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ISSUE 4, 2001

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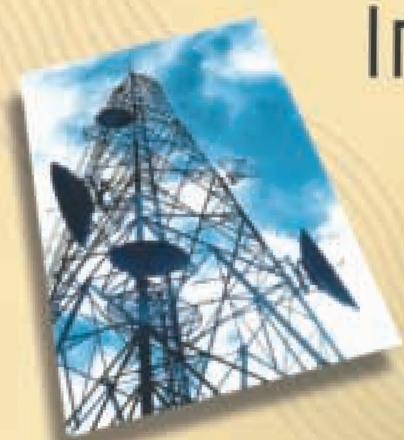

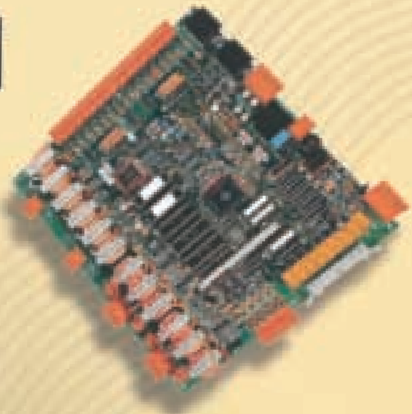

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NEWS

Joint Cory Cogeneration Project Financed

ATCO Power Ltd. and SaskPower International Inc. have announced the completion of a $182 million bond financing for the Cory Cogeneration Project. The 228-megawatt (MW) project is under construction at the Potash Corporation of Saskatchewan's (PCS) Cory Mine near Saskatoon. The $227 million project is being developed through a joint venture between ATCO Power and SaskPower International. Construction of the project began in March of this year and the facility is expected to be fully operational by November 2002.

RBC Dominion Securities and BMO Nesbitt Burns underwrote the bonds which have been rated A(low) by Dominion Bond Rating Service. Project bonds were placed with institutional investors in Canada and in the United States. The financing has a 24-year term.

SaskPower will purchase the electricity generated by the project to meet future energy needs, while the thermal energy will be sold to PCS-Cory for use in its processes at the site.

Tony Pullman, Vice President, Finance & Administration of ATCO Power said, "This financing demonstrates the growing appetite for and acceptance of Canadian project bonds in both Canada and the U.S."

ATCO Power is a world leader in the development of environmentally progressive electricity generation facilities. It has built, owns and operates power plants in Canada, the United Kingdom and Australia. It has built eight new natural gas fired projects worldwide since 1993, with a total capacity of 2,000 MW, and has four more projects under construction in Alberta. ATCO Power also operates three coal-fired generating stations in Alberta with a capacity of over 1,600 MW.

SaskPower International is a wholly owned subsidiary and the development arm of SaskPower. SaskPower has an installed capacity of 2,980 MW and maintains more than 150,000 kilometres of power lines. The corporation operates three coal-fired generating stations, seven hydro stations and four natural gas stations.

Settlement Reached With Grand Rapids Fishers

The Grand Rapids First Nation, the Grand Rapids Fishermen's Cooperative, the Grand Rapids Fishermen's Association, the Government of Manitoba and Manitoba Hydro signed a settlement agreement today, resolving all the outstanding issues and concerns of the Grand Rapids fishers related to impacts of the Grand Rapids Hydroelectric Project on the local fishery.

"The Grand Rapids fishery has and continues to play an important role in the lives of the people of the community," said Greg Selinger, Minister responsible for Manitoba Hydro. "This settlement is a key step in the development of a viable commercial fishery that will have a lasting benefit for the community. We are pleased to have worked with the fishers and Manitoba Hydro to realize this historic agreement."

The settlement negotiated by the parties is worth approximately $7 million and provides for:

- ongoing financial support in the form of subsidy to offset increased costs of future commercial fishing activities;
- annual cash distributions to retired fishers;
- the establishment of a trust fund to be used for certain capital projects (the fund will also provide financial support to assist individuals in retiring from, or entering into, the commercial fishery);
- a one-time cash distribution to active fishers, non-active fishers, retired fishers and the estates of deceased fishers who fished during the period of 1965 to 2000 (the cash distribution will also assist in addressing outstanding debt incurred by the Grand Rapids fishers in mitigating the impacts of the project); and
- the enhancement of local fish stocks.

"We are very glad to have been able to reach an agreement that will benefit all of our people," said Chief Douglas Ballantyne, Chief of the Grand Rapids First Nation. "The agreement will provide valuable resources to the fishers and the fishery of Grand Rapids. I am confident that the settlement will go a long way to ensure a viable future for our community. This is a good deal for our community."

Alpheus Cook, President of the Grand Rapids Fisherman's Cooperative said that "the fishers of Grand Rapids have worked long and hard to get a fair agreement. It was forty years ago that Manitoba built the hydro development project and this agreement will go a long way to satisfy what the fishers have been asking for. I congratulate them, Manitoba Hydro and the Province for taking the time to come up with an agreement that recognizes our situation and will mean a healthy fishery in the future."

The fishers had expressed concerns that the construction and operation of the Grand Rapids Generating Station adversely affected fish populations, and consequently, the profitability of the fishery within their traditional fishing areas on the lower Saskatchewan River and on Lake Winnipeg in the vicinity of Grand Rapids.

Commenting on the settlement, Oscar Lathlin, Minister of Conservation, said, "This agreement provides Grand Rapids fishers with hope for a sustainable future for their industry. By providing funding to support a healthy commercial fishery, the settlement sets the stage for economic development opportunities for the community. We are pleased to have had the opportunity to resolve this long outstanding issue between the Grand Rapids Fishers, the Grand Rapids First Nation, Manitoba and Manitoba Hydro. I commend the fishers of Grand Rapids for all their hard work and determination to address those issues affecting their livelihood."

Bob Brennan, President & CEO of Manitoba Hydro, said the settlement demonstrates Manitoba Hydro's commitment to working with those affected by the Corporation's projects. "I am, of course, very pleased with the outcome of these negotiations. We have achieved a mutually beneficial solution to a long-standing issue. And, I look forward to an improved relationship between Manitoba Hydro, the Grand Rapids First Nation and the Grand Rapids fishers."

Also in attendance at the announcement was Eric Robinson, Minister of Aboriginal and Northern Affairs, Rosann Wowchuk, Minister of Agriculture and Food, and Robert Buck, Mayor of Grand Rapids.

NTPC files General Rate Application

The NWT Power Corporation (NTPC) filed a General Rate Application (GRA) to the Public Utilities Board (PUB). In the application, the Corporation outlines a need to increase its revenue by some $16 million in 2001-2002. This additional revenue is needed to meet the escalating cost of providing safe, reliable electrical energy to customers.

"There have been a lot of changes in our business environment since the last time we filed a GRA with the PUB in July

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1996," notes Judy Goucher, Chief Financial Officer of NTPC. "Take the cost of diesel fuel for example. Most of the communities we serve in the NWT use power generated by diesel engines. The cost of diesel has increased by over 60 per cent, sending our costs soaring." Investment in new plant and equipment to meet the demands of our customers, the cost of borrowing, inflation and a reduction in sales in the NWT, have all contributed to a higher cost of operation.

While NTPC's application seeks greater revenue for the Corporation, the impact on customers will be cushioned. "Because of the Territorial Power Support Program, and with the removal of the recent fuel rate rider, most residential customers for example would likely see an increase in their monthly power bills of about $20 - $25," says Goucher.

Under the Territorial Power Support Program (TPSP), the rate paid for the first 700 kWh used per month by residential customers throughout the NWT is tied to the Yellowknife base rate - currently 15.76 cents. This is comparable with rates in other Canadian jurisdictions. "Providing power in the north is more challenging than in other parts of Canada," noted Goucher. "Unlike other electricity utilities, we operate a system of independent power plants that, for the most part, are not interconnected, and we service communities and a small customer base spread over a huge geographic area. Add in harsh weather conditions, and you begin to see why our employees are justifiably proud of our ability to provide such reasonably-priced, reliable power even operating in this challenging environment."

A General Rate Application process is open and interactive and provides an opportunity for NTPC and its customers to communicate on the Corporation's business operations. "Under the direction of the PUB, the Corporation will work with community and customer representatives to reach an agreement on a revised schedule of rates that will allow the Corporation to continue to provide customers with safe, reliable electrical energy" says Goucher.

Because the GRA process is comprehensive, takes a long time to finalize and reflects the actual cost of generating and distributing electricity to customers today, the Corporation has filed a separate application with the PUB requesting approval to charge customers an interim refundable rate. "We maintain it is better to pass on the actual cost of service to customers at the time of delivery" said Goucher. "This will make the transition from the old rates to the new rates easier for our customers". Because the cost of items like diesel fuel has increased so dramatically, it is critical that the Corporation maintains a financial position that in no way jeopardizes continued supply. "Like every other business, the Corporation must operate prudently and with due regard to its customers" said Goucher. "This is not the first time that the Corporation has requested approval to charge interim refundable rates and the Application has been filed with the interests of customers and the Corporation in mind".

Transalta Buys Interest In Mercury Electric

TransAlta today entered into an agreement to purchase a minority interest in Calgary-based Mercury Electric Corporation for $5 million. Mercury Electric Corporation is a privately held independent power producer focused on serving the distributed generation and oilfield marketplaces.

"We're continuing to build our investment in distributed generation," says Dawn Farrell, TransAlta's executive vice-president, Corporate Development. "Mercury Electric is one of the leading distributors of microturbines and has successfully applied this technology to flare gas markets. We look forward to a long association with them."

"This is a great opportunity for Mercury to move forward in developing cost effective, on-site generation facilities for our customers, which provides them with security of supply and long term energy price stability," said Richard Kline, president and CEO of Mercury. "We believe that our relationship with TransAlta will open up further opportunities for Mercury in the growing distributed generation and cogeneration markets. The credibility and experience which TransAlta brings to Mercury through their longstanding service in the Alberta and international power markets will clearly enable us to build on our successful distributed generation efforts."

This is TransAlta's second investment in a distributed generation company. The first was a $5.2 million investment in The ADCO Group of Companies announced April 9. ADCO and Mercury have different approaches to delivering distributed generation. Participation in both of these companies will give TransAlta better visibility of how small generation provides solutions to customer needs.

Distributed generation, often natural gas-fired, uses small-scale electric generators close to the user or load being served, rather than large centralized power stations. Distribution and transmission costs are reduced as power is generated directly on the user's site, which is particularly effective in remote areas or when lines cannot be upgraded.

TransAlta is building a portfolio of investments in emerging power and environmental technologies. The company aims to increase the competitiveness of TransAlta's core businesses and gain exposure to the growing markets for distributed generation and renewable energy. Through its Technology and New Ventures group, TransAlta follows emerging power technology trends and leverages its experience as a strategic industry venture partner with investments in promising new firms.

As an IPP, Mercury employs a range of power generation solutions from 75 kW to 20 MW. Mercury is the exclusive Western Canadian distributor of the Honeywell Power Systems Parallon 75 (R) microturbine, and has preferred distribution rights for waste gas and oilfield applications throughout the Americas. Mercury is the largest Honeywell microturbine fleet owner and world leader in employing microturbine technology for waste gas mitigation, turning an environmental liability into useful energy.

TransAlta is an international electric energy company with more than $7 billion in assets. The company is focused on achieving strong earnings growth and enhancing its competitive edge as a low-cost operator of generation and transmission assets, and a successful developer of gas-fired independent power projects. The company is concentrating its growth in Canada, the United States, Australia and Mexico. TransAlta owns and operates more than 8,000 megawatts of generation plus significant transmission assets in Alberta.

Ontario Energy Board and IMO "Stay the Course" for Fall 2001 Market Readiness

In a joint letter issued April 27th to all electricity market participants, the OEB and IMO stated they are committed to their existing schedule for participants to be market ready by the fall 2001, and will continue to monitor progress towards this goal.

The milestones and timelines related to the OEB/IMO Electricity Market Readiness Plan are available on the organization's respective web sites:

- www.oeb.gov.on.ca
- www.theIMO.com

On April 23rd, Energy Minister Jim Wilson announced that the government is "confident that conditions necessary to open the electricity market to competition will exist by May 2002" — or possibly earlier, if all the necessary conditions exist. One of the necessary conditions is for market participants to be market ready. Therefore, the OEB and IMO intend to maintain the momentum towards readiness and to hold to their existing schedule that targets market readiness for the fall 2001.

National Energy Board Releases Electricity Market Assessment

Even with rising electricity demand in recent years, most Canadian provincial electricity markets are adequately supplied according to a report released today by the National Energy Board.

The Board's latest Energy Market Assessment report entitled Canadian Electricity Trends and Issues examines electricity demand and generation in Canada and provides a province-by-province analysis of trade, regulatory developments (including restructuring initiatives) and electricity prices.

"We consulted a variety of stakeholders including those in generation, transmission and distribution companies, marketers, end-users, consumer groups and government agencies to prepare this report," says Board Chairman Ken Vollman. "Our analysts found that Canada has a regionally diverse market and, therefore, the extent of industry restructuring depends

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on the characteristics of the individual markets."

The report notes that most Canadians, except for Albertans, have experienced stable electricity prices during the last few years. Canadian electricity generation is predominantly hydro-based and, as such, is cost-competitive with many North American jurisdictions. In fact, most hydro-rich provinces have surplus energy available for domestic and international trade.

As part of its mandate, the Board continually monitors the Canadian supply of all energy commodities (including electricity, oil, natural gas and their byproducts) and the demand for Canadian energy commodities in both domestic and export markets. This report is part of a series of Energy Market Assessment Reports and focuses on current issues specifically related to electricity.

