Hydro Québec

# HydroTech

Recherche et Développement
Institut de recherche d'Hydro-Québec – IREQ
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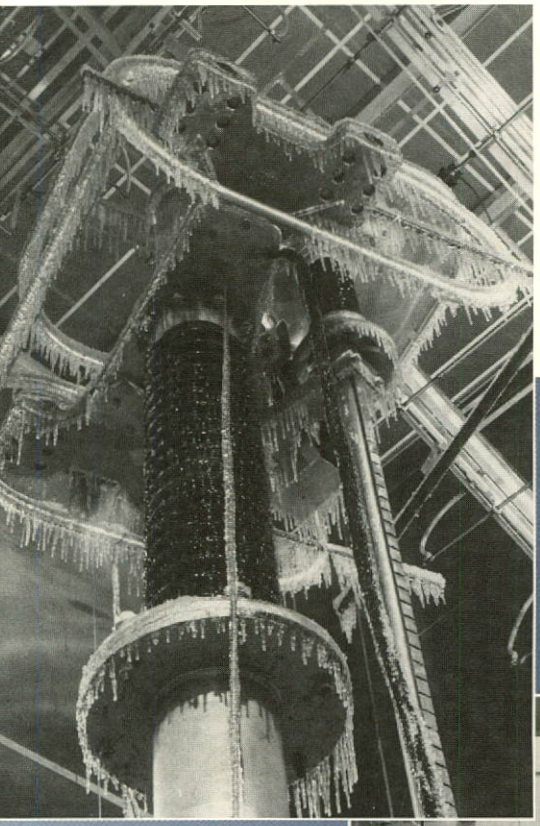
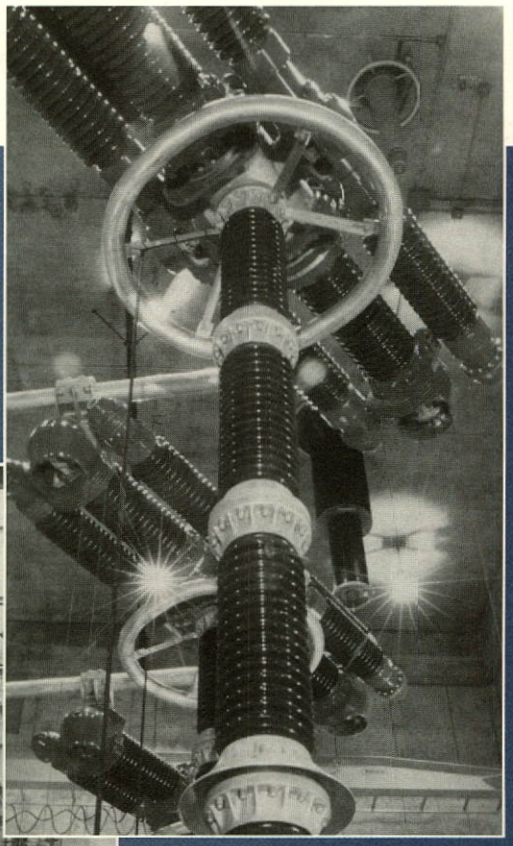
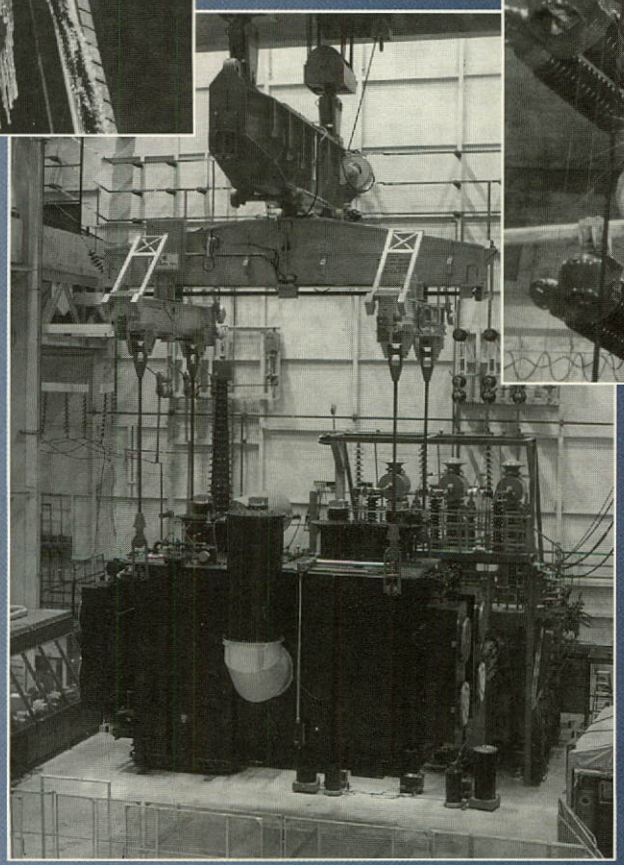
## ISO Guide 25



Mechanical and environmental testing



High-power testing



High-voltage testing

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# IREQ's high-power and high-voltag receive ISO Guide 25 accreditation

**It was with great pride that IREQ's high-voltage and high-power laboratories received an accreditation certificate issued by the Standards Council of Canada (SCC). After conducting an in-depth review, the SCC found that the two laboratories complied with the international specifications in ISO/IEC Guide 25 (commonly referred to as "ISO Guide 25"), as well as with its own requirements. Both are now officially accredited laboratories, which confirms their capability to conduct tests that fall within the scope of their accreditation, the most extensive ever granted in this field to any Canadian laboratory.**

### High-power laboratory

The high-power laboratory conducts electrical, mechanical and environmental tests on apparatus and related components at the request of Hydro-Québec departments and outside clients. Its staff of 70 is involved in two main areas: electrical and mechanical testing. Its installations include a high-voltage station used for direct and synthetic testing at voltages of up to 800 kV, an 80-kV medium-voltage station, a high-current station, an experimental line, and several test areas designed for mechanical and environmental testing, and heat-run and accelerated-aging tests.

### High-voltage laboratory

IREQ's high-voltage laboratory is unique in North America in terms of testing lines and equipment rated at voltages up to 2100 kV AC and ±1200 kV DC. With a staff of 48, the high-voltage laboratory comprises an impressive test hall (80 m x 67 m x 50 m high); a special test area for power transformers and shunt reactors; two pollution chambers; a high-voltage underground-cable test facility; and an experimental line.

### Testing on a wide range of products

Together, the two laboratories offer the necessary range of voltage, power and environmental conditions for conducting tests on a wide variety of apparatus such as circuit breakers, transformers, capacitors, interrupting and disconnecting switches, insulators, surge arresters, metal-clad equipment, busbars, connectors, sleeves, fuses, line hardware, batteries, cables, grounding assemblies, bushings, boom trucks and insulating tools.

## ISO/IEC Guide 25 accreditation

ISO/IEC Guide 25 accreditation pertains to testing and calibration laboratories. "Laboratory accreditation" is formal recognition by an authoritative body that a laboratory is competent to carry out specific tests or specific types of tests. It represents an assessment of the supplier's quality system and of the technical capability or competence of its personnel. In addition to the overall specifications regarding the supplier's systems (in conformance with ISO 9002), Guide 25 requires a certain level of competence among technical staff. Moreover, it stipulates that well-defined test and calibration procedures be used. It also sets more specific requirements regarding the calibration and management of equipment, including references to national and international standards applicable to laboratories. Such accredition must also be considered as an independent and relatively specialized form of certification, one that is separate from quality management systems certified to ISO 9000.

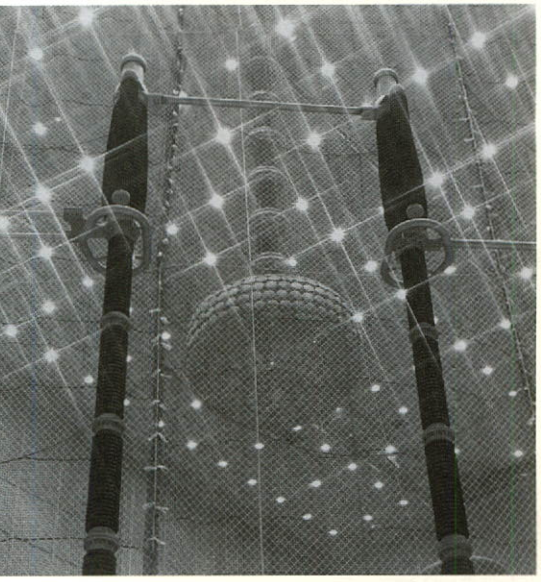
*(Source: Peter S. Unger, "ISO 9000 versus ISO/IEC Guide 25 for Laboratories," CAL LAB, March-April 1996, p. 19-24, American Association for Laboratory Accreditation.)*

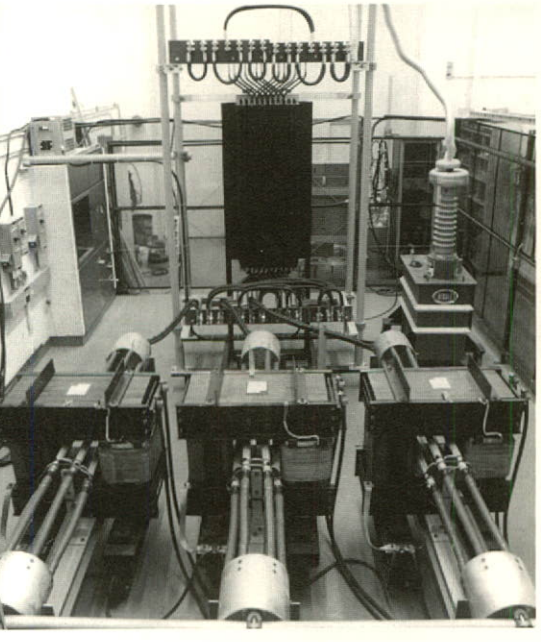
# e laboratories

The SCC accreditation covers a very extensive testing capability which, it should be pointed out, is available not only to Hydro-Québec but also to outside utilities and manufacturers in Québec, Canada, the United States and abroad. All of the tests are carried out in accordance with generally recognized industry standards such as IEC, ANSI, IEEE, CEA and NEMA, as well as Hydro-Québec's own specifications.

