see page 5

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Mr. Macaluso has more than 20 years experience in the electricity industry. As the CEO of the EDA, Mr. Macaluso spearheaded the reform of the EDA to meet the emerging competitive electricity marketplace, and positioned the EDA as the voice of Ontario's local electricity distributors, the publicly and privately owned companies that safely and reliably deliver electricity to over four million Ontario homes, businesses, and public institutions.

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Scott Rouse is a strong advocate for proactive energy solutions. He has achieved North American recognition for developing an energy efficiency program that won Canadian and US EPA Climate Protection Awards through practical and proven solutions. As a published author, Scott has been called to be a keynote speaker across the continent for numerous organizations including the ACEEE, IEEE, EPRI, and Combustion Canada. Scott currently serves as Chair of the Canadian Industry Program for Energy Conservation (CIPEC) - Energy Manager Network and is a professional engineer, holds an M.B.A. and is also a Certified Energy Manager.

WELCOME DAVID W. MONCUR, P.ENG., M. Naqvi & Assoc.

We welcome David W. Moncur to our editorial board. Mr. Moncur has 29 years of electrical maintenance experience ranging from high voltage installations to CNC computer applications, and has conducted an analysis of more than 60,000 various electrical failures involving all types and manner of equipment. Mr. Moncur has chaired a Canadian Standards Association committee and the EASA Ontario Chapter CSA Liaison Committee, and is a Past President of the Windsor Construction Association.

IEEE PES GENERAL MEETING HAS SOMETHING FOR EVERYONE

By Don Horne

Delegates attending an IEEE conference in Las Vegas this year.

The theme for this year's Power Engineering Society's General Meeting is "Meeting the World's Energy Needs Through Innovation & Technology", examining policy, infrastructure and workforce issues on an international level.

Set against the backdrop of the city by the bay, San Francisco, California, the June 12-16 conference will provide delegates with the opportunity to participate in many high-quality technical sessions and tours, committee meetings, networking opportunities and more. In addition, special student events and entertaining companion activities are planned throughout the week.

Conference registration, major luncheons, receptions and most other events will be held at the San Francisco Hilton Hotel, along with the majority of the technical sessions and committee meetings. Other sessions and meetings are planned in the nearby Westin St. Francis.

The General Membership Meeting is slated for Monday, June 13 at 8 a.m. in the Hilton's Grand Ballroom. IEEE Power Engineering Society President Hans B. Püttgen will provide an overview of PES accomplishments over the past year and he will touch on the Society's objectives and agenda for this year. There follows an open Q&A session, which will allow members to ask Dr. Püttgen and other Governing Board members to discuss specific issues.

A plenary session - led by Dr. Püttgen - will commence at 9 a.m. immediately following the General Membership Meeting in the Grand Ballroom. This year's theme will provide the framework as the speakers address policy, infrastructure and workforce issues facing the international electric energy industry.

Candidates for 2006-2007 PES offices and Division VII Director will be available during the hours of the Poster Session to members individually. It is a great opportunity to meet with the individuals who will be steering PES into the future, and to discuss your ideas and concerns with them before elections are held later in the year.

The always popular Awards Luncheon will be held on Tuesday, Noon-2 p.m. in the Grand Ballroom, where IEEE and PES award winners are honored for their outstanding achievements.

Technical panel and paper sessions are scheduled each day of the conference, from Monday through to Thursday, with tutorials scheduled on Friday. The tracks to be addressed at this meeting are:

• Understanding and Responding to System-Wide Events;

• Securing New Sources of Energy;

• Improving Reliability and Power Quality;

• Using Innovative Measurement and Control Techniques to Improve Customer Service; and

• Surviving New Markets and New Structures.

Please check back for the specific schedule of meetings, presenters and presentation titles.

The Power Engineering Education Committee will present nine full-day and half-day tutorials during the meeting. Full or one-day conference registration is required in order to attend any of these courses, at a cost of $150 each (in addition to the conference registration fee).

A feature of the PES General Meeting technical Program is the Poster Session, with all poster session papers presented at a combined session on Monday from 5-7 p.m. in the Grand Ballroom. Committee meetings are scheduled for each day of the conference, with additional meetings scheduled for the Saturday and Sunday preceding the meeting.

Numerous innovative and technical tours have been planned for those who have registered for one-day or the full conference.

The 2005 Showcase of Innovation runs from Sunday through to Thursday, with manned booths from area industries featuring new and upcoming electrical power products and services; in particular, those on the cutting edge of the industry. Displays of literature and material about PES programs and future meetings, and a booth devoted to IEEE membership, products and publications are available near the registration area.

The IEEE Power Engineering Society is offering a one-day short course in Power Systems Basics for Non-Engineering Professionals on Thursday. Policy makers, regulatory and energy agency leaders, power marketers and brokers, and those in the legal profession who deal with energy issues are encouraged to attend this short course. The course provides non-engineering professionals who work within the power industry a better understanding of electric power systems, planning, operations and regulatory frameworks, enhancing communication with engineers and decision-making capabilities. Concepts are explained in simple-to-understand terms, and conference registration is not required to attend.

The General Meeting runs from June 12-16 and is open to all IEEE members.

GETTING FIXED AND MOBILE DATA FROM ONE INFRASTRUCTURE

By Deanna Vincent, Microwave Data Systems

Deregulation and consolidation among energy companies around the world means doing more with less in a dramatically competitive environment. Pairing new systems with existing infrastructure and combining and mobilizing large field forces are just some of the challenges that exist.

Some leading-edge electric utilities are using the same private wireless infrastructure for fixed automation and the mobile computing needs of their field service operations.

The use of industrial wireless networks for substation and distribution automation, as well as supervisory control and data acquisition (SCADA) systems is accepted practice in the electric utility industry. Radio modems help monitor demand overtime and overheating, distribution, load balancing, pole top switching, isolation of faults and control or reclosure switches.

Now, the new mobile capability allows critical data and applications, such as service needs and work orders, to be pushed out to the field. These utilities see increased efficiency from their field service teams and their customers see faster response times to service requests. The result? More efficient operations, lower costs, reduced response times and satisfied customers.

The age of deregulation means customers have choices. If you're not operating at maximum productivity and efficiency and delivering service to customers in a timely fashion, you're opening the door for them to find another provider who is. That's why so many utilities are leveraging one private wireless infrastructure for field service dispatch, outage restoration, and asset management.