TransCanada Power, L.P. Terminates Acquisition Discussions

TransCanada Power, L.P. (the Partnership) today announced that discussions with Westcoast Energy Inc. (Westcoast) surrounding the potential purchase of some of Westcoast's power generation facilities have terminated without agreement. The Partnership will continue to pursue other acquisition opportunities in the power generation sector.

TransCanada Power, L.P. is a Canadian limited partnership that offers investors solid cash flows and growth prospects. The Partnership's units trade under the symbol TPL.UN on The Toronto Stock Exchange. TransCanada Power, L.P. owns seven power plants in Canada and the United States with total generating capacity of 328 megawatts. A wholly owned subsidiary of TransCanada PipeLines Limited manages the Partnership and the operations of the assets owned by the Partnership, and owns 41.6 per cent of the Partnership.

Ontario Power Generation and Bruce Power Complete Lease Agreement for Bruce Nuclear Stations

Ontario Power Generation (OPG) and Bruce Power today announced the successful financial close of the transaction related to Bruce Power's lease of the Bruce nuclear power stations from OPG.

Bruce Power is now the licensed operator and will lease the Bruce A and Bruce B stations until 2018. The total value of the transaction is more than $3.2 billion, representing one of the largest public/private transactions in Canadian history.

There is also an option to extend the lease for up to a further 25 years.

"Today's transaction is positive news for employees, the community, the electricity consumer and the nuclear industry," said Ron Osborne, OPG President and Chief Executive Officer. "This agreement injects private equity into the Bruce facilities and represents a major step towards opening the Ontario electricity marketplace to competition. The agreement allows OPG to concentrate on accelerating the performance improvements under way at its Darlington and Pickering facilities."

"The successful conclusion of this transaction is a tribute to the many people who have worked to see this historic agreement through to completion," said Robin Jeffrey, Chairman Designate of British Energy plc and Chairman of Bruce Power. "Bruce Power looks forward to playing a vital role in the success of nuclear power in Canada."

"The teamwork we have seen during transition is an example of what Bruce Power can do by achieving through people," said Duncan Hawthorne, Chief Executive Officer of Bruce Power. "I really would like to say 'thank you' for the support and enthusiasm we have received from employees, the unions and the local communities."

The Bruce Power stations are located near Kincardine, Ontario, about 250 km northwest of Toronto

The $3.2 billion transaction includes an initial payment of $625 million, before various closing adjustments, paid in three installments, as well as annual lease payments. The lease payments include monthly fixed payments and periodic variable payments. The variable payments include a net revenue-sharing arrangement and supplementary payments for the management of used fuel. In total, fixed and variable payments are estimated to be about $150 million in calendar year 2002.

Bruce Power is a partnership among British Energy, the UK's largest electricity generator, Cameco Corporation (15 per cent), the world's largest uranium fuel supplier and the two main unions representing employees on the Bruce site, the Power Workers' Union (up to 4 per cent) and The Society of Energy Professionals (up to 1.2 per cent). British Energy's current interest of 85 per cent will reduce progressively to 79.8 per cent as the unions take up their full equity interest in Bruce Power by May 2003.

"This transaction represents a major step forward in our North American strategy, enabling us to deploy both our existing nuclear operating skills and our experience of trading in competitive markets," said British Energy Chairman, Sir John Robb.

"Our partnership with British Energy, the Power Workers' Union and The Society of Energy Professionals underscores the confidence we all share in the future of nuclear electricity," said Bernard Michel, Cameco's Chair and Chief Executive Officer and a member of the Bruce Power Board of Directors. "We are pleased to leverage our uranium expertise in this unique opportunity that builds on Cameco's long-term strategy to grow profitably in the nuclear industry."

Bruce Power welcomes some 3,000 employees who are transferring from OPG to Bruce Power effective today. As part of the positive relationship with the unions at the Bruce site, Bruce Power is honouring the current collective bargaining agreements and will safeguard existing pensions and other benefits.

"This event marks the beginning of a new era for our employees and the local communities," said Dennis Fry, Power Workers' Union Executive Board member and PWU nominee to the Bruce Power Board of Directors.

"Based on the principles of 'Safety First' and employee empowerment that we share with Bruce Power, we are looking forward to working with our partners to make Bruce Power both a business and employment success."

Don MacKinnon, Power Workers' Union President, said the Bruce transaction deserved top marks for its positive impact on air quality in Ontario and surrounding jurisdictions. "Bruce Power and Ontario Power Generation's commitment to improving nuclear performance at their respective stations means the production of more clean-air electricity."

"We have successfully entered, not only into a partnership with new owners but, into an entirely different atmosphere," said representatives of The Society of Energy Professionals. "It's our past accomplishments that have allowed us to get to where we are today and it will be our future actions and behaviours that will determine our success in this new environment," said Society Unit Directors John Hebb, Rod Sheppard and Bob Wells. "Congratulations Bruce Power. We look forward to working with you to secure exciting and long-term working relationships and career challenges for both our members and communities."

The Bruce nuclear power stations include four operating reactors at the Bruce B station, with a capacity of 3,140 megawatts, and four laid-up reactors at the Bruce A station.

Following a condition assessment that confirmed the technical feasibility and economic soundness of restarting two Bruce A reactors, Bruce Power recently announced the launch of a program to restart the two reactors by 2003. The restart is conditional on obtaining regulatory approvals and achieving performance targets for the four operational reactors at Bruce B. The two Bruce A reactors have a capacity of 1,500 megawatts.

All the output from the Bruce stations will be sold into the new Ontario electricity market, scheduled to open to competition by May 2002. In the meantime, the output will be sold to OPG under transitional arrangements.

Ontario Power Generation is an Ontario-based company, whose principal business is the generation and sale of electricity to customers in Ontario and to interconnected markets. OPG's goal is to be a premier North American energy company focused on low-cost power generation and wholesale energy sales while operating in a safe, open and environmentally responsible manner.

The Bruce Power stations are located near Kincardine, Ontario, about 250 km northwest of Toronto. ET

INDUSTRY EVENTS

2001 IEEE/PES SUMMER MEETING:

Powering A New Wave

Vancouver, BC • July 15-19, 2001

The 2001 IEEE/PES Summer Meeting Committee extends a warm invitation to its colleagues around the world to attend the 2001 IEEE Power Engineering Society Summer Meeting in spectacular Vancouver, British Columbia.

This premier conference will focus on innovative technologies and market changes that are revolutionizing the electric power industry, and how embracing these changes will Power a New Wave of technological advancements and business success. The technical program will comprise a broad choice of paper and panel sessions, technical and standards committee meetings, tutorials, inspection tours and student activities. Complementing the technical program will be a number of exciting social events and companion activities that will provide unique insights into one of the world's most beautiful cities.

The theme of the meeting is Utilization, Reliability and Control of the Power System - Megawatt and Beyond. The technical program is focused on four preferential topics:

Utilization: utilization beyond conventional limits; secondary use of the system for telecommunications and other purposes; impact of power electronics on end-use utilization; asset management techniques.

Reliability: market environment; reliability standards and compliance; integration of legacy systems into the new reliability standards; reliability versus economics and in-situ testing of components; impact of inexpensive, widely dispersed distributed generation and storage, including fuel cells; implications of 'micro' versus the present 'mega' systems.

Control: direct load control; wide area monitoring and control; distributed generation control.

Computation: Internet- and Web-based computation for power engineering; symbolically assisted computational tools.

The 2001 Summer Meeting commences on Sunday, July 15th, with recreational activities, registration and the Welcome to Vancouver evening reception.

The technical program begins on Monday with the PES general membership meeting, followed by the plenary session, and continues through Thursday.

Hotels and Facilities

Technical sessions and main activities will be headquartered in the Hotel Vancouver and the Hyatt Regency Hotel, located at the corner of Georgia and Burrard Streets in the heart of downtown Vancouver. Some meetings will be scheduled in other nearby hotels. Meeting registration will be at the Hotel Vancouver.

Arrangements have been made with the Hotel Vancouver, Hyatt Regency Hotel and other hotels to provide accommodations for meeting delegates. All hotels are in close proximity to the headquarter hotels. Hotel information, rates and booking procedures are provided on the Hotel Registration Forms and on-line at www.ieee-spm2001.org/html/register.html.

It is anticipated that hotel accommodation will be in high demand in Vancouver this summer. Delegates are strongly encouraged to make hotel requests in advance of the June 11th deadline to secure accommodations at the IEEE room rate.

General Membership Meeting

The PES General Membership Meeting will be held on Monday, July 16th, at 8:00 a.m. in the British Columbia Ballroom of the Hotel Vancouver. Complimentary coffee and rolls will be available prior to the meeting. All members are encouraged to attend this meeting where Power Engineering Society President Don Volzka and the PES Governing Board will discuss Society goals and issues, and respond to questions from the membership.

Plenary Session

The Conference Plenary session will be held on Monday, 16 July, immediately following the General Membership Meeting, in the British Columbia Ballroom of the Hotel Vancouver. The Plenary session will include a panel of leaders from industries that both rely on and provide support to the electric power industry. They will address the topic 'Powering a New Wave — Megawatt and Beyond', describing their vision of the changing needs and requirements of the electric power industry, driven by advances in technology and increasing customer choice. Panelists will represent views from the Information Technology, telecommunications, manufacturing, transportation and electric utility sectors.

Showcase of Innovation

The 2001 Summer Meeting will feature a special display of the newest and most innovative developments in power engineering today. The Showcase of Innovation will introduce breakthrough technologies from around the world that will have a profound influence on the power industry in the 21st century.

Tutorial Courses

As with past meetings, tutorials presented at the PES Winter meeting will be again offered at the PES Summer meeting. There will be three informative and timely tutorials, sponsored by the PES Power Engineering Education Committee. The fee for each tutorial is $150 US/$225 CDN, in addition to the conference registration fee. The sessions are:

Power System Fundamentals

(Tuesday, 8:00 a.m. to 5:00 p.m.)

The Power System Fundamentals tutorial is offered for those who are working in the electric power industry and would like an opportunity to learn or review some of the basics of power system engineering. The tutorial assumes participants possess a general engineering background. The topics include three phase circuits, symmetrical components and sequence networks, power transformers, the per unit system and power flow, symmetrical and unsymmetrical faults, system protection, automatic generation control, and power system transient stability. Computer demonstrations will be given at appropriate points during the class. The tutorial registration will include notes that will be provided by the instructor.

Electromagnetic Transient Program Applications to Power System Protection

(Wednesday, 8:00 a.m. to 5:00 p.m.)

Sponsored by the PES Power System Relaying Committee, the Electromagnetic Transient Program Applications to Power System Protection tutorial will cover the capabilities of the electromagnetic transient program (EMTP) and make power system protection engineers more aware of its potential applications in the areas of power system protection, relaying modeling, and relay testing. The tutorial covers the fundamental EMTP modeling issues and provides guidelines for modeling key power system components, instrument transformers, and protective relays. The material is focused on modeling of low and slow front transients that are applicable to power system protection modeling. The course does not provide modeling guidelines for fast and very fast front transients. The tutorial will focus on the following areas: EMTP solution basics, applications to power system protection, fault induced transients, network equivalent representations, synchronous machines, power transformers, transmission lines, nonlinear elements, relay input sources, control systems (tacs), relay models, and bibliography.

Voltage Fluctuations and Lamp Flicker in Electrical Power Systems

(Thursday, 8:00 a.m. to 5:00 p.m.)

The Voltage Fluctuations and Lamp Flicker tutorial will address issues associated with voltage and lamp flicker and will specifically focus on the existing IEC flicker standards and their possible adoption in North America. The tutorial content will cover a history of voltage flicker, a detailed discussion of the flicker limits, and numerous application case

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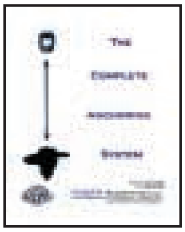

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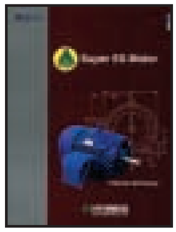

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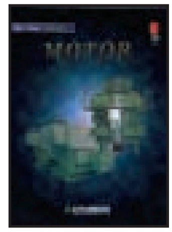

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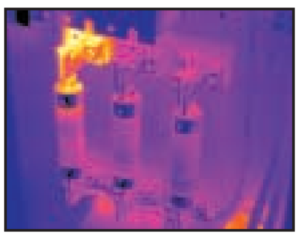

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Continued from page 13

studies involving various fluctuating loads, including welders, arc furnaces, and wood chippers.

The tutorial will familiarize practicing engineers with these flicker measurement and application procedures. The instructors will include internationally recognized experts in the field of flicker measurement, prediction, analysis, and mitigation.

Awards Luncheon

The Awards Luncheon will be held at noon on Tuesday in the Hyatt Regency Hotel. Registrants may purchase luncheon tickets for $15CDN / $10USD. Join us in recognizing distinguished members of the Power Engineering Society for their outstanding contributions to the electric power industry.

Technical and Standards Committee Meetings

Committee meetings are scheduled on each day of the conference. A listing will appear in the preliminary and final Meeting Programs. Please check the Meeting Program for scheduled dates, times and locations.

Late changes will be noted on errata sheets and will be posted in the Registration area.

Technical Tours

A variety of tours are planned that will heighten technical interest and provide an opportunity to see the city of Vancouver and the surrounding area. Attendance will be limited for each tour so be sure to book early! The planned tours are:

BC Hydro / Powertech Labs Hydrogen Research and Demonstration Centre

(Monday 1:30 p.m. to 5:00 p.m.)

