensure transparent integration of the SUN workstations and the CRAY supercomputer. The data preparation and graphics handling of the results are always performed on the SUN workstations, while calculations can be performed on the CRAY at the user's request. In this way, users benefit from transparent access and the supercomputer's high execution capacity.

Méthodes numériques
(Numerical Methods)

MODELING OF SERIES COMPENSATION IN THE ST600 STABILITY PROGRAM

The transient-stability studies related to the implementation of series compensation on Hydro-Québec's transmission system called for the development of a numerical model of the equipment involved.

This model will offer power system planning and operation engineers a means of conducting simulation studies that were impossible hitherto. It allows them to accurately represent the behavior of a series compensator and the initiation of its surge arrester when serious disturbances occur on the system.

The model components include the capacitor, the arrester, the spark gap and the by-pass circuit breaker. An automatic overload protection device controls the triggering of the spark gap, while an automatic overcurrent protection device controls the operation of the circuit breaker. These two automatic controls were modeled in cooperation with the department concerned, namely the Vice-présidence Planification du réseau, using equipment characteristics supplied by manufacturers.

A new version of the ST600 transient-stability program has been produced. It incorporates substantial improvements which should ensure optimum use is made of series-compensator modeling.

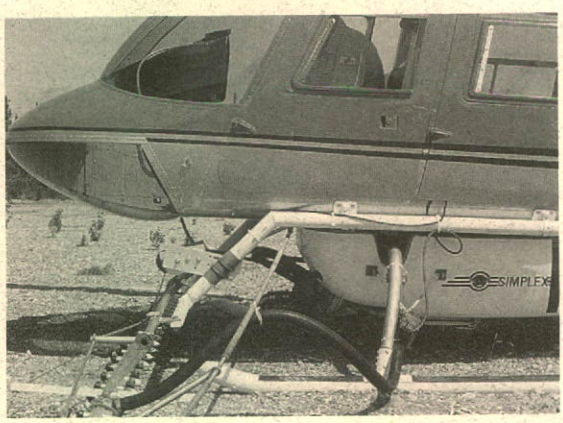
The model and the new version of ST600 have been validated by Hydro-Québec's specialists in automatic controls and protection devices. The devices will be available to all ST600 users on the SUN system and on the CRAY supercomputer early in 1991.

Méthodes numériques
(Numerical Methods)

CONTROLLED AERIAL SPRAYING

An instrument designed to control the accuracy of the spraying of herbicides has been developed at the request of the Manicouagan Region and transmission lines specialists at Hydro-Québec. Vegetation on high-voltage rights-of way is regularly sprayed with chemical products in the Manicouagan Region and, since many of the areas are inaccessible by road, aerial spraying is used.

To protect the environment, the spraying must be restricted to the right-of-way and avoid affecting areas such as lakes, rivers or roads, which are sensitive to these chemicals. Hydro-Québec makes use of helicopters for this work because they fly at low altitudes and low speed, and are thus able to meet the accuracy requirements.



A device has been developed to improve the accuracy of herbicide spraying operations by helicopter.

Experience with aerial spraying has shown that accuracy depends on controlling the helicopter speed in relation to the ground. The speedometers in helicopters, however, are based on the pitot static principle, which establishes the speed with respect to the ambient air rather than the ground. IREQ experts have therefore designed and built a speedometer based rather on the Doppler effect, which determines the speed with respect to ground.

The next stage in the development of this prototype will be to incorporate various other parameters such as the volume of herbicides used, the average helicopter speed, the average flow rate and, especially, real-time control of the flow rate in terms of the flying speed.

The new device was tested during spraying operations last summer and the results are very conclusive. The process has several advantages, both economic and environmental, and is efficient from the human resources point of view. The Manicouagan Region and Zimmers Helicopters provided excellent cooperation throughout the course of this project.

Électronique
(Electronics)

The distribution-related studies performed by TAI groups all reflect Hydro-Québec's basic values: service quality with respect to the product and the electric power supply; the health and safety of the public and utility personnel. For example, a new nonfragmenting surge arrester has been developed, of which 500 units have been installed in the field for evaluation. Work has continued on the development of distribution transformers with magnetic circuits made of amorphous steel, the preparation of a power quality measurement protocol, and development of a power system disturbance monitor. A study has been initiated to investigate damage due to phase-to-ground arcing faults on 347/600-V secondary distribution systems and another to investigate the aging of underground cable joints. A protocol for the assessment of corrosion-resistant paints for underground transformer vaults has been developed. Many tests on distribution apparatus were performed at the high-power laboratory. A signal acquisition system has been designed for measuring lightning currents on the power system and monitoring the reaction of equipment. An evaluation of connector reliability and a study of the diffusion of pentachlorophenol into the environment continued. Lastly, a project was initiated on the pre-failure energy limit of transformer tanks and their mechanical stresses.

Internal arcing during tests on distribution surge arresters at the high-power laboratory.

NONFRAGMENTING POLYMER-CONCRETE SURGE ARRESTERS

Hydro-Québec is on the point of replacing most of the surge arresters on its distribution system with new nonfragmenting devices in an effort to comply with the latest safety requirements.

The standard recently adopted by the utility contains the most stringent requirements in the world in fact and, in order to meet them, researchers have developed what is known as the ZQTS surge arrester, which has a nonfragmenting polymer-concrete housing rather than the conventional porcelain. The work was performed under a joint project with Joslyn Canada for the Direction Distribution.

Some 500 units have been installed for field tests in the utility's Saint-Laurent, Richelieu, Montmorency and La Grande regions for testing. This certification phase will allow the arresters to be validated under real operating conditions.

Development of a technically safe surge arrester had become imperative in view of the fact that transformers cannot be left without adequate overvoltage protection. Otherwise, losses could reach an estimated 16 per 1000 units a year, seven times more than for transformers without protection. By limiting transformer losses, the new surge arrester will allow Hydro-Québec to reduce the risks associated with transformer failures as well as the number of service interruptions caused.

Information about the performance of the nonfragmenting arrester has been sent to Ontario Hydro and electrical utilities in Italy, Belgium and France, and a number of units have gone to Italy already for design tests according to European standards.

Appareillage électrique
(Electrical Apparatus)

TRANSFORMERS WITH AN AMORPHOUS-STEEL MAGNETIC CIRCUIT

Work continued throughout the year on the development of a 100-kVA distribution transformer comprising an amorphous-steel magnetic circuit. The project was initiated the previous year as a joint Hydro-Québec — Ferranti Packard undertaking.

The main advantage of amorphous steel is its low iron loss, which is three to five times lower than that of grain-oriented silicon steels. However, if the iron loss is to be reduced sufficiently for this application, i.e. below 0.20 W/kg at 1.3 T and 25°C, it is essential to overcome the technological problems raised by the physical and chemical nature of amorphous materials.

The research team therefore had to develop three completely new electromagnetic systems for handling steel ribbons 12.8 cm and 17 cm wide and winding them round the electric circuit. A first magnetic circuit has been produced and sent to Ferranti Packard, which is responsible for designing and manufacturing the electric circuits.

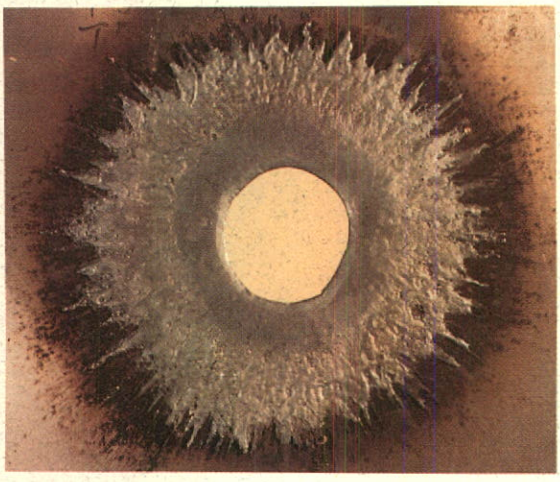
Technologie des matériaux
(Materials Technology)

POWER QUALITY PROTOCOL

Hydro-Québec has spent over one billion dollars in the last ten years in its effort to improve service quality throughout the provincial distribution system. So far it has concentrated largely on service continuity, although not to the detriment of an aspect which has taken on heightened importance with the increasing use of electronic equipment, namely power quality.

In pursuit of its commitment to encourage a more rational use of electricity, Hydro-Québec recommends its industrial customers to install equipment such as electronic stabilizers and variable-frequency drives, which offer a means of controlling the system with a view to reducing electricity consumption. However, these electronic controllers can disturb the operation of sensitive machines and the utility must therefore proceed very slowly, step by step, in its promotion of such devices. The real impact of this measure on power quality must be assessed at regular intervals but no standards exist by which to measure it. IREQ therefore undertook to draft a protocol for power quality measurement at the request of Hydro-Québec's distribution department and the Canadian Electrical Association.

The first stage of the work consisted in determining the useful parameters for the study and sampling system voltages at over 100 sites across Québec. At 14 of these sites, steady-state voltages and currents were recorded over a period of 48 hours, creating a total of 400,000 million measured values. Analysis of this data will now be used to define the minimum criteria to be fulfilled in order to guarantee the accuracy of the power quality assessment. The



Erosion of a steel plate by a power arc.

power system disturbances will be measured in a future measurement campaign using a relatively inexpensive instrument now being developed by the IREQ research team. Five copies of this instrument will be used in 1991 to assess the power quality at more than 30 sites on the distribution system. This second stage in the project will provide an opportunity to optimize the field sampling and measuring methods.

Appareillage électrique
(Electrical Apparatus)

POWER QUALITY MONITOR

A project was initiated at the beginning of the year for the Direction Distribution in an aim to develop a means of identifying problems related to power quality. This work led to the design of a prototype monitor. The new troubleshooting instrument will be used to evaluate and interpret disturbance phenomena on the distribution system.

These phenomena fall into four categories: a first type of flicker characterized by very slow variations in the voltage amplitude, which can be anywhere from once per second to once a day; a second type of flicker with amplitude modulations occurring between once and 25 times per second; periodic waveform distortions (harmonics) whose frequency can reach 3000 Hz; and very short-duration impulses.

No commercial instrument exists for dealing with these various phenomena simultaneously. The present version of the prototype developed at IREQ allows harmonics and the second type of flicker to be analyzed by weighting the results with the aid of a method proposed by the Union internationale d'électrothermie (International Union for Electric Heat). The other two functions will be added next year and the complete system, available on a portable computer, should be finalized by March 1992.

Méthodes numériques
(Numerical Methods)

SECONDARY ARCS

An arcing fault occurring in a customer vault on a 347/600-V secondary distribution system can damage property and equipment in addition to creating a safety hazard for users. Hydro-Québec's distribution department therefore requested IREQ to study the extent and nature of the damage caused by phase-to-ground faults over a current range from 1 A to 16 A at interelectrode distances or gaps of 12.5 mm to 50 mm.

It was observed that in the case of arcs between rod electrodes, erosion of the electrodes (in mm^3/C) is almost always identical, regardless of their spacing and the arc current; in fact, the phenomenon depends mainly on the electrode material. On the other hand, the erosion of the plate in a rod-plate configuration shows a considerable difference before and after perforation: before, the rate is identical to that on bare steel rods but afterwards it shows a fourfold increase.

The ambient power arc, which has a direct bearing on the pressure rise in the vault, can reach a value of 2 MW for 16-kA arcs with a length of approximately 50 mm.

As far as the fire hazard is concerned, organic materials such as plywood and phenolic compounds that are exposed to an arc tend to decompose but do not ignite. However, the risk of combustion is greater in materials such as perforated plywood which allow the air to flow.

The findings of all these studies should lead to a better understanding of the phenomena that can result in fire or deflagration.

