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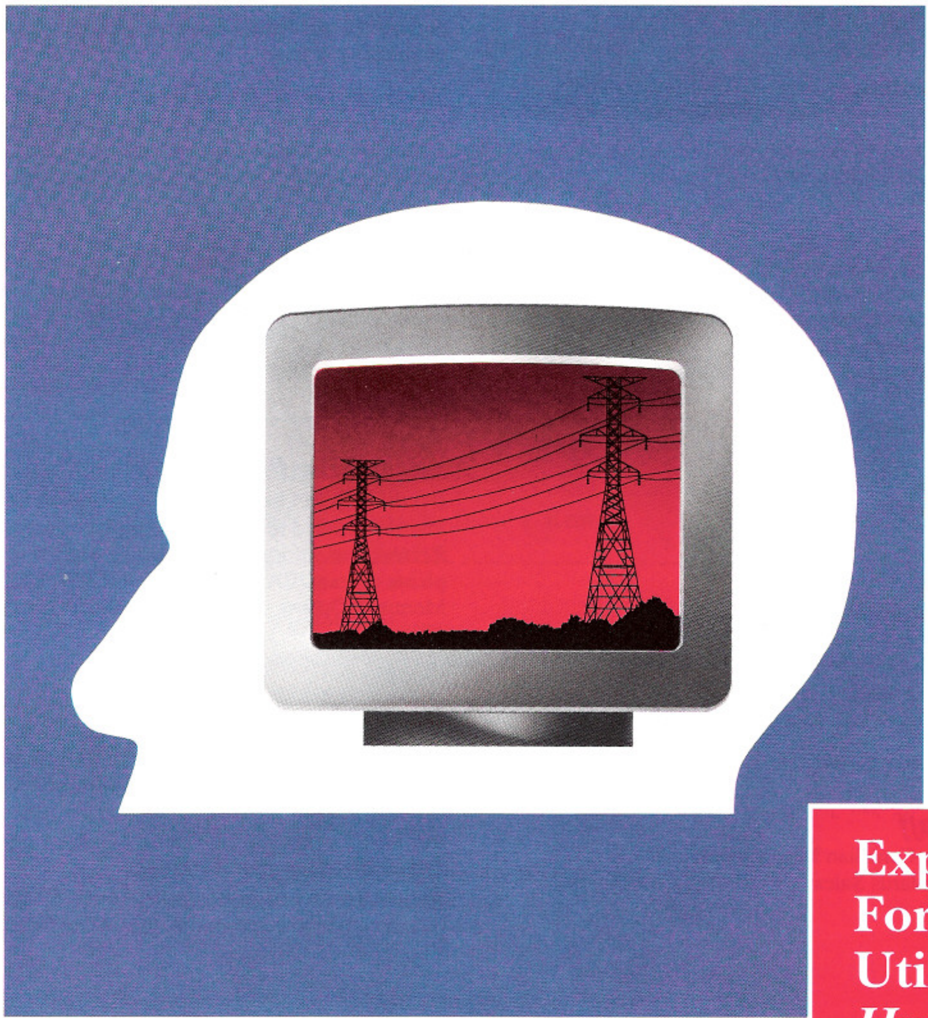

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Mailing address:
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L3T 2A6
Canada

Telephone: (416) 881-1930
Fax: (416) 881-2057

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(i) Canadian members of IEEE;

(ii) Canadian members of the profession and community who are non-members of IEEE;

(iii) the associated academic (i.e. universities, colleges, secondary schools, etc.), government and business communities in Canada.

In this context, the *IEEE Canadian Review* also serves as a forum to express views on issues of broad interest to its targeted audience. These issues, while not necessarily being technologically-oriented, are chosen on the basis of their anticipated impact on engineers or their profession and the augmented academic, business and industrial community, or even the community at large.

To ensure that the *IEEE Canadian Review* have the desired breadth of issues and that the required depth of analysis be achieved, five Associate Editors are responsible for identifying issues and screening articles submitted to the *IEEE Canadian Review* according to the following general themes:

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2- International affairs
3- Technology
4- Industry scene
5- Education

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National Affairs
Francis Dupuis
Hydro-Québec,
Montréal, Québec
(514) 289-4608

International Affairs
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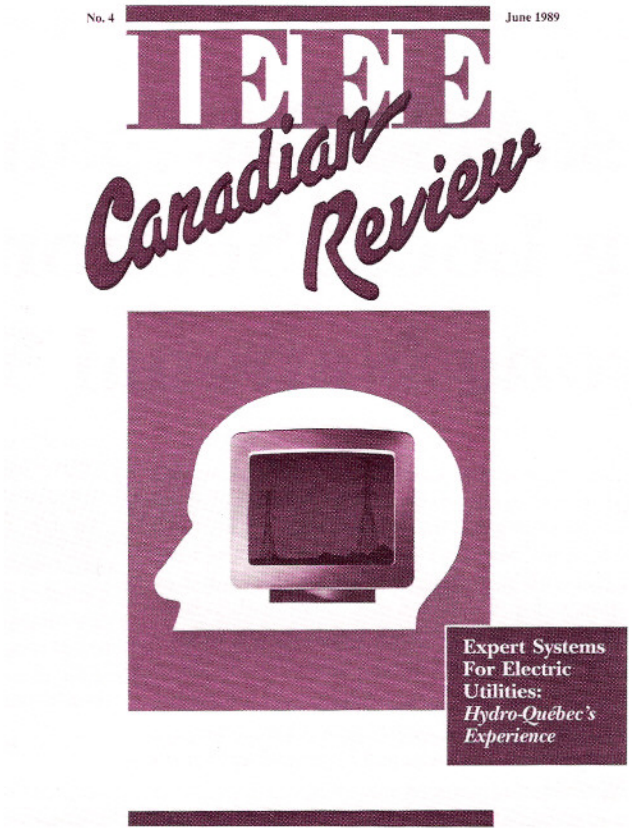

As development tools mature and knowledge-engineering approaches critical mass in some organizations, expert systems begin to make important inroads in industry. In this issue, we survey a number of applications as expert systems penetrate the electric power industry.

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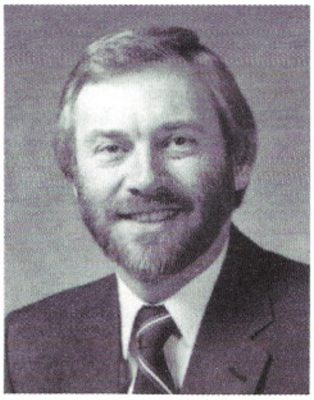
IEEE CANADA: Strong Local Sections - A Strong National Society

by Dr. Robert T.H. Alden
Director, IEEE Canada



Recently, I attended the annual meeting of the IEEE Kingston Section. This is one of our relatively smaller Sections of about 300 members. The setting was magnificent in the Senior Officers Mess of the Royal Military College on the shores of Lake Ontario. The events of that evening told of an equally inspiring story that epitimizes the vitality and strength of IEEE. A story of technical excellence, application of technology, and the annual revitalization of our volunteer leadership.

The recognition of technical excellence took the form of the presentation of IEEE Fellow certificates to two members of the Section. Paresh Sen was recognized for his work in power electronics, and Peter McLane for his work in digital communications.

Michael Davies, a newspaper publisher, described his use of computer technology. He discussed the significant difficulties for both management and employees in implementing changes in working conditions and contracts. He also stressed the necessity to adapt to state of the art computer technology for the very survival of his business.

The handing over of the 'care of the Section' from the outgoing to the incoming executive committee was performed with typical friendliness and good humour. It reminded me that our Institute continues to attract a large number of highly dedicated and competent professionals who volunteer their time and energies.

In driving home the following day, I crossed over the aging railway line connecting Toronto and Montreal. A little later, I passed by the plant of UTDC (the Urban Transportation Development Co.), and I thought about the sad state of our Canadian railroad system, and the lack of vision of our current political leadership. We have (had) a heritage of primacy in transportation, energy and communications which is being decimated by short-sighted, political, self-serving decisions. We have the specialized knowledge and facilities to build a modern high-speed rail system that could save energy, reduce pollution as well as highway and airport congestion, and popularize travel between our two largest concentrations of French- and English-speaking Canadians. Instead, we hear of massive passenger rail shutdowns being planned.

Where is the voice of electrical, electronic and computer experts that have the competence to speak out on how to use modern technology in our national interest? In reflecting on that one meeting in Kingston, it was clear to me that we are the people who know, and that we should start to speak up. Why is there a need to speak out? The Kingston publisher is part of the private sector with a personal vested interest in success. He had to modernize or "go broke". The public sector has no corresponding pressure point. Our political leaders have different vested interests, and the general public does not understand. If we do not act, and apply pressure with informed opinion, then we will all pay the price of a lower standard of living. To speak out nationally, we need a Canadian Society with credibility and a broad membership base. Let's create the Canadian Society of IEEE out of the Canadian Region, and with headquarters in Canada and full membership in IEEE International.

