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ELECTRICITY TODAY
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INDUSTRY EMBRACING RENEWABLE PORTFOLIO STANDARDS

By Todd Wolfe and Kristi Sebalj

Creating an adequate renewable portfolio standard (RPS) for Ontario, along with other electricity generation and conservation initiatives, to promote renewable energy development has never been more critical.

Though unrelated to power supply issues, the August 2003 blackout, affecting 50 million people in Ontario and parts of the U.S. delivered a wake-up call to Ontario's energy consumers. Dramatic in its impact, the blackout was one of many events drawing attention to Ontarians' voracious appetite for power. New-found concern with electricity consumption and pricing may be too little too late, however. Ontario's Electricity Conservation and Supply Task Force announced in its January 2004 Final Report, that, "without new supply and substantial conservation efforts, Ontario could have insufficient power to meet its peak requirements by 2006. By 2014, the province would have only half the generating capacity it needs to ensure adequate and reliable electricity service." (1) Echoing these thoughts, Energy Minister Dwight Duncan stated that Ontario needs to refurbish, rebuild, replace or conserve 25,000 MW of generating capacity by the year 2020 to meet growing demand while replacing coal-fired generation to avoid an energy crisis. That 25,000 MW represents 80 per cent of Ontario's current installed generating capacity and requires an investment of $25 to $40 billion. (2)

Some suggest that, used in conjunction with other instruments, an RPS will be the most important policy tool to promote renewable energy development in North America over the next five to10 years.

A recent U.S. study by the Union of Concerned Scientists estimates that more than 355,000 jobs would emerge if the U.S. obtained 20% of its electricity from wind, solar and other renewables (nearly twice the jobs created to generate the same amount of electricity from fossil fuels)

RENEWABLE PORTFOLIO STANDARDS DEFINED

An RPS is one way to ensure that a minimum specified amount of renewable energy is included in the electricity sources serving a region. Government policy accomplishes this by requiring electricity consumers, retailers or distributors, as the case may be, to make sure a specific percentage of their portfolio comes from renewable energy sources (renewables). This system (a market mechanism) encourages the most cost-effective renewable energy generation with minimal administrative involvement. Some suggest that, used in conjunction with other instruments an, RPS will be the most important policy tool to promote renewable energy development in North America over the next five to10 years. (3)

Tradable renewable energy certificates (or credits) (RECs) that represent the environmental attributes of the renewables for which they are issued, are often used in conjunction with an RPS. An RPS creates demand for RECs by obliging electricity distributors to supply a specified portion of their power sales from renewable sources. A distributor (unless a generator itself) purchases energy with accompanying RECs from a generator and submits the RECs to the regulator to clear its obligation. Tradable REC systems have several attributes, including ease of compliance, demonstration and tracking, improved market liquidity, flexibility for suppliers to meet their obligations, and lower cost of compliance.(4)

RENEWABLE ENERGY SOURCES THAT QUALIFY UNDER AN RPS

Renewables are normally defined as energy sources that cannot be depleted and are self-replenishing, can generally be replaced, will always be available, can be sustained indefinitely, and are essentially non-polluting.(5) Renewables include wind, solar, biomass, geothermal, water, tidal and, sometimes, other sources. A specific RPS may stipulate that only certain categories or sub-categories of renewables qualify. For example, electricity from "large hydro", the definition which varies and can be controversial, is typically excluded from RPS in the U.S. (6) Large hydro results in no greenhouse gas emissions and is virtually inexhaustible but some past hydro projects have created substantial reservoirs and ecological change. In Canada, however, large hydro accounts for a significant portion of the energy base. (7)

RPS BENEFITS TO INDUSTRY AND SOCIETY

At present, renewable energy tends to be more expensive than traditional energy sources because of higher generation costs, limited resource availability, inability to take advantage of economies of scale, its intermittent nature (with, for example, solar and wind), increased sys-

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tem costs, and ancillary costs such as grid-connection, infrastructure strengthening, and planning or siting. Despite these drawbacks, recent technological advancements have improved renewables' relative economic position and a well-structured RPS can help put renewables on even economic footing with other sources. (8)

The most obvious advantages of promoting renewables are cleaner air and an improved environment. But, renewables provide other advantages such as igniting new capital investment, increasing domestic manufacturing, and creating new jobs. A recent U.S. study by the Union of Concerned Scientists estimates that more than 355,000 jobs would emerge if the U.S. obtained 20% of its electricity from wind, solar and other renewables (nearly twice the jobs created to generate the same amount of electricity from fossil fuels). (9)

According to the President of the Canadian Wind Energy Association, the federal government's recent commitment to develop 4,000 MW of new wind energy generation in Canada (10) will produce approximately $6 billion in investment and more than 40,000 direct and indirect person-years of employment. (11) Large consumer savings may also be in the cards. The Union of Concerned Scientists claims that a 20% RPS would save U.S. consumers more than $35 billion on electricity bills through 2020 along with $14 billion in lower natural gas bills as a result of reductions in the demand for and price of natural gas. (12) Further advantages include increased national energy security and cost predictability through reduced dependence on fossil fuels and foreign imports, increased energy diversity, decentralized electricity supply, technological advancements, and the opportunity to export technologies, management and know-how. (13)

A RENEWABLE PORTFOLIO STANDARD IN ONTARIO

THE HISTORY OF AN RPS IN ONTARIO

In June 2001, the Ontario government established a Select Committee on Alternative Fuel Sources (SCAFS). In its Final Report, tabled a year later, SCAFS recommended that an RPS be put into place by June 30, 2003 and urged that it "be amongst the most aggressive in North America". (14) In the fall of 2003, the government announced its plan to introduce legislation to implement a "Green Power Standard" that "will be the biggest single commitment to renewable power by any jurisdiction in North America". (15) Before the government could follow through on its plans, however, the August 2003 blackout crippled Ontario and several U.S. jurisdictions. In the election held soon after, both major political parties included a proposed RPS in their platforms. Proposing an RPS of 5% of all Ontario generation from new renewables by 2007 and 10% by 2010, the Ontario Liberal Party took the government reigns in October 2003.

In its January 2004 Final Report, the Electricity Conservation and Supply Task Force stated that the government should move quickly to implement the RPS if it planned to achieve its stated goal of an additional 5% (1,350 MW) of Ontario's

power from renewable resources by 2007 and 10% (2,700 MW) by 2010. (16) The government responded in April, 2004 by launching a Request for Proposals (RFP) seeking a first tranche of 300 MW of new, renewable electricity capacity. The RFP received an overwhelming response from the industry, with proposals for almost 15 times the amount of renewable electricity the government sought. (17)

THE CURRENT SITUATION IN ONTARIO

The government plans, in the near future, to announce the successful bidders under the 300 MW RFP and sign twenty-year power purchase agreements. The contracts will be for electricity from new facilities generating renewable electricity from wind, solar, biomass, biogas, bio-fuel, landfill gas, and water sources. (18) Among renewables in Ontario, "waterpower is expected to continue to make a significant contribution to Ontario's renewable supply objectives, with the potential to increase capacity and energy by at least 50%." (19)

In addition to the 300 MW RFP, Bill 100, the Electricity Restructuring Act, 2004 (ERA), (20) is currently making its way through the Ontario Legislature. One of the ERA's purposes is to promote the supply and capacity of electricity from alternative and renewable energy sources. If the ERA is enacted as proposed, the newly created Ontario Power Authority (OPA) will assess electricity resources and develop integrated power system plans and procurement processes to help the government meet its goals for electricity supply generated from alternative and renewable energy sources. The OPA would become responsible for present and future RFPs in Ontario. The ERA defines alternative energy as a source prescribed by the regulations or that satisfies the regulations' criteria that can be used to generate electricity through a cleaner process than other generation technologies Ontario used before June 1, 2004. A renewable energy source satisfies criteria the regulations prescribe, is renewed by natural processes, and includes wind, water, biomass resources or products, solar energy, geothermal energy, tidal forces and other energy sources that may later be prescribed.

Although Ontario has made progress toward establishing an RPS, the ERA, as well as a Renewable Supply Objective under government RFPs, does not yet provide Ontario with the kind of legislated, detailed RPS that has proven successful in more experienced jurisdictions, such as Texas. The Texas model, which has received considerable positive press, is described below. (TEXAS MODEL?)

RENEWABLE PORTFOLIO STANDARDS ACROSS CANADA

OTHER CANADIAN JURISDICTIONS

Most Canadian jurisdictions have or are soon to be adopting goals for incorporating renewable energy into their generation mix. However, like Ontario's, most of these provinces' programs and policies are still in their infancy, compared to the detailed, mandatory, and highly organized legislated RPS of some other jurisdictions.

Several programs at the federal level support renewable development, including bioenergy, small hydroelectric energy, solar, earth and wind energy development. For example, the federal government recently announced its support for

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TWINNING WIND AND COAL COULD HELP WITH ONTARIO FOSSIL FUEL PHASE OUT

By Aidan Foss, Nicole Foss, and Bill Kemp

Wind is the fastest growing source of electrical power both in Canada and worldwide. It is clean and the fuel is free. However, it is also intermittent, non-dispatchable, often invisible to system operators, and makes little contribution to the maintenance of system frequency and voltage. The twinning of wind with a complementary energy source can overcome these difficulties, increasing the value of wind power and the potential for incorporating it seamlessly into the system as quickly as possible. In Ontario, the provincial plan to phase out coal-fired generation provides a unique opportunity to increase wind-power penetration substantially in the short term through twinning it with coal. Modular wind generation can be progressively increased as coal-fired generation is progressively reduced, the combination being fully dispatchable. As coal is phased out over time, newer and cleaner generation technology, capable of providing both energy and ancillary services, can be brought on line to support wind power. The role of coal would be to facilitate the transition.

THE POWER SYSTEM

The power system, with electricity produced on demand just as it is required, is a huge technological achievement. Vast interconnected networks have evolved which operate effectively as a single machine, its components rotating in synchrony from Ottawa to Miami. The same power system structure - based on large-scale, remote generating stations inter-connected through transmission and controlled from the centre - is standard world-wide. However, this traditional model is now subject to an unprecedented array of challenges. One significant challenge is emerging from the evolution and growth of small-scale, environmentally-friendly generation technologies such as wind.

Coal could be used to help in its potential phase out in Ontario.

Under central control, both large generation and transmission maintain frequency and voltage profiles and synchronism across the network. Built-in redundancy of both components acts to ensure the resilience of the system to most power system disturbances. The safety margin offered by this redundancy may be compromised if coal-fired generation is eliminated by 2007 as planned, and access to essential ancillary services, which currently maintain the integrity of the system, may be lost.

The defining characteristics of wind generation, namely its small scale and as well as the intermittent and imperfectly predictable nature of the energy source, do not allow it simply to be slotted into place as fully equivalent to traditional generation. In other words, wind cannot by itself provide dispatchable power to replace existing firm capacity or offer ancillary services. It is therefore necessary to understand the contribution to the system of the generation that wind is poised to displace, and to explore mechanisms for retaining those services while also capturing the very considerable environmental benefits offered by wind power.

ENERGY BALANCING & FREQUENCY MANAGEMENT

When we turn on a light, most of the electricity comes from the rotors of the large generators in the power system. Their speed defines the system frequency. If more energy is being consumed than is being produced, these rotors decelerate, reducing the system frequency. Balancing energy supply and demand in real time is all about frequency management, which large coal and hydro plants are well able to provide. They can be dispatched to follow projected load changes, employ governors for frequency regulation and operate part-loaded or with fast-start to offer reserve. Wind, on the other hand is 'take-what-you-can-get'. Essentially, it displaces base-load generation, with no contribution to frequency management.

Large Coal & Hydro	Wind
Provides firm generating capacity	No firm generating capacity
Dispatched centrally – load follows	Self-dispatches
Employs governor with droop for frequency control	No droop control
Can be part loaded or fast-start for reserve	No part-loading or fast-start reserve

NETWORK AND VOLTAGE MANAGEMENT

Large generation provides a number of services for managing the integrity of the power network. These include network voltage regulation through controlled alteration of rotor excitation, mitigating voltage fluctuations, enhancing robustness to loss-of-synchrony using power system stabilizers, and black start. Wind generation, on the other hand, typically employs induction generators with no excitation control, can be a source of voltage flicker, and requires a utility supply for operation.

Large Coal & Hydro	Wind
Regulates network voltages to dispatched levels	No voltage regulation
Mitigates voltage fluctuations	Potential source of voltage flicker
Enhances robustness through employing stabilizers	Stabilizers not employed
May offer black start	Black start not offered
Visible to operator	Often invisible to operator

In the operation centres of power utilities, the status of large generation is generally visible to an operator, and can be dispatched accordingly. Small generation is often invisible and self-dispatches, which can pose difficulties for system management. As the percentage of distributed generation increases over time, this problem could become increasingly acute, potentially limiting the penetration

of wind power technology to below what could otherwise be achievable.

TWINNING WIND WITH COAL

Twinning wind with other energy sources solves several potential problems at once, thereby increasing the value of wind energy to the power system. The combined plant would represent firm capacity, it would be able to contribute to frequency and voltage management, and it would be visible to system operators and subject to conventional dispatch. Wind can be twinned with large or small hydro, where these resources are found in areas of sufficient wind energy density, or can be constructed in tandem with pumped storage capacity. It can also be twinned with regenerative fuel cells, gas, biomass, or modular clean coal technology*, all of which have the necessary flexibility, once these technologies have been fully developed and sufficient capacity has been brought on to the system.

In the short to medium term, an opportunity exists to twin wind with conventional coal, as wind and coal have complementary characteristics. Twinning would facilitate both a modular increase in wind generation and a controlled phase-out of coal-fired units, while maximizing benefits to the system. Coal could be used to provide the ancillary services backbone to enable increased penetration of wind-power, thereby facilitating the government's initiative for 10% (2700 MW) of renewable energy in Ontario by 2010. Building wind turbines at or near the sites occupied by existing coal plants has several distinct advantages. Much of the coal-fired generation is close to lakeshores where some of the best wind resources are found. The existing coal plants are also close to centres of demand, hence the requirement for additional network infrastructure is likely to be minimal.