BENEFITS OF A PRIVATE WIRELESS NETWORK

The blackout that crippled the Northeast and parts of Canada in August 2003 was proof that a private infrastructure is the only acceptable solution where the nation's - and world's - critical infrastructure is concerned.

Relying on a public network for critical communications in this situation would have been disastrous and would have guaranteed utilities the same fate as the public - no way to communicate. This occurred at exactly the time when communications were needed the most. And because private networks were in place, utilities were able to continue communicating and restore power in a matter of hours for most customers.

Accessing data and information without cable and wire means you have the ability to monitor and control data and make critical decisions when communications are cut off by other means, such as downed power lines during a storm.

A private wireless network also means lower cost of ownership since you have one-time, up-front set up and installation costs versus ongoing monthly operating fees with a wired or cellular solution.

While reliability, availability, and low cost of ownership are certainly significant benefits of a private wireless network, the greater benefit is the additional bandwidth that allows integration with an existing infrastructure and accommodates future growth as well as current applications such as voice, video and mobile data solutions.

ADVANTAGES OF A MOBILE DATA SOLUTION

Imagine doing your job like you did in the good old days - snail mail instead of e-mail, filing cabinets instead of shared directories, pad and paper instead of a laptop. Needless to say, with every advancement made in technology our lives have become more productive, more efficient.

In many instances, however, the field service teams are still doing their jobs much the same as they always have - relying on someone else to provide the most accurate and up-to-date information that exists. The problem is that information isn't always current, which often means spending more time, energy and money to accomplish the job.

Empowering the field force by wirelessly extending an organization's network can increase productivity, improve efficiency and reduce costs in several ways.

Giving your field crew the ability to input information as they receive it, also means the most current and updated information is entering the system as it happens. Paper work isn't being turned in at the end of the day for data entry in the next 24-plus hours.

A wireless solution that enables automatic vehicle location (AVL) using global positioning system (GPS) not only means more efficient, but safer operations as well.

The ability to track and dispatch the field service team means that the most efficient routing of vehicles and personnel occurs, saving time and getting customers back up and running as soon as possible. No more waiting for a response to find out which trucks are in the area. It also keeps workers safer by no making unnecessary trips in an emergency when conditions are already chaotic.

In addition, productivity is increased by decreasing what is commonly referred to as "windshield time" - the amount of work-related time spent in a vehicle. Having access to information from the vehicle and the ability to plan ahead means a significant reduction in trips for either supplies or information.

MULTIPLE APPLICATIONS, ONE INFRASTRUCTURE

The case for field force automation is an obvious one - increased efficiency, productivity, safety and customer satisfaction. But which wireless solution makes the most sense?

CDPD has already been - or is in the process of being - phased out and is being replaced by next-generation cellular technology. However, the ongoing, monthly fees add up quickly presenting a

Continued on Page 23

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MAXIMIZING THE PERFORMANCE OF ETHERNET MEDIA IN HIGH NOISE ENVIRONMENTS

By Bob Lounsbury, Rockwell Automation

As Ethernet enters the control and automation arena, the performance becomes increasingly important. In control and automation applications, message response time is extremely critical. In addition, excessive jitter within the response time can be catastrophic to the reliability in control systems, where tight control loops are required. Residual and burst errors are the two primary types of errors that have a direct impact on the response time. The two types of errors can be quantified by both inherent and external influences. Residual errors are caused by poorly designed and or matched physical layer and network components. Each component in the link will contribute to the overall performance. Burst errors are the primary component of control jitter. Most burst errors are caused by events such as noise bursts common to the industrial environment. For example a contactor open/closing or a motor starting/stopping will produce intermittent noise bursts that can couple into poorly designed networks and corrupt data. Designing a system with emphasis on specific parameters can enhance the immunity to electrical noises and will ultimately reduce response time and reduce response jitter.

Common Mode Rejection (CMR) has a direct impact to the BER of a system where noise is present in the environment. High CMR performance is accomplished by minimizing the unbalances in the link. In a system where the CMR is poor, common mode noise voltages (burst and continuous) will appear as differential voltages that will degrade the signal to noise ratio of a communications system. Low signal to noise ratio has an inverse affect on the BER performance of a communications system.

Minimizing the residual errors in a communications system will reduce the message response time. Minimizing the burst errors in a system will reduce the jitter in the message response time. Therefore, the goal in any control network is to minimize the residual and burst errors to an acceptable level. Thus, by minimizing the errors in a control system the more applications ethernet will be capable of serving.

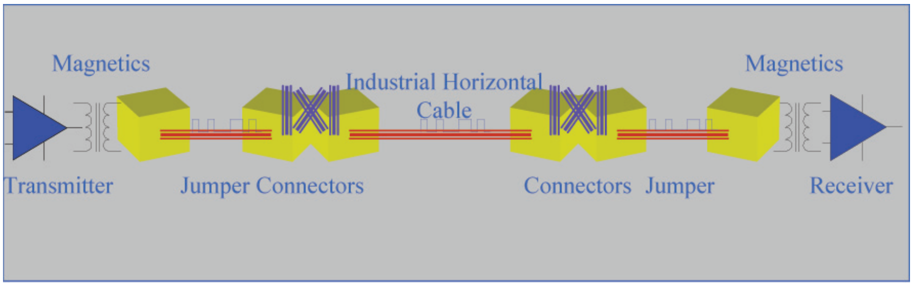

Figure 1 Typical Ethernet Industrial Channel

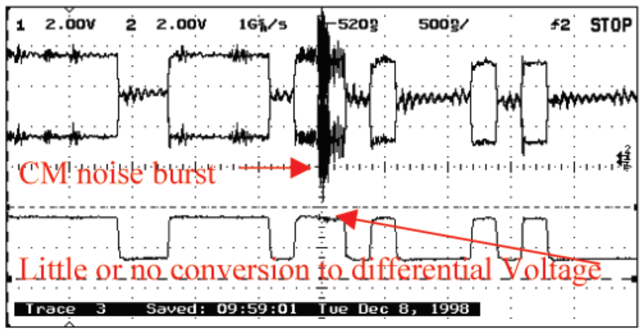

Figure 2 Common Mode Noise Burst

INTRODUCTION

This article describes the mechanisms and parameters within the transceiver, magnetics, cable and connector designs that influence their performance in noise. Figure 1 is an example of a typical Industrial Ethernet channel. This paper will quantify their individual contribution in terms of error rates. We will find that there are two types of errors in a system residual errors and burst errors. The two error types, burst and residual, contribute errors that sum up to a total error rate that cause an overall degradation to the system performance. Excessive error rates will ultimately limit the potential applications for Ethernet. Each of the two error types affects the system in different ways. For example, the residual errors will limit system performance but can, in some cases, be worked around since the errors are present all the time. Burst errors will cause random short interruptions in communications. It is the burst errors that will cause intermittent machine shut downs and is perhaps the most difficult to isolate and correct.