It is interesting to note that in the case of the high-power laboratory, the accreditation extends to 105 standards and specifications and pertains to both electrical and mechanical tests, while the high-voltage laboratory has received accreditation for a total of 85 standards, enough to fully meet the needs of both large and small electric utilities and manufacturers. ■

**High-voltage tests on an $SF_6/CF_4$ circuit breaker**



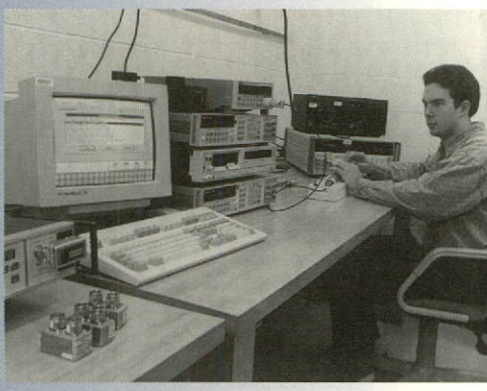


**Mechanical and environmental testing on a circuit breaker**

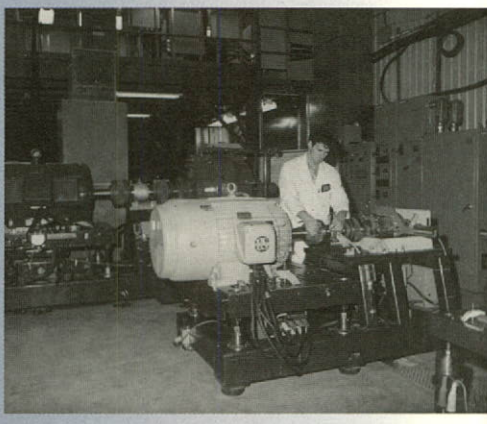
**Aging tests on stator bars**

## Other accredited laboratories

Two other IREQ test installations were accredited over the past two years. The Calibration Laboratory received official accreditation confirming the capability of its calibrating measurement devices for the DC voltage, current and resistance, with the scope of the accreditation extended to include



**Calibration**



**Testing the performance of motors at LTEE**

AC voltage and current, AC ratio, capacitance, frequency and power measurement (see *Hydro-Tech*, Summer 1996). Hydro-Québec's electrochemical and electrical technology laboratory, LTEE, which conducts studies and testing in the utilization of electricity for industrial, residential and commercial users, has received accreditation for its test facilities for studying the performance of induction motors and test benches for lighting systems.

# New system for inspecting circuit breakers in service

**Hydro-Québec's high-voltage circuit breakers are getting older but, until now, no effective method has been devised to check their mechanical condition during operation at a reasonable cost and without having to dismantle them. Pending installation of the MONITEQ system on most of these breakers (see article on p. 13), new methods are needed for checking the condition of this equipment in order to ensure its safe operation.**

To this end, a project was initiated in an aim to design a system that would primarily be used to measure the blasting time of air-blast circuit breakers in service. Using pressure sensors, the internal pressure of the tanks is measured as well as the overpressure produced at the exhaust as a result of breaker opening operations. The new system, which is portable, easy to install and user-friendly, operates once the circuit breaker has been deenergized. It consists of the following components:

- 32-channel data acquisition system, with 12 bits per channel and a sampling rate of 1 kHz, equipped with pressure sensors to carry out the measurements and easily fitting into one or two cases for transport;
- Laptop computer which includes a database, processing functions and an interface for displaying the information obtained using the verification tests; the software must be fully configurable and operate independently of the type of sensor being used.

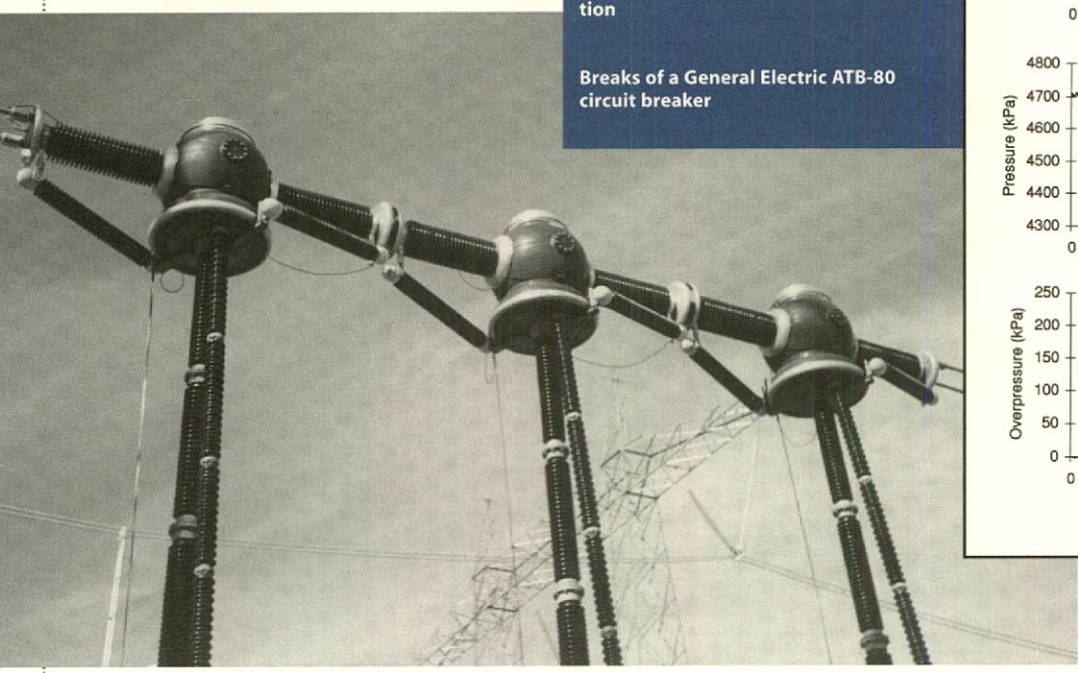
Based on the processing of data and the overpressure measurements, it should be possible to determine the blasting time of each valve as well as the interval of time between the command signal and blasting in relation to previously obtained results and the time the contacts take to separate. Too great a variance from the results anticipated would point to a mechanical defect. Additional data could also be obtained on circuit breaker operation based on the maximum value of the measured overpressure or the overpressure signal waveshape.

### Initial validation tests at Chamouchouane substation

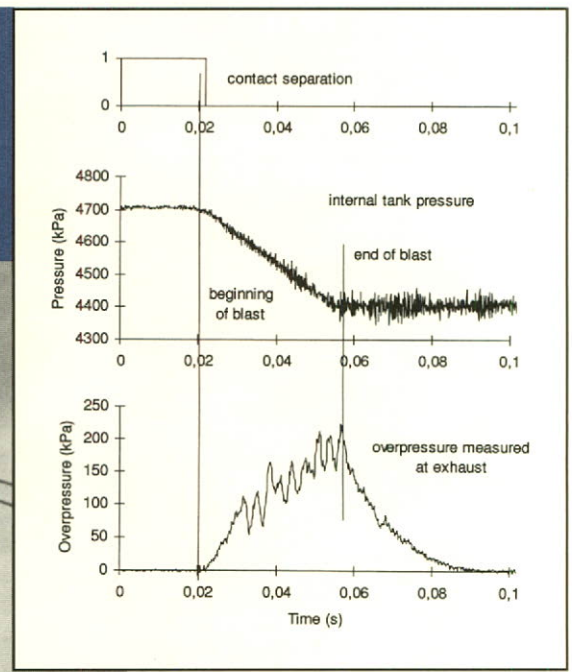
Although they were not very old, many General Electric ATB-80 type circuit breakers have failed in service over the past several years. However, the cause of these sudden failures has still not been determined. At Chamouchouane substation in northern Québec, nine ATB-80 breaker heads were rehabilitated and slightly modified, but operating personnel could not guarantee their reliability during switching operations. The Electrical Apparatus department was therefore asked to use the verification system, then in the process of being developed, to take measurements during blasting.

Two types of measurements were made on the ATB-80 circuit breaker. First, a reading of the internal pressure in the compressed-air tank of the break was taken, after which the overpressure was recorded at the exhaust. An analysis of the results showed that, despite minor anomalies, all of the nine heads were operating adequately. These substation checks in some way allowed the measurements, specially designed to characterize circuit breaker blasting, to be validated.

The project, which was carried out at the request of the Facilities Maintenance and Dam Safety department, was coordinated by Gaétan Daigneault and a team from IREQ's Electrical Apparatus department. ■



**Breaks of a General Electric ATB-80 circuit breaker**




**Overpressure and internal pressure measurements on an ATB-80 circuit breaker at Chamouchouane substation**

# The SCC-4: A new generation of ground-wire power tap

**Over the past two decades, IREQ's researchers have developed different generations of capacitive dividers supplied by the overhead ground wire or high-voltage line conductors, thus allowing remote communication stations or villages not on the distribution system to be hooked up to a power supply. Over the years, each new generation of the capacitive-divider technology has been marketed by the firm CEGELEC B.G. Checo worldwide.**

The SCC-4 at Boucherville substation

The need to develop innovative solutions once again became pressing when Hydro-Québec implemented its fibre-optic telecommunications network, which required that new installations be set up, especially in remote areas where there are high-voltage lines but no distribution system. At the request of the utility's Telecommunications group, IREQ's Electrical Apparatus department and CEGELEC therefore undertook to study the feasibility of 2- and 20-kW sources supplied by the overhead ground wire and, subsequently, to develop a 1- to 2-kW preproduction unit.

Early in 1996, a first capacitive source was put in operation and validated after tests were carried out at 735-kV Boucherville substation, not far from Montréal. The source supplies 1.5 kW of power at an output voltage of 120 V AC; the voltage is sine-shaped but its amplitude fluctuates according to the voltage of the overhead ground wire, with the latter varying only by ±5%. The source comprises a filter damper, patented by Hydro-Québec, and an antiferroresonance circuit. This circuit is crucial considering that the transformer is hooked up directly to the overhead ground wire, contrary to the 2-MW, three-phase SCC-3 capacitive divider system installed at Rivière-Sainte-Anne substation in the Gaspé region (see *Hydro-Tech,* Fall 1995, p. 17). Equipped with all the required protective relays and directly connected to the conductors of a 161-kV line, this substation was also developed jointly by Hydro-Québec and CEGELEC B.G. Checo.