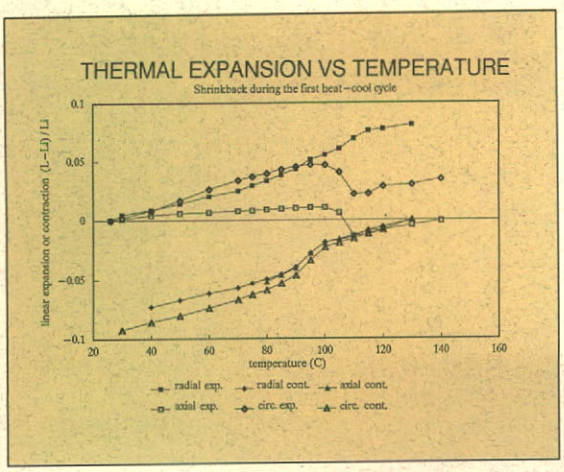
Appareillage électrique
(Electrical Apparatus)

AGING STUDIES OF JOINTS ON THE UNDERGROUND DISTRIBUTION SYSTEM

Several studies were conducted over the year for Hydro-Québec's Direction Distribution on the aging of cable joints on the underground distribution system. These components have a high failure rate and consequently represent a weak spot. Earlier studies had identified the leading causes of these failures — dielectric breakdown at interfaces, partial discharges, poor contact of connectors, the presence of water and electro-thermomechanical effects — but not the aging factors themselves.

This, then, is the aim of the studies now under way. Once the main aging factors have been determined, the research team will be able to improve the test conditions for accelerated aging, ready for simulating the real situation. In addition, nondestructive tests will be performed to try to predict the residual lifetime of joints in service. For this purpose, various analytical techniques that could shed new light on the condition of joints are currently being investigated in collaboration with the Physics Department of the Université du Québec à Trois-Rivières.

Câbles et Isolants
(Cables and Insulation)



Thermal-expansion curves (points with positive values) for small cubes of cross-linked polyethylene removed from distribution cable insulation; the contraction curves are those with negative values. These curves, obtained during a first heating-cooling cycle, show the "shrink back" phenomenon often observed in extruded cables.

CORROSION PROTECTION FOR UNDERGROUND VAULTS

Work continued throughout the year on the assessment of different corrosion-resistant paints and other materials for underground vaults. This project was initiated at the request of Hydro-Québec's Saint-Laurent Region and the distribution department. An evaluation protocol specially designed for vault conditions has been developed and validated so that the different paints proposed by suppliers can be evaluated under typical operating conditions.

The Natural Sciences and Engineering Research Council has awarded the Université de Sherbrooke a research grant matching the contribution Hydro-Québec has made to this jointly funded project.

Chimie des matériaux
(Materials Chemistry)

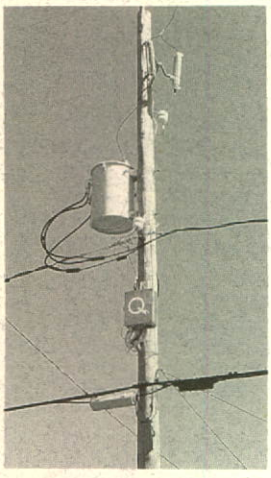
PROTECTION AGAINST INTERNAL ARCING FAULTS

The past 12 months have seen a large volume of tests on switches, metalclad enclosures, grounding assembly components, surge arresters and manholes in an aim to improve protection for people and property in the vicinity of a fault on the distribution system. First, for various manufacturers, internal-arc resistance tests were performed in conformity with EEMAC standard G-14-1 at currents of up to 48 kA, three-phase, on metal-enclosed switchgear.

Other test programs, for Hydro-Québec's distribution department and different administrative regions, were conducted at three-phase currents ranging from 5 kA to 18 kA and the results served to determine the duration of the internal-arc resistance of 27-kV SF_6 switches.

In addition, for the same department, short-circuit withstand tests were conducted on grounding electrodes and accessories, including clamps, ground pads, connectors and cables. The short-circuit resistance of various grounding assemblies was tested by varying the current over a range from 8 kA to 12 kA.

Yet other work for the same department took the form of tests performed in accordance with Canadian standard CSA-C233.1-87 to verify the behavior of pressure-limiting devices used on distribution surge arresters subjected to internal arcing faults of 121 kA and 500 A generated by a fuse wire or by thermal runaway.



Demonstration of a lightning-current measuring system for distribution networks.

Lastly, tests on electric arcs ranging from 4 kA to 16 kA that occur in underground vaults were performed for IREQ's electrical apparatus specialists to measure the arc energy, pressure rise, impact noise, temperature rise and projections, and to observe the behavior of reinforced-concrete manholes under arcing conditions.

Laboratoire Grande puissance
(High-Power Laboratory)

CERTIFICATION OF 27-KV THREE-PHASE DISTRIBUTION SWITCHES

Certification of three types of switches at the high-power laboratory called for a series of tests in conformity with ANSI C37.71. Tests were therefore performed on a 600-A SF_6 overhead switch, a submersible switch with the same characteristics and a 200-A oil-immersed switch in a base-mounted transformer.

The validation process involved a wide range of tests: current-breaking tests on mainly active loads; no-load transformer, no-load cable, withstand and short-circuit-making tests at 12.5 kA; dielectric withstand, partial-discharge and temperature-rise tests; and, lastly, mechanical making and breaking tests at temperatures as low as -50°C.

Laboratoire Grande puissance
(High-Power Laboratory)

LIGHTNING-CURRENT MEASUREMENT ON POWER LINES

Every year produces further evidence of the role of lightning in unplanned system outages. In addition to multiple failures, often of short duration, severe storms can cause serious damage to distribution equipment. Many lightning-related phenomena also make their impact felt. The nature of these different phenomena is not known exactly, however, and many questions remain unanswered. For example, why do some fuses melt following a discharge whenever the discharge current is slow in decreasing? And why do some surge arresters fail after being subjected to discharges with a particularly steep front?

Some of these operating conditions have been reproduced and analyzed in the laboratory but for practical purposes no simple method exists for monitoring distribution system equipment. To meet this need, IREQ researchers have developed a signal-acquisition system of which four prototypes were installed this year in the Laurentides Region. Starting in 1991, the number will be increased to 25 to cover the Saint-Laurent, Richelieu and Montmorency regions which, with the Laurentides Region, are the areas most affected by lightning in Québec. The experiment should continue for three to four consecutive lightning seasons.

The system comprises a current sensor with a digital measurement and acquisition circuit and a telecommunications circuit. The former serves to record the exact time of the event and store the current waveshapes (the current variations can be in the sub-microsecond range). The latter is an original circuit designed at IREQ, which provides direct access to the same current waveshape information by cellular telephone. The arrester current and the transformer neutral current are recorded simultaneously. All the electronic circuits have been designed and manufactured by the Québec City firm, CPU Design.

This project has brought together specialists in several fields from this and other research groups at IREQ and involved cooperation with the distribution department and the Laurentides Region.

Lignes aériennes
(Overhead Lines)

CHARACTERIZATION OF ELECTRICAL CONNECTORS

Despite significant progress in the general area of electrical contacts, much remains to be learned about the degradation mechanisms of electrical connectors used on distribution systems. This lack of information is not without repercussions on the validity of technical specifications, connector use and maintenance, and the general reliability of the entire power system. It is obviously difficult to establish an optimum maintenance schedule if the in-service degradation rate of these connectors cannot be determined accurately.

IREQ was therefore requested to assess the reliability of connectors used on the Hydro-Québec distribution system, mainly for the purpose of upgrading the technical specifications and acceptance criteria. An accelerated-aging method was developed in order to verify the behavior of electrical connectors in a saline environment.

The tests consisted in subjecting the connectors to short-duration, high-intensity current cycling followed by a longer period of cooling. The operating conditions simulated in these tests were so severe as to cause rapid deterioration, proving that this method is an efficient alternative to its time-consuming counterparts in current use, providing a useful means of verifying the design of connectors proposed by manufacturers.

Technologie des matériaux
(Materials Technology)

ENERGY LIMIT FOR DISTRIBUTION TRANSFORMERS

Under some circumstances, distribution transformers can explode in response to pressure building up inside the tank. A study was therefore initiated at the request of the Direction Distribution to determine the mechanical stresses that transformer tanks can withstand. This limit cannot be defined without first having an idea of the different parameters involved and accurate measurement of the values of these parameters.

The study revealed that when the transformer's dielectric strength is reduced, for example, by aging of the insulation or an excessively high overvoltage, an internal fault can occur which inevitably creates an electric arc in the oil. The arc temperature can reach several thousand degrees Celsius and decompose the oil into carbon and different combustible gases. This phenomenon accounts for the pressure rise in the tank which may result in explosion and oil spills.

The aim of the work under way is to analyze these failures and identify the tank's weak spots. It is also intended to evaluate the pressure in a tank exposed to fault conditions, as well as the limit pressure that tanks can withstand without sustaining damage or jeopardizing personnel safety or equipment. The research team will therefore determine the points on the tank where the pressure reaches its highest value, together with the associated current amplitudes and durations. Many internal-fault tests will be performed at IREQ's high-power laboratory on different types of transformers equipped with pressure transducers.

The project will also be used to validate a computer program designed to model oil-containing tanks and to calculate the pressure and shock waves. The program has already reduced the volume of required tests by predicting the most severe faults that can be expected. It should soon be possible, therefore, to predict the pre-failure energy limits of different types of equipment without resorting to lengthy series of laboratory tests.

Appareillage électrique
(Electrical Apparatus)

ENVIRONMENTAL DIFFUSION OF PCP

Under a mandate from the Vice-présidence Environnement, members of IREQ's materials chemistry team have developed an analysis protocol for studying the environmental diffusion mechanisms of pentachlorophenol (PCP) in wood. This wood preservative has been analyzed both for newly treated poles and poles already installed on the distribution system. The protocol therefore had to cover the extraction not only of PCP but also the oil used as the solvent, from the same sample. The concentration of both these components can now be determined by a single treatment of the sample. The new tool provides a means of tracing the distribution of PCP from the surface of the pole to the very centre as well as along the entire length, in water and in the soil.

The results show that the oil and the PCP are not distributed evenly in the pole. The distribution depends on the species of wood and the preservative application process. Analysis of samples from poles installed between 1957 and 1981 reveals that the residual concentration of these two products does not depend on the age of the poles. In fact, the concentration is higher in poles treated in 1957 and 1958 than in those treated recently. The origin of these apparent discrepancies must now be sought, perhaps in the standards prevailing at the different times that monitoring was conducted.

Chimie des matériaux
(Materials Chemistry)

Taking a sample from a PCP-treated wood pole.

LTEE, Hydro-Québec's electrochemical and electrical technologies laboratory, pursued its activities related to the efficient use of electricity in the industrial, commercial and residential sectors. Development of a second version of the heat pump with nonelectric backup (PACANE) began together with a comparative study of different heat pump models. A dual-climate environmental test chamber has been built for studying potential energy savings in the commercial and residential sectors. At the industrial level, laboratory and factory tests were successfully performed, especially on drying processes, and two heat storage methods were assessed. In the work on plasma-based processes, studies were conducted on baghouse dust treatment, vitrification of incinerator waste, opening of tap holes in arc furnaces, and surface grinding of granite slabs. As for activities related to industrial chemistry and electrochemistry, the focus was mainly on the production of ethylene glycol, the extraction of soluble proteins in the agro-food sector, and the recycling of acid waste.

Melting of ferromanganese and opening of tap holes using 80-kW and 150-kW plasma torches. These tests were also performed at 300 kW.

INDUSTRIAL PLASMAS

Technology transfer to industry, the pivot for this group's activities, took several forms in 1990. Patented processes were perfected, potential clients for some of the technologies conceived at LTEE were identified and negotiation of various operating licences and agreements began.

One of the first processes to be developed is for the treatment of baghouse dust in arc furnaces and recovery of the metal content without pre-agglomeration. The dust is injected into the plasma furnace where it forms a falling film on the wall surface of the sleeve surrounding the arc. The process was tested in a pilot facility equipped with a 300-kW furnace. An agreement is being negotiated with a client for the installation of a 5-MW plant.

A vitrification process for ashes from incinerators has also been developed. It is based on the use of a plasma furnace which immobilizes the ashes and prevents them from dispersing into the environment. The ashes to be processed can be in powder form or, on the contrary, comprise particles of various sizes. Subsequent leaching tests show that this process meets environmental standards and negotiations are under way with several interested clients.

Another development consists of a process involving the use of a plasma torch to open tap holes in arc furnaces, an operation usually done with oxygen lances, guns or drills. A marketing licence is being negotiated.