From a differential communications systems perspective, an ideally balanced network will be infinitely immune to common mode noise. This is a bold statement and, of course, this is only true if the transceivers are designed to withstand infinite common mode offset.

Networks that use transformers for coupling the energy on and off the network, help to eliminate the common mode offset voltages through isolation. Further balancing is accomplished by data encoding and scrambling techniques. An example is Manchester encoding. X-OR-ing the data with clock produces a transition rich signal called Manchester Encoding. This technique inherently produces balanced data and is efficient from the standpoint that the clock information is encoded and transmitted with the data.

Ethernet's 10baseT and 100BaseT

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Ethernet

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systems are transformer-coupled networks. DeviceNet is a nontransformer, direct connect network. DeviceNet maintains a 2.5 Volt bias on the differential pair.

CMR only matters if there is common mode noise. In a factory environment the noises presently span a wide range of frequencies. In addition, there is a diverse range of noise coupling mechanisms. Figure 4 is an example of some common noise generating devices and their corresponding frequency ranges. We must not forget that a device not only generates harmful fundamental frequencies, it also generates harmonics that can be just as disruptive to communications networks. The red bars indicate the additional range caused by the third harmonic.

In this paper LCTL and CMR will be used interchangeably. Each component in a channel has a quantifiable level of Common Mode Rejection (CMR). From the CMR and the common mode noise voltage level, the differential voltage can be calculated using the relationship in Equation 1.

There are two voltages that will travel within the channel, 1) differential voltage and 2) common mode voltage. The magnitude of the resultant differential voltage is a function of the magnitude of the noise source, coupling, resultant channel CMR and the insertion losses of the channel. The magnitude of the common mode voltage is a function of the magnitude of the noise source, coupling and Common Mode Attenuation (CMA) of each device in the channel. The common mode voltage will be converted to a differential voltage in each device; as a result, each device will then contribute to the resultant differential voltage within the channel.

$$V_{differential} = VCM_{noise}\, 10^{\left(\frac{-\,cmr_{component}}{20}\right)}$$

Equation 1 Common Mode to Differential Conversion

As mentioned before, the factory environment has many different noise generating devices that span a wide frequency range. Their coupling mechanisms are either magnetic or electric field or both. Isolation techniques from these fields are different for both. Products designed for the industrial environment must be subjected to some level of EMC and EMF testing to determine the product's ability to survive in these harsh environments. One of the most critical noise tests is Conducted Immunity. This test uses a special coupling clamp to produce a uniform electric and magnetic field from 150 KHz to 80 MHz. With respect to Figure 4, this test covers all except the Spread Spectrum (ISM) bands in the 900 MHz and 2.4 GHz areas. The interfering voltage levels for this test are typically 10Volts RMS.

In an industrial control network, the cable typically spans from machine to machine interconnecting many control devices. The cable is physically the largest single device in the channel. As a result, the cable has the ability to pickup coupled noises from adjacent conductors and, in addition, may act as an antenna to receive and/or radiate RF noises. Therefore, the focus of this research is ultimately to determine the level of CMR performance needed for industrial ethernet cables. To determine the required CMR, the cable's actual CMR will have to be correlated to the magnitude of errors under the controlled test conditions.

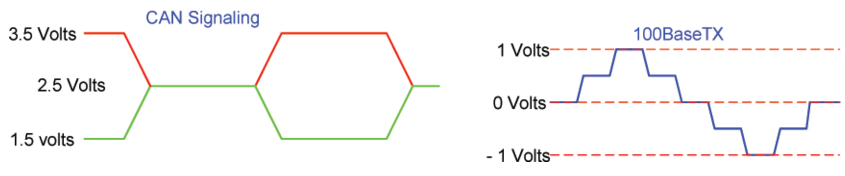


Figure 3 Signaling Examples

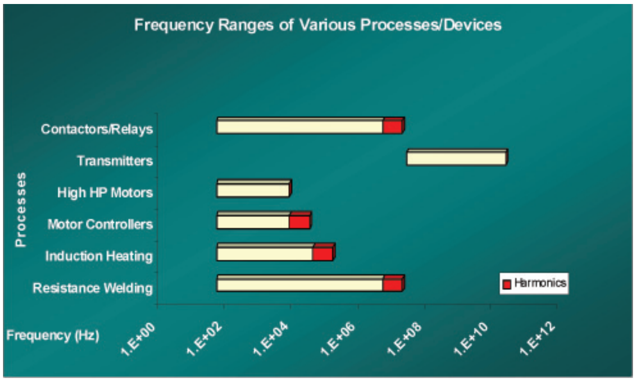


Figure 4 Noise Ranges of Common Industrial Machine Devices.

METHOD

Determining the CMR value needed for industrial cables is a 3 step method that is described in the next paragraph.

The first step in the process was to write a test CMR procedure and to measure the CMR of the cables used in this study. This procedure provided a systematic method for testing the cable to obtain consistent results from test lab to test lab and test sample to test sample. The common mode noise to differential mode noise voltage was then determined in the second step of this process. The noise test was performed on each of the 4 pairs within several cable samples. The method to be described later was used with an oscilloscope and RF probe to measure the converted differential noise voltage through a Balun. The final test was to measure the Bit Error Rate under the same noise conditions. The results were then compared together and will be presented in the following pages of this paper.