The first two units of the new capacitive source were put into operation last August at Lac Édouard, located north of La Tuque in the central part of Québec. The work carried out was part of a development project headed by IREQ's Measurement Systems department and initiated at the request of the Telecommunications group.

At the same time, research work continued with a view to improving and simplifying the antiferroresonance circuit as well as validating another type of source which regulates the output voltage using the IVACE system (self-controlled variable inductor with air gaps) for which Hydro-Québec holds patents in about thirty countries.

As the above R&D projects have confirmed the viability of ground-wire power taps over 20 kW on Hydro-Québec's 735-kV transmission system, researchers are planning to develop direct and indirect capacitive coupling power taps on lines at lower voltages. Before doing so, however, they must still find economically viable and safe methods of protection. ■

# Study on the rehabilitation of water stops used in concrete hydraulic structures

**Water stops are inserted into the concrete of all hydraulic structures under construction. They are very complex and costly to replace or repair. Up till now, few studies had been carried out to determine the best repair methods and products.**

In addition to absorbing and reducing the effect of hydrostatic forces applied to hydraulic structures, water stops also prevent water from seeping through the construction joints, despite the movement between adjacent blocks of concrete caused by mechanical, thermal, hydraulic or chemical stress.

In the specific case of dams, water stops are placed perpendicular to adjacent blocks of concrete along the vertical construction joints at a distance of 30-60 cm from the upstream or downstream face of the dam. They may also be placed along horizontal construction joints, as in the case of those found some 30 cm from the surface of a dam crest.

Initially, water stops installed along the joints were made of copper or steel. However, the stiffness of these materials could eventually cause the concrete to crack, damage the surface of the hydraulic structures, or favor water infiltration. During the 1950s, researchers developed flexible and more effective water stops, and these soon came into widespread use.

Despite this new technology, there were still instances of the concrete cracking as a result of the additional stress caused by the water stops. Moreover, replacing damaged water stops is very time-consuming and costly since their exact location must be known and the many joints must be redone. However, it is crucial that this repair work be carried out, especially in places where joint movement and the water load are considerable. Over the years, various repair products and techniques have been developed but it is not known precisely how efficient they are and little has been published to this effect.

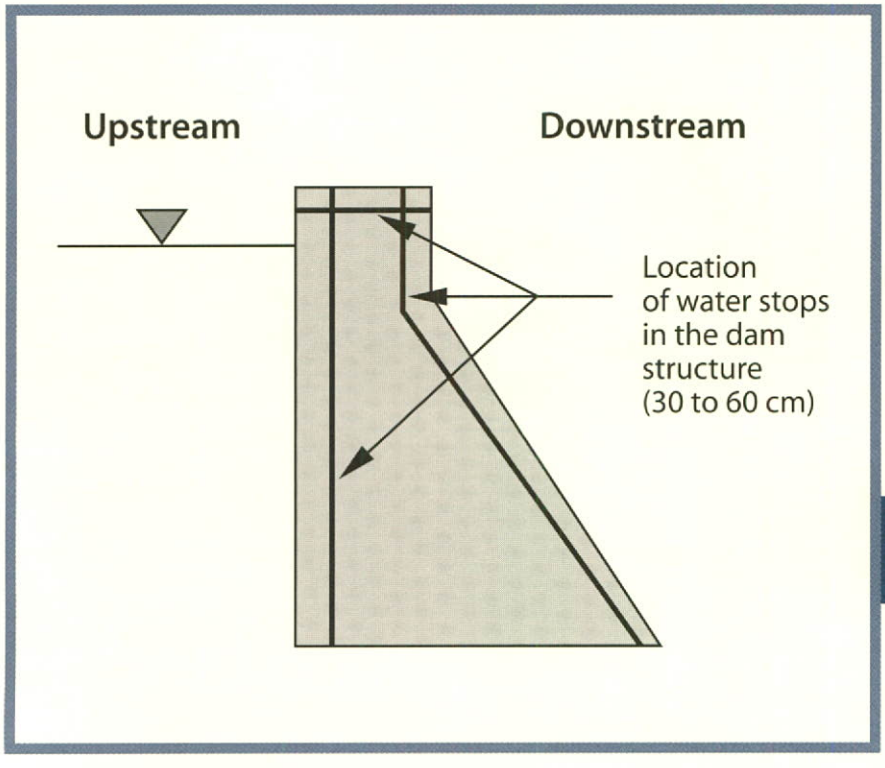
No construction industry standards or guidelines have yet been drawn up describing the types of water stops that are best suited for the various repair jobs that need to be done. Specialists at IREQ therefore initiated a study in 1993 to determine the best methods and products for repairing water stops in dams.

In all, 18 materials were selected for the study, one vinylester resin and 17 polyurethane resins. Seven of these consisted of 1-component hydrophilic resins, five of 1-component hydrophobic resins, and five others of 2-component resins. All of the materials were subjected to preliminary tests which consisted of a viscosity test (at 23°C, 15°C and 5°C), a test to determine the product's chemical compatibility with water (at the same temperatures), as well as a freeze-thaw and drying-wetting test (at -17.8°C and 4.4°C).

Only four of the resins, i.e. three 1-component hydrophilic polyurethane resins and one 2-component resin, were retained for further testing of permeability and bond strength. These tests were carried out on a special test assembly. Results seem to indicate that the hydrophilic resins would not be adequate for the purpose at hand.

In light of this last series of tests, the 2-component polyurethane resin – a homogenous, dense and compact material with a relatively high viscosity – performed very well and seems to be the product that best meets the criteria defined under the study.

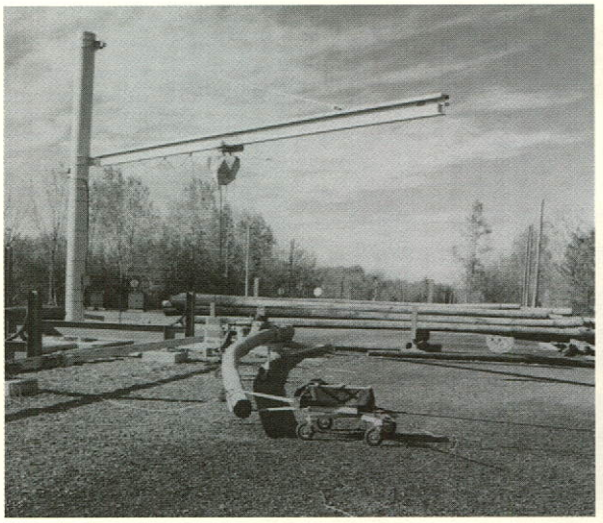
The project was headed by researcher Jahangir Mirza from the Materials Technology department and funded by Hydro-Québec's Mauricie Region. ■




**Cross section of a dam and location of water stops**

# New techniques for assessing the loading strength of wood poles

**Some two million wood poles are used in Québec for the distribution of electricity and telephone communications. However, as they are very vulnerable to environmental conditions (rot, damage caused by ants, accidents), about 40,000 of them must be replaced every year. A study has shown that about half of these poles could be reclassified and reused, thus saving the utility about $8 million a year. A team of researchers from IREQ began to study inspection methods using instruments to help determine the residual load strength of the poles, with their expertise in the field leading to unexpected spinoffs.**



Loading capacity of wood poles tested at Bell Canada's laboratories

Gamma-ray density indicator

How is the load strength of a pole accurately assessed? The problem is a considerable one and brings up other issues such as how to determine the residual strength of a seemingly healthy pole or measure the residual life of poles that are damaged. In short, researchers are hoping to develop diagnostic methods that take into account safety, lower replacement costs, and improved power-service quality.

The current method consists in a visual inspection, hammer sounding, and the extraction of a core sample from the actual pole. Although efficient, it has certain disadvantages in that it relies on human experience and subjectivity. In addition, certain factors prevent an adequate inspection from being carried out such as the presence of knots, the direction of the wood fibres, uneven density, effects of moisture and temperature, etc.

Our research team therefore undertook, in conjunction with Bell Canada and Ontario Hydro, to devise methods based on a more objective and rational determination of pole strength that is less dependent on subjective or environmental factors. After reviewing the state-of-the-art, a development program was initiated at IREQ in 1992 with the aim of providing, as expediently as possible, high-quality instruments that would meet the requirements of the client, in this case the utility's Distribution group.

### Two highly efficient inspection devices

Eight instruments were evaluated and tested as part of the program. They rely on different inspection principles such as wave propagation, instrumented drilling, hammer sounding, needle probes, electrical conductivity of the wood, and radiography of the wood section over the entire length of the pole. All of the devices were subjected to stringent performance tests. The same validation procedure was used in every case; it involved taking measurements on the poles using the new instruments and then subjecting the poles to a standardized static bending test where a pulling force was gradually increased until the poles ruptured. The following step involved correlating the results and establishing trends based on an observation of the degradation process. To date, some 300 poles have been tested in this way.

Once the studies were completed, two instruments were then retained for potential application. The first, the gamma-ray density indicator, takes an X-ray of a section of the pole by generating a mean density value. The device may be moved from one end of the pole to the other. Two prototypes of the device were evaluated; the second one allowed the moisture of the wood to be measured without any contact with the test object. The more recent one, known as Polux, is used to perform ground-level measurements on the pole. It involves recording the driving resistance of two metal needle probes inserted into the wood while measuring the moisture between the two probes using electrical conductivity.

The gamma-ray density indicator and the Polux device have been perfected to such a level that they may soon be used as part of the utility's pole inspection program. Nonetheless, no instrument is flawless and human expertise is still required. This is why an integrated method was developed which combines visual inspection with the use of a measuring device. This approach also requires that a representative data base be built which would help make appropriate decisions as regards safety and maintenance. ■

## Unexpected spinoffs

The know-how developed in this project was put to use in a most unexpected way: our specialists were called upon to assess the wood beams of the Saint-Denys church in Québec City. The rotting wood required fast intervention in order to maintain the structural integrity of the building. As the saying goes, God truly works in mysterious ways…

# Automated analysis of dissolved gases in insulating oils

**Two of the utility's regional laboratories now use a new technique developed at IREQ for analyzing dissolved gases in insulating oils. With this method, which is simpler to use and yields better results, one of the most crucial steps in equipment monitoring has become automatic.**

The analysis of dissolved gases in insulating oils is one of the most important steps in the equipment diagnostic process. In fact, it reveals what is happening inside the equipment without the need to dismantle the apparatus and examine it from the inside. It allows the presence of phenomena such as hot spots, electric arcs and partial discharges to be determined and the necessary measures taken before any unforeseen shutdowns occur.

