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Power Generation, Transmission & Distribution, Utilization

CANADIAN ELECTRICITY FORUM

OVERHEAD TRANSMISSION AND DISTRIBUTION

- Multi-use 'AirStair' Improves Line Crew Productivity Significantly
- LIDAR/Image Solutions for the Electrical Utility Industry
- Changing the Guard: Polymer Replaces Porcelain for Surge Arresters

RENEWABLE GENERATION TECHNOLOGIES

Could Canada Lose Its Fuel Cell Technology Edge?

TRANSFORMERS AND SUBSTATIONS

- Innovative Concept Cuts Typical Delivery Time for Turnkey Substations
- Transformer Winding Resistance Testing of Fundamental Importance
- Using Gas-in-Oil Standards to Improve Accuracy of DGA Results and Diagnoses

METERING, MONITORING AND ENERGY MANAGEMENT

- Commercial and Industrial AMR: The Time Is Now; Are the Options Ready
- How Enterprise Energy Management Systems Help Maximize Power Reliability
- Meter Data Everywhere: Online Energy Information Services

– SEE ELECTRICITY TODAY AT THE AMRA 2002 INTERNATIONAL SYMPOSIUM –

AND MORE...

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IN THIS ISSUE

UPFRONT

RENEWABLE GENERATION TECHNOLOGIES

TRANSFORMERS AND SUBSTATIONS

ELECTRICAL INDUSTRY RESTRUCTURING

OVERHEAD TRANSMISSION AND DISTRIBUTION

GENERATION

METERING, MONITORING AND ENERGY MANAGEMENT

POWER QUALITY

ELECTRICAL SAFETY

INDUSTRY NEWS

PRODUCT AND SERVICE SHOWCASE FOCUS

ADVERTISER INFORMATION

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EDITORIAL

Ontario Liberal Plan A Breath of "Fresh Air"

As Ontario sets new records for electricity consumption and smog this past summer, provincial Liberal leader Dalton McGuinty unveiled an ambitious plan for cleaning up the air.

Anyone who dared ventured outside on any +30°C day, was astonished at how bad the air in Southern Ontario has become. Global warming from greenhouse gases? Only U.S. President George Bush would disagree.

McGuinty didn't need to be convinced how serious our air pollution problem has become in southern Ontario and politics being what it is, the air we breathe has breathed new life into the Ontario Liberals' hopes for the upcoming election. McGuinty has some statistics to bolster his argument and his election plan: doctors say smog causes 1,900 premature deaths annually in Ontario; it necessitates 13,000 additional emergency room visits; and costs the province $1.1 billion in health care and lost productivity.

He claims that Ontario Power Generation's five coal-fired plants are the biggest source of pollution in the province — casting them as "Enemy Number 1", and has promised that (if elected) he will shut them all down by 2007. There is some merit to his argument. However, more than half of Ontario's air pollution comes from U.S. power plants and other sources and no amount of retooling here would eliminate crossborder pollution.

With that laudable goal the centrepiece of the Liberal strategy — closing OPG's coal-fired plants would cut emissions of four of the worst pollutants by 20 per cent— McGuinty's critics are quick to condemn his clean-air plan. They claim McGuinty's proposed clean-power initiatives could not begin to bring sufficient replacement power on stream in such a tight time frame. And pointing to the province's inability to generate enough power this summer to keep up with demand, they warn that Ontario would suffer blackouts and huge price spikes if McGuinty were to follow through on his promise to close the dirty coal plants.

However, the McGuinty plan makes a convincing case that enough new power generation can be brought on stream to make up for the 7,500 megawatts (MW) of power now generated at OPG's coal-fired plants. Citing information from the Independent Market Operator, which oversees Ontario's electricity supplies, McGuinty notes that 4,500 MW of clean new power will come on stream in the next two years as a result of repairs to nuclear facilities and construction of natural gas plants already underway. In addition, the IMO has identified another 5,400 MW of new capacity from private sector natural gas plants that are now in the planning stage.

Randy Hurst, Executive Editor and Publisher

The fastest way, McGuinty says, to get these proposed plants up and running would be for Queen's Park to announce the closure of the coal plants.

Finally, the new government sponsored initiatives in McGuinty's plan — the addition of a third turbine at Niagara Falls, and the investment of more than $150 million a year in new renewable energy generators — would contribute another 1,750 MW, bringing total new capacity to 11,600 MW of power.

That, together with a new conservation plan designed to reduce Ontario's power consumption by 5 per cent, would appear to be more than sufficient to maintain a balance in supply and demand without the capacity of the coal-fired plants.

But, McGuinty's clean-air plan goes well beyond the elimination of coal.

In a welcome move, McGuinty would double Queen's Park's current contribution to public transit by dedicating 2 cents per litre of the provincial gasoline tax to municipal bus, trolley and subway investment.

And he would promote cleaner fuel by requiring the oil companies to introduce clean-burning Ethanol into gasoline — starting at 5 per cent in 2007 and rising to 10 per cent by 2010.

In this overall plan, there is a breath of fresh air in more ways than one.

Not only would the plan improve our air quality, but it would take Ontario three-fourths of the way to meeting the province's share of the country's obligations to cut greenhouse gases under the Kyoto protocol on climate change.

On the subject of Kyoto, this November, The Electricity Forum is sponsoring a forum titled: "Innovative Opportunities: Implementing Renewable Generation Technologies" where we will examine the political, economic and technical application of emerging small scale generation options into the current Canadian energy mix. For more information, visit:

http://www.electricityforum.com/forums/courses.htm

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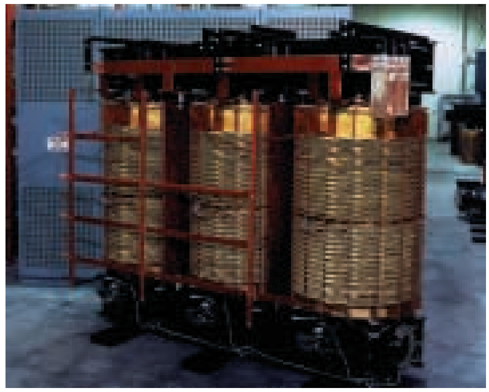

RENEWABLE GENERATION TECHNOLOGIES

Canada Could Lose Fuel Cell Technology Edge to Growing Global Competition, Says New Report

Canada could lose its leadership position in fuel cell innovation unless a national strategic partnership between government and the industry is quickly implemented, according to a report released today by Fuel Cells Canada and PricewaterhouseCoopers.

Governments across Canada helped the fuel cell industry become a global leader by investing approximately $150 million over the past 20 years. However, the level of support has not kept pace with the needs of the industry or the investments being made by other countries such as the U.S.

PricewaterhouseCoopers managing partner for British Columbia and study leader, John Webster, says partnerships between government and the fuel cell industry are critical to sustain Canada's leadership position.

"The industry needs to work with government so that the policies and resources are put in place to keep Canada at the leading edge of fuel cell development. In particular, the industry must capitalize on its competitive advantage in innovation and commercialization."

The report is the most comprehensive review ever of the potential long-term economic benefits for Canada of the fuel cell industry. It was commissioned by Fuel Cells Canada, an association representing 46 companies in the fuel cell sector.

Fuel Cells Canada chairman, Ron Britton, says countries like the U.S. and Japan are investing heavily to help their fuel cell sectors overtake Canada. The U.S. in particular has become strongly focused on the potential economic benefits of fuel cells and the hydrogen economy.

"From the federal administration in Washington D.C. down to state governments, substantial incentives are being offered to the fuel cell sector. Almost every day new initiatives are announced and U.S. state officials are actively encouraging Canadian companies to relocate south of the border."

Britton says a strong fuel cell sector is good for Canada because it creates high-paying jobs and generates economic growth in a technology sector that PricewaterhouseCoopers forecasts will be worth $46 billion worldwide by 2011.

He adds that a national strategy for the development of the fuel cell industry will help government achieve its goal of elevating Canada to one of the world's top five countries for technology innovation by 2010, and make it easier to meet the country's targets for reducing green house gas emissions.

He says Fuel Cells Canada would like government to consider four areas of partnership in a national fuel cell strategy:

- Regulation and policy
- Funding programs
- Fiscal policy
- Procurement policies

According to the PricewaterhouseCoopers report, the North American fuel cell industry is expected to provide 108,000 direct and indirect jobs in the stationary sector, and 33,000 direct and indirect jobs in the transportation sector by 2011.

It says the impact fuel cells will have on the world is comparable to other global "change technologies" such as electricity, the telephone, television, personal computers and the Internet.

PricewaterhouseCoopers is the world's largest professional services organization. In Canada, PricewaterhouseCoopers LLP and its related entities have more than 5,900 partners and staff and offices in 26 locations. PricewaterhouseCoopers refers to the Canadian firm of PricewaterhouseCoopers LLP and other members of the worldwide PricewaterhouseCoopers organization.

Headquartered in Vancouver, British Columbia at the National Research Council Innovation Centre, Fuel Cells Canada is a non-profit, national industry association. It is the prime source of services and support to Canadian corporations, educational institutions and business alliances promoting, developing, demonstrating, and deploying fuel cell and related products and services in Canada. Its mission is to advance Canada's world-leading fuel cell industry. For more information visit their website at www.fuelcellscanada.com.

Understanding Fuel Cell Technology and Applications

What is a fuel cell?

A fuel cell is an electrochemical device that produces electricity without combustion by combining hydrogen and oxygen to produce water and heat.

What are the different types of fuel cells and how do they work?

A fuel cell chemically combines hydrogen and oxygen to produce water, heat, and electricity. There are many different types of fuel cells each with their own specific operating principles. A few of the different types of fuel cells include:

1) Alkaline fuel cells (AFC);
2) Direct methanol fuel cells (DMFC);
3) Phosphoric acid fuel cells (PAFC);
4) Proton/polymer exchange membrane fuel cells (PEMFC);
5) Molten carbonate fuel cells (MCFC); and
6) Solid oxide fuel cells (SOFC).

For more information on the specific operating principles of these fuel cells, please visit any of the following Fuel Cells Canada member companies' web sites:

Direct Methanol:
www.methanex.com
Proton/Polymer Exchange Membrane
www.ballard.com
www.hpower.com
www.hydrogenics.com
www.palcan.com

Continued on page 9

Canada's latest newcomer loves low temperatures

Transformer oils from Nynas never come in from the cold. They don't have to.

Our TFOs have excellent low temperature characteristics while also offering high solubility.

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Understanding Fuel Cells
Continued from page 7

Solid Oxide
www.fuelcelltechnologies.ca
www.globalte.com

What is the history of fuel cells

The Fuel Cell was first developed by William Grove, a Welsh judge with intense scientific curiosity. In 1839 Grove was experimenting with electrolysis (the process by which water is split into hydrogen and oxygen by an electric current), when he observed that combining the same elements could also produce an electric current. Other scientists paid sporadic attention to fuel cells throughout the 19th century. From the 1930s through 1950s Francis Thomas Bacon, a British scientist, worked on developing alkali fuel cells. He demonstrated a working stack in 1958. This technology was licensed to Pratt and Whitney where it was utilized for the Apollo spacecraft fuel cells.

In Canada, early research into the development of fuel cells was carried out at the University of Toronto, the Defense Research Establishment in Ottawa, and at the National Research Council — also in Ottawa. Most of this early work concentrated on alkaline and phosphoric acid fuel cells. In 1983, Ballard Research began development of a Polymer Electrolyte Membrane fuel cell under a contract with the Defense Research Establishment in Ottawa. Over the past twenty years Canadian companies, with some government support, have developed a world-leading position in the development and commercialization of fuel cells and related products.

What is the difference between a fuel cell and a battery?

Fuel cells and batteries are both electrochemical devices that produce electricity, however the fundamental distinction between them is that batteries store “fuel” (the chemicals that react to produce electricity) internally, whereas fuel cells use external fuel storage. The implication of this difference is that when a battery’s “fuel” is spent, the battery must either be disposed or recharged whereas with a fuel cell, one can simply refill its storage tank and go, without having to replace the entire cell or wait for it to “recharge” (i.e. restore the chemicals to their original state).

What are the possible uses of fuel cells?

The possible uses for fuel cells are boundless. A fuel cell is simply a device that takes a fuel and, in combining it with oxygen (air), produces electricity. Therefore it can be used in virtually any application requiring electrical power. Fuel cells can be used instead of internal combustion engines or batteries to power vehicles ranging in size from small mopeds to large transit buses and transport vehicles, or in small consumer devices such as laptops and wireless phones. Large fuel cells can replace existing power plants to provide electricity for a large number of users, or in smaller, distributed power generation plants to supply the electrical needs of a factory, a neighbourhood, or an individual home. Basically, a fuel cell can supply clean (low or no emissions), quiet, vibration-free electricity without the need to frequently dispose of the cell when its fuel is spent or wait long periods of time for recharging.

What fuels can be used in a fuel cell?

A variety of fuels may potentially be used with fuel cells since a fuel cell operates on the simple reaction of hydrogen (H2) and oxygen (O2) to produce water (H2O). The oxygen may be taken directly from air, while the hydrogen may be delivered either in pure form, from liquid or gaseous storage tanks, or extracted from hydrocarbon fuels including methanol (CH3OH), gasoline (a mix of various hydrocarbons), natural gas (CH4), propane (C3H8), and others through the use of a reformer. Much research and development is currently focused on developing either standalone or integrated reformers for extracting hydrogen from hydrocarbon fuels or fuel cells that can be powered directly by fuels such as methanol.

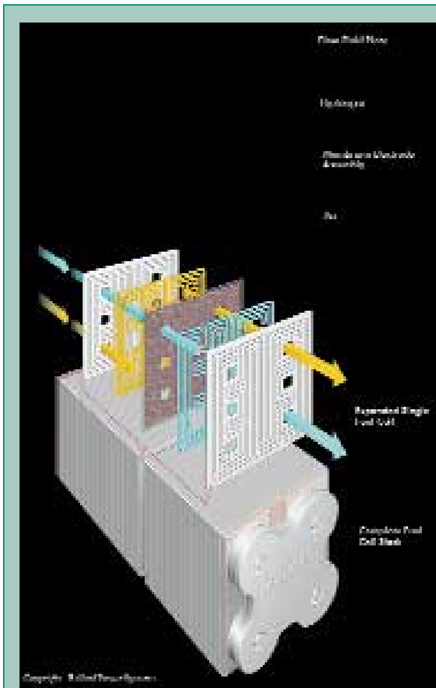
Can landfill or biogas be used to power fuel cells?

Yes. Landfill or biogas (among other fuels - see previous question) may potentially be used either directly or indirectly (after undergoing reformation) in fuel cells.

How does a fuel cell generate heat?

In any process, there are inefficiencies and/or losses. In a fuel cell, the useful work is electricity; however, not all of the energy contained in the hydrogen and oxygen can be turned into electricity. Inefficiencies in the fuel cell turn some of the available energy into heat. In a fuel

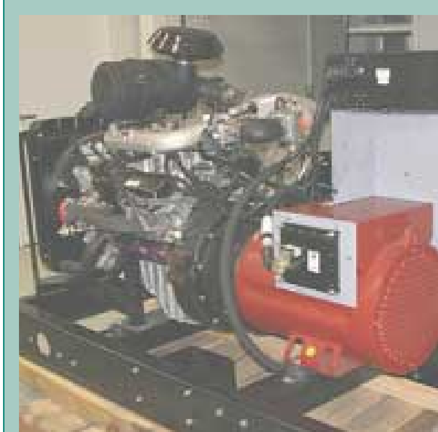
Continued on page 54



The illustration above shows the detail of a Ballard® fuel cell stack showing the flow field plates which supply the bodies of fuel and air to either side of the proton exchange membrane. Stacking together more cells increases the voltage produced; increasing the cell’s surface area increases the current produced.

In July 2002, Ballard introduced the Ecostar#8482; ES080-42N-S Genset (shown below), based on the 4.2L Ford V6 natural gas engine, capable of producing 80 kW for standby and back-up power applications. The first high-speed natural gas fueled generator set (Ecostar#8482; genset) operates at double the speed of conventional gensets to produce nearly twice the power. As a result, the Ecostar#8482; Genset also has the lowest cost per kilowatt of any genset at this power level.

(Photos: Ballard Power Systems)



TRANSFORMER AND SUBSTATION REPORT

Innovative Concept Cuts Typical Delivery Time for Turnkey Substations

Liberalization and deregulation of the electrical energy markets are rapidly changing the rules of power distribution, increasing cost pressure on utilities and network operators the world over. This, in turn, is putting pressure on companies — ie, operators and substation suppliers — to find suitable means of reducing costs without sacrificing quality. One way is to simplify the processes involved in engineering, constructing and operating substations. Another is to move away from the huge variety of traditional configurations and technologies and focus only on those that best fit the functions substations perform. The definition of their main function is simple: to connect different networks and transfer electrical energy within and/or between networks with a good margin of safety. If, now, the technical realization of the functions is not defined in too much detail, and a 'functional specification' is provided instead, a considerable potential for cutting costs is freed up.

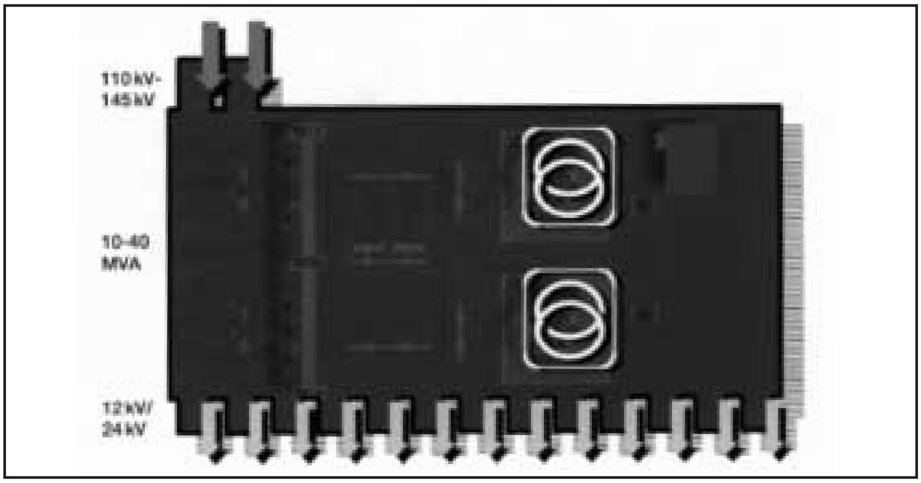


Figure 1: Basic functionality of PS-1 substation solutions

Analyze and define

The general functional requirements of typical substations remain unaffected by the market changes now taking place. An analysis of these requirements by a multinational team put together by ABB, and interviews with customers to validate the results, showed that for certain typical subtransmission and distribution applications, the substation can be depicted as a 'black box' in which voltage is transformed and power from an incoming network is distributed to a number of outgoing feeders. Based on the analysis that was carried out, ABB has developed a totally new substation concept, called PS-1. PS-1 solutions define complete, pre-engineered transformer substations which are quick to install and commission, and which feature clear technical functionality, optimized for the specific task. From the evaluation of the functional configurations of typical substations, ABB was able to define substations with the following basic technical functionality which could be realized:

- Connection to the HV network with up to two lines (110–145 kV)
- Transformation with up to two power transformers (each 10–40 MVA)
- Connection to the MV network with up to 20 feeders (12/24 kV)

Additional requirements are possible; for example, requirements related to the substation site or environment that make it necessary to choose between air-insulated switchgear (AIS) and gas-insulated switchgear (GIS), or which dictate the basic insulation level (BIL) or the short-circuit current. A factor that is always of relevance is the availability required of the substation. This is an essential parameter when evaluating the functions and, in turn, the economy of a substation, and therefore played a key role in the choice of configurations that are now part of the PS-1 substation portfolio.

Pre-design and optimize

What the functional analysis showed was that it was possible to focus on a limited number of substation layouts. It was seen that this clear definition and limitation has advantages that span an entire substation project – from the initial planning to the detailed interface engineering, production, assembly and testing, right through to the civil works, transport, installation and commissioning.

By standardizing all the process stages, material flows and transport paths, the entire process can be simplified, and thus optimized.

Operators, too, benefit from the process optimization, since it enables them to reduce their efforts in the areas of planning, supervision and maintenance.

Top priority was given to developing a clear definition, and underlay the entire approach to the PS-1 project. For instance, all the substation equipment is identified at the conceptual stage. And with the exception of some residual adaptation of external interfaces, for example for integrating the substation into the protection and control system of the connected grid, the project engineering is also finalized during the concept development phase. The internal design is based entirely on IEC/ANSI standards. Also defined in detail are the supply management, production processes, logistics and installation, significantly shortening the project cycle times usually needed for traditional substations.

Substation configurations

A comprehensive availability analysis was carried out to determine the typical substation types and connections, and so allow a definition of the functional substation configurations for the PS-1 portfolio. The comprehensive study covered high-voltage AIS as well as high-voltage GIS technology (for the sake of simplicity only the results for GIS are considered in the following).

Based on this analysis, two types of substation were defined:

- Main substations, which have either

Actual 110/12 kV PS-1 substation

an infeed from the transmission network or more than two connections to the sub-transmission network.

- Transformer substations, which are connected to the sub-transmission network on the HV side via one or two circuits. These fulfill mainly local supply functions, eg by acting as an infeed to the distribution level at medium voltage (MV). They typically have one or two HV/MV transformers rated between 10 MVA and 80 MVA.

Of these two types, the transformer substations were identified for the PS-1 GIS and AIS portfolio. In the next step, the substations were divided according to their main function in the network, which, in turn, defines the type of connection:

- Single-circuit or double-circuit radial connection: These substations have only a supply function, ie they serve only to feed the network.
- Loop connection: Such substations interconnect other transformer or main substations. Apart from the supply function, they also have a transfer function.

In each case, the substation availability was determined using the widely accepted and internationally validated probabilistic calculation method. This systematically considers the failure behavior of specific equipment parts and all relevant failure scenarios. On the basis of the quantitative availability analysis and the cost of the respective equipment, four of the ten investigated configurations were chosen for a PS-1 GIS portfolio [1].

Taking shape...

While availability is key, there are also other parameters which are relevant when choosing a substation configuration. These, in turn, are affected by factors such as the operation of the substation or its maintenance strategy. A solution was developed for the HV parts of PS-1 substations — for AIS as well as for GIS — to allow a flexible response to the requirements of different application areas. For AIS, eight configurations were chosen, including the one shown in Figure 2; for GIS, four configurations were picked.

...with state-of-the-art equipment

An important factor in the AIS as well as the GIS PS-1 substation is the role played by state-of-the-art equipment. For example, ABB's latest circuit-breaker equipment finds use in the AIS solution, while in the GIS solution, ABB's compact gas-insulated HV switchgear reduces the space required to a minimum.

To extend the application area, polymer insulators are used throughout PS-1. Low sensitivity to pollution is just one of this component's material-specific characteristics.