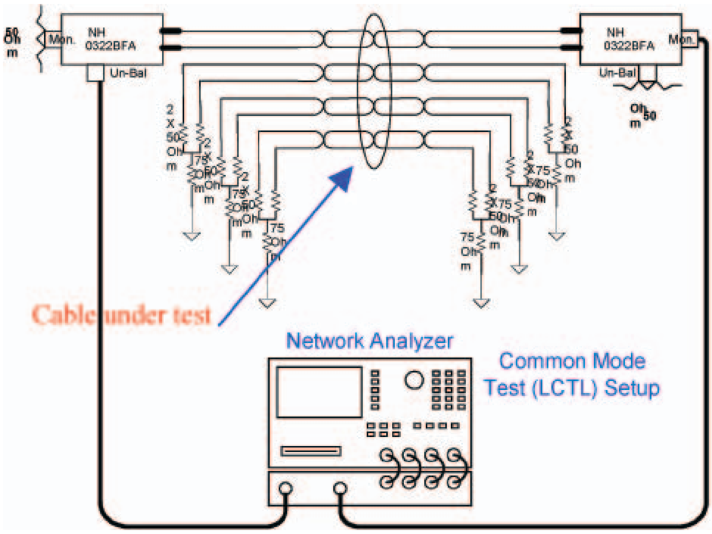
MEASURING THE CMR OF A CABLE

As mentioned in the previous section of this paper, the CMR of the cable was obtained using a detailed test procedure. Using a Network Analyzer, the CMR and Attenuation of the BALUNS determined. The data will be used in the final cable CMR value. Finally the cable's CMR and Attenuation is measured. This process was automated to fur-

Continued on Page 12

Equation 2 CMR of a Cable

$$LCTL = LCTL\_Raw - \frac{Balun\_CMR}{2} - \frac{Balun\_Differential\_Attenuation}{2} - (Cable\_Attenuation\_Raw - Balun\_Differential\_Attenuation)$$



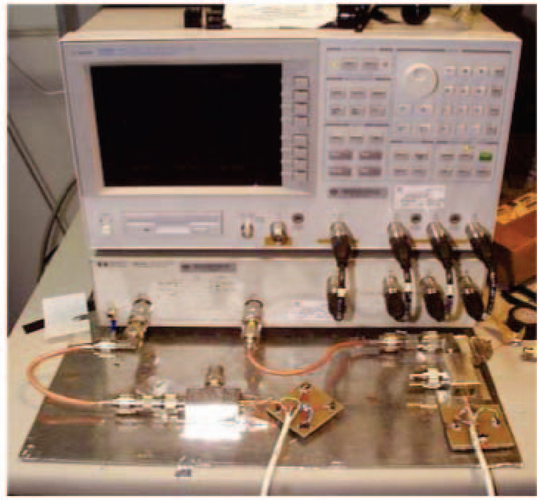


Figure 5 CMR Test Fixture Schematic

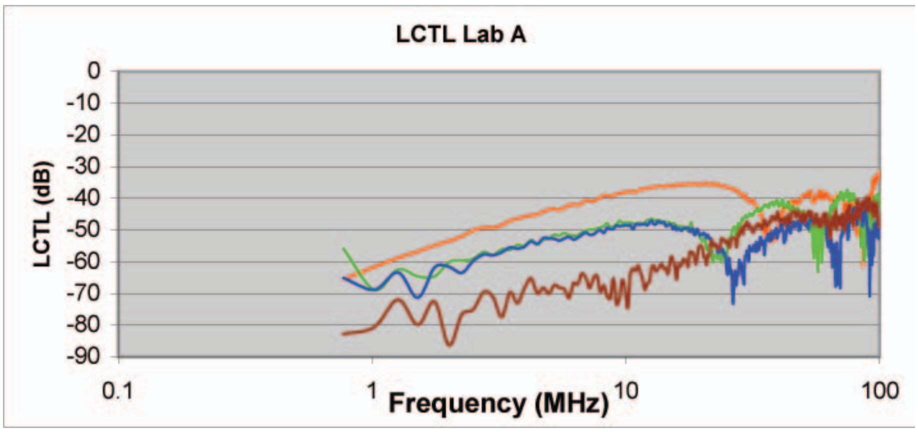


Figure 6 CMR Test Results Lab A

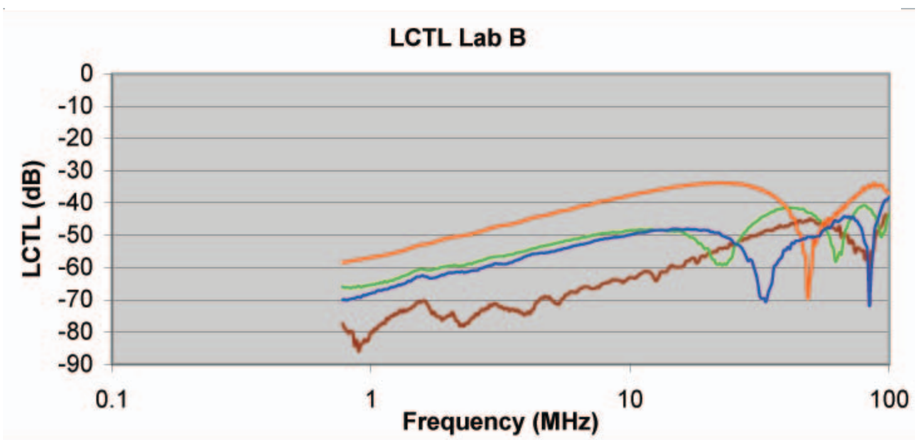


Figure 7 CMR Test Results Lab B

Ethernet

Continued from Page 11

ther enhance the repeatability of the test. The CMR and Attenuation is measured from 772 KHz to 100 MHz. The CMR of the cable is obtained from the Network Analyzer's raw data and the following relationship as defined in Equation 2

The measurements were performed at two different labs (A and B.) The following graphs will show an excellent correlation between the two labs Figure 6 and Figure 7. The CMR measurements were within 1 dB between the two labs.