The Vancouver area is a world leader in fuel cell and hydrogen technologies. Not a day goes by that we don't hear news of this rapidly evolving breakthrough technology. BC Hydro and its research subsidiary, Powertech Labs Inc., have embarked on a bold strategy to lead the development of hydrogen supply infrastructure for transportation and stationary/portable power markets, using sustainable electricity sources for hydrogen production.

This informative tour to Powertech Labs' 11,500 square meter facility in Surrey will include a presentation on BC Hydro's hydrogen development plans and inspection of test and demonstration facilities for vehicle on-board hydrogen storage and fueling.

The tour will conclude with an inspection of BC Hydro's 75 kW microturbine generator demonstration project and a visit to the largest high voltage test hall on the West Coast.

E-Comm Emergency Response Center

(Monday 2:00 p.m. to 4:30 p.m.; Thursday 9:00 a.m. to 11:30 a.m.)

Did you ever wonder what happens when you dial '911'? This tour will show you!

E-Comm is an integrated communication center that provides coordinated and cooperative emergency relief with common dispatch and response for fire, ambulance and police. This facility went operational last year and is a showcase in North America for the support of public safety in normal and disaster operations.

Stave Falls Generating Station Redevelopment

(Tuesday 9:00 a.m. to 4:30 p.m.)

This is BC Hydro's newest hydroelectric generating station, placed in service in 1999 right next to the original Stave Falls plant which went into commercial service in 1912. The original plant is now a Visitor Center which focuses on the past, present and future of electric generation. This is a 'must see' tour of the new and old and includes lunch on the shores of beautiful Hayward Lake.

General Motors Place "Behind the Scenes"

(Wednesday 8:30 a.m. to 11:00 a.m.; Wednesday 2:00 p.m. to 4:30 p.m.)

This is the downtown home of the NBA Vancouver Grizzlies and the NHL Vancouver Canucks. This tour is a 'behind the scenes' view of a modern sports complex which is also a venue for world class performers.

Experience the 'broadcaster view' along with the extensive control and operation features that can convert a facility for 18,000 people from basketball to ice hockey or to a rock concert in less than 18 hours.

Bombardier Transportation Assembly Plant

(Wednesday 8:30 a.m. to 11:00 a.m.; Wednesday 2:00 p.m. to 4:30 p.m.)

In 2000, Bombardier opened a manufacturing and assembly plant to produce the rail cars for the new Vancouver Skytrain rapid transit Millennium Line extension. The plant will also serve markets on the West Coast and in Asia.

This tour shows what goes into modern light-rail rapid transit vehicles with linear induction-motor propulsion and other advanced technology features. You will see the assembly process from the raw shell to a fully assembled and tested vehicle.

Conference Proceedings

One copy of the 2001 IEEE PES Summer Power Meeting Conference Proceedings, in CD format, will be provided at no charge to each conference delegate including students (companions and media excluded).

Additional CD copies can be purchased at the conference for $50 US / $75 CDN, or after the conference from IEEE Customer Services.

Registration Information

Advance registration, with an "Early Bird" discount, is offered to conference delegates and companions who register by June 11th. Fees for advance registration are $295 US / $442 CDN for IEEE Members, $425 US /$637 CDN for non-IEEE Members, $10 US/$15 CDN for IEEE Student Members, and $30 US/$45 CDN for Companions.

After June 11th, fees are $345 US/$517 CDN for IEEE Members, $475 US/$712 CDN for non-IEEE Members, $15 US/$22 CDN for IEEE Student Members, and $35 US/$52 CDN for Companions.

IEEE Life Members, their Companions and members of the press may attend free of charge. All attendees, including presenters, are required to register and to pay the appropriate fees. IEEE Student Members are required to have proper student identification cards.

Non-members are invited to join the IEEE and PES at the meeting. The $130 US/$195 CDN differential between member and non-member registration fees can be applied toward first-year membership dues.

For More Information

For more information, please check the Summer Meeting web site: www.ieee-spm2001.org, the PES web site (http://www.ieee.org/power) and future issues of IEEE Power Engineering Review.

Specific questions also may be directed by email to info@ieee-spm2001.org. ET

POWER QUALTIY Q&A

Our Expert Offers Answers to Frequently Asked Questions About Power Quality

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

Question:

We have a number of resistance welding machines in our plant. I have heard that they can create power quality problems. What kind of problems can occur and how can I determine if I have them?

Answer:

A resistance welder will typically perform a series of welds in its cycle, each of which can draw several hundred amperes for a very short time. If insufficient attention was paid in the design of the distribution system, some significant problems can occur.

First, one must consider the effect of voltage drop on the feeders supplying the welder. If the conductors have too much resistance for the peak current, the voltage will degrade momentarily during the weld such that other loads on the circuit may malfunction or 'drop out'.

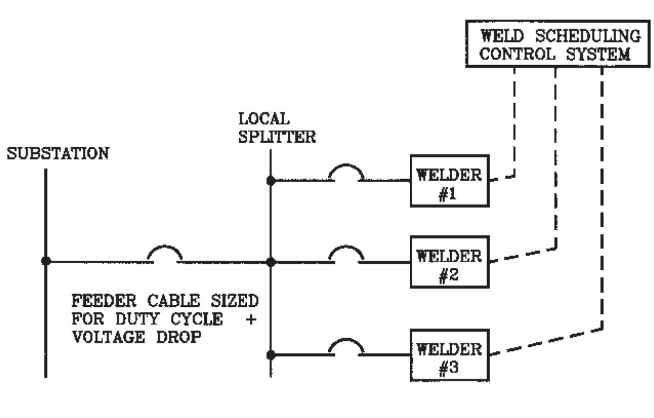
Second, the conductors feeding the welder must be of sufficient size to handle the heavy ampere duty cycle of the welder. If the feeder is too small, the cable and connections may overheat and fail.

The best way to avoid problems is to supply each welder with its own properly sized feeder connected to a 'stiff' bus in the plant. This may be impractical in some cases and thus some compromises must be made.

If multiple welders are connected to one feeder, it may be necessary to schedule the occurrence of the welds with a PLC or some means of control. In this way two or more welds will not 'hit' at the same time creating a severe voltage drop or current draw beyond the feeder cable capacity. Other sensitive loads should be removed and placed on a more stable bus.

Power quality problems associated with resistance welders are electronic equipment malfunctions, contactors dropping out, bad welds, and overheated connections.

An audit of the distribution system by a professional engineer should uncover any potential problems. Monitoring equipment capable of capturing fast transients can also identify damaging situations. Proper design in the first place can save a lot of woe down the road.



TYPICAL RESISTANCE WELDER SCHEDULING

Question:

We have a delta connected secondary distribution system in our facility. I've been told that this is an undesirable type of distribution from a power quality standpoint. Can you explain this?

Answer:

The delta-delta transformer was a very popular means of providing the main system voltage in process plants and other critical processes where continuity of service was important. Because the delta-connected secondary has no hard connection to ground, one phase could go to ground without affecting the phase to phase voltages on the system. The theory was that if a fault occurred, the system remained operational while one

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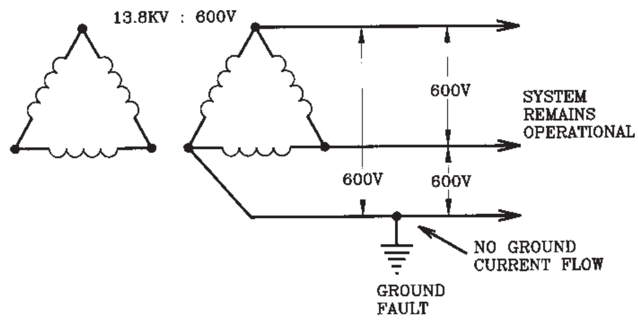
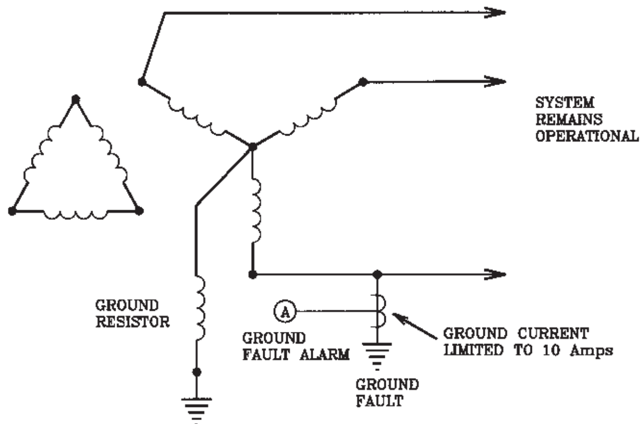
Power Quality Q&A,
Continued from page 15



FAULT CONDITIONS FOR DELTA SECONDARY



FAULT CONDITIONS FOR HIGH RESISTANCE WYE SECONDARY

looked for and repaired the fault.

However, with the explosion of electronic equipment on our power systems, some concerns about power quality have arisen.

Because the secondary is effectively floating with respect to ground, disturbances have the potential for raising voltage levels. The creation of noise is more prevalent. In severe cases, arcing ground faults have raised system voltages to more than twice normal levels, destroying motors and lighting throughout the plant.

The modern day practice for critical systems is to utilise a grounded wye secondary with a high resistance in the ground leg. This allows a phase to ground fault without tripping off the system. The fault current is restricted to around 10 amperes, which can activate an alarm to indicate a ground fault.

The difference is, that because the secondary is grounded, the susceptibility to electrical noise and elevated voltage levels is greatly reduced.

The same effect can be achieved on older delta systems by installing grounding resistors or a zigzag transformer to tie the system to ground and still maintain system continuity.

David is the President of Wintek Engineering. You can forward your questions or comments to him at wintek@wintek-eng.com. Some of these questions will be addressed in future issues of Electricity Today ET

Power Management System Helps Plant Reduce Energy Demand

by L.E. Crossley, P.Eng. and M. Demysh, P.Eng.

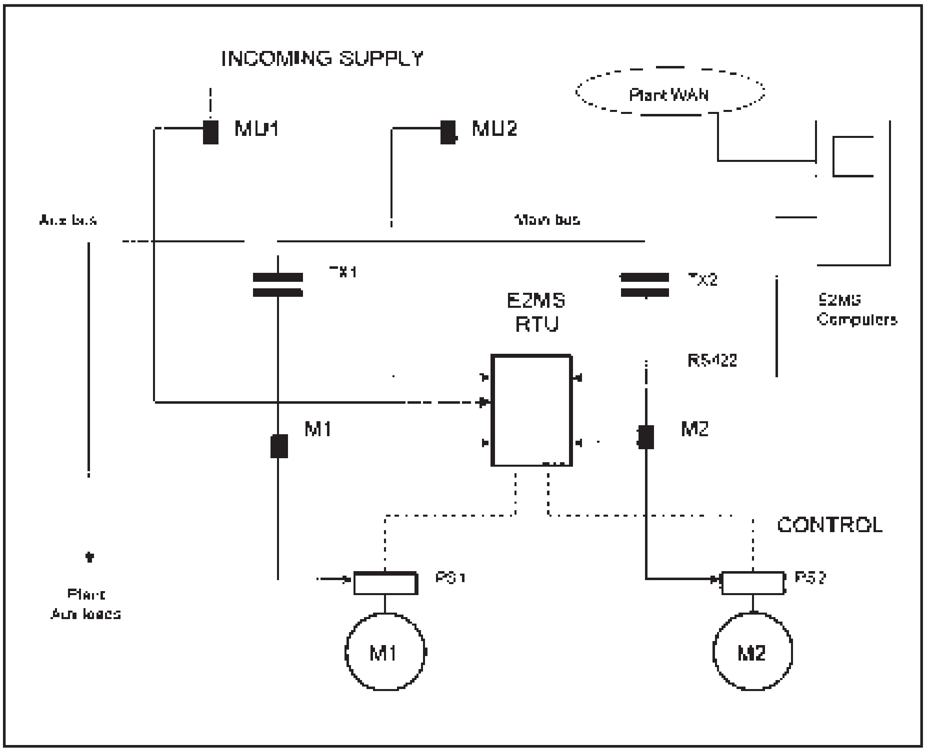


Figure 1

Diversa Cast Technologies is a manufacturing company specializing in producing aluminum, gray and ductile iron automotive lost foam castings. A power management system is currently installed at their plant in Guelph, Ontario. This power management system is a real time demand management system allowing plant management to reduce operating costs through the automatic control of plant furnace loads with minimum interference to production levels. Based on demand control savings alone the payback for this system is under 8 months.

Experience with this system has proven that the overall demand can be reduced while improving productivity and energy consumption efficiency. The system is fully integrated with the Linamar plants wide area network permitting multiple users to access the system's real time and historical data from their existing desktop computers.

System Design

The Diversa Cast plant has an installed potential load of about 5000 kW made up of two coreless induction melters and supporting equipment. The first melter is rated at 2750 kW with 8000 lbs capacity and is used for iron batch melting in the off peak periods from 11pm to 7am.

The second melter is rated at 1250 kW with a 2700 lb capacity and is used for aluminum heal melting in the on peak periods. The plant operates on 3 shifts 5 days per week. The utility power contract provides power using a time-of-use (TOU) contract with on-peak demand penalties.

The system is shown in Figure 1. Computer equipment is installed in a free standing panel located in the plant's office area and is linked by an RS422 instrument cable to a remote terminal unit (RTU) panel located out in the vicinity of the two melters. The RTU contains data acquisition equipment consisting of a data processor, digital input/output modules and power supplies.

The plant has two utility power infeeds and two sets of meters. One feed supplies the plant auxiliary equipment while the other supplies the two melters. Each meter has two isolated output contacts providing kWh and kVARh pulse signals proportional to the energy being used. These pulse signals are wired to the RTU panel and are supplied by 24V dc power from the power supply in RTU.