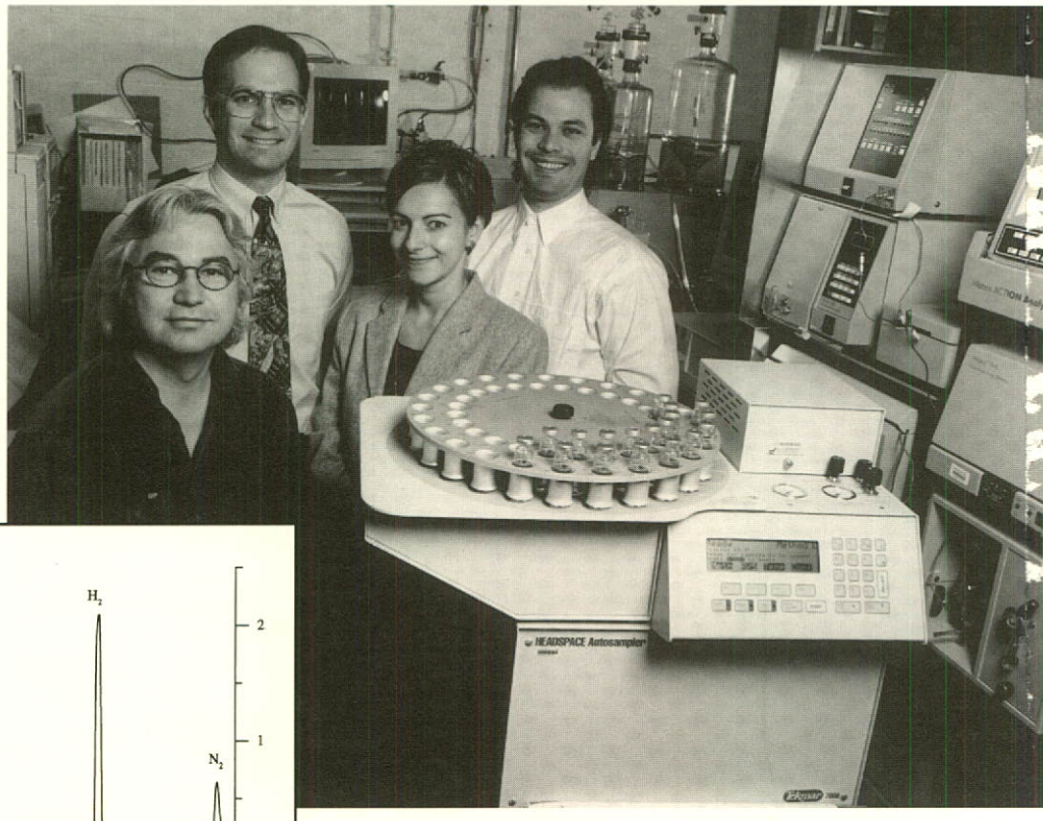
The analytical technique that had been used up till now in Hydro-Québec's laboratories consisted in manually injecting in a gas chromatograph part of the gases collected in a vacuum-extraction system during degassing of the oil sample. In addition to requiring much handling on the technician's part, the method involved the use of a large volume of mercury, a toxic substance. It also lacked sensitivity in detecting trace amounts of gas (<2% V/V) and required that a technician always be present.

Hence, in an effort to find a technique to replace this time-consuming process, the Materials Chemistry department undertook to develop a method based on the use of a headspace sampler that would allow the gases to be automatically introduced into a gas chromatograph. This has now been accomplished, thanks to a research team led by Roland Gilbert: the method developed at IREQ was recently adopted by two of the utility's regional laboratories, the Centre d'entretien électrique de Trois-Rivières and the Jeanne-d'Arc laboratory in Montréal.

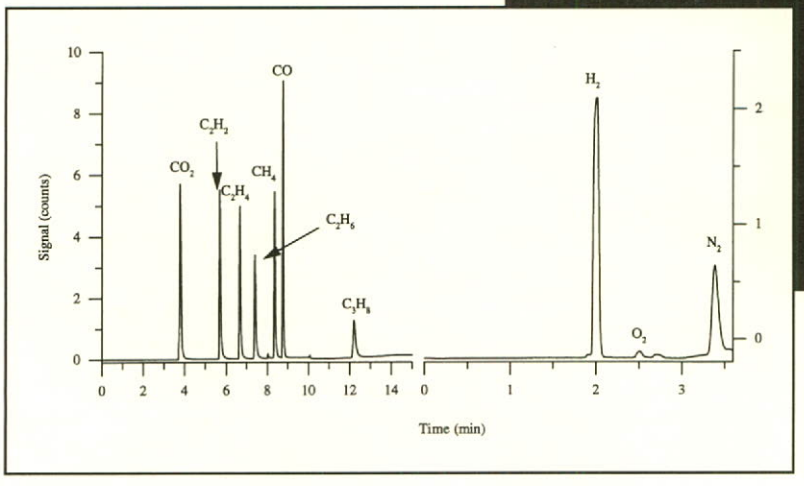
The new technique consists in bringing an oil sample into contact with a gas phase in an enclosed vessel pre-purged with argon. As a result of the thermodynamic equilibrium created, the volatile substances, including the dissolved gases, are partially transferred into the gaseous phase. Then, once equilibrium has been attained, an aliquot portion of the gas phase is injected into the chromatograph.

The method has the dual advantage of not using any mercury and of not being affected by samples containing dissolved gases at low volumes. With respect to the chromatography, the replacement of packed columns with capillary columns increases the resolution and sensitivity. The major advantage of the technique, however, resides in the fact that the process has become fully automated, which allows analyses to be done around the clock in order to meet demand. As a result, our laboratories have been able to reduce the time required for analysis and the operating costs, while at the same time increasing productivity.

As a final note, it should be mentioned that to maintain such a high analysis load on a day-to-day basis, the project team has devised a quality assurance and control program that allows the system to be monitored daily and to check the accuracy of results. ■




The research team responsible for developing the new technique for analyzing dissolved gases in insulating oils: l. to r., Roland Gilbert, Yves Leblanc, Sylvie Charbonneau and Jocelyn Jalbert.



# Publications, reports and addresses

*Documents filed at IREQ and LTEE documentation centres**

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**Audet, M.** *Rapport de stage en programmation de robots manipulateurs*, 96-196.

**Audette, L., Godin, A., Hazel, B.P., Jasmin, C., Vallée, A.** *Documentation des exigences V.1.0*, 95-395.

**Bhérer, J., Tremblay, C.** *Manuel de l'utilisateur du logiciel Khameleon*, 95-163.

**Blanchette, Y.** *Influence d'une recompression des manchons ACSR 2 sur leurs performances mécaniques*, 96-209.

**Boisvert, S., Nguyen-Duy, P., Lanouette, C.** *Failure Analysis and Metallurgical Evaluation of Different Components of Power Transmission Lines in Libya*, 96-154.

**Bourdages, M.** *Cordage isolant pour travaux sous tension*, 96-295.

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**Cantin, B.** *Compatibilité électromagnétique du géoradar GSSI SIR-3 utilisant les sondes 500 MHz et 1 GHz*, 96-014.

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**Casoria, S.** *Étude d'exploitation du RMCC sur modèle dynamique du réseau H.-Q. 96 au simulateur IREQ: Phase I*, 95-367.

**Couderc, D.** *Caractéristiques de l'isolation laminée au polypropylène (PPLP) utilisée dans le câble 800 kV de Sumitomo Electric*, 96-189.

— *Rapport final d'expertise effectuée sur six condensateurs de disjoncteurs de type PKV*, 96-142.

— *Rapport final sur la dissection d'un câble et d'une jonction PILC 15 kV*, 96-187.

**De Guise, N., Lafond, C., Meunier, R., Nolet, A., Vanier, G.** *Plan de validation: Norme documentaire V.1.0*, 95-397.

**De Guise, N., Lafond, C., Meunier, R., Vanier, G.** *Plan de validation: Processus V.1.0*, 95-398.

**Drapeau, J.-F.** *Développement de méthodologies d'essais sur isolateurs à haute tension sous conditions de verglas et de neige*, 96-206.

**Dubé, B., Nguyen, D.L., Valette, A.** *Modèles actuels documentés des équipements des centrales Gentilly-2 et Bécancour*, 96-259.

**Gagnon, D.** *Étude et modélisation des composantes des systèmes de télécommunications par fibres optiques: Modèles de base (mise à jour)*, 96-191.

**Gaudreau, A., Daigneault, G., Gendron, P.** *Mesure du soufflage d'un disjoncteur GE modèle ATB-80 au poste Chamouchouane*, 96-213.

**Giroux, P., Bilodeau, H., Giguère, F.** *Étude au simulateur: Ajout de deux branches inductives aux compensateurs statiques du poste Chamouchouane: Volume I: Rapport final*, 96-081.

**Goulet, J., Lafleur-Tighe, A., Leroux-Demers, T., Meunier, R., Rochefort, M., Vallée, A.** *Plan d'action 1995-1996: Démarche en génie logiciel et génie système de la DTR (Dégel-DTR)*, 95-396.

**Haj-Maharsi, Y.** *Modèles numériques en temps réel des transformateurs TTC et TT sur C30: Manuel d'usager*, 96-150.

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**Koch, B., Gaudreau, A.** *Arcs dans une enceinte de petit volume: Partie 2: Arcs libres monophasés et triphasés dans une enceinte hermétique ou ventilée*, 95-021.

— *Interrupteurs Joslyn PT6 au $SF_6$: Défaut d'arc interne*, 96-162.

**Lafleur-Tighe, A., Osmolski, G., Rosu, C., Théorêt, M., Valiquette, D.** *Introduction à la gestion des configurations V.1.0*, 95-399.

— *Plan de gestion des configurations: Norme documentaire V.1.0*, 95-400.

**Lamarche, L.** *Mesures des variations de l'affaiblissement d'un lien par câble de garde à fibres optiques (CGFO) de 220 km entre mai 1995 et mai 1996*, 96-260.

**Lamarche, L., Gagnon, D.** *Mesures des variations de l'affaiblissement d'un lien par câble de garde à fibres optiques (CGFO) de 220 km en fonction de la température (-37°C à 30°C) et du temps*, 95-253.