About the IEEE

The Institute of Electrical and Electronics Engineers, Inc. (IEEE), with headquarters in New York, is a transnational organization with 300,000 members in 137 countries. The world's largest engineering society, its objectives are technical, professional and societal.

The IEEE's technical objectives center on advancing the theory and practice of electrical, electronics, communications and computer engineering and computer science. To meet these objectives, it sponsors conferences and meetings, publishes a wide range of professional papers and provides educational programs. In addition, the Institute works to advance the professional standing of its members. It also has a mandate to enhance the quality of life for all people through the application of its technologies, and to promote a better understanding of the influence of these technologies on the public welfare.

Today, the IEEE is a leading authority in areas ranging from aerospace, computers and communications to biomedical technology, electric power and consumer electronics. When it began its second century in 1984, it rededicated itself to Innovation, Excellence, the Exchange of information and the quest for improved Education. In so doing, it underscores the initials IEEE.

IEEE Canada is the Canadian entity of this transnational organization, with approximately fifteen thousand members. The Canadian Region is divided into twenty Sections, each centered in a Canadian city, from Victoria, B.C., in the west, to St. John's, Newfoundland, in the east. For information on whom to contact in your area, the many IEEE products and services available, or how to join IEEE, write, phone, or fax our IEEE Canada office (page 2).

IEEE Conferences in Canada

by David J. Kemp
Manitoba Telephone System
Winnipeg, Manitoba

The IEEE serves the needs of its members in many ways. It is the world's largest publisher of technical periodicals and journals. In addition, it holds more meetings and technical seminars than any other technical organization in the world. IEEE Canada, which is IEEE's Region 7, hosts a wide variety of these conferences.

Conferences serve several valuable purposes in addition to the Institute's information-dissemination and scientific-advancement roles. They often generate revenues enabling worthwhile endeavours such as student branch support and awards. Volunteers achieve professional development and growth through their participation in the business-oriented planning and organization activities. Corporations benefit through product or application exposures as well as direct sales leads contributing to revenue growth.

Vertical and Horizontal Conferences

Events are generally described as vertical or horizontal in their treatment of program design. A vertical event addresses topics or issues in a specific field. Vertical conferences are most often sponsored by one of the IEEE's 35 Technical Societies serving the world-wide membership in a specific technical area.

In contrast to vertical conferences, horizontal events provide information or education in a broad spectrum of technical areas, or as it has been said, "Something for Everyone". Horizontal events are typically run by geographic IEEE entities such as Sections or Regions and are frequently co-sponsored by other organizations.

One characteristic of vertical conferences appears to be their geographic diversity. For instance the International Symposium on Multi-Valued Logic was held in Kingston in 1984 but has also been previously hosted by Winnipeg and Madrid.

Regional Events

In the past, major Regional events have been regularly hosted by Toronto and Montréal. ELECTRONICOM in Toronto and MONTECH in Montréal have attracted not only Canada-wide participation from attendees and exhibitors but also significant international participation. Future venues of these events are being examined to ensure a close match of industry needs and program content.

However, flexibility is also a landmark of IEEE's organizational make-up. For instance, Winnipeg hosts an annual Microelectronics Conference and Exhibition under the MICONEX banner. Serving technical and business needs, this conference has addressed specific microelectronic topics such as VLSI, and other areas such as aerospace and robotics. In addition to this, the sections within the Western Canada Council sponsor an annual WESCANEX Conference which rotates through different cities from Victoria to Winnipeg.

Canadian Achievements

Canada's unique expertise in communications results in several events being staged in various centres. A few examples are the International Symposium on Subcriber Loops held in 1983, INFOCOM 1989 which will be held in Ottawa, and the bi-annual Pacific Rim Conference on Communications, Computers and Signal Processing, the next of which will be held in Victoria in 1989.

A showcase of Canadian achievements will be featured at the October 22-24, 1989 State of the Art Symposium in Toronto. This premier event is being sponsored by the Canadian Region and the Toronto Section. The Conference themes will cover Education and People Development, Communications, Power, Computing, Industrial Automation, as well as Research and Development.

Several on-going international technical conferences regularly choose Canada as their host. Past examples include the1985 Power Engineering Society's Summer Power Meeting in Vancouver and the 1987 and 1991 Petroleum and Chemical Industry Technical Conference (PCIC), held respectively in Calgary and Toronto.

The rich diversity of Canada's electro-technology is evident not only in the broad array of topics previously mentioned but also including conferences on Antennas and Electromagnetics, Radio Sciences, High Voltage Direct Current, Teleradiology, Ultrasonics, Ocean Sciences, Plasma sciences and environmentally-related topics such as PCB's. These are but a small sample of the successful vertical conference activity in Canada.

Evolution

Conferences are not static. They are evolving to meet the ever-changing needs of business and international trade competition. Events are exhibitor-sensitive, moving into more vertically-oriented, highly focused plans. More vertical orientation also meets the career trends to technical specialization. Similarly, the internationally-oriented business view of technology and markets is increasingly served, in turn, by international forums for technical exchange and marketing.

IEEE Canada encourages conference activity in several ways which could be summarized as invitation, invention and evolution. For instance, technical Societies are invited to conduct their regular vertical events in Canada where they will find enthusiastic volunteers and charming facilities. On the other hand, other entities are encouraged to create new, on-going or one-time events to satisfy unique needs. Finally, evolution will carry us into the future with success as existing events will change shape and scope to meet ever-changing and demanding requirements.

Organizing Support

To foster growth, IEEE Canada is served by a Conference Advisory Committee. This national body is mandated to provide financial and knowledge support to ensure excellence and growth in Canadian conference endeavours. Combined with IEEE Headquarters, local organizers can be assured of advance (seed) funding, no-cost insurance and planning assistance. Excellent, comprehensive planning guides are available which treat, in detail, the steps and methodology to assure success.

If potential organizers wish to explore support to undertake meetings, symposia, or conference events, the IEEE Canada Office is prepared to discuss and encourage member initiatives. The full-time staff and volunteers are prepared to serve.

The Strategic Implications of Canada's Choice of Submarine

Beyond the cancellation of the Canadian nuclear-powered submarine program due to budget compressions, the strategic environment remains.

by R. Jack Daniel
Vickers Shipbuilding and Engineering Ltd.
(Member, Trafalgar Consortium)
Ottawa, Canada

Canada is a maritime nation with important interests and resources in and adjoining three oceans. A claim to sovereignty brings a responsibility to police such waters and territories.

The maritime threat to Canada's interests has historically been from submarines. It remains so today, from nuclear submarines against which surface anti-submarine forces are disadvantaged and vulnerable unless supported by some other appropriate means.

Le Canada est une nation maritime qui possède d'importants intérêts et ressources dans trois océans. Les impératifs de la souveraineté nationale entraînent la responsabilité de surveiller et de protéger ces eaux et les territoires afférents.

La menace maritime aux intérêts canadiens vient historiquement de sous-marins. Cette menace demeure, notamment de la part de sous-marins à propulsion nucléaire contre lesquels les forces anti-sous-marines de surface sont vulnérables à moins d'être soutenues par d'autres moyens appropriés.

Discussion in the media concerning Canada's intention to acquire a force of nuclear-powered submarines has been concerned largely with cost in the context of the other financial calls upon the government. There has been little informed public discussion of the two competing designs, nor has there been discussion of how such acquisition would fit in with Canada's foreign policy aims. This policy, developed during the present century, has been to preserve Canadian independence and independence of action, politically, militarily and economically, and not to be drawn inexorably into situations and commitments over which Canada has no control, as was the danger in the early part of this century through its close association with Britain and, in the latter half, through a similarly close association with the United States.

To demonstrate this independence, Canada, in common with many other nations unable to defend themselves against the massive threats that might be deployed against them, has sought security in collective associations. These associations can either be political in nature, such as the League of Nations, the United Nations, the Commonwealth and less directly the Organisation of American States, or they can be military in nature, such as the North Atlantic Treaty Organisation (NATO) and various agreements with the U.S. The wish to make these associations effective is perhaps one of the reasons why Canada is usually at the forefront of nations offering peace-keeping forces and observers to the United Nations.

The purpose of politico/military alliances is deterrence. An attack on one member will be regarded as an attack on all and such an attack will result in the aggressor paying a price, hopefully a higher price than he is willing to risk. Deterrence operates at all levels as Herman Kahn has described, from "recalling one's ambassador for consultations" to the "threat of insensate nuclear exchange".