The power consumption of the two melters is monitored by power transducers mounted on the melter power supply units. These transducers provide pulse outputs which are also wired to the RTU panel.

The load on each melter is controlled by the system's computers by effectively changing the operator set points by adjusting the potentiometer load control settings. The degree of control required at any time is calculated by comparing the utility metering input information with the plant's desired demand limit set point.

System Operation

The system's RTU continuously obtains electrical information from the plant's two main utility meters MU1 and MU2, and from the kWh transducers M1 and M2 located on the two melters.

The control software module monitors the energy being used and forecasts the plant's demand in accordance with the power utility billing algorithm used at the plant. By comparing the forecast demand with the desired set point demand, as determined by plant management, the computers issue control command outputs to raise or lower melter loads. These output signals are sent to the RTU panel where they operate digital output modules.

These modules in turn are connected to demand control modules mounted in the control sections of the melter power supply units PS1 and PS2. Resistance is inserted or removed from each of the melters electronic control circuits by the

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RTU output modules, to control demand.

The system users are provided with a real time graph of overall plant load versus time, with the set target load displayed, together with full analysis tools for historical and cost analysis. In addition to the overall plant total, the load on each individual melter is also shown.

The control of demand is smooth and is applied equally to both melters in three stages. Reloading of the melters is automatic after the load has fallen to the restart level as defined in the system configuration. Every time a control operation takes place the activity is written into a control log together with the time, date and demand at that time.

The load target is password protected and may be changed at any time by authorized users when on the control screen. The output control levels are computed on a minute-by-minute basis using the utility metering signals. The system has several major communication routines.

These routines are:

(a) The one minute read, on the minute, of all RTU metering counter registers. This information is used for real time load prediction calculations and for load control.

(b) The 15 minute read and clear, on the 15 minute mark, of all RTU metering counter registers. This information is filed and used for historical analysis purposes.

(c) The one minute control signal to update the outputs in the RTU in accordance with the load forecasts.

The data values returned to the computers are scaled and stored in files ready for display and analysis. Menu driven routines provide access to the stored data and logs for analysis purposes.

System Software

The software consists of the major modules as shown in Figure 2.

The real time core module contains all the functions necessary to provide data acquisition and analysis as follows:

Communications module: This module provides the data acquisition functions and interface with the control equipment via the RTU.

Display module: Provides the user interface with the system both in graphical and spreadsheet format using Windows 98/NT system software.

Analysis module: Provides graphical and spreadsheet analysis of the stored data including maximums, minimums, coincident demand data, energy use and load factors.

Report module: Provides reports on power use and plant running costs including bill verification by generating utility bill.

Database filer: Stores the data and configuration parameters in ODBC compliant database.

System and cost configuration module: This module allows the number of points to be entered, identified and utility metering algorithms assigned together with energy and demand costs.

Diversa Cast has chosen the automatic demand control option whose operation was described earlier. Other options such as alarm scanning and internet communications may be added to the overall product at a future date.

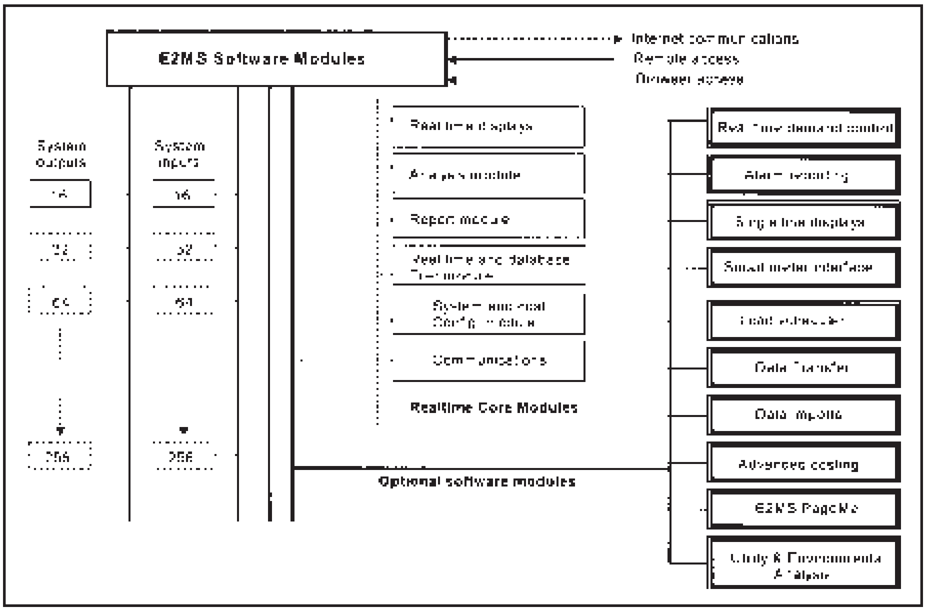

Figure 2: Software Modules

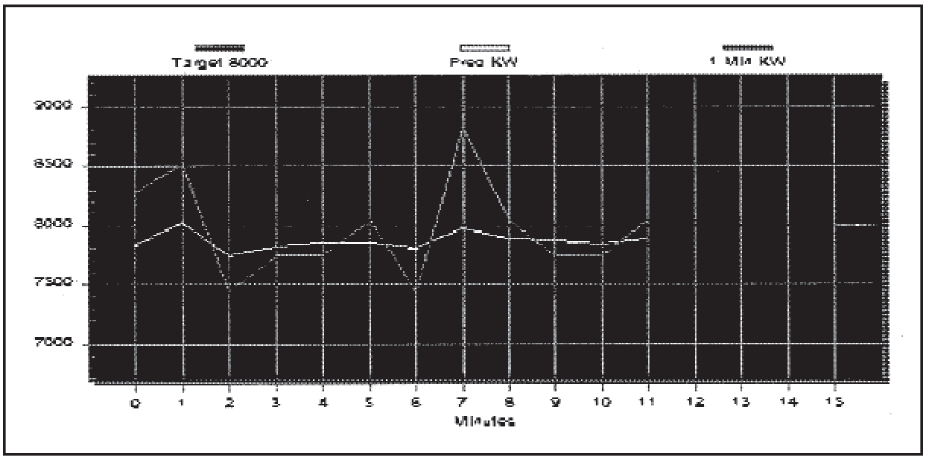

Figure 3: Portion of the Load Control Screen

System Installation and Commissioning

The system was installed by Diversa Cast Technologies electrical staff and commissioned by E2MS. After all wiring was completed, the melter control shedding components were commissioned. Each melter was provided with a three-stage load shed unit that was installed in the melter power supply control section. Each of three output modules in the RTU panel collectively control the shedding and reloading of a melter. Each output module was test energized in turn and its adjustable resistance adjusted for the desired degree of load cut-back.

The cut back in load is progressive so that as each output module is activated, the amount of running load on the melter is reduced. Final checks with each melter running at full load were carried out to verify that the load reduction percentage was as required by the plant management.

Once the melter controls were completed, the utility and melter metering signals were verified and the meter multipliers set in the system configuration software.

Attention was then focused on the

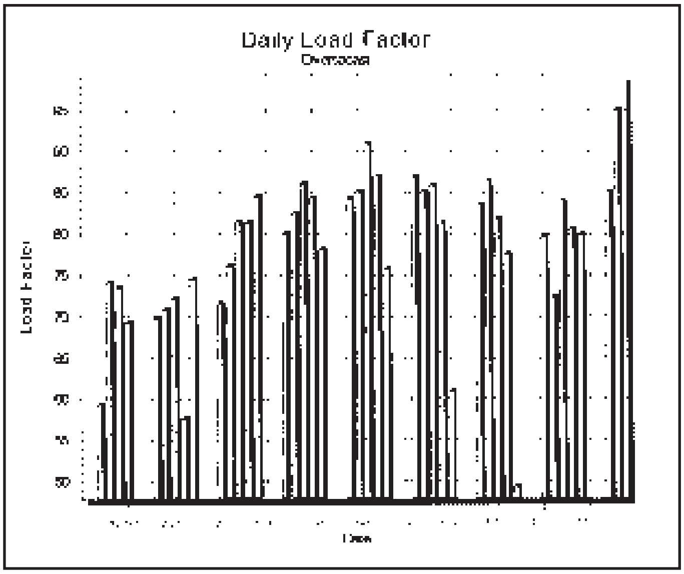

Figure 4

commissioning of the computer equipment and the associated software.

Figure 3 shows a portion of the load control screen. The user can set the target that the load control is to operate to. The display, updated once per minute, shows how the load is being controlled using the billing window as a time base.

Plant Experience with the System

The system was commissioned February 14, 2000 and has been in operation for approximately two months. The installation proceeded around production with minimal interference or delays in the melting and pouring schedules. The software has been fully operational without any unscheduled downtime.

The system was started in a monitoring mode for the first two weeks of operation to allow Diversa Cast Technologies to establish a baseline of energy demand and consumption for the plant. The demand control was then turned, on based on initial measurements for the plant melt requirements and base load.

Initial reaction from plant operators was hesitant, as it appeared to limit their ability to meet production melting requirements. This was due to the fact that operators were constantly adjusting power levels of the furnaces to meet a shared combined kW requirement between the two furnaces. Also, power was added to the system until the bath achieved the appropriate release temperature.

By modifying furnace operating procedures and appropriate operator training, Diversa Cast Technologies was able to take advantage of the available power to melt quicker and more efficiently. Operators now utilize the system along with the furnace power management system to input a preset energy kWh count along with a total kW power input. This allows the system to monitor and control the overall power input based on the demand target while allowing the furnace power management system to input the appropriate amount of energy count to the melt bringing the heat to the necessary release temperature. The overall benefit of this procedural change is that operators can now input more power over shorter periods of time to achieve higher melt rates.

Many benefits have been realized beyond the initial project justification based on demand control alone. One of the indirect benefits of limiting demand energy is that the overall Load Factor or efficiency in the way we use our energy has improved. Figure 4 shows a bar graph of the daily load factor since commissioning for the on peak periods which has grown from an average of 70 per cent utilization to an average of over 80 per cent.

Another tangible benefit is that power factor penalties can be significantly reduced by controlling when and how the peak for the plant is set. For instance, if the plant power factor is low, the peak can be reset at the end of the month using the furnaces, which are more efficient, to balance the plant power factor.

This power factor savings also occurs now because the furnace operators are able to apply higher power to the melt without worrying about accidentally resetting the peak for the month.

The software is accessible from anywhere on the WAN which allows anyone with the appropriate permissions to access and view the plant energy, cost and control information. Cost accountants as well as production managers now have the ability to get an instantaneous calculation of the electrical demand and consumption billing for budgeting and planning purposes. This system is also a valuable tool to measure productivity and effectiveness of the plant and melting operations.

As Ontario progresses towards deregulation of electrical energy and as energy costs will continue to escalate, the power management system will be an invaluable tool in helping Diversa Cast Technologies control and manage its energy and production costs.

Les Crossley is Executive Vice President, Engineering at E2MS Inc., and M. Demysh, is Engineering Manager at Diversa Cast Technologies Inc. ET

TRANSFORMER MAINTENANCE

Measuring Transformer Oil Resistivity:

Standard Methods May Not Be Completely Reliable

by Kjell Sundqvist

Resistivity is a very fundamental property of transformer oils. Ideally the oil should not conduct an electric current at all and therefore it should have a very high resistivity. It is desirable that this property, or its antithesis, conductivity (the ability to conduct electricity) is measured and recorded. Currently, two standard methods are used (IEC 247): The measurement of resistivity and the measurement of dielectric dissipation factor, tan ∂.

There is good reason to question the use of resistivity measurement, especially when it comes to alternating current applications. A working group within the International Electrochemical Commission is currently working on a review of IEC 247.

A prerequisite for a substance being able to conduct an electric current is that charges can be transported through the substance. In a fluid, it is ions that are transported. Oil has a very low conductivity, since ions, or compounds that are ionizable, do not normally occur in it. The more impurities oil contains, the greater the risk that there are ionizable impurities, and therefore that conductivity will increase.

A measure of conductivity thus provides information about a property that is of direct interest, while at the same time indicating the degree of impurities.

The three methods of measurement in IEC 247 are for permittivity, dielectric dissipation factor, and resistivity. In all three methods, oil is placed in a cell and an electric voltage is applied between two surfaces in the cell. This apart, the methods have some essential differences.

The measurement of permittivity assumes that the cell forms a capacitor with a certain capacitance. Accordingly, alternating voltage is used. If, instead of oil, there is air, or even better, a vacuum, the capacitance will be higher than if there is any conductive material between the surfaces. Thus, capacitance is measured first with oil, then with air in the cell. The ratio between the capacitance with oil and the capacitance with air is called permittivity. The theoretical minimum value is 1.

When measuring the dielectric dissipation factor, tan ∂, alternating voltage is also used. Here, however, it is the phase displacement, or loss angle, that is measured. An alternating voltage can be described as a sine shaped curve. When the alternating voltage is applied over a capacitator, a current arises in the cords connected to both of the surfaces. This current can also be described as a curve. If the impedance in the circuit only consists of capacitance, the curve describing the current deviates by 90 degrees compared with the voltage curve. If, however, there is a current going through the oil, the current curve deviates. The more current, the greater the deviation. It is the tangent on the deviation that gives a measurement of conductivity: the lower the value, the lower the conductivity (=higher resistivity).

The Usefulness of Methods

The resistivity measurement according to IEC 247 means that a continuous voltage that gives an electric field of 250 volt/mm is applied to the cell containing oil. The current is measured after 60 seconds. Resistivity is the ratio between the strength of the electrical field and the current (unit Ωm).