A recent report by the David Suzuki Foundation** has identified the potential for Ontario to build 8000 MW of wind generation by 2012. The largest wind turbines are now around 4-5 MW, and require wind speeds of 15m/s to achieve their design output. The space available on existing coal-fired generating sites obviously cannot accommodate a comparable level of wind-power output. (For instance, one recent wind farm proposal would involve 150 MW of wind generation on 11,000 acres of land.) Additional land may, however, be available in the vicinity and wind turbines can also be interspersed with other new or existing developments, or with farmland, in order to make more effective use of available land.

Coal-fired Generation in Ontario

Nanticoke	8 units	3920 MW	1972-1978	L Erie	Low sulphur US coal
Lambton	4 units	1975 MW	1969	St. Clair R	US coal & SO2 scrubbers
Lakeview	4 units	1140 MW	1962	L Ontario	Low sulphur US coal
Thunder Bay	2 units	306 MW	1963, 1982	L Superior	Canadian coal
Atikokan	1 unit	211 MW	1985	Inland	Canadian coal

The Ontario government has announced its intention to phase out coal-fired generation by 2007 for environmental reasons. This could, however, be a problematic political promise to keep, given the looming imbalance between electricity supply and demand in Ontario. As we have seen, there is also more to withdrawing an energy source from the system than simply replacing it with another. Wind would be an excellent choice on environmental grounds to replace some of the existing coal capacity, but the provision of essential ancillary services must also be taken into account. Retaining the newest and cleanest coal units as transitional support for dispatchable wind power, and for their ancillary services value, until other cleaner options are ready to take over the role, would enable wind power to make an enhanced contribution to the province's electricity needs as soon as possible.


Courtesy Michael Milligan

The Ontario government hopes wind plays a bigger role for generation in the future.

* Clean coal technology reduces emissions of SOX and NOX, but not CO2.

** Smart Generation: Powering Ontario with Renewable Energy

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LARGEST SOLAR POWER PILOT PROJECT OPENS IN TORONTO

By Mark Burton

Toronto Hydro-Electric System Limited recently installed the city's largest industrial solar power pilot project generating system on the south side of its downtown service centre. The pilot project is part of an ongoing effort to promote clean energy technology and reduce smog.

The Ontario capital has had many smog alerts in recent years and green-energy supporters are hoping the launch of the Toronto's largest industrial solar power generating system will increase interest in solar technology.

"We do hope to see some copycats," said Joyce McLean, Director of Environmental Affairs at Toronto Hydro Energy Services Inc., "We certainly know that consumers really want to see this happen. They want to see companies embrace solar and wind energy particularly in a city like ours where we have significant air quality issues."

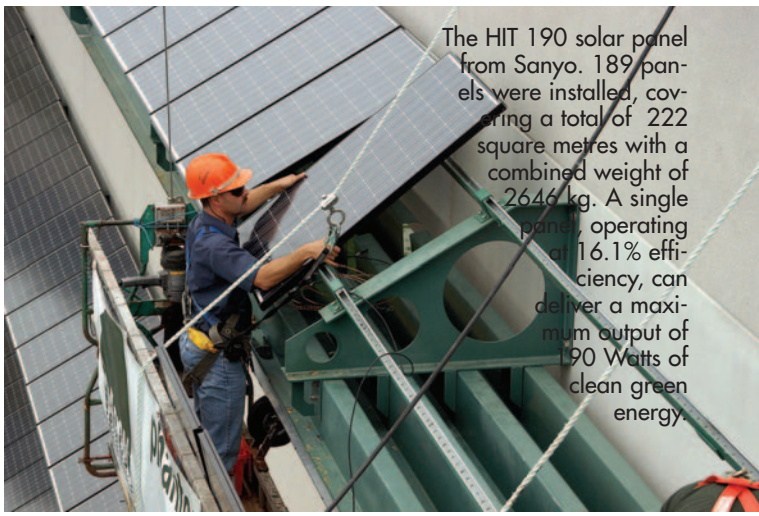
Hydro officials estimate it will eliminate 37.8 tonnes annually of carbon dioxide emissions. Ontario's five coal-fired power plants produce 18 per cent of the province's carbon dioxide emissions. In contrast, solar power burns none of the fossil fuels that are major sources of air pollution.

Number of Smog days in the City of Toronto. (source: City of Toronto)

Air pollution rose significantly in Toronto over the past decade; there was just one smog alert in 1993, rising to high of 20 in 2001.

The pilot project, which took three months to design and build, will provide 36 kiloWatts of 'zero emission, green' power to the Commissioners Street building, located in the port lands of Toronto. The system supplements grid power to the facility, which is particularly useful during peak hours when the sun is strongest and when electricity is likely to be priced at a premium and at its dirtiest. It will be enough to supply 12% of the work centre's entire lighting load for 800 employees, or enough 'green' energy to run fourteen to fifteen residential homes.

The system consists of 189 solar panels, or "modules". Each solar module, which is 0.8 metres by 1.3 metres or three



The HIT 190 solar panel from Sanyo. 189 panels were installed, covering a total of 222 square metres with a combined weight of 2646 kg. A single panel, operating at 16.1% efficiency, can deliver a maximum output of 190 Watts of clean green energy.

feet by 4.5 feet in size, produces 190 watts of power. The panels themselves require almost no maintenance, are easy to operate and emit no sound, radiation or waste.

The project is the result of a well coordinated partnership between Toronto Hydro, Sanyo Canada Inc., which provided the system's solar panels; Toronto Hydro Energy Services Inc. who provided the design engineering and general contractor services, Phantom Electron Corporation as the installing contractor; as and Xantrex, a Canadian company that provided the inverters needed to transform the sun's rays into consumable power.

The barrier to solar energy is price. Toronto Hydro isn't shying away from the high price relative to the electricity produced. The entire system cost the company around $300,000. Consumers who wish to purchase solar panels are looking at approximately $1,000 for each panel. It would take between 10 and 20 of the panels to power someone's home, but the panels are guaranteed for at least 20 years and can make breathing in Toronto a lot easier.

David O'Brien, President and CEO, of Toronto Hydro Corporation said, "The cost of renewable energy is not competitive with traditional sources of energy from a monetary point of view, but it won't be long before we see more of these. And the more of these you make, the more competitive it becomes. The point of the matter is that eventually fossil fuels will no longer be able to sustain the electricity demands of this province or this country or this world. This is the future, so we have to be prepared to spend a little more to advance the future of this technology and that's what this is all about."

Few solar markets in the world today are cost-competitive without government support, except for niche markets such as off-grid power for rural electrification, water pumping, emergency signs and phones.

Representatives of Sanyo state that Japan has been using solar technology for some time now, as have numerous European countries.

Toronto Hydro officials hope federal and provincial governments will soon take alternative energy sources more seriously and provide incentives to people ready to install them.

"I strongly believe senior levels of government, both the provincial and federal governments, should take the lead in investing in this technology and should provide incentives for it," O'Brien said. "To get this technology working is not a difficult thing to do and solar power could eventually prove profitable for Toronto Hydro." Mr. O'Brien is currently in negotiations with the provincial government and the Ontario Energy Board

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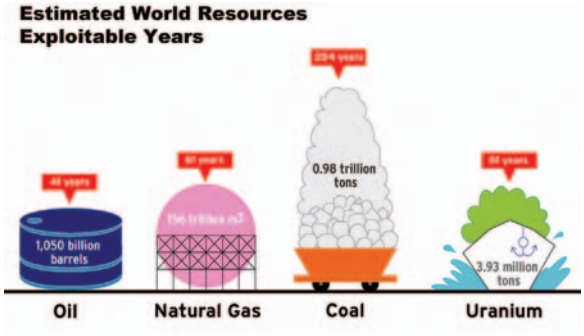

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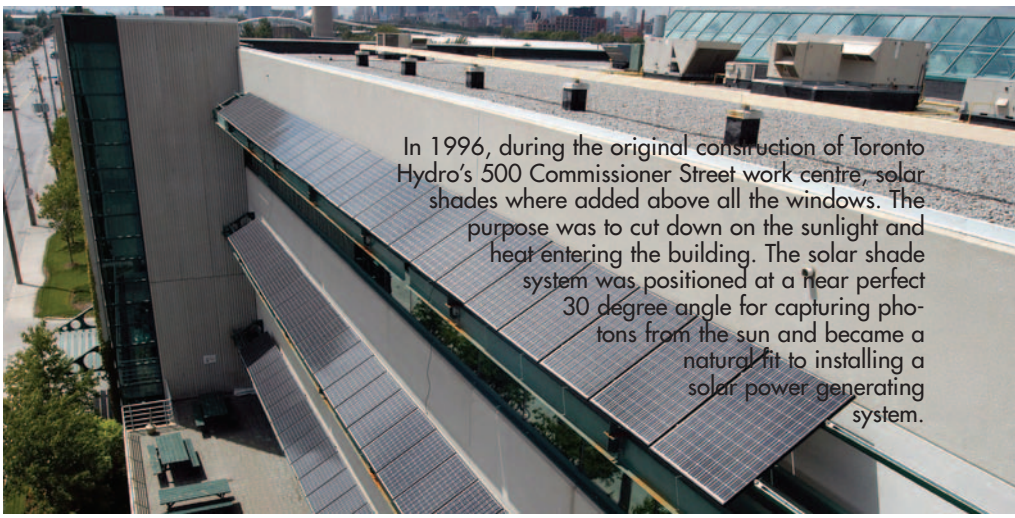


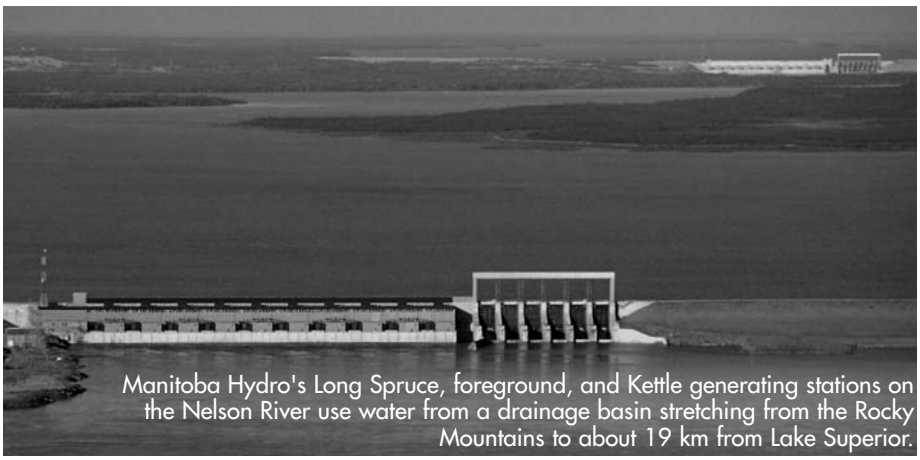
In 1996, during the original construction of Toronto Hydro's 500 Commissioner Street work centre, solar shades where added above all the windows. The purpose was to cut down on the sunlight and heat entering the building. The solar shade system was positioned at a near perfect 30 degree angle for capturing photons from the sun and became a natural fit to installing a solar power generating system.

MANAGING A DROUGHT:
WHAT DOES A HYDROELECTRIC UTILITY DO WHEN THE RAIN STOPS?

By David Cormie, P.Eng

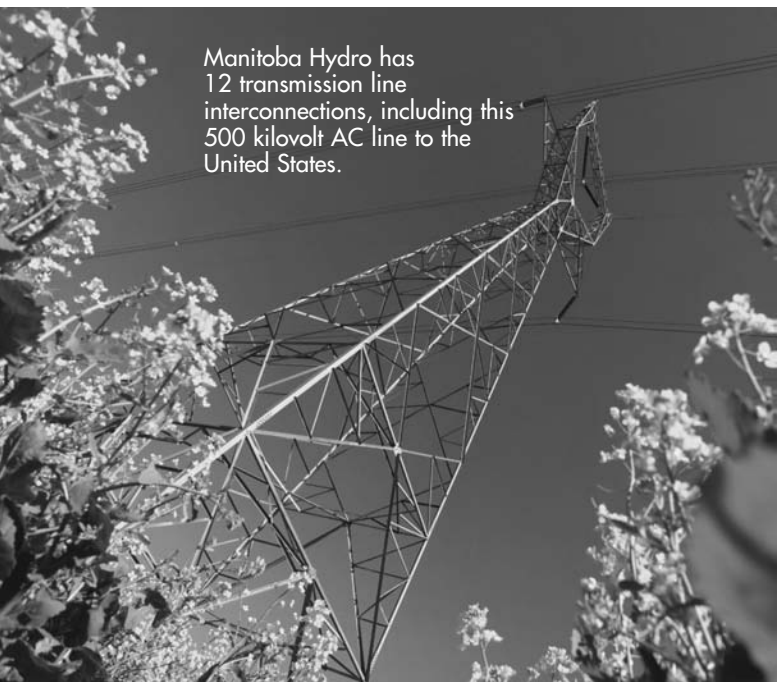
For almost two years, from the summer of 2002 until the spring of 2004, the province of Manitoba, Canada, found itself in the midst of one of the worst droughts in 60 years. Manitoba Hydro, a provincially owned energy utility that normally generates over 95% of its electricity from hydroelectric generating stations, found itself a net importer of electricity for the first time since 1988. Costs associated with power purchases skyrocketed and the utility sustained a net loss of $436 million in the 2003-04 fiscal year, the largest in the corporation's history.

But, the lights stayed on. Using its reservoirs, transmission line interconnections to neighbouring regions, and thermal generating stations, Manitoba Hydro was able to manage one of the worst droughts on record, ensuring both domestic and export customer needs were met while also limiting the financial risks to ratepayers. The utility's power system, designed for such events, functioned as planned.



Manitoba Hydro's Long Spruce, foreground, and Kettle generating stations on the Nelson River use water from a drainage basin stretching from the Rocky Mountains to about 19 km from Lake Superior.

Historically, Manitoba experiences a drought, on average about once every ten years. However, the drought period in 2002-2004 was more severe. Precipitation amounts in some of the province's eastern watersheds during the fall and winter of 2002-03 were the lowest or second lowest in over 100 years. Total energy stored in the reservoirs contributing to Manitoba Hydro's generating capability reached a 27-year low and Lake Winnipeg, one of the utility's most important reservoirs, reached its second lowest level since it began to be regulated for power production purposes. By the summer of 2003, energy in reservoir storage was down from the average of 16,000 gigawatt-hours to 8,000 gigawatt-hours and the dry conditions were severely affecting hydroelectric production capabilities.