Membership of an alliance brings obligations, not only to have a voice in the direction of the alliance but to contribute in due measure to the forces upon which the effectiveness of the alliance depends. Clearly, nations contribute according to their means. It has been widely recognized within Canada that, for many years, Canada's contribution as a proportion of gross national product spent on defence has been low, only Iceland and Luxembourg among the NATO nations having spent a lower proportion.

Most nations possess the means to police and, if necessary, to defend the territories and waters to which they claim sovereignty. Indeed, there is a view in international law that a nation cannot claim sovereignty in the absence of such means. Where a nation is a member of an alliance and its territories and waters have strategic significance to the alliance, it is assumed that the nation will provide the necessary forces to exercise surveillance and presence in those regions or enter into contingency arrangements for other members of the alliance to help. Better a friend than a potential aggressor.

One should remember that Canada is a maritime nation, with the longest coastline in the world, washed by three oceans. The Canadian Arctic extends over 2.5 million square miles and the Canadian continental shelf, which is equal to 40% of Canada's land area, is rich in fish, gas, oil and mineral resources. More than 90% of her overseas trade is seaborne. The traditional pattern of trade has been with Europe through the Saint Lawrence and East Coast ports but this pattern is changing with the emergence of the Pacific Rim nations as advanced manufacturers and traders. The increased importance of Pacific trade and the increase in naval activity in that theatre by other nations underlines the requirement for an increased Canadian maritime presence on the West Coast.

NATO and the Maritime Threat

NATO is a defensive alliance in which the industrial and military might of North America is of cardinal importance. The assumption is that an aggressor would seek to interrupt the transport of men, equipment and materials across the Atlantic Ocean. The credibility of NATO's deterrent posture with land and air forces in Europe is predicated on the assumption that the alliance has the means and the ability to maintain that "sea-bridge" to Europe. Canadian naval forces have an important role in this respect.

In the event of hostilities, the attacks would be made by aircraft and submarines using conventional warheads at the outset to avoid nuclear escalation. Submarines would be armed with anti-shipping missiles, torpedoes and mines as well as cruise missiles for shore targets. In the Atlantic and Pacific theatres, aggressor submarines would have to make long ocean approaches to reach focal points during which they would be vulnerable to detection and attack by allied submarine, surface and air anti-submarine warfare (ASW) forces. By far the most effective of these ASW systems is the nuclear-powered submarine.

The Soviet Navy has concentrated the major part of its submarine, air and surface forces in the Northern Fleet in the vicinity of the Kola Peninsula. The second major concentration is the Pacific Fleet of Petropavlovsk. Submarines move from one fleet to the other by the Arctic route through the

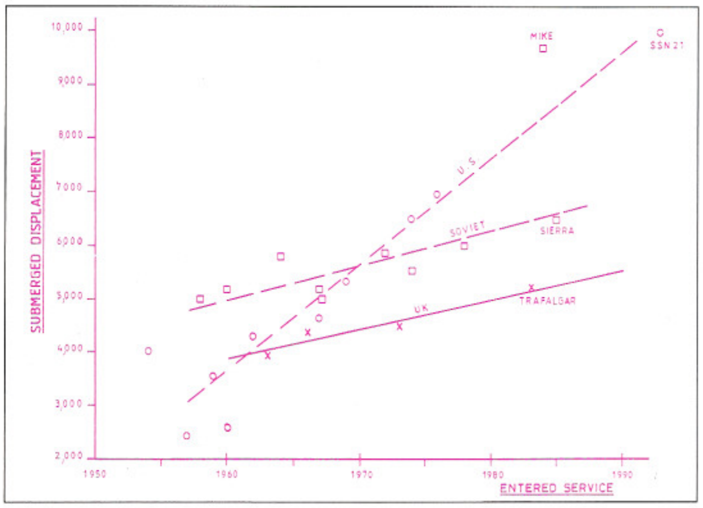


Figure 1 The evolution of the size of U.S., Soviet and British nuclear-powered submarines

Bering Strait. Like the U.S. and the British, the Soviet submariners are well versed in Arctic operations.

The other principal access route to warmer waters is via the Norwegian Sea to the Atlantic Ocean through the Greenland, Iceland and United Kingdom (GIUK) gaps, an operation that would be hazardous in war. A third access route would be through the passages of the Canadian arctic archipelago. It must be assumed that such passages have been fully reconnoitred by the Soviet Navy and that the absence of recent reported activity does not indicate an absence of interest.

NATO forces would seek to restrict access through the GIUK gaps by means of minefields, submarines, patrol aircraft and surface ASW forces and thus to limit an aggressor's capability to launch missile strikes against Canadian, U.S. and European targets, lay mines and attack shipping. Advances in surveillance and communications techniques by satellites and other means make it possible for aggressor aircraft and submarines to be supplied with real-time information regarding potential surface warship and merchant targets. In a similar manner, allied submarines would be given the latest intelligence on possible aggressors and vectored to position by the maritime commander.

In hostilities, the effectiveness and eventual survival of allied surface ASW forces would depend upon the deterrent presence of allied nuclear-powered submarines (SSNs). This is a consideration that has hardly been mentioned in the media discussion of frigates versus SSNs, namely the vulnerability of surface ASW forces in the absence of friendly SSNs. This requirement materially affects the required SSN characteristics and places a premium on speed for sprint and drift and end-run tactics apart from the more obvious need to match the speed of the surface force on occasion.

The Soviet, U.S. and U.K. Navies have placed a significant part of their deterrent missile force in nuclear-powered submarines. Successive generations of missiles have been given increased range and accuracy; increased range to increase the volume of ocean in which the launching submarines may be concealed and increased accuracy to ensure a successful attack from those extreme ranges. This has resulted in bigger missiles and bigger submarines to carry them: the 18,000 tonne OHIO Class in the U.S. Navy, the 25,000 tonne TYPHOON Class in the Soviet Navy and the 16,500 tonne VANGUARD Class in the British Navy. The Soviet submarines can launch their SS-N-20 missiles against North American targets from the Arctic Ocean and can surface through 3 meters of ice. This Soviet policy of concentrating its missile submarines in defensive "bastions" close to their bases, supported by SSNs, surface forces and aircraft, and where all maritime activity can be monitored, is in recognition of the ability of British and U.S. attack submarines to detect, track and intercept Soviet submarines in the open ocean by virtue of the Allies' superior silence, sonar and high speed.

Whether, at the outbreak of war, it would be better to use attack submarines to attempt to neutralize the Soviet ballistic missile submarines in their bastions and thus deter the use of nuclear missiles by upsetting the nuclear balance (the U.S. Navy "forward strategy") or whether it would be better to preserve the nuclear balance as an indication that the NATO powers do not intend to initiate a nuclear exchange, are important decisions for Ministers, but they do not affect the choice of submarine for Canada.

Canada's Submarine Requirement

The emphasis of the 1987 Defence White Paper was to review the mission and composition of Canada's forces and their disposition within the framework of the existing agreements in NATO and the defence of North America. The Canadian Navy's role remained as before with the added commitment to a force of nuclear-powered submarines able to operate in the Arctic Ocean. The Minister of National Defence emphazized at that time the intention to acquire a proven design with proven under-ice capability. In the ensuing debate, alternative technological solutions were advanced, such as fixed surveillance arrays, minefields, diesel-electric submarines, frigates and aircraft, but patently no combination of these alternatives could fulfil the open ocean roles and the under-ice deterrence function and all lack the versatility and cost-effectiveness of the nuclear submarine.

Without doubt, Canadian nuclear submarines would spend the major portion of their operational time in the open waters of the Atlantic and Pacific Oceans. If they are to operate in an essentially coastal patrol role within the present NATO commands, this alone would not necessitate Canada acquiring nuclear-propelled submarines since developing technology applied to basically diesel-electric submarines might produce a boat that is just good enough for this, at less cost.

There is however the pressing need for Canada to provide a credible submarine ASW capability in support of her frigates with speed, sonar and stealth characteristics compatible with intercepting potentially hostile cruise-missile-armed submarines one thousand miles' distance from Canada's shores. This requirement can only be met by submarines with performance characteristics similar to modern British and U.S. attack boats. The British categorize such submarines as "fleet submarines". It avoids the evocative word "attack" and is more descriptive of the many roles that a modern nuclear submarine can undertake.

Although the open ocean requirement is important, it is the Arctic capability that clinches the need for the nuclear-powered submarines. Only nuclear-powered submarines can operate safely in the Arctic Ocean and provide that evidence of presence essential to deter intruders, aggressive or otherwise. Nuclear-powered submarines also bring the ability to transit between the Atlantic and Pacific Oceans and hence the savings in total force levels made possible by the ability to rapidly reinforce either theatre in an emergency.