The three methods essentially measure the same property, but the different methods of measuring means that their practical useability and relevance varies.

When it comes to new transformer oil used in a modern transformer for alternating current, conductivity is so low that it is not in itself of any significance. The reason for measuring it, in spite of this, is because an increased value is an indication that the oil is contaminated. Contamination by an ioniz-

able substance can lead to other properties of the oil being affected, e.g. its life expectancy.

It is therefore important to use a method that correlates well with the content of ionizable impurities.

Permittivity measurement is seldom carried out, since it gives only small variations, regardless of degree of contamination.

Resistivity measurements as such have the potential for supplying relevant data. Unfortunately this does not apply to the resistivity measurement according to lEC 247. One problem is that the values from resistivity measurements are dependent on time. At the precise moment when the voltage is applied, the current is considerably stronger than after 60 seconds, which is when the measurement is carried out.

What happens is that as sonn as the current is applied, the few ions that are in the oil start to move towards the surface that has the opposite charge to their own. When positive ions start to collect at the negative pole, an excess of positive charges arises there. This repels other positive ions and thus impedes the current. Since there were already from the start very few ions, there are soon none left that can move towards the negative pole.

A corresponding process occurs at the positive pole. Thus, the current lessens and settles at a constant level. According to lEC 247, the current should be measured after 60 seconds, i.e. long after the initial peak current. Depending on the viscosity of the oil, and the character of the ionizable substances, the point in time when the current becomes constant can be displaced.

New Methods of Resistivity Measurements

There are other methods of resistivity measurements, which measure the current after a very short time using low voltage. These methods have been shown to correlate well with the dielectric dissipation method, tan ∂.

A project is currently in progress within Cigre Task Force 15.02.04 (which is part of lEC) to develop a method that will measure resistivity and capacitance at the same time (from capacitance, tan ∂ can be calculated). This work has not yet been completed, but one fact was established at an early stage: the conductivity of a fluid must be determined when the fluid is in thermodynamic balance. In order for it to be in this state, high electrical load and/or electrical load over a long period has to be avoided.

When measuring the dielectric dissipation factor, alternating current is used, which means that the phenomenon whereby charges accumulate on the surface never materialise. It could be said that the method is more relevant just because it measures alternating voltage, since it is the characteristics in the case of alternating voltage that are of interest. However, this argument is weak, since it is not actually conductivity/resistivity that is of interest, but their correlation with the level of impurities.

The conclusion is that resistivity might as well be measured, but not using the present standard method. Since there is a standard measure for the measurement of the dielectric dissipation factor and this gives relevant results, there is today no reason to use any other method. It will only be when an equally good method for measuring resistivity is in existence that it will be of interest to discuss which method is best. The work in lEC also involves a review of tan ∂ measurement. There is also scope for improvement here. For the moment, however, it is the best tool in the quality control of transformer oil.

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MOTORS AND DRIVES

Electric Signature Analysis:
New Technique for Identifying Problems in Operating Electrical Equipment

by Donald V. Ferre

Electric Signature Analysis (ESA) is a diagnostic and analysis technique that is being used to analyze motors, generators, alternators, transformers, and other electric equipment. This new technology has the ability to test operating electrical equipment and identify a variety of mechanical and electrical problems.

ESA is used to evaluate rotors, stators, and rotor-stator air gap conditions in electric motors. This is one of its prime uses. In many cases, a one-time test can be used to determine if problems are present in the motor. More often, trending is required to determine severity and changes in conditions.

Current and voltage data are acquired directly from the Motor Control Center (MCC), while the equipment is in operation. The collected data is then used to determine phase imbalance, motor load, power factor, power harmonics, and the impact of the driven equipment on the motor. Rotor bar as well as stator health and rotor-stator eccentricity (air gap) characteristics are also assessed. In addition, degraded bearings can also be observed from the traces. ESA is particularly helpful in accessing mechanical conditions when it is not possible or convenient to make vibration measurements.

Figure 1 shows the three phase current sine waves for a 15 HP motor driving a pump. The unbalance in current is about 38 per cent, much higher than acceptable to continue running this motor. When the motor was taken from service and opened up, a turn-to-turn short encompassing nearly half of one phase was observed.

Figure 2 shows the current spectrum of one phase of a motor driving a compressor. The rotor has broken rotor bars as evidenced by the amplitude of the pole passing sidebands around the line frequency peak at 59.97 Hz.

Figure 3 shows the peaks evident in the current spectrum of a motor that has a broken bearing.

The peaks highlighted by cursors are a result of the modulation of the current draw of the motor by the broken bearing.

For DC motors and motors with separate power supplies, such as variable frequency drives, ESA monitors the power supply and can point out problems in it.

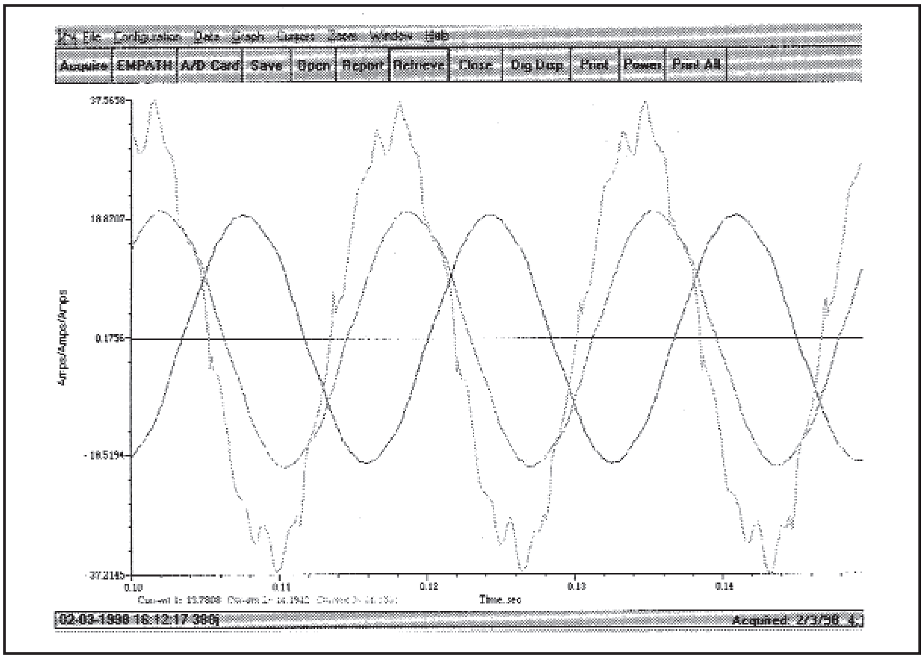

Figure 1: Three phase currents of 15 Hp motor with a severe turn-to-turn short.

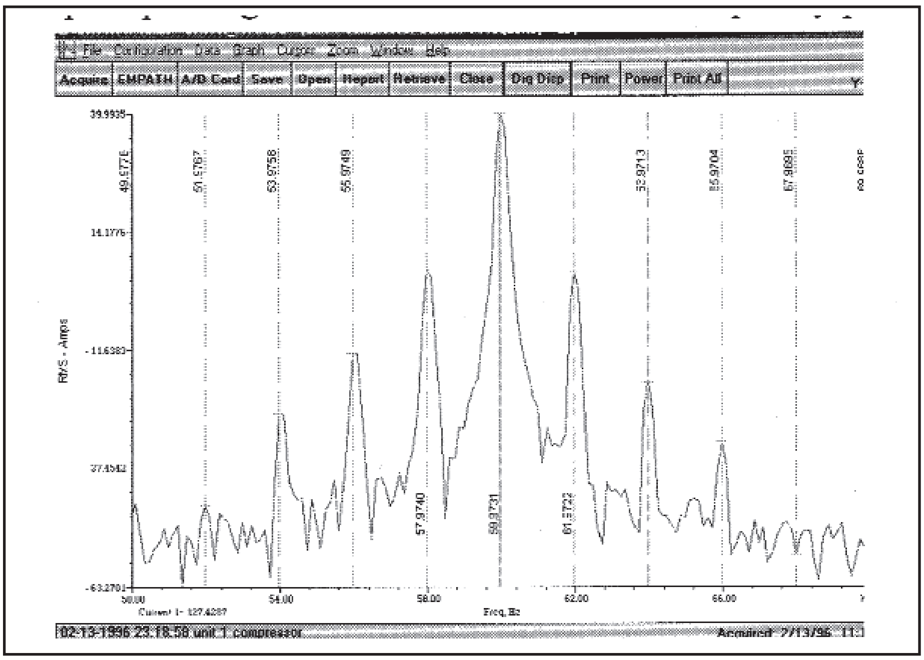

Figure 2: Current spectrum of 300 Hp motor showing pole passing sidebands to line frequency.

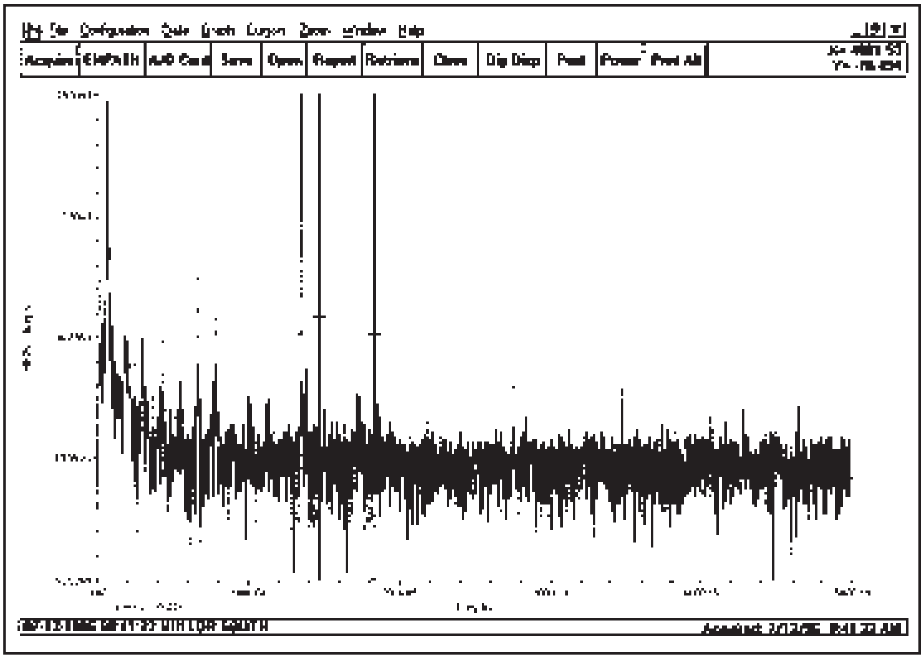

Figure 3: Current spectrum of a 200 Hp motor showing a bearing damage pattern.

Figure 4 shows the armature current spectrum for a DC motor. The large peak at 360 Hz indicates the DC drive is full-wave-rectified. The large peaks at 120 and 240 Hz indicate problems in the control circuitry of the DC drive.

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Trending of Motor Data

ESA becomes even more useful, however, for trending motor indications; because, in some cases, a motor's base-line signature may not be known. The ideal information a predictive/preventive maintenance engineer needs to know is, 'How long until I need to replace or repair this motor?'

Rarely can a one-time test provide this data. However, trending will give this input by providing an indication of how quickly a motor condition is changing. For example, if an indication of rotor degradation appears, it may not be clear from one test how rapidly the rotor circuit is degrading. Testing over several weeks or months will confirm if the rotor is stable and not changing. The number of starts and stops that a motor experiences is very important regarding rotor change. A motor with a high on-off duty cycle is much more likely to show rapidly increasing rotor degradation than a motor that runs constantly. These types of operating conditions can be factored into the trending data to provide a much clearer indication of motor health.

Figure 5 shows the current spectrum of a 1750 Hp motor that has 'soft foot'. The 'soft foot' shows up as static eccentricity, or air gap variation. The peaks highlighted by the cursors are the rotor bar passing peaks indicative of static eccentricity. This condition can be determined with a single test. Degrading static eccentricity will be seen as the peaks grow in amplitude.

Monitoring the Driven Load

In some cases, it is the driven load that is more important to the Predictive/Preventative Maintenance professional than is the motor. In this case, ESA is used to differentiate between the motor and load characteristics. This has been successfully demonstrated on pulverizers at coal-fired power plants, on motor-operated valves, pump motors, and in other areas.

Figure 6 shows the demodulated current spectrum of a motor driven by a variable frequency drive. The motor drives a belt that drives a fan. The peaks in the spectrum are the belt passing peak at 5.64 Hz, the second harmonic of belt passing at 11.24 Hz, motor running speed at 22.05 Hz and fan blade passing at 41.44 Hz. The VFD was running at about 45 Hz and the motor has four poles.

Figure 7 shows the demodulated spectrum of a DC motor driving a gearbox. The peaks at 8.62 Hz and multiples are from one of the shafts in the gear box. Sidebands are evident around the peak at 8.62 Hz; these come from gear meshing modulation on the shaft. The numerous peaks at the lower end of the spectrum come from the gearbox shafts and from the hunting tooth frequencies in the gear meshing.

Monitoring the Power Supply

The power supply, a variable frequency drive or the power coming in on the bus, are all-important components of the load-driving system. In some cases, the power supply contributes to the problems being experienced with the motor. ESA is used to diagnose problems in the power supply and can provide insight into the root cause of motor problems that can be obtained in no other way.