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# Upcoming conferences


## The 10th International Symposium on High Voltage Engineering (ISH'97)

**ISH'97 will be held at the Palais des Congrès in Montréal from August 25 to 29, 1997 and will be hosted by Hydro-Québec's research institute (IREQ), IEEE and CIGRE. Over 1000 delegates are expected to take part in the symposium, scheduled to take place in conjunction with a major technical trade show.**

ISH'97 will follow along the lines of previous symposia over the past 25 years and will cover all aspects of high-voltage engineering. Topics presented at the technical and poster sessions include the calculation and measurement of electric fields, solid and liquid dielectrics and insulations, power system electromagnetic compatibility, industrial applications of high-voltage technologies, and discharge physics and insulation characteristics of air-gaps.

Held at the same location from August 26 to 28, 1997, the ISH'97 technical trade show will allow participants to exhibit state-of-the-art technologies and offer their professional services to the international electrical engineering community. The trade show will highlight progress made in R&D as well as the latest developments in science, technology and industry. For more information, please contact Dr. F.A.M. Rizk at the ISH'97 Secretariat, JPdL Multi Management Inc., 1410 Stanley, Suite 609, Montréal (Québec) Canada H3A 1P8, Tel.: (514) 287-1070, Fax: (514) 287-1248. The IHS'97 home page on the Internet is at: http://www.ireq.ca/ish97 ■

## International Conference on Digital Power System Simulators '97 (ICDS-1997)


**The International Conference on Digital Power System Simulators '97 (ICDS-1997) will be held in Montréal from May 28 to 30, 1997. This is the second international conference on the design, implementation and application of real-time digital power system simulators.**

The conference features two main areas of interest: the design and implementation of simulator hardware and software, and the modeling and application of power system simulators. Co-sponsored by Hydro-Québec and Électricité de France, among others, the conference will allow participants to study the most recent specifications on aspects related to digital power system simulation.

Papers presented at the conference will deal with digital simulator software and hardware design, interface design, and modelling constraints. The advantages, disadvantages and requirements related to hybrid technology, maintenance, training, hardware and software upgrades, and new applications will also be covered. For additional information, please contact: Eileen Dornier, 1800 boul. Lionel-Boulet, Varennes (Québec) Canada J3X 1S1, Tel.: (514) 652-8200, Fax: (514) 652-8835, E-mail address: icds97@sim.ireq.ca ■

# MONITEQ: Both a monitoring system and a "black box"

**The MONITEQ high-voltage circuit-breaker monitoring system has on numerous occasions proven itself as a failure precursor. However, when an incident occurred on August 6, 1996, the system demonstrated that it can also function as a "black box" for recording operating parameters.**

In January 1996, the MONITEQ system was installed on three circuit breakers at Lévis substation, including one 245-kV PK-type air-blast unit used for the capacitor banks. This 230-42 circuit breaker had been operating without any problem until last August 6, when it failed during an opening operation carried out for the purpose of withdrawing the capacitor bank from the power system. For reasons unknown at the time, the failure resulted in the destruction of phase C.

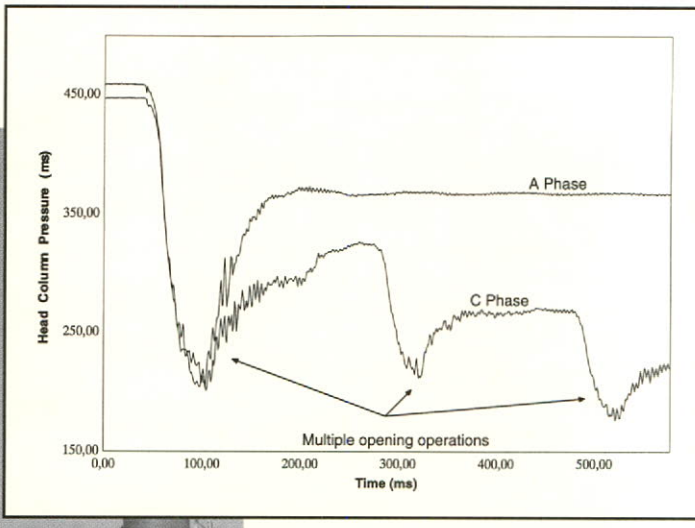
This event occurred despite the fact that the equipment was constantly being monitored from IREQ's laboratories. All parameters seemed normal and there were no early signs of potential failure. Thankfully, the MONITEQ system had not been damaged and was able to record all the operating parameters of the destroyed circuit breaker. As soon as the MONITEQ team was made aware of the situation, it proceeded to closely examine the pressure signals of the tanks of the various phases, of the operating-coil current, of the phase C nominal current and of its position contact. The following conclusions were drawn:

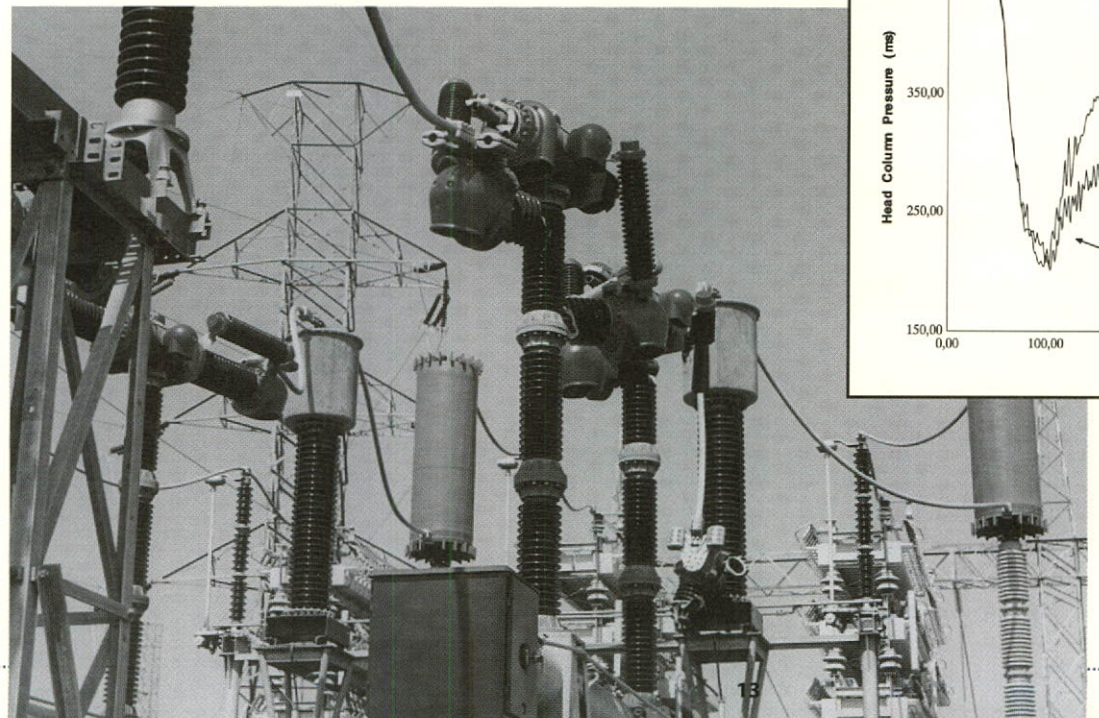
- The nominal current had been interrupted as normal after 43 milliseconds;
- The position contact signals of the rods confirmed the opening of the contacts; the break thus occurred at the right time;
- The tripping-coil signal seemed normal; a single opening command had been sent to the breaker's pneumatic drive mechanism;
- However, a major anomaly had appeared on the pressure signal of the phase C tank. Upon examining the graphs (see figure below), it was determined that phase C had received several successive opening commands, which caused an overall drop in the pressure of the circuit breaker, followed by a decrease in the dielectric strength of the breaks. This excessive decrease in pressure resulted in an inter-contact restrike, thus causing the loss of the phase.

The failure was traced to the pneumatic drive mechanism, where the opening electrovalve piston was stuck in the open position, which in turn led to a series of pressure drops. Without this indication, the problem with the piston would have remained undetected.

Once the defective part had been located, the cause of the failure was sought out. A correlation study was done of the circuit breaker opening log included in the monitoring system and the temperature signal in the single-pole cabinet. The study revealed that excessive temperature had caused the piston's seals to dilate, which blocked the electrovalve piston, finally leading to the loss of phase C. To prevent the recurrence of such an incident, the research team drew up a new set of recommendations on the rehabilitation of PK-type circuit breakers.

At the time this unforeseen failure occurred, MONITEQ was able to detect the faulty part and then determine the cause of the defect, which could not have been located otherwise. This is how, through a retracing of the causes of the failure, that MONITEQ can be seen as playing the role of a "black box." ■

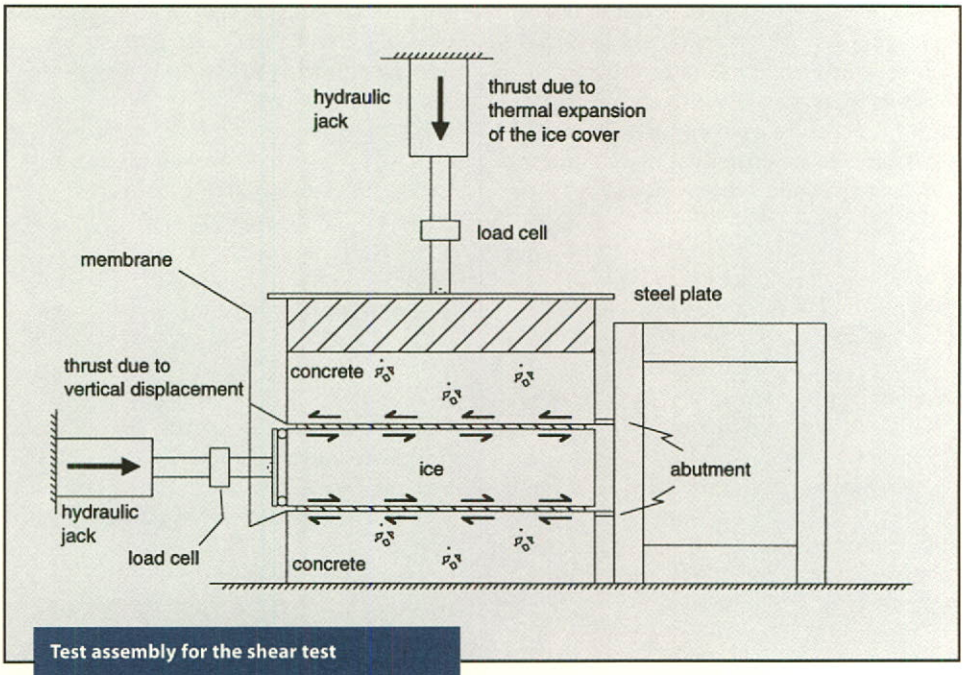


**230-42 circuit breaker at Lévis substation after the August 6 event**

# New materials for improving the weatherability of the upstream face of concrete dams

**Hydro-Québec's dams are exposed to harsh climatic conditions which cause frequent drying-wetting and freeze-thaw cycles, thus contributing to the aging and deterioration of the concrete. A research team from IREQ's Materials Technology department has conducted a study on different types of impervious and durable coatings which could be installed on the upstream face of dams.**




Test assembly for the shear test

Scaling, cracking, erosion and swelling of concrete are among the main signs of deterioration resulting from harsh climatic conditions. However, damage caused to dams may be minimized by reducing the amount of water that seeps through the cracks and joints, which in turn decreases the cumulative effects of freezing and thawing.