PS-1 is also the first integrated substation concept to encompass extensive standardization and optimization of the power transformers. The medium-voltage switchgear that is used is equipped with advanced bay computers that perform safety, control, measurement and communications functions. In addition, all cubicles have active safety features such as an arc fault protection. Worth mentioning, too, is the overall protection and control equipment. This is based on digital relay systems to allow easy integration of the substation into the sur-

Continued on page 12

Continued from page 11

rounding networks.

With all these advanced features, the PS-1 substation is well equipped to benefit from ABB's Industrial^{IT} initiative which has been developed to help companies achieve integrated, real-time solutions for automation and information across their enterprises. Seamless linking of substation automation, substation asset management and collaborative business systems in real time is the key to ensuring a more reliable and more efficient energy supply in the future.

'Start-to-finish' logistics

Everything about PS-1, from the definition of the project to final commissioning of the substation, has been optimized with that one ambitious goal in mind – 'to cut in half the typical delivery time for turnkey substations'. For example, the project specifications are reduced to a functional description of the station and clarification of external interfaces. The PS-1 configurator (a software tool) can be used to quickly collect functional parameters and convert them into a system layout — including the selection of suitable equipment and comprehensive documentation.

Planning is the next process to benefit: integration of the substation into the local network is limited to final adjustments, which are made simple by the standardized equipment interfaces.

Production, assembly and preliminary testing all proceed faster with PS-1. To save time on the actual site, important substation components are pre-assembled and have their functionality thoroughly checked before leaving our factories.

Pre-preparation of the equipment for site installation also has the advantage that it considerably shortens the time required for the civil works. The PS-1 components arrive on the site together and on time. Installation is completed much faster than with traditional projects. Commissioning, too, progresses faster as a result of the pre-testing of parts in our factories. Planning and supervision of the installation by the customer is also minimized thanks to the process optimization achieved with PS-1.

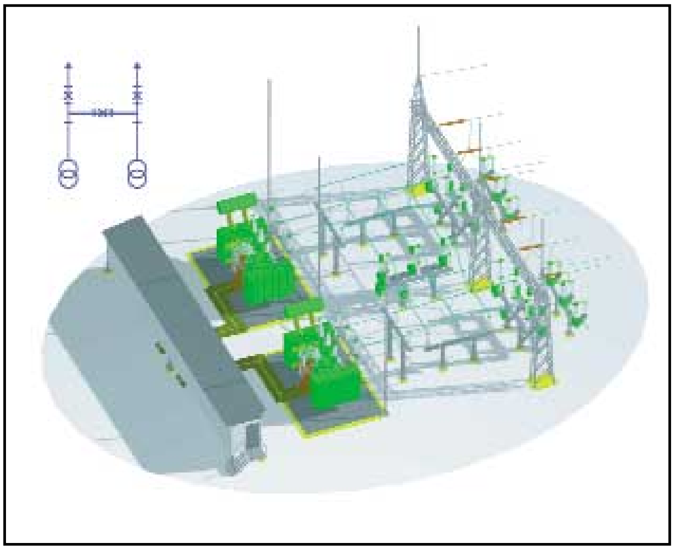


Figure 2: Example of a PS-1 substation layout (AIS solution). Configuration for a substation which feeds into a medium-voltage network and has to maintain a moderate level of load transfer between the connecting substations.

Success breeds success

With the PS-1, ABB offers network operators and industry in general a substation concept designed especially for today's market environment. PS-1 is the successful answer to market demand for innovative substation solutions that cut costs without compromising quality or reliability. The success of the concept is already turning into a market success.

These substations have been delivered to very different customers for various applications in many parts of the world. Utilities in Brazil, Romania and Sweden, for instance, have installed them in their subtransmission and distribution networks.

But not only utilities appreciate the benefits of PS-1: customers in industry whose strategic goal is to have their own network access are also choosing PS-1. For example, PS-1 substations are already supplying electrical energy to oil exploration facilities, a paper mill and a large car factory. Walgreens, the US drugstore retailer, has also chosen a PS-1 substation to supply the power for its new product distribution warehouse in Ohio. The substation will convert electricity at 115 kV to the required facility distribution voltage of 12.47 kV. More recently, an independent power producer in Germany has decided in favor of PS-1 to feed energy from its new wind farm into the network of the local utility.

All of these customers have chosen PS-1 not only to take advantage of the speed with which the substations can be constructed and energized, but also in recognition of the fact that it sets new standards for the future. And, just as importantly, PS-1 does this without compromises, providing the same functionality and guaranteeing the same high reliability as traditional substations.

Article reprinted from ABB Review, Number 1, 2002. **ET**

Transformer Winding Resistance Testing of Fundamental Importance

Winding resistance measurements in transformers are of fundamental importance for the following purposes:

- Calculations of the I^2R component of conductor losses.
- Calculation of winding temperature at the end of a temperature test cycle.
- As a base for assessing possible damage in the field.

Transformers are subject to vibration. Problems or faults occur due to poor design, assembly, handing, poor environments, overloading or poor maintenance. Measuring the resistance of the windings assures that the connections are correct and the resistance measurements indicates that there are no severe mismatches or opens. Many transformers have taps built into them. These taps allow ratio to be increased or decreased by fractions of a percent. Any of the ratio changes involve a mechanical movement of a contact from one position to another. These tap changes will also be checked during a winding resistance test.

Regardless of the configuration either wye or delta, the measurements are made phase to phase and comparisons are made to determine if the readings are comparable. If all readings are within one percent of each other, then they are acceptable. Keep in mind that the purpose of the test is to check for gross differences between the windings and for opens in the connections. The tests are not made to duplicate the readings of the manufactured device which was tested in the factory under controlled conditions and perhaps at other temperatures.

Transformer Characteristics

A transformer is considered a passive device capable of storing and delivering finite amounts of energy. Practically all transformers utilize magnetic material for shaping the magnetic fields which act as the medium for transferring energy. The relationship between the magnetic-field quantities and the electric circuits with which they interact plays an important part in describing the operation of the device. The magnetic material determines the size of the equipment, its capability, and introduces limitations because of saturation and loss on the performance.

Essentially, a transformer consists of two or more windings interlinked by a mutual magnetic field. These windings are simply coils of wires, inductors. Transformer characteristics can now be analyzed using some simple formulas.

The voltage across an inductor is proportional to the time rate of change of the current through it.

$$v = L \frac{di}{dt}$$

It should also be noted that an abrupt change in inductor current also requires an abrupt change in the energy stored in the inductor, and this sudden change in energy requires infinite power at that instant; infinite power is not part of the real world. The inductor current must not be allowed to jump instantaneously from one value to another. If an attempt is made to open-circuit a physical inductor through which a finite current is flowing, an arc will appear across the switch. This is useful in the ignition system of an automobile, but hardly an event to be witnessed during testing of the windings in the transformer.

The energy stored in an inductor with a circulating current can be represented by the formula:

$w(t) = 1/2\, I^2 L$ where,

$w(t)$ = Energy as a function of time

I = Current in amperes

L = Inductance in Henries

Before the desired current will flow (for testing purposes), this energy requirement must be met and implies that some time requirement will also be necessary before the measurement can be made. This time requirement applies only to the charging time. Additional time must be allowed to stabilize the current before a measurement can be made.

The ultimate time required to make a reading is limited by an inherent time lag between the application of a steady current and the time the magnetization of the core becomes stable. Depending on the size and the construction of the transformer, testing times could be very short for small transformers or very long for the larger, highly inductive transformers.

Continued on page 14

Continued from page 13

Testing Equipment

Prior to modern digital electronic equipment, the Kelvin Bridge was used. Batteries, switches, galvanometers, ammeters and slidewire adjustments were used to obtain resistance measurements. Current regulators were constructed and inserted between the battery and the bridge. Input voltage to the regulator of 12 volts dc from an automobile storage battery provided output currents variable in steps which matched the maximum current rating of the bridge on the ranges most used on transformers. The current regulator increased both speed and accuracy of the bridge readings. The approximate 11 volt availability was used to speed up the initial current buildup and tapered off to about 5 volts just before the selected current was reached and regulation started.

When the regulation began, the current was essentially constant in spite of the inductance of the windings and fluctuation of the battery voltage or lead resistance.

The testing times have been greatly reduced using modern microprocessor based test equipment. Direct readings are available from digital meters with automatic indications telling when a good measurement is available. On some testers, two meters are available allowing two resistance measurements at the same time.

Caution: Because of the enormous amount of energy that can be stored in a magnetic field, precautions should be taken before disconnecting the test leads from the transformer that is under test. Never remove the leads during the testing process and always allow for enough time to completely discharge the transformer being tested. Large transformers can require several minutes to discharge.

Most newer winding resistance testers today have indicators telling when it is safe to remove the leads.

Principles of Operation

The basic idea is to inject a DC current through the winding to be measured, and then read the voltage drop across that winding.

Electrical testing instruments apply the dc current through the winding and an internal standard current shunt. After both DC voltage drops are measured they are ratioed and the display is read as resistance on the front panel meter. This method allows for the lead resistance to be omitted since the reading is independent of the current. In addition, no multiplication factors will be needed when changing current ranges.

The DC current source must be extremely stable. Refer to formula for DC voltage across a transformer below:

$$v = I * R + (L\, di/dt)$$

where,

v_{dc} = voltage across transformer winding
I = DC current through transformer winding
R = resistance of the transformer winding
L = inductance of the transformer winding
di/dt = changing value of current (ripple)

Assume that the tester has a very stable current source (i.e., no ripple), then di/dt is zero and the term L di/dt becomes zero.

Tap Changers

Tap changers are divided into two types: On-load and Off-load. The on-load tap changer allows section of ratio change while the transformer is in service. This would mean the ratio of a transformer can be changed while power is still passing through it. The most common example of this type of on-load tap changer is a Voltage Regulator.

On-Load Tap Changer

The Adwel International Ltd. (ETI) Model WRT-100 resistance tester is ideally suited to test on-load tap changers because the instrument can be left on while changing from tap to tap. This allows the operator to take measurements very quickly without discharging, then re-charging the transformer for every tap. The winding resistance tester will rebalance after every tap change.

If the tap is defective (open) or if there is even a fraction of time when the circuit is open, the winding resistance tester will automatically go into its discharge cycle. This gives the operator a clear indication by a panel light of a possible fault within the tap changer. For this open condition, no damage will be done to the transformer by the test set.

Off-Load Tap Changer

This style tap changer requires that the tap changer must be discharged between tap changes. In order to change taps, the transformer has to be taken out of service or at least disconnected from the load. This type of tap changer may typically go bad faster than an on-load because of inadvertent changing of the taps while still in service.

The resistance tester will still work on this changer but it must be discharged between tap changes.

Safety

Although some items of inspection may be accomplished without de-energizing the transformer, the winding resistance measurement is not one of them. To provide maximum safety to the worker, both the high-voltage and low-voltage leads should be disconnected from the transformer. Preferably, there should be a visible break between the transformer terminals and the high- and low-voltage lines.

Conclusion

Transformers are very reliable devices and can provide service for a long time if maintained and serviced regularly. Transformer failures, when they occur, are usually of a very serious nature, which may require costly repairs and long downtime. The best insurance against transformer failure is to ensure that they are properly installed and maintained.

Make sure that the winding resistance test is included when a transformer is tested. Modern self-contained instruments make testing easy and accurate.

Keep good records on the values of resistance found and compare them with previous readings for deviations.

From Adwel International Ltd. For more information visit www.adwel.com. **ET**

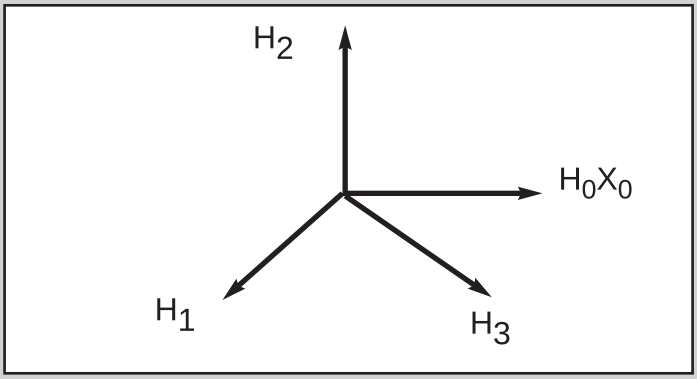
Case History: Overheated Joints

This case history involves a 17.9/22.4 MVA – 34.5 – 13.8 kV autotransformer with all aluminum windings.

Unfit for Service

Abnormal D.C. resistance measurements were obtained between high voltage terminals during routine maintenance testing. All other routine test results were normal.

This utility checks D.C. resistance as a routine maintenance test on all transformers with tap changers to determine if contact problems exist.



Dara Collection

The following measurements were recorded:

Terminals	D.C. Resistance
$H_1 - H_2$	0.142
$H_2 - H_3$	0.153
$H_3 - H_1$	0.153
$H_1 - H_0X_0$	0.072
$H_2 - H_0X_0$	0.072
$H_3 - H_0X_0$	0.084

Similar measurements were recorded on all tap changer positions. All tap changer contacts were inspected and found to be in good condition. It was then determined that a bad connection in the H_3 winding was the problem.

The transformer manufacturer was consulted to determine possible locations for the bad connection. The manufacturer sent an Internal Assembly drawing for the specific transformer and indicated which connections to check.

A defective crimped joint was found at the connection of the H_3 winding neutral-to-neutral bus lead. The joint had overheated to the extent that the conductors and connector fell apart when the insulating tape was removed.

Analysis

The electrical tests indicated that the H_3 winding had a high resistance connection. This was confirmed by the internal inspection.

Repairs were done. The damaged conductors were removed and new conductor spliced in place to remake the connection. The conductors were reinsulated with paper tape.

The following measurements were recorded:

Terminals	D.C. Resistance
$H_1 - H_2$	0.1410
$H_2 - H_3$	0.1406
$H_3 - H_1$	0.1433
$H_1 - H_0X_0$	0.0714
$H_2 - H_0X_0$	0.0712
$H_3 - H_0X_0$	0.0716

The transformer was cleaned, refilled, retested and returned to service.

Case History Source: IEEE C57.125-1991.

TRANSFORMER AND SUBSTATION REPORT

Using Gas-in-Oil Standards to Improve Accuracy of Dissolved Gas Analysis Results and Diagnoses

By M. Duval

Dissolved gas analysis (DGA) is widely used to monitor the condition of transformers and other pieces of oil-filled equipment in service. Wrong diagnoses may be drawn, however, if the DGA results coming from the lab are not accurate. For instance, an electrical fault may be mistaken as a thermal fault, which may have serious consequences for the equipment. Several CIGRE and IEC round robin tests (RRTs) have shown that the repeatability (precision) of DGA labs is generally good, but that their accuracy (deviation from true value) is often poor.

The only way to reliably determine accuracy is to run gas-in-oil standards. The procedure for preparing gas-in-oil standards consists in dissolving known amounts of gases in degassed oil [1]. This procedure has been incorporated in IEC and ASTM Standards [2,3]. The most recent RRTs organized by CIGRE using gas-in-oil standards are summarized in [4] and in a more complete form on the CIGRE website (www.cigre.org). The results obtained from these RRTs indicate an average accuracy of ± 15 per cent at medium gas concentration levels (10-100 ppm), for the 25 international participating laboratories. The corresponding (intra-laboratory) repeatability of participating labs was ± 7 per cent on average at these gas levels. A typical example of CIGRE-RRT results using DGA gas-in-oil standards is indicated in Table 1. Only gas extraction methods used in North America are indicated in this Table. Head space and Partial Degassing methods correspond to Methods C and A of ASTM D3612-01, respectively. The Shake Test method is described in [5].

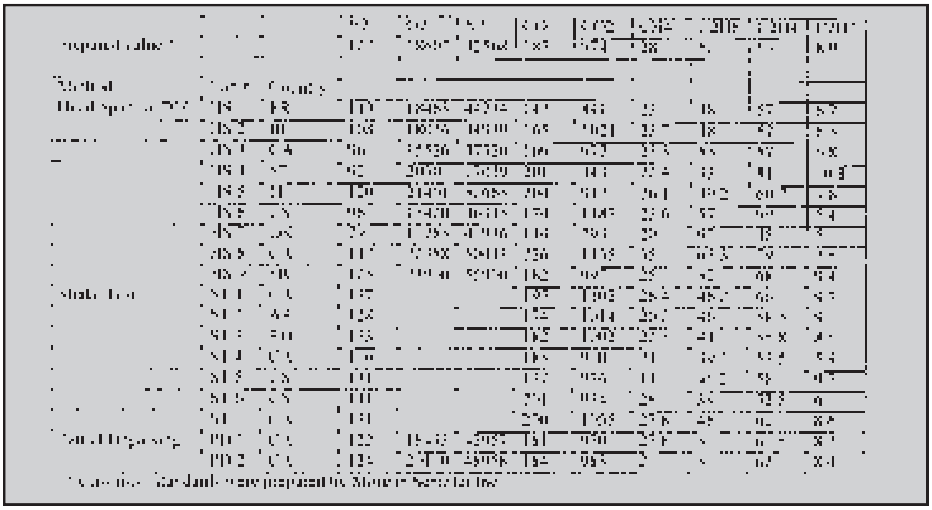


Table 1: typical CIGRE-RRT results (inppm)

Figure 1: Evolution of gas content of a commercial gas-in-oil standard with time (only C2H4 indicated here as an example)

Some laboratories are, of course, more accurate than average and others worse, as is well known in the industry. Laboratories which did not participate in the RRTs can determine their own accuracy, and eventually work to improve it, by running gas-in-oil standards. For most routine labs, however, preparing gas-in-oil standards is time-consuming and costly, and requires highly skilled personnel dedicated to this preparation.

Fortunately, gas-in-oil standards for DGA are now available commercially from Morgan Schaffer Inc. in Montreal, Canada [6]. These gas-in-oil standards are prepared following the specifications and basic concepts of ASTM and IEC Standards and contain certified amounts of dissolved gases. They have been recognized and used successfully during several CIGRE and IEC-RRTs.

These commercial DGA oil standards are currently provided in glass syringes of 30 ml. The shelf life of batches of gas-in-oil standards has been tested thoroughly and no significant changes in gas concentrations were observed over a period of several months. Figure 1, for example, indicates the DGA analyses performed over a six month period on a batch of gas-in-oil standards containing a prepared value of C_2H_4 of 97 ppm. The small, oscillating variations in gas content are related to the intra-lab reproducability of DGA analyses on the batch of oil standards over this long period of time. Similar results are observed for the other DGA gases.

Gas-in-oil standards are most useful for laboratories to determine the accuracy of their DGA results, and to improve it by detecting their hard-to-find biases. Accuracy should be checked each time a significant lab condition has changed (new operator, new equipment or a major piece of equipment like a gas extractor) and ideally at regular, frequent intervals. When outsourcing DGA analyses, gas-in-oil standards can also be used to verify if accuracy specifications are met by suppliers. This will ensure more accurate and reliable DGA and diagnoses.

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[1] M.Duval and Y.Giguere, Doble Conferences, 10C-01 (1984).

[2]. IEC Publication 60567, Clause 6.2 (1992).

[3]. ASTM Method D 3612-01, Annex A2 (2001).

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[5]. R.Berube, Electricity Today, 8 (7), p.21 (1996].

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M.Duval is with IREQ, Varennes, Canada ET

ELECTRICITY INDUSTRY RESTRUCTURING

Financial Derivatives in Ontario's New Electricity Marketplace

By Ron W. Clark

The Ontario electricity market opened on May 1, 2002. While it is possible to participate directly in the physical electricity market (which entails registration with Ontario's Independent Electricity Market Operator ("IMO")) many parties negotiate privately to enter into financial derivative contracts, such as swaps or contracts for differences that have the effect of reducing or eliminating price volatility for the parties. Derivatives arrangements are usually associated with the wholesale electricity markets. This article examines the forms of agreement that are commonly used by parties entering into financial arrangements to fix the price of wholesale electricity in the Ontario market.

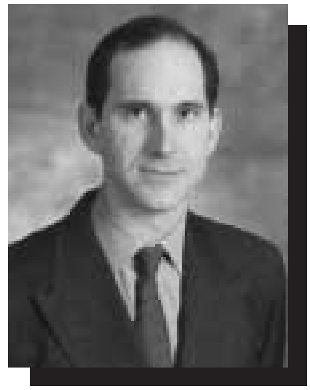
Swaps

Swaps (or "contracts for differences") are individually negotiated transactions in which each counterparty to the swap agrees to exchange periodic cash flows based on differences over time in the state of one or more specified underlying reference price. In the case of swaps in the Ontario electricity market, the reference price is the IMO's Hourly Ontario Electricity Price. A swap agreement is conceptually the same as a series of forward contracts, the primary difference between the two products being that a swap features less credit risk because there are more frequent settlements of cash flows between the parties during the life of the agreement.

Hedging Electricity Prices

A hedger in the Ontario electricity market is a party, such as a wholesaler or retailer of electricity, who desires to reduce or eliminate risks associated with changes to the spot price of electricity in Ontario.

For example, a retailer will enter into a fixed price contract with a customer. The price risk associated with this contract can be off-loaded by entering into a wholesale swap arrangement with an electricity wholesaler that fixes the price that the retailer will pay for electricity. The retailer thus makes money only on the spread between the price the retail customer pays for a given quantity of electricity and the price it "pays" (or at least has fixed for itself) to the wholesaler. The actual mechanics of the wholesale relationship are different than those at the retail level; if the spot market price drops during a particular period with reference to a certain quantity of electricity, the retailer pays the wholesaler the difference between the fixed price and the floating price. If the spot market price rises, the wholesaler pays the retailer the difference.


Ron W. Clark

However, often the quantities arranged in the wholesale market may not match those sold at the retail level. Thus, while price risk may be eliminated, a retailer may still be subject to volume risk for a particular quantity of electricity. Speculators, on the other hand, may take a position in the financial markets and make money by taking a view on whether electricity prices will rise or fall. In the process, speculators assume the risk that hedgers are trying to avoid.

Forms

Ontario wholesale electricity arrangements that are purely financial can be referred to as over-the-counter ("OTC") transactions. Many OTC derivative contracts that fix the price of electricity use the International Swaps and Derivatives Association ("ISDA") form of contract. Even where the ISDA form is not used, the concepts used in the ISDA form still appear in the contract. The ISDA contract consists of a master agreement, a schedule and a confirmation for the various transactions.

Changes to the master agreement, elected options, and additional provisions are all contained within the schedule to

Continued on page 18

Continued from page 17

the master agreement. The current ISDA form is the 1992 Master Agreement. For Canadian purposes there are two master agreement forms; namely, the multicurrency-cross border and the local single currency form. While the local single currency form is somewhat simpler, the multicurrency-cross border version is generally used for Canadian transactions.