The plasma torch was used for another application: surface grinding of granite slabs. Propane torches have traditionally been used for this purpose but their flame is not very hot and consequently they are not the most efficient tool. The plasma torch, with its very high temperatures, increases productivity and, furthermore, allows much thinner slabs to be treated than its propane counterpart. Agreements for the marketing of this process are being negotiated.

Plasmas industriels
(Industrial Plasmas)

NEW VERSION OF THE HEAT PUMP WITH NONELECTRIC BACKUP

A second version of the heat pump with nonelectric backup (PACANE) is currently under development for the utility's Québec markets group. The novel feature of this second-generation heat pump is the closed-circuit use of a glycol-based liquid as coolant. The developers believe that in backup mode the pump will need less than 500 W of demand power.

Four prototypes of the new pump will be installed in the homes of residential customers during the next 12 months to assess its efficiency under normal operating conditions. The test campaign should be completed by the end of winter 1992.

Also, in order to gather data for a rigorous comparison of heat pump energy efficiency, different models will be tested simultaneously under normal operating conditions. A test method is now being developed for this purpose which involves the use of identical buildings exposed to the same weather conditions. The method will be validated during the winter 1991. The second part of the test program will consist in simultaneously testing the behavior of about 15 different makes of heat pumps under real operating conditions.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

PROJECTS IN THE RESIDENTIAL SECTOR

The main thrust of work on energy savings was to increase LTEE's role in the residential and commercial sector by developing new test facilities to meet the ever-increasing needs of Hydro-Québec's Groupe Marchés québécois.

One of these facilities is an environmental chamber, construction of which began towards the end of the year. The test chamber comprises a single room of standard architecture and dimensions. On three of its six sides (two walls and the ceiling) it is exposed to rigorously controlled outdoor weather conditions including temperatures as low as -25°C. The three remaining sides (the other two walls and the floor) are exposed to the conditions found in a typical Canadian home.

Once completed, this test facility will be an excellent tool for identifying and understanding the factors that determine people's thermal comfort level. Its main purpose, however, will be to determine the energy savings offered by various home accessories such as programmable electronic thermostats and convection or radiation heaters under normal conditions.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

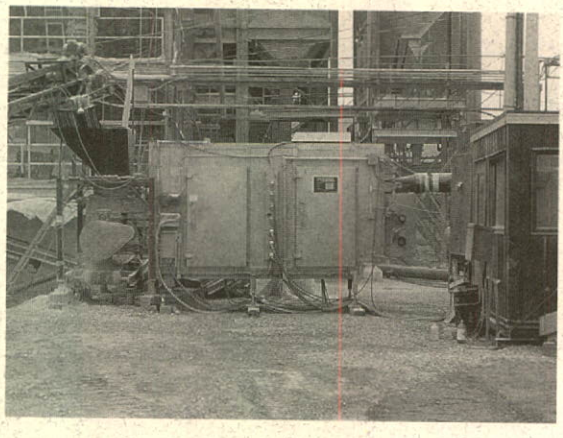
PROJECTS FOR INDUSTRY

Several major technologies aimed at increasing energy efficiency in industry were implemented over the year. For example, the Thetford Mines firm, Industries Granirex, has acquired a 400-kW infrared aggregate drier developed by a team of researchers at LTEE. A more modest acquisition was made by Sylvania, which has purchased a short-wave infrared oven following demonstration tests at the Shawinigan laboratories.

A number of in-house developed pilot facilities were taken to different plants during the year for field demonstration purposes. At Calcaires Bedford, for instance, the energy efficiency of a conveyor-type drier was compared to that of a stationary rotary unit. A test lasting 72 consecutive hours proved very conclusive.

Another infrared pilot drier at LTEE was installed in the production line at Hodgest-Ply Company for two weeks. The plant's drying capacity rose by 50%.

The infrared drier developed at LTEE for granular materials was tested at Calcaire Bedford Inc.'s plant, where the aggregate ranges from fine particles to 5-cm pebbles. An average feedrate of 3 tonnes/hour was maintained for three days.



Many smaller-scale tests and demonstrations were also performed for some 50 companies anxious to save energy and improve their competitive edge. Mention might be made of the milk pasteurization tests using an induction fluid heating system that were conducted jointly with the STELA Laboratory of the Université Laval, and an industrial-size plastic-sheet heating mechanism developed at LTEE was built and subsequently installed at an industrial site.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

HEAT STORAGE FOR ENERGY CONSERVATION

Two methods of accumulating heat are under investigation at LTEE to determine the quantity of energy that can be saved by heat storage.

The first is based on local units of sensitive heat storage, as used for many years in Europe and, more recently, in the United States. To be able to study the thermal behavior of these units, LTEE acquired a calorimeter last summer and plans to put it into service early in 1991. The tests performed with this apparatus will allow the researchers to decide whether this storage method lends itself to the Québec context.

The second method involves the use of gypsum panels impregnated with paraffin, a material which undergoes a phase change. A measurement campaign was initiated last fall on two experimental structures and a typical single-family house which had been covered with these gypsum panels. The measurements will continue until summer 1991 in cooperation with the Montréal firm Parinova and Domtar laboratory personnel in order to validate this storage method.

Électrotechnologies industrielles
(Industrial Electrotechnologies)

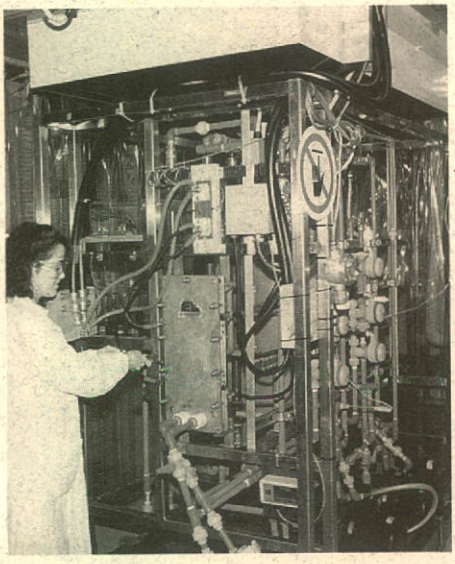
ORGANIC ELECTROSYNTHESIS

The development and marketing of processes for manufacturing ethylene glycol and products with a high added value continued this year, in accordance with agreements signed with Hydro-Québec's Industrial Markets Group and various industrial partners. This three-year program was initiated after a series of marketing studies on the potential for using electricity in synthesizing commercially promising chemicals.

The objective of this year's work, which was carried out on prepilot test benches, was to optimize the processes developed to meet the technical and commercial viability criteria. The test facilities are equipped with filter-press type electrochemical cells offering electrode surfaces of 100 cm^2 and 400 cm^2 and current-density levels of the order of 5 kA/m^2. Since the electrosynthesis technologies currently being tested tend to be general in nature, over 50 different chemicals offering good market potential can be tested. In addition, a patent application has been filed for a new chemical reduction process.

The group is already making plans for the pre-industrial demonstration, in fall 1991, of the processes it has developed. The pilot plant to be used for this purpose, which will be equipped with a 200-kW electrochemical cell, should be completed by June 1991 and commissioned during the following months. Meanwhile, economic and marketing studies have begun, with a view to confirming the competitive edge of electrochemical processes over their traditional counterparts.

Chimie et Électrochimie industrielles
(Industrial Chemistry and Electrochemistry)



Pre-pilot test facility for developing organic electrosynthesis processes.

MEMBRANE SEPARATION

In a program under way to promote separation techniques based on the use of membranes, the research team focused on electrodialysis, a separation technique of particular interest to electrical utilities such as Hydro-Québec. Two applications were assessed: extraction of soluble proteins in the agro-food business and recycling of acid waste from industrial effluents.

The protein-electrocoagulation process being tested in cooperation with the Canadian government's Food Research and Development Centre in Sainte-Hyacinthe, Québec, is an electrodialysis-based method of extracting proteins with a high added value, from aqueous solutions. The process has been tested successfully on different types of protein including soybeans and alfalfa.

Acid waste, for its part, represents a major environmental hazard. Tests were performed this year to demonstrate the potential of electrodialysis in recycling industrial effluents containing large amounts of acid. The results obtained so far are sufficiently conclusive for testing to continue next year.

The past 12 months were also devoted to establishing links with various industrial partners in Québec likely to make use of electrodialysis processes, which offer a generally high energy efficiency and are therefore strongly recommended in Hydro-Québec's energy conservation program. To ensure all these processes will be readily available to industries throughout the province, discussions have begun with leading international manufacturers of membranes in order to dovetail development work at LTEE with world marketing activities.

Chimie et Électrochimie industrielles
(Industrial Chemistry and Electrochemistry)

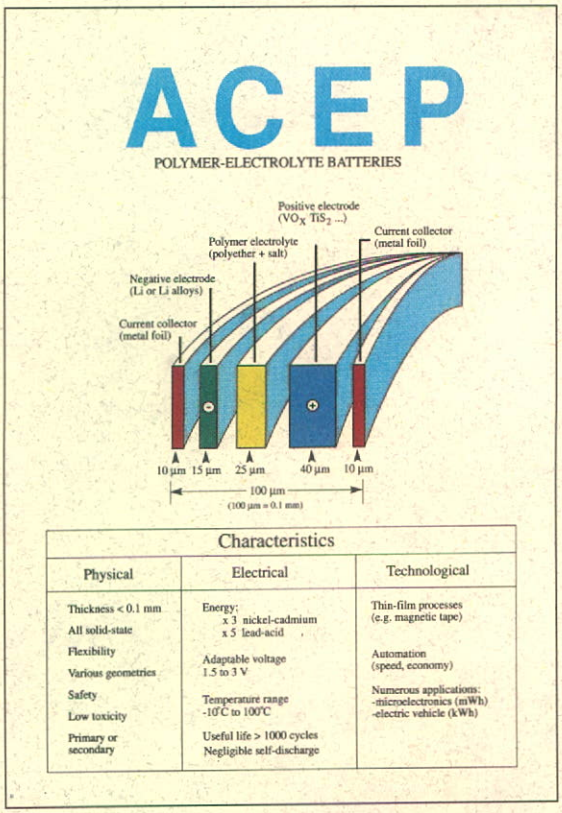
An agreement has been signed with the Japanese firm Yuasa Battery Co. to set up a jointly owned company, ACEP Inc., which will be responsible for the development, manufacture and marketing of the new polymer-electrolyte batteries developed at Hydro-Québec's research laboratories. Work continued, meanwhile, on the evaluation of PCB destruction technologies and on the development of various expert systems within the utility. Studies on the production and transportation of hydrogen continued throughout the year apace with development work on an automated system for reorganizing meter-reading routes.

YUASA — HYDRO-QUÉBEC AGREEMENT ON THE PRODUCTION OF ACEP BATTERIES

Under an agreement between Hydro-Québec and the Japanese firm Yuasa Battery Co. of Osaka, one of the largest battery manufacturers in the world, the ACEP polymer-electrolyte battery is to be made by a new company known as ACEP Inc., which will be responsible for the battery's development, production and marketing. Jointly owned by the two partners, this fledgling company will begin operations in January 1991 at its head office in Montréal.

The agreement provides for a first plant to be built in Japan by 1993 for the production of small batteries for electronic devices and consumer goods such as calculators, cellular phones, portable computers, credit or identity cards with memories, games, personal radios, etc. A second plant will be built in Québec around 1995.

The ACEP polymer-electrolyte battery lends itself to a wide range of electronic consumer goods. An agreement has been signed with Yuasa Battery Co. for the industrial development and marketing of this new battery.



Characteristics		
Physical	**Electrical**	**Technological**
Thickness < 0.1 mm	Energy:	Thin-film processes (e.g. magnetic tape)
All solid-state	x 3 nickel-cadmium	
Flexibility	x 5 lead-acid	Automation (speed, economy)
Various geometries	Adaptable voltage 1.5 to 3 V	
Safety	Temperature range -10°C to 100°C	Numerous applications: -microelectronics (mWh) -electric vehicle (kWh)
Low toxicity	Useful life > 1000 cycles	
Primary or secondary	Negligible self-discharge	

The all-solid-state ACEP battery is completely different from existing batteries. It is based on the use of thin-film electrodes and a polymer electrolyte, which means that it can be produced in thicknesses of no more than 0.1 mm (100 µm), the equivalent of two sheets of paper. All its components are nontoxic and, since they include no liquid products, there is no risk of leakage or corrosion.