MEASURING THE COMMON MODE TO DIFFERENTIAL NOISE CONVERSION

All Industrial control equipment must be certified, compliant to relevant industrial environmental noise standards. Perhaps the most comprehensive industrial standards and testing is the European Union's, CE (European Commission) testing. The European Union requires that all industrial control products be tested in accordance with IEC61000-4-6 (Conducted Immunity). The IEC standard defines the test configuration and methods for conducting the tests. This specific test is a simulation of potential noise coupling modes at levels

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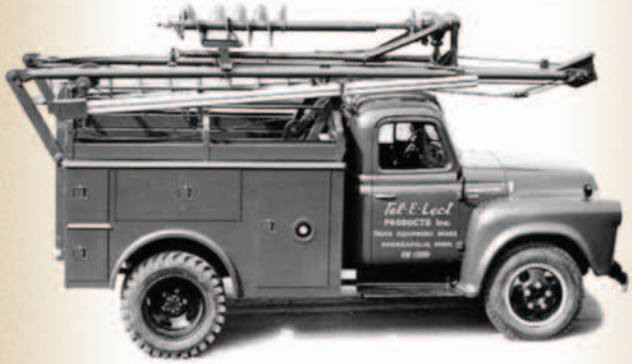

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1986 – Developed the Commander 6000 Series

1989 – Introduced the Telecon II

1989 – Introduced the General
- Introduced Fiber Optic Controls

1990's

1992 – Developed the "92" Series

1992 – Developed the Commander 7000 Series

1995 – Introduced the Commander 4000 Series

1997 – Introduced the latest Generation of Radio Controls

1998 – Develop the L4000 Series

1999 – Introduce the XL4000 Series

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2003 – Redesigned the Commander 5000 & Commander 6000 Series
- Introduced the New Generation of the the Telecon Digger Derrick

2004 – Introduced the RC Series Radio Controlled Digger Derrick

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Ethernet

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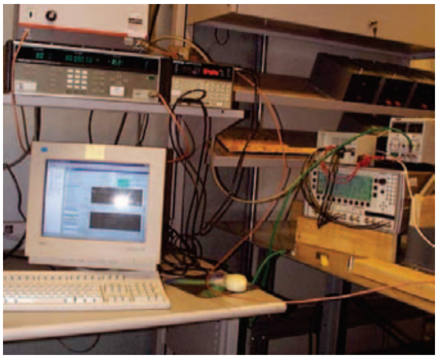

Figure 8 IEC 61000-4-6 EM Automated Test Fixture

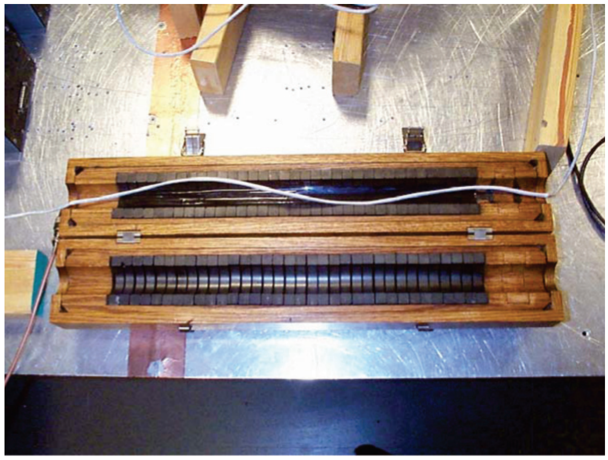

Figure 9 IEC 61000-4-6 EM Clamp

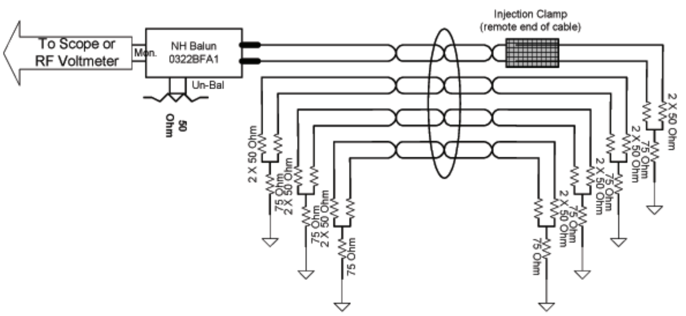

Figure 10 Test Fixture Schematic

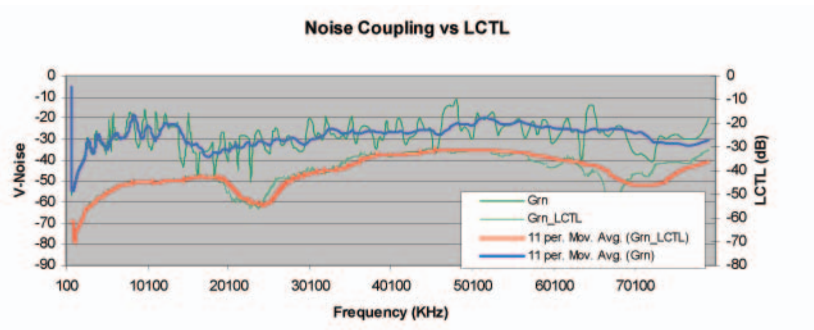

Figure 11 Differential Coupled Voltage EM Clamp Oscilloscope

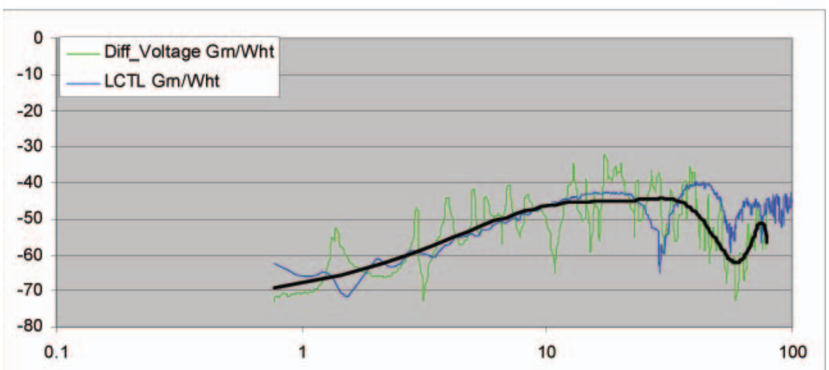

Figure 12 Differential Coupled Voltage EM Clamp RF Probe

common in harsh industrial environments. Figure 8 and Figure 9 are examples of an automated IEC test system used for compliance testing to the IEC standards. The EM (Electro Magnetic) clamp in Figure 9 couples noises to the system's communications, power and control cabling.