The ISDA master agreement features the following provisions; general conditions relating to the various transactions; withholding tax provision; provision for default interest; representations by both parties; specifications of the events of default and termination; calculation of damages; assignment provisions; currency provisions; allocation and expenses; governing law; notification addresses and miscellaneous interpretation provision

Netting and Set-off

The master agreement provides that when, in respect of the same transaction and the same currency, both parties owe each other money, then the person owing the higher amount pays the other the difference. If the parties desire to net amounts in respect of more than one transaction, then they need to so specify in the schedule or in a specific confirmation.

Netting is distinguished from setting-off. Setting-off is generally contemplated in a default situation and is affected against amounts payable under other contracts. Such contracts may include only those between the two parties, or those between the two parties and any of their affiliates.

Taxes

If a Canadian party enters into an ISDA master agreement with a foreign counterparty, the Canadian party may be faced with tax withholding obligations in respect of interest. Since derivative instruments are priced without consideration of taxes, the ISDA master agreement contains a mechanism by which the applicable party must gross-up its payments to put the counterparty in the same position as if there was no tax withheld.

Events of Default and Termination

Section 5 of the ISDA master agreement specifies certain default and termination events, while section 6 deals with the parties' rights and remedies in the event of early termination. Much of the schedule is dedicated to options and clarifications relating to these two sections, and the schedule can also be amended to customize these terms. Significant time and effort will likely be spent by each party ensuring that it is satisfied with the credit worthiness of the other party to the transaction. Credit risk may be sufficiently reduced through a parental guarantee or other credit support device.

The ISDA master agreement allows the parties to identify specific entities and transactions where a default will be deemed to be a default of the agreement as a whole. Such specified transactions or parties would likely be those with which the counterparty has dealt, or parties who have provided credit support. Events of default in the agreement include normal and expected events of default such as: the failure to pay or deliver when required pursuant to a transaction; any other breach of the agreement; a failure in a credit support document; a misrepresentation; a bankruptcy or other insolvency event; or a merger that obstructs any one of the merged party's obligations, including credit support obligations.

> ...A retailer will enter into a fixed price contract with a customer. The price risk associated with this contract can be off-loaded by entering into a wholesale swap arrangement with an electricity wholesaler that fixes the price that the retailer will pay for electricity. The retailer thus makes money only on the spread between the price the retail customer pays it for a given quantity of electricity and the price it "pays" (or at least has fixed for itself) to the wholesaler. The actual mechanics of the wholesale relationship are different then those at the retail level; if the spot market price drops during a particular period with reference to a certain quantity of electricity, the retailer pays the wholesaler the difference in between the fixed price and the floating price. If the spot market price rises, the wholesaler pays the retailer the difference.

The parties can also choose to include a cross-default provision. The cross-default provision must be elected in the schedule to be effective. This provision merely specifies a cross-default as between the parties to the contract if any default occurs in respect of borrowed money, provided that the amount of the borrowed money is in excess of a threshold amount. The threshold amount is negotiated and then specified in the schedule as either a dollar amount, or a percentage of a party's equity.

In addition to "events of default", there are "termination events", which trigger different remedies. Termination events are essentially "no fault" events that include the following: illegality (i.e., where a law changes, rendering any transaction unlawful or preventing a credit supporter from performing its obligation); a tax event which results in a gross-up amount having to be paid or a new withholding tax to be withheld (as mentioned earlier in this article); and a tax event which arises upon the merger of either of the parties. In addition, if so elected by the parties to the agreement, a merger of a credit support provider can be treated by the other party as a termination event if the creditworthiness of the resulting entity is materially weakened by the merger. The parties are also free to specify additional termination events in the schedule.

Remedies

In the event that only one party is affected by a termination event, the unaffected party must calculate its resulting losses or gains on the basis of either (1) market quotes, if that method was elected and is feasible, or (2) the loss of bargain or cost to replace the unaffected transaction, adjusted for any amounts owing by one party to the other.

If the termination arose as the result of an event of default, the applicable remedy will depend on the elections of the party as set forth in the schedule to the master agreement. The parties can elect that the "first method" or the "second method" will apply and that either the "loss" method or the "market quotation" method will apply. The "loss" method requires the non-defaulting party to calculate its losses and costs (or gain, in the event of a negative loss) resulting from termination of the transactions which includes "any loss of bargain, cost of funding or, at the election of such party both without duplication, loss or cost incurred as a result of its terminating, liquidating, obtaining or re-establishing any hedge or elating trading position (or gain resulting from any of them)". The "market quotation" method requires the non-defaulting party to obtain a market quote for the terminated transaction if one is available, and to calculate the loss if a market quote is not available for the terminated transaction.

The “second method” requires the non-defaulting party to pay to the defaulting party any gain it might achieve as a result of the early termination, contrary to the “first method”, which does not require such gain to be disgorged. Unless the parties specify otherwise, the “market quotation” and the “second method” apply by default. Any resulting amount payable by one party to the other is subject to any set-off that is specified in the schedule or otherwise permitted by law.

Confirmations

The master agreement provides that confirmation in respect of each transaction may be made orally, by fax, or by exchange of electronic messages on an electronic messaging system. Many parties amend this provision because enforcing or approving a transaction that has only been agreed to by a telephone call between the traders may be difficult for evidentiary reasons, particularly because of the Statute of Frauds which requires that an agreement over a term of one year be in writing.

Parties may also provide that a confirmation supplied by one side may become binding if the other side takes no action within a certain period of time. Or, the preference may be that the transaction lapses if the confirmation is not responded to.

Locational Marginal Pricing

For the first 18 months after May 1, 2002, the Hourly Ontario Electricity Price or HOEP will be a uniform market-clearing price within Ontario calculated on a congestion-free basis. Settlements for generators and consumers will be based on metered energy. During this initial 18-month period, the IMO will collect and publish locational pricing data to determine the extent of congestion in the Ontario market and will recommend whether to move to some form of congestion pricing after this initial period. This change could result in locational marginal pricing, in which individual market clearing prices would be established for various locations in Ontario. Because wholesale electricity arrangements generally refer to the HOEP as the reference price, they must account for the possibility that HOEP will be replaced by differential pricing at different locations in Ontario.

Credit Support

The ISDA Credit Support Annex is a standard form document that provides for credit support between parties to the ISDA master agreement. The Annex provides for the levels at which calls may be made for specified security. Such security may not be required so long as, for example, the contracting party or its “credit support provider” (usually a corporate parent) has a specified credit rating. The credit support provider may be bound to support the credit of the contracting party by guarantee.

The Annex provides that failure to post the agreed to collateral will constitute an event of default. The Annex also sets out certain rights and remedies with regard to posted security and contains representations and warranties relating to the security.

Just as the master agreement is a form to which changes can be made in a schedule, the Annex is a form containing 12 sections, referred to as “paragraphs”. Changes to and customization of the

Continued on page 20

Continued from page 19

Annex can be made in "Paragraph 13", which is a separate document in which parties can fill in blanks and alter wording. The parties can specify, for example, acceptable types of security, e.g. cash, letter of credit, etc., valuation and timing issues, conditions precedent and other specific items.

Ontario personal property security law imposes certain non-waivable obligations on a secured party with respect to collateral in its possession. These provisions may conflict with certain contractual provisions in the Annex that allow the secured party to deal with the collateral freely. Specific provisions should be added in the case of an Ontario secured party to deal with this issue.

Choice of Law and Choice of Forum

Where the wholesaler and the retailer are both Ontario corporations, they will naturally choose Ontario law to govern their contracts and will choose Ontario as the forum in which to litigate their disputes.

However, where the wholesaler is, for example, a Delaware corporation operating in Michigan, and its guarantor is located in New York, the situation is less clear cut. The parties may have to negotiate which law will apply and where any disputes may be tried. Furthermore, the law or forum chosen for the contracting parties may be different from those applicable to the guarantees.

Market Disruption Events and Disruption Fallbacks

Standard ISDA Definitions (including the 2000 ISDA Definitions, the 1993 ISDA Commodity Derivatives Definitions, and their respective supplements) may be used to provide for alternative approaches in the event that the HOEP or other agreed to reference price is unavailable. These include postponement until a reference price is once again available, prices offered by alternative internationally recognized dealers, or a negotiated fallback price. Parties may choose one or a combination of these alternatives. However, in the context of the Ontario electricity market, parties may also wish to make reference to the IMO-determined administrative pricing provisions contained in the IMO's market rules.

Conclusion

Financial derivatives in the form of the ISDA master agreement and associated documents are somewhat complex to practitioners not familiar with them. However, they provide a standardized yet flexible instrument for wholesale counterparties to allocate risks associated with the price of electricity in the Ontario market.

Although many of these provisions are still the subject of intense negotiation, it is expected that, as the market matures, they will become more standardized and the costs, time and effort necessary to negotiate these types of transactions will be reduced.

Ron W. Clark is a lawyer in the corporate/commercial and energy practice areas of Power Budd LLP in association with CMS Cameron McKenna in Toronto, Canada.

Ron advises numerous electric utilities, retailers, corporations and municipalities, domestically and internationally, on corporate and regulatory issues relating to the electricity industry. **ET**

Multi-Use "AirStair" Improves Line Crew Productivity Significantly

Hydro One (a successor company of Ontario Hydro) is one of the largest transmission and distribution companies in North America with about 17,500 miles of transmission lines and 72,000 miles of distribution lines throughout the province of Ontario. The transmission lines are supported by various types of steel and wood structures and cross terrain ranging from farmland to extremely rugged territory often in remote or environmentally sensitive areas.

For more than 50 years, Hydro One (and its predecessor Ontario Hydro) utilized its own fleet of helicopters to maintain and provide access to these corridors for all sorts of work applications. In the early 1960's, the company had two Sikorsky S-58T helicopters which were used to hoist powerline maintainers onto the structures for large maintenance projects. This helped reduce the need for corridor access roads and increased the efficiency of the crews. In the late 1980's, these two helicopters were replaced with a single AS 332 Super Puma which performed the same functions. But, in the mid 1990's, the helicopter was sold.

Realizing a continuing need to be able to maximize staff productivity and access structures efficiently in hard-to-reach locations, one of the veteran pilots, John Bosomworth, conceived a design which could be used on the remaining fleet of helicopters for line maintenance work.

The concept was named 'AirStair' and is attached to a Eurocopter AS 350B2, AStar helicopter.

This multi use design can be utilized as a delivery and pick up device for transporting powerline maintainers as well as some limited work station applications. With a small crew, productivity improvements with the AirStair have proven to be significant. There is no need for ground travel from one structure to the other; climb up the structure, perform the work, then climb down. This eliminates fatigue on line maintainers and the necessity to belt and unbelt numerous times while climbing.

The concept was named 'AirStair' and was attached to a Eurocopter AS 350B2, AStar helicopter.

With a small crew, productivity improvements with the AirStair have proven to be significant. There is no need for ground travel from one structure to the other, climb up the structure, perform the work, then climb down (Photo: Graeme Oxby/www.goxby.com)

The device was structurally engineered by an aircraft engineering company and has stringent weight limitations and weather conditions must be strictly adhered to. The company has a very strict, in-depth training program for pilots and linemaintainers on use of the AirStair. The training program — which includes detailed documentation of the procedure along with the use of specialty tools which were designed specifically for the 'AirStair' — must be completed by both pilots and line maintainers. This

Continued on page 22

Continued from page 21

makes everyone's role easier to accomplish, with the highest level of safety.

"In my experience, having worked on transmission poles and towers, I enjoy the 'AirStair' as it eliminates the fatigue from climbing," explained Derrick Brydges, a Hydro One powerline maintainer who worked with Bosomworth in the development of the equipment. "You are delivered right to your work location. Other applications, such as climbing inspections, one only has to climb from the top down."

Late in 2001 there was a need identified to install marking devices on the skywire of a multi-circuit transmission line in Burlington adjacent to Lake Ontario. This line is located in the flight path of the Trumpeter Swan, an endangered species nearing extinction in Ontario. A few of the birds had struck the nearly invisible skywire, and were injured or killed after falling to the beach below. The conventional method of installing these markers would have been very time consuming and extremely costly.

Late in 2001 there was a need identified to install marking devices on the skywire of a multi circuit transmission line in Burlington adjacent to Lake Ontario. The conventional method of installing these markers would have been very time-consuming and extremely costly. As a result, the Helicopter section agreed to perform the task with the 'AirStair'.

As a result the Helicopter section agreed to perform the task with the 'AirStair'. The bird diverters were successfully installed in a very short timeframe at a much reduced cost.

Since this spring, the 'AirStair' has been utilized on two skywire replacement jobs — a 115 KV on H-Frame double wood pole structures with the circuit alive and, more recently, on a 115 KV double circuit steel tower structures. Both jobs were completed on schedule with positive feedback from both crew and supervisors.

Hydro One continues to look at other applications for the 'AirStair'.

See ad on page 11.

Is Ontario's Electricity Market Working?

By Jonathan Dickman-Wilkes

Ontario's wholesale electricity market has been open to competition for three months and the lights are still on. So, it's working. But is it working well? How do we know? Most consumers who have checked market energy prices posted by the Ontario's Independent Market Operator (IMO) (www.theimo.com), as shown in Figures 1 and 2 probably feel the market is operating well, because prices have on average, been relatively soft.

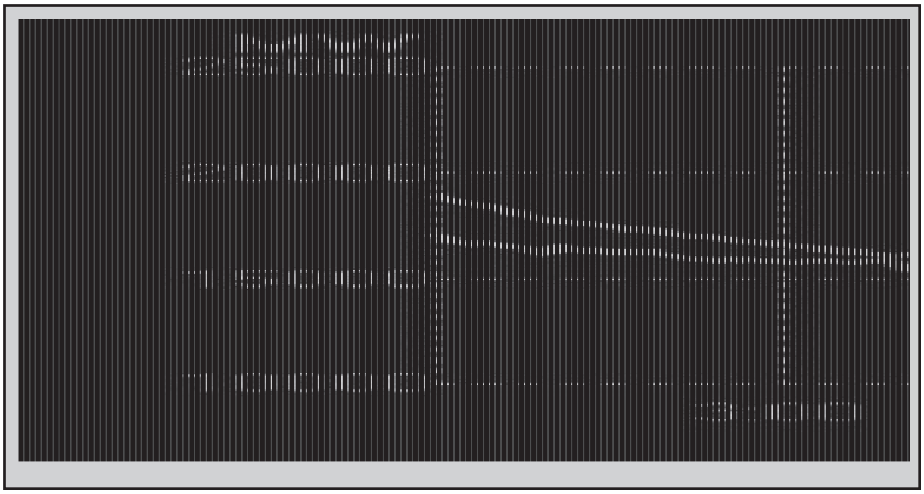


Figure 1: IMO Ontario Daily System Dispatch and Pre-Dispatch Demand

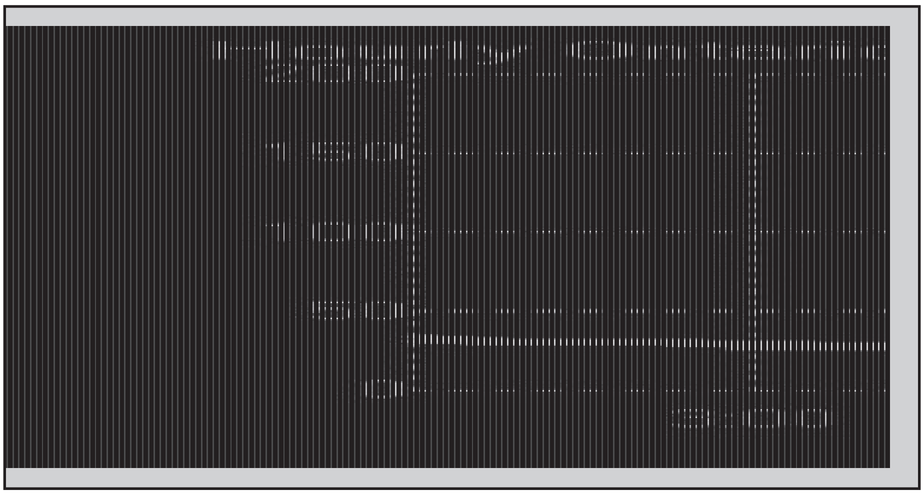


Figure 2: IMO Ontario Daily Dispatch and Pre-Dispatch HOEP

SIGNS OF MARKET PERFORMANCE [1]

Given the characteristics of wholesale electricity markets in general and the unique structure of Ontario's market in particular, standard economic tests to evaluate the performance of markets may be unreliable. However, there are measures that can be applied to electricity markets as indicators of market performance. Here we will examine three of these: apparent bidding behaviour, price differentials between Ontario and its competitive interconnected markets, and timing and volumes of imports and exports across the interconnections.

Bidding Behaviour

In an ideal, fully competitive electricity market with 1) an abundance of capacity, 2) many suppliers, 3) open transmission access, and 4) an uncongested transmission system, baseload generators would offer energy at their incremental cost of production. In a competitive market, generators will assume that they will not be setting the market-clearing price that is paid to all suppliers. To bid more than their incremental cost of production reduces the chance that the baseload generator will be dispatched, but would not be expected to increase the dispatch price. Generators with peaking resources, on the other hand, will be likely to mark up their marginal cost based bids to ensure that they are able to cover their fixed costs over the limited number of hours that they run. Hydro-electric generators with storage capacity have a more complex decision. At any point in time, their offer would need to reflect the future value of the energy stored in the reservoir — they can use it now (if their bid is accepted) or use it later when prices might be higher — and their expectations of additional flow into their reservoir.

Given a good understanding of the Ontario supply stack (each generating unit's size and marginal cost), the planned outage schedule (which units will not be available and when), and monitoring other dynamic variables such as forced outages and hydroelectric storage levels and expected rainfall, one can attempt to 'predict' the market clearing price for any given system demand. This market-clearing price is simply the point of intersection between the supply and demand curves. A comparison of this predicted market-clearing price can then be made with actual demand-price pairs experienced in the marketplace. Demand-price pairs for each hour from May 1 to July 23 relative to our illustrative supply stack are shown in Figure 3.[2]

Based on our market analysis, it appears that actual prices have closely tracked the expected marginal costs of generation for demand levels up to approximately 18,000 MW (these are primarily off-peak hours). This suggests that generators have been offering energy at prices quite close to their marginal costs, an indication that the market is perform-

Continued on page 24

Continued from page 23

ing as one would expect under workable competition. When market demand exceeds 18,000 MW or so, the price-demand pairs exhibit much lower correlation with our predicted supply curve. This can be attributed to the storage hydroelectric generation offer strategies that are priced on the basis of opportunity costs and are likely to be reflective of prices in interconnected markets. In addition, at these higher demand levels forced outages of generators can result in sudden increases in the need for available generation. This can produce dramatically higher market prices for short time intervals and results from generator ramping rate restrictions and the relatively short time interval over which dispatch is optimized. Therefore, when there is a shortfall in generation as a result of an unscheduled generator outage or higher demand than forecast, significantly higher cost generation must be called on to provide energy while lower cost resources are ramping up.

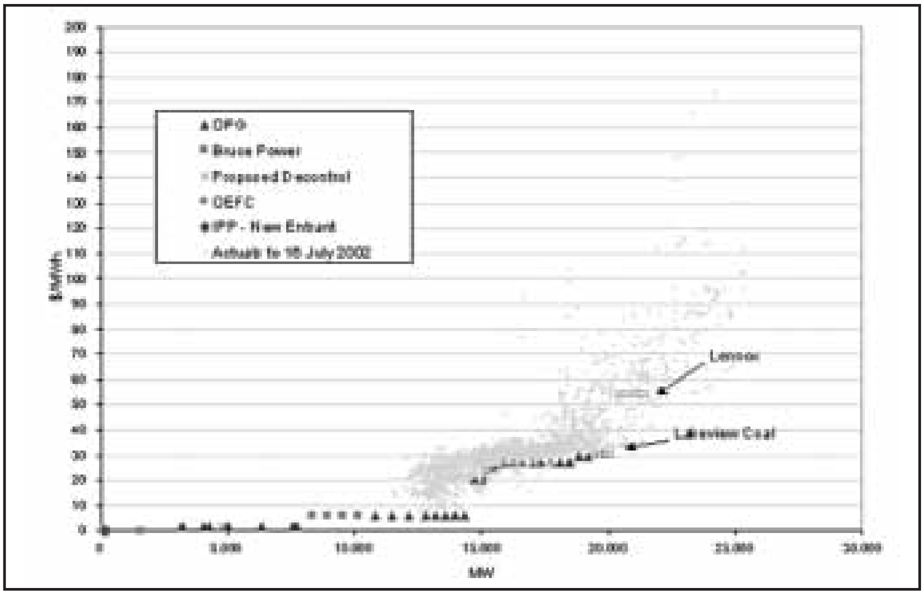


Figure 3: Ontario Demand-Price Pairs, May 1 to July 16

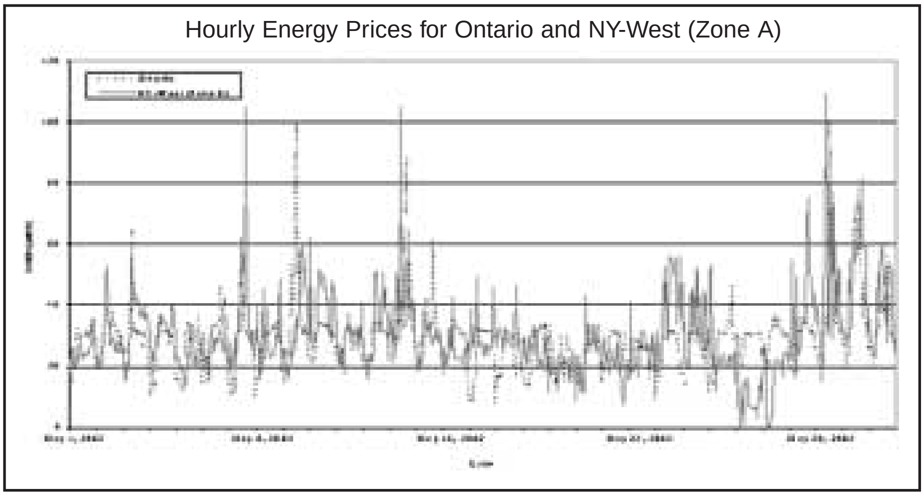


Figure 4: Ontario Demand-Price Pairs, May 1 to July 23

Influence of Interconnected Markets

Two additional indicators one can use to test a market's functionality are: the relationship between the local market price and prices in interconnected markets, and power flows across interties in relation to the prices. In an 'ideal' regional electricity market with unlimited transfer capabilities between regions, there would be one price throughout the market. This is in fact how economists define markets, i.e., based on the absence or presence of significant price differentials. In reality however, there are always some physical limits to the transmission capacity between regions and, to the degree that these constraints are significant, they are likely to define the market. Although Ontario is physically connected to Minnesota, Manitoba, Michigan, and Quebec, we look to the New York ISO, because it is the most transparent of Ontario's interconnected markets and a market with which Ontario has significant transfer capability such that price differentials should be minimized. Ontario is connected to New York at two locations. The larger is at Niagara Falls which connects Ontario with the New York West or NY Zone-A market. This interconnect has an export capacity of approximately 2100 MW (to New York) and an import capacity of approximately 1500 MW (into Ontario). The other interconnection with New York is near Cornwall, but the capacity of this interconnect is only 400 MW. Figure 4 shows the Ontario and New York West hourly energy prices for the period from May 1 to July 23. For most hours, the Ontario hourly energy price (HOEP) closely tracks that in New York West. During price excursions (spikes), differentials are seen for various reasons including the inability to change import and export schedules within the hour and the fact that these price excursions are often the result of unplanned generator outages and thus are short-lived, i.e., until additional low-cost generating capacity can be scheduled to fill the deficit.