In addition, ACEP batteries represent a so-called "surface technology": in other words, the energy and power requirements of a given application are met simply by increasing the surface area of a given thin-battery configuration. Their applications range from microbatteries used in electronics to batteries for vehicle propulsion. They offer an outstanding service life of 500 to 1000 deep-discharge cycles and an energy capacity per unit of weight three to five times that of lead and nickel-cadmium batteries. The ACEP technology lends itself to simple, highly automated industrial processes for mass production.

The agreement with Yuasa culminates more than ten years of research at IREQ and LTEE with contributions from several outside partners including Elf-Aquitaine and the University of Grenoble in France, where the polymer-electrolyte battery was originally conceived. Work continues on the development of larger batteries for electric vehicles, which should be ready for marketing by the year 2000. It is planned to locate the first production plant in Québec, and the second in Japan, again, to balance out the battery production between the partners.

Projets de développement
(Development Projects)
Chimie des matériaux
(Materials Chemistry)
LTEE

PCB DESTRUCTION TECHNOLOGIES

Hydro-Québec's action plan on PCB management includes on-going research into mobile technologies for destroying PCBs. This year, final tests were performed on a mobile incinerator built by Vesta Technology Ltd. at Swan Hills in Alberta. The tests were conducted in conformity with rigorous quality assurance guidelines under the general responsibility of Environment Canada. While Chem Security of Alberta directed the tests at Swan Hill, a researcher with the Cables and Insulation Group, which has developed great expertise in the analysis and evaluation of PCB by-product toxicity, took part in the interpretation of the results obtained. The final report is expected early in 1991.

Pilot experiments were conducted on mobile decontamination technologies that use solvents and autoclaves for transformers slightly or heavily contaminated with PCBs. Testing will continue in spring 1991 on use of the same technologies to decontaminate capacitors.

During the year, TAI and Hydro-Québec's Groupe Environnement prepared a joint report which was presented to the Québec commission of enquiry into hazardous waste. Furthermore, the utility has agreed to join a consortium involving the federal and provincial environment departments for the purpose of setting up a PCB waste elimination program.

Projets de développement
(Development Projects)
Câbles et Isolants
(Cables and Insulation)

EXPERT SYSTEMS

Task force on expert systems

The past 12 months were devoted partly to assessing and strengthening the task force on expert systems, whose initial mandate was due to expire on December 31, 1990. The task force's activities were submitted for analysis to Digital Equipment Corporation's Artificial Intelligence Technology Center, which concluded that the horizontal structure of the task force had helped bring together key people in the Hydro-Québec activities concerned and thereby achieve a high level of efficiency.

The steering committee of the task force had been mandated to launch and finance a number of projects on expert systems, to organize training sessions for managers, and to form working groups. These activities transformed the task force from an ad hoc group to a permanent clearing house. So far its role has been to train multidisciplinary teams with support from various Hydro-Québec departments but from now on it will welcome full-time representatives from departments interested in using expert systems. This move will allow better planning of long-term projects. Moreover, the mandate has now been expanded to cover all aspects of the utility's activity.

Under the revised mandate, all Hydro-Québec's resources and skills in the field of expert systems will be pooled, forming a critical mass that represents the entire utility and providing a channel through which this new engineering field can become known throughout Hydro-Québec.

Knowledge engineering course

The task force has set up a knowledge engineering course in cooperation with the Centre de recherche informatique de Montréal (CRIM) in an aim to develop skills in artificial intelligence on a company-wide basis. This postgraduate course has been given to about 20 students during the fall 1989 and winter 1990 sessions. The development of new skills should create new centres of interest in all the departments concerned. Introductory courses on expert systems have also been given to members of Hydro-Québec senior management.

Among the expert systems in development, mention should be made of the following:

The LANGAGE system

LANGAGE is a generalized expert system for processing power system alarms detected at regional control centres. This general-purpose system with its database and parameter set can be adapted to all control centres, in fact. The software was only at the prototype stage at the beginning of the year but is now a pilot product ready for implementation at Hydro-Québec's nine regional control centres. LANGAGE, one of the most sophisticated expert systems in Québec, is among the rare systems to be used in real time. With its rapid and effective processing capability for power system-control-related alarms, it represents a significant milestone in Hydro-Québec's goal to achieve total quality.

The SUBAREX system

SUBAREX, an expert system designed to assess the safety of earth- and rockfill dams, was developed by Hydro-Québec in cooperation with other departments (Direction Sécurité des barrages, Groupe Équipement, La Grande Region) and the CRIM. Since SUBAREX uses knowledge which is both fuzzy and incomplete, novel representation methods have been developed including a knowledge base which is now being validated.

The knowledge acquisition process has fostered stimulating exchanges between Hydro-Québec's regions and specialists in various fields.

The TRANSEPT system

TRANSEPT is an expert system used for the preliminary design of high-voltage transmission systems. The original prototype could process point-to-point AC systems but the latest version applies equally well to DC as to AC transmission.

The two major advantages of TRANSEPT are its efficiency and rapidity on the one hand, and on the other hand, its focus on the fundamental aspects of power system design. It is thus particularly well equipped to incorporate improvements and to handle problems of increasing complexity. Its designers plan to add reliability and insulation-coordination modules in the near future.

GIRICO Symposium 1990

Last September, the Groupe inter-universitaire de recherches informatiques (GIRICO) held a symposium on expert systems in Québec. The Hydro-Québec task force helped to organize this event, which was attended by some 300 representatives from universities and industry. In addition to two papers presented at the symposium, others, dealing mainly with the TRANSEPT and LANGAGE expert systems, were given at other international scientific conferences.

Projets de développement
(Development Projects)

EURO-QUÉBEC INTERCONTINENTAL HYDROGEN TRANSPORTATION PROJECT

Under an agreement signed last year by the Commission of the European Communities and the Québec government, a feasibility study on the intercontinental transportation of energy in the form of hydrogen continued on both sides of the Atlantic. The Québec aspects of the project are managed by Hydro-Québec, whose counterpart in Europe is the German firm Ludwig-Bölkow-Stiftung (LBS). Some 20 industrial partners are contributing technically or financially to the project.

This $4.2-million undertaking involves a technical and economic evaluation of a full hydrogen production, transportation and utilization cycle. One possible scenario was to build a 100-MW electrolysis plant in Sept-Îles on the north shore of the St. Lawrence River and ship hydrogen from there to Hamburg, the European receiving and marketing centre. Several fuel transportation methods have been proposed together with various possible uses, both in Québec and in Europe.

The two partners carried out their scheduled activities in 1990. In Québec, the project was divided among different task forces according to the work involved and the expertise of the participating organizations.

In Europe, at least ten technical reports have been issued and are now being studied. An economic-analysis model, which will serve mainly to analyze the scale factors, is close to completion. The number of reports produced so far, most in their final version, totals 19: 16 submitted by industrial partners, two preliminary reports about a technical and economic analysis, and a preliminary report on the potential impacts on the environment and public health.

The final report on the second stage of the project, which is scheduled to appear in March 1991, will synthesize all the studies undertaken and establish the guidelines for technological and economic decision-making. The project has been presented at three international conferences and to two Japanese delegations. The final stage will begin immediately after the final report is tabled. Depending on the decisions made, this pilot phase of the project will call for an investment of between $500 and $900 million.

Projets de développement
(Development Projects)

AUTOMATED REORGANIZATION OF METER-READING ROUTES

In 1990, Hydro-Québec made the decision to use technology developed by the Montréal firm Logiroute Systems Inc. to put together an automatic system for reorganizing meter-reading routes. This technology naturally had to be adapted to Québec needs.

The first task was to design a prototype for testing the performance of the new system in a typical sector, Mille-Îles, early next year. This prototype will be used to plan implementation of the system, which is scheduled to begin in spring 1991 across the entire territory served by Hydro-Québec.

Another task was to make an initial evaluation of this technology's marketing potential in North America. The users targeted include electrical distribution utilities and any other companies whose activities include metering consumption (oil and gas).

Projets de développement
(Development Projects)

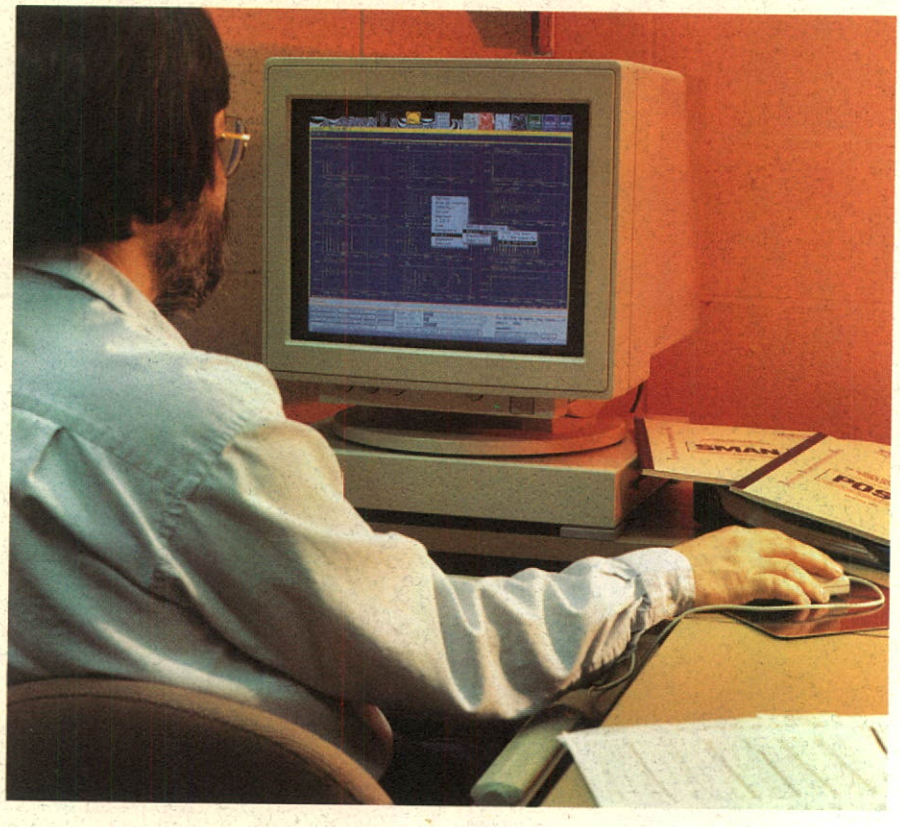
Work finally drew to a close this year on the installation and commissioning of the new power system simulator, which was immediately used for the multiterminal DC system studies under way. Among the various measuring, acquisition and processing systems developed over the year, mention should be made of the LISAC acquisition and control system developed in connection with a program of tests on HVDC cables for the under-river crossing, the high-power laboratory's new measuring system, and the integrated signal storage, display and mathematical processing package for Hydro-Québec's mobile digital acquisition system. A partial-discharge measuring system has also been designed and built for transformer testing.

SIGNAL-PROCESSING SOFTWARE FOR A MOBILE DIGITAL ACQUISITION SYSTEM

A joint project with the power system testing and technical expertise team in the Maisonneuve Region has produced an integrated signal storage, display and mathematical processing software package for the mobile digital data acquisition system developed at IREQ. The easy-to-use package, which has menus and is mouse-driven, was created using a series of software engineering tools developed at IREQ.

The new software has been specially designed for SUN workstations that use UNIX and are linked to the Ethernet system. Using the existing laser printers and editing software of the SUN workstations, analysts in the Maisonneuve Region will be able to perform all tasks from data acquisition to drafting of the final reports, in the same computer environment at the test site itself. The system was recently put to intensive use at Radisson substation.

The mobile digital data acquisition system allows mathematical processing and display of signals.



The software is suitably interfaced to operate with Hydro-Québec's power system simulation programs. It is now used on a regular basis by the power system studies group at IREQ and, occasionally, by other TAI groups, as well as the power system planning department. It is also proving useful at Gentilly 2 nuclear power station for display and processing of operating data.

Mesure et Informatique
(Measurement and Data Processing)

INSTALLATION OF A NEW MEASURING SYSTEM AT THE HIGH-POWER LABORATORY

Upgrading of the testing facilities at the high-power laboratory has led to the design of a new measuring system for the three main test chambers. All the signal measuring, acquisition and processing hardware for this system was developed during the year and a first prototype was installed and put into service in one of the chambers.