The goal of the experiment was to determine if there is correlation between the cable's CMR and the differential voltage produced by the common mode coupled voltages. This is the second step in determining the relationship between CMR and BER performance of the cable system. The test cables were terminated the same way as in the previous CMR testing (Figure 10.) The noise coupling tests were performed twice, once with a oscilloscope and second with a RF probe, for differential voltage measurement. The graph in Figure 11 has both the coupled differential voltage versus frequency and the CMR test results from the previous test. Note that a dual scale was used for the graph in Figure 11 to help separate the two curves.

A polynomial regression line fit was added to reveal the performance trend. The graphs in Figure 11 and Figure 12 indicate there is a correlation between the CMR performance and the Common Mode to differential voltage conversion when noise is coupled to the cable. The other pairs in the cable exhibited the same behavior.

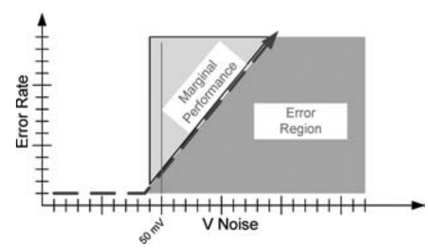

Figure 13 Error Model for Ethernet systems.

MEASURING THE BER PERFORMANCE

In the third and last phase of the investigation, the BER versus Noise was quantified. A set of transceivers is used to encode and decode (4B/5B) the data on and off the cable under test. In addition, the transceivers provide scrambling of

Continued on Page 17

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Ethernet

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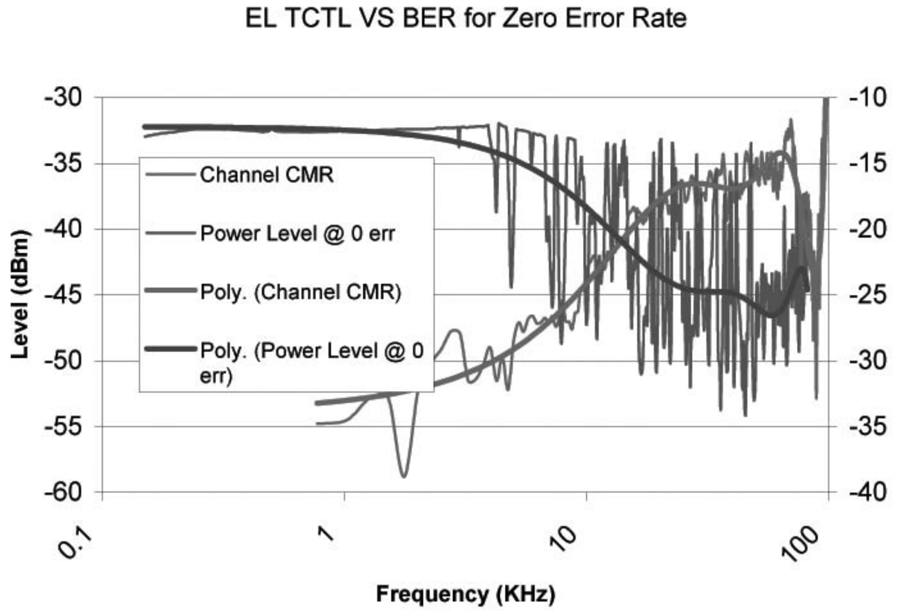

Figure 16 Power Levels for 0 BER in Noise

the data and MLT3 signaling on the wire. Even though ethernet traffic is packet in nature, a greater resolution on BER can be determined by performing error checking on a bit level. Therefore, a continuous 7 bit pseudo random data stream was used for the following BER measurements. There are other factors that affect the error performance in a channel. For example, the receiver in a channel does not respond below a differential Voltage of 50mV (receivers make use of adaptive filters to enhance data recovery). The adaptive filter not only helps to adapt the receiver to the length of the cable and cable characteristics, it also helps in enhancing the Signal to Noise performance by changing the bandwidth of the receiver. Two conditions must be met before a system can begin to take errors. The noise must exceed the receiver's threshold and the S/N ratio must be degraded enough to increase the probability of an error occurring as shown in Figure 13.

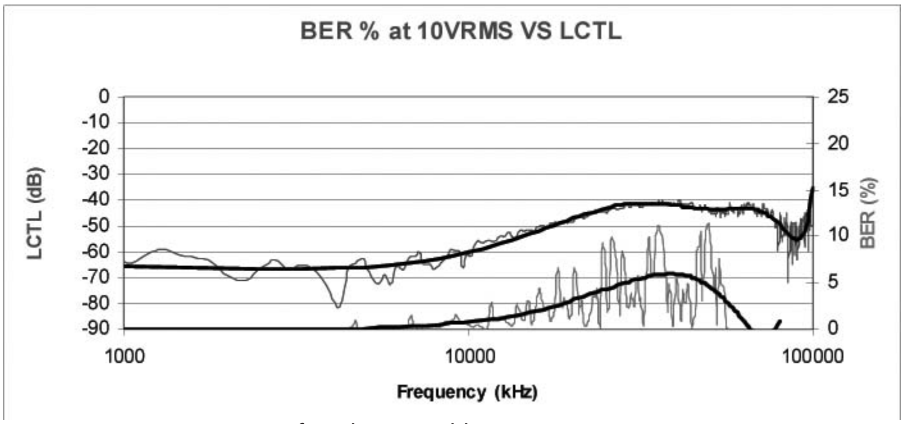

Figure 14 BER versus CMR of a Ethernet Cable

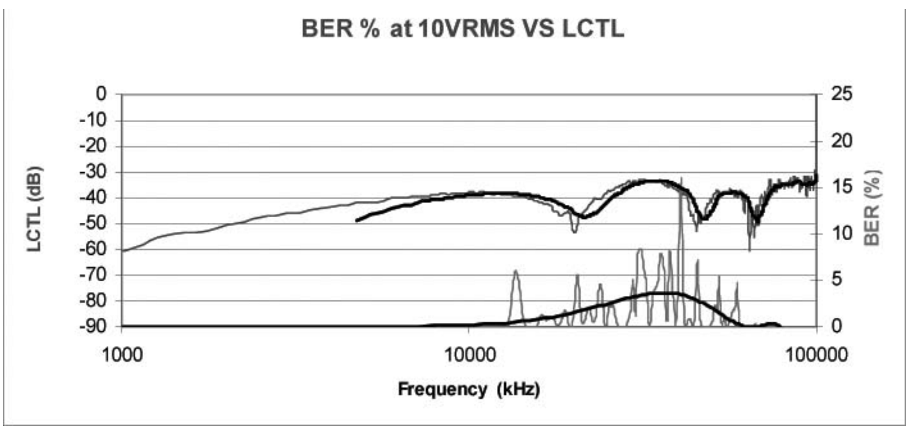

Figure 15 CMR versus BER Sample 2

COMPARING THE RESULTS TO THE BER PERFORMANCE;

Figure 14 shows the relationship of BER versus frequency on one scale and the CMR (LCTL) versus frequency on another scale. Note that as shown by the error rate, as the CMR approaches 40 dB the cable system is more susceptible common mode noise.