Initially, interties were developed primarily for system reliability purposes. In competitive markets, interties continue to play an important role in system reliability, but serve another important purpose. Interties allow trading between markets, which enables traders within interconnected markets to arbitrage price differentials. With sufficient transmission and flexible market rules, the net effect is that the lowest cost generation is available to serve load in these markets. One would expect that in a workably competitive market, New York would be importing power when the prices in New York are higher than those in Ontario, and vice versa. Figure 5 shows pricing differentials and transmission flows between Ontario and New York West for May.

Because the power flows shown in the figure include flows to and from New York Zone A and Zone D (the IMO doesn't publish data for transmission flows from New York Zone A and Zone D separately), the results shown in Figure 5 are more difficult to interpret. Overall, however, the chart suggests that power generally flows from New York to Ontario whenever the Ontario price is lower than the New York price and vice versa, as one would expect in an effective regional market.

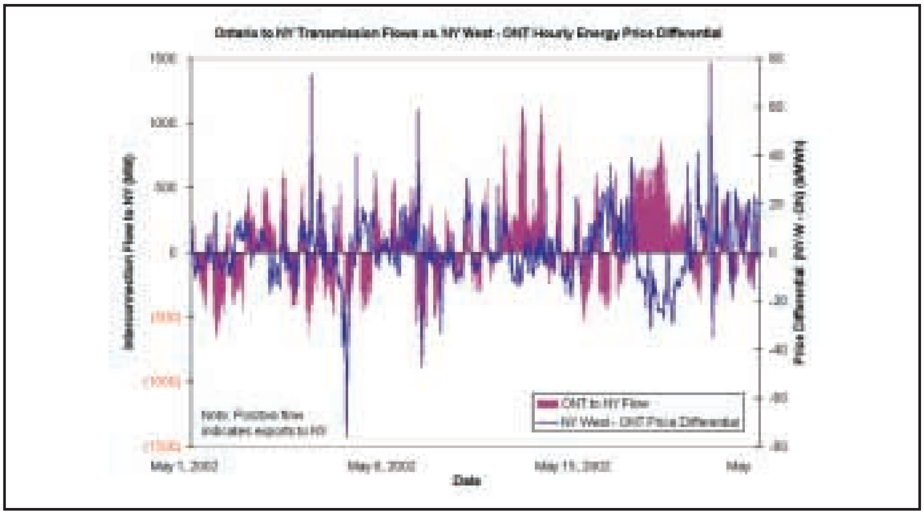


Figure 5: May 2002 Ontario-New York West Transmission Flows

Market Issues

Probably the most contentious market design issue that has arisen thus far is from the market rule pertaining to intertie transactions.

Once import offers are accepted by the IMO based on a similar offer process as is used for internal Ontario generation ,the quantity and minimum price of these imports are set and remain constant for the hour. This is because intertie schedules cannot change within the hour. This is called the import offer guarantee (IOG). Simply, if the IMO expects that imported energy will be required to meet Ontario demand for the next hour, the importer is guaranteed of being paid at least his offer price regardless of what actually happens during the hour. Thus, importers are guaranteed their accepted offer for the full hour, even if demand drops off or increased amounts of supply are available at lower offer prices and as a result their energy is not needed. In contrast, Ontario-based generators must offer energy into the five-minute energy market [3] and the IMO can respond dynamically to their offers based on actual system demand and supply.

In a simplified example of how this rule would work, if the IMO needs 25,000 MW of supply to meet demand on a hot day and Ontario-based generation can supply 23,000 MW, the IMO would need to import 2,000 MW from outside Ontario. If the offer for this imported power is higher than the most expensive power from among the various Ontario-based generators comprising the 23,000 MW of 'native supply', the IMO would set the five-minute price based on the most expensive of the Ontario offers, not on the 2,000 MW of imports needed to match demand. The IMO would still have to pay for the 2,000 MW of imports, but the cost of this power would not be reflected in the market-clearing price.

The cost of any imported power, subject these rules, is borne by all consumers through the IMO uplift charges, not through spot prices. Although uplift charges have typically been in the range of \$1-\$5/MWh, during periods of high demand, hourly uplift charges have

Continued on page 26

Continued from page 25

exceeded $100/MWh, largely as a result of these two rules. What is important to bear in mind is that during these infrequent periods when uplift charges are high, market-clearing prices could have been much higher in the absence of these market rules.

From a consumer perspective, these rules have helped to dampen the volatility of spot prices. From an Ontario generator's perspective, these rules have reduced revenues and could ultimately deter new generators from entering the Ontario market.

Lower price volatility and less extreme price spikes should be good news for most consumers. However, consumers that locked into a fixed price contract in an effort to mitigate their price risk may be disappointed to learn that they are still exposed to volatility in uplift charges, which (to our knowledge) are not covered in any electricity contracts. Thus, while these market rules dampen spot price volatility, they create new risks which suppliers have not yet been able to offer consumers protection from. It is probably only a matter of time before someone offers 'uplift charge' guarantees.

Summary

The Ontario electricity market, although just three months old, appears to be working reasonably well. Prices in many hours have been closely related to the underlying marginal costs of generation, prices in Ontario and New York have tracked well most of the time, and power flows between New York and Ontario are generally responding to any price differentials between the markets.

The primary market performance issues appear to be related to market rules and how imports are integrated into the market. Changes to these rules could have a significant impact on the volatility of spot prices, particularly during periods of high demand, as well as on the relative attractiveness of the Ontario market for new generators.

References

[1] In economics parlance, workable competition is used to characterize a market that is less than perfectly competitive. This review does not offer an opinion on the competitiveness of the Ontario wholesale power market.

[2] This supply stack is dynamic and changes with load and general market conditions. The supply stack would contract during shoulder periods as generators schedule maintenance, and expand during peak periods as generators attempt to ensure availability to capitalize on higher market prices.

[3] Typically consumers refer to the hourly energy price, but in the wholesale market, energy is traded in five-minute intervals.

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GENERATION

SaskPower Plant Designed for "Black Start" Capability

By Zark Bedalov, P.Eng, Naval Tauh, P.Eng, and Waldemar Ziomek, PhD,MSc.

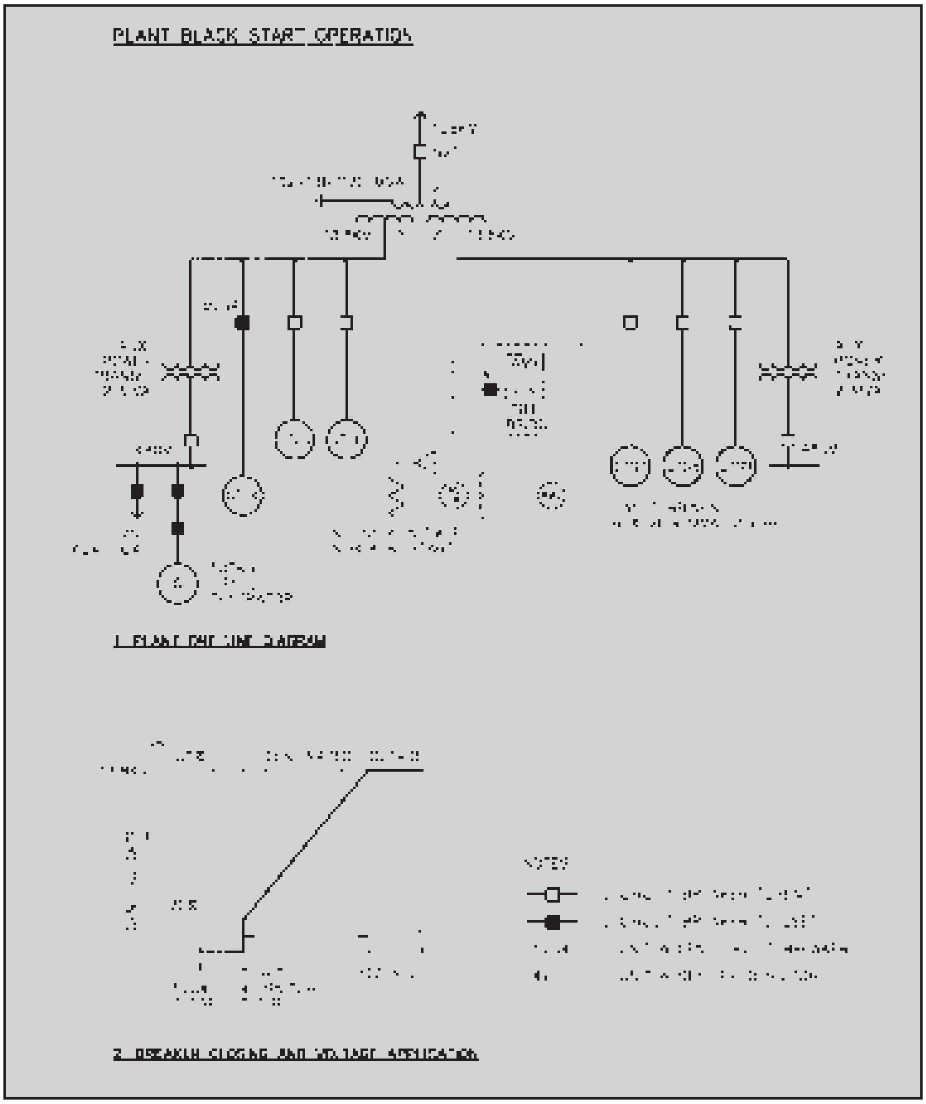
The question is: Can a small generator furnish full magnetizing current to a large transformer during a black start, without being tripped?

Black Start

A new power plant built by SaskPower was designated as 'a black start capable'. The most recent blackout occurred about 5 years ago when a large part of the provincial power system collapsed due to a severe winter storm. During such situations, the power plant relies on its own emergency power sources to initiate power restoration. The new plant included a 500kW diesel to enable power system restoration following a blackout. The unit is capable of running the station service load and starting up one gas turbine generator.

Typically, the emergency lighting fed from the plant batteries comes on immediately. This is followed by an automatic start of the diesel engine within 15 seconds from the onset of a power outage. The delay is necessary in order to ascertain validity of the outage.

Having restored power to the station services, one gas turbine generator is started up and connected to the main transformer. This critical phase, if successful, is followed by adding load to the transformer and the transmission system to complete the power restoration.



Plant Configuration

The new plant as shown in Fig.1 comprises six relatively small gas turbine generators connected to the low voltage windings of a large step-up transformer. Each unit is connected through its own breaker. During a black start the transformer is energized from its low voltage side instead of high voltage side as is the case during normal power plant operation and synchronization. Black start is generally not a big concern for power plants. However, in this case, since the MVA ratio of generator to transformer (26.9/102MVA) is relatively low, there was a concern that the generator may not be able to provide the full magnetizing current to the transformer in order to establish the nominal voltage at its terminals. Consequently, the generator may overexcite at the instant of breaker closing and trip by its voltage restraint overcurrent relay.

Transformer Magnetizing Current

Pauwels, the transformer manufacturer was contacted to provide details on the expected magnetizing current, for the condition of 100 per cent and 20 per cent voltage applied to the Y winding while the windings X and Z were held open. The transformer is of the core form type. The expected magnetizing currents (Peak, RMS and Average) were calculated based on the known formulae (1,2) and are shown on Graphs 1 and 2. While the steady state magnetizing current is small, the peak inrush current is large even at 20 per cent voltage and can cause problems with the generator protection.

The flux required by a transformer is equal to the normal steady state flux plus a DC transient component. The initial transient current depends upon the magnitude of the supply voltage at the instant the transformer is energized, the residual flux in the core, and the impedance of the supply circuit. If the unit is energized as the voltage passes through zero, the transient is at its maximum. The current is

Continued on page 28

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further magnified by the residual flux, which is estimated to be in the order of 70 to 80 per cent of the nominal flux.

In the worst case scenario, a value of flux approaching 300 per cent of nominal can be attained, thus causing appreciable saturation of the magnetic core and a massive inrush magnetizing current in the order of 8 to 10 times full load current. The transient component decays rapidly during the first few cycles and more slowly thereafter. The damping is caused by the R/L factor, which is initially high due to the core saturation (L low) and decreases as the core becomes less saturated. Finally, the inrush current is limited by the source impedance, the generator impedance in this case, according to the equation;

$$I_i = I_{io} / (1+Iio*X_s)$$, where;

I_{io} is the inrush current neglecting the supply source impedance.

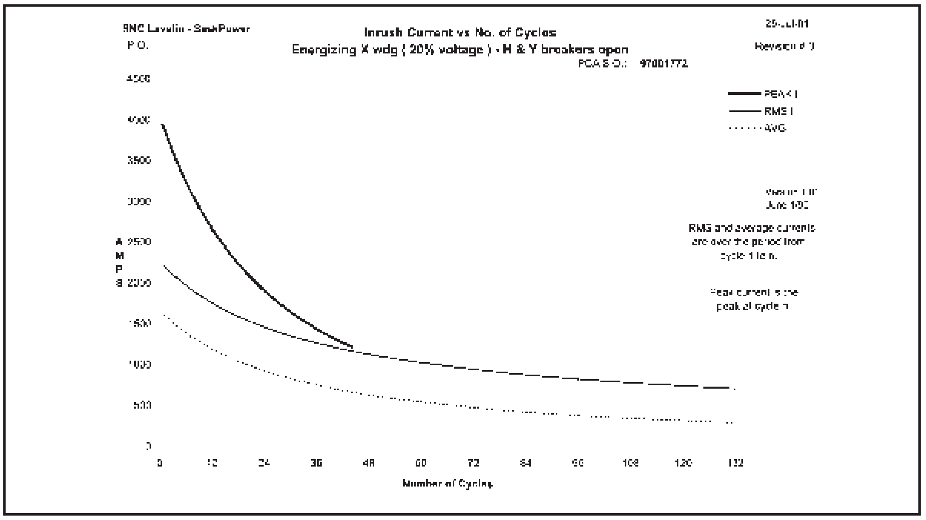
X_s is the effective source supply impedance in per unit on the transformer kVA base.

Results

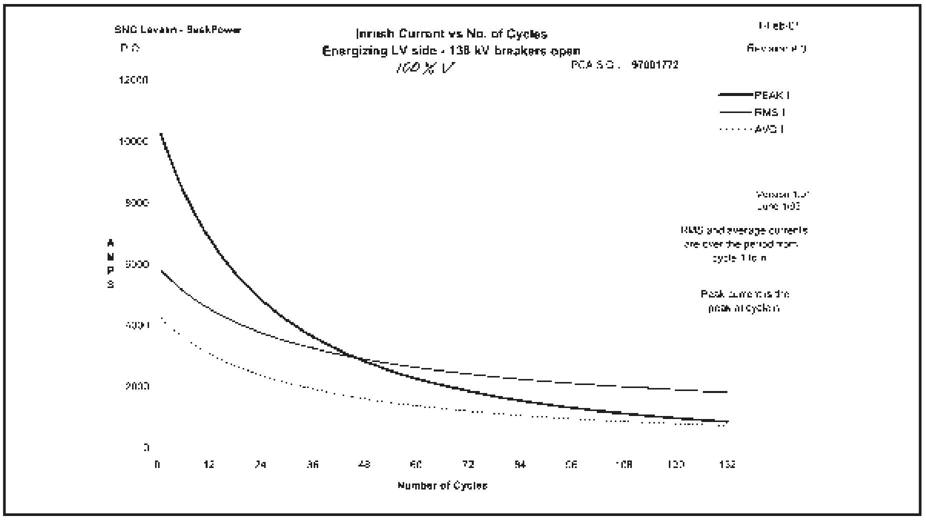
In order to limit the inrush current, it was decided to close the field breaker with a 20 per cent voltage. The voltage was gradually increased to 100 per cent over a period of 120 seconds. The value of the remnant flux in the core was not known. Furthermore, there were no means available of knowing and/or controlling the timing of the field breaker closure with respect to the magnitude of the supply voltage on its sine curve.

Graph 3 captured by a PML, model 7600 meter, shows the results of the test. The meter samples 128 samples/cycle and calculates various RMS values every 1/2 cycle.

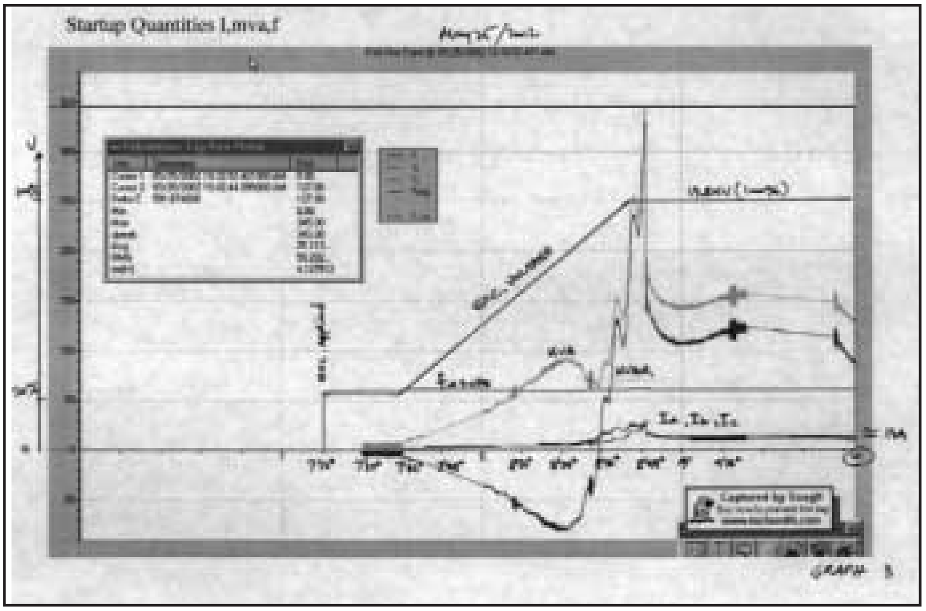
The black start test and the procedures implemented were successful. The inrush current, dictated mainly by the transformer remnant flux, was not excessive and was limited by the generator source impedance. The generator GTG 4 successfully energized the main step-up transformer to its full voltage without tripping and proved that the new plant in present configuration is 'black start capable'.



Graph 1



Graph 2



Graph 3

References:

[1] Blume L.F. et al, Transformer Engineering, J.Wiley & Sons, Inc., New York 1959

[2] Electrical T & D, Ref. Book by Westinghouse Electric Corp., Pittsburg, PA, 1964

Zark Bedalov is Principal Electrical Engineer with SNC-Lavalin, Vancouver, Naval Tauh is T & D Engineer with Saskpower, Saskatoon, and Waldemar Ziomek is Electrical Engineering Manager with Pauwels Transformers, Winnipeg. **ET**

Commercial and Industrial AMR: The Time Is Now; Are the Options Ready?

By Carolyn Kinsman

A number of recent industry events — such as energy shortages, deregulation and competition, and customer demands for more choice and control of energy bills — has caused utilities to think again about where their Automatic Meter Reading (AMR) dollars should be invested. Utilities now focus on an entirely different customer segment than what historically has been viewed as the prime target for AMR: residential full-scale deployments.

Because of increasingly urgent energy supply issues and dropping profit margins, utility managers are turning their efforts and actions toward the acquisition and implementation of AMR systems that address the C&I (Commercial and Industrial) sector. The data acquisition may be expensive, but capital investment provides more bang for the buck by delivering instantly recognized, valuable information in the form of interval data for individual customer load profiling.

Today's leading utilities deal with load forecasting issues, potential energy shortages, customers' rage at high energy prices and the imminent threat that valuable large customers (base load) ultimately may leave their system. Utilities are also faced with the grim realization that they know little or nothing about:

- Customers' individual load profiles
- Specific customer pattern of use
- Associating information with their current 'one size fits all' rate schedules
- Resulting impact of each customer's use on the overall load factor and peak demand
- Utility's bottom line

Recently utilities have readily invested in acquiring the above type of customer information — and major meter manufacturers see exponential growth and profits in solid-state meter sales. Most new meter purchases include a modem under glass or some type of transmitter connected to the digital output from the solid-state meter.

Many American PUCs are making laws that require 15-minute reads with daily downloads for billing settlements in deregulating states. Information acquisition for the purpose of managing demand, pricing and billing is evident in deregulated states and has spilled over into other states beginning to deal with demands for more information from enlightened customers.

Utilities Are Learning More About Their Customers

Using customer information is credited largely to the initial forays of alternate power suppliers presenting graphical information to customers on a secure web site. From all fronts, utilities are being forced to learn more about their customers. Some immediate discoveries resulting from using customer information include:

- Rate class discrepancies: customers in the same rate class easily can vary in profitability to the utility — from more than 50 percent to below 38 percent.
- Need for new pricing structures: customers at the high end of a rate class understand that they are subsidizing the high-cost customers and the bulk of the utility infrastructure. Multi-service territories provide multi-site customers better service and pricing options. These customers now know they can secure better rates by aggregating their load and outsourcing their power requirements, resulting in competitive long-term energy procurement contracts.

Carolyn Kinsman

- New generation lead time: Planning new energy generation construction to alleviate anticipated energy shortages makes for lengthy and costly deliberation processes with environmentalists and politically volatile consumer advo-

Continued on page 30

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cacy groups. Shifting of load and managing demand augments existing power supply and delivery resulting in postponing or eliminating the need for intensive long-term capital investment. AMR information offers nearly immediate load and capacity relief for minimal investment when considering cost and time spent to incorporate new generation facilities.

As the need for customer information grows stronger in the C&I sector, residential AMR systems appear to have no need to initiate the purchase of this high-tech metering equipment, software and telecommunications lines. But the groundswell of steady commitment in utility budgets for the capital investment necessary to purchase C&I AMR technology continues to increase. Why? Because utilities can no longer ignore the value of the timely interval data provided by AMR.

For the first time utilities can:

- Determine individual customer profitability.
- Provide information to build more comprehensive pricing for customer retention, maintaining valuable base load.
- Provide information that lets customers consolidate their energy purchases and modify patterns of use.