This measuring system offers a means of using 24 high-speed channels at an acquisition rate of 1 million samples per second. Acquisition is DC at 150 kHz with a maximum attenuation of 3 dB. Each channel offers a choice of filters, a 12-bit analog-to-digital converter and an input of 0.1 to 1000 V crest. Signal transmission is by optical fibre.

The measuring system also has 12 Mbytes of random-access memory, which is directly accessible from the workstation. The signal measuring, acquisition and selection software has now been developed, thereby completing the system.

Mesure et Informatique
(Measurement and Data Processing)

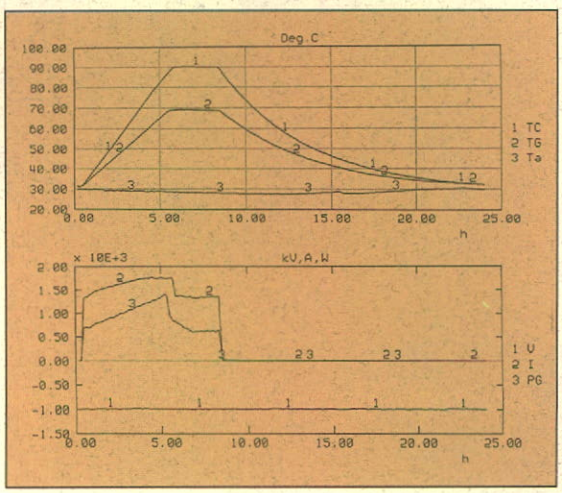
THE LISAC SYSTEM

A new acquisition, processing and control system, LISAC, has been developed in connection with a program of tests on HVDC cables for the under-river crossing. Based on a specialized interpreter language, LISAC has proven its superior performance during a 12-month period of type tests at the high-voltage laboratory and demonstration tests at the outdoor cable testing facility. Multi-purpose as well as flexible, this is a useful tool for the control of slow and repetitive procedures. The encouraging results obtained have led to the development of a control program for pollution tests at the high-voltage laboratory.

The high-power laboratory has also used LISAC for current cycling tests on electrical connectors in which the system successfully underwent more than 375 seven-hour cycles. The laboratory personnel are now planning to use LISAC for various other tests, including mechanical tests in a 315-kV duct bank, sealed-battery testing and accelerated-aging tests on connectors. The system has also been used on occasion for transformer tests, and an acquisition test was successfully performed on a generator busbar supplied at 18 kA.

The present version of LISAC, which was originally designed for a PC386-type microcomputer, has now been adapted for SUN workstations. Icons, windows and a mouse make it easy to use for test personnel and IREQ is therefore planning to install it in half a dozen testing areas in its main laboratories.

Mesure et Informatique
(Measurement and Data Processing)



Thermal-cycling type test on an underground 500-kV DC cable for the under-river crossing (LISAC system)

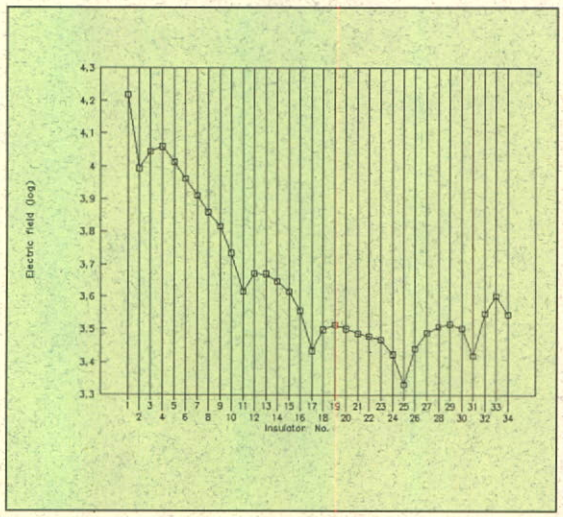
PARTIAL-DISCHARGE MEASUREMENT FOR GENERATOR MONITORING AND PREVENTIVE MAINTENANCE

A research program on the measurement and interpretation of partial discharges with a view to increasing generator availability has been initiated at the request of Hydro-Québec's apparatus specialists. Discharges are known to be associated with the aging of generators, and the latter could obviously be used to better advantage if more accurate data can be obtained about their lifetime and maintenance requirements. It is very difficult to obtain appropriate measurements and a satisfactory interpretation of partial discharges, however, mainly because of ambient noise. Research into this particular problem led to the development, this year, of a reliable measuring system equipped

with new partial-discharge sensors which eliminate background noise. The new system has been installed on many generators at the Manic-Outardes complex, three La Grande plants (La Grande 2, 3 and 4) and Beauharnois generating station. Improvements to the system installation and calibration methods and in the noise-rejection technique should make it considerably easier to interpret the discharge spectra in generators. This will be the research team's task in 1991-92.

Câbles et Isolation
(Cables and Insulation)

Distribution curve of the electric field along an insulator string obtained by the new detector device for faulty insulators. Minima indicate the presence of punctured units.



COMMISSIONING OF THE NEW POWER SYSTEM SIMULATOR

Use of the new power system simulator commissioned this year has exceeded all expectations. A total of seven test areas were used for studies for as many Hydro-Québec departments. Of these, three areas were combined to allow the entire Hydro-Québec 735-kV system, the Radisson-Nicolet-Des Cantons-Sandy Pond DC system, static compensators and part of the New England system to be simulated for the multiterminal DC system studies.

These three test areas can also be used separately if required. Furthermore, they are equipped with an IREQ-designed system allowing simultaneous recording of over 600 signals to which every work-station in the laboratory has access.

The design of the controls and protection systems for new compensators at Chamouchouane substation was verified at a fourth test area, while a fifth served for an analysis of the effects of installing series capacitors on transient overvoltages at the terminals of 735-kV circuit breakers.

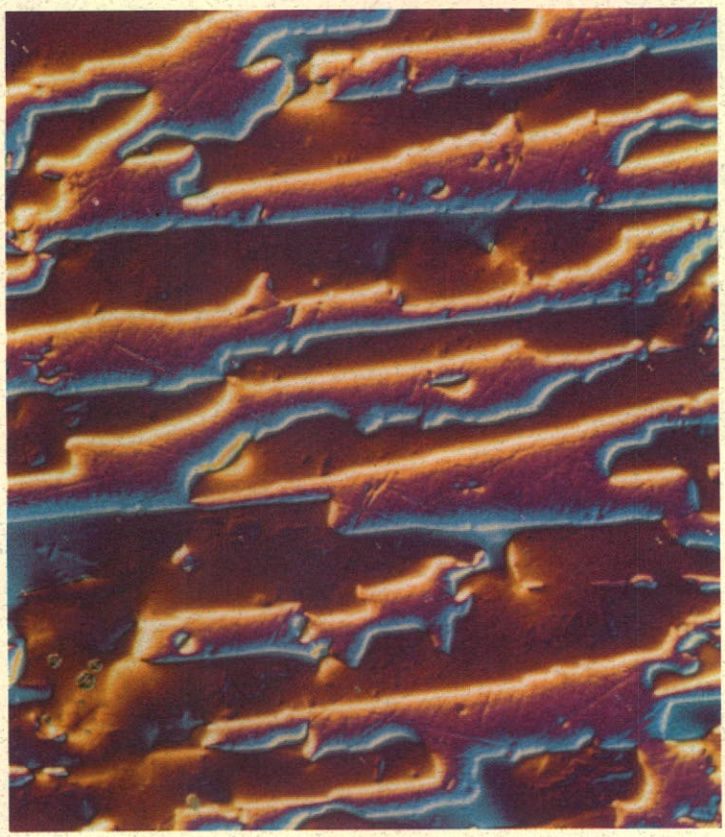
The sixth test area, which is designed to simulate a second configuration of the Hydro-Québec 735-kV system in detail, will be used to assess the impact of series capacitors on the stability of static compensators. Lastly, the seventh test area is dedicated to protection studies and is equipped with the waveform playback system designed at IREQ.

The design, flexibility and capacity of Hydro-Québec's power system simulator make it an unprecedented tool which can be used by several teams at a time to simulate highly complex systems in fine detail.

Simulation de réseaux
(Power System Simulation)

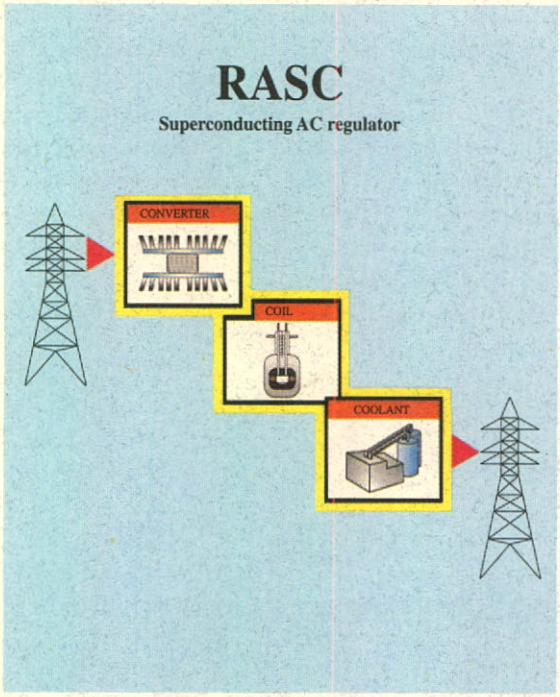
Commissioning of the new system simulator was completed this year.

The main areas of activity explored in 1990 include superconductivity, thermonuclear fusion, hydrogen production, traction batteries and telerobotics. For example, a study was initiated on the impact of superconducting AC regulators on power system stability. IREQ members continue to contribute to the Superconductor Technology Consortium, which has had a very productive first year, patenting conductor texturing and manufacturing processes. With regard to fusion, the tokamak was reassembled and put back into service in summer, equipped with new internal coils for creating a magnetic-diverter configuration; the scientific research program has started up again, along very promising avenues. Meanwhile two research projects on electrolysis materials for hydrogen production were launched, as work continued on ACEP batteries for electric vehicles. The development of control and vision systems for remote manipulators and the design of new tools were the focus of telerobotics activities.



Textured microstructure of a ceramic superconductor at the critical temperature of 92 K. (Photo: Industrial Materials Institute)

The modeling of a superconducting AC regulator was completed during the year as well as technical and economic studies.



MODELING OF A SUPERCONDUCTING AC REGULATOR

A study has been undertaken jointly with Hydro-Québec's power system planning group on the implementation of superconducting AC regulators and their impact on the transient stability of the power system. The role of this regulator would be similar to that of a static compensator, with the additional advantage that it allows active-power exchanges.

Because of this capacity to exchange active power with the system, the superconducting AC regulator is believed to excel the static compensator in performance. It consists essentially of a superconducting coil, which absorbs and stores energy, and a forced-commutation AC/DC link to control the active-reactive power exchanges. Superconductivity eliminates resistive losses in the coils, guarantees an extremely rapid response time and offers almost perfect energy-exchange efficiency.

The superconducting coil comprises 4-μm diameter niobium-titanium filamentary wire, within a CuNi matrix, braided into cables. These cables are then wound into coils which are arranged to form toroidal-shaped magnets. With these toroids, it is possible to build a superconducting AC regulator of up to 300 MJ and 300 MVA, giving an MVA/MJ ratio that meets the needs of the power system.

Several studies are now under way to establish the reliability and economic viability of this new technology. A joint project with the Service Réseau principal, for example, involves modeling an AC regulator based on the use of a superconducting magnet energy storage (SMES) system. The model has been designed and validated for the ST600 transient-stability study program used at Hydro-Québec for power system planning studies. Its characteristics are drawn largely from models of static compensators now being implemented in the ST600 program.

As far as structure is concerned, the model is based on a current source with controlled phase and amplitude to allow adjustment of the active and reactive power of the regulator. The flexibility of the structure is such that three submodels of varying complexity have been developed. The model itself is also very flexible, especially from the point of view of adjustment (setting parameters) and analysis (ratio variables).