Manitoba Hydro has 12 transmission line interconnections, including this 500 kilovolt AC line to the United States.

Manitoba Hydro's system is designed to be able to meet the firm power requirements of its customers even at water levels equal to the lowest on record. Three major reservoirs — Lake Winnipeg, Cedar Lake, and Southern Indian Lake — are the key, allowing Manitoba Hydro to maintain water reserves for use during extreme drought, thereby increasing the dependability of the system. Without water reserves, the utility could only dependably generate about 16,000 gigawatt-hours a year under lowest flow conditions. When reserves are included, that figure jumps to approximately 21,000 gigawatt-hours.

In the 2003-04 fiscal year, Manitoba Hydro generated only 18,500 gigawatt-hours from hydroelectric resources, choosing to reduce hydraulic generation and retain water reserves. The utility operates in a conservative mode, recognizing the extreme importance of a continuous supply of electricity. With no reliable long-term weather forecasts available, and the duration and severity of a drought unknown, Manitoba Hydro's planners always assume a drought will continue and therefore maintain appropriate water reserves to

ensure an adequate supply of electricity is available to serve load. If an option to purchase power exists, the utility will pursue that option instead of depleting its reservoirs.

In most situations, Manitoba Hydro will have more resources available than needed, but decisions are made to protect against those times when conditions are worse than expected. This conservative approach, while bolstering the reliability of the electricity supply, does come at a significant financial cost when droughts happen. In the 2003-04 fiscal year, Manitoba's sole electricity provider purchased over 9,700 gigawatt-hours of electricity with the total cost of fuel and power purchased amounting to $569 million, an increase of $418 million from the previous year.

Manitoba Hydro is able to import purchased power using 12 transmission line interconnections to utilities in Saskatchewan, Ontario and the United States. Together, these lines are capable of importing approximately 1,340 megawatts (MW). In a normal year, Manitoba Hydro will export approximately 1,900 MW during the summer and 800 MW during the winter months.

This past January, imports into Manitoba averaged 1,000 MW each hour— a swing of 1,800 MW from normal during peak hours — with the majority coming from utilities in the Mid-Continent Area Power Pool. This 1,800 MW swing in normal power flows was one of Manitoba Hydro's biggest concerns when planning for winter operations. The utility kept its gas-fired generation in reserve to guard against unforeseen transmission line overloads or generation outages. Also, gas-fired generation was used to cap the price of purchased electricity when spot market prices jumped above the cost of producing electricity with natural gas. During the winter of 2003-04, Manitoba Hydro used gas-fired generation, the most expensive option for producing electricity, about 5% of the time. Manitoba Hydro also has the option to use its one coal-fired unit at its Brandon Generating Station if necessary. This fuel diversity helps the utility limit its financial vulnerability to high electricity and gas prices. The use of the coal-fired unit during the winter of 2003-04 is estimated to have saved Manitoba Hydro $24 million compared to using gas-fired generation or purchasing imported power.

Between the reservoirs, interconnections, and thermal stations, Manitoba must also fulfill its long-term contractual obligations to supply approximately 4,000 gigawatt-hours to export customers each year. The province's normal export capability was going to be compromised as the drought took hold. In the summer and fall of 2002, the utility ceased taking on additional short-term export sale commitments. The only obligations that remained were the long-term firm sales that had been negotiated years earlier.

With the failure of the snowmelt and rainfall runoff in the spring of 2003, Manitoba Hydro pursued offsetting purchases to these long-term sales; essentially buying back the power it had previously agreed to sell. In other cases, the utility arranged for other suppliers to deliver power to the contract customer. Both options not only limited the demand that needed to be met by Manitoba Hydro, but also freed up trans-

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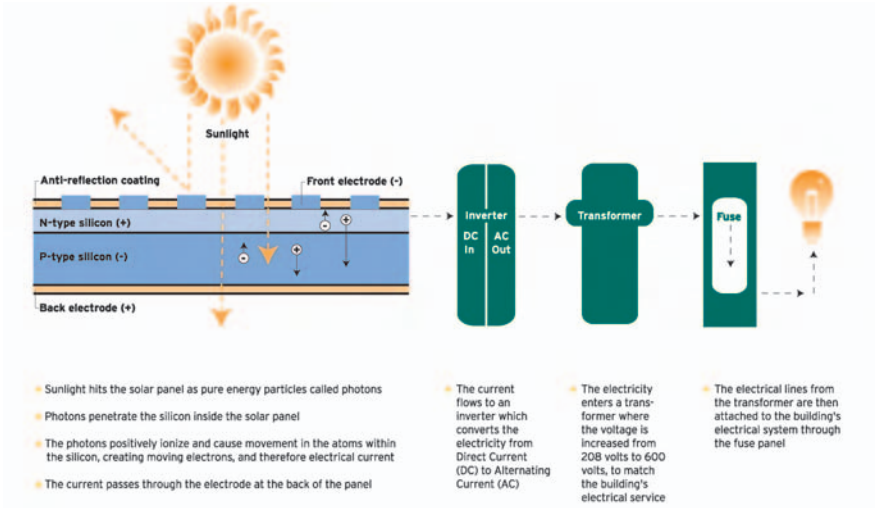

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about the possibility of providing greater incentives for the use of alternative energy sources, including solar power.

Rob McMonagle, Executive Director, Canadian Solar Industries Association, is encouraged that one of Canada's largest utilities is getting involved with solar energy.

"Governments and utilities are starting to realize there's something about solar that will make it attractive in the very near future," said McMonagle. The use of solar power could become widespread if government provides the right kinds of subsidies.

Long-term, low-interest loans, McMonagle believes, could provide the necessary encouragement to home or business owners who might see the initial costs of solar technology as a barrier. McMonagle adds that the Ontario government does have a goal to convert 100,000 homes to solar power within five years.

There are other barriers as well, say solar advocates. A key to making solar power and other distributed energy technologies attractive will be the introduction of smart metering systems that allow consumers to better manage their electricity use, and adjust consumption patterns during more expensive peak and cheaper off-peak times of the day. Net metering, the ability to send surplus power back to the grid for credit, will also play an important role in advancing the use of solar systems in businesses and in households.

"We're still up in the air with net metering," said McMonagle. "Local utilities need rules in place so they can allow power from local generators to flow back into the grid in an orderly way. Rules are also needed that instruct utilities how to price that incoming power."

The province plans to have 800,000 smart meters installed in Ontario by the end of 2007. By 2011, all households are expected to have such systems.

While growing at a rapid pace, solar electric energy globally still only accounts for around 0.1% of world's energy demand. Toronto Hydro officials say manufacturers and energy producers should get behind solar power and start making investments in it then advances in technology and increased production will lower the cost. When coupled with the push to curb global warming and for utilities to go green, solar energy may heat up.

This project is the second green energy project undertaken by Toronto Hydro. In 2003, the company presented North America's first urban wind turbine at the Exhibition Place in partnership with WindShare. The total electricity output of the solar system and wind turbine combined is enough to power up to 255 homes as the municipal utility continues to promote a 'conservation culture' for the people of Ontario.

For additional information, visit;

- Toronto Hydro Corporation: http://www.torontohydro.com/corporate/initiatives/green_power/index.cfm
- Ontario Ministry of Environment: http://www.ene.gov.on.ca
- Ontario Ministry of Energy: http://www.energy.gov.on.ca
- Canadian Solar Industries Association:http://www.cansia.ca

Mark Burton is the Communications and Public Affairs Consultant for the Toronto Hydro Corporation. He has an extensive background in the electrical utility industry having worked a variety of jobs in the past seventeen years. **ET**

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developing 4,000 MW of wind power in Canada, quadrupling the original Wind Power Production Incentive target. (21)

New Brunswick is one of the provinces working toward an actual RPS. The province has recently retained the services of a U.S. company that helped create RPSs for several U.S. jurisdictions. A regulation under the Electricity Act is expected to legislate New Brunswick's RPS by early 2005. New Brunswick Power has set a target of 100 MW of wind energy by 2010. (22) In Nova Scotia, the government recently accepted the Electricity Marketplace Governance Committee's RPS recommendation of 5% of total electricity supply from renewable resources by 2010. (23) And, Prince Edward Island announced that it would commit to an RPS of at least 15% by 2010 and evaluate opportunities to have 100% of its electrical capacity acquired through renewable energy sources by 2015. PEI will meet its short-term goal of 15% renewables by 2010 by establishing an additional 40 MW of wind capacity. (24)

Under British Columbia's Energy Plan, electricity distributors must pursue a voluntary goal of obtaining 50% of new electricity from clean sources, including wind, solar, tidal, wave and geothermal energy, as well as fuel-cell technology, small- and micro-hydro products, cogeneration products, and non fossil-based fuels. (25) The Alberta Climate Change Plan sets a goal of increasing the renewable and alternative energy portion of total provincial energy capacity to 3.5% by 2008. Over the five years that ended February 2004, renewables (active or under development) had increased 600% in Alberta; Alberta generates 52% of the wind production in Canada. (26) In Saskatchewan, government-owned SaskPower's goal is to ensure that all of the province's new electricity needs until 2010 will be met through environmentally friendly sources like wind power, small hydro, and distributed generation projects. The utility has also established the very successful GreenPower program where consumers, paying a small premium, receive wind-generated electricity. (28)

Manitoba, Quebec, and Newfoundland and Labrador are all large hydroelectricity producers. Ninety-five per cent of Manitoba Hydro's electricity is hydro, with an additional 5% of its current generating capacity allocated to wind development. (29) Besides being one of the largest hydroelectricity producers in the world, Quebec has at least 260 MW of existing small hydro, 102 MW of wind and 296 MW of Biomass capacity. (30) Additionally, Hydro-Quebec recently accepted a total of 990 MW of wind power bids in response to a call for tenders. (31) Newfoundland and Labrador satisfies approximately 90% of its electricity needs through renewable hydro and exports large amounts of power through Quebec. A combination of tax incentives and wind viability assessments is moving the province forward in its development of renewable energy resources, including a 25 MW wind demonstration project. (32)

The Yukon, Northwest Territories and Nunavut renewable energy strategies focus on reducing their dependence on generating electricity from diesel fuel. Nunavut in particular is looking to develop wind farms as a stable source of electricity. (33)

RENEWABLE PORTFOLIO STANDARDS ACROSS THE WORLD

Because RPS development in Canada is relatively new, valuable lessons can been learned from jurisdictions with more well-established and time-tested RPS.

In addition to the U.S. examples examined below, many Western European countries as well as Australia and Japan have developed or are developing an RPS. Particularly in the

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area of wind energy development, the RPS of countries like Denmark, Germany and Spain, using attractive feed-in tariffs, have provided a notable lead over Canada, with 15%, 5% and 5% of electricity coming from wind respectively. In Canada the figure is only 0.4%.

As for the U.S., 17 states, including New York most recently, have adopted an RPS. (36) Among these, the Texas program's early success garnered much attention. Texas has become one of the leading wind power markets in the U.S. due, in large part, to a well-designed and carefully implemented RPS. The Texas experience suggests that an RPS can effectively drive renewable power development and encourage competition among renewable energy producers. The Texas RPS is characterized by detailed RPS regulations established by the Texas Public Utilities Commission (TPUC). The RPS contains annual renewable energy purchase obligations which began in 2002 and end in 2019 (specifically, 400 MW of eligible new renewables by 2003, 850 MW by 2005, 1400 MW by 2007, and 2000 MW by 2009 and through 2019). All electricity retailers in competitive markets share the obligation to purchase a certain percentage of renewable power based on their proportionate yearly electricity sales (publicly-owned utilities need meet the RPS only if they opt-in). Renewable power plants commissioned after September 1, 1999, and all renewable plants with less than 2 MW capacity, regardless of installation date, are eligible. Eligible renewables include solar, wind, geothermal, hydro, wave, tidal, biomass, biomass-based waste products, and landfill gas. A system of tradable RECs with yearly compliance periods tracks the Texas system. TPUC establishes rules and enforces compliance while an independent system operator serves as REC trading administrator. Penalties are the lesser of $0.05 or 200% of mean REC trade value in the compliance period for each missing KWh. (37)

The Texas RPS's success has been attributed to the following factors:

(i) Detailed regulations and a committed public utilities commission,

(ii) Predictable long-term purchase obligations that lead to new development and economies of scale,

(iii) Sure and strong penalties for electricity suppliers failing to meet their RPS,

(iv) The various benefits of tradable renewable energy certificates (ease of compliance demonstration and tracking, improved liquidity in the market, flexibility for suppliers in meeting their obligations, and a lower cost of policy compliance), and

(v) The U.S. federal production tax credit for wind projects, and favourable transmission rules and siting processes. (39)

Not all U.S. RPS policies are "Texas-size" success stories, however. The following factors have been posited as reasons for more sluggish results in some states: (i) inadequate attention to the relationship between the renewable energy purchase requirement and eligible renewables, (ii) applying RPS to only a small percentage of the market, (iii) uncertain size of the purchase standard and its end date, and (iv) insufficient enforcement of the purchase requirement. (40)

CONCLUSION

As Ontario and other Canadian provinces move forward with the implementation of something called an "RPS", the U.S. experience reinforces that a clear, detailed, and carefully designed RPS forms the foundation for successful development and expansion of renewables.

Several challenges become apparent upon close examination of Ontario's "RPS" as it now stands. Though it may sometimes be referred to as such, Ontario's Renewable Supply Objective is not a true RPS. The Renewable Supply Objective being implemented through the government's RFPs may evolve into an obligation being placed on loads and load serving entities, though it is not at this stage yet. (41) By contrast, a true RPS is a market-type mechanism for achieving supply mix objectives. An RPS requires electricity consumers, retailers or distributors, as the case may be, to ensure that a specific percentage of their portfolio comes from renewables. In Ontario, distributors do not purchase power as in other RPS jurisdictions; they simply pass power through to consumers. As such, an Ontario "RPS" may never fit the industry definition.