Survey Results

A survey conducted by Automated Communication Links Inc. in 2001 showed that more than 24 Southern electric utilities implemented an Automatic Meter Reading system solution mainly to address the acquisition of increased interval data.

Though many respondents differed in the frequency in which the data must be delivered to the utility head-end for presentation and/or billing, the majority stated that they needed the information available in the format and granularity specified by the Public Utilities Commission.

Survey results also showed that large, important C&I customers wanted information provided at the level of detail meaningful to their procurement, budgeting and management requirements.

In all cases, utilities expressed concern for acquiring accurate data that could be validated, estimated and edited to a standard that could be converted into a bill settlement, and accurate for passing on to the Alternate Energy Providers.

C&I AMR Requires More Than Turnkey Solutions

The value proposition and cost analysis is less strenuous for the purchase of C&I AMR. However, few utilities truly appreciate the technical requirements, system solutions and service delivery options for C&I AMR when compared with the simplistic, turnkey solution options generally reviewed in residential AMR.

System solutions used in C&I AMR for small utilities (under 20 three-phase meters) historically has consisted of selecting the meter vendor, using that vendor's software and connecting the meters using dedicated telephone lines. For utilities automating more than 20 three-phase meters, the choice generally includes the purchase of MV-90 software (a somewhat defacto utility software standard), providing the utility with several meter types and access to various meter protocols.

This software maintains a level of flexibility and competitiveness in purchasing multivendor meters. Through the years, MV-90 software has offered a certain amount of flexibility in using shared phone and cellular lines for connecting the meter to the utility head-end.

With growth of deregulation, competition and customer demands for more data, utilities that appreciate the value of the data in these early installations now want to automate more C&I meters. Here lies the rub. The cost per meter with the communications link now becomes a factor as utilities drill below the 750 kW range. The cost of the software and its ability to manage the interrogation process as is, or with customer or enhanced modifications, also becomes a major factor moving forward.

Complex Choices

What is the utility to do? Choices are complex to say the least:

1. **Should the utility just expand the existing system?**
   - Is it possible to expand it?
   - When does the cost of dedicated lines and line-sharing devices make this option no longer viable?

2. **Should the utility search for a new vendor system solution?**
   - Who are these new vendors?
   - What do they do about the required protocols they need to read the various meters in their service territory?
   - What is the risk of making a break from the defacto standard?
   - Is it worth it?
   - Can standards such as ANSI 12.19 make a difference and will they be beneficial in the long term?

3. **Looking at choice no. 1 or 2, can the telecommunication aspect of the puzzle be more effective with a choice other than emulating a telephone link?**
   - What about public RF networks?
   - Can packet data serve the purpose, cut costs and add stability to the data transfer process?
   - Will meter manufacturers incorporate the transceiver or modems into their solid state meters?

4. **Should the utility relinquish control of the meters to an outsource service bureau?**
   - If significant expertise in data and telecommunications is required, outsourcing might be the answer.
   - Are there companies that do this?
   - Can utilities still retain control over the data and the customer?
   - Does this start a process that will cause utilities concern later as deregulation and competition unfold?

Tip of the Iceberg

This is the tip of the C&I iceberg. Politics play a heavy role in C&I metering today. Unlike residential AMR, big money and big players already are established and making money in this industry segment. Newcomers also are investing heavily. And why not? They see C&I as the segue to ultimately gain utilities' residential AMR business as well

Carolyn Kinsman is president of Automated Communication Links Inc., based in Oakville, Ontario, Canada. Contact Kinsman at aclinc@aol.com.

This article originally appeared the July/August 2002 issue of AMRA News, the official publication of AMRA. AMRA is an international nonprofit membership organization founded to address standardization, justification and deployment practices in the application and advancement of enhanced customer-service and resource-management technologies.

The association's mission is to provide AMR information and educational resources worldwide by advocating standards and the use of advanced metering technologies. Members receive numerous benefits including publications, market reports and discounted registration fees to AMRA's annual symposium.

For more information, visit www.amra-intl.org. **ET**

Meter Data Everywhere: Online Energy Information Services

By Bob Fesmire

The internet has allowed utilities to offer a variety of new products and services to their customers, among them online bill payment, remote monitoring, and load profiling and analysis. While all of these services might fall under the heading of "energy information services" (EIS), the focus of this article is on those online services that provide energy customers with access to usage data and analytic tools with which to evaluate it. Different EIS offerings come with their own value propositions, but for energy customers to truly understand their usage — and in turn control their costs — they must first have access to consumption data in a form that allows them to act in a timely manner. That implies an online service.

Of course, utilities have provided usage data for years in paper reports or files on diskette. Web-based services, however, have given customers their first chance to really work with that data and have an immediate impact on their bottom line. Given the rate at which businesses are adopting internet-based tools, it seems safe to say that traditional delivery methods for energy usage data are on the way out — they simply cannot compete with the economics or the level of service offered by web-based solutions.

Is There a Market for This?

EIS, as a force in the utility industry, is still in its infancy and perhaps, as a result, there is relatively little data available with which to gauge the level of adoption of various types of EIS among utilities and their customers. Two studies conducted by E Source, however, offer an encouraging baseline. The first, published in June 2000, looks at what end-users want — and are willing to pay for — in EIS. (E Source plans to release a second edition by the end of 2002.) The second study, published in December 2001, looks specifically at meter data analysis services.

The business case for energy customers' use of EIS essentially comes down to saving money. Be it in the form of a better rate schedule, participation in load curtailment programs or any number of efficiency improvements, any energy cost reduction strategy starts with understanding energy usage. According to the December 2001 E Source study, 30 per cent of the customers surveyed currently get some form of EIS either from their utility or internally.

However, almost all of these customers view the service as "free" in that they do not pay for it directly. This may explain why, as shown in Figure 2, users of meter data analysis services in the other E Source study rated them comparatively lower than did users of other types of EIS. As Exhibit 3 indicates, however, there is a significant number of major energy customers who view energy usage data and analysis as something worth paying for.

Things to Consider

There are a few things important for utilities to keep in

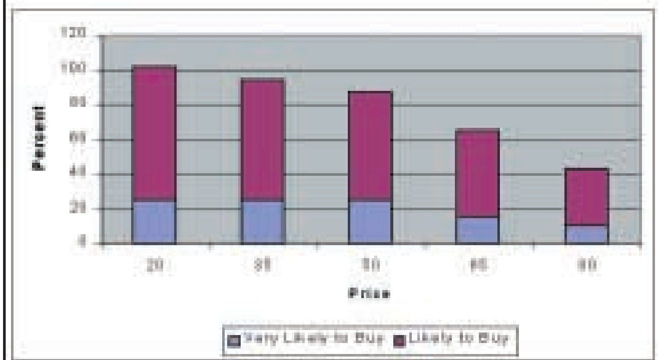

Figure 1: Price Points for Energy Usage Analysis Services *Source: Energy Information Services: What Do Customers Really Want? (E Source, June 2000)*

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Continued from page 31

mind when setting out to offer EIS to their customers that will have a decisive impact on the program's success.

Advanced Metering

Automated meter reading, or at the very least interval metering, is a prerequisite for offering EIS to customers. Obviously, you can't deliver interval meter data over the internet if you're not collecting it in the first place. In many cases, customers may not be prepared to pay for the equipment needed to deliver the service, though they may be ready to pay for the service itself. Utilities should consider sharing the cost of advanced meters, or offering financing to customers so they can mitigate the up-front costs associated with EIS. Some of the most successful EIS programs have included assistance for customers to swap out old meters.

Pricing the Service

As noted in the 2001 E Source study, nearly all of the current EIS users were receiving the service without explicit cost, either from an internal department or from their utility. A word of caution is warranted here because, if customers become accustomed to receiving EIS for free, they may tend to discount the value of the service.

Experience has shown, though, that a modest per-meter-per-month fee is usually enough to preserve the perception of value in the customer's mind while serving to offset the cost of EIS for the utility, if not generate a profit.

In addition, as the EIS field evolves and different types of services become available, utilities may find that they can offer a "base" service for little or no cost and charge an additional fee for "premium" services, much like the pricing model adopted by the cable TV industry.

Why Outsource?

Probably every utility IT department will be tempted to build an EIS in-house. There are, however, several compelling reasons why an outside solution is a better choice:

Shorter implementation time

Vendors can have their EIS product installed and running much sooner than an internal IT department can develop and deploy a similar application.

Access to the latest technology

Working with an outside vendor, utilities can reap the benefits of the supplier's ongoing development efforts. For example, a few vendors frequently introduce product enhancements to their entire customer bases at no additional cost as part of their monthly service fees.

ASP

Application Service Providers (ASPs) provide EIS over the Internet from a remote location — the utility does not need to maintain software on-site, buy additional hardware, or devote IT resources for running the service.

Service Level Agreements

Outside vendors can offer a guarantee on system uptime, performance, security and reliability that internal IT departments cannot.

Freeing up internal resources

Utility IT departments have many competing priorities. By outsourcing EIS, IT staff can focus on supporting the

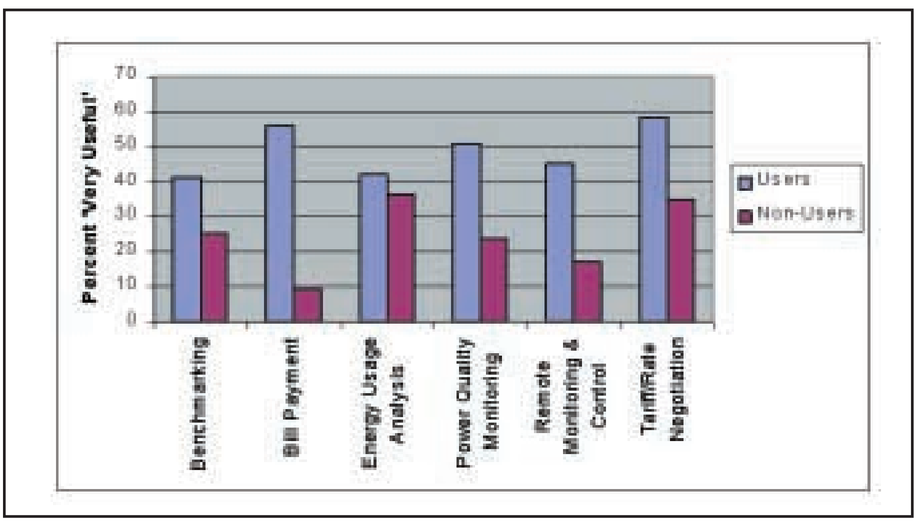
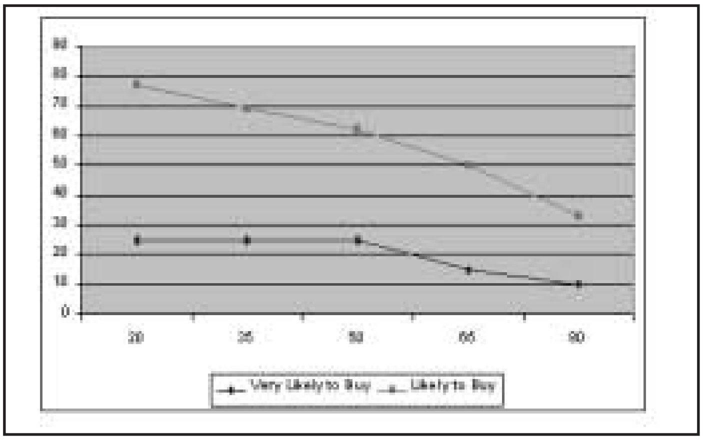


Figure 2: Perceived Usefulness of EIS Among Users and Non-Users *Source: Energy Information Services: What Do Customers Really Want? (E Source, June 2000)*



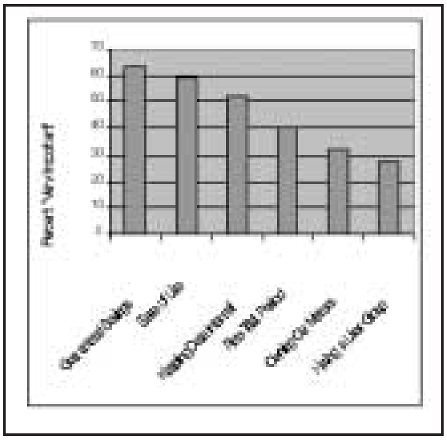


Figure 3: Key Factors in Customer Acceptance of EIS *Source: Meter Data Analysis Services: Making the Most of Interval Data (E Source, December 2001)*

core business and leave the application development to a vendor whose only job is application development.

Perhaps the best reason to work with an EIS vendor rather than pursuing in-house development lies in avoiding re-invention of the wheel. Vendors have already gone through the process of developing, testing and implementing EIS applications, and so they bring a level of experience to the process that a utility IT department simply cannot match. And why should it?

The utility enterprise has a host of critical IT functions that must be supported by internal staff. EIS represents uncharted territory for most utility IT professionals and as such it is extremely difficult for these groups to implement an EIS program that will continue to serve the needs of top customers.

As new technologies and processes are developed, a vendor is in a much better position to make enhancements available as the utility's users become more sophisticated.

Keys to Successful EIS Implementation

As time goes by, the cost of providing EIS will continue to go down. As utilities and their customers become more savvy with regard to such services, it will likely become easier for energy providers to deliver energy information services to their major customers. For the time being, however, there are several important elements to consider.

Data is a Burden, Information is an Asset

Many commercial and industrial customers, even large companies, do not have a dedicated energy manager on staff. More often, the responsibility for monitoring the organization's energy usage falls to a facilities manager, or perhaps even a group of people. Cutting utility costs, for example, often begins in the finance department. With that in mind, it's a good idea for utilities to consider offering a service that places ease of use above bells and whistles.

Figure 3 shows the percentage of customers surveyed who rated the given attributes a '6' or '7' on a seven-point scale in E Source's study. As the data shows, most energy customers rank user friendliness as an important consideration in choosing an EIS vendor. The utility offering the service should too.

A good rule of thumb is to ask yourself what the training requirements are for the service you are considering. If it takes more than 15 minutes for a customer to learn, or more than one to two minutes a day to use, chances are that most customers will not be willing to put in the time required to get value out of the service. And they certainly won't be willing to pay for something they don't use.

Focus on Usage Analysis

Energy customers are most likely to glean value (i.e. cost savings) from EIS if the service allows them to understand their energy usage. Other services are certainly worth investigating, but the core of any EIS should include usage analysis. EIS users and non-users alike indicate this service is valuable to them, and they are willing to pay a reasonable fee to receive this information.

Outsource or Die

As discussed earlier, there are numerous advantages associated with choosing an EIS vendor over in-house development. EIS vendors, who spend all day every day developing and improving EIS applications, are simply better able to deliver a working, saleable product than are internal IT departments. Save your IT staff for what they are best at and leave the EIS development to those who do it for a living.

Promote the Service

A utility can do everything right — find a great EIS vendor, find the right price point, offer an easy-to-use product — and still have their EIS program fail. Customers need to be educated, not only about what to do with the service once they have it, but about the service itself. And if the utility's own account managers have not bought-in to the value of EIS, there is little chance that the customers they serve will see its value either.

If you are committed to delivering value-added EIS, then marketing those services — both internally and externally — has to be part of the commitment.

Start with account managers. These are the people who must understand what EIS offers and really believe in the product. They may find value in using the service themselves in order to understand their customers' usage patterns. Once the main customer contacts are on board, you can begin promoting the service to end users. Again, it is important to remember that many customers have never had access to the detailed, timely information that EIS provides and they may not immediately see how it will help them in their day-to-day work.

Many customers who might make use of EIS are apprehensive about paying for such services when they aren't really sure how it will help their bottom line. A savings guarantee is a way utilities can address those fears and make customers more willing to sign up for EIS programs.

EIS is, ultimately, about partnership. The utility shares information with its customers that helps them save money by operating more efficiently. In this way, EIS has the potential to transform utility customer relationships. Gone are the days when all the customer ever saw of their energy provider was a monthly bill — today utilities have an unprecedented opportunity to become partners in their customers' success.

Bob Fesmire is with ABB Inc. **ET**

POWER QUALITY Q&A

Our Expert Offers Answers to Frequently Asked Questions About Power Quality

By David Windley, P.Eng., C.I.M.

Question:

We are specifying a drive system that will have a process loop to control drive speed. We are being asked if we want a 4-20 mA or 0-10 VDC signal input. What is the difference?

Answer:

The choice for your application is dependent primarily on the type of control you are looking for, wiring distance, and the susceptibility to noise.

For many years, the typical production line has used 0-10 volts VDC as the primary control voltage. It provides an easily measured signal that can be modified by ratio, adding, subtracting, offsetting or other arithmetic function. This is very useful for complex tensioning and torque control. However, since it is dependent on a steady voltage level, transients, sags, swells and electrical noise can modify the signal giving undesirable variation in the signal and the drive system.

The process industry has used 4-20 mA for many years because it is a current controlled variable. A steady current is required for control and the voltage varies to maintain it.

Hence, voltage drop or fluctuations have little or no effect in normal applications. The signal is zeroed at 4 mA instead of 0 mA to distinguish between a true zero and a faulty transmitter or wiring.

A basic rule of thumb is to use a 0-10 VDC voltage signal for short distances where the control requires complex interaction with other devices. This is typically a factory line application.

In process applications, where single loop controls extend over long distances or where electrical noise is a factor, the 4-20 mA signal is the preferred choice.

Either type of signal should be isolated from power conductors in its own conduit from a safety standpoint and for electrical noise considerations.

Preferably, the signal would be carried on a shielded, twisted pair cable. The rules for grounding the shield are the same. Usually this means grounding the source end and isolating the cable shield from ground everywhere else.

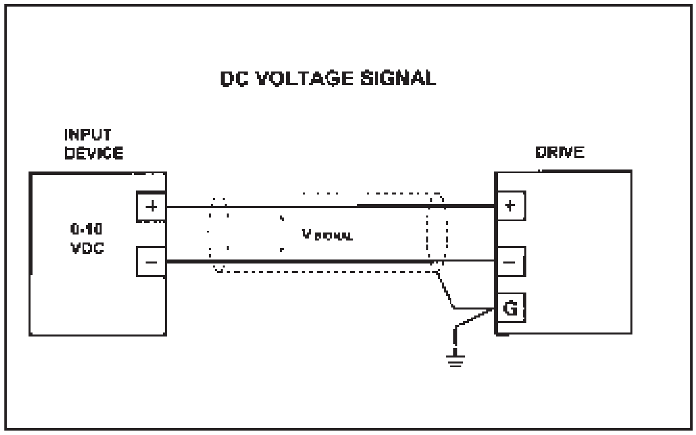
Always minimize the number of cable breaks or terminations.

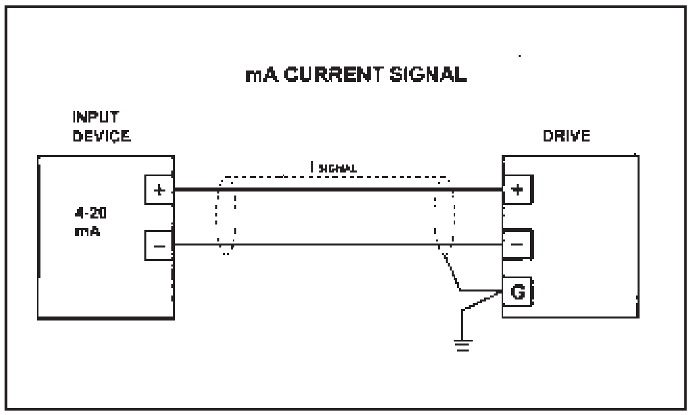
Question:

A while ago, we had a problem with a drive generating transients that affected other sensitive loads. What can we do to avoid this in the future?

Answer:

Normally, drives and other electronic equipment are pretty much maintenance free and don't get much attention until something isn't working correctly. I have seen a case where the drive was still performing its required function and yet was sending damaging transients into the power system. The only symptom was the periodic failure of an electronic board in equipment on the other side of the plant.





The best preventative maintenance (or in this case, predictive) is to use an oscilloscope or other instrument to periodically look at the voltage and current waveforms of the drive or electronic device. Use a constant load so that the waveform can be compared from time to time. In fact, when the equipment is first commissioned take a snapshot to establish a base condition. You now can compare the output waveform with what is expected from the equipment manual.

Generally, there should be symmetry. If not, a problem may be present. This may result in a catastrophic drive failure in the near future. A heads-up in this regard may save a couple of days production.

The other way to head off problems of this sort is to periodically monitor the power system looking for transients and other unusual phenomena. This can be accomplished with a permanent or portable instrument that is capable of measuring and capturing very fast transients. Some equipment has built-in analysis tools such as the ITIC curve to evaluate whether the transients are of a concern or not. You should be able to store and upload the data into a PC for analysis. In this way, you can begin to look for the problem before it starts to cause significant damage to sensitive electronic components.

David is the President of Wintek Engineering. You can forward your questions or comments to him at wintek@wintek-eng.com. ET

OVERHEAD TRANSMISSION & DISTRIBUTION

LIDAR/Image Solutions for the Electrical Utility Industry

By Robert Iantria

The electrical utility industry is faced with many challenges with regards to transmission line corridors. For example, the connection of generation stations and substations to the end user requires an extensive network of transmission lines that travel through a variety of terrain and varying landuse. Electrical utility companies managing linear power corridors are faced with asset management and the physical maintenance of the hardware network itself. Issues for the industry include:

- Design — route and hardware
- Asset management — towers, insulators, wire (position, type, condition)
- Maintenance — corridor ROW and hardware
- Liability Issues — danger trees and cultural encroachment
- Upgrading and rating - line voltage and modeling of catenary sag
- Refurbishment — lifespan of towers and hardware replacement

Assessment of these and other issues is ongoing. Ignoring any one of these issues can be very costly.

LIDAR has become a valuable tool to the electrical utility sector in that it replaces many traditional survey methods with a single data source. Processed LIDAR data enables the measurement of catenary clearances and ground DEMs and the classification of vegetation, tower and wire distributions. When coupled with video and photos acquired from the same airborne platform, a complete inventory of terrain types, hardware conditions and corridor access points can be constructed to create a comprehensive dataset which can be integrated into CAD, GIS and PLS-CAD packages for mapping, modeling and reference databases.

When coupled with video and photos acquired from the same airborne platform, a complete inventory of terrain types, hardware conditions and corridor access points can be constructed to create a comprehensive dataset which can be integrated into CAD, GIS and PLS-CAD packages for mapping, modeling and reference databases.

The technologies utilized to acquire this detailed dataset require an integrated instrument suite flown from an airborne platform. These technologies are briefly explained below.

LIDAR Technologies

To master the task of collecting vast corridors of terrain data, airborne LIDAR "LIght Detection And Ranging" systems have been developed for acquiring data for route selection and for asset management of existing transmission networks. This technology utilizes a laser to accurately measure distances. The laser is only one element of the LIDAR system, however. LIDAR requires a suite of support instruments, most of which are used to establish position and orientation of the laser with the point being sampled on the ground.