The model will be used to assess the effect of implementing superconducting AC regulators at the most suitable locations on the 1996 configuration of the Hydro-Québec power system. Transient-stability studies will be performed to determine whether the regulator can eliminate the need for static compensators, ease the strain on series compensators, and offer equal or better stability. These studies should be completed by June 1991.

Meanwhile an investigation has begun on the North American marketing potential of this new technology. If the transient-stability studies are conclusive, Hydro-Québec plans to set up a partnership with a group of industrial firms that have mastered the technologies needed to build a prototype 22-MJ 10-MVA modular unit. A number of government agencies are also expected to join the original partners, in particular the Fonds de Développement de la Technologie du Québec and Industry, Science and Technology Canada.

Projets de développement
(Development Projects)
Technologie des matériaux
(Materials Technology)
Méthodes numériques
(Numerical Methods)

SUPERCONDUCTIVITY-RELATED ACTIVITIES

The Superconductor Technology Consortium formed by Hydro-Québec, Atomic Energy of Canada Limited and Canada Wire and Cables Limited has had a very productive year. It has patented a conductor texturing process which should reduce production time and is planning to file a second patent for the manufacture of very-high-density conductors.

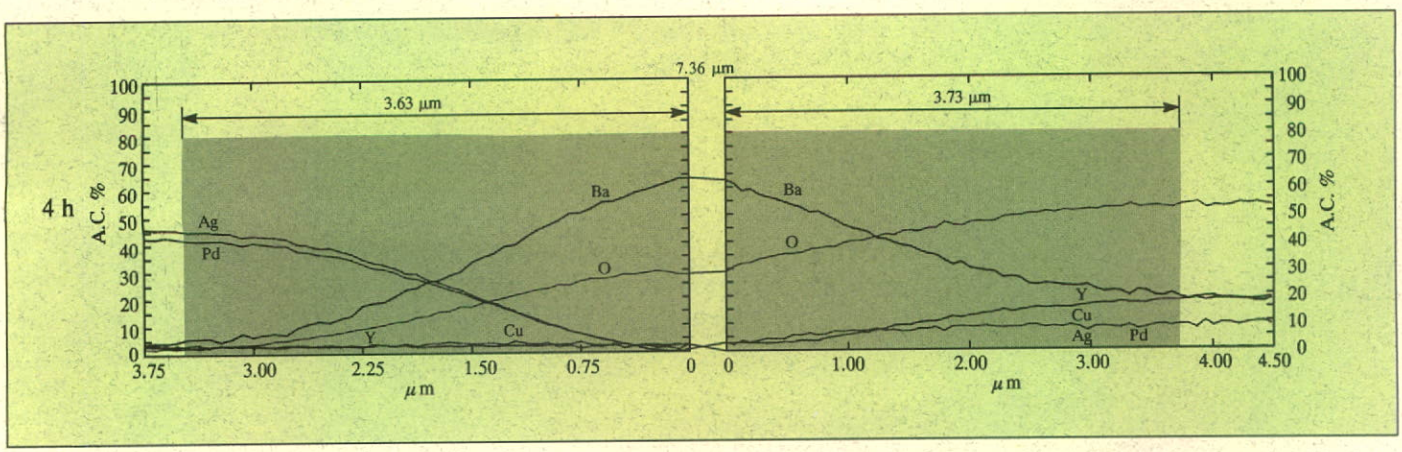
Several wire and ribbon manufacturing processes were assessed during the year. Bulk samples were also produced, some of which are very promising and have excellent intrinsic properties: critical temperature of 92 K, inter-grain critical current density of 10 kA/cm^2 at 77 K and 0 T. Some samples of sheathed wire showed a critical current density above 1 kA/cm^2. Other texturing processes are now being studied with a view to raising the critical current density. The ultimate aim is 10 kA/cm^2 in a field of 1 T.

Agreements have been signed with contractors — Industrial Materials Institute, École Polytechnique de Montréal and Université de Sherbrooke — which will provide the Consortium with the expertise and know-how it needs in order to achieve its objectives.

Further intense research has been conducted on the new phases of YBaCuO and BiSrCaCuO derived by prolonged mechanical ball-milling. Two students at McGill University and the École Polytechnique in Montréal, who are contributing to this work, have completed their master's degrees on this topic.

Papers were submitted to several scientific journals or presented at conferences. Furthermore a scientific network has been set up to promote collaboration with Cambridge, Wisconsin and Ottawa universities, Brookhaven National Research Laboratory, NIST in Boulder, Colorado and other institutions.

Technologie des matériaux
(Materials Technology)



Interfacial reaction (baryum segregation) between a superconductor and its metallic sheath.

TELEROBOTICS ACTIVITIES

In a project launched last year with McGill University and the Centre de recherche en informatique de Montréal to develop a telerobotics environment, a control system and a simulator known as Kali and Kaligraph were put into service together with a force wrist and a guiding system for the laboratory robot. By the end of 1990, this robot should be able to carry out specially programmed tasks in various sequences.

A vision system has now been incorporated into the robotics environment and a series-parallel link between the new robot control system and a workstation has been designed in an aim to optimize the results.

The robotics team also contributed to the development of a remote-manipulator system by Hydro-Québec's distribution department by providing technical assistance with the evaluation of tenders and with the development work itself. It also helped to develop an insulation system for the remote manipulator and a tie-wire removal device. Various tests were conducted in order to analyze the performance of stereoscopic vision systems that will eventually allow linemen to operate the system from the ground.

Lastly, links with universities helped the IREQ team to develop computer vision software known as OASIS, which will be used to analyze and segment surface images, a grip-all clamp stick and a pole-type saddle for remote manipulation. Master's theses on computer vision were submitted to Université Laval by two members of the telerobotics team during the course of the year.

Électronique
(Electronics)

MAGNETIC FUSION

Hydro-Québec's magnetic-fusion research activities, which have been conducted under the umbrella of the Canadian Centre for Magnetic Fusion (CCMF) since 1988, continue to focus on the operation of the Varennes tokamak facility. The CCMF, a joint venture of Hydro-Québec, Atomic Energy of Canada Limited and the Institut national de recherche scientifique (INRS), now has a staff comprising some 90 representatives from various organizations and government agencies including Hydro-Québec, INRS, MPB Technologies and Canatom. The Centre's scientific expertise has thus been enhanced over the years, apace with its contribution to the development of fusion, a promising new energy source with little environmental impact.

The merits and success of the CCMF scientific program were acknowledged in 1990 in the form of a 40% increase in its annual budget, bringing it to $14 million. Hydro-Québec and the Canadian government are the main financial backers of this program.

Reassembly and resumption of service

The early part of 1990 saw the reassembly of the tokamak, which had been dismantled the previous year for the installation of new components, including internal coils for creating a magnetic-diverter configuration and other coils for the rapid control of the horizontal position of the plasma. Delicate in design, these coils were produced at IREQ's machine shops. They were installed at the same time as two new power supplies, one for controlling the vertical position of the plasma, the other for applying polarizing currents.

At the same time, significant improvements were being made to the diagnostics to increase their measuring accuracy and enhance the experimental program. This work was followed by an intensive commissioning period lasting until June when the first plasmas were produced. The scientific research program, for its part, resumed in the fall.

Scientific contributions

In spite of the complexity of the new diverter configuration and the high expectations, start-up proceeded in September with very gratifying results. Successful diverter operation, after long years spent in the planning, fabrication and installation stages, marked an important milestone in the tokamak research program. Results showed that the diverter met all expectations with regard to the reduction of impurities in the plasma.

Tests were performed on a new material for the walls of the tokamak device, boronized graphite. Under a joint project with the Japanese firm Toyo Tanso and the University of California at Los Angeles, a test limiter made of this material was fabricated and subjected to tests. The preliminary results of these tests were encouraging and well received at scientific conferences held in the fall. They will be analyzed in depth in 1991 and further experiments are planned.

A major part of the experimental research consisted in measuring the effect of polarization on the plasma properties and confinement. For this study, the tokamak had been fitted with insulated limiters and neutralization plates so that currents flowing in these plasma-facing components could be measured and currents could be injected into the plasma from external circuits.

The CCMF team discovered that this unique magnetic-diverter/polarization configuration offers a means of controlling the impurities in a tokamak in a heretofore unexpected way. These early results will be validated in more detailed experiments in order to gain a better understanding of the basic mechanisms involved and to promote this significant advance at the international level.

During the year, the CCMF's theoretical research team pursued its modeling studies, which included both analysis and interpretation of the experimental results using, for the most part, computer models.

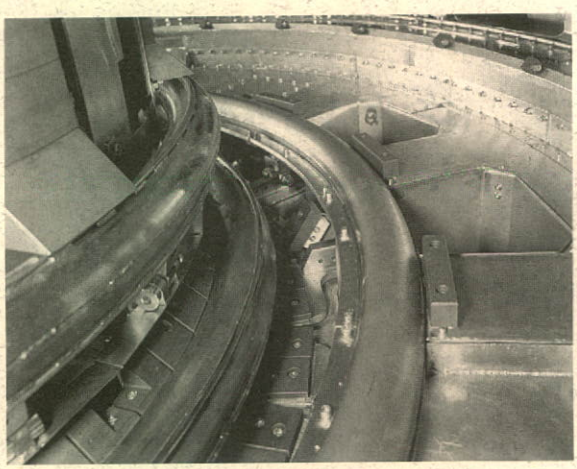
Other activities at the Centre in 1990 comprise the seconding of two senior researchers to the Next European Torus (NET) team at Garching in Germany. Their major contributions were related to the design of the fusion reactor, ITER, planned to be built as a multinational project early next century. The CCMF and its facilities have benefitted tremendously from contributions to ITER in the form of study contracts in areas where its expertise has been used in the development of this far-reaching project.

Fusion — CCMF

RESEARCH PROJECTS CO-FUNDED BY THE HYDROGEN INDUSTRY COUNCIL

The Hydrogen Industry Council, an umbrella organization for the key participants in Canada's hydrogen industry, is helping to finance two two-year research projects on materials used for electrolysis.

The first study concerned the behavior of semiconducting coatings of solid electrolytes employed in the high-temperature (800 to 1000°C) reversible electrolysis process. With this process it is possible to produce hydrogen or, conversely, to generate electricity from hydrogen. The work focuses on the production of thin films of metal oxides — perovskites and, in particular, lanthanates — and their ion and electron transport properties. Of particular interest is the cathodic sputtering technique, which consists in applying the coating to the electrolyte in a rarified argon and oxygen atmosphere.



Positioning of the internal coils in the Varennes tokamak.

The second project involved the development and characterization of anodic materials that offer better stability and a higher performance for the electrolysis of alkaline aqueous solutions. Researchers believe that in the near future it will be economically viable to produce hydrogen from these solutions, provided electrolyzers can operate at far higher current densities than they do at present. From this point of view, the use of new catalytic materials for oxygen evolution and raising of the electrolyzer operating temperature represent two avenues of research worth exploring. Electrochemical processes for depositing the materials and preparing the anode surface are specially interesting in this respect.

Chimie des matériaux
(Materials Chemistry)

OTHER HYDROGEN-RELATED STUDIES

Three cost studies concerning different hydrogen applications were conducted during the year. The first involved comparing the cost of producing hydrogen by electrolysis with that of reforming natural gas. The costs of various ways of storing energy using hydrogen were also studied together with those of transporting electrical energy over long distances in the form of hydrogen. The findings show that it is not economically viable to use hydrogen as an energy carrier at present and many improvements are needed before this technology reaches its break-even point.

Also in relation to hydrogen, two doctoral theses on hydrogen evolution materials and mechanisms of were successfully defended at the Université de Sherbrooke. The work of the two students was supervised jointly by a university professor and one of the Materials Chemistry group's research scientists.

Chimie des matériaux
(Materials Chemistry)

RESEARCH CONTRACT FOR ACEP APPLICATIONS TO ELECTRIC TRACTION

IREQ's polymer-electrolyte battery research team has won a $400,000 contract to study the application of ACEP batteries in the propulsion of electric vehicles. This two-year contract was awarded by Transport Canada and the Québec Transportation Department under an intergovernmental agreement on the development of transport facilities. It is in fact part of a much larger project worth $1 million.

The project involved is just one more in a vast program of research launched a decade ago in an aim to develop all-solid batteries with thin-film lithium and composite electrodes, and a polymer electrolyte. (See the article on page 44.)