Neither Ontario's 300 MW RFP nor the ERA provide for the kind of detailed legislated RPS that has proven successful in Texas. No legislation establishes a REC system, for instance, or verifies that renewable power is generated, sold or consumed. Taking into account the nature of Ontario's energy-supply system, where bids are made to the Independent Electricity Market Operator by energy producers and the OPA makes up price when renewable energy producer bids fall short, difficulties arise in calculating what percentage of the energy Ontario uses actually comes from renewables. If the percentage of renewables in

the actual energy mix cannot be ascertained, how will Ontario verify whether it has reached its goal of 5% of all generation from renewables by 2007 and 10% by 2010.

If weaknesses such as these cannot be rectified, Ontario's RPS is destined to remain an RPS in name alone. Still, the recent provincial government commitments mark a much-needed and significant first step toward a true RPS and the substantial associated benefits to generators, consumers and all those who share our air shed.

REFERENCES

(1) Electricity Conservation and Supply Task Force, Tough Choices: Addressing Ontario's Power Needs, Final Report to the Minister January 2004 (Ontario Ministry of Energy, 2004) at 1.

(2) Ontario Ministry of Energy news release, "New Vision for Electricity Sector Will Mean New Supply, Increased Conservation, Stable Prices" (April 15, 2004), online: http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&body=yes&news_id=59.

(3) The Conference Board of Canada, Renewable Energy in Canada Final Report, (The Conference Board of Canada, 2003) at 4.

(4) Ibid, at 5; R. Wiser and O. Langniss, The Renewables Portfolio Standard in Texas: An Early Assessment, (US Department of Energy Lawrence Berkeley National Laboratory, 2002) at 6, 8-9.

(5) Ontario, Legislative Assembly, Select Committee on Alternative Fuel Sources: Final Report (3rd Session, 37th Parliament 51 Elizabeth II, June 2002) at 67.

(6) Hydro-electric power is often sub-categorized into "large hydro" and "small hydro". There is some debate over what is considered "small" hydro. In Canada it is not uncommon to refer to a 20-25MW project as small, and in the USA to consider 30 MWs small. However, an International Energy Agency sponsored website states that "a value of up to 10 MWs is becoming generally accepted." Source: supra, note 3 at 21.

(7) Ibid.

(8) P. D. Hunt, Backgrounder on Renewable Portfolio Standards (Climate Change Central, 2002) at 3.

(9) Clean-Edge: The Clean-Tech Market Authority, "20% Renewable Energy Standard Would Save Consumers $49 Billion and Produce 350,000 Jobs in U.S., New Analysis Finds" (September 2004), online: http://cleanedge.com/story.php?nID=3188.

(10) "Nowhere are the challenges and opportunities of sustainability more evident than in the way in which we use and produce energy. The Government will place increased focus on energy efficiency and energy research and development. It will engage stakeholders in developing comprehensive approaches to encourage increased production and use of clean, renewable energy and to promote greater energy efficiency. This will build on efforts already underway, including support for windpower production in Canada, stimulated by a quadrupling of the Wind Power Production Incentive." Source: "Speech from the Throne, October 5, 2004", online: http://pm.gc.ca/eng/sft-ddt.asp.

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HARMONIC SHARING FOR EFFECTIVE DETECTION OF TRANSFORMER INRUSH CONDITION IN DIFFERENTIAL PROTECTION SCHEMES

By Larry Lawhead & Randy Hamilton

Differential protection generally is considered to be the "best" protection for any given zone-of-protection on a power system. It is sensitive, secure and faster than other options. It is particularly appealing for protection of power transformers, due to the critical nature in the power system configuration. Fast clearing is desired to minimize damage for internal faults. Security is important, since a transformer will need to be tested after an operation (no reclosing). Transformer differential protection generally has been recommended for transformers 10MVA and above (4,5), but the economics of multi-function, numeric relay platforms and the overall decrease in cost per function has led to expansion of differential protection to circuits where it previously was not justifiable.

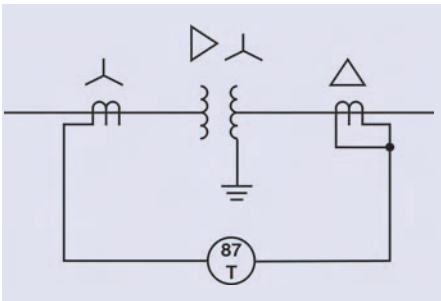

Fig 1: Transformer differential protection - one line

The nature of power transformers creates several complications for the application of phase differential relays. The relay scheme must compensate for the differences between the magnitudes of the measured currents on each transformer winding and the phase angle shift associated with the transformer connections. Additionally, the zero sequence source provided by a grounded WYE transformer winding must be accounted for in the scheme. This historically has been accomplished using CT ratios, Relay TAP settings and CT Connections. Additionally, the relay scheme must accommodate errors due to differences in CT performance, which may result from unequal accuracy classes, different connected burdens, or saturation due to DC offsets. Through current restraint (Percentage restraint) has been used effectively to provide security for these concerns.

One of the major concerns when applying differential protection to power transformers is ensuring security during transformer energization. Transformer energization creates a true unbalance (differential condition), but is not a fault, and the differential relay must not trip. Security of transformer differential protection schemes is dependent on detecting the magnetizing inrush currents of the protected transformer and associated blocking of differential operation due to inrush related, non-fault, unbalance currents.

The inrush waveform is highly distorted and rich in harmonics. Years of evaluation have shown that transformer inrush creates currents with high second harmonic content (6, 8). The evaluation of harmonic content in the energization currents has been the primary means of inrush detection in transformer differential relays for many years and several generations of protective relay technologies. The vast majority of transformer differential relaying schemes use the amount of harmonic content of the measured waveform to determine that an energization is taking place. The normal differential element is blocked for this condition, also known as Harmonic Inhibit. Faults during energization are detected by supervising the restrained element with an unrestrained element, set above the largest expected energization magnitude.

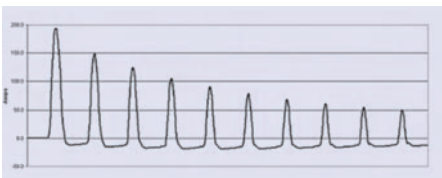

Fig 2: Transformer Inrush (One Phase)

Thresholds for defining energization generally have been fixed between 12% and 32%, depending on relay type. One Study (7) determined that magnetizing inrush waveforms would include at least 17% second harmonic. Recent transformer designs, however, may have inrush currents with 2nd harmonic content as low as 7% (2). Undesired operations of differential relays during energization (a.k.a. False Trips) have been encountered by many utilities. Historically (in the electromechanical implementation), transformer differential relays have been applied as single-phase elements, with a separate relay for each set of transformer windings. Phase shift compensation was accomplished through the CT connections. Inrush detection was limited to evaluating the harmonic content of the currents available within the specific relay element. In addition to the previously noted issues with harmonic levels, it is possible for the subtraction effect of the relay connection to reduce the amount of second harmonic currents seen by the relay (1). One of the complications of energization currents is that transformer inrush is not a consistent condition. The currents will vary from one energization to the next. Perhaps more significantly, inrush is not a balanced condition. The energization currents are not equally distributed between the individual windings. This can complicate the process of identifying inrush in a relay system, if a specific phase does not have sufficient harmonic content to be recognized as energization.

The advent of solid state and numeric technologies has allowed refinement of this technique to optimize security while maintaining sensitivity. One of the primary differences in these newer relay implementations is three-phase packaging. That is, a single relay unit will include all three of the phase differential

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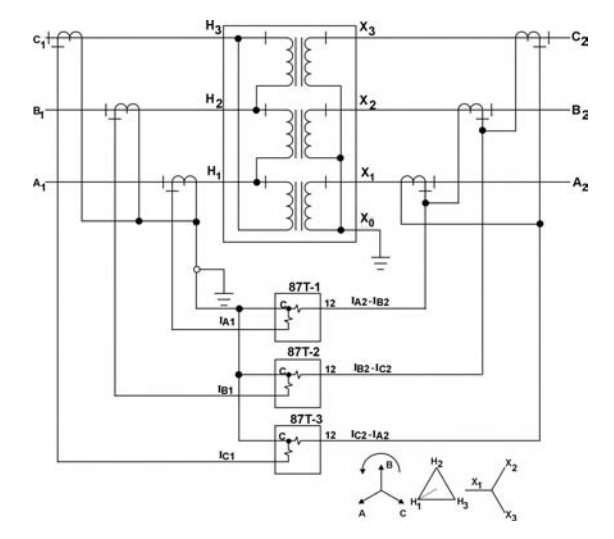

Fig 3: Transformer differential Single Phase Relay Configuration

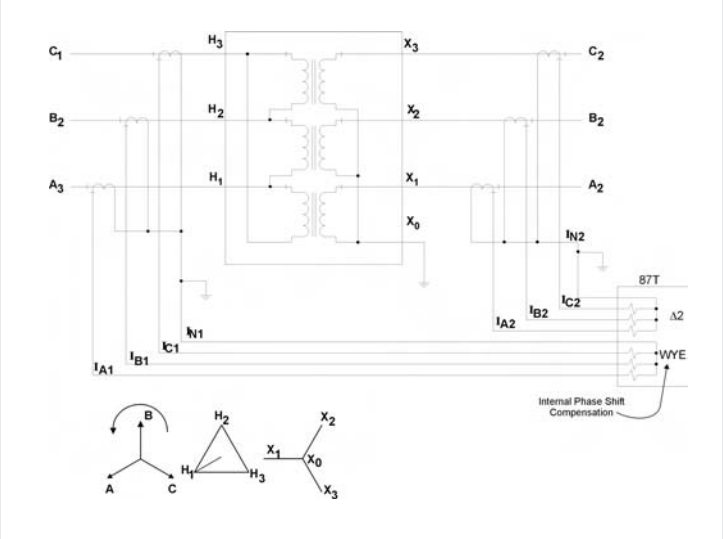

Fig 4: Transformer differential Three Phase Relay Configuration

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elements in one relay unit. Besides the space and economic benefits, this allows the opportunity to look at all of the currents associated with an event to more effectively determine if an unbalance is due to an energization event. Another dramatic advantage of numeric relay systems is the ability to record system events, allowing analysis and evaluation. All of the waveforms presented in this article are derived from relay data recordings.

Having all of the signals available in the relay allows each protective element (phase) to look at the overall system conditions. For example, if any of the phase elements detects an inrush condition, it could send a blocking signal to the other phases, to ensure that they properly restrain. This generally is known as cross blocking. While secure, it does raise the possibility of undesired restraint if a transformer is energized while faulted.

Another technique is harmonic sharing.

For this technique, the incoming currents are filtered to extract the fundamental signals (for faults and load) and the second harmonic signal (for inrush). The three inrush signals (2nd harmonic) are then summed to create a single harmonic signal, representing the overall inrush currents. The inhibit threshold is adjusted to accommodate the larger overall signal resulting from the summing. For example, 18% summed harmonic is used rather than 12% independent harmonic. Each phase element of the 87T function compares its specific fundamental current with the summed harmonic signal and makes an independent decision whether to inhibit for energization. This provides improved security for situations with unreliable harmonic content. Sensitivity is maintained for faults during inrush conditions, as the fundamental current in the faulted phase (unbalance) should easily override the sum of the second harmonic currents associated with energizing the unfaulted phases.

CASE 1 – TYPICAL ENERGIZATION:

The waveform above shows an energization of a 67/12.47kV, 18MVA transformer recorded by a numeric relay. The transformer is energized from the high voltage side, with the secondary side open. The Circuit 2 currents (LV side) are zero, so the Circuit 1 currents will reflect as the differential current - the unbalanced nature (phase-to-phase) of the inrush currents can be seen in this case. The A and C phase inrush currents are close in magnitude (within 3% at first peak); while the B phase peak is significantly less (27% less). There is significant CT saturation evident on the C phase signal, including a substantial offset of the "flat spot". The transformer was energized with an open secondary, so the Circuit 2 signals are not shown. They are accounted for in the spreadsheet calculations and the associated charts.

Figures 7 and 8 show the signals developed internal to a numeric relay for the Fundamental and the 2nd harmonic unbalance currents (Iop). These are the unbalance magnitudes that define the operation of the relay. They are plotted with the same scale 8 for easy compari-

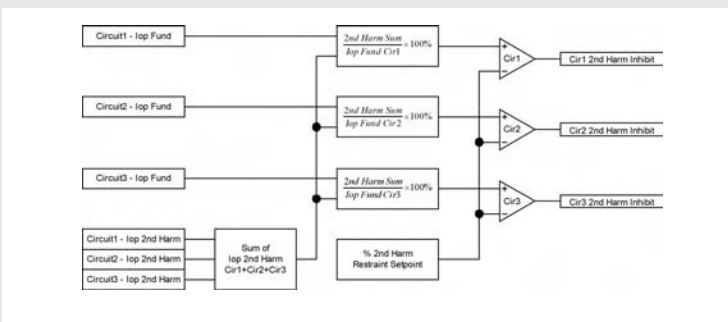

Fig 5: Harmonic Inhibit Detail

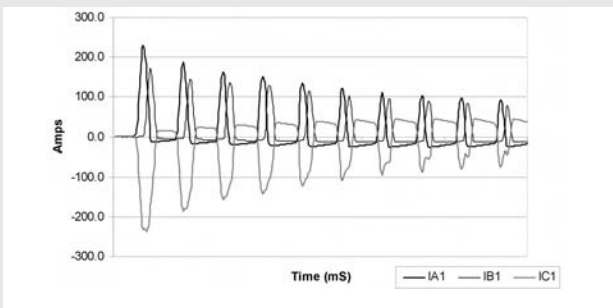

Fig 6: Transformer Inrush Current Case 1

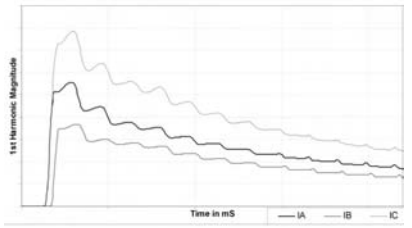

Fig 7: Fundamental Unbalance Current - Case 1

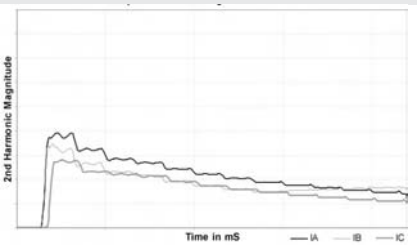

Fig 8: 2nd Harmonic Unbalance Current - Case 1

son, but the specific values are not included, as they relate to internal calculations. The differential relay will determine if a specific situation is transformer inrush, based on the ratio of the harmonic current to the fundamental current. Note that the restrained trip element of a differential relay must be delayed long enough for the second harmonic unit to accurately measure the 2nd harmonic content (approximately 1 cycle).