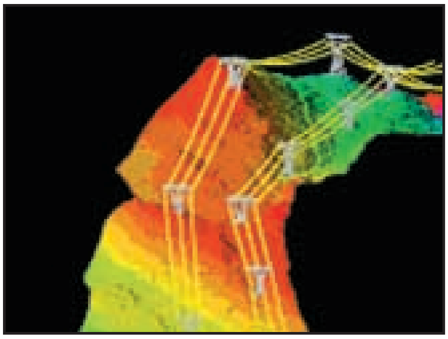
Configuration of LIDAR mounted to Bell helicopter

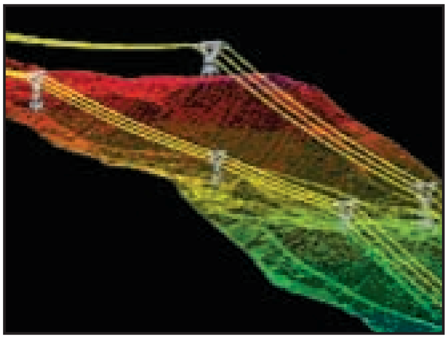
The main components used in LIDAR systems include:

- Positioning system (GPS/IMU)
- Laser ranging system

Position information is vital to the definition of accurate X, Y and Z attributes of the terrain and transmission corridor data. Typically, LIDAR is flown from either a fixed wing aircraft or helicopter. Differential GPS is used to obtain aircraft

Orthomosaic image of transmission lines created from digital stills





Examples of transmission lines rendered from LIDAR data

positional accuracies ranging from 0.05 - 0.2m. This defines the platform position. The platform is, however, experiencing pitch, roll and yaw due to aircraft motion. This motion affects the orientation of the laser pulse. These angular translations are measured by an Inertial Measurement Unit (IMU). Also encoded into the data is a time stamp from a high precision clock.

The laser used in many LIDAR systems sweeps through an angle range acquiring a swath scan of data points. Typical sample intervals for the laser pulses range from 5-30KHz.

Imagery Technologies

As LIDAR records only reflected hits of the terrain and transmission lines, imagery is essential to fill in the visual detail of the surveyed area. This visual data can be used by repair crews, for example, to determine what kinds of equipment to take to a site, the scale of the repair and the nearest access point to the site.

During the acquisition of LIDAR data, low-cost high-quality imagery sources such as video and digital stills can be logged and encoded with position and time stamps common to the acquired LIDAR data.

Apart from having a visual record of the entire survey line on tape, video imagery can be captured by computer and displayed onto a PC. By running a calibration routine the display's co-ordinate system can be geometrically corrected and transposed into a mapping coordinate system thereby enabling the position of attachment points or any number of attributes about the lines, the vegetation and the land use of the surveyed corridor to be mapped.

Digital stills afford much higher resolution of the surveyed corridor and can be rectified and stitched together to create orthomosaics of areas of interest. These images often serve as base maps for the layering of GIS data.

Integrated LIDAR and imagery systems offer cost-saving, comprehensive surveys and flexibility of data use for the electrical utility sector. The hard copy maps, digital data and video generated from a single pass provide accurate detail to populate GIS and CAD systems and provide the information needed by those responsible for managing transmission networks.

Robert Iantria is with Terra Remote Sensing Inc. **ET**

ELECTRICAL SAFETY

Controlling Electrical Hazards

Electricity travels in closed circuits, and its normal route is through a conductor. Electric shock occurs when the body becomes a part of the electric circuit. The current must enter the body at one point and leave at another. Electric shock normally occurs in one of three ways. Individuals — while in contact with the ground — must come in contact with both wires of the electric circuit, one wire of an energized circuit and the ground, or a metallic part that has become "hot" by contact with an energized conductor. The metal parts of electric tools and machines may become energized if there is a break in the insulation of the tool or machine wiring. The worker using these tools and machines is made less vulnerable to electric shock when there is a low-resistance path from the metallic case of the tool or machine to the ground. This is done through the use of an equipment grounding conductor — a low-resistance wire that causes the unwanted current to pass directly to the ground, thereby greatly reducing the amount of current passing through the body of the person in contact with the tool or machine. If the equipment grounding conductor has been properly installed, it has a low resistance to ground, and the worker is protected.

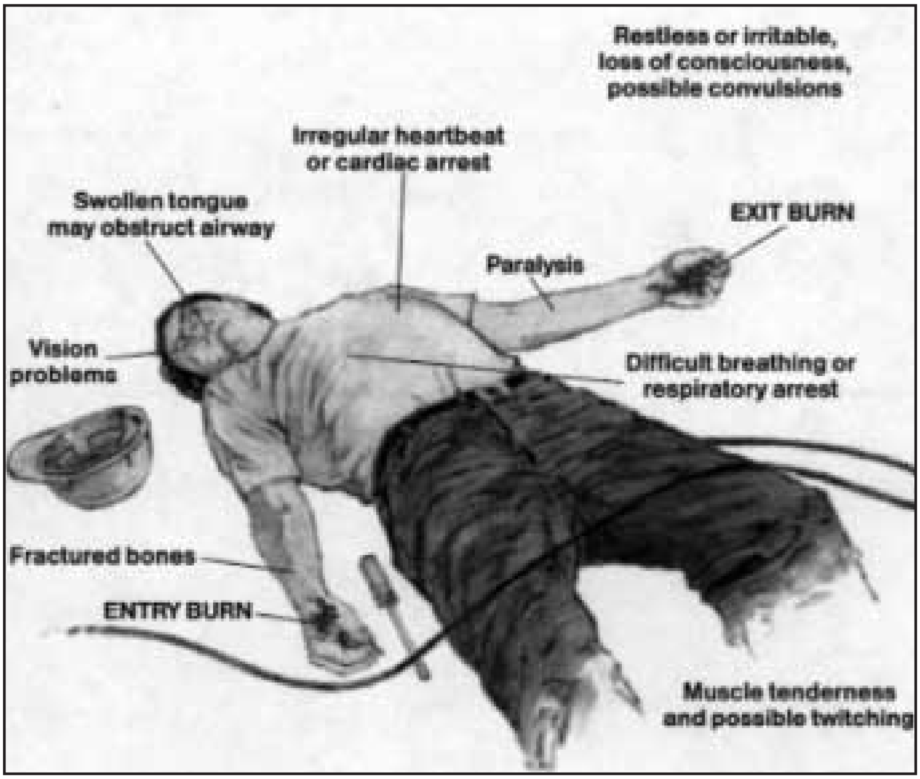
The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors: the amount of current flowing through the body (measured in amperes), the path of the current through the body, and the length of time the body is in the circuit. Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person.

The effects of electric shock depend upon the type of circuit, its voltage, resistance, current, pathway through the body, and duration of the contact. Effects can range from a barely perceptible tingle to immediate cardiac arrest. A difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill. Muscular contraction caused by stimulation may not allow the victim to free himself or herself from the circuit, and the increased duration of exposure increases the dangers to the shock victim.

For example, a current of 100 milliamperes for 3 seconds is equivalent to a current of 900 milliamperes applied for .03 seconds in causing ventricular fibrillation. The so-called low voltages can be extremely dangerous because, all other factors being equal, the degree of injury is proportional to the length of time the body is in the circuit.

Severity of the Shock

The most common shock-related injury is a burn. Burns suffered in electrical accidents may be of three types:



A worker with an electrical injury may have any number of signs and symptoms

electrical burns, arc burns, and thermal contact burns. Electrical burns are the result of the electric current flowing through tissues or bone. Tissue damage is caused by the heat generated by the current flow through the body.

Electrical burns are one of the most serious injuries you can receive and should be given immediate attention. Arc or flash burns, on the other hand, are the result of high temperatures near the body and are produced by an electric arc or explosion. They should also be attended to promptly. Finally, thermal contact burns are those normally experienced when the skin comes in contact with hot surfaces of overheated electric conductors, conduits, or other energized equipment. Additionally, clothing may be ignited in an electrical accident and a thermal burn will result. All three types of burns may be produced simultaneously.

Electric shock can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric shock can cause bruises, bone fractures, and even death resulting from collisions or falls. In some cases, injuries caused by electric shock can be a contributory cause of delayed fatalities. In addition to shock and burn hazards, electricity poses other dangers. For example, when a short circuit occurs, hazards are created from the resulting arcs. If high current is involved, these arcs can cause injury or start a fire. Extremely high-energy arcs can damage equipment, causing fragmented metal to fly in all directions. Even low-energy arcs can cause violent explosions in atmospheres that contain flammable gases, vapors, or combustible dusts.

Burns and Other Injuries

Electrical accidents appear to be caused by a combination of three possible factors: unsafe equipment and/or installation, workplaces made unsafe by the environment, and unsafe work practices. There are various ways of protecting people from the hazards caused by electricity. These include: insulation, guarding, grounding, electrical protective devices, and safe work practices.

Preventing Electrical Hazards
Insulation

One way to safeguard individuals from electrically energized wires and parts is through insulation. An insulator is any material with high resistance to electric current. Insulators — such as glass, mica, rubber, and plastic — are put on conductors to prevent shock, fires, and short circuits. Before employees prepare to work with electric equipment, it is always a good idea for them to check the insulation before making a connection to a power source to be sure there are no exposed wires. The insulation of flexible cords, such as extension cords, is particularly vulnerable to damage. It is generally required that circuit conductors (the material through which current flows) be insulated to prevent people from coming into accidental contact with the current. Also, the insulation should be suitable for the voltage and existing conditions, such as temperature, moisture, oil, gasoline, or corrosive fumes. All these factors must be evaluated before the proper choice of insulation can be made.

Guarding

Live parts of electric equipment operating at 50 volts or more must be guarded against accidental contact. Guarding of live parts may be accomplished by:

- location in a room, vault, or similar enclosure accessible only to qualified persons;
- use of permanent, substantial partitions or screens to exclude unqualified persons;
- location on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons; or
- elevation of 8 feet (2.44 meters) or more above the floor. Entrances to rooms and other guarded locations containing exposed live parts must be marked with conspicuous warning signs forbidding unqualified persons to enter. Indoor electric wiring more than 600 volts and that is open to unqualified persons must be made with metal-enclosed equipment or enclosed in a vault or area controlled by a lock. In addition, equipment must be marked with appropriate caution signs.

Grounding

Grounding is another method of protecting employees from electric shock; however, it is normally a secondary protective measure. The term “ground” refers to a conductive body, usually the earth, and means a conductive connection, whether intentional or accidental, by which an electric circuit or equipment is connected to earth or the ground plane. By “grounding” a tool or electrical system, a low-resistance path to the earth is intentionally created. When properly done, this path offers sufficiently low resistance and has sufficient current carrying capacity to prevent the buildup of voltages that may result in a personal hazard. This does not guarantee that no one will receive a shock, be injured, or be killed. It will, however, substantially

Continued on page 42

Continued from page 41

reduce the possibility of such accidents — especially when used in combination with other safety measures.

Circuit Protection Devices

Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload, or short circuit in the wiring system. Fuses, circuit breakers, and ground-fault circuit interrupters are three well-known examples of such devices. Fuses and circuit-breakers are over-current devices that are placed in circuits to monitor the amount of current that the circuit will carry. They automatically open or break the circuit when the amount of current flow becomes excessive and therefore unsafe. Fuses are designed to melt when too much current flows through them. Circuit breakers, on the other hand, are designed to trip open the circuit by electro-mechanical means. Fuses and circuit breakers are intended primarily for the protection of conductors and equipment. They prevent over-heating of wires and components that might otherwise create hazards for operators. They also open the circuit under certain hazardous ground-fault conditions.

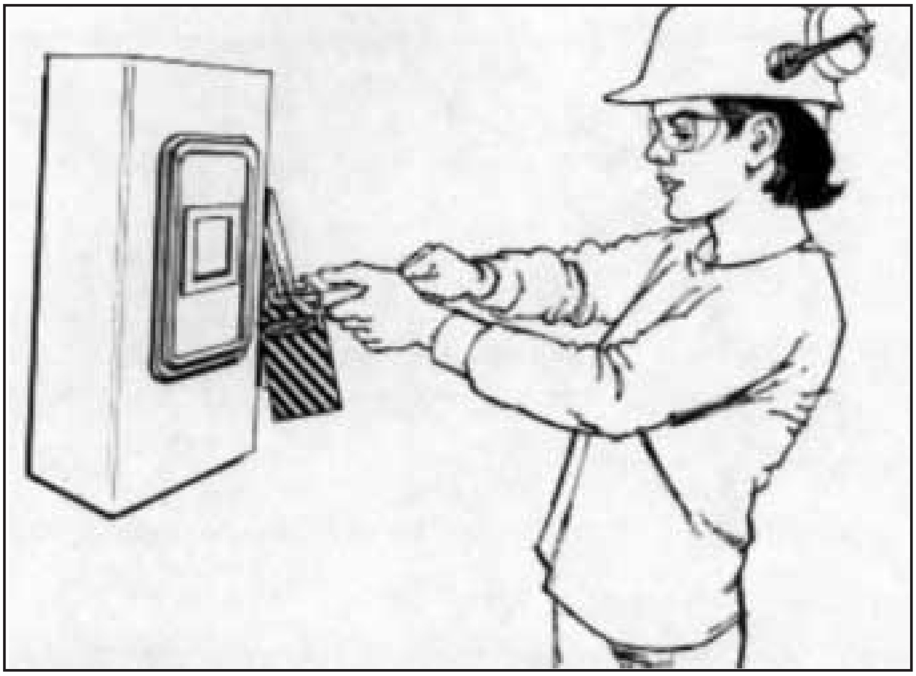
The ground-fault circuit interrupter, or GFCI, is designed to shut off electric power within as little as 1/40 of a second. It works by comparing the amount of current going to electric equipment against the amount of current returning from the equipment along the circuit conductors. If the current difference exceeds 6 milliamperes, the GFCI interrupts the current quickly enough to prevent electrocution. The GFCI is used in high-risk areas such as wet locations and construction sites.

Safe Work Practices

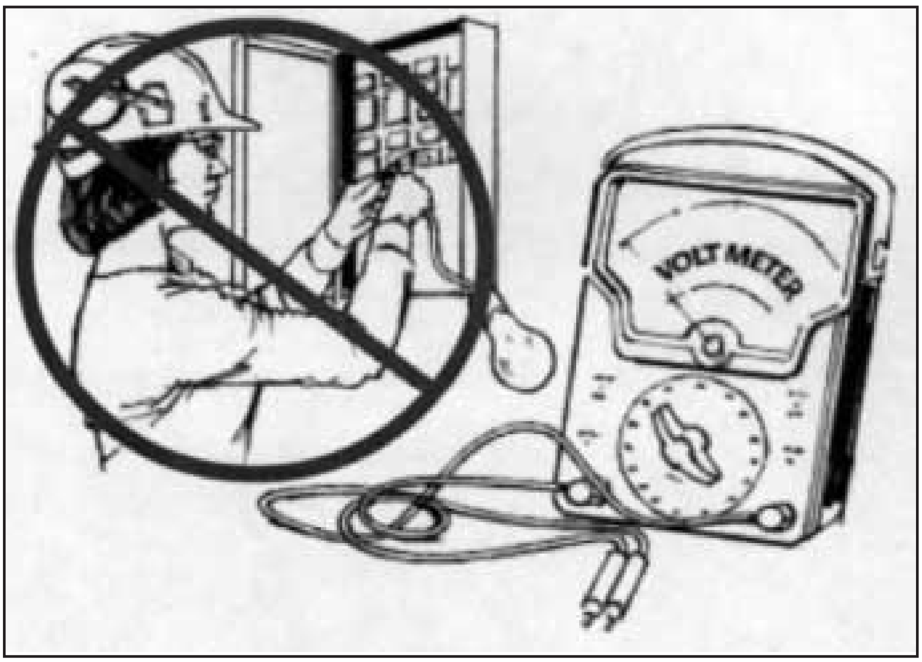
Employees and others working with electric equipment need to use safe work practices. These include: de-energizing electric equipment before inspecting or making repairs, using electric tools that are in good repair, using good judgment when working near energized lines, and using appropriate protective equipment.

Training

To ensure that they use safe work practices, employees must be aware of the electrical hazards to which they will be exposed. Employees must be trained in safety-related work practices as well as any other procedures necessary for safety from electrical hazards.



Apply a lock to the electrical disconnect switches before working on the equipment.



Use approved portable meters and leads, not an improvised lamp test

De-energizing Electrical Equipment

The accidental or unexpected sudden starting of electrical equipment can cause severe injury or death. Before ANY inspections or repairs are made — even on the so-called low-voltage circuits — the current must be turned off at the switch box and the switch padlocked in the OFF position. At the same time, the switch or controls of the machine or other equipment being locked out of service must be securely tagged to show which equipment or circuits are being worked on. Maintenance employees should be qualified electricians who have been well instructed in lockout procedures. No two locks should be alike; each key should fit only one lock, and only one key should be issued to each maintenance employee. If more than one employee is repairing a piece of equipment, each should lock out the switch with his or her own lock and never permit anyone else to remove it. The maintenance worker should at all times be certain that he or she is not exposing other employees to danger.

Overhead Lines

If work is to be performed near overhead power lines, the lines must be deenergized and grounded by the owner or operator of the lines, or other protective measures must be provided before work is started. Protective measures (such as guarding or insulating the lines) must be designed to prevent employees from contacting the lines. Unqualified employees and mechanical equipment must stay at least 10 feet (3.05 meters) away from overhead power lines. If the voltage is more than 50,000 volts, the clearance must be increased by 4 inches (10 centimeters) for each additional 10,000 volts. When mechanical equipment is being operated near over-head lines, employees standing on the ground may not contact the equipment unless it is located so that the required clearance cannot be violated even at the maximum reach of the equipment.

Protective Equipment

Employees whose occupations require them to work directly with electricity must use the personal protective equipment required for the jobs they perform. This equipment may consist of rubber insulating gloves, hoods, sleeves, matting, blankets, line hose, and industrial protective helmets.

Tools

To maximize his or her own safety, an employee should always use tools that work properly. Tools must be inspected before use, and those found questionable, removed from service and properly tagged. Tools and other equipment should be regularly maintained. Inadequate maintenance can cause equipment to deteriorate, resulting in an unsafe condition. Tools that are used by employees to handle energized conductors must be designed and constructed to withstand the voltages and stresses to which they are exposed.

Good Judgment

Perhaps the single most successful defense against electrical accidents is the continuous exercising of good judgment or common sense. All employees should be thoroughly familiar with the safety procedures for their particular jobs. When work is performed on electrical equipment, for example, some basic procedures are:

1. Have the equipment de-energized.
2. Ensure that the equipment remains de-1energized by using some type of lockout and tag procedure.
3. Use insulating protective equipment.
4. Keep a safe distance from energized parts.

Summary

The control of electrical hazards is an important part of every safety and health program. The measures suggested in this article should be of help in establishing such a program of control. The responsibility for this program should be delegated to individuals who have a complete knowledge of electricity, electrical work practices, and the appropriate standards for installation and performance. Everyone has the right to work in a safe environment.

Through cooperative efforts, employers and employees can learn to identify and eliminate or control electrical hazards.

Material from the Workers Compensation Board of British Columbia and the U.S. Department of Labor . **ET**

POWER QUALITY

Harmonic Mitigation of 12-Pulse Drives with Unbalanced Input Line Voltages

By Karl M. Hink

In the mid 1960s when power semiconductors were only available in limited ratings, twelve-pulse drives provided a simpler and more cost effective approach to achieving higher current ratings than direct paralleling of power semiconductors. This technique is still employed today in very large drive applications. A typical diagram of a large twelve-pulse drive appears in Figure 1. The drive's input circuit consists of two six-pulse rectifiers, displaced by 30 electrical degrees, operating in parallel. The 30-degree phase shift is obtained by using a phase shifting transformer. The circuit in figure 1 simply uses an isolation transformer with a delta primary, a delta connected secondary, and a second wye connected secondary to obtain the necessary phase shift. Because the instantaneous outputs of each rectifier are not equal, an interphase reactor is used to support the difference in instantaneous rectifier output voltages and permit each rectifier to operate independently. The primary current in the transformer is the sum of each six-pulse rectifier or a twelve-pulse wave form.

Theoretical input current harmonics for rectifier circuits are a function of pulse number and can be expressed as:

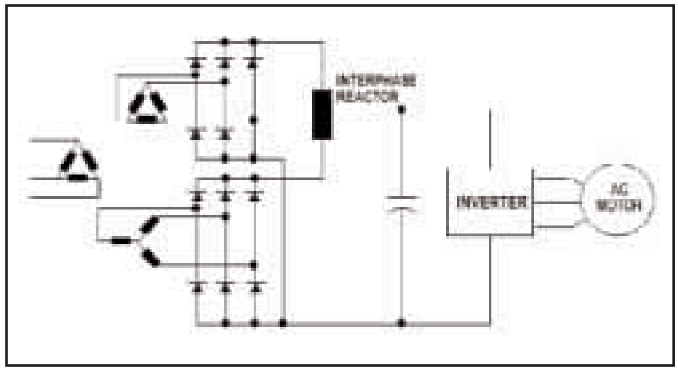


Figure 1

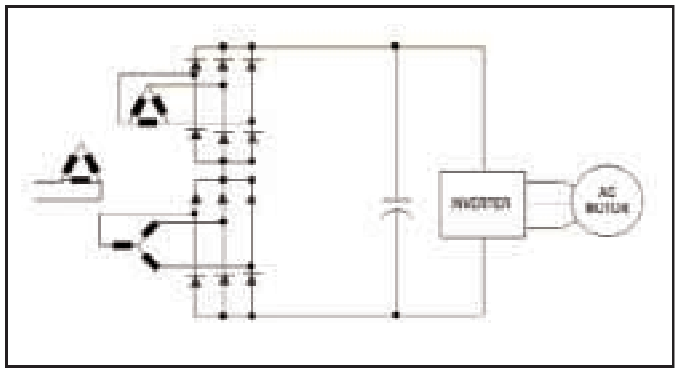


Figure 2

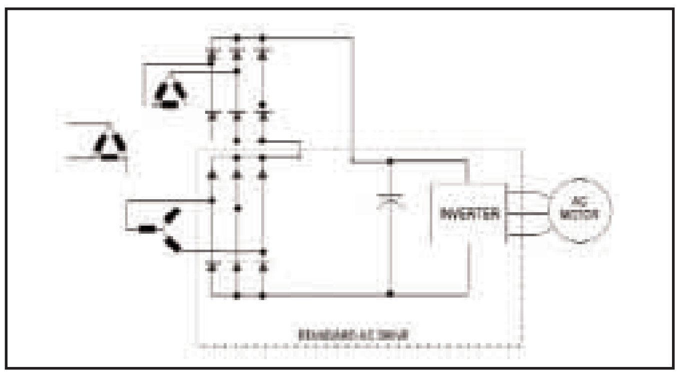


Figure 3

$h = (np \pm 1)$ where n= 1, 2, 3,... and p = pulse number

For a six-pulse rectifier, the input current will have harmonic components at the following multiples of the fundamental frequency.