The most common repair technique in current use consists in replacing the old concrete with new one. However, over the long term the new concrete will still be prone to the same problems. One of the solutions being proposed is to install a durable impervious coating on the upstream face of dams. Used mainly in Italy and France, this technique helps decrease the damage caused by freeze-thaw cycles by partially reversing the water saturation process.

Some of the impervious coatings applied to concrete dams include thin metallic sheets, bitumen-based coatings, and synthetic geomembranes (prefabricated or sprayed). At the present time, it would seem that synthetic geomembranes offer the best protection against water seepage.

Eight geomembranes were therefore selected and tested in view of determining their properties and behavior under various types of stress. During an initial testing phase, standard tests were used to measure the tensile, puncture and pull-off strength of the product in order to establish how factors such as the freeze-thaw cycle, UV radiation and low temperature affect the mechanical properties of the geomembranes. Four of the products with the best performances were singled out for a second series of tests.

The ice that forms in winter on the reservoir surface exerts varied and complex forces (i.e. compression, shear and occasionally tension) on the dam which could potentially damage the geomembrane. The purpose of the second series of tests was to measure the bonding (shear strength) of the ice that forms on the geomembrane. The test product's resistance was studied using a test bench where the normal load corresponding to the horizontal thrust caused by the thermal expansion of the ice was varied.

All the geomembranes tested exhibited similar behavior by significantly reducing the bonding of ice to the upstream face of the dam. It can therefore be assumed that a geomembrane could provide added protection to the dam against the effects of ice. It was also noted that the geomembranes performed well during the shear tests; they remained intact, despite displacements of several millimetres that normally occur during this type of test.

The PVC-B and polyurethane-A membranes yielded the best results during laboratory testing: not only did they substantially decrease bonding to ice but they performed very well during tensile, puncture and pull-off tests, even after 500 freeze-thaw cycles and intense exposure to UV rays. In addition, they still exhibited excellent properties at -30°C.

The study of these geomembranes is a step in the right direction and contributes to our understanding of the behavior of such products. It would be interesting to conduct such studies on a larger scale by applying one of the recommended geomembranes on the surface of a dam. By installing measuring instruments, the actual stresses and deformations to which the geomembranes would be subjected, still unknown, could be determined. This information could then be used in the building of customized models and in predicting the behavior of new materials.

The study was headed by Benoît Durand from IREQ's Materials Technology department and was conducted in collaboration with Montréal's École Polytechnique. The project team consisted of Stéphane Tremblay (IREQ), Yolaine Germain and Gilles Houde (École Polytechnique). The project was initiated at the request of Hydro-Québec's Dam Safety and Maintenance group and the Mauricie Region. ■

# Vitrification technology successfully demonstrated by LTEE in South Carolina

**Hydro-Québec's electrochemical and electrical technology laboratory, LTEE, has developed high-tech know-how and equipment in the area of plasma torches and DC electric arcs. The laboratory recently put its know-how to the test when it was asked by a South Carolina firm to conduct *in situ* vitrification testing of contaminated soil.**

The U.S. firm Westinghouse Savannah River Company (WSRC) manages the Savannah River Site, located in Aiken, South Carolina, on behalf of the U.S. Department of Energy. As the soil of some of the basins at this site was contaminated by radioactive waste, the WSRC was asked to see to its decontamination over the next 10 years. The utility therefore began to study processes involving *in situ* vitrification of contaminated soil using plasma torches.

Plasma torches are electrical systems used to heat gases at high temperatures, ranging from 2000°C to 10,000°C. LTEE, which owns several furnaces and electrical supply systems used to perform tests at power levels ranging from 15 kW to 1500 kW, is also equipped with a mobile unit capable of supplying torches rated from 100 kW to 1 MW. The unit, which comprises a transformer, control and cooling systems, tanks, a compressor and various cables and hoses, is mounted on three trailers each 15 m in length.

To carry out the decontamination program, the WSRC contracted LTEE to lease some of its equipment and lend its expertise for the project. Under the agreement that was reached, the WSRC has use of the mobile unit and the 1-MW plasma torch, and is able to call upon LTEE's expertise and know-how to keep an eye on its facilities and testing.

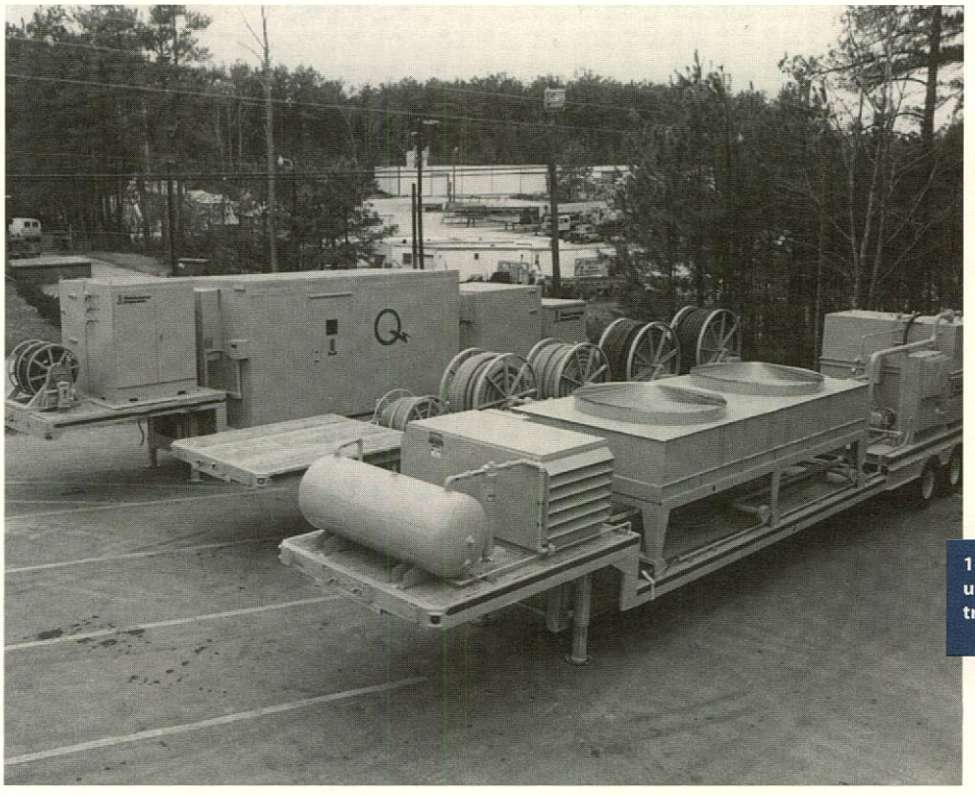
After conducting laboratory performance tests at 100 kW, the WSRC decided to carry out other field tests at 1 MW. As it chose a non-contaminated site adjacent to a contaminated basin, the tests required that an entirely autonomous process be developed which could be set up in the field.

The process consists in boring holes in the contaminated soil and inserting at the desired depth a plasma torch which, once fired up, heats the ground until a vitrified bulb appears. The torch is then gradually removed to allow a vitrified column of soil to form. The procedure is repeated in each of the boreholes until the soil has fully vitrified. This process has the advantage of encapsulating the contaminants and preventing them from spreading into the surrounding area.

The equipment was transported to the site in September. During the first half of October, the facilities and test assembly were set up and the first series of tests was conducted. As these helped the project team make adjustments to the equipment, the following two weeks were spent on modifying the test assembly. During the first half of November, *in situ* vitrification of the soil was done using a plasma torch operating at 900 kW.

The plasma-torch vitrification tests having proved conclusive, LTEE is quite hopeful that its know-how will be called upon for the remainder of the project, which consists in vitrifying the remainder of the site over the following years.

The project was headed by Camille Lemire and Marcel Déry from LTEE's High-Temperature and Power Electronics department. ■



1-MW plasma-torch mobile unit mounted on three 15-m trailers

# Induction heating: A technology that is making strides on several fronts

**Research into induction heating, a technology that is highly energy efficient, flexible to use and has a wide range of industrial applications, has led to the development of more concrete solutions to a number of problems. However, in order to make its mark in a number of different fields, this technique must evolve to meet increasingly stringent industrial requirements.**

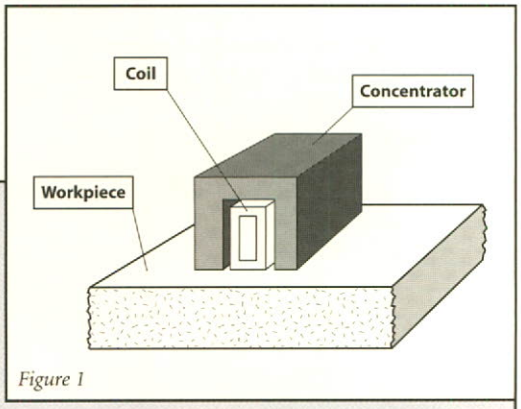


*Figure 1*



*Figure 2*

**Diagram showing the operation of the concentrator and the distribution of heat**

Induction heating has been studied at length at Hydro-Québec's electrochemical and electrical technology laboratory, LTEE, since the latter was first set up in 1987. Research has focused on the following areas:

- modeling of electrical, magnetic and thermal phenomena with respect to the load (inductor, part to be heated) by taking into account the non-linearity of the physical characteristics;
- optimization of the parameters used to increase energy efficiency;
- validation of the results in the laboratory and in an industrial setting.