Figure 9 shows the percent 2nd harmonic signal associated with the first energization (case 1), without harmonic summing. After the initial "noise" associated with the DFT signal processing, each of the phases has well above the typical thresholds of around 12% second harmonic. C phase, the lowest, has a second harmonic signal that is 35-40% of the fundamental signal. Notice that this is the phase with the significant saturation. A and B phase have more second harmonic signals greater than 75% of the associated fundamental.

CASE 2 –TYPICAL ENERGIZATION:

The waveform in Figure 10 (Case 2) is another energization of the same transformer, again with the secondary side open. Note that the inrush characteristics differ between energization cases. This time, the overall peak is about 20% lower than before and the decay is faster (at 9 cycles, it is half the previous case). A and B phases are almost equal (within 0.5%

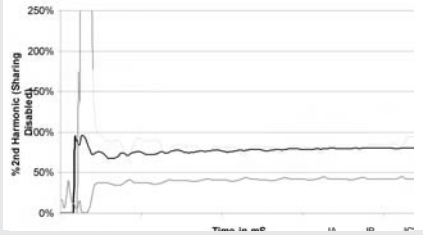

Fig 9: Second Harmonic Content - Case 1 (Without Sharing)

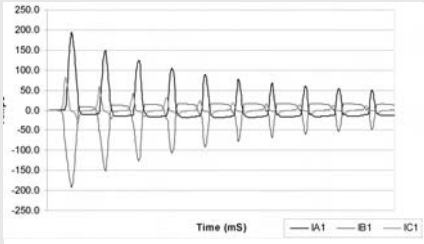

Fig 10: Transformer Inrush Current Case 2

at first peak), and C phase is dramatically less (58% less). The C phase signal has both positive and negative peaks (bipolar).

Analysis of this case shows that, again, there is plenty of harmonic content to properly inhibit. Phases A and B have

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POWER-GEN ENERGIZES FLORIDA

It's time again for Power-Gen International. Professionals from electric utilities, independent power producers, merchant plants, co-generators and self-generators are traveling from around the world by plane, bus or car to Orlando, Florida for world's largest power generation show. Don't forget the unregulated generation subsidiaries, industrial facilities, project development companies, architect/engineering firms, OEMs and others who will also be either attending or exhibiting at the show. That's more than 18,000 attendees from 75 countries expected to come to Power-Gen.

The show starts on November 30 and ends December 2, 2004. It will feature presentations from more than 200 speakers in 12 tracks. These tracks will feature a broad range of business and technical issues including power industry trends, merchant plants and convergence, NOx control, environmental issues, and fossil technologies. Generation topics such as gas turbine technologies, on-site power, plant performance, emerging technologies among others will also be covered.

Mr. Randy Zwirn from Siemens will open Power-Gen with the welcome address at the key note session. The first presentation will follow his address:"The Turbulent Power Market - Picking the Profitable Wave"

- Mr. Ershel Redd, Jr., NRG Energy
- Mr. Larry Kellerman, Goldman Sachs
- Mr. Tom D. Kilgore, Progress Ventures, Progress Energy

Power-Gen International will also offer an in-depth curriculum of Competitive Power College pre-conference courses, four Mega-Sessions focusing on large frame gas turbines, renewables, international power markets and mercury control; a technical tour to the Curtis H. Stanton Energy Center, targeted roundtable Networking Breakfasts and an International Networking Reception.

More than 1,000 Exhibiting companies from around the world will be showing their wares and networking on the world's largest industry exhibit floor. POWER-GEN International is also the platform for numerous new product launches and unveilings, while showcasing such products and services as boilers, turbines, engines, boiler water and feedwater treatment services, computer hardware and software, controls and instrumentation systems, engineering and construction services, generators, plant electrical systems, pumps, valves and valve actuators and more.

POWER-GEN International is presented by Power Engineering magazine and owned and produced by PennWell Corporation based in Tulsa, Okla. For more information, call toll-free at +1-888-299-8016 (in the U.S.), direct at +1-918-831-9160, or visit the POWER-GEN International website at www.power-gen.com. **ET**

EXHIBIT HALL HOURS

Tuesday, November 30, 11:30 a.m.-6:00 p.m.
Wednesday, December 1, 9:00 a.m.-5:00 p.m.
Thursday, December 2, 9:00 a.m.-2:00 p.m.

CONFERENCE PROCEEDINGS

Conference proceedings are provided on CD-ROM and may be picked up in the Exhibit Hall during exhibit hours in the PennWell booth #3336. Full delegate conference attendees are eligible for our complimentary CD-ROM. Non-Delegates may purchase a copy of the proceedings at the registration desk. Tickets will be provided upon check-in at registration and redeemed at the PennWell booth.

LUNCHEONS

Delegate luncheons are included in the full delegate registration fee. Non-Delegates may purchase a ticket at the registration desk at the Orange County Convention Center, North/South Building. Lunch tickets will be available for $25 each day.

Delegate luncheons will be served beginning at 11:30 a.m. on Tuesday, November 30, and Wednesday, December 1.

PARKING

Parking is available at the Orange County Convention Center. The parking rate is $5.00 per vehicle upon entry with no in/out privileges. No overnight parking is permitted.

SHUTTLE BUS SERVICE

Shuttle bus service will be provided to and from the convention center and official hotels throughout the three days of the conference. Hotels within walking distance where there is no shuttle service are noted on the hotel map. Additional shuttle service will be available on the morning and afternoon of November 29. Please refer to the hotel registration form for a listing of official hotels.

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NFPA 70E requires this level of personal protective equipment when operating non-arc-resistant switchgear.

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Reduced downtime. Arc-resistant retrofits can generally be done in less time than switchgear replacements.

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more than 50% second harmonic, compared to the associated fundamental currents. Phase C has dramatically higher second harmonic. This is a combination of the relatively higher second harmonic (due to the bi-polar waveform) and comparatively lower fundamental current.

CASE 3 –TYPICAL ENERGIZATION:

The waveform in Figure 13 is another energization of a distribution type transformer. This is a different location than the previous cases, but a similar system configuration. Again, the secondary is open, and Circuit 2 currents are zero. The inrush is typical in most regards, but closer examination shows a couple of differences. Note that there is a small "blip" of A and B current before the energization, and that the C phase current doesn't start until about half cycle into the event. There also is a significant DC offset (decaying) to the C phase bipolar waveform

Evaluation of the waveforms shows that the C phase fundamental rises much faster than the associated harmonic signal, resulting in an extremely large % harmonic signal during the transition. There is less harmonic signal in Phases A and B than the previous cases, but still well above the typical 12% threshold.

CASE 4 – ENERGIZATION WITH LOW HARMONICS:

The next set of waveforms is from a 69/12.470kV, 15/20/25MVA transformer connected to a radial distribution system. While this transformer is energized with the loads open, there is a station service transformer connected to the transformer secondary, but outside the zone of protection. So when the main transformer is energized, the station service transformer also will be energized. While the station service transformer is outside the differential zone, there may be some degree of sympathetic inrush from the distribution transformer. This installation had problems with tripping during energization, and the user switched to a numeric relay specifically for data recording to analyze their situation. Figures 14 and 15 show an inrush condition, with both circuits (Circuit 1 is HV, circuit 2 is LV) included.

Both of these waveforms show significant distortion.

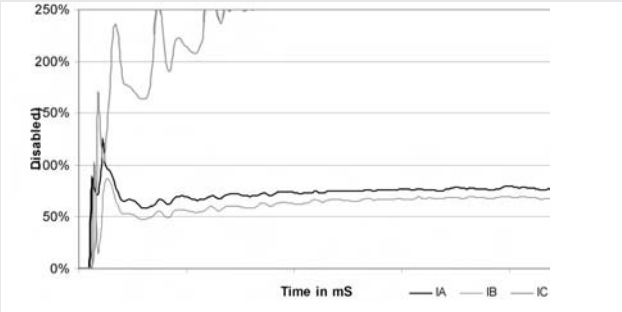

Fig 11: Second Harmonic Content - Case 2 (Without Sharing)

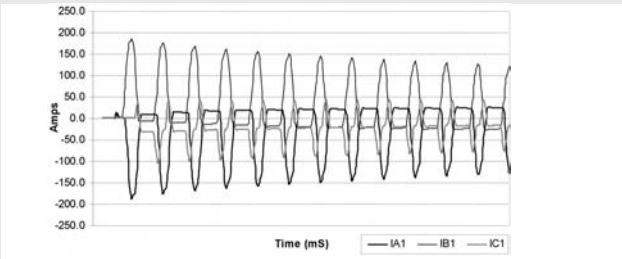

Fig 12: Transformer Inrush Current Case 3

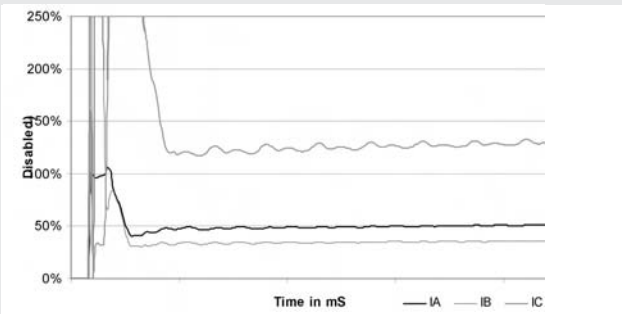

Fig 13: Second Harmonic Content - Case 3 (Without Sharing)

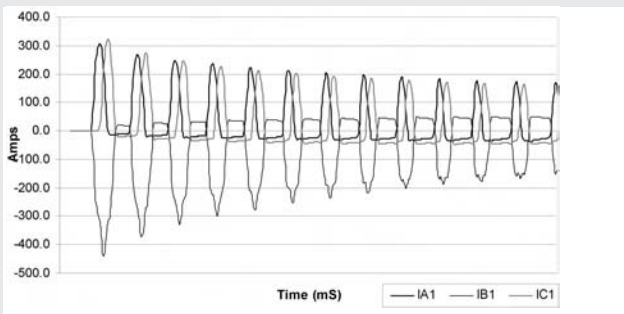

Fig 14: Transformer Inrush Current, High Voltage Side - Case 4

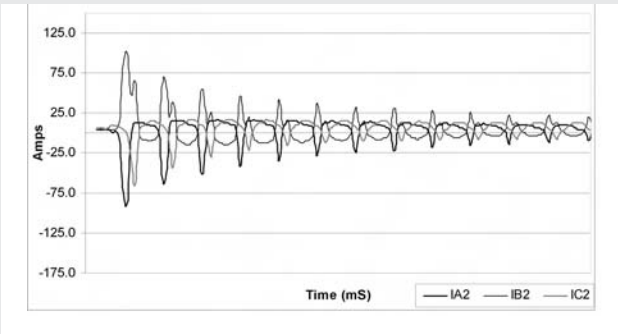

Fig 15: Transformer Inrush Current, Low Voltage Side - Case 4

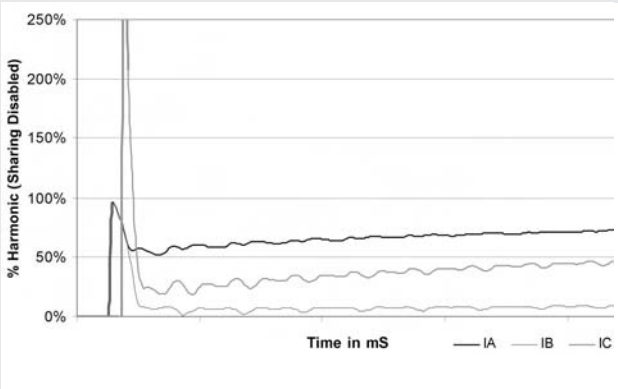

Fig 16: Second Harmonic Content - Case 4 (Without Sharing)

There is substantial DC offset to all three phases of both HV and LV side. Also, the B phase signal on the HV side, in particular, shows significant saturation. Evaluation of the signals internal to the relay shows typical fundamental unbalance current signals, but very low 2nd harmonic signals. As a result, the B phase element's percent harmonic, without sharing, is well below normal thresholds, around 7-10%. This is likely the cause of the insecurity. Note the C phase signal is lower than usually seen (20-25%), but still comfortably above the threshold.

By implementing harmonic sharing, as discussed previously, we create a single, "known good" harmonic signal. Each phase element of the differential relay uses this summed signal to make its independent restrain decision. In this case, the difference is dramatic.

With harmonic sharing, the overall percent harmonic signal is significantly higher. The problem B phase rises from under 10% second harmonic to over 50% second harmonic. Even with the higher threshold of 18%, the safety margin exceeds 2:1, compared with being insecure with sharing disabled.

SUMMARY

The availability of data recording in numeric relay systems has provided a whole new level of data for analyzing relay operations and evaluating system conditions. The additional capabilities of numeric systems can allow improved protection capabilities. The use of harmonic sharing in transformer differential protection gives the ability to improve security for some inrush conditions, while maintaining sensitivity.