It is of course a requirement that the cost of the program is acceptable and that the acquisition and ownership of the nuclear-powered submarines should not present an environmental hazard nor be considered to compromise Canada's position as regards nuclear non-proliferation. The importance to be given to each of these factors will depend eventually on political judgement.

Three aspects of potential hazard to the environment from submarine reactors have been said to give concern, the hazards arising from normal operations, from accidents and from waste disposal. In British designs, there is no hazard arising from normal operation. No radioactive substance is discharged freely from the submarine. The nuclear core is contained within its massive pressure vessel which is itself contained with a sealed and shielded section of the submarine hull, so that those on board receive less radioactivity than they would when crossing the ocean in an aeroplane. The structure of the reactor compartment is designed to contain the results of any accident with zero leakage and, of course, the submarine's hull provides a further level of containment. This standard of containment is far more comprehensive than many of the world's civil power stations that contain much more radioactive material: witness Chernobyl. Comparison with civil nuclear reactors is also relevant in the question of the disposal of radioactive waste where the amount of such material arising from the submarines would be a very small percentage of that produced by Canada's nuclear power industry each year and should perhaps be viewed in that light.

Figure 2 The British TRAFALGAR Class nuclear-powered submarine.

The requirement as regards cost is that the program should be affordable and cost effective. Without question, not to build anything at all saves money. But this avenue also reduces the authority with which Canada's voice is heard in international affairs and it will frustrate Canada's efforts towards a balanced fleet and thus make her surface naval forces that much more vulnerable. On a more mundane level, it will not produce the several thousand employment opportunities the submarine programme would create over the next half-century nor would it bring new technology to Canadian industry with its potential spin-off into civilian products.

British nuclear-propelled fleet submarines are remarkably cost-effective. They cost about half the cost of the U.S. Navy's bigger LOS ANGELES Class. The cost per tonne weight of the TRAFALGAR Class submarine is about 100 thousand dollars and the cost per tonne weight of the U.S. submarine is about 140 thousand. Small nuclear-powered submarines are even more costly on a dollars per tonne weight basis than either of the above.

A very simplistic approach to the choices between fleets of submarines, based on a basket of capabilities and cost, shows the 5,200 tonne vessel to be twice as cost-effective as a smaller nuclear submarine. However, this treatment is too broad brush. In smaller numbers and addressing realistic deep ocean operational scenarios, it can nevertheless be argued that the available sum of money would buy a greater operational capability when spent on medium-sized submarines than on a slightly larger number of small nuclear submarines.

Some Design Considerations

The three nations that operate submarines in the Arctic know full well how hostile the environment is and the special design provisions that must be made. This includes a robust sail and casing to withstand ice-loading, short range side scan and upward looking sonars, closed circuit TV, navigation systems that work in the polar region, redundancy in the propulsion system and communications systems that can receive signals under-ice. Forward hydroplanes should be forward and retractable where good hydrodynamic design considerations require them to be and not on the sail. It will be noted that the U.S. Navy has returned to the forward location of hydroplanes in the later ships of the LOS ANGELES Class.

Much was written a year ago about a device that would enable small submarines to surface through Arctic ice. Not much has been heard of this recently. The critical factor is the upward force that the submarine can exert on the underside of the ice and this relates to the submarine's displacement. In round terms, given adequate sail and casing strength and stability, a 3000 tonne submarine might penetrate ice 5/8 meters thick, a 5000 tonne submarine can penetrate ice 1 meter thick and a 25000 tonne submarine, ice 3 meters thick. Attention must also be given to submarine systems and the maximum redundancy/duplication provided in the main propulsion plant and final drive.

There are no short-cuts and making these provisions requires a submarine to be bigger than would be the case if under-ice operations were not a consideration.

The introduction of nuclear energy for propulsion totally changed submarine design. With the certainty of abundant power, gone was the tyranny of designing the smallest possible submarine because of limited battery capacity. Now, designers are limited only by cost. The avoidance of detection and counter attack is no longer a question of smallness but of a submarine's ability to detect and classify a possible target before it is itself detected; a question of sonar and stealth.

It took time for designers and naval staffs to recognize these possibilities. It was a gigantic step in the 1950s to go from 1,500 tonne diesel-electric submarines to 3,500 tonne nuclear-propelled submarines. Only subsequently have designs been optimized properly to exploit this revolutionary warship type, hence the progressive increase in size of U.S., Soviet and British nuclear submarines.

Figure 1 shows how the size of nuclear attack submarines in the British, Soviet and U.S. Navies has increased over the years as successive designs have entered service. Given the prerequisite that these first-rate submarines should carry a substantial number of weapons and have a submerged speed in the region of 30 knots, the increase in size is almost entirely due to sonar and stealth to provide the biggest and most comprehensive sonar outfit in the most silent submarine. The sonar arrays must gather the maximum amount of the minute quantity of energy that reaches the submarine from a distant source for processing and classification. Size is important. The sonar must also be configured to enable it to be used to estimate the range of distant sources and provide data to the submarine's computers. All arrays must be configured within the submarine's streamlined form in positions of minimum hydrodynamic noise and maximum "visibility".

Stealth is the ability of the submarine to conceal its presence. The principal requirement is that the submarine should not radiate measurable quantities of noise into the distant field and that the noise that does escape should be indistinguishable from ocean noise. Above all, it should not change in intensity or pattern since, just as a hunter notices the sudden movement of an otherwise invisible animal, so the hostile sonar will detect a change in the "noise pattern".

Compared with diesel-electric submarines, the nuclear submarines of the late 1950s and early 1960s were noisy, with propulsion gearboxes and reactor main coolant pumps known offenders. These difficulties have been entirely overcome in the British submarines - a coin will remain on edge on a TRAFALGAR gearbox at full power and the main coolant pumps are equally vibration free.

In fact, in evidence to Congress, the U.S. Navy has stated that the submarines of the TRAFALGAR Class are quieter than the quietest diesel-electric submarine in service - the British OBERON. Several of the techniques used have been licensed to the U.S. for their use in submarines.

In parallel with the development of silent machinery and systems, much research in the U.S.A. and the U.K. has gone into alternative propulsion methods in search of smaller, cheaper and more silent submarines. In particular, studies were pursued regarding turbo-electric drives and the elimination of the main coolant pumps by the use of natural convection. The problem with natural convection reactors is maintaining the required convection and temperature regime when the submarine is manoeuvring. Unless the reactor is made tall, necessitating a bigger diameter submarine, pumps must be provided and run when there is the possibility of significant manoeuvring (see *IEEE Canadian Review*, December 1988). In war, an experienced submarine commanding officer must always be prepared to manoeuvre and hence it is reasonable to assume that, in order to avoid the possibility of a change in the submarine's "noise pattern", the reactor would operate with the pump running; thus, the claimed advantage for small, natural convection reactors is largely illusory and, in return, there are the through-life problems anticipated in integral reactors and steam generators.

Turbo-electric submarines are attractive but were found to be power-limited and to present the designer with a Catch 22 situation in which it is not possible to produce a submarine to match the hostile submarine threat. As an illustration of this problem, the power of a 24 knot, 2900 tonne submarine would have to be nearly doubled to match TRAFALGAR's speed. In practice, of course, this would require bigger machinery and a bigger submarine and if the bigger submarine is achieved by adding length, the shape becomes even more disadvantageous and resistful and thus even more power is required to achieve the speed. There will have to be a dramatic breakthrough in technology, such as battleworthy superconductivity, to change this situation.

Conclusion

The cornerstones of Canada's defence are membership of NATO and bilateral arrangements with the U.S. Geography and history have cast Canada as a maritime nation with vital interests in three Oceans, the Atlantic, the Pacific and the Arctic.

Canada's strategic aims require a presence in these oceans, principally in a deterrent anti-submarine role. A balanced force is required: frigates, helicopters and aircraft are not enough. They must be supported by nuclear-powered submarines which, for credibility, must themselves be comparable in performance with the perceived threat and equally at home beneath the Arctic ice or in the deep, broad oceans.

Forensic Electrical Engineering Anyone?

Somewhere, there should be gathered a "Chamber of Electrical Horrors" which could record past errors and their results.

by John F. MacMaster
MacMaster Engineering Ltd.
Calgary, Alberta

The appellation "forensic" as applied to electrical engineering is rapidly becoming the new glamour symbol short for Sophisticated Trouble-Shooting and Reporting of Electrical Accidents.

The Oxford Dictionary defines "forensic" as:

1. pertaining to, connected with, or used in Courts of Law, and
2. a speech or written thesis maintaining one side or the other of a given question.

In fact, "2." above accurately describes the initial step with which the engineer is concerned, and if performed satisfactorily and with efficiency (so important to the engineer), the time-consuming and expensive alternative "1." involving Court action is rendered unnecessary.