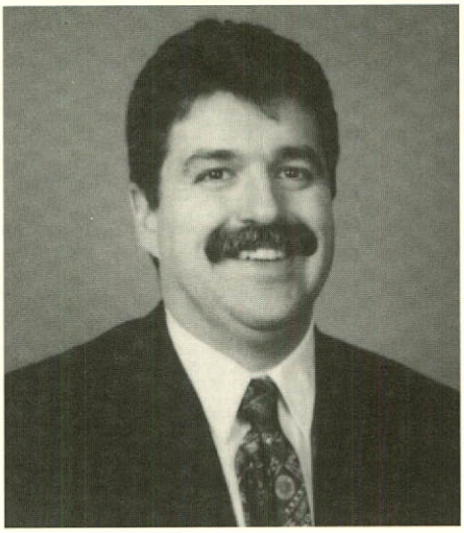
LTEE has two induction generators of about 100 kW each which are capable of covering a frequency range of 1-2 MHz, as well as FLUX2D software. In almost ten years, this equipment has contributed to the success of several industrial projects. One such project, recently carried out on behalf of an industrial client, consisted in solving an unusual thermal processing problem involving the bilateral heating of a thin piece of steel only 4 mm wide. To this end, a special inductor was designed that would serve to narrow the focus of the magnetic field (see Fig. 1).

The digital simulation, which was carried out with the help of the FLUX2D software program, clearly showed that by using a field concentrator a metallic part can be heated more quickly and selectively. Furthermore, as illustrated in Figure 2, the temperature distribution on the surface of the part varies widely, depending on whether the inductor is equipped with (curve 1) or without (curve 2) a field concentrator. In fact, a substantial increase in the power being transferred is noted when a concentrator is used.

Once the simulation studies were completed, LTEE acquired an inductor equipped with a concentrator and using a new magnetodielectric material – FLUXTROL – with physical properties that are particularly well suited to this application. The results of the laboratory and factory tests were very consistent with the digital simulation. ■

## Governor General's Gold Medal awarded to Sabin Boily

**Sabin Boily, a researcher at IREQ's Materials Technology department, was recently awarded the Governor General's Gold Medal for 1994-95. This prestigious prize is granted to a student who has achieved academic excellence and made a substantial scientific contribution to a research centre and his or her university.**



Throughout his doctoral studies at INRS-Énergie et Matériaux, Sabin Boily was known for his superior academic achievement and a very high grade point average. In addition, his examiners praised the high quality and originality of his thesis which dealt with the fundamental study of plasma created by laser and its application in thin film deposition. The research, which was supervised by Professors Mohamed Chaker and Henri Pépin, greatly contributed to increasing knowledge in the field of plasmas and materials. At the INRS-Énergie et Matériaux institute, Mr. Boily helped implement a research program in the

# New study on protective relays has substantial spinoffs

**Electric utilities, just like manufacturers, have been increasingly using power system simulation studies to evaluate the performance of protective relays. IREQ's Power System Simulation department, in conjunction with Hydro-Québec's Automatic Controls department, has just obtained a contract with a Finnish utility for a protective relay study. With this new contract, Hydro-Québec is making inroads into the European market in a fine example of internal partnership.**

Last June, the Finnish firm IVO (Imotran Voima Oy) launched a call for tenders for a study on the behavior of the protective relays of 400-kV AC lines used to transmit electricity between Finland and Sweden. Series compensation will soon be added on these lines as well as capacitor banks that will account for 70% of the line impedance. The project will be carried out jointly by IVO and its Swedish partner, Svenska Krafnät.

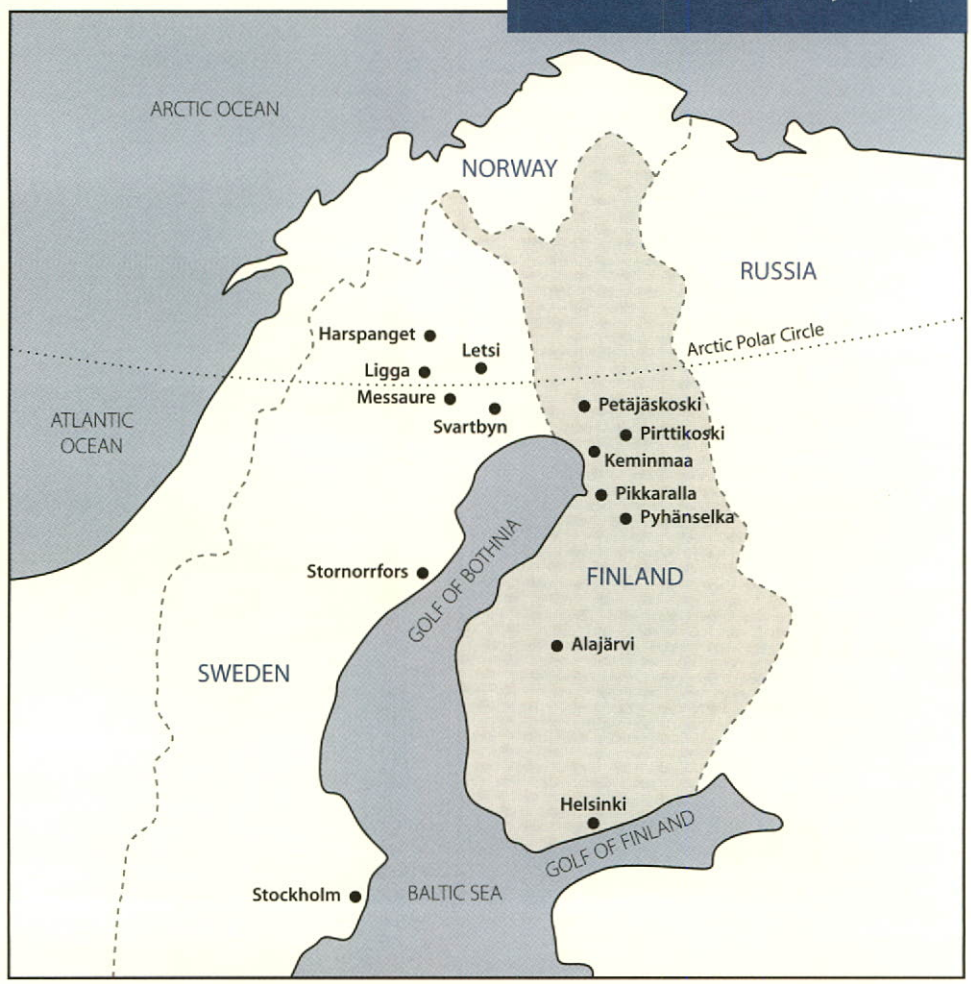
The contract involves analyzing three relays manufactured by Siemens (7SA513), GEC Alsthom (PXLN) and ABB (REL531), all digital distance relays not in use at Hydro-Québec. Since the manufacturers could not guarantee delivery before the end of the year, the study was broken down into three phases. The first, for which a report was submitted on October 31, covered the Siemens relay. It also included an evaluation on the client's part of the various services provided by our laboratories, as well as a demonstration of the different types of studies that can be conducted. As the prospects seemed promising, the go-ahead was given for the analysis of the other two relays with a report scheduled to be handed in by the end of the year.

In a highly competitive world market, the contract with IVO bears witness to the competence of IREQ's power system simulation laboratory, which has been able to capitalize on its independent status, competitive rates, and recognized expertise in the area of protective relay studies.

This is the first time IREQ's Power System Simulation department has joined forces with the utility's Automatic Controls department (part of the Equipment Maintenance and Dam Safety group) for a project which takes full advantage of their respective know-how in the study, simulation, installation and field operation of relays. In fact, the partnership opens the door to many other similar opportunities worldwide.

This first contract will lead to substantial spinoffs both for the Power System Simulation department and for the utility as a whole, especially where the European market is concerned. Not only will it increase the utility's visibility, but it will also give Hydro-Québec the chance to test new products on the world market. ■

**A protective relay study for 400-kV AC lines was carried out for a Finnish utility.**




field of plasma-assisted processes used to manufacture materials.

During his studies, he received an FCAR grant *(Fonds pour la formation de chercheur et l'aide à la recherche)* and a Natural Sciences and Engineering Research Council of Canada grant. At the same time, Mr. Boily was actively involved in the scientific and social life of the INRS-Énergie et Matériaux institute. He has always demonstrated strong leadership skills and initiative, particularly when chairing various committees, through his involvement in the university's student association, and when participating in social activities. ■

# System for the remote signalling of fault indicators installed at Guy substation

**In an effort to improve the power-service continuity index of underground distribution substations, a team from the Electrical Apparatus department is in the process of installing a system for the remote signalling of fault indicators at Guy substation. The power-service continuity index represents the average number of hours of service interruption per customer per year.**

Modeled after IREQ's circuit breaker monitoring system, the signalling system is used to remotely transfer data on the state of each indicator as well as the approximate values of the instantaneous current flowing in each phase. The system is also used to continuously monitor the sampled signals while warning users as soon as one of the programmed alarm thresholds has been exceeded. To help manage the power system load, the system allows users to draw up trend charts based on an observation of these signals over a certain period of time.