This performance was observed on several cables as shown in Figure 14 and Figure 15. What is noted is the first sample in Figure 14 has a worse case CMR of –40dB and has a BER of 12%. The second sample in Figure 15 has a worse case CMR of 32dB at which the BER is 8%. The difference between the two tests (CMR and BER) is in the coupling methods. In the CMR testing the energy is coupled directly on to the cable through BALUNS. In the BER test, the noise is coupled through the cable jackets using the EM (Electro Magnetic) clamp. Both methods couple the energy onto the cable common mode. It is theorized that the cable jacket provides some dielectric path to enhance or detract from the cables ability to reject noise. Therefore, a jacket can have a positive influence on the performance in noise by providing physical separation from a noise conducting structures. The graphs do show

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Ethernet

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that there is an inverse relationship between the CMR performance and the susceptibility to noise (susceptibility to noise increases as the CMR performance decreases).

Other methods were tried in measuring a cable's ability to pass data in noise. The automated testing was configured to determine the noise power level for a zero error rate. By iteratively reducing the power until the BER analyzer's error count is zero and then recording the power level, the power level (dBm) versus frequency was obtained. This process was repeated for each frequency point from 150KHz to 100 MHz. Again the measured CMR was plotted on the same graph (different scale) with the power level for zero errors. Once again the trend analysis shows the same profile. The absolute power levels cannot be compared because of the difference in the methods.

CONCLUSION

The test results suggest that there is sufficient evidence that the CMR is related to the common mode differential voltage conversion of a cable system. In addition, the test results indicate there is a reasonable relationship between the cable CMR and the system BER performance. This is an important relationship as the system performance can be predicted based on a given CMR parameter.

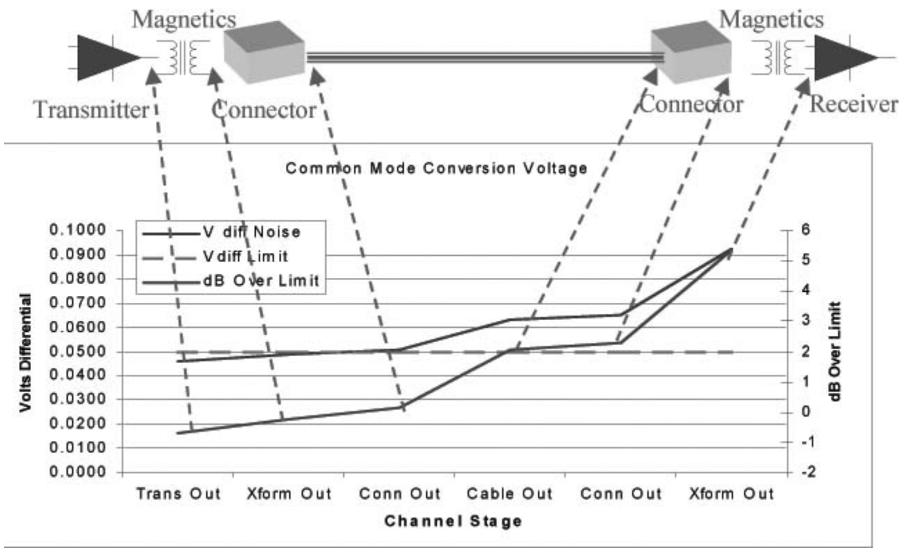

Figure 17 CMR System Budget

As Ethernet moves into the Industrial Control arena, the system will need to be hardened to withstand the harsh environments both from a materials and noise performance perspective. Poor CMR performance will manifest itself in the form of burst errors when noise is present. This paper concludes that there is a need for a CMR specification for ethernet industrial control cables. Early on testing indicated that the CMR should be -35 dB as indicated in the error versus interference level graph (Figure 16). To achieve error free traffic, the interference power levels had to be decreased by as much as 35 dB. Based on the latest testing, the value should be on the order of –45 dB to –55 dB.

The following analysis in and the associated shows a budget for each component in a typical industrial ethernet channel. Each component in the channel contributes to the overall CMR performance.

The budget assigns CMR values to each component. Taking the 45 dB CMR cable specification and inserting it into the budget below in the system still falls 5.25 dB short of the 50 mV receiver thresholds. The values in were chosen based on data sheets and desired performance. For example, the transformers are available with 60dB CMR, cables are not readily available with 45 dB and better CMR values. The connectors were estimated at 60 dB. Connectors are a minor influence in the channel, however they cannot be ignored.

Component	DB	Source
CMR Transceiver	35	Est.
CMA Transceiver	0	n/a
CMR Transformer	60	Spec
CMA Transformer	1.2	Spec
CMR Cable	45	Meas.
CMA Cable	2.9	Meas.
CMR Connector	60	Est.
CMA Connector	0.2	Spec

Table 1 Proposed CMR System Budget

FERC SYNDICATES WEB CONTENT TO FACILITATE INFORMATION SHARING

By Don Horne

The U.S. Federal Energy Regulatory Commission (FERC) implemented Really Simple Syndication (RSS) on its website recently, and in doing so, the Commission joined the ranks of a growing number of federal agencies taking advantage of RSS technology to reach more users and to quickly distribute important content. RSS is commonly used on blogs and many news organization websites.

Over 97 percent of those surveyed on the Commission's website indicated that they wanted RSS implemented.