The electrical engineer's involvement could be defined as:

"the application of engineering knowledge, experience and skills to the examination, analysis, assessment, and accurate reporting of electrically-caused or associated damage".

The *pursuit of the truth* in this type of work is demanding, fascinating, revolting in some cases, and always challenging, as every case presents a different puzzle to be solved, different people to deal with, and often requires research into unfamiliar fields.

Frequently, the engineer is called in long after the fact, (two years after in one case) when the trail has long gone cold, the "finger prints" long wiped off, and the memories of those involved are confused and uncertain. In such cases, the existence of written testimony of witnesses at the time and photographs taken by them or news photographers are most valuable and may yield essential information to solve the enigmas.

The essential objective is the establishment of the absolute truth of the case, impartially, without fear nor favour, based on the incontrovertible facts. This is the sublime target.

Unfortunately however, the absolute truth is sometimes as illusive as a rainbow, and the engineer must content himself with presenting his opinion based on conclusions drawn from such evidence as is available to him.

The majority of cases are initiated by Insurance Adjusters who seek guidance in assessing liabilities for their company, but occasionally, when litigation is involved, a legal firm will call upon an engineer to act as an expert witness. In this situation, his capabilities may well be challenged by another forensic engineer working for the adverse party, and it becomes a case of "may the best man win". This is another cogent reason for exerting every effort to leave nothing to doubt in one's unremitting search for the truth.

The Case of the Exploding 7500 HP Motor

Back in the early 1970's, our forensic-type projects started with an urgent call to inspect and report on an explosion in a large, pipe-ventilated induction motor which drove a gas compressor in a large gas processing plant.

The expertise required in forensic engineering calls on one's abilities as an observer, photographer, investigator, diplomat, writer, sometimes linguist, interpreter (to non-electrical persons), educator and, of course, versatile engineer. In short, one must be a veritable electrical Sherlock Holmes...

L'expertise requise par la pratique de l'ingénierie légale met à rude épreuve des talents d'observateur, de photographe, d'investigateur, de diplomate, de rédacteur, parfois de linguiste, d'interprète (pour ceux qui ne sont pas versés en électricité), d'éducateur et, évidemment, d'ingénieur versatile. En somme, il s'agit d'être un véritable Sherlock Holmes de l'électricité...

Arriving at the site, we were shown the motor which had the end covers removed to show burn marks rising from the inside ends of both bearings and the corresponding "fried" patches of stator winding insulation above.

The galvanized sheet steel ventilating ducts were burst, bent and draped over the adjacent equipment, and everywhere echoed the ominous stillness of a giant at rest !

The centrifugal compressor was driven from the 1800 r.p.m. motor through a gear speed increaser, and the lube oil systems of the motor, gear unit and compressor were supplied by a common system, as was the seal oil system which supplied oil at higher pressure than the gas to the compresssor bearings. This was necessary to prevent the gas escaping past the compressor bearings.

The two electrically-driven lube pumps (one as stand-by) were further backed-up by steam turbine driven-pumps, a true "belt and braces (suspenders) system" which apparently was considered to be fool-proof.

The *Moment of Truth* came when the electric power supply failed, and the following sequence of events occurred:

1. All electric motors stopped including the 7500 hp driver, and the lube pumps, but this was allright because
2. the steam-driven pumps took over and maintained the pressure, until
3. the steam boiler auxiliaries also "died" and the steam pressure eventually did the same, and then
4. the high pressure gas in the compressor overcame the seal oil pressure and escaped into the lube oil system, and...

(continued on page 15)

Expert Systems for Electric Utilities: Hydro-Québec's Experience

Groundbreaking applications in the electric utility field may be typical of many future uses in other industries.

Radu Manoliu and André Lemire
Hydro-Québec
Montréal, Québec

Power system analysis involves a large number of activities that are knowledge-intensive and non-algorithmic, and therefore presents a significant potential for the use of expert systems. Eight projects of special interest are described.

L'analyse des réseaux électriques comporte un nombre important d'activités de nature cognitive et non algorithmique. Il s'agit donc d'un domaine propice à l'utilisation de systèmes experts. On traite ici huit projets qui retiennent particulièrement l'attention.

If power systems are to achieve a high degree of reliability and efficiency, they must use the most powerful and promising technologies available. In this regard, artificial intelligence, more specifically expert systems, could have interesting potential. The technology of expert systems is worth investigating because most power system activities are knowledge-intensive.

According to Harmon and King, the authors of the well-known book *Artificial Intelligence in Business*, two waves of expert system applications will take place. The first will last until the beginning of the 1990s and will be dominated by medium-sized applications designed to solve specific problems. Proliferation of this type of expert system will have the merit of fostering a favorable attitude toward this technology and contributing to the training of large numbers of knowledge engineers. It will also reap the first economic rewards for this new technology.

The second wave, which will feature much larger systems, will start to have an impact early in 1992 and will peak at the turn of the century. These expert systems will be far more apt to reproduce human reasoning, to the point that they will even rival human experts at times. This second wave will herald a veritable revolution likely to shake the very foundations of present-day methods of processing and disseminating information, as well as the decision-making process.

This scenario has been confirmed by market development projections. A prestigious consulting firm from the UK predicts a 6.6-fold increase in the market between 1986 and 1992 for Canada and the United States alone, or a sales volume of US $1.9 billion in 1992 for expert-system software and hardware.

Researchers at Carnegie-Mellon University, the Electric Power Research Institute, a group of Japanese utilities and Hydro-Québec have attempted to assess the potential expert systems offer electrical utilities. The following conclusions can be drawn from their findings:

1- Since the potential applications of expert systems in the electrical industry are determined by its know-how, the potential benefits are virtually unlimited.
2- Current applications lack coherence and do not follow any coordinated plan.
3- Most applications are experimental.
4- The areas of application explored so far represent only the tip of the iceberg.

The existing applications for expert systems in electrical utilities are found in the following areas: planning, system diagnosis, equipment diagnosis, engineering and design, decision-making and training.

The Hydro-Québec System

At the beginning of 1988, Hydro-Québec's installed capacity was 25 000 MW, of which 93% was hydro power. Its total sales in 1987 were $5 billion. The transmission system consists of 33 000 km of lines, of which 33% is 735-kV lines. The distribution system consists of 99 000 km of lines. Projects now under way will add 3 000 MW.

The Project Selection Process

Hydro-Québec's process of selecting candidate expert system projects begins with an analysis of the problems involved in light of established criteria. Two basic questions must be asked:

1- Is the expert system possible?
2- Will the expert system be useful?

To arrive at logical answers, two evaluation grids have been developed, the first designed to eliminate unsuitable candidates, the second to rank those that remain according to a scale of relative values.

First grid: Is the expert system possible?

a) Is the problem essentially heuristic and difficult to solve by conventional algorithmic methods?
b) Is local expertise available?
c) Is that expertise acknowledged by the users?
d) Is knowledge engineering available?
e) Does a data processing infrastructure exist?
f) Is the size of the system reasonable?
g) Is the degree of difficulty manageable?

Second grid: Will the expert system be useful?

a) Is the expert system justified?
- Does it offer significant, measurable, economic advantages?
- Is it in keeping with the utility's development plan?
b) Is the expert system necessary?
- Is there a need to transfer the expertise to a larger group of users?
- Is expertise disappearing?
- Is there a need for training?
- Has a need been identified for expertise in a hazardous environment?

Hydro-Québec's Expert Systems Projects

TRANSEPT - *Expert system for the preliminary design of a transmission system*

Planning of transmission system facilities is based on an immense body of knowledge, which is scattered throughout the utility. TRANSEPT is a preliminary design tool that can establish a score of alternatives. It takes into account the number of lines, voltage, compensation and system stability margin, while at the same time allowing the user to assess the financial impact of these various parameters.

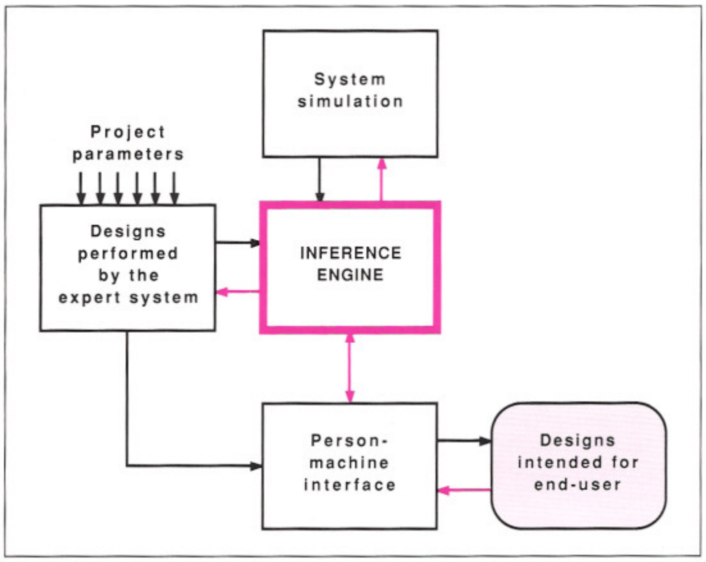


Figure 1 Block diagram of the TRANSEPT expert system

The purpose of TRANSEPT is to select a reduced number of alternatives that help the designer with the various design stages. The block diagram of TRANSEPT is given in Figure 1. This expert system can integrate algorithmic models and simulation models with the expert's knowledge and experience.