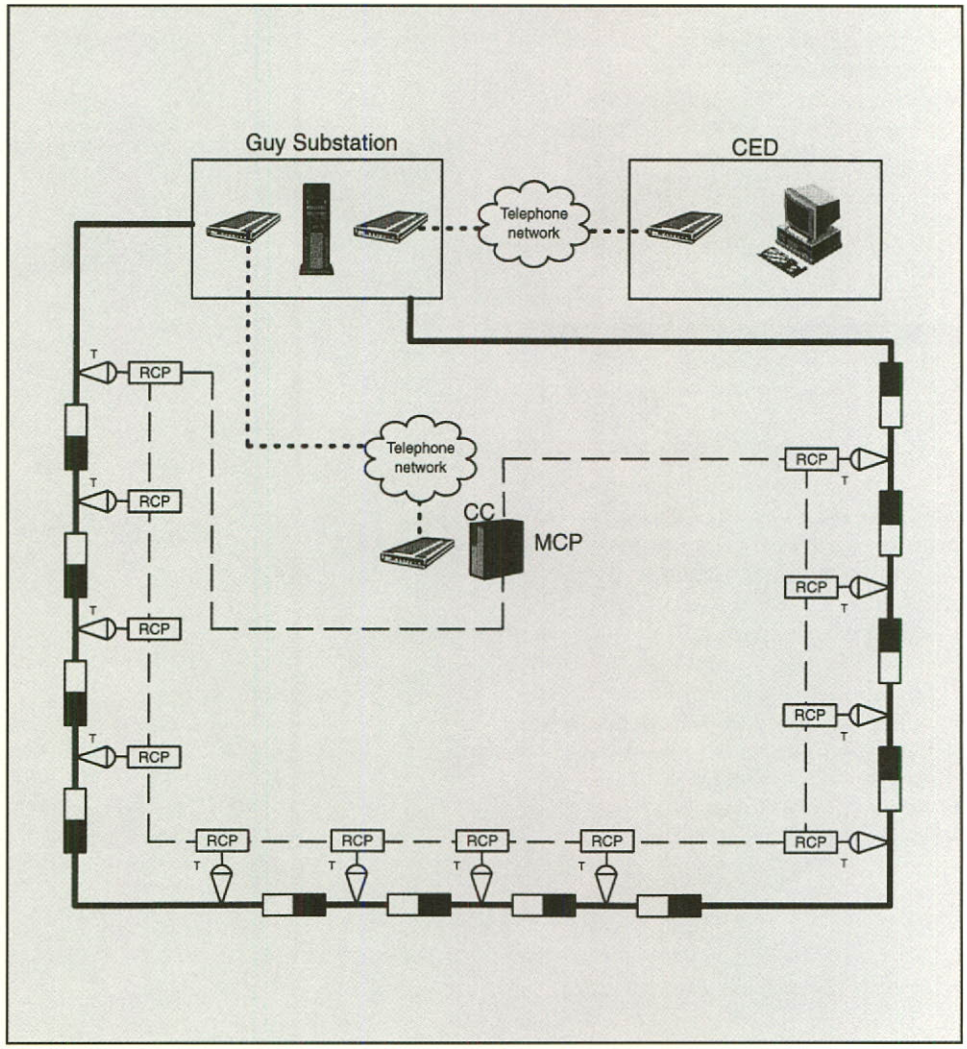
With 23,635 customers and 16.1 kVA of average load, Guy substation, located in downtown Montréal, was chosen as the site for the implementation of the remote signalling system due to its strategic location, its availability, and the problem with parallel feeders.

The project comprises two phases, the first of which has been successfully completed. It involved installing remotely signalled fault indicators on the cable heads of the 21 parallel feeders of the substation's 25-kV RCL lines. Each of the parallel feeders, which were initially to serve as a combined main line and backup line, is equipped with a single circuit breaker which, in case of a fault on a line, isolates both lines at the same time. The opening of the circuit breaker allows the Distribution Control Centre (CED) to simultaneously determine which parallel feeder is presenting a problem, but it is impossible to detect which of the two lines is faulty solely through remote signalling of the circuit breaker's condition. In such a case, a technician is sent to the substation to solve the problem.

Once the defective line has been identified, the operators in turn dispatch a patrol crew to try to determine the exact location of the fault. After the circuit breaker has opened, it usually requires about an hour for all the work to be carried out and the location to be determined. The first phase of the project served to eliminate the initial intervention of the technician by locating the faulty line early on, thus reducing service interruption by about a half-hour.

Projected for implementation in 1997, the second phase of the project, headed by Gaétan Daigneault, involves installing remote fault indicators in transformer vaults strategically located along the substation lines. Should a fault occur, the technicians would then be able to have direct access, thus decreasing the response time by another half-hour.

Considering that Hydro-Québec is granting more and more importance to total quality and customer service, the power-service continuity index becomes a deciding factor in assessing each substation's performance. By decreasing the number of outages and their duration, the utility also minimizes the loss of revenue while improving customer service. If the results of this pilot project prove conclusive, Hydro-Québec can already anticipate installing the remote signalling system in other substations. ■




**Implementation of the remote signalling system. The solid lines represent the 25-kV lines in Guy substation, while the dashed lines represent the fiber-optic links.**

# IREQ now provides services in CAD and rapid prototyping

**In addition to its usual expertise in mechanical design, IREQ's Robotics Division now also offers services in rapid prototyping. This state-of-the-art technique combines computer-assisted design (CAD) with the automated manufacturing of ABS plastic parts. Its advantage resides in its speed of execution and low cost.**

Examples of models created using CAD and rapid prototyping

An important stage in the production process, the manufacturing of prototypes had always required that models made of wood or other substitution materials be shop-built and that parts be constructed of actual materials. As this process had always been time-consuming and costly, IREQ's Robotics Division recently developed a method for building parts using "Fused Deposition Modeling" (FDM). This technology uses polymer filaments (ABS) to virtually build, through successive layers, the prototypes previously modeled by CAD.

Once the parts have been manufactured and assembled, the model's mechanical design is validated by checking whether all the parts have been properly integrated, any potential interference between them is determined and the model's functional capacity is assessed. This approach also allows various practical aspects to be quickly evaluated such as the feeding of the electrical wires into the components or the integration of the electronics. Once this step has been completed and the necessary adjustments made, second-generation prototypes are then built using the required materials as well as machining and moulding techniques.

Graphical simulation is another tool used at IREQ. It serves to demonstrate the finer points of how new tools and instruments operate, as well as various work methods. Our specialists have already used this process to design several prototypes, including automatic conductor grips and grounding clamps, as well as various transmission and distribution system tools and devices.

Other types of rapid prototyping methods are found on the market, such as those based on the use of laser techniques or layers of paper that are superimposed and cut up. But the ABS heating and fusion method is one of the least costly available. The parts manufactured using this technology are usually sturdy enough to be assembled with metal parts, thus allowing realistic and often highly complex models to be built.

These techniques have been applied by the Robotics group in its own R&D projects dealing with the robotization of on-site maintenance tasks. The methods are also used by other departments within the utility as well as by industrial designers or manufacturers. ■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*Cover*

**Left photo:** Icing tests on a grounding disconnect switch

**Middle photo: High-voltage tests on a power transformer**

**Right photo: High-power tests on a 735-kV circuit breaker**

*Cette publication est disponible en français sur demande.*

## Research and development

# A key element for performance and partnership

**Hydro-Québec has made some choices. It has made a decision to become a commercially oriented utility, one that is competitive and profitable. It intends to become a strong force in the market, one that is capable of competing with the top-rated electric utilities in North America.**

Within this new context, which requires the utility to compensate for a slow economic recovery, increase its productivity gains, and reduce its expenditures and investments, what, then, will be the role of research and development?

### R&D and the utility

According to Hydro-Québec's new Senior Director of Research and Development, Roger Bérubé, "R&D must help the utility become more competitive not only right now but also tomorrow and the day after that, as well as next year and in five and ten years time. We must use our researchers' initiative and capacity for innovation to maintain Hydro-Québec's strong competitive edge in the future."

In order to meet this objective, however, some difficult choices need to be made. For instance, there will be some changes as to how fundamental research is done; it will most probably be in keeping with an approach that will allow the utility to reduce its investments by relying on joint ventures.

For their part, the new business processes in generation, transmission and distribution – which are currently being implemented – will have to take into account the utility's competitive position over the medium and long term, in addition to considering the short term. These processes will also have to include the necessary means to meet the challenge of deregulation. R&D constitutes a crucial element to this end, one that must be given prime consideration. It will thus be up to the new R&D senior management to help identify the long-term issues that affect both processes and research.

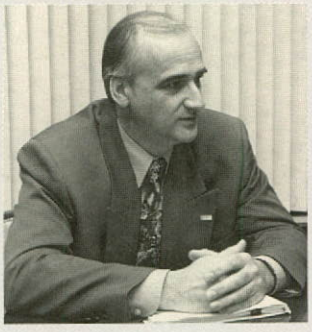
"Companies that have weathered the worst storms are the ones that have usually been able to capitalize on their R&D," says Mr. Bérubé. For research and development contributes to diversification efforts and Hydro-Québec knows full well that it can no longer merely rely on selling electrical power. It must also develop a range of products and market them; basically technological products, which constitute a major niche for R&D activities.

### R&D and joint ventures

Hydro-Québec has announced that it intends to invest $50 million over the next three years in R&D-related joint ventures. These funds will allow the utility to explore larger-scale marketing opportunities as well as find financial partners for longer-term projects. According to Mr. Bérubé, "this amount must be seen as a gateway, a means to build on our successes. The greater our success, the more opportunities we will have. Today's market is full of opportunities and I am convinced that, by being ingenuous and persistent, with the assets and competitive advantage that we have, we will be in a position to maintain our activities at their formerly high level.

"This partnership must not be limited to the Québec industry. We must capitalize on IREQ's international leadership and take advantage of this leverage to expand our partnerships. This would be done on a commercial basis, however, and would favor those who rely on self-financing, who present a benefit to the utility and strengthen our competitive advantage." ■

## Roger Bérubé appointed Senior Director for Research and Development and General Manager of IREQ



A graduate of Université Laval in electrical engineering, Roger Bérubé first began working at Hydro-Québec in 1971. When he was appointed in November to the new position of senior director, he had been vice president for the Saguenay Region since 1995. From 1992 to 1995, he was director of Equipment Maintenance and Dam Safety and two years prior to that, he was executive director for the Mauricie Region. Mr. Bérubé has also held various positions at Hydro-Québec as departmental and divisional manager as well as engineer in many technical functions related to power system and facilities management, automatic controls, telecommunications and transmission lines and apparatus.

A member of the *Ordre des ingénieurs du Québec,* the board of directors of CITEQ *(Centre d'innovation en transport d'énergie du Québec),* and the *Centre québécois de recherche et de développement de l'aluminium (CQRDA),* Mr. Bérubé has been responsible for many functions which have led to his involvement in national and international technical committees such as the Canadian Electrical Association (CEA), the Canadian Committee on Large Dams (CANCOLD), the Canadian Dam Safety Association, the International Committee on Large Dams (ICOLD), and the International Conference on Large High Voltage Electric Systems (CIGRE).

Hydro Québec