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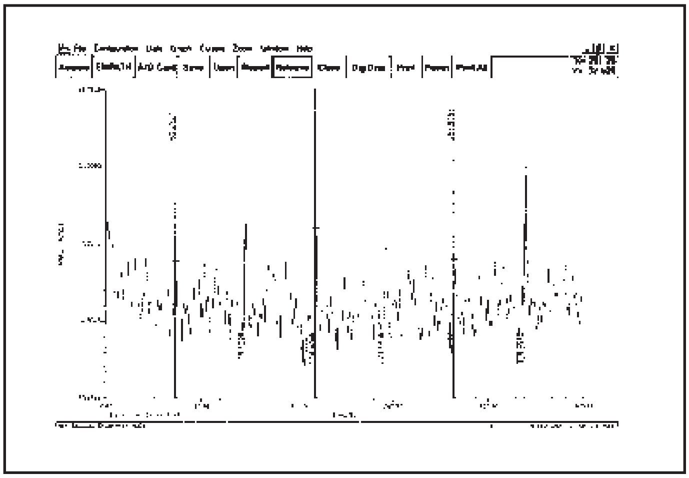

Figure 4: Current spectrum of DC motor showing drive characteristics.

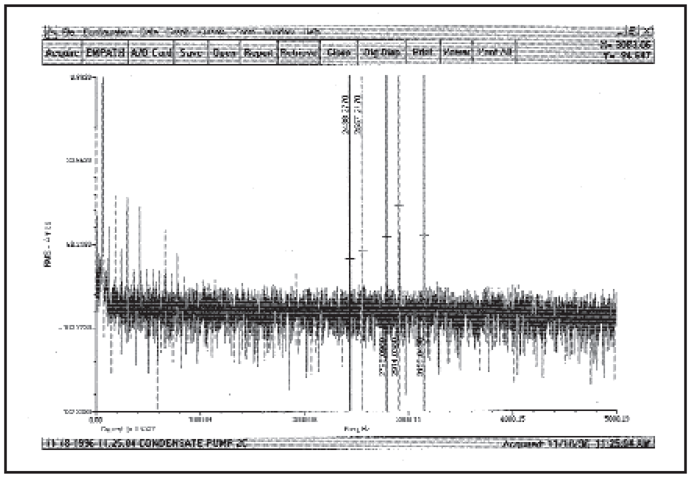

Figure 5: Current spectrum of 1750 Hp motor showing rotor bar passing pattern.

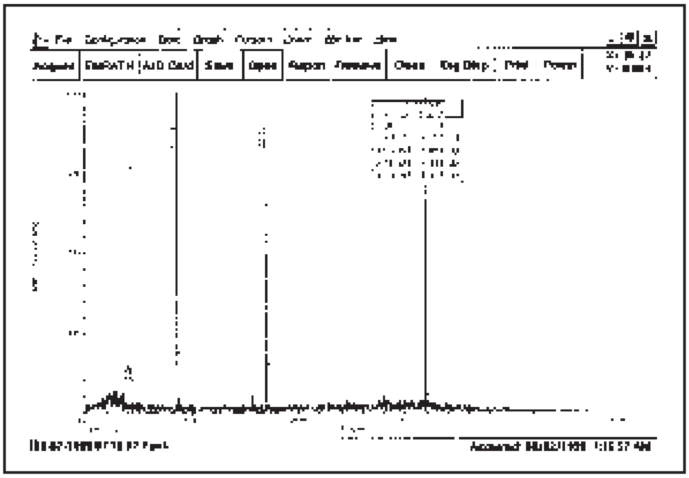

Figure 6: Demodulated current spectrum showing belt passing, motor running speed and blade passing.

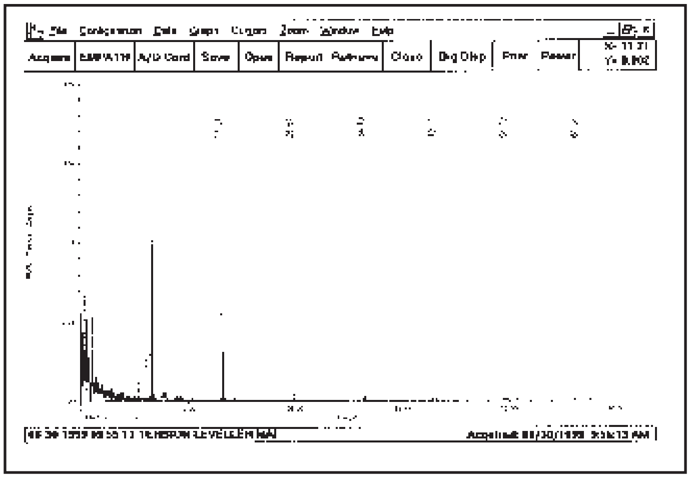

Figure 7: Demodulated current spectrum of DC motor showing gearbox features.

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Figure 8 shows the voltage supplied by a VFD when the VFD is being overdriven by high voltage. Note first the peak at 52 Hz, the drive output line frequency. Then note the large number of peaks near 2975 Hz which arise from the chopping frequency of the VFD.

In this case, the motor being powered by this VFD was being destroyed because of the high frequency ripple riding on the VFD line frequency.

Inrush Testing

ESA is also useful for inrush testing. Inrush testing can provide data on the motor and the power circuit, including breakers. This information can be used to help diagnose motor or power supply problems that can be used to improve motor performance. In one case, breaker bounce was detected and enabled the plant maintenance engineer to understand why the plant struggled to bring the motor on line.

Figure 9 shows the inrush for a 9,000 Hp motor attached to a pump. Note that it takes over 11 seconds for this motor to

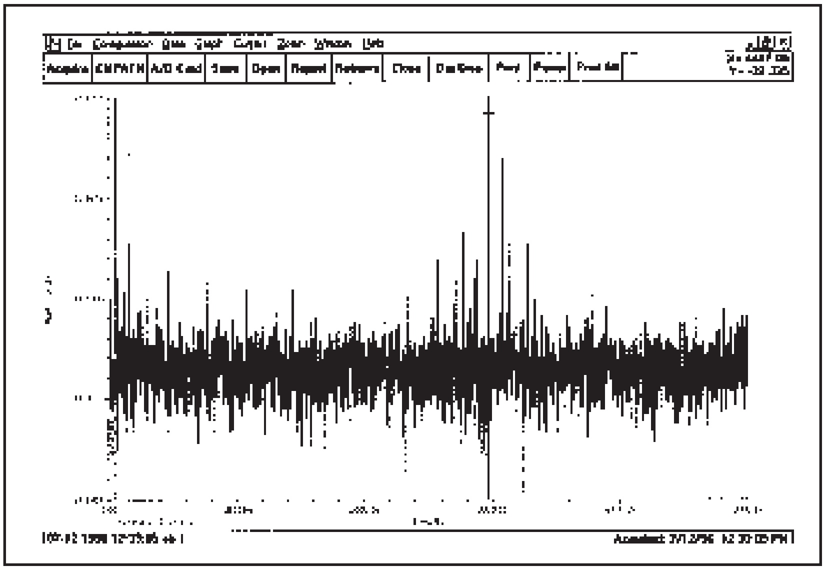

Figure 8: Current spectrum of VFD showing line frequency and chopping frequency peaks.

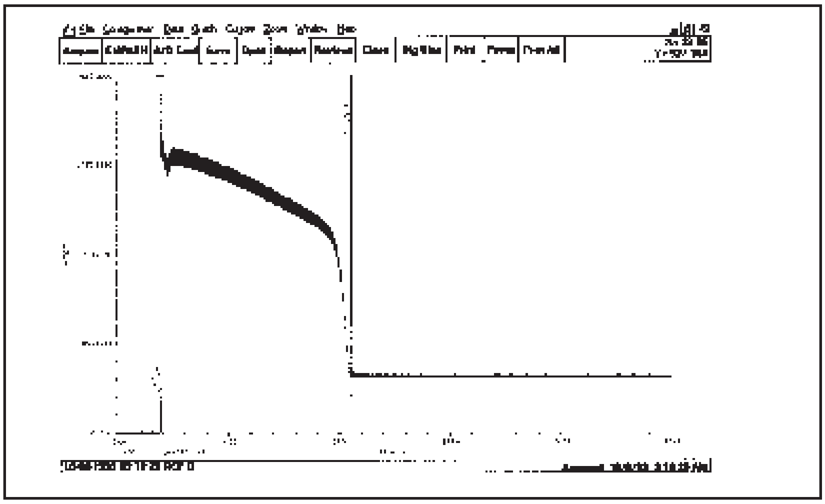

Figure 9: Inrush current of 9000 Hp motor and pump requiring almost 11 seconds to start.

come to its normal operating speed. Most motors achieve standard operating speed in a second or less, but this 9,000 Hp motor/pump represents a very large mass to bring up to speed.

Conclusion

ESA is a valuable tool used to monitor and diagnose the power supply, the motor and the driven load. ESA can be used to perform a one-time test or periodic testing to track and trend equipment performance. ESA is remote, non-intrusive, and is invisible to the equipment being monitored.

Data acquisition takes less than two minutes per motor. LAN-based, continuous monitoring of motors is readily accomplished.

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MOTORS AND DRIVES

Designing Refiner Motors to Withstand Switching Voltage Transients

By R.H. Rehder, W.J. Jackson, and B.J. Moore

During the past 25 years, the capacity of typical single-disc thermal mechancial pulp refiner motors has increased by a factor of three (see Figure 1). With pulp output concentrated in fewer machines, the reliability associated with larger motors becomes increasingly significant.

Stator winding insulation systems are a critical component affecting over-all motor reliability. Paralleling the development of TMP pulping technology since the 1970s, has been the introduction and continuous improvement of high-voltage (up to 15 kV) resin vacuum pressure-impregnated (VPI) stator insulation systems. The use of improved materials along with a more comprehensive understanding of the physics related to the aging and failure mechanisms of dielectric systems have resulted in stator insulation systems that achieve the high reliability expected of larger refiner motors.

In the past, insulation systems for refiner motors have been primarily designed and tested based on line-frequency voltages. Some equipment, such as switchgear and transformers, was designed for occasional lightning and switching surges, and impulse testing used to verify an impulse withstand level or basic impulse level (BIL) for the equipment. In the past 20 years, triggered by the introduction of vacuum circuit breakers, rotating machine designs have taken into account switching surges as a design parameter.

In the 1950s, turn-to-turn insulation was based on line-frequency voltages of the order of 100 or 200 volts RMS per turn. Then it was realized that transient and surge voltages caused severe turn-to-turn voltage stress, and the first issue of IEEE 522 [1] recommended a two per unit voltage capability with a 0.2 microsecond rise time based on line-to-ground peak voltage. Most manufacturers selected their turn-to-turn insulation to meet this two per unit factor. Investigations by utilities [2,3,4] in the mid-1980s established that operation of both vacuum and air-magnetic circuit

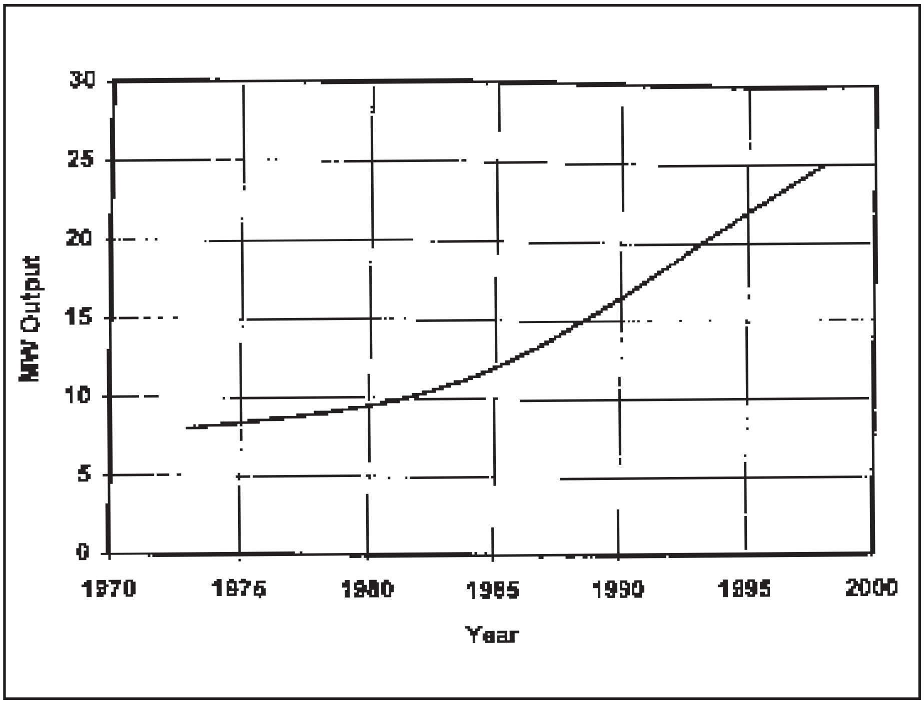

Figure 1: Growth in typical 4-pole TMP refiner motor output

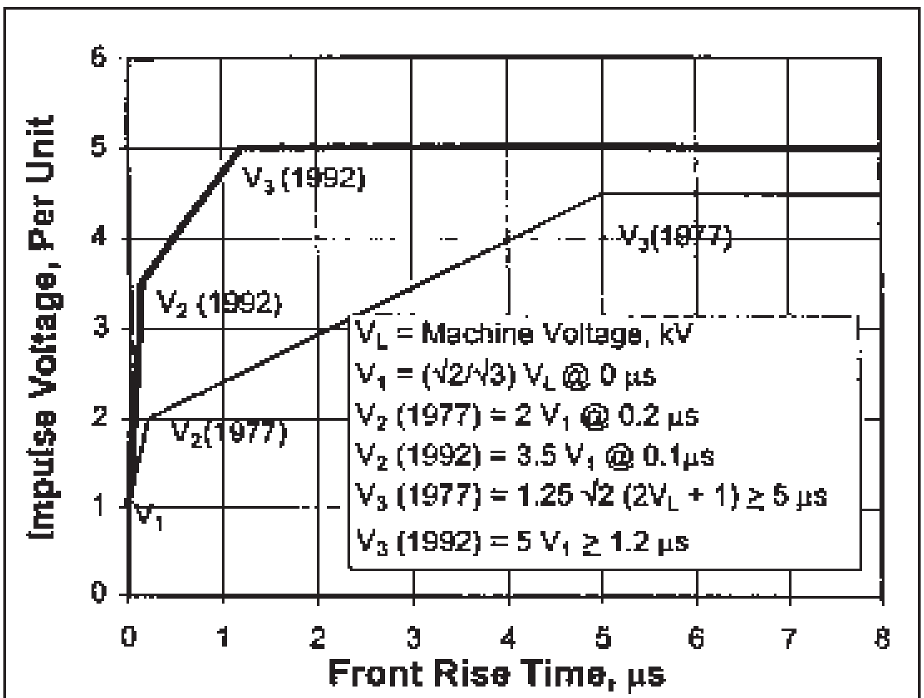

Figure 2: Combined electrical impulse withstand envelopes — from Figs. 1 and 2 of IEEE 522