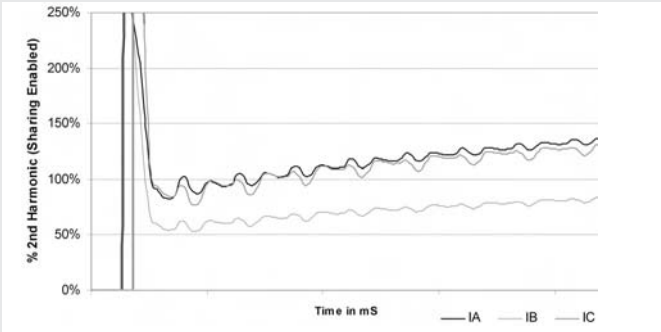

Fig 17: Second Harmonic Content - Case 4 (With Sharing Enabled)

Larry Lawhead is currently the Principal Application Engineer for Basler Electric. He is also a member of the IEEE-PES and is active on the Power Systems Relay Committee.
Randy Hamilton is a Senior Electrical Design Engineer for Basler Electric Company. He has worked for Basler for more than 20 years, with experience in test and design in the areas of magnetic transformers, power supplies, voltage regulators, and, for the last five years, protective relays. **ET**

ELECTRICAL WORKERS' PROTECTIVE CLOTHING AND EQUIPMENT

By Paul F. Gelinas

Electricity is an unseen hazard, and as such must be viewed somewhat differently than other, more recognizable hazards. The use of electricity in everyday life is so common that most of us do not think of it as dangerous. It is hard to imagine that behind those innocent-looking 110-volt household wall plugs there is enough energy to be fatal.

Consider, then, with power transmission systems and industrial work places, where energy levels are much higher, what havoc can be wreaked on the human body. Electrical safety should be a major concern in any setting, especially where workers will be exposed to energized, unguarded electrical circuits. This article deals with protective clothing and equipment available against electrical hazards. Perhaps a review of the basics of electricity is in order. Voltage, current, and resistance are three terms which are central to the understanding of how electric power is transferred. One of the easiest ways to visualize the flow of electrical energy through a wire or conductor is to think of water flowing through a pipe.

Voltage: measured in volts, can be visualized as the water pressure pushing the water through the pipe.

Current: measured in amperes, can be visualized as the total amount of water flowing past a point per unit of time.

Resistance: measured in ohms, can be visualized as the friction or any device that tends to retard or remove energy from the flow of water.

The pipe wall is analogous to the insulating covering on a conductor. The flow of electrons is much the same as the flow of water in that it always seeks the lowest level or ground.

Ohm's Law governs the current passing through a circuit. Current (i) is equal to the voltage (v) divided by resistance (r), or $i = v/r$.

The higher the resistance of a circuit is, the lower the current that will pass for any given voltage. A high-quality rubber or plastic film presents a very high resistance (good insulation), whereas metals present a very low resistance (good conductor). Human skin, when dry and unbroken, has a relatively high resistance, whereas perspiration and blood present a relatively low resistance. Water and wet earth also offer very low resistance. Dry air has extremely high resistance, but if it becomes ionized it presents extremely low resistance. All of these characteristics help to explain how and when electricity becomes most dangerous to those working close by.

Workers performing tasks on or near exposed energized electric circuits face three major hazards:

1. Electrocution
2. Arc flash
3. Arc blast

It is fair to say that hazard number one, electrocution, is the most recognized. The results of hazards number two and three are poorly understood and less recognized, but pose dangerous, even mortal risk given sufficient energy levels.

Electrocution takes place when current enters and exits the human body, making it a conductor. To accomplish this, one part of the body must be at a higher potential or voltage than some other part. If the skin resistance is low enough, then the current flowing through the body will be great enough to cause problems, and it does not take much. Current levels of one milliampere (0.001 ampere) can barely be felt; current levels of 16 milliamperes (0.016 ampere) will contract arm muscles to the extent that the average man can barely release his grip. At 20 milliamperes (0.020 ampere) respiratory muscles can be paralyzed; at 100 milliamperes (0.100 ampere) the ventricular fibrillation threshold is reached, and at two amperes cardiac arrest occurs.

The current that finds its way into the body is the important factor in determining the damage done. At low voltages - below 600 volts-the skin may present enough resistance to keep current flow through the body from reaching dangerous levels. Perspiration, wet locations or open wounds can create conditions where hazardous levels of current will flow through the body if contact with energized circuits occurs. Once current is flowing, heating of tissue or organs may result in severe burning.

When considering electric arcs, it is key to understand that energy dissipated is the dominant factor in determining the level of hazard that exists. Scuffing your shoes over a carpet when the weather is dry can generate relatively high voltages, perhaps 10,000 or 20,000 volts. The resulting spark (arc flash) releases only a minute amount of energy because there is very little supply of current. On the other hand, a 480-volt circuit in an industrial plant with perhaps 30,000 amps of current available can cause an arc of such magnitude as to seriously injure or even kill a person standing within a few feet in as little as one-tenth of a second.

Arc flash occurs when the insulating material between energized conductors at different potentials breaks down. The flow of current will be sustained if the air between the two conductors becomes ionized. This process can release a large amount of the available energy and produce harmful levels of light and mostly radiant heat. With sufficient available electrical energy, the heat can be strong enough to cause serious, even fatal burns to a person that is nearby. Extensive testing has been done in an effort to rate clothing for protection against the thermal energy released by arc flash.

Arc blast occurs due to the rapid expansion of the gases surrounding the arc. This expansion has characteristics of an explosion and can burst apart the surrounding materials, propelling bits and pieces at very high speed. This shrapnel can do serious harm to the human body unlucky enough to be in its path. The expanding air itself can also inflict physical injury to a person that is nearby, and even break open protective clothing, exposing the skin to greater damage from the heat. It should be noted that ratings

on protective clothing do not represent any level of protection from arc blast.

OSHA (Occupational Safety & Health Administration for the U.S. Ministry of Labour) has created a substantial number of electrical safety regulations, while the National Fire Protection Association (NFPA) has published a standard that deals with electrical safety in the workplace. The National Electrical Code (NEC) details how electrical systems are to be constructed to achieve a good combination of practicality and safety. The American Society for Testing and Materials (ASTM) has developed standards that deal with the production, care, use, inspection and testing of rubber insulating items such as gloves, sleeves, line hose and blankets that are used as personnel protective equipment (PPE) against electrical shock. In addition, there are standards on protective clothing for arc flash. The sheer weight of the regulations, codes and standards reflects the serious and deadly nature of hazards created by electricity.

Development of most safety programs involves the same steps:

1. Assess hazards
2. Alert workers of identified hazards
3. Train workers to recognize hazards
4. Develop safe work procedures
5. Qualify workers involved
6. Select PPE
7. Train workers in care & use of PPE

There are a number of ways to protect workers against the hazards created by the use of electricity. The best way is never to allow a worker to be exposed to an energized electrical circuit.

The National Electrical Code, National Fire Protection Association Standard 70E, and the OSHA regulations attempt to create an environment in which energized circuits are shut down and secured or physically separated from any worker by means of a suitable insulated guard, or by enough distance to prevent unsafe approach. However, even when a system has been placed in a "work-safe" condition, by disconnection and locking out all sources of energy, checks must be made to ensure that is indeed the case. Here, workers may be exposed to circuits that could still be energized. There are also some circumstances which would be made unsafe by disconnecting the source of electrical power. These include, but are not limited to, ventilation and alarm systems, traffic control systems, light sources and medical life support equipment. In other cases, a worker may be required to perform certain tasks on energized electrical circuits such as monitoring, troubleshooting, modifying or repairing equipment. Often, significant economic cost or the inconvenience to large numbers of people may require work on or near energized circuits. The OSHA regulations make allowances for such cases for qualified workers properly trained in safe work practices and the use of special techniques, equipment and PPE. Assessing hazards, developing safe work practices, selecting appropriate PPE and training employees are the responsibility of management.

Workers must be responsible for implementing the prescribed work practices and wearing PPE as necessary. Insulating rubber gloves, sleeves, line hose and blankets have the primary func-

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tion of providing the worker with an insulating barrier so that inadvertent contact with energized circuits will not cause electrocution. All of these items are rated as to the level of voltage that can be safely contacted. The ratings for these items are spelled out in OSHA 1910.137 and ASTM D120. Gloves are rated in six classes - 00, 0, 1, 2, 3 and 4. Each class is rated for use at a maximum voltage and must be tested before first use and regularly thereafter at a voltage, greater than the maximum-use voltage as specified by OSHA 1010.137. Protector gloves, usually made of leather, must be worn over the insulating rubber glove to protect against damage that might degrade the dielectric characteristics. Leather gloves will offer some protection against arc flash. Thorough visual inspection is required before each day's use. Sleeves, blankets and line hose are similarly rated and require regular electrical testing and visual inspection.

The workers must be properly trained in the care and use of this type of PPE. ASTM D120-95 is the industry standard for electrical insulating gloves. According to OSHA, gloves meeting this standard are acceptable for use at the rated voltage.

Clothing for protection against arc flash is rated in terms of the protection provided against burns. An ATPV (Arc Thermal Protective Value) is listed on all garments meeting ASTM F1506 and is defined as the maximum incident thermal energy that the fabric can support before the wearer will suffer the onset of second-degree burns. Burns are classified in three categories. First-degree burns represent pain, where the skin becomes red but does not blister. Second-degree burns involve blistering of the skin, and the epidermis must regenerate. Third-degree burns cause the epidermis to be destroyed; the skin cannot regenerate itself and scar tissue forms.

Materials used for flame-resistant (FR) clothing include 100 percent wool; 100 percent cotton, both treated and untreated; treated 88 percent cotton/12 percent nylon; polybenzimidazol (PBI); Kevlar; Nomex; or combinations of these fabrics. Flame-resistant treatment of fabrics will increase the ATPV. It is most important that laundering instructions are followed to avoid washing out these treatments and lowering the level of protection. Para-aramid fibers add strength to the fabric to prevent their breaking open due to arc blast energy. Generally, wool is not used as an outer fabric because its low tear strength makes it very weak and apt to burst open from the force of an arc blast, leaving the skin exposed to burning. Untreated synthetic materials such as polyester, rayon, acetate and nylon are not used at all due to the fact that they will melt at high temperatures and aggravate any burn injury.

OSHA 1910.269 states in section (l)(6)(iii): The employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee.

Note: Clothing made from the following types of fabrics, either alone or in blends, is prohibited by this paragraph, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered or that the clothing is worn in such a manner as to eliminate the hazard involved: acetate, nylon, polyester, rayon.

When selecting FR clothing for protection against arc flash, the clothing rating must be greater than the exposure that may be encountered if an arc occurs. There are methods for calculating the incident energy that will be produced during an arc event if enough information is available. During the hazard assessment process, the following data must be gathered to help determine this energy level:

- Circuit voltage
- Maximum fault current
- Distance from worker to arc centerline
- Potential arc gap
- Maximum arc duration
- Determination if the potential arc is in an enclosure or in free air
- Multi- or single-phase arc

An easy-to-use computer tool is available from Duke Power called the Duke Power Heat Flux Calculator, a DOS-based program that will estimate from the information listed above the incident radiant heat energy in calories per square centimeter. This calculator may be downloaded free of charge from www.Arcflash.com. ARCPRO(r) software, from Ontario Hydro Technologies (OHT), is another option. This software is more elaborate, accurate and user-friendly, but must be purchased. The chart below lists the Hazard Risk Category, Clothing Description, Total Weight of Clothing and Minimum ATPV for that clothing set. This data represents typical protective clothing systems. There has been no formal testing done on gloves. If voltage-rated gloves are required, the leather protectors worn over the rubber gloves provide good arc flash protection. The use of 100 percent cotton gloves under the rubber insulating gloves will add an additional layer of protection. Gloves made of multiple layers of flame-resistant material pro-

vide the highest level of arc flash protection.

Hazard Risk Category	Clothing Description (Number of clothing layers is given in parentheses)	Total Weight of Clothing (oz./yard^2)	Minimum Arc Thermal Performance Exposure Value (ATPV)* or Breakopen Threshold Energy (EBT)* Rating of PPE cal/cm^2
0	Untreated cotton (1)	4.5 - 7	N/A
1	FR shirt and FR pants (1)	4.5 - 8	5
2	Cotton underwear plus FR shirt and FR pants (2)	9 - 12	8
3	Cotton underwear plus FR shirt and FR pants plus FR coverall (3)	16 - 20	25
4	Cotton underwear plus FR shirt and FR pants plus double-layer switching coat and pants (4)	24 - 30	40

ATPV is defined in the ASTM P S58 standard arc test method for flame-resistant (FR) fabrics as the incident energy that would just cause the onset of a second-degree burn (1.2 calories per square centimeter.) EBT is defined as the highest incident energy, which did not cause FR fabric breakopen and did not exceed the second-degree burn criteria.

Heavy leather gloves also provide good protection. Heavy leather work boots will provide good arc flash protection for the feet. The NFPA 70-E Standard recommends this type of footwear for incident energy exposure levels of five calories per square centimeter and higher.

Face shields are available that can withstand about eight calories per square centimeter of incident energy. Hoods made of one or more layers of flame-resistant material are available with or without a face shield for the more severe hazard risk categories.

Insulated tools, voltage detectors, safety glasses or goggles, signs and barricades are additional equipment that can be employed to keep workers safe around electrical circuits. The 2002 National Electric Code now requires warning signs in areas where the potential for arc blast and flash exist.

110.16 Flash Protection. Switchboards, panelboards, industrial control panels, and motor control centers in other than dwelling occupancies that are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

The new requirement is intended to reduce the occurrence of serious injury or death due to arcing faults to workers who work on or near energized electrical equipment. The warning label should remind a qualified worker who intends to open the equipment for analysis or work that a serious hazard exists and that the workers should follow appropriate work practices and wear appropriate personal protection equipment (PPE) for the specific hazard.

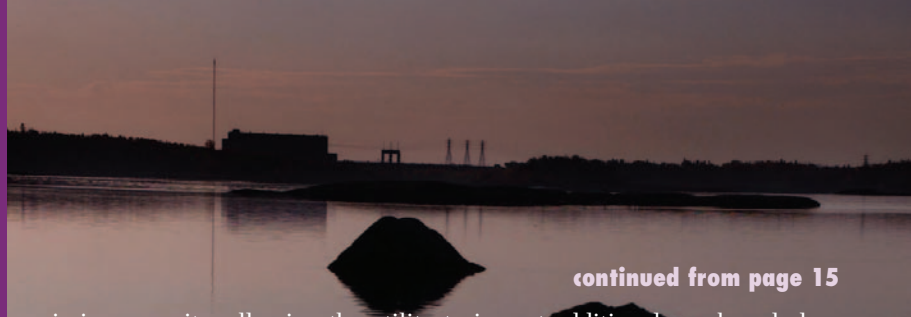
Balancing the need for a certain level of protection with the freedom of movement that any job requires is a constant battle when it comes to the selection of PPE. The comfort of the worker adds another aspect so important that it simply cannot be ignored in the selection process. To help overcome these conflicting needs, workers who will actually be wearing the PPE must be involved in the selection process. This step adds another layer to the decision-making process, but often provides valuable insight into the needs of workers, who will be much less apt to ignore the selected PPE if their voice is heard in the selection process.