5, 7, 11, 13, 17, 19, 23, 25, 29, 31, etc.

For the twelve-pulse system shown in figure 1, the input current will have theoretical harmonic components at the following multiples of the fundamental frequency:

11, 13, 23, 25, 35, 37, etc.

Note that the 5th and 7th harmonics are absent in the twelve-pulse system. Since the magnitude of each harmonic is

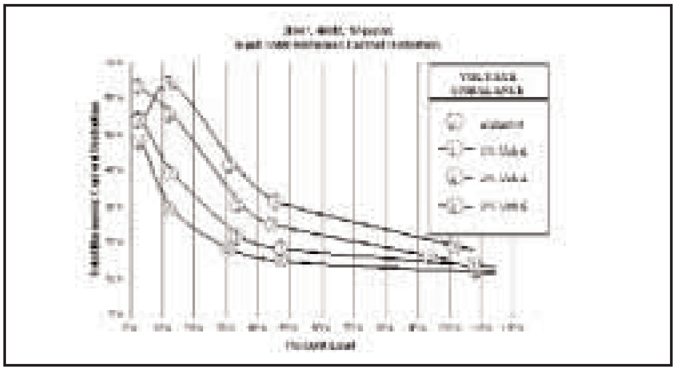


Figure 4

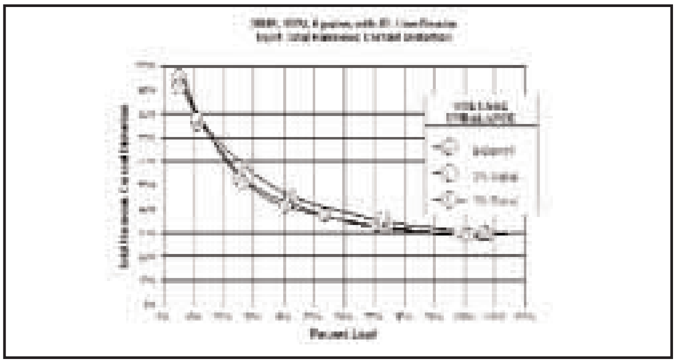


Figure 5

proportional to the reciprocal of the harmonic number, the twelve-pulse system has a lower theoretical harmonic current distortion.

The problem with the circuit shown in figure 1 is that the two rectifiers must share current exactly to achieve the theoretical reduction in harmonics. This requires that the output voltage of both transformer secondary windings match exactly. Because of differences in the transformer secondary impedances and open circuit output voltages, this can be practically accomplished for a given load (typically rated load) but not over a range in loads. This is a very significant problem of the parallel twelve-pulse configuration.

A twelve-pulse system can also be constructed from two six-pulse rectifiers connected in series. In this configuration, two six-pulse rectifiers, each generating one half of the DC link voltage, are series connected. Refer to figure 2. In this connection, problems associated with current sharing are avoided and an interphase reactor is not required. For applications where harmonics rather than high current ratings are the issue, this solution is much simpler to implement than the parallel connection.

Using the series rectifier connection, it is very easy to construct a twelve-pulse drive from a standard six-pulse drive if the six-pulse drive has its DC bus terminals available or permits access to one side of the DC bus. Many standard AC drives provide terminals in the DC bus to accommodate an external DC link choke. These same terminals can be used to add an external rectifier converting the drive to twelve-pulse operation. Refer to figure 3. In this case there is no need for extra circuitry to control inrush current for the second rectifier. The net result is a system solution well within the means of many system integrators.

There are many fine textbooks and articles in which rectifier circuits are examined and analyzed in detail. However, most of the analysis is performed under the assumption of balanced three-phase line voltages. Our practical experience suggests that this assumption is not valid for many industrial and commercial power systems, particularly systems with nonlinear loads. As we traveled around the United States working primarily with drive applications, our impression was that most power systems were operating with 1 per cent to 3 per cent unbalance at the point of utilization.

ANSI C84.1 - 1995 defines percent voltage unbalance as:

$$\frac{100 \text{ X (max. deviation from average voltage)}}{\text{(Average Voltage)}}$$

This same standard also reports that based on field surveys, 98 per cent of power systems are within 0 - 3.0 per cent voltage unbalance range and 66 per cent are within 0 - 1.0 per cent unbalance at the point of common coupling. The standard recommends that electric supply systems be designed and operated to the limit of a maximum voltage unbalance to 3 per cent when measured at the electric utility revenue meter under no-load conditions. Load unbalance within the building power distribution system adds to the utility unbalance at the point of utilization.

To determine how a twelve-pulse drive system operates under unbalanced line voltage conditions, we constructed a 30 HP twelve-pulse drive from a standard delta delta-wye isolation transformer and standard six-pulse drive using the series bridge connection shown in figure 3. An auto transformer could have been used in place of the isolation transformer. The auto transformer costs less and requires less mounting space, but the isolation transformer was selected because it provides better performance and is readily available from stock. The system was tested with line voltage unbalance ranging from 0 per cent to 3 per cent and with loads ranging from 5 per cent

Continued on page 46

Continued from page 45

to 110 per cent. The input total harmonic current distortion, THID, is shown in figure 4. THID varied from 12 per cent at full load with balanced line voltages to 65 per cent at 17 per cent load with a 3 per cent unbalance. The data show that the harmonic performance of twelve-pulse drives degrades rapidly with increasing line voltage unbalance. Many users expect that THID should not exceed specified limits from no load to full load. The graph reveals that THID in twelve-pulse drives is very much a function of load. Good performance also requires balanced line voltages.

To determine how a six-pulse drive system operates under unbalanced line voltage conditions, we tested a 30 HP drive with a 5 per cent line reactor operating from a power source with a 1 per cent impedance. This system was tested with line voltage unbalance ranging from 0 per cent to 3 per cent and with loads ranging from 5 per cent to 110 per cent. The total harmonic current distortion, THID, is shown in figure 5. THID varied from 29 per cent at full load with balanced line voltage to 95 per cent at 5 per cent load with a 3 per cent line voltage unbalance. The harmonic performance of the twelve-pulse drive is significantly superior to a six-pulse drive under all conditions of line unbalance.

It is interesting to compare the performance of the twelve-pulse drive with a standard six-pulse drive fitted with an MTE Matrix Harmonic Filter under similar conditions of unbalanced line voltages. This filter is a type of low pass harmonic filter designed to work with standard six-pulse drives. A Matrix Harmonic Filter was tested feeding a 30 HP six-pulse drive. This system was tested with line voltage unbalance ranging from 0 per cent to 3 per cent and with loads ranging from 5 per cent to 110 per cent. The input total harmonic current distortion, THID, is shown in figure 6. THID varied from 4.7 per cent at full load with balanced line voltage to 9 per cent at 25 per cent load with a 3 per cent line voltage unbalance. The low pass filter provides better harmonic performance than the twelve-pulse system throughout the load range and is significantly less sensitive to voltage unbalance. At 25 per cent load with a 1 per cent line voltage unbalance, the twelve-pulse drive has an input total harmonic current distortion of 29 per cent while the six-pulse drive fed from a low pass Matrix Harmonic Filter has a THID of 7 per cent under the same operating conditions.

Conclusion

Drives are applied in heating, ventilating, and air conditioning applications because loads are variable and users demand energy efficiency and comfort. Varying loads result in load unbalances within building power distribution systems which add to the utility line voltage unbalance at the point of common coupling.

Harmonic mitigation techniques which are not effective with line voltage unbalances of 1 per cent to 3 per cent at the point of utilization will not as a practical matter achieve useful results. The data in this report show that a standard six-pulse drive fed from a low pass Matrix Filter provides superior harmonic performance to a twelve-pulse drive in applications with variable loads and line voltage unbalances ranging from 0 per cent to 3 per cent.

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Powering the New Digital Economy:
How Enterprise Energy Management Systems Help Maximize Power Reliability

By John Van Gorp and Bill Westbrock

The rapid adoption of information technology ("IT") and increasing dependency on sophisticated production processes has dramatically increased the importance that organizations attach to highly reliable supplies of electrical energy. Enterprises such as large data and communications centers, Internet hosting facilities, online retailers, and manufacturers with sensitive processes (such as computer chip plants) find even brief interruptions to be disruptive and expensive.

These "digital economy" operations require near 100% uptime, and the aggregate load that these businesses represent is growing at a phenomenal rate. By the year 2010 the digital economy is expected to consume between 40 to 50 percent of the energy used in the United States[1]. Even "old economy" enterprises are increasingly dependent on automation equipment and Internet-enabled solutions for manufacturing, procurement and 24-hour customer service call centers.

Unfortunately, there is a large disparity between the reliability that the power grid can provide and what these organizations require. Thus, nearly all organizations that require high nines power incorporate an array of specialized equipment to help ride through power interruptions. However, each component often operates independently. An enterprise energy management ("EEM") system offers the distributed information and control capabilities that can help better integrate these components, ensure their performance and, in turn, guarantee maximum uptime.

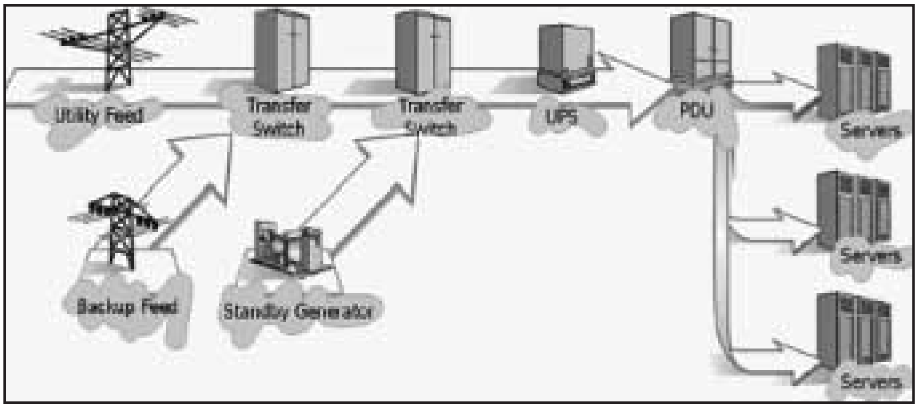

Figure 1: Typical assets in a high-reliability power system

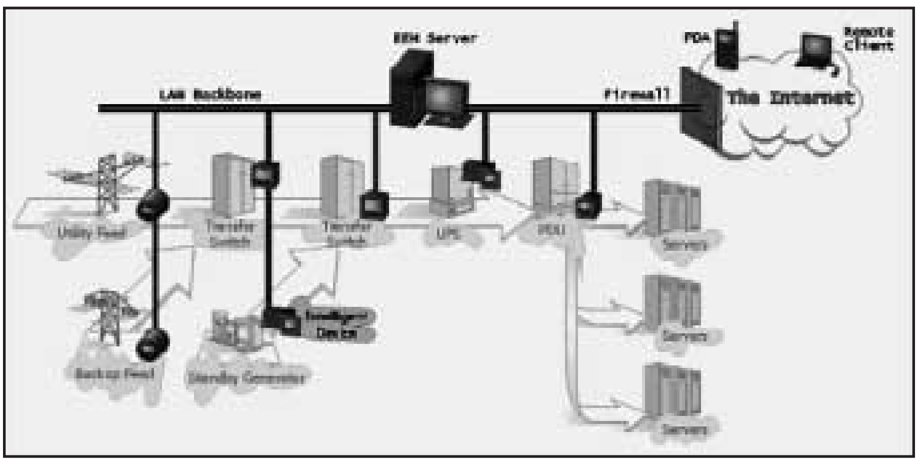

Figure 2: EEM system "layer" on top of power reliability system

Power Reliability Components

The power grid was developed to deliver "three nines" of clean, reliable power; that is, it provides a constant flow of energy 99.9% of the time. This translates to less than nine hours of downtime a year. This is sufficient for lighting systems and motor loads, but new digital assets and processes require very precise streams of electrons at highly regulated voltages, translating to power reliability as high as "six nines" (99.9999%, or less than 30 seconds of downtime a year) or higher[2].

Typical loads found within power sensitive businesses can include banks of computer-based data servers, communications switches, or manufacturing processes run by automation equipment. To ensure these loads are kept fed with clean energy, these businesses normally deploy a variety of specialized power reliability equipment to make up the difference between what they need and what the power grid can supply [see Figure 1].

Transfer Switch

A transfer switch is responsible for connecting one or more power-sensitive loads to one of several possible power sources, ideally making the transition between sources as transparent as possible. A transfer switch may be used to switch from one utility feed to another, or from a utility feed to an on-site generator.

Generator

On-site generation is responsible for supplying power to critical loads when the utility supply is not available. In deregulated markets, a company's energy manager may also elect to turn on an onsite generator when it becomes more economical to run than the price of energy available from the power grid[3]. Diesel generators have traditionally been used to provide on-site generation, but new power sources such as microturbines and

Continued on page 48

Continued from page 47

fuel cells are increasingly being used.

Uninterruptible Power Supply (UPS)

A UPS acts as the short-term *buffer* between the continuity and quality of energy supplied by the power grid and that required by critical loads. The UPS will draw from a temporary power source (such as batteries or a flywheel) as needed to maintain stability until on-site generation can be brought online to provide power.

Power Distribution Unit (PDU)

A PDU is the interface between the power reliability system and critical loads, normally accepting power from this system and distributing it to the loads on separate circuits. To increase reliability, the PDU may also include a static transfer switch (STS) that can transparently switch between a primary and backup power source.

Each of the components described above must interact seamlessly with the others to provide high-nines reliability. However, components often come from several different manufacturers and are not typically integrated tightly together.

A transfer switch, for example, may receive a signal indicating an outage on the main utility service and switch over to a feed from on-site generation without knowing the complete status of that on-site power source. A UPS may know that the primary utility service has failed and draw power from temporary power storage equipment (such as batteries or a flywheel) without knowing the status of on-site power generation.

This lack of comprehensive management over this collection of components has an impact on the highest level of reliability that can be achieved. Without an infrastructure for system management, failures can leave facility personnel in the dark as to exactly what happened. An outage lasting several hours can, depending on the customer affected, be very expensive. Personnel at SEH America (a semiconductor manufacturer) estimate that a plant shutdown for several hours would mean revenue and productivity losses of $1 million US.[4]

How can long-term reliability be improved?

What is needed is an information system that can monitor the electrical and physical characteristics of power reliability components and provide facility personnel with the tools they need to achieve the highest uptime possible.

A Layer of "Energy IT"

An enterprise energy management system is composed of intelligent devices, communication links and software that combine to form a layer of "energy IT" that rides on top of key power reliability system components and critical loads [Figure 2]. The EEM system monitors the key electrical and physical characteristics of each power reliability component and critical circuit, within a single facility or across multiple facilities, and provides operations personnel with the information they need to extract the highest possible reliability from the system as a whole.

Figure 3: Typical EEM intelligent devices

Intelligent devices

Microprocessor-based devices within an EEM system are permanently installed at key power distribution points, or on critical equipment, turning electrical and other physical measurements into digital data [Figure 3]. These devices are considered "intelligent" because they provide much more functionality than simple transducers. Often included are a variety of data manipulation features such as local data archival, power quality analysis, and alarming on critical conditions. Some devices also include manual and automated control capabilities over external equipment. Multi-port, multi-protocol communications allow each device to share its information with a variety of systems and users simultaneously.

Communication links

A variety of communications technologies may be used to move data captured by intelligent devices back to head-end EEM software. Traditional methods include dialup telephone lines and dedicated copper cabling, while newer systems make increasing use of existing corporate infrastructures and standard networks such as Ethernet LANs, public digital wireless and the Internet.

Software

The head-end EEM software retrieves data from the network of intelligent devices for further display and analysis, as well as permanent archival. From the important data gathered from each device "node" the EEM software delivers the useful information in a form that operators require to properly manage their digital assets. The software can also aggregate and archive data in an industry-standard format, and provide access to real-time and logged information to multiple users simultaneously through customized graphical screens [Figure 4].

The EEM system also makes use of Internet and wireless technology to make critical reliability information and condition alerts more widely available (through web browsers, pagers, cell phones and PDAs).

Maximizing Uptime with EEM

With an enterprise energy management system in place, the important steps can be taken to ensure that a business achieves the level of "nines" of reliability they are targeting.

Benchmark performance

The performance of the power reliability system as a whole as well as the performance of individual components can be benchmarked against design specifications and industry standards.

For best results, the power reliability system should be monitored continuously, or what is termed "24/7", so that its performance can be reviewed over time and to ensure that no relevant data is missed. When configured to provide performance benchmarks, the EEM system can be used to help answer several questions:

- When the electrical output of UPS equipment is compared to the electrical input, is this equipment performing to specifications in its ability to mitigate disturbances?
- When critical loads are subjected to electrical disturbances that are judged acceptable by industry standards (such as SEMI F47 and ITIC) do they "ride through" the disturbance and continue to operate as expected?
- Are increasing loads on facility electrical circuits stressing the capacity of certain power reliability system components?

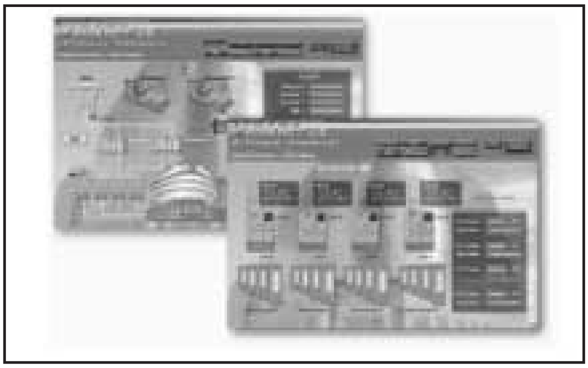

Figure 4: Typical EEM software screens

Test key system functions

Critical system functions are tested whenever possible to ensure correct operation, and the EEM system can play an important role in the verification and documentation of these tests:

- Streamline system commissioning. During the construction of a data center the EEM system is used to verify and document the proper operation of the reliability equipment as it is commissioned. This helps provide consistency and decreases the overall cost and time necessary for the testing process.
- Perform start-up tests with on-site generation and document the results of the test. The EEM system can provide high-speed trending of relevant electrical and physical data (such as voltage and frequency stability, power output, and various generator pressures and temperatures).
- Monitor automatic transfer switch tests, such as transfers from the utility feed to on-site generation. Intelligent devices in the EEM system can capture the data required to assess the performance of transfer switches (including voltage and current waveforms as well as timestamps for switch operations).
- Verify UPS switching operation. It is important to test the ability of UPS equipment to switch between the primary energy source (normally the utility) and a secondary energy source (often a bank of battery cells). An EEM system can be used to verify that the output of UPS equipment remains within specifications during switching tests and that the batteries are recharged correctly after a generator has switched in as the primary UPS source.
- Verify static transfer switch (STS) operation. In the event of a primary UPS failure the EEM system can verify that the static transfer switch inside a PDU successfully switched over to a backup power source.

Capture and analyze system failures

Power reliability systems are complex systems, and equipment or system failures can affect the supply of energy to critical loads. Intelligent devices in an EEM system can perform the same job as the "black box" flight recorders used on aircraft, providing the data needed to analyze failures and quickly identify what corrective actions are required. Consider the following scenarios:

- Backup systems fail to keep critical loads energized during a utility outage. Where in the normal sequence of events did the power reliability system fail? Is one piece of equipment responsible for the failure, or is a more complex interaction involved? The information provided by an EEM system can help in finding the answer.
- Several servers in a data center occasionally reboot for no apparent reason, and the electrical circuits feeding these servers are under suspicion. What did the electrical output of the UPS equipment look like at the time the servers rebooted? What about the quality of energy received from the utility? Disturbance data captured by an EEM system can help answer these questions.

Conclusion

The energy needs of the digital economy pose a great challenge: this sector is expected to consume a significant portion of the energy generated in the near future, and the quality of this energy must be exceptionally high. Yet the existing power grid infrastructure was never designed to support the reliability required by these new power-sensitive businesses.

Why do these organizations consider this greater reliability so valuable? Consider the following quote from Jeff Byron, former energy director for Oracle Corporation: "What's the self-sufficiency worth to us? Millions of dollars per hour. It is so important, you almost can't calculate the value to us and our customers… The digital economy depends on uninterrupted supplies of the highest quality electricity."[5]

Although it is common practice to increase uptime by deploying power reliability equipment, it is difficult to achieve the highest reliability possible when components are loosely integrated and the information required to manage a system of this complexity is missing.

The solution is an enterprise energy management system that acts as a "digital nervous system", pulling together all power reliability components into a single, coordinated system and providing the information required to maximize uptime.

Given the cost that companies like Oracle assign to downtime, many digital economy firms will find the increased reliability made possible by an enterprise energy management system to be invaluable.

References

[1] "Emerging Power Technology", Stephens Inc.
[2] "The PowerChip Paradigm", Huber Mills
[3] "Enabling Distributed Generation", Power Measurement
[4] "SEH America Ensures Power Quality", Huber Mills
[5] The Wall Street Journal, May 11, 2000

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OVERHEAD TRANSMISSION & DISTRIBUTION

Changing the Guard: Polymer Replaces Porcelain for Surge Arresters

By Torbjörn Skytt and Hans E.G. Gleimar

'Standing guard' may be the best description of what surge arresters do, but it says nothing about the qualities they need to perform and survive. Designed to protect power grid components against lightning and switching transients, the arresters themselves are exposed to hazards such as earthquakes and vandalism. Traditional porcelain doesn't therefore sound like the best kind of material for their housing, and it isn't.

Surge arresters are safety devices which quickly and effectively limit the overvoltages that can arise in transmission networks following lightning, switching and other transient events. Without them, these surges could damage valuable equipment in the high-voltage grid. Utilities therefore install them routinely as a precaution.

Evolution of the surge arrester

The earliest form of overvoltage protection was a simple air gap between electrodes but, inevitably, its breakdown voltage varied with the weather. It was followed by a 'conventional' arrester with series-connected spark gap and voltage-dependent silicon carbide resistor, all enclosed in a porcelain housing.

These early devices have long since been superseded by a new generation of gapless arresters with series-connected, highly non-linear zinc oxide (ZnO) varistors. Each varistor block is a dense ceramic body made up of ZnO and small amounts of other metal oxides. ZnO, and the technology behind it, is proven in the field, and it serves its purpose well. Traditionally, the housing of the arrester has been made of porcelain. For various reasons – porcelain arresters may shatter and have become a target for vandals – manufacturers have long sought a replacement material, one that is safer and easier to handle.