The explanations provided by TRANSEPT are extremely useful in securing user acceptance of proposed alternatives, as well as training new experts in system design. The TRANSEPT prototype was completed in 1988 and is now being validated.

SEPIDE - *Expert system for interpreting events*

Hydro-Québec has set up a large data base designed to detect and record in detail all changes in status occurring on the transmission system. After an event, the changes in status recorded in this data base are analyzed by the SEPIDE expert system which produces an explanation of the event which makes it possible to evaluate the situation. This activity is essential if the utility is to maintain the high level of reliability expected by its customers. Moreover, the maintenance schedule depends entirely on the results of this type of analysis.

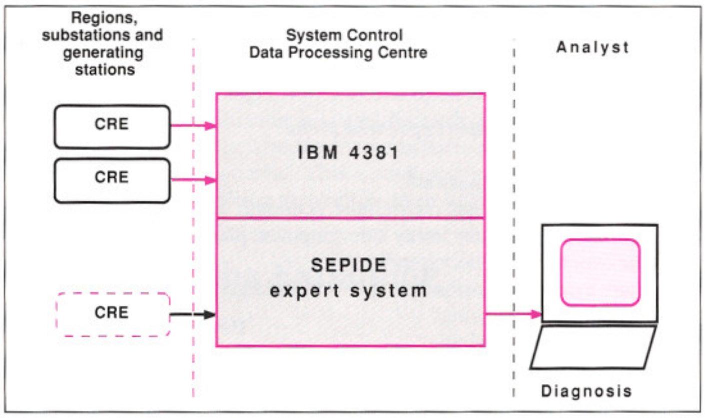


Figure 2 Block diagram of the operating environment of the SEPIDE expert system

The purpose of the SEPIDE project is to automate real-time or off-line interpretation of all transmission system events forming part of normal system operation (70% of them being automatic-control operations). Figure 2 shows the data base that comprises the chronological records of events (CRE) and constitutes the system's main input. The SEPIDE prototype was developed in 1987 to establish the principles underlying this system and to demonstrate its feasibility. A SEPIDE pilot project has been installed and is now being validated.

Expert System for Alarm Processing

The task of subtransmission system operators is becoming increasingly demanding as a result of the greater complexity of facilities as well as a substantially greater volume of information supplied by each installation. When equipment failures occur, these operators must quickly analyze the alarms and changes in status to establish fault diagnoses. The diagnoses enable them to take the necessary measures for power system restoration.

Operators are, however, frequently faced with complex analytical problems that require several minutes of reflection. These delays affect the quality of service because they prolong the outages. Moreover, the outages may increase in number if appropriate action is not taken swiftly.

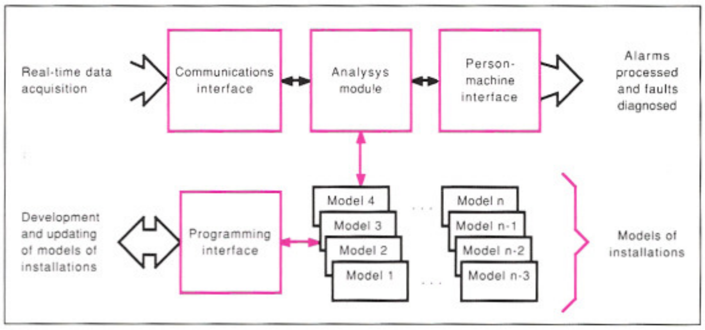


Figure 3 Block diagram of the alarm processing expert system

This alarm processing expert system shown in Figure 3 is designed to improve the processing of alarms and changes in status received by subtransmission system operators. On the basis of the alarm sequences and changes in status, the expert system automatically establishes concise, real-time diagnoses identifying the origin and consequences of a disturbance. These diagnoses enable subtransmission system operators to accelerate their analysis and more effectively manage the information that reaches them. The pilot project was completed in March 1989. It is now processing alarms from a dozen facilities in the Maisonneuve Region in order to ensure its validation in a real operating environment.

SEDA - *Expert system for equipment diagnosis*

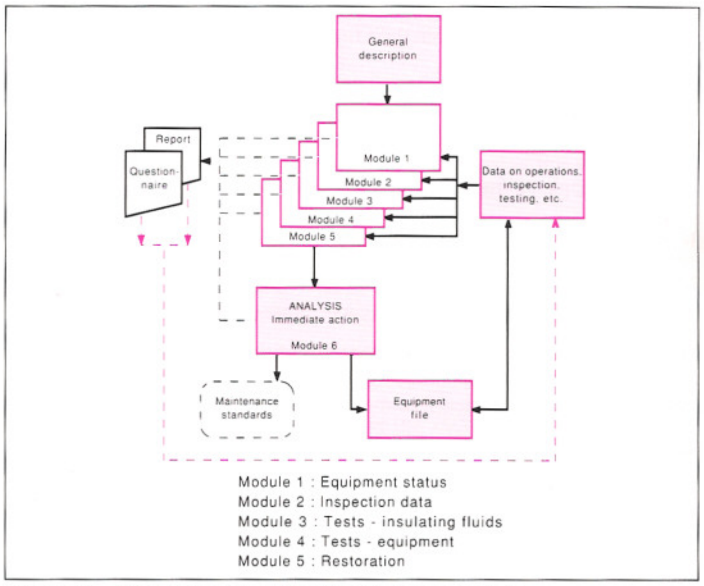


Figure 4 Block diagram of the SEDA expert system

The SEDA project reflects Hydro-Québec's efforts to discover better ways of determining or diagnosing the in-service state of its equipment. For this purpose, it has implemented preventive maintenance, management and monitoring systems in recent years. The advantages of these tools appear to be obvious. Today, the decision to develop an expert system for diagnosis of large power transformers is based on far-reaching experience in solving specific problems related to this type of equipment using the rules deduced and facts observed over long years of operation. This expertise must now be directed to the level of foremen and crew leaders.

The SEDA expert system, shown in the block diagram in Figure 4, is designed specifically for diagnosing phenomena that occur in large power transformers during automatic tripping.

SUBAREX - *Expert system for dam surveillance*

Dam surveillance is the responsibility of regional personnel. Design and behavior-analysis expertise is, however, spread among the various units of the utility, including those at Head Office. The result is on-site inspections followed by multiple exchanges of information, and then evaluations, consultations and proposed solutions.

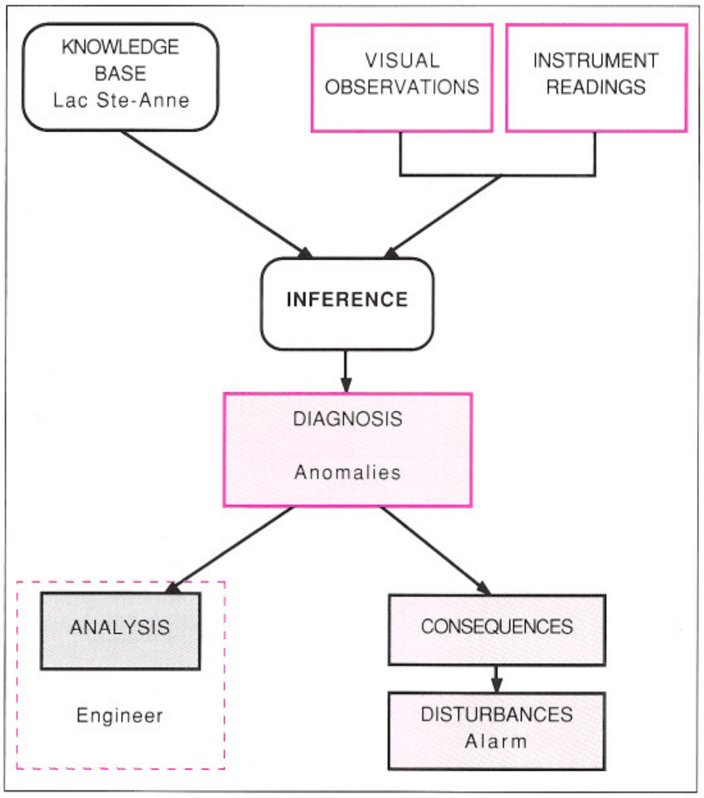


Figure 5 Block diagram of the SUBAREX expert system

SUBAREX, illustrated in Figure 5, is a tool for diagnosing the safety of earth dams on the basis of facts observed and sounding data. This tool, which initially will be intended for inspectors, will be used by regional personnel to make decisions as swiftly as possible within a high-expertise technical framework. A subsequent version will be intended for engineers to facilitate their evaluations of the structural and operational safety of dams and to monitor changes in their behavior. A pre-prototype used to demonstrate the feasibility of the system is now being developed.