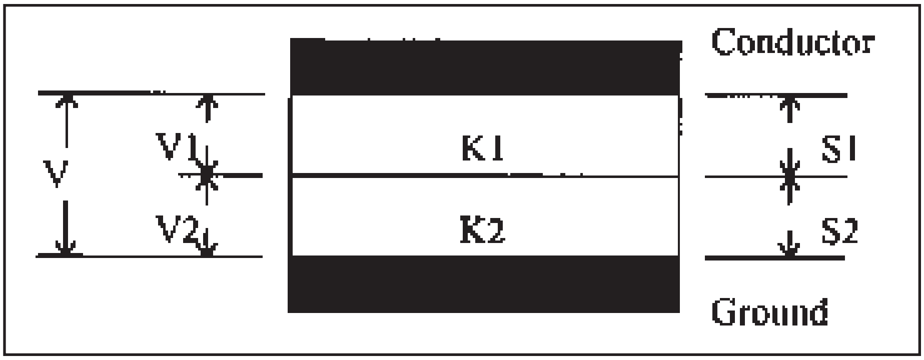

Figure 3: Stress Distribution — two dielectrics in series

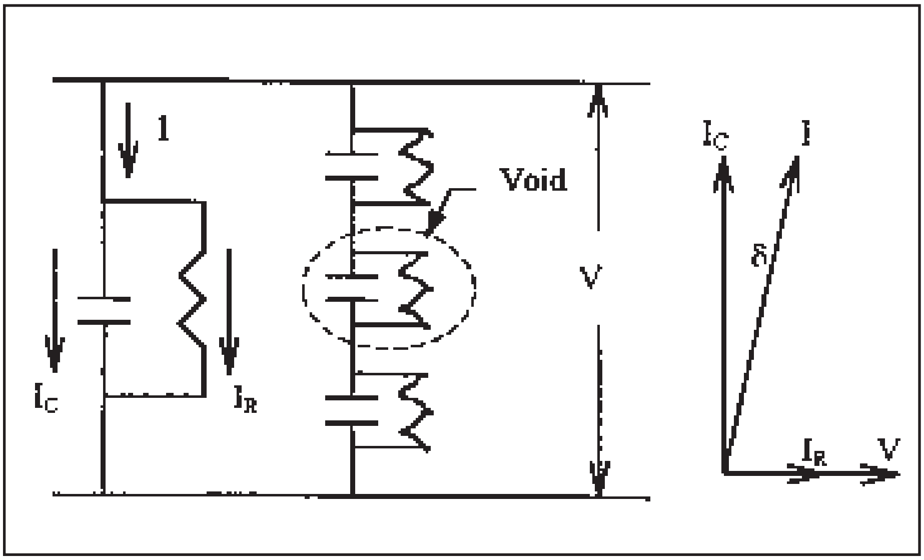

Figure 4: Parallel equivalent circuit for solid insulation with void

breakers introduced multiple voltage surges or spikes that had a peak magnitude at the motor terminal box as high as 4.6 per unit (line-to-ground peak voltage), with a rise time to peak as low as 0.1 microseconds.

Subsequently, IEEE Guide 522 was revised to include a 3.5 per unit test value instead of a two per unit level for those applications that could be termed as high surge applications, Fig. 2. NEMA standard MG 1-1993, Part 20.87.5 [5] recognizes the higher impulse withstand envelope of IEEE 522, but the motor buyer must specify the increased capability at the time of purchase. These switching transients are not continuous and usually occur on circuit breaker opening and closing operations. There are still some motor manufacturers that have not changed their design practices to use the 3.5 per unit value in place of the previous two per unit recommendation, and therefore their turn-to-turn insulation could be at risk under some breaker operating conditions.

Some vacuum breaker manufacturers realized early in their development of the vacuum interruptors that re-strikes could create voltage spikes and they supplied, with their switchgear assemblies, suitable surge suppressors or arrestors to limit the peak transient voltages [6]. Every feeder breaker designated for motor switching was equipped with these suppressors. Some manufacturers of vacuum interrupters have introduced different metals into their contacts to reduce restrike transients, but this can have an adverse effect on the interrupting capability of the contact design. Careful design of the breaker mechanism with sufficient wipe and contact separation speed can also improve the transient switching performance of vacuum breakers. There are a number of technical papers describing the re-strike phenomenon [7,8,9].

Transient Effects

The transient voltages have a rise time of 0.1 to 0.2 microseconds to crest value. This fast rate of rise is equivalent to a frequency between 1.25 and 2.5 MHz. The transient is a traveling wave phenomenon that impinges on the motor stator winding, stressing the turn-to-turn insulation of the first turn. As the transient travels along the turns of the first coil, it loses some of its energy due to capacitive leakage to the grounded stator and capacitive coupling between turns. At the end of the first coil there is a change in the surge impedance due to the shape of the series connection to the second coil. This results in a minor voltage reflection, increasing the voltage stress on the last turn of this first coil.

As the transient passes to each of the remaining coils, the crest voltage and the rate of rise of that crest decrease. Therefore, transient-related insulation failures usually occur as a turn-to-turn fault on the first or terminal coils in a machine. Transients with slower rise times ($\geq$5 μ-msec, corresponding to a frequency of 50 kHz) distribute themselves over the winding more gradually, resulting in lower turn-to-turn voltage stress. The voltage stress distribution in the machine from terminal to neutral connection will vary from machine to machine depending on the surge impedance of the winding. Using the IEEE 522 surge factor of 3.5 per unit, the required turn insulation capability can be selected on the basis of the following formula:

$$Vt\ 3.5(Vp\text{-}p/\sqrt{3})\ (\sqrt{2})/T$$

where:

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Vt = turn-to-turn voltage capability in crest volts;
Vp-p = phase-to-phase RMS voltage at system frequency;
T = number of turns per coil.

As an example, the minimum required turn-to-turn voltage capability for a motor on a 13.8-kV system with a five-turn coil would be 7.9 kV crest per turn. The turn-to-turn insulation thickness will probably be in the range of 1.0-mm (40-mil), so the average voltage stress is approximately 7.9 kV peak volts per mm (200 peak volts per mil). Ground wall insulation, conductor to ground average stress, is in the range of 2.8 kV peak volts per mm (70 peak volts per mil).

In general, the turn-to-turn insulation is stressed higher than the ground wall insulation, and therefore the turn-to-turn insulation should receive special attention both from a design and a manufacturing standpoint.

Void-Free System

The distribution of electric stress with more than one dielectric in series is inversely proportional to their respective dielectric constants.

In a system with two dielectrics, Fig. 3, the voltage distribution follows the relationship:

$$V_1 = [K_2S_1 / (S_1K_2+S_2K_1)]\ V$$

where:
V_1 = voltage across insulation with dielectric constant K_1;
V_2 = voltage across insulation with dielectric constant K_2;
V = total voltage across system;
S_1 = thickness of insulation with dielectric constant K_1;
S_2 = thickness of insulation with dielectric constant K_2.

For example, assume a turn-to-turn insulation that has a thickness of 1.0 mm (40 mils), and a 0.025-mm- (1 mil-) thick air gap or void occurs in the insulation. Based on an insulation with a dielectric constant of 3.5 and with the dielectric constant for air as 1, the voltage across the air gap will be 8 per cent of the total voltage applied. With a 7.9-kV voltage stress, the air gap or void will have 633 peak volts or 447 volts RMS. This stress in the air is too high and the air breaks down with a partial discharge. The partial discharge activity will cause deterioration of the insulation with time, and ultimately there will be a failure of the insulation system.

Electrically, the insulation system can be represented by parallel or series connections of a resistor and a capacitor. Figure 5 is a parallel representation, one branch having a void in the solid insulation; it also shows a vector diagram, where the angle δ is known as the loss angle. Poor insulation systems will have a large loss angle because the I_R vector (leakage current) will be large. The tangent of this angle is referred to as the dissipation factor (DF) or tan delta, which is often considered as a measure of the quality of the insulation system. Poorly compacted or void-filled insulations will have a high DF. For rotating machines with VPI insulation systems, the DF for a full phase winding at rated voltage should be less than 4 per cent, or the tangent of the loss angle must be less than 0.04.

Paschen's Curve

The breakdown characteristics of air can be approximated by a modified Paschen's curve, Fig. 5. If the voltage stress across the air gap or void in the system is greater than the breakdown strength of the air, as was the case in our example, then partial discharges will occur and the system will deteriorate with time. Note that there is a minimum voltage at which breakdown can occur. Gaps smaller than 6 μm (0.24 mils) will require higher voltages to break them down. It also indicates