Now, ABB has introduced a new surge arrester to replace the porcelain type. Called PEXLIM (Polymeric EXcellent LIMiter), it has a very special housing made from a polymer, silicone rubber. The blocks of zinc oxide used in it are exactly the same as those used in the ceramic arresters.

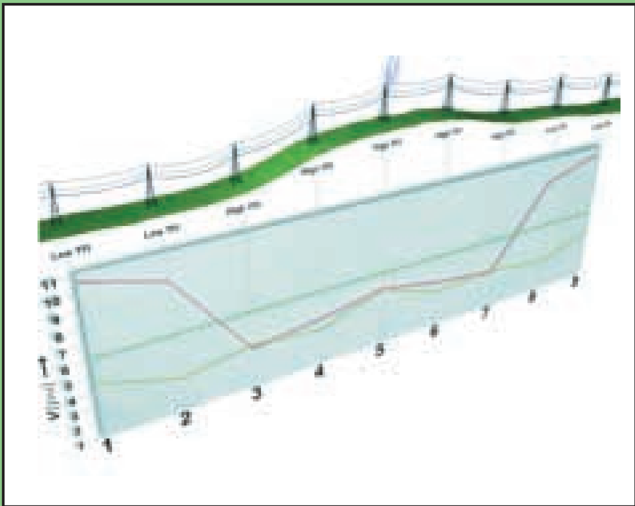
Installing polymer-housed surge arresters on a transmission line – now a safer and simpler task

Designed to break down

The varistors, which are stacked on top of each other, protect the high-voltage grid from overvoltages through a combination of semiconducting and insulating properties. During continuous high-voltage operation, the varistors draw a current of around 1 mA. At this voltage level the current is almost purely capacitive. The resistive component of the current is just a few tens of microamps. The surge arrest sequence is normally as follows: in the event of an overvoltage the arrester draws a higher current and limits the overvoltage to a value that is determined by its current-voltage characteristic. When the overvoltage disappears, the current drops immediately. Choosing an arrester is always a compromise — a trade-off between the required protection level and

Water droplets on a polymer arrester housing. Current is not conducted as easily as on a porcelain housing, where the water spreads out to form a uniform layer.

Earthquake-resistant surge arrester with polymer housing



Result of installing surge arresters along a section of transmission line with high tower footing impedance (TFI). It can also be seen that arresters are needed at the low TFI towers at the ends of the section.

V	Voltage across insulators
Red	Arresters in towers 3-7
Yellow	Arresters in all 9 towers
Green	Normal line insulation strength (BIL)

the transient overvoltages that can be tolerated. The arrester is deliberately intended to be the 'weakest link' in the power grid, ie it is deliberately designed to break down in the event of an overload in order to protect other, more expensive equipment.

New 'packaging material' has better characteristics

The new, lightweight insulation material retains the effective basic function of the arrester while at the same time improving a number of other properties and considerably enhancing product safety and ease of handling. It was developed in collaboration with ABB Corporate Research and leading polymer manufacturers.

The advantages of silicone rubber over ceramic include:

- Considerably better durability. Silicone rubber is resilient, yet solid and compact. Since its housing is not fragile, this arrester can even be placed in unfenced areas without any risk to people or animals.
- Water-repellent. Silicone has a hydrophobic surface, which repels water droplets. These join together and then run off, so the current is not conducted as easily as it is on surfaces where the water spreads out to form a smooth layer.
- Large reduction in weight. Silicone rubber is much lighter than porcelain, which reduces the overall weight of the arrester. In fact, ABB has succeeded in reducing the weight by a full 50 per cent, making the arresters easier to transport and handle. Mounting these arresters on transmission pylons or hanging them on transmission lines is also safer and easier. Another advantage of these arresters over heavier arresters is that they permit alternative locations and methods of installation 2 .
- Better for the environment. Silicone rubber does not contain any environmentally harmful substances, and once it has reached the end of its useful life it can be used as filling material (eg, for construction work), or it may be incin-

Continued on page 52

Continued from page 51

erated (400–500°C), leaving only harmless sand.

- Good resistance to aging and harsh weather conditions. During development of the arrester ABB improved the manufacturing process as well as the properties of the housing material. these arresters show good resistance to aging and high operational reliability, even in harsh weather conditions.
- Repels dirt and contaminants. The silicone rubber surface repels dirt and contaminants, enabling them to be washed away by rain.
- Good electrical properties, resistance to light, UV radiation and fire. The silicone rubber used by ABB contains components that improve its fire retardance and resistance to light and UV radiation, reduce salt-induced erosion and ensure good electrical properties. Silicone rubber also copes well with leakage currents due to good electrical load bearing ability and insulation properties.

New applications

The properties of this type of arrester make it highly suitable for use in earthquake-prone areas. Its low weight and excellent ability to absorb earthquake stresses ensure that the arrester is not shattered by tremors. Where extra-long arresters are used, any harmonic oscillations can be controlled by suitable bracing arrangements .

In addition, the new, lighter arresters can replace more expensive and maintenance-intensive equipment. They can be hung from transmission pylons and at various points along the line to further safeguard the availability of the grid . Porcelain-housed arresters are too heavy for most applications of this kind and could be a hazard should they become damaged.

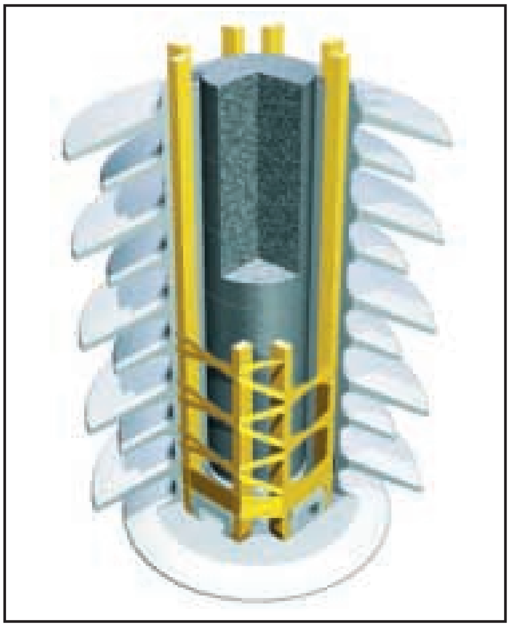
ABB is also collaborating with others in the development of 'compact' transmission lines. These are lower and narrower and have weaker magnetic fields, and the lighter PEXLIM arrester is of vital importance to their performance.

And for transmission grids where grounding, and therefore availability, has been a problem in the past, the polymer arrester also offers an attractive solution. Because of the risk of falling porcelain this would not be a feasible option without the shatter-proof PEXLIM arrester.

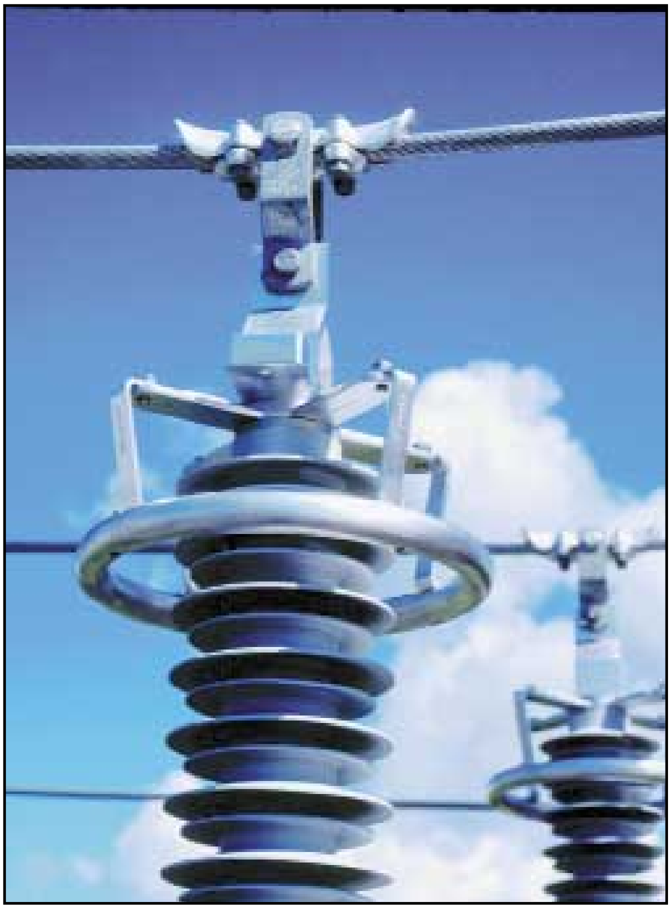
Technical data for PEXLIM arresters

System voltage	52–170 kV	52–420 kV	52–420 kV
Rated voltage*	30–162 kV	30–360 kV	30–360 kV
Nominal discharge current	10 kA	10 kA	20 kA
Line discharge class	Class 2	Class 3	Class 4

**The rated voltage is the parameter on which operational and safety characteristics are based. The choice of rated voltage for an arrester is a compromise between the desired degree of protection and the tolerance vis-à-vis the transient overvoltage. Selection of a higher rated voltage increases the ability of the arrester to cope with transient overvoltages, but reduces the safety margin for the specific insulation level.*



The polymer housings of PEXLIM surge arresters have fewer components than the previous generation of arresters with porcelain housings.



PEXLIM arresters installed on transmission lines in a 400-kV grid. The hollow insulator is also made of polymer.

New material — integrated production

Silicone rubber is a highly reactive substance and its production requires special expertise, clean manufacturing conditions and constant climate conditions. All of this makes the production process relatively complex.

The silicone rubber is cast in a single piece around the stack of zinc oxide blocks forming the active component. The adhesion properties of silicone rubber are very important, as there are not allowed to be any holes in the finished product. The injection-molding process for the polymer housing has been tested in collaboration with key suppliers and now meets high standards of reliability and productivity.

ABB Switchgear is currently manufacturing the third generation of these products by means of a proprietary production process, specially designed tools and a silicone rubber compound that has to meet very strict manufacturing requirements.

Tests on finished arresters are carried out using special test equipment and are the same as those for arresters with porcelain insulation.

Spin-off benefits for ABB include a much better understanding of polymer technology and the properties of silicone rubber. This knowledge will also be valuable in many other areas of the power transmission field.

An investment in the environment

Installing arresters to protect other, usually more expensive, equipment lets utilities transmit heavier loads over their power grids, reducing the need to invest in new lines and avoiding all the problems associated with them. In fact, the new arresters offer benefits for the environment throughout their life cycle, from production to disposal. The lower weight itself means that transport and handling have less impact on the environment, while also permitting installation close to the protected equipment, saving space and cost. In addition, ABB's integrated production process is emission-free.

Growing market share

After achieving a successful breakthrough in the lower voltage systems, these arresters are now rapidly gaining ground at the higher voltage levels. ABB has already supplied these arresters to North America for use in an 800-kV grid.

When ABB began selling polymer arresters the technology was still relatively expensive but, in the meantime, it has become very competitive. Delivery times are short and the product has gained a reputation for excellent technical performance.

Utilities are changing from porcelain to polymer insulation at a fast rate, and ABB has doubled production capacity for PEXLIM to meet growing market demand. The lead times have been considerably shortened by fine-tuning the process parameters and by introducing statistical methods and leaner logistics. Some countries now ask only for polymers. Last year, PEXLIM constituted over half of arrester production for applications up to and including 245 kV. This dramatic success is fueled by a growing market share and by replacement of ABB EXLIM porcelain arresters.

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Understanding Fuel Cells
Continued from page 9

cell, the inefficiencies are associated with four distinct processes:

- Activation Losses;
- Fuel Crossover Losses;
- Ohmic or Resistance Losses;
- Mass Transport Losses.

Activation losses are associated with the activity of the fuel cell — i.e. its ability to dissociate hydrogen and drive the chemical reaction at low temperatures. Activation losses are governed by the temperature and pressure of the reactants, the construction of the cell, and the type and amount of catalyst used.

Fuel crossover losses are caused by leakage or diffusion of fuel between the fuel cell anode and cathode. Essentially the fuel is "short-circuiting" its normal reaction path and reacting with oxygen directly at the cathode. As the electrons participating in the reaction have not been forced to travel through an electrical circuit to complete this reaction (and do useful work), the only energy produced is in the form of heat.

Ohmic or resistance losses are the result of the electrical resistance of the cell to current.

Mass transport losses occur when the ability to maintain adequate concentrations of hydrogen and oxygen in the fuel cell is limited by high demand.

All of these losses combine to produce heat in the fuel cell.

How big can a fuel cell be?

Fuel cells can be manufactured as large or small as necessary for the particular power application. Presently, there are micro fuel cells that are the size of a pencil eraser and generate only a few milliwatts of power while there are others large enough to provide the electrical needs of hundreds of homes. Since an individual fuel cell may theoretically produce an open circuit voltage of approximately 1 V, their power output is fully scalable by varying the cross-sectional area of each cell to obtain the desired current and by stacking multiple cells in series to obtain desired voltage.

What are the advantages of using fuel cells?

Fuel cells are clean, highly efficient, scalable power generators that are compatible with a variety of fuel feed stocks and can therefore be used in an assortment of power generation applications. In particular, they offer several advantages over other technologies:

Fuel cells produce electricity without combustion, which means that, unlike internal combustion engines, they generate little (if any) noise, vibration, air pollution, or greenhouse gases and operate at high efficiencies over a wide range of loads.

In small consumer devices and for powering zero emission vehicles, fuel cells, unlike batteries, avoid the need to replace the cell or undergo a lengthy recharging cycle when its fuel is "spent". Additionally, since fuel cells store their fuel in external storage tanks, the maximum operating range of a fuel cell-powered device is limited only by the amount of fuel that can be carried.

In distributed power generation applications, fuel cells reduce the load on the grid and also eliminate (or reduce) the need for overhead or underground transmission lines, which are expensive to install and maintain, and result in power losses/efficiency reductions. Since fuel cells are scalable and can be installed on site, they reduce the need for large power generation plants (and the environmental impacts of such large scale plants).

Are there any safety issues with fuel cells or their fuels?

Fuel cells are equally safe as existing technologies. For a discussion of the safety aspects related to fuels for fuel cells please refer to any of the following web sites:

Canadian Hydrogen Association
www.h2.ca
International Association for Hydrogen Energy
www.iahe.org
Natural Resources Canada
www.nrcan.ca

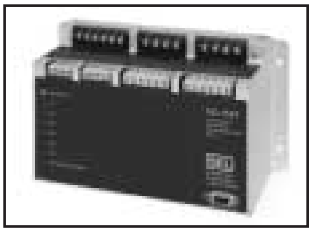
When will fuel cell-powered products be available?

Fuel cells will be available in commercial quantities in the very near future. While several companies do currently sell fuel cell power generation units, they are primarily used in pre-commercial field trial and demonstration installations.

From Fuel Cells Canada's "Fuel Cell Technology: FAQ". www.fuelcellscanada.ca **ET**

CLASSIFIEDS

PRODUCT SHOWCASE



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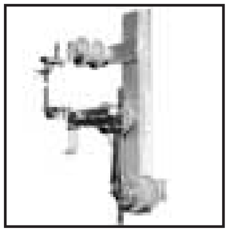

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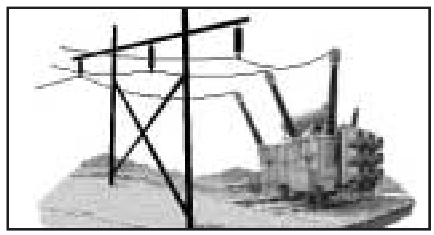

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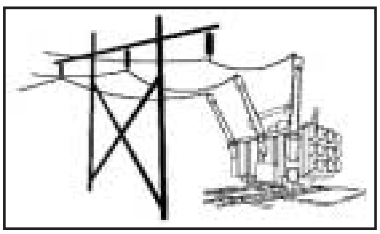

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NEWS

Irving Oil submits permit application for proposed cogeneration facility at Irving Oil Refinery

Irving Oil announced that it plans, along with TransCanada Energy Ltd, a wholly owned subsidiary of TransCanada PipeLines Limited, to develop a cogeneration facility at the Irving Oil Refinery in Saint John, New Brunswick. The proposed facility would use natural gas as a fuel to produce power and steam. The project would cost an estimated $80 million (CDN), and would create approximately 200 jobs over the course of construction.

"We have always said - perhaps to the point of being boring about it - that being part of the process to bring natural gas to this region and making the recent investment in our refinery would make these types of additional projects possible, and would attract other companies to invest in this region," said Kenneth Irving. "We're very excited about this project's potential to add yet another building block to the regional energy infrastructure, and to broaden the foundation for future investments."

The proposed project supports New Brunswick's Energy Policy, and would further enhance energy efficiency and operational reliability at the Irving Oil refinery. The White Paper on New Brunswick Energy Policy (January 2001) states, "The province will promote cogeneration as the most energy efficient electricity generation option."

An Order in Council was issued from the New Brunswick government earlier this year, permitting Irving Oil to generate power at the facility. The current application to the Department of Environment and Local Government, in accordance with New Brunswick environmental assessment regulations, is the next step in the process to build the proposed facility.

Founded in 1924, Irving Oil is a regional energy processing, transporting and marketing company focusing on supply chain management and customer service. The company serves customers in Eastern Canada, Quebec, and New England with a range of finished energy products, including gasoline, diesel, and home heating fuel, and complementary products and services.

Alberta To Overhaul Deregulated Power Industry

On August 21st, Alberta announced it plans to make several changes to the power industry it deregulated two years ago, including a controversial move to take away major cities' authority to set consumer electricity rates.

Alberta Energy Minister Murray Smith said the moves, which also include setting up an independent system operator and giving more power to the market surveillance body, were necessary to attract more competition to the industry in the western Canadian province.

Political and industry critics of Conservative Premier Ralph Klein's deregulation initiatives, which came into force during the California power crisis in early 2001, have complained consumers have never been able to choose between power providers because too few players participate.

Under the changes, slated to be enacted in the legislature next spring, the Alberta Energy and Utilities Board will have final say over the rates charged by the big municipally owned utilities, Edmonton's Epcor Utilities Inc. and Enmax Energy Corp. of Calgary.

Since deregulation, the utilities have expanded operations beyond their city limits, so they should be subject to the same regulation as private companies operating elsewhere in the province, the government said.

Calgary Mayor Dave Bronconnier has already blasted the idea as an attempt by the provincial government to force a sale of Enmax to private investors. Bronconnier was elected last year after promising to put the brakes on previous plans to sell the utility.

Among other changes to the Electricity Utilities Act is the establishment of an independent system operator to assume responsibility for such market operations as the Power Pool, where spot electricity prices are set, as well as system control and long-term transmission planning.

In addition, the Market Surveillance Administrator, responsible for making sure the industry is competitive, will report to the Energy and Utilities Board. It currently reports to the council of the Power Pool. — Source, Reuters

Brascan Power Buys Lake Superior Power Plant

Brascan Power, the energy subsidiary of Brascan Corp. is buying the remaining 50 per cent of the Lake Superior Power Generating Facility in northern Ontario from Duke Energy for $65 million.

Brascan Power, which already owns 50 per cent of the power plant, said in a release today that it will pay for the acquisition with $30 million in cash and will assume $35 million in debt of the partnership.

The deal is expected to close after Brascan Power gets required regulatory approvals.

"The acquisition of the remaining 50 per cent interest in the Lake Superior Power facility furthers our growth strategy of investing in high-quality, low-cost generating assets which provide sustainable and growing cash flows," said Harry Goldgut, chief executive officer of Brascan Power.

"This investment gives us 100 per cent ownership of a unique cogeneration facility. It also diversifies our power base while creating significant value through the operating synergies achieved in our combined, existing assets in northern Ontario," Goldgut said in a release today.

The Lake Superior Power facility, in Sault Ste. Marie, is a 110-megawatt, natural gas-fired cogeneration plant. The plant operates in conjunction with Brascan Power's 16 hydroelectric power plants in northern Ontario, which together produce a total of over 940 megawatts.

All of the plant's energy production is under long-term contract to the Ontario Electricity Finance Corp.

"The sale of our interest in the Lake Superior Power project is an example of Duke Energy's ability to capture shareholder value through active management of our asset portfolio and allows us to recycle capital across the enterprise," said Bruce Williamson, president and chief executive officer of Duke Energy global business development.

"Although we are divesting of this asset, we will continue to be able to serve markets and customers in Canada through other business interests," he said.

Duke Energy, based in Charlotte, N.C., is a diversified multinational energy company with an integrated network of energy assets. It has a portfolio of natural gas and electric supply and a delivery and trading business with customers across North America and in other key world markets.

Brascan Corp. is a conglomerate with operations in the real estate, financial and power generation sectors. Its power division, Brascan Power, has hydroelectric power facilities in North America. **ET**

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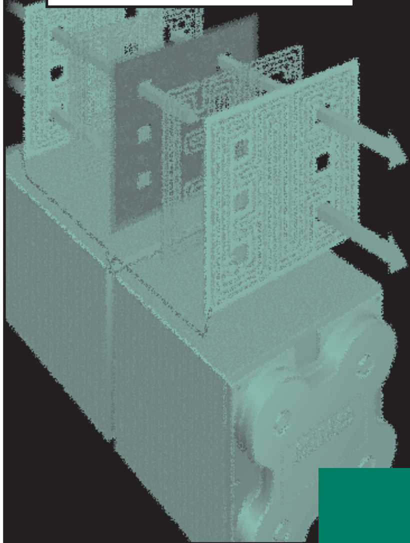

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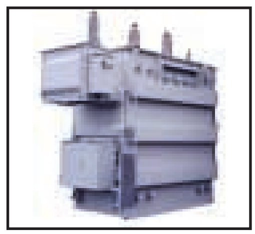

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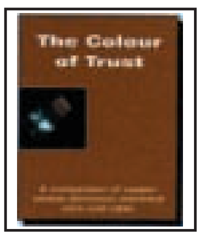

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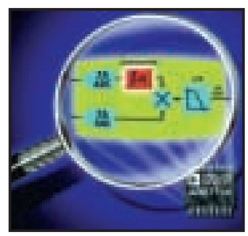

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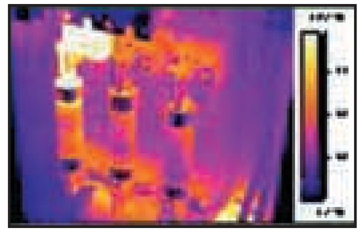

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Nynas Canada Inc.	8,56	www.nynas.com	—-
NxtPhase Corporation	49	www.nxtphase.com	www.electricityforum.com/products/nxtphase.htm
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Rondar Inc.	40	www.rondar.com	www.electricityforum.com/products/rondar.htm
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Surplec Inc.	23	www.surplec.com	www.electricityforum.com/products/surplec.htm
Terra Remote Sensing Inc.	63	www.terraremote.com	—-
Trackflow Inc.	61	www.trackflow.com	—-
Wintek Engineering	56	www.wintek-eng.com	—-

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