ENERGEX - *Expert system for the ENERGIE III model*

The ENERGIE III model is used to simulate the operation of hydroelectric complexes. Before the model can be used, however, it must be calibrated, a task that demands a high level of expertise and effort.

The purpose of the ENERGEX expert system, shown in the block diagram in Figure 6, is to concentrate varied and intuitive experience in the form of precise rules that facilitate the use of the ENERGIE III model, while at the same time ensuring a quasi-optimum solution in terms of firm energy generated. ENERGEX will bring about substantial savings by accelerating the design cycle of hydroelectric complexes. A pre-prototype has been evaluated and validated, and the prototype is now being developed.

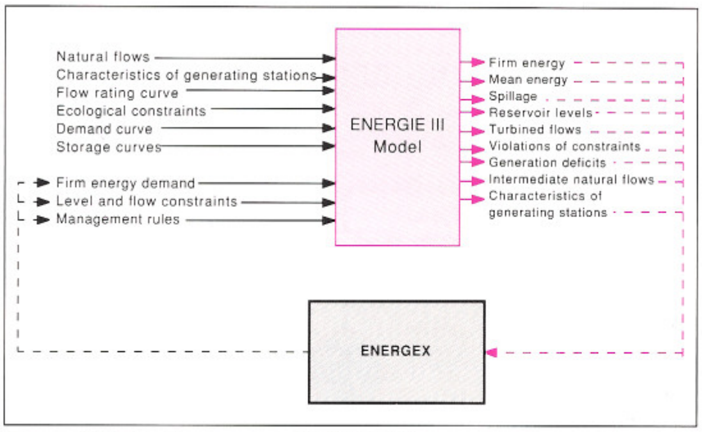


Figure 6 Block diagram of the ENERGEX expert system

EXSEMBLE - *Expert system for producing substation layouts*

Substation design involves extremely diversified knowledge, which has been partly standardized but is found throughout the utility. In the first stage, EXSEMBLE unifies this expertise and uses computer-aided design software to produce a type-II 120-25-kV substation layout.

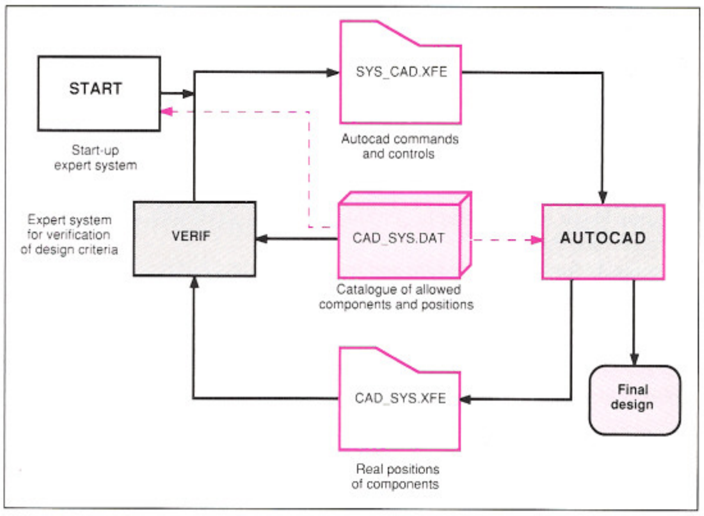


Figure 7 Block diagram for integrated EXSEMBLE application

EXSEMBLE, which is shown in the block diagram in Figure 7, constitutes an interactive link between the knowledge base and the computer-aided design software.

As the first prototype of this kind, the EXSEMBLE project opens a very promising avenue for intelligent support of computer-aided design in all engineering activities using a high concentration of standards.

SAGE - *Expert system for management of energy exchanges*

Management of energy exchanges with neighboring power systems involves a large quantity of information that requires real-time processing by dispatchers. The purpose of the SAGE expert system is to support energy-exchange management while at the same time maximizing sales revenues and minimizing purchasing costs and contractual penalties. Moreover, SAGE will standardize energy-exchange approaches and strategies, while ensuring a high level of flexibility with respect to new constraints, strategies and calculation tools.

The SAGE expert system, shown in the diagram in Figure 8, will use real-time information from the System Control Centre (SCC) and a production-management plan established by the NUMA mathematical model, as well as rules based on energy-exchange contracts and Hydro-Québec management standards. SAGE will establish the program for final exchanges on the basis of this information and these rules.

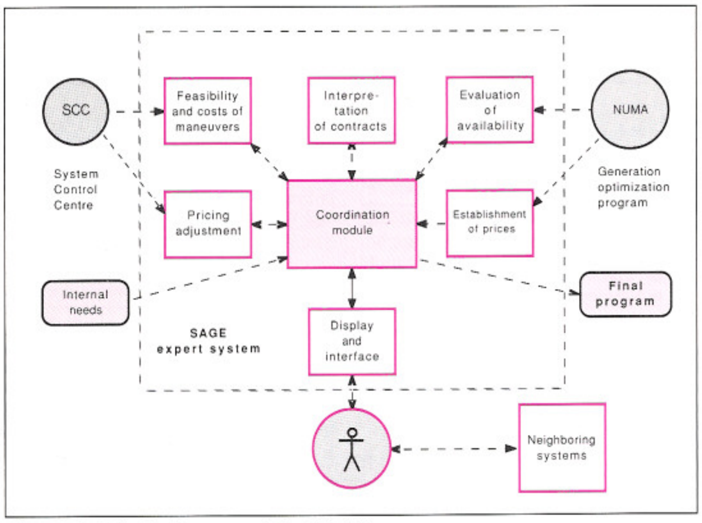


Figure 8 Block diagram of the SAGE expert system

Development Tools

One of the main problems to be faced in building an expert system is to select the appropriate tools since their features have a considerable influence on the quality of the system developed, especially its user-friendliness and performance.

To allow the designer to make an enlightened judgment, Hydro-Québec has developed a two-tier selection grid, one concerning the knowledge engineer and the other the end-user.

The first grid, which concerns the knowledge engineer, is used to compare the properties of the problem to be solved with the characteristics of the proposed tools. It affects the following elements:

- knowledge representation: production rules, predicate logic, semantic networks, frames;
- control: forward, backward and mixed chaining, bidirectional chaining, blackboard architecture;
- logic: use of variables, negation processing, etc.

The second grid, which concerns the user of the expert system, focuses on the following:

- user-friendliness;
- explanations: explanation of reasoning and justification of conclusions;
- interfaces: graphic, data bases, signals, etc.

The characteristics of the tools considered are evaluated by means of performance coefficients established using these grids. These coefficients are then used to compare the candidate tools with the characteristics of the problem to be solved. At the same time, Hydro-Québec endeavors to be economical with respect to the number of tools it employs in order to maintain reasonable budgets and limit training requirements for knowledge engineers. The price/performance graphs published by Harmon, Maus and Morrissey in their book *Expert Systems - Tools and Applications*, albeit very preliminary, are a good resource for tool selection.

Tool	Expert system
Goldworks	ENERGEX SUBAREX TRANSEPT
OPS 83	ALARM PROCESSING SYSTEM
Rulemaster	EXSEMBLE SEDA SEPIDE

Table 1 Tools used for the expert systems developed by Hydro-Québec

Table 1 shows the tools selected for the projects referred to in this paper. The reader will notice a polarization around certain tools. Subsequent experience, project evolution, user reaction and the advent of new tools on the market could modify this pattern. As well, developments in problem knowledge between the feasibility study and implementation of the finished product may entail a modification of the tool selected, in particular after the prototype stage. Moreover, in certain cases, different environments may be required for development and for operations.

All these expert systems were developed on 386-type personal computers, with the exception of the Alarm Processing Expert System, which was developed on MicroVax-GPX, as well as SEPIDE, which was developed on HP 9000.

Organization

In his book *Expert Systems in the Workplace*, O'Farrell cites four criteria for ensuring success in the development and implementation of expert systems in a utility environment. These criteria are:

a) perceptive selection of projects and project specifications with well-defined objectives;
b) emphasis on domain experts;
c) presence of a "champion" of the cause;
d) appropriately structured organization.