The ACEP-Traction project comprises three scientific and technical studies. The team's first task will be to identify, characterize and optimize electrode materials such as lithium, vanadium and manganese oxides, and titanium sulphide, as well as synthesizing and characterizing new polymers that could be used as electrolytes at temperatures ranging from 60°C to 100°C. The next task will be to perform cycling tests simulating the charge-discharge utilization profile of a traction battery in order to evaluate its behavior under steady-state and extreme conditions; these tests will provide a basis for the preliminary definition of a large-battery configuration — over 200 Wh — that meets the traction requirements. The third and last aspect of the project will consist in an assessment of the industrial manufacturing technologies available for thin-film materials and battery assembly. Upon completion of all these tasks, the team will be to ready proceed with the preproduction of prototypes, the next phase in this research, development and demonstration project.

Chimie des matériaux
(Materials Chemistry)

As in past years, many agreements were signed with a view to marketing various products developed at Hydro-Québec. For example, the M3I software, a computerized power outage management system, has been purchased by the City of Los Angeles and a subsidiary set up to develop this system. Hydro-Québec has purchased a large share of the capital stock of Ultra Optec, and signed a licensing agreement with this Québec firm for the development of four measuring and detection devices. The utility has also acquired shares in Automatisation Famic, which will develop a real-time and a supervisory-control system, ALCID and SICC, for substations and generating stations. Lastly, an agreement has been signed with Vibro-Meter, a Hydro-Québec subsidiary, to market two new measuring systems.

The power outage management system, M3I, has been purchased by the City of Los Angeles and a subsidiary has been created to market this microcomputer-based system.

MARKETING OF M3I SYSTEM AND CREATION OF A SUBSIDIARY

Hydro-Québec's instantaneous interactive-image processing system, M3I, was the subject of a major contract in 1990: the Los Angeles Department of Water and Power has purchased this new outage management system. M3I offers utilities a means of computerizing all the operating functions of an electrical distribution network on a PC. Formerly known as CED-Micro, the system was developed in a pilot project undertaken jointly by the Saint-Laurent Region and TAI.

The contract comes on the heels of an agreement signed last year with the same U.S. utility which covered the implementation of a prototype outage management system. The prototype was delivered early in 1990 and has since been used to assess the reliability of the utility's distribution network. The Los Angeles Department of Water and Power subsequently invited a dozen North American firms including Hydro-Québec to bid on the design, implementation and maintenance of an Electric Trouble System (ETS) for its entire power grid. Hydro-Québec won the contract.

As soon as the agreement was signed, Hydro-Québec created a subsidiary, M3I Systems Inc., to carry out the project. Largely owned by another Hydro-Québec subsidiary, Nouveler, the new company will be responsible for developing and marketing computer systems for the operating and distribution centres of electrical and other (telephone, gas or water) utilities. M3I Systems Inc. hopes to attain annual sales of around $20 million in the medium term. Although North America is its first target, the company plans to benefit from the marketing initiatives already taken by TAI in Europe and Asia.

Bureau de commercialisation
(Commercial Development Bureau)
Projets de développement
(Development Projects)

ACQUISITION OF ULTRA OPTEC CAPITAL STOCK

Hydro-Québec, through its subsidiary Nouveler, has acquired a large share of the capital stock of the Boucherville company, Ultra Optec. This company makes and markets various devices based on ultrasonics, optics, electronics and laser technologies, and develops signal- and image-processing software.

Ultra Optec also contributes to research and development projects in the fields of laser-ultrasonics and optics with the Industrial Materials Institute in Boucherville, a branch of the National Research Council Canada.

Hydro-Québec's participation allows this company to build and market measuring, detection and testing instruments developed at IREQ or in other Hydro-Québec departments.

The agreement signed between the two parties has already led to the awarding of manufacturing and marketing licences to Ultra Optec for four devices: a partial-discharge detector, a microhmmeter, an audio cable identification system and a remote-controlled phasing device. All four products will go on the market in 1991 and will soon be followed by other products.

Bureau de commercialisation
(Commercial Development Bureau)

COMMERCIAL DEVELOPMENT OF SICC AND ALCID

A licence was awarded last December to Automatisation Famic Inc. of Saint-Laurent, Québec, for the commercial development of the SICC and ALCID systems. On the same occasion, Hydro-Québec, through its subsidiary Nouveler, bought capital stock in this company.

These two systems were developed as a means of dealing with the ever-larger capacity and complexity of Hydro-Québec's power grid, which are making heavy demands on generating station and substation control. The last few years have seen a constant increase in the volume of station data to be collected and functions to be performed. The basic functions of measurement, control and protection are now flanked by others, equally essential for more efficient control and monitoring, such as sequence-of-events recording, annunciation, and local automatic controls. At the same time, supervisory-control requirements at the

level of regional and central control centres have become even more stringent. These new functions have made installation and management of control systems so complex that Hydro-Québec has developed a computerized system for power system control for substations and generating stations.

As commercial-development activities progressed, work also continued on the refinement and implementation of ALCID and SICC throughout the year. The former is a distributed intelligence system, which is used for real-time and supervisory control at substations, while the latter, SICC, covers the same functions but at the level of generating stations. Both systems have benefitted from all the latest developments in microcomputer and communications technologies. They incorporate all control functions apart from protection, i.e. alarms acquisition, equipment monitoring and operation, measuring, adjustment of settings, automatic reclosing, service restoration, line changeover, capacitor bank switching, load-shedding and load pick-up. Other automatic controls can easily be programmed and added to the system.

Bureau de commercialisation
(Commercial Development Bureau)

TWO LICENCES AWARDED TO VIBRO-METER

Two measuring systems developed by the Maisonneuve Region's Power System Testing and Technical Expertise team were recently the subject of a marketing agreement. The first system, MESSIRE, consists of a simplified method of measuring the energy efficiency of individual turbines, which was designed and built to meet the needs of Hydro-Québec's Service Équipement de production for a project on preventive turbine-generator maintenance based on monitoring.

MESSIRE combines software, transducers and computers to perform real-time continuous measurements of the water passing through the turbines and the energy efficiency of each unit. MESSIRE'S main function is to detect decreases in efficiency due to wear or mechanical failure or increases in load losses due to obstructed trashracks. The system has been validated on a Kaplan turbine at Carillon generating station and is currently being evaluated with a view to using it throughout the Hydro-Québec power system. Several American utilities seem interested in MESSIRE's potential to optimize river flow management.

The second measuring system, known as ECOR, was designed for monitoring and adjusting the speed governors of turbine-generators. It is therefore used as a maintenance tool for speed governors, which contribute to turbine security, generation reliability and power system stability.

The firm responsible for marketing these two systems is Hydro-Québec's subsidiary, Vibro-Meter, which is already marketing the air gap measuring device developed for generators. The two new products will be available in FLUKE and PC versions. They are the first to be marketed of a whole collection of computer programs and systems designed by Hydro-Québec for optimizing the operation of hydroelectric generating stations.

Some twenty specialized computer programs developed by the utility are now being marketed by affiliated companies in fifty different countries.

Bureau de commercialisation
(Commercial Development Bureau)

Throughout the year, Hydro-Québec International (HQI) pursued its goal to promote and market the utility's expertise. This Hydro-Québec subsidiary is now active in some 30 countries in Africa, Asia, the Caribbean and South America. Members of TAI participated in the organization of a number of international scientific conferences in Montréal.

AFRICA

Cameroon

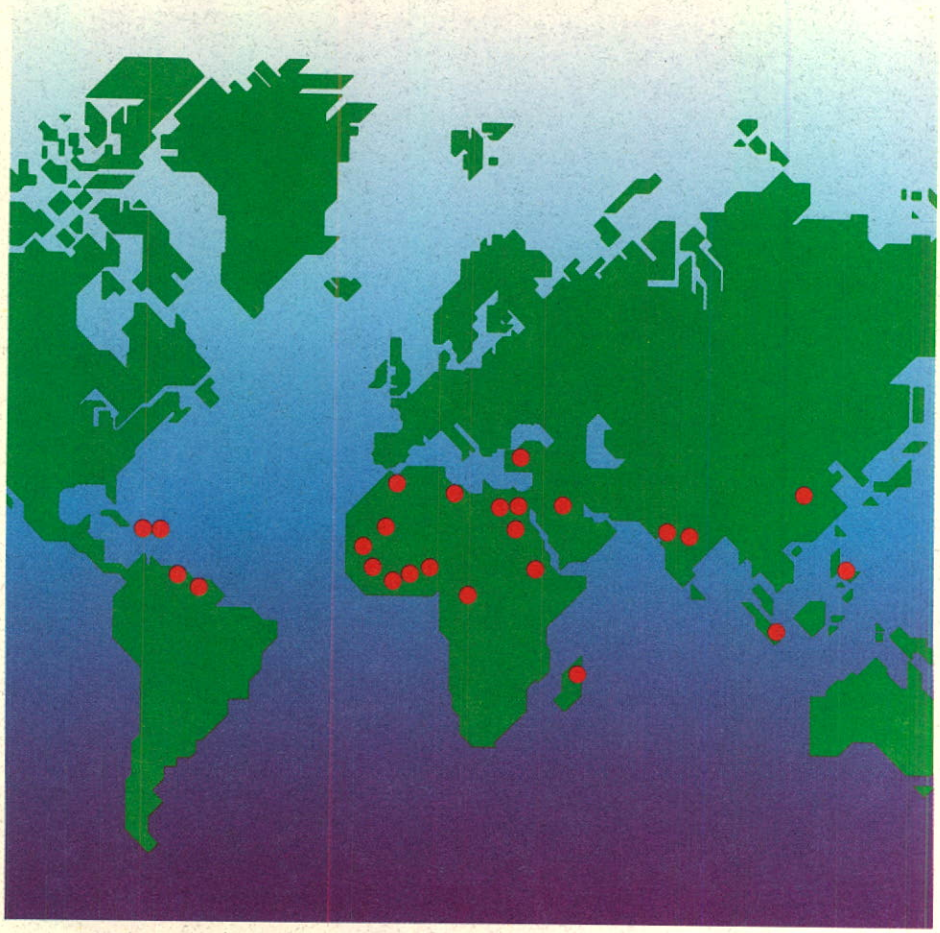
This year again, collaboration with SONEL, Cameroon's national electricity company, took the form of a comprehensive training and technical assistance program set up several years ago. Under a more recent contract to provide cooperation and institutional support, some ten Hydro-Québec specialists are now working in various areas of activity at SONEL. The training program for the utility's engineers, technicians and managers continued for the sixth consecutive year at institutional organizations in Québec and in different Hydro-Québec departments.

Egypt

Two managers and four engineers from the Egyptian Electricity Authority came to Hydro-Québec for training in power system control. These training sessions were organized as part of a project to set up a power system control centre in Cairo, which has been undertaken by Ontario Hydro.

Ethiopia

In 1990 a feasibility study of the Halele-Werabesa hydroelectric project was initiated for the Ethiopian Electric Power Authority. HQI is working in cooperation with consulting engineers from the Montréal firms Rousseau, Sauvé, Warren and ACRES on this project.



Ghana

Work began at the end of 1990 on an electrification project for the Hohoe-Jasikan region. Undertaken for the Electricity Corporation of Ghana, this project consists in setting up a power distribution network with a North American grounding system. Completion is expected some time in 1991.

Guinea

A new technical assistance contract in cooperation with Price-Waterhouse was initiated in 1990. Three Hydro-Québec experts in power generation, transmission and distribution have been seconded for a two-year period to Guinea's national electricity company, ENELGUI.

Ivory Coast

Five Hydro-Québec specialists have been seconded for one to two years to government agencies in the Ivory Coast. One is acting as advisor on accounting and financial matters to the national electricity company, three others are involved in the areas of transmission and distribution, and the fifth, a distribution engineer, is working with the major projects control division.

Mali

HQI, in a consortium formed with Tractebel, has been supervising the construction of a 230-km stretch of 150-kV line between Bamako and Ségou which began last year. This line will constitute one of the main arteries of Mali's electric grid and will supply a number of 15-kV and 30-kV medium-voltage systems The engineering studies were completed in 1988, four years after they began.

Meanwhile, an expert in equipment standardization has joined the procurement specialist seconded in 1989 for a two-year period with the national utility, EDM.