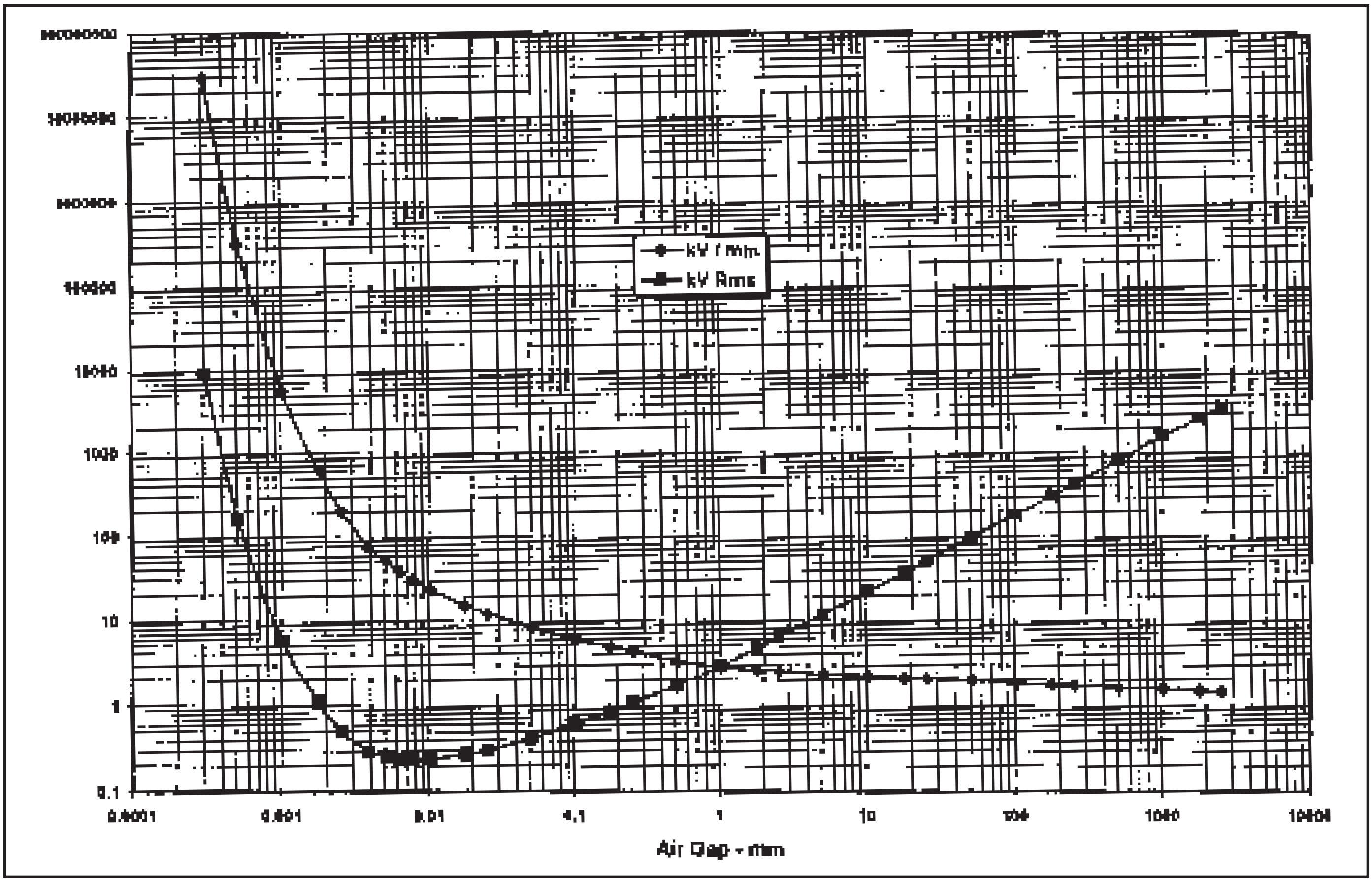

Figure 5: Paschen's curve — breakdown of air

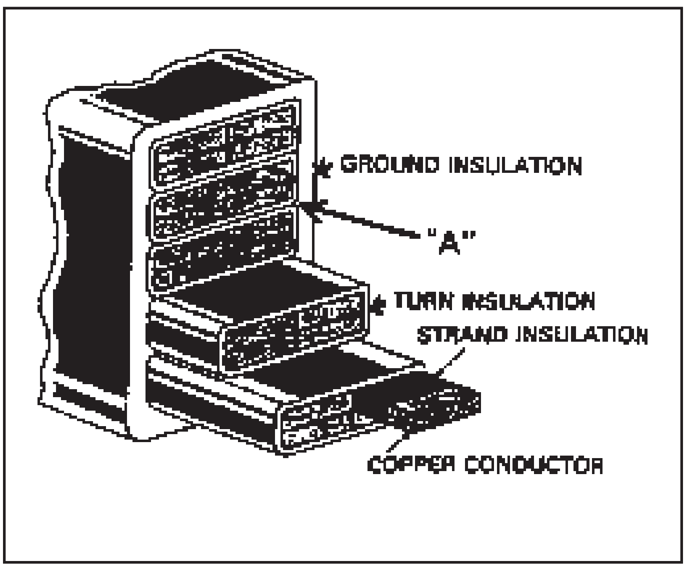

Figure 6: High-voltage coil cross-section

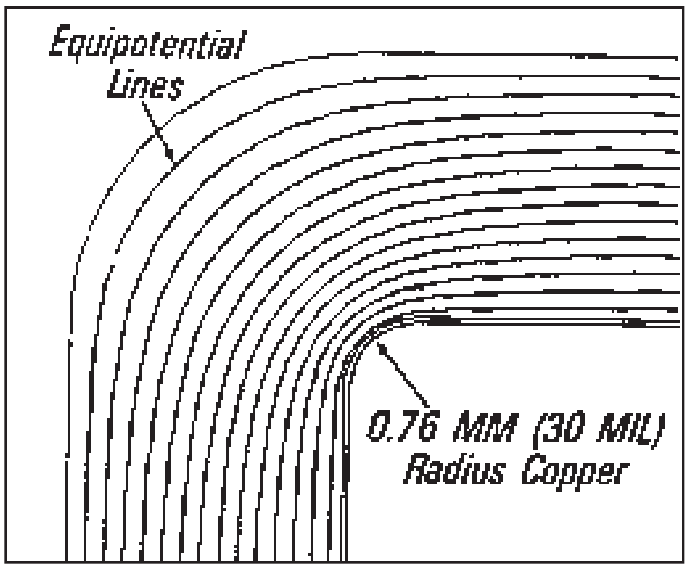

Figure 7: Equipotential lines at corner of stator coil

that as long as the voltages are below 280 volts RMS, partial discharge would not occur and very small air gaps would not be critical. The curves are based on standard atmospheric pressure and using electrodes with a diameter of 12.7 mm (1/2 inch). A decrease in electrode diameter will lower the breakdown value. High frequencies in the megahertz range will also lower the breakdown voltage.

Areas of Concern

The cross section of a large high-voltage coil is shown in Fig. 6. In VPI systems, there have been some manufacturing problems in ensuring that the impregnating resin penetrates between turns to eliminate air voids in this area. As well, there is concern in filling the triangular space between turns at the location marked "A" in Fig. 6 [10].

Some manufacturers use a resin with a very low viscosity to ensure that there is complete penetration. The disadvantage to this low-viscosity approach is the tendency for the resin to flow out of larger void areas during the time between the impregnation of the resin and the baking process to cure the resin. One of the ways to overcome these difficulties is to use

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resin rich mica tapes for the turn insulation. The tapes are applied to the strand bundle as the coil bobbin or loop is formed. After spreading, the slot sections of the coil are placed in a press and heat and pressure are applied. The heat and pressure causes the resin, which is now already in the turn-to-turn location, to flow and displace any air during the curing process.

As the coil section is held within irons during the pressing procedure, the turn package is rectangular, with a flat surface along the sides of the coil and the air spaces at "A" have been eliminated. The ground wall insulation is applied over these pressed turns and the conventional VPI process is followed for the remainder of the insulation system. The major benefit of the pressed turn is minimizing the chance of air voids in a critical area of the system. On high-voltage coils the VPI resin must work its way from outside the coil, through the thick ground wall insulation, and with the pressed turn system the VPI resin does not need to penetrate beyond the turns to the strands.

The electrical stress is highest at the surface of the conductor. Dielectric field plots have indicated that the electrical stress at the corners of the coil, next to the copper, can be double the stress along the side of the coils. Figure 8 is a diagram showing the equipotential lines at the corner of a stator coil. Note that the lines are closest together next to the copper. Therefore, voids or deficiencies in the insulation next to the strands and turns are critical, and damaging partial discharges will occur first in these areas. For this reason, the use of corona-resistant enamels as a strand insulation can delay the propagation of a fatal carbon track through the insulation and increase the life and reliability of the system.

The use of non-film-backed tapes, the elimination of corona-sensitive materials and the use of fillers to give corona-resistant characteristics to tapes and resins also improves life. Figure 8 is a curve of voltage endurance showing the extended life that can be achieved with the use of corona-resistant materials.

Using Capacitors

Provided the turn-to-turn insulation has been designed to meet the 3.5 per unit surge factor, capacitors, arrestors and resistors would not be required to protect the stator winding turn insulation. However, capacitors and arrestors have been applied for many years and they will protect against power system surges due to system switching operations and lightning strikes on the supply system. They do slope the wave front of surges and minimize the magnitude. This distributes the stress in the winding and will reduce transient partial discharge activity. They are good insurance.

The addition of series resistors with the capacitors to critically damp the motor, cable and supply system so that multiple restrikes on vacuum breakers do not occur, has some disadvantages. The resistors reduce the amount of wave sloping produced by the surge capacitors. The selection of the resistors is dependent on the surge impedance of each specific cable run from the switchgear to the motor terminals, as well as the impedance of the source bus and its connected loads, such as other motors. If additional motors are added to the bus, or conversely a motor is removed, then the resistors lose some of their effectiveness and should be replaced. Non-inductive resistors are complex to design, particularly considering that they must be capable of withstanding any initial single surge voltage, terminal to terminal. Non-inductive resistors are usually counter wound so that electrical clearances are limited.

Conclusions

New motors are available that are capable of withstanding potential re-strikes produced by vacuum interrupters. Older motors, designed to the two per unit surge value, should have arrestors and capacitors, and it may be practical to add partial discharge monitors to the machine so that there would be an advanced indication of deterioration due to transient partial discharges caused by breaker operations [11].Adding resistors in series with the surge capacitors is adding complexity to the installation and additional insulation paths to ground.

These factors could be adversely affecting reliability relative to a motor designed initially to meet the 3.5 per unit turn-to-turn levels described in IEEE 522 along with the use of advanced corona-resistant materials.

Purchasers of large refiner motors should specify a stator insulation system that is capable of meeting the higher IEEE surge withstand envelope.

Furthermore, all stator coils should be impulse tested individually after installation in the stator but prior to connection.

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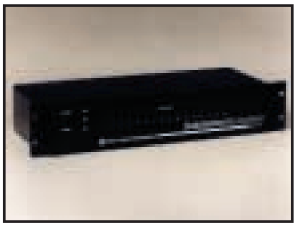
SHOWCASE



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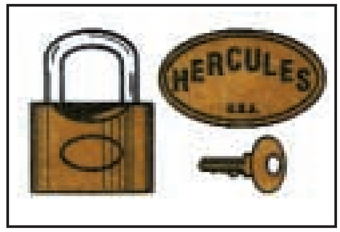

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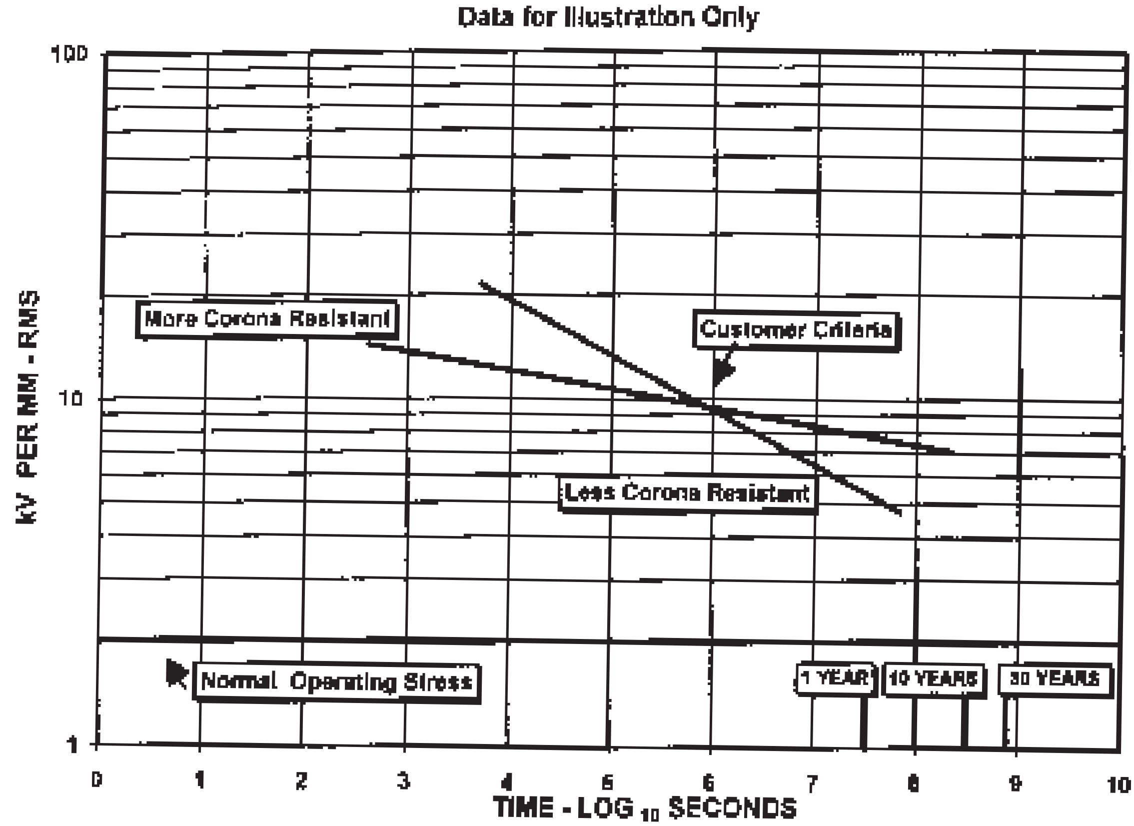

Figure 8: Voltage endurance curves — standard and corona-resistant materials

Continued from page 31

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W.J. Jackson and B.J. Moore are with GE Canada. R.H. Rehder is a consultant. This article is based on a paper presented at the 86th Annual Meeting of the Technical Section, CPPA, in Montreal, QC. ET

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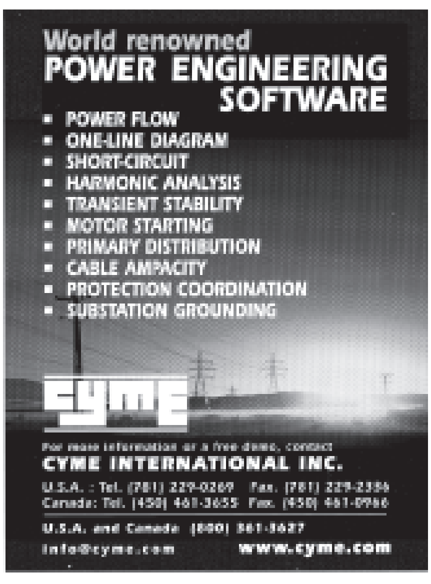

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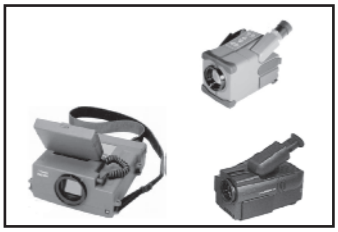

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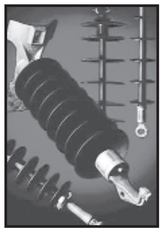

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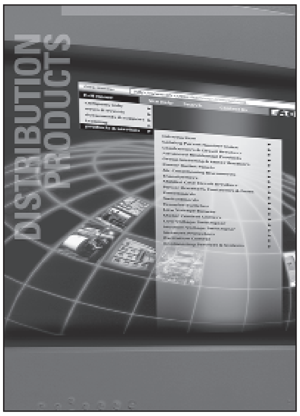

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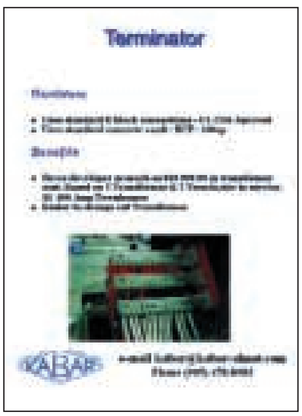

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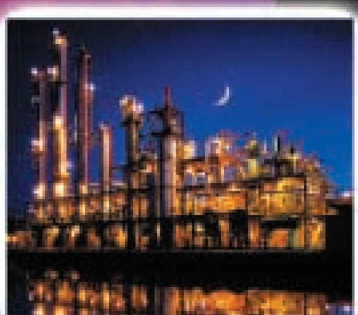

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