The following is a partial list of standards which touch on protective clothing and equipment for electrical workers:

OSHA 1910.137 Electrical Protective Devices
OSHA 1910.268 Telecommunications
OSHA 1910.269 Electric Power Generation, Transmission and Distribution
OSHA 1910.331 Electrical- Safety-Related Work Practices- Scope
OSHA 1910.332 Electrical- Safety-Related Work Practices- Training
OSHA 1910.333 Electrical- Safety-Related Work Practices- Work Practices
OSHA 1910.334 Electrical- Safety-Related Work Practices- Equipment
OSHA 1910.335 Electrical- Safety-Related Work Practices- Safeguards
NFPA 70-E Standard for Electrical Safety Requirements for Employee Workplaces- 2000 Edition
ASTM D120-95 Standard Specification for Rubber Insulating Gloves
ASTM F496-01 Standard Specification for In-Service Care of Insulating Gloves and Sleeves
ASTM F696-97 Standard Specification for Leather Protectors for Insulating Gloves and Mittens
ASTM F1117-93 Standard Specification for Dielectric Overshoe Footwear
ASTM 1236-96 Standard Guide for Visual Inspection of Electrical Protective Rubber Products
ASTM 1506-98 Standard Specification for Protective Wearing Apparel for Use by Electrical Workers When Exposed to Momentary Electrical Arc and Related Thermal Hazards.

Paul F. Gelinas is Vice President at Comasec Safety, Inc., which develops and manufactures protective gloves worldwide. He has managed the company since 1987, and holds a BS in Electrical Engineering from Worcester Polytechnic Institute.

This article first appeared in the 2003 Grey House Safety & Security Directory and is reprinted with permission by Grey House Publishing, Millerton, NY. For more information on the Grey House Safety & Security Directory or other Grey House reference publications, visit www.greyhouse.com. **ET**



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mission capacity, allowing the utility to import additional purchased electricity and decrease the need to draw from water reserves.

Manitoba Hydro's retained earnings allowed the utility to absorb the costs of the low water flows experienced over the last two years, cushioning ratepayers from the financial shock of the drought. However, the cost of this drought was more severe than anticipated and it will be necessary for Manitoba Hydro to rebuild those earnings.

In January 2004, the utility began that rebuilding process when it applied to the Manitoba Public Utilities Board (PUB) for an increase in electricity rates. In July, after public hearings, the PUB granted an average 5% increase in electricity rates across all customer classes.

But more importantly, the water situation in Manitoba has dramatically improved. Rain across Manitoba Hydro's drainage basins throughout the spring and summer has returned water supplies to normal. Above-normal snowfall in the southern and eastern watersheds late last winter in combination with spring rainfall has led to above-normal flows from the Winnipeg River drainage area — Manitoba Hydro's most productive watershed. These high flows have replenished reservoirs, a dramatic turn-a-round from the situation experienced just one year ago.

With this improvement in hydroelectric generation and the resulting resumption of normal export activity, the utility is forecasting a return to profitability in the current fiscal year.

David Cormie manages Manitoba Hydro's Power Sales and Operations Division and is responsible for managing the utility's energy resources. A professional engineer, David has worked with and studied Manitoba Hydro's hydraulic system for over 25 years. **ET**

The Seven Sisters Generating Station was one of 14 generating stations affected by the drought conditions in Manitoba between 2002 and 2004.

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(11) Canadian Wind Energy Association news release, "Throne Speech Confirms Wind Power as Major Energy Opportunity for Canada" (October 5, 2004), online: http://www.canwea.ca/en/NewsReleases.html.

(12) Supra, note 9.

(13) Supra, note 8 at 3.

(14) Supra, note 5 at 16.

(15) Ontario Ministry of Energy news release, "Ernie Eves Government Introduces Standard to Increase Green Energy" (July 3, 2003), online: http://www.energy.gov.on.ca/index.cfm?fuseaction=archives.news2&news_id=37&body=yes.

(16) Supra, note 1 at 72.

(17) Ontario Ministry of Energy news release, "McGuinty Government to Increase Supply of Renewable Energy" (April 28, 2004), online: http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&body=yes&news_id=60; Ontario Ministry of Energy news release, "McGuinty Government Sparks Interest in Green Electricity" (June 24, 2004), online: http://www.energy.gov.on.ca/index.cfm?fuseaction=english.news&body=yes&news_id=64.

(18) Ontario Ministry of Energy, Request for Proposals for 300 MW of Renewable Energy, online: http://www.ontarioelectricityrfp.ca at 3, 32 and 53.

(19) Quote from Paul Norris, President, Ontario Waterpower Association.

(20) Bill 100, An Act to amend the Electricity Act, 1998 and the Ontario Energy Board Act, 1998 and to make consequential amendments to other Acts, 1st Sess., 38th Leg., Ontario, 2004 (1st reading 15 June 2004).

(21) Supra, note 11; Natural Resources Canada website, "Programs", online: http://www.canren.gc.ca/programs/index.asp?CaId=107&PgId=622.

(22) New Brunswick news release, "Province Moving Forward on Renew-

able Energy", (May 7, 2004) online: http://www.gnb.ca/cnb/news/ene/2004e0544en.htm; Sustainability Now, "Wind Power Overview for Canada" (March 2004), online: http://www.sustainability.ca/index.cfm?body=SourceView.cfm&ID=645.

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The foregoing provides only an overview and does not constitute legal advice. Readers are cautioned against making any decisions based on this material alone.

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DATA QUALITY ISSUES AND SOLUTIONS FOR ENTERPRISE ENERGY MANAGEMENT APPLICATIONS (PART II)

By Greg Thompson, Jeff Yeo, and Terrence Tobin

Editor's Note:
This is the second of two parts on Enterprise energy management systems. In our last issue, we discussed the importance of managing energy with reliable data and the impact of poor data quality on energy solutions. This issue will continue the discussion on data quality issues for EEM applications by covering typical data quality responsibilities and workflow and considerations that should be taken when choosing a data quality solution.

TYPICAL DATA QUALITY RESPONSIBILITIES AND WORKFLOW

Addressing energy-related data quality issues takes a combination of the right tools and the right process. Using a data quality software application can address individual issues; however, a commitment from management and the availability of the proper resources is needed to ensure data quality assurance is an ongoing process.

Data quality needs a champion to drive the program and one or more data stewards to execute the necessary steps. Given the importance of energy as a key commodity for an organization, and in turn its impact on profits, the champion can be anyone from an executive through middle management level, including corporate energy managers, operations or facilities managers, or engineering managers.

In terms of day-to-day execution, data cleansing tasks are typically assigned to one or more people within a facility management group, someone with a title such as data administrator, or clerical staff specially trained in the data quality tools and rules. Often, it makes more sense for a business to concentrate on its core competencies and outsource the data quality function to an energy management services company.

In general, it is always best to fix data problems up front rather than later. That is why the data cleansing process should be positioned at the point where collected data first enters the enterprise energy management system, before it makes it through to the data warehouse (Figure 5). If this is not done, data problems within the data warehouse start to affect critical calculations and decisions, and can propagate further problems before they are isolated and corrected.

To be most effective, an EEM system is configured to include a front-end data staging area. Data in this area has already been parsed and translated into the proper units as necessary. The staging area acts as the raw data input to the data quality process. In most cases, only after the data is validated or corrected as necessary is it passed on through to the EEM system's data warehouse (or data mart).

In some special cases, it may be desirable to allow data entering the staging area to be passed on to the data mart without validation, despite the potential for data errors or gaps. This will allow some users that require near "real-time" data to benefit, even if there is an issue with a few readings. In this case, the data quality process can be run on the data at the next scheduled time. If data issues are identified at that point, they will be addressed and the cleansed data will then propagate to the data mart.

Beyond the real-time inputs to the EEM system, the data quality tools can also be used to validate and cleanse data in previously stored databases before it is integrated within the EEM system database.

During the data quality validation process, data problems are flagged, both visually on screen and, if desired, through alarm annunciations. The user can then decide on the best course of

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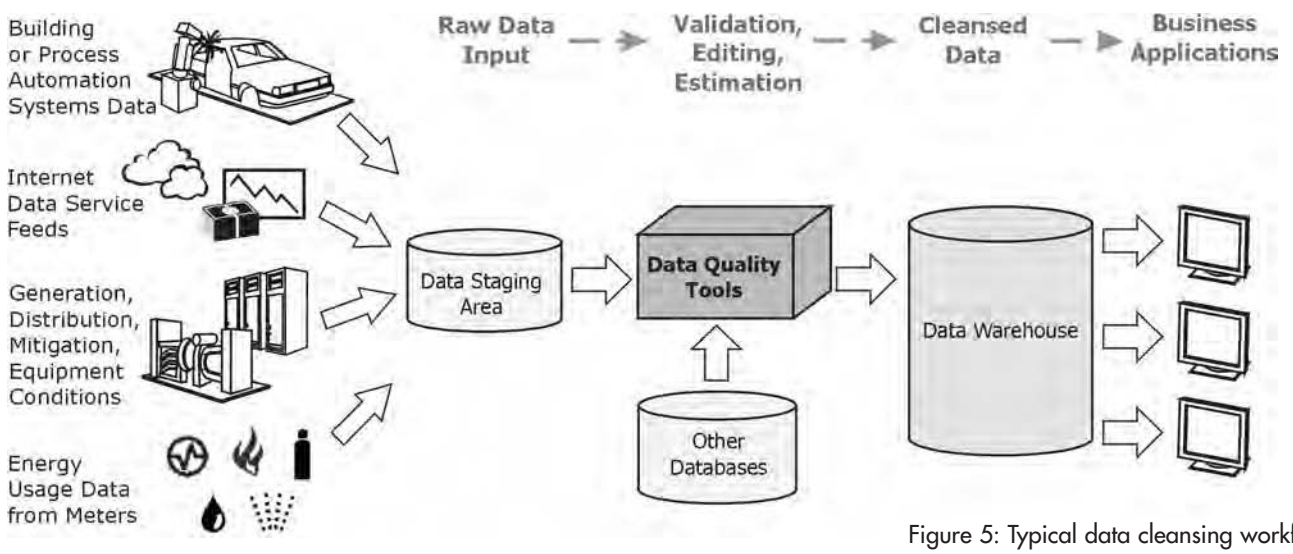

Figure 5: Typical data cleansing workflow

HYDRO QUÉBEC'S MULTITERMINAL HVDC STORY

By Daniel Soulier
and Bob Fesmire

IN THE BEGINNING

In 1986, Hydro Québec (HQ) began commercial operation of an HVDC transmission line between its Des Cantons station and the Comerford station of New England Electric System (now National Grid USA). The 450 kV line was capable of transmitting 690 MW of power, and provided a controllable link between the Québec and New England AC systems. These facilities were actually the first phase of a much more ambitious project to accommodate the power transfers required by a new firm energy sales contract to New England for the delivery of 70 TWh over a ten-year period terminating in September 2001. Thus, the combined needs of the firm energy contract, internal load increase and generation development in northern Québec lead to the expansion of the HVDC system both north and south with multiple terminals in Québec and New England. The project HQ and NEES undertook would become what is still today the world's largest multiterminal HVDC transmission system.

WHY HVDC?

The HQ system operates isolated from the rest of the North American grid. Even though isolated generation or load has been used in the past to exchange power with adjacent systems, HQ was challenged with developing electrical interconnections with neighboring markets to expand market opportunities for its hydro resources. Setting this objective, HQ began to develop and build interconnections in the early 1980s, including several DC interconnections (back-to-back) that were put successfully into operation.

The advantages of DC transmission are well known—fewer line losses, greater control, a smaller footprint — but there were other factors that were of particular relevance for HQ.

The most immediate concern was supporting the load growth of Southern Québec, the province's most populated area. At the time, the 735 kV AC line running south from the hydro units on the La Grande river did not have sufficient transmission capacity to accommodate future generation expansion. So, HQ sought to increase the transmission capacity of this corridor and also enhance the future reliability of Québec's power supply. Additional 735 kV lines were contemplated to expand the transmission system.

HQ also wanted to facilitate transmission contracts to deliver more power to the U.S. Northeast, so additional DC converter capacity was required between Québec and New England. In addition, security of the power supply to New England requires isolation of HQ generation into the NE system. All these needs were optimized with the addition of a new DC line from James Bay to Boston with intermediate substations in southern Québec. The multiterminal system offers even greater flexibility in that HQ is able to use generation units to supply power directly to Boston, or alternatively to run in a split configuration, "two bipoles" mode to serve HQ loads on the Québec AC system and import from the U.S. simultaneously.

ENTER DEREGULATION

The full multiterminal system was commissioned from 1989 to 1992, with the first deliveries to New England states of the firm energy contract beginning in 1990. Since that time, the company's bilateral long-term contract ended and, of course, regulation of power markets has gone through several convulsions. But, the Québec-New England line is still used today to support HQ and New England imports needs, and also to enable third parties to deliver power to U.S. and Canadian customers.

The current Hydro Québec/National Grid multiterminal HVDC system is largely unchanged from the one commissioned twelve years ago. It consists of over 1,500 km of ±450 kV HVDC lines stretching from Radisson in northern Québec to Sandy Pond station near Boston. In between are substations at Nicolet, Des Cantons and Comerford. Originally, the Comerford and Des Cantons stations were to be able to operate like Nicolet as input/output points. However, after evaluating the costs and benefits of this capability—particularly the extensive testing requirements—HQ/National Grid elected to forego the integration of Comerford and Des Cantons into the multiterminal scheme. Des Cantons and Comerford can still be used as a separate two-terminal line when the Sandy Pond terminal is off.