Morocco

Two preliminary studies were completed early in 1990. The first concerned the construction of a mini-hydroelectric generating station near a village in the Atlas Mountains, while the second involved a distribution system for some 50 Moroccan villages. These two studies were carried out for Morocco's Department of Energy and Mines, in cooperation with the Montréal firm of consulting engineers, Dessau.

Senegal

A Hydro-Québec specialist seconded in 1987 to Senegal's government-owned utility continues to act as technical advisor in the field of accounts receivable.

Senegal River Development Organization

Further economic studies have been conducted for the project related to the future transmission line to carry electricity from the Manantali hydro plant in Mali to the three member countries of the Organization, Mali, Mauritania and Senegal.

In the last few years, HQI has carried out several power system planning, design and line routing studies for the Organization. It has been assisted in this work by Dessau consulting engineers.

Togo

A specialist in stock management and procurement from Hydro-Québec's Saint-Laurent Region continues his two-year assignment to Togo's electrical utility. His work is due to finish in the fall of 1991.

Tunisia

A Hydro-Québec specialist in high-voltage transmission technology gave a seminar in Tunis as part of a 12-month expertise and training contract, which began in November 1990.

ASIA

Bangladesh

Further work on Bangladesh's power system control centre was performed in 1990. This centre has been entirely designed, installed and commissioned by HQI over the last few years.

China

Hydro-Québec continues to offer technical assistance to various electric power research institutes in China. A number of Chinese engineers and specialists have come to Hydro-Québec for training in various areas of activity such as power system simulation, telemetering, remote control, power system protection, conductor vibration, etc.

In the meantime, a feasibility study was launched in 1990 in relation to the Xiaslangdi hydroelectric project. A Hydro-Québec specialist in plant rehabilitation spent four months in China working on this project.

India

Technical consultancy assistance was provided to Bharat Heavy Electricals Ltd. regarding system studies for static-var compensation equipment for flicker control at a steel plant owned by Hindustan Development Corporation in Gwalior.

One of TAI's power system studies experts continued to lend assistance in a special R&D project approved by the Indian Planning Commission. The ultimate aim of this project is to build up the national utility's expertise in HVDC system design, installation and operation. Work has already begun on the construction of an experimental 400-MW, 200-kV link some 200 km long. The TAI expert not only took part in the commissioning of the first phase of this line,which was completed in October 1989, but is acting as consultant for the design of the second and third phases.

Malaysia

Over the next ten years, the Sabah interconnected power system in Malaysia will have another ten or so substations and generating stations added to the five that already exist. First, however, it will be necessary to set up a national dispatching centre for real-time control of the power system and, considering the inadequacy and precarious state of the present carrier-current communications network, install a reliable modern (probably microwave) telecommunications system.

The project dates back to May 1987 when HQI replied to an international call for tenders by Lembaga Letrik Sabah. Its winning bid covered all the engineering and assistance requirements, from the feasibility study to supervision during the commissioning of the dispatching and telecommunications systems. All equipment will be supplied key in hand by the manufacturer who submits the best bid. The project could also include the construction of a building to house the new dispatching centre. The Groupe Équipement will act as prime contractor for this project with Hydro-Québec experts taking charge of power system control, automatic-control and telecommunications planning, systems engineering, architecture, factory follow-up, site supervision, commissioning tests, training, etc. The project is expected to cost over $30 million and to take over two and a half years to complete.

Philippines

An IREQ expert is currently working as a consultant to review the studies of a DC link between the future geothermal generating station on the island of Leyte and the Luzon geothermal plant.

CARIBBEAN AND SOUTH AMERICA

Dominican Republic

In a joint project with the Montréal firm Sofati, HQI has just signed a first agreement with the Dominican Republic under which the two companies will upgrade and operate the electrical distribution system in the capital, Santo Domingo. Upon completion of the four years this work is expected to take, HQI and Sofati will operate the system for a further eleven years.

Guyana

A corporate diagnostic study has been undertaken at Guyana Electric Corporation for the United Nations Industrial Development Organization. The main focus of this study was on the company's financial structure and rates.

Haiti

Two studies were carried out for Haiti's electricity company in 1990. One dealt with the master plan for the nation's electricity service, the other with company training requirements.

Venezuela

Under the terms of a technical-assistance contract signed with the HQI-BELT consortium in 1987, Hydro-Québec continued to provide Electrificación del Caroní with expertise on 800-kV transmission.

MULTINATIONAL ELECTRICAL INTERCONNECTIONS

Egypt-Turkey

A joint study with Ontario Hydro on the interconnection of the power systems owned by Egypt, Iraq, Jordan, Syria and Turkey continued over the year. Amman, Jordan, is the chosen headquarters of the agency formed by these countries to handle the management aspect of this study. A Hydro-Québec specialist has been seconded to Cairo for the duration of the project.

Persian Gulf

A study of the interconnection of power systems operated by Persian Gulf countries, which was initiated last year, continues to mark progress. The study was undertaken jointly with Lavalin for the Gulf Cooperation Council. In addition to Bahrein, headquarters of the committee responsible for this study, the countries include Kuweit, Saudi Arabia, Qatar, Oman and the United Arab Emirates.

Zaire-Egypt

Work was completed this year on a contract signed in 1989 to establish the terms of a mandate for study an interconnection between Zaire and Egypt. This contract was undertaken for the African Development Bank.

ACTIVITIES RELATED TO THE FRANCOPHONE SUMMIT

Many activities took place this year under the auspices of Hydro-Québec's cooperation and training program for electrical utilities, which was launched at the request of the Québec government in 1987 following the Francophone Summit. The objective of this program is to make Hyrdro-Québec's technological expertise and administrative know-how available to other utilities to enable them to meet their own needs in fields such as power system planning, operation and management. Hydro-Québec has earmarked $5million for this five-year program, which is managed by HQI.

Various training and cooperation projects were carried out in 1989 in several French-speaking African countries:

An interconnection study was performed and a subregional master plan was developed in region C of Africa, which includes Mali, Senegal, Mauritania, the Gambia and Guinea-Bissau.

— The possibility of setting up a telecommunications network for power system management at SONEL, the national electricity company of Cameroon.
— A feasibility study was conducted to assess energy generation and distribution in Bissau, capital of Guinea-Bissau.
— Two seminars on grounding practices on North American distribution systems were held, one in Niger, the other in Burkina Faso.
— Regideso, Burundi's national electricity company, had its financial adjustment plan updated by HQI representatives.
— Three Hydro-Québec specialists contributed to a seminar on marginal costs and rates in Madagascar.
— A technical and economic mission was organized to analyze the feasibility of a pilot project for the STEG in Tunisia using Canadian SCC-2 (capacitive-coupling power supplies) technology for planned rural development in that country.
— Haiti's government-owned utility, EDH, has hosted three Hydro-Québec missions to provide technical and economic assistance. Members of the utility have worked with ten specialists from Hydro-Québec to gather the data needed to develop short-, medium- and long-term solutions to Haiti's power supply problems (generation, transmission and distribution).

IEEE TRANSFORMER COMMITTEE MEETING

This year, Hydro-Québec was asked to organize the twice-yearly meeting of the Transformer Committee of the Institute of Electrical and Electronics Engineers. This committee is responsible for promoting and coordinating the activities of the Power Engineering Society, one of the branches of the IEEE, in the area of power and instrument transformers. Its work consists mainly in drafting or revising IEEE and ANSI (American National Standards Institute) test standards for transformers and other apparatus involved in the transmission of electrical energy.

TAI's two permanent members on this committee were responsible for the organization. The meeting took place in Montréal on October 21-24, 1990, and drew the record number of 257 engineers. The activities organized for the participants included a visit to the high-voltage laboratory at IREQ, which attracted some 200 members.

Mesure et Informatique
(Measurement and Data Processing)

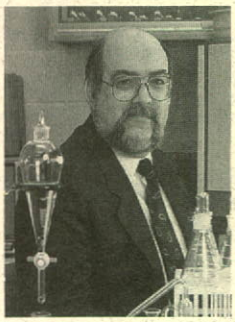
ICEC-IEEE HOLM CONFERENCE ON ELECTRICAL CONTACTS

The 15th International Conference on Electric Contacts (ICEC) and the 36th IEEE Holm Conference on Electrical Contacts were held jointly in Montréal in late August — the first and last time this century that Canada was hosting these conferences. The purpose of this biennial event is to provide an international forum for presenting and discussing the latest developments in the field of electric contacts and recent advances in materials and processes in electric, electronic and telecommunications equipment.

One of IREQ's senior researchers was Chairman of the Organizing Committee for the conference. The 300 participants had a choice of 86 presentations covering a wide variety of topics and had an interesting tour of the research and testing facilities in Varennes.

Technologie des matériaux
(Materials Technology)

Guy Bélanger, Manager, Service Chimie des matériaux, was elected Fellow of the Academy of Science of the Royal Society of Canada.



Roland Gilbert, senior researcher, Service Chimie des matériaux, was made a Fellow of the Chemical Institute. He also received, jointly with Claude Lamarre, the Electrical Power Research Institute (EPRI) Award for his studies on morpholine decomposition.

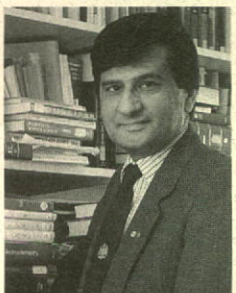
Claude Lamarre, senior researcher, Service Câbles et Isolants, shared with colleague Roland Gilbert the EPRI Award for his work on morpholine decomposition in nuclear power stations.

Michel Landry, senior researcher, Service Appareillage électrique, was elected researcher of the year in his department.

Sarma Maruvada, senior researcher, Service Lignes aériennes, was appointed Chairman of CIGRÉ Study Committee 36, Interference.

Ashok K. Vijh, O.C., fellow research scientist, Vice-Présidence Recherche, was honored several times during the year. He was named Officer of the Order of Canada in recognition of his significant contributions in the field of electrochemistry and the advancement of science in Canada and throughout the world.

The Chemical Institute of Canada awarded him the Canada Palladium Medal, the highest distinction in the domain of chemistry research in this country. Dr. Vijh was also elected by Royal Society of Canada colleagues to the position of Director of the Applied Sciences and Engineering Division.



(From 1. to r.) Michel Bourdages, Guy Saint-Jean (TAI), Michel Mondor (Joslyn Canada), Robert Jones (R&D 100), Robert Giraldeau (TAI) and Daniel Dumont (Joslyn Canada)

R&D 100 AWARD

The American magazine Research & Development selected the ZQTS surge arrester as one of the most innovative products of the year. This non-fragmenting arrester with its polymer-concrete housing was developed jointly with Joslyn Canada. The TAI team comprised Michel Bourdages, senior researcher, Service Lignes aériennes, Guy Saint-Jean, Manager, and Robert Giraldeau, technician, both of the Service Appareillage électrique.

MICA PRIZE

The Conseil de l'industrie électronique du Québec awarded its MICA prize to the PAVICA vibration sensor and analyzer for overhead lines, which was developed by senior researchers Jean Brunelle and Claude Hardy, Service Mécanique, and Jacques Bélanger, technician, Service Électronique. The St. Lambert (Québec) firm Roctest is now marketing this device.

(From 1. to r.) Jacques Bélanger, Jean Brunelle and Claude Hardy

(From 1. to r.) Marie-Claude Pétrin, researcher, Jean-Luc Fihey, senior researcher, Raynald Simoneau, senior researcher, Jacques Larouche, technician, Raynald Rioux, technician (both of Service Technologie des matériaux), Serge Turcotte, technician (Services techniques), Martin Beaudoin, researcher (Service Électronique), Tony Di Vincenzo, technician and Bruce Hazel, senior researcher (Service Technologie des matériaux)

RESEARCH TEAM OF THE YEAR

The cavitation research team of the Service Technologie des matériaux was voted IREQ's research team of the year. Its achievements include the development both of new materials, such as Hydroloy steel (IRECA) to minimize damage by cavitation and increase turbine service life, and repair processes, in particular those based on the use of robots.

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*Louis Masson is now Vice President, Power System Planning

**Toby Gilsig is now President and Chief Executive Officer of M3I Systems Inc.

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April 1991

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