Hydro-Québec satisfied criteria a) and b) from the outset by developing the above-mentioned selection grids and by creating multidisciplinary teams, each comprising the domain expert, the end-user and the knowledge engineer, who report to the same authority. Moreover, special attention is given to developing clear and well-documented mandates involving precise objectives.

In addition to this, a Task Force on Expert Systems has been set up. It comprises highly motivated individuals from various administrative units of the utility. This horizontal structure facilitates communications and controls interdepartmental and professional competition. Thus criteria c) and d) are also satisfied.

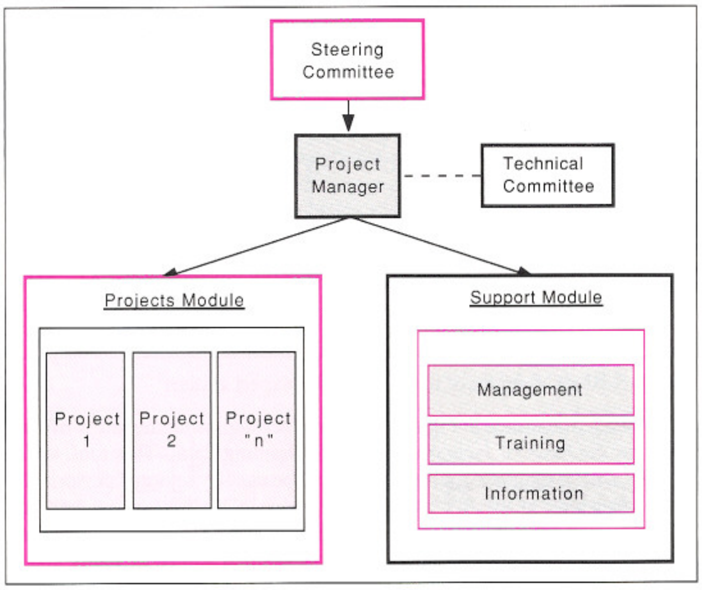


Figure 9 Structure of the Task Force on Expert Systems

Hydro-Québec's Task Force on Expert Systems, the structure of which is shown in Figure 9, is responsible for initiating and taking concerted action to introduce expert-system technology to the utility's main areas of activity. Its mandate includes the selection, development, implementation and marketing of expert systems in areas related to generation, transmission, distribution and use of electricity.

The Task Force reports to a Steering Committee comprising senior management representatives from the departments involved in activities related to expert systems, under the responsibility of the Vice-President, Development and Technology Marketing.

A Technical Committee, consisting of managerial personnel from the main units involved in expert-system projects contributes to the orientation of the Task Force's general activities, while current activities fall under the responsibility of a Project Manager.

This flexible structure is designed to establish horizontal liaison allowing dialogue between the various participants under the umbrella of the hierarchy without necessarily passing through it. These aspects are reflected in the organization of every compartment of the Task Force. Its basic structure, for example, is represented by the Projects Module and the Support Module, in which all the human resources allocated to a project or a support activity are concentrated, regardless of the department to which they belong.

The Projects Module comprises all activities related to expert-system projects. These are carried out by teams under the management of a coordinator. The teams comprise knowledge-engineering specialists, domain experts and computer specialists, who are assigned to the projects at the time the terms of reference are negotiated for the studies to be conducted.

The Support Module covers training, project management (planning, follow-up, cost control, etc.) and dissemination of information on expert-system technology throughout the utility. The participants in these activities are delegated by their respective units and have specific mandates.

Conclusion

It is clear that large electrical utilities can benefit significantly from expert-systems technology. In Hydro-Québec's specific case, this conclusion is founded on the following factors:

- There is a large number of potential expert-systems applications in the electrical utility environment.
- Substantial expertise usually exists in areas related to electric power systems within the utility.
- Significant scientific data processing resources exist within the utility which can potentially be retrained to become knowledge engineers.
- The need to transmit expertise to the coming generation is increasingly pressing.
- This technology, over the next decade, will affect most activities related to information processing.

Acknowledgments

Thanks are due to Toby Gilsig, Elie Saheb, Roger Beauchemin, Paul Chicoine, Oscar Dascal, Sergio del Pozo, Réal Galipeau, Jean-Louis Jasmin, Miguel A. Marin, Donald McGillis, Jean-Marc Pelletier and Gia Tong Vuong for their invaluable assistance with the preparation of this article.

Forensic Electrical Engineering Anyone? *(continued from page 10)*

5. the flammable gas migrated along the piping to finish inside the motor.

   This, in turn, was not too serious as, before the compressor drive motor could be energized, the cooling air fan was programmed to run for several minutes to purge the motor and air ducting completely with fresh air. Now enters the human factor, Murphy's Law if you like.
6. The regular staff electrician who normally started the motor and knew the routine of the automatic start scheme was away on vacation and in his place was an outside contract electrician who was clearly not familiar with the system.
7. When asked to restart the compressor, he could not get it to start from the local panel for some reason not apparent to himself, so...
8. He attempted to start the motor by going to the 5 kV main switchgear and tried to close the motor circuit breaker manually, thereby circumventing the automatic sequence involving the purge cycle, and **then BOOM**!

The problem now confronting the engineer was created by the contract electrician swearing that he did not actually close the circuit breaker and energize the motor. So what ignited the gas inside the motor?

It could not have been the explosion-proof, anti-condensation heaters, nor remanent heat in the motor frame. The one possibility offered was that the stator winding was momentarily energized sufficiently to cause a burst of corona which could have caused ignition in the gas-air mixture inside the motor frame and/or ducts. Who knows for sure?

A solution offered to avoid a recurrence was to keep the seal and lube oil systems separated as is the practice on a major Canadian gas pipeline.

The Case of the Pop-up Toaster That Wouldn't

In contrast to the previous example was the day a Fire Investigator arrived with a toaster crammed full of charred popcorn, and requested an explanation for its failure to operate correctly.

Apparently, it had been switched on with the toast properly inserted and the owner had been distracted by having to leave the house in a hurry.

Shortly after, a neighbour had noticed smoke emanating from the kitchen and called the Fire Department which arrived quickly, doused the fire, grabbed the toaster, and returned to the Fire Hall.

The toaster was handed to the City Electrical Department who looked at it, decided it wasn't their problem and promptly sent it back to the Fire Department as received!

From the Fire Department, it found its way into the hands of a Fire Investigator who was not electrically-inclined, and so the enigmatic entity gravitated to the electrical engineer to pass judgement.

First question : Why or how did the popcorn get into the toaster?

Answer: The toaster was on the kitchen counter under a cupboard, so that as the toast pyrolyzed and broke into flame, the flames licked up and burned a hole through the bottom of the cupboard, and on the bottom shelf of the cupboard, there was a bag full of popcorn which promptly cascaded into the toaster.

After painstakingly removing the carbonized popcorn with tweezers, it was possible to see the various components and trace the circuit.

It became apparent that the release mechanism for the pop-up consisted of a bimetal switch which deflected when heated until it closed a circuit through a diminutive solenoid which, in turn, pulled the latch to release the spring-loaded platform and eject the toast.

EUREKA ! One end of the coil of hair-thin wire had parted, thus no pop-up, but also the bottom plate with the manufacturer's name, rating and CSA stamp was missing which suggested "Finger Trouble". This was somebody else's problem !

Conclusion

Several important thoughts are evoked by this aspect of electrical engineering which deserve consideration.

1. The vast majority of electrical damage cases are the result of ignorance of electricity and of the enormous power that lurks silently in those seemingly inert and harmless conductors. One seldom, if ever, hears of electricity involved in a criminal context.
2. As electrical engineers, we have an enormously diverse field of endeavour but we also have a vast store of knowledge and experience in the various IEEE Journals to which we can refer.
3. Somewhere, there should be gathered a "Chamber of Electrical Horrors" or "Compendium" which could record past errors and their results. Only the bare facts of the cases should be given, such as those above, without any names mentioned, but which would act as guide-posts for those who come after us to spare them from falling into the same traps.
4. The Electrical Protection Branches of the Department of Labour do provide some feedback to C.S.A. through the Provincial Code and Advisory Committees, and this is eventually recorded in the Canadian Electrical Code. However, lives and equipment could be saved if electrical accidents could be dealt with more expeditiously for general knowledge and guidance.


Le LTEE, des électrotechnologies à votre mesure
Le Laboratoire des technologies électrochimiques et des électrotechnologies d'Hydro-Québec (LTEE) met l'électricité au service de l'industrie
•
séchage, chauffage et traitement des matériaux par rayonnement infrarouge, hautes fréquences, micro-ondes, induction, résistance
•
applications des plasmas
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procédés électrochimiques et électrométallurgiques
LTEE
600, rue de la Montagne
Shawinigan
Québec (Canada) G9N 6T6
(819) 539-1400
Télex : 05-837267
Bélino : (819) 539-1409
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