The often-cited reliability of HVDC systems has been borne out by HQ's experience. Aside from planned outages to perform testing and maintenance on substations, the multiterminal system has experienced no major outages over its 14 years in operation. And while New England and Québec were not as affected as others during the August 2003 blackout, the HVDC system did go through all AC voltage fluctuation and frequency excursion that the New England island underwent. Reliability and controllability afforded by the multiterminal HVDC system surely shielded the HQ system from this major disturbance while assuring a reliable power supply to the New England system.

Inside the valve hall at Radisson

Hydro Québec's experience has made it a global authority on implementing HVDC systems. As a result, the company has provided consulting and engineering services to utilities exploring HVDC in countries such as China, Philippines, India, Australia and the U.S. As economic and social changes place greater and greater demands on electricity infrastructure, the advantages of HVDC are likely to make it a more common solution for grid operators worldwide.

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An aerial view of the Radisson HVDC converter station.

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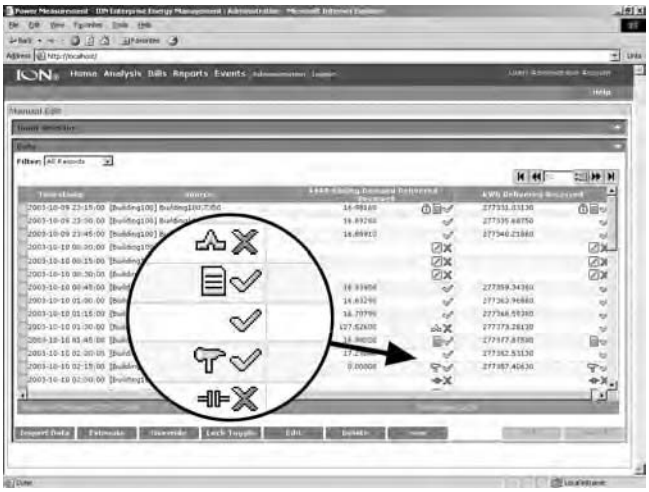

Figure 6: Typical data quality estimation and editing screen. Highlighting (from top to bottom) test result indicators for: spike test failure, edited and passed, validated with no errors, failed test override, and gap test failure.

action based on the options described above.

The system can also help identify persistent data quality issues from a particular incoming data feed, such as a faulty remote meter or other device, an Internet interruption, or a communications network problem. A maintenance protocol can be set up to flag the appropriate technical staff to investigate the source of the problem. If a meter or other data source exhibits an intermittent problem, a decision can be made on whether to repair or replace by comparing that cost to the ongoing man-hours and cost of repeated error correction using data quality tools. The data quality system may also uncover recurring problems with a particular data entry method or other process.

How often the data quality tools need to be used to cleanse data depends on a number of system conditions and the workflow preferences of the user:

System size. The greater the number of data sources (e.g. number of metering points), the higher the probability of data problems, and the harder it is to identify and correct problems. Data problems are often compounded due to sheer size of the data. The user may wish to run the data quality process more often (daily instead of weekly) to keep on top of the workload.

Real-time data requirements. Monthly data cleansing, well before the billing date, may be sufficient for tenant billing. For real-time applications such as load management, energy procurement, etc., data may be required more frequently and thus the data will need to be cleansed often to deliver up-to-date reliable data.

System topology. Some types of communications (e.g. modem links), may be inherently less reliable than others (e.g. hardwired). The geographical breadth of a system may also affect the reliability of data collected from remote points. Both of these issues may create higher frequencies of data problems that need to be addressed more often.

Variety of data types. The number of distinctly different sources of data (electric meter, gas meters, weather feed, RTP feed, etc.) will add to the complexity of the EEM system and, in turn, influence the expected rate of data errors or gaps.

Efficiency. As mentioned above, the sooner a problem is discovered the easier it is to fix; therefore, the data quality process should be run more often rather than less.

CONSIDERATIONS WHEN CHOOSING A DATA QUALITY SOLUTION

Data quality tools can be effective in addressing data quality problems, but only if they are well designed. If a business intends to have in-house responsibility for the data cleansing process, a number of criteria should be considered when choosing a solution:

Flexible and modular. The data quality system should be flexible enough to align with utility standards to support bill verification and energy procurement. It should also be able to adapt to evolving internal business standards. A modular architecture is an additional advantage, as it allows for sub-components or features to be added or engaged as required for testing of different kinds of problems.

Applicable to all EEM data sources. Data quality tools should be

designed for a "whole system approach", available to cleanse not only metered electrical energy data, but also data representing other energy sources like gas, steam, etc. Further, they should be able to validate external data feeds such as weather, real-time pricing (RTP) rate forecasts from the ISO/RTO, etc.

Notification system. The system should allow data administrators to subscribe to desired information and be notified when necessary, for example when a dead source is detected, or when a data quality report has been run and shows data issues. Notification methods should include email, pager, and other convenient options.

Report generation. Reporting tools should provide scheduled or on-demand reporting, listing detail and rollups on all data quality performance. The data quality reports and, ideally, the bills generated by the EEM system should both reflect valid data statistics.

Audit trails and raw data backup. A complete audit trail should be provided for any data that has been edited. This should indicate the user that executed the change, what was changed and how. For data that has been changed, the complete raw data set should be retained in a backup file and be accessible in case a particular data cleansing step needs to be reversed.

Security. Different password protected access levels should be provided. This can include "view only" access for some users, while "administrator" access allows viewing and the ability to make changes to the data.

Override capability. The system should allow an administrator to override an error indication for what first appears as an error but may be valid data (e.g. a meter is showing zero energy usage due to a known power outage.)

Ease-of-use. The data quality process must be cost effective, so the tools must be efficient and easy to use. A number of features can help in this regard. For example, error indicators on data quality screens should provide quick links to view the supporting data. Ideally, this should also be a feature of bills generated by the EEM system. Data should be clearly marked to differentiate between valid, estimated or corrected data.

CONCLUSIONS

Enterprise energy management systems represent the key to energy-related savings and productivity improvements, but their effectiveness is significantly influenced by the quality of data they deliver. As with all business intelligence systems, the right tools and processes must be in place to avoid data quality issues that could otherwise seriously affect business decisions, tenant relations and return on investment. New data quality tools available for industrial, commercial and institutional energy consumers help ensure the intelligence delivered by EEM systems is accurate, complete and timely.

Whether businesses choose to dedicate in-house staff to the data quality process or outsource it, the design features of the data quality application are critical. Due to typical EEM system breadth, the variety of networking methods, and the number and types of data sources, a comprehensive set of data quality tools is needed to identify and compensate for all potential data quality problems. The data quality solution chosen should provide the flexibility and modularity needed to adapt to evolving business rules and needs. It should also be applicable to all EEM data sources beyond energy metering, including external feeds such as weather and real-time energy pricing. Finally, to be cost-effective, data quality tools must be easy and efficient to use.

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Jeffrey Yeo, P.Eng., is a Senior Software Architect for Power Measurement. He's worked in electrical system maintenance, planning and forensics within the mining industry prior to joining Power Measurement in 1993. Since then he has held positions in product testing, field service engineering, and software development.
Terrence Tobin is the Corporate Communications Manager for Power Measurement. He began his affiliation with Power Measurement in 1988 and has held a variety of positions including Director of Marketing Communications and Brand Manager. **ET**

DEFINING THE ROLE OF LOCAL ELECTRICITY DISTRIBUTORS IN ONTARIO'S ELECTRICITY MARKET

By Ken Quesnelle

As decisions are made, and legislation is put into motion, we come closer to better defining the role of electricity distributors in Ontario's electricity market – an evolution that continues to have direct economic, social and political impacts on a wide range of interests, including municipalities, residential customers and businesses of all sizes.

Led by government legislation and a new strategic vision for the province's electricity industry, every facet of Ontario's electricity system is being re-evaluated. Change, often significant change, will be the operative word for Ontario's local electricity distributors into the foreseeable future.

The Provincial Government's energy strategy is altering the roles and responsibilities of those who deliver power to Ontario's homes and businesses. For Local Distribution Companies (LDCs), the hope is that what has been put into motion this year will set the stage for 'getting it right' for the future of the province's electricity market.

Local distributors are a fundamental and vitally important part of Ontario's electricity market and have a long and distinguished history that dates back to the very origins of the province's electricity system almost a century ago. We carry a proud heritage that draws on our continuing service to our local communities – facilitating and promoting local economic development and maintaining our community's system of electricity wires.

In fact, the province's electricity distribution industry provides employment to almost 10,000 Ontarians and invests well over half a billion dollars in the province's infrastructure every year. Distributors are on the frontline of electricity matters, acting as customers' points-of-contact and providing customer service through regular repair and maintenance, call centres, education campaigns and emergency response.

PUTTING IN PLACE A SUSTAINABLE ELECTRICITY POLICY FOR ONTARIO

The government has clearly indicated that they want to work with electricity distributors in developing and putting into place a sustainable electricity policy for Ontario.

Ontario's distributors recognize the importance that the implementation of substantial and timely conservation measures have with the government. Local distributors, and the Electricity Distributors Association (EDA), continue to work closely with the Ministry of Energy and the Ontario Energy Board (OEB) to accomplish regulatory reform to facilitate these important goals for the electricity sector and the province's electricity ratepayers.

Bill 100, the Electricity Restructuring Act, 2004, provides the framework for this new energy strategy and the creation of a "conservation culture" in the province. The legislation deals primarily with supply and conservation issues, reassigns responsibilities to different entities, and sets out the roles and responsibilities for the new Ontario Power Authority (OPA). It is expected that this piece of legislation will be passed into law by year's end.

The proposed legislation also addresses Demand-Side Management (DSM) and Demand Response (DR) initiatives. Although we welcome the government's recognition that LDCs are crucial partners in the implementation of conservation programs, the role that distributors will play in offering DSM programs remains vague.

LDCs have consistently advocated that a voluntary and commercially focused approach to DSM would best achieve the government's goals. Yet there are outstanding issues that remain. First, there are the substantial transition costs that will be incurred by distributors in offering various programs. Secondly, there is the issue of lost revenue resulting from a reduction in electricity consumption when DSM activities are put into place.

The challenges faced by distributors in implementing effective DSM programs is a specific example of where regulatory uncertainty is having a negative affect on realizing the government's goals to reform Ontario's electricity industry.

A greater degree of regulatory certainty must exist in order for initiatives such as DSM to not only work, but flourish and help in the creation of a "conservation culture" that the government has envisioned for the province's future.

CHANGES TO THE REGULATORY REGIME INSTRUMENTAL IN SHAPING THE FUTURE OF ONTARIO'S ELECTRICITY DISTRIBUTION INDUSTRY

In recent years the electricity distribution industry has taken a number of detours on the road to an envisioned end state. The lack of a clear and definitive role for local distribution companies has been a contributing factor to many of these detours. Past political intervention has resulted in creating a poor investment environment and poor public policy.

What is ultimately required is a stable, regulatory environment that provides a degree of stability for distributors. Not only would this enable the industry to develop sound corporate strategies, but it would allow LDCs to pursue related business opportunities, such as investments in conservation programs.

Provincial legislation and changes to the regulatory regime are going to be instrumental in shaping the future of Ontario's electricity distribution industry. For both municipally and privately owned distributors there is a need for regulatory certainty and objective-based regulation.

In the coming years the Ontario Energy Board has a unique opportunity to re-engineer the regulatory regime for the province's electricity distributors. This will benefit consumers by enhancing the operations of LDCs, it will ensure that Ontario's distribution industry is efficiently structured, and it will streamline costly regulatory processes.

In developing a regulatory end-state, the OEB cannot approach the task with a view that utilities were basically unregulated prior to 1999. The "new" regulation must reflect the fact that for the past century LDCs were indeed regulated, not simply by Ontario Hydro, but also by the powerful forces at work via municipal ownership and the local hydro-electric commissions. These systems were effective in ensuring responsibly run utilities.

The ratemaking work of the next couple of years should be used as a tool in order to transition to a more efficient and effective regulatory regime that works for all parties.

In the current regulatory system, the OEB is effectively investigating all LDCs, yet there are no swift and effective penalties for those who are non-compliant. An outcome-based form of service quality regulation would do a better job at protecting customers, and achieve the same results in a more cost-effective way.

Streamlined regulation is an attempt to adjust distribution rates and regulatory processes to align customer and LDC interests, thereby:

- Lessening the need for intrusive regulation;
- Improving the efficiency of LDCs; and,
- Enabling resulting cost savings to be passed directly to customers and shareholders.

There are three main components to the distribution industry's vision of streamlined regulation: rate design, benchmarking between distributors, and measuring quality of service.

Objective, performance-based regulation will accomplish two things. First, it will encourage benchmarking between distributors and help to create a level playing field. This will help in measuring efficiency gains and signal when and where there are cost saving advantages to be had.Secondly, it will have the effect of increasing the flexibility and efficiency of the OEB. Ultimately, it will be the OEB who provides the details of how to implement the government's broader agenda. It is our contention that this part of the OEB's mandate will be greatly enhanced with the successful implementation of a regulatory mechanism that measures both performance and results.

More importantly, it must be recognized that a regulatory regime that gives credence to the creative ingenuity of distributors will allow entrepreneurship to thrive. It's a results-orientated approach that uses objectives and pre-determined desirable outcomes as its model, yet maintains a degree of flexibility. We should not view the approach to regulation as one-size fits all. Distributors service distinct communities throughout Ontario, each with its own unique characteristics: weather, geography, and aptitude for technological change, to name a few. We must look to creating a regime that is results oriented and that recognizes these differences and builds on similarities.

The benefits for Ontario's electricity consumers are clear: more electricity conservation; lower distribution rates; and, lower regulatory charges.

Throughout 2005 the OEB will be working with the LDC industry to establish revenue requirements to set 2006 distribution rates. The last such exercise took place in 1999. This represents a unique opportunity to establish a level playing field amongst different distributors, and allow the OEB to gather sufficient information to move the distribution industry confidently and swiftly into a streamlined regulatory regime that will benefit all electricity customers.

Ken Quesnelle is the Vice-President of Woodstock Hydro Services Inc. and Chair of the Electricity Distributors Association (EDA).The EDA represents Ontario's local electricity distributors, the publicly and privately owned companies that safely deliver electricity to over four million Ontario homes, businesses and public institutions. **ET**

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