The Commission is syndicating only the content of the website that falls under "What's New at FERC", which includes the most important news, decisions and events. Depending on the success of the initial news feed, the Commission may establish news feeds for electric, natural gas, LNG and other items. The Commission will also be working with the Department of Energy, NERC, RTOs, ISOs and State and international energy organizations to encourage the use of RSS news feeds. RSS may be a more efficient tool to help regulators, energy companies, financial analysts, the press and others aggregate information and share it with a wider audience. Rather than searching dozens of energy websites for relevant information several times each day, RSS enables users to automatically aggregate all relevant content from numerous websites on their own computer desktops.

Rather than searching dozens of energy websites for relevant information several times each day, RSS enables users to automatically aggregate all relevant content from numerous websites on their own computer desktops.

RSS is not the same thing as the Commission's eSubscription application. The Commission's RSS feed will only provide users with the most important content of the FERC website that falls under "What's New at FERC". eSubscription is ideal for tracking all correspondence for specific dockets and projects pending at FERC. eSubscription does require that users electronically register with a valid email while RSS does not.

Rich Site Summary (RSS) or Really Simple Syndication is a technology used to distribute a website's content to users in real time.

RSS is an easy way to gather a wide variety of content in one place on your computer.

Information is delivered to your news aggregator or feed reader, freeing you from having to visit a website multiple times a day to find content.

Special browser-like applications called news aggregators and feed readers are required to use RSS feeds. Each aggregator and feed reader should have more detailed instructions on how to set up feeds. Feed readers also provide the flexibility to adjust how often the reader checks for new items in the RSS feeds to which the individual subscribes. ET

A GUIDE FOR POWER FACTOR TESTING OF POWER & DISTRIBUTION TRANSFORMERS

By Richard O. Babcock, Megger

The transformer is probably one of the most useful electrical devices ever invented. It can raise or lower the voltage or current in an ac circuit, it can isolate circuits from each other, and it can increase or decrease the apparent value of a capacitor, an inductor, or a resistor. Furthermore, the transformer enables us to transmit electrical energy over great distances and to distribute it safely in factories and homes. Transformers are extensively used in electric power systems to transfer power by electromagnetic induction between circuits at the same frequency, usually with changed values of voltage and current.

Power factor testing is an effective method to detect and help isolate conditions such as moisture, carbonization, contamination in bushings, windings and liquid insulation. In addition to power factor testing, transformer excitation current measurements will help detect winding and core problems.

DEFINITIONS

Step-Down Transformer: A transformer in which the power transfer is from the higher voltage source circuit to a lower voltage circuit.

Step-Up transformer: A transformer in which the power transfer is from the lower voltage source circuit to a higher voltage circuit.

Autotransformer: A transformer in which at least two windings have a common section.

Load-Tap-Changing Transformer: A transformer used to vary the voltage, or phase angle, or both, or a regulated circuit in steps by means of a device that connects different taps of tapped winding(s) without interrupting the load.

Excitation Current (No-Load Current): The current which flows in any winding used to excite the transformer when all other windings are open-circuited.

Tap (in a transformer): A connection brought out of a winding at some point between its extremities, to permit changing the voltage, or current, ratio.

Delta Connection: So connected that the windings of a three-phase transformer (or the windings for the same rated voltage of single-phase transformers associated in a three-phase bank) are connected in series to form a closed circuit.

Y (or Wye) Connection: So connected that one end of each of the windings of a polyphase transformer (or of each of the windings for the same rated voltage of single-phase transformers associated in a polyphase bank) is connected to a common point (the neutral point) and other end to its appropriate line terminal.

The Delta Connection is so connected that the windings of a three-phase transformer are connected in series to form a closed circuit

Zigzag Connection: A polyphase transformer with Y-connected windings, each one of which is made up of parts in which phase-displaced voltages are induced.

Tertiary Winding: The third winding of the transformer and often provides the substation service voltage, or in the case of a wye-wye connected transformer, it prevents severe distortion of the line-to-neutral voltages.

TWO-WINDING TRANSFORMERS TEST CONNECTIONS

For all transformer testing, including spare transformers, ensure the following safety conditions are observed:

- The transformer must be taken out of service and isolated from the power system.
- Ensure the transformer is properly grounded to the system ground.
- Before applying any voltage on the transformer, make sure that all bushing current transformers are shorted out.
- Never perform electrical tests of any kind on a unit under vacuum. Flashovers can occur at voltages as low as 250 volts.
- If the transformer is equipped with a load tap changer, set the unit to some step off of neutral. Some load tap changers are designed with arrester type elements that are not effectively shorted out in the neutral position even with all the bushings shorted.
- Connect a ground wire from the test set to the transformer ground.
- Short all bushings of each winding including the neutral of a wye-connected winding. The neutral ground must also be removed. The shorting wire must not be allowed to sag.
- Refer to section 3, Table 3 in the Delta 2000 manual for test connections and the insulation tested.
- Connect the high voltage lead to the high side bushings for tests 1, 2, and 3. Ensure that the high voltage cable

extends out away from the bushing.

- Connect the low voltage lead to the low voltage bushings.

- For tests 5, 6 and 7, connect the high voltage lead from the test set to the low voltage bushings of the transformer and the low voltage lead from the test set to the high voltage bushings. (Note) Test 5, 6 and 7 normally are not conducted unless there appears to be a problem with tests results obtained in tests 1, 2 and 3.

- Individual tests should be performed on each bushing. Bushings equipped with a potential/test tap should have the UST test performed and the GST hot collar test on those without test taps. Transformer windings must remain shorted for all bushing tests. Refer to the APPLICATION GUIDE FOR POWER FACTOR TESTING OF BUSHINGS.

- For transformers that have wye-wye configuration, and the neutrals internally cannot be separated, short the high voltage bushings and the low voltage bushings together and perform a GST test. Test voltage should be suitable for the rating of the low voltage winding.

TEST PROCEDURE

For all power factor testing, the more information you record at the time of testing will ensure the best comparison of results at the next routine test. Test data should be compared to the nameplate data. If nameplate or factory readings are not available, compare the results of prior tests on the same transformer or results of similar tests on similar transformers. If at all possible, power factor and capacitance readings should be taken on new transformers. Field measurements of power-factor and capacitance can differ from measurements made under the controlled conditions in the factory. Therefore, the power-factor and capacitance should be measured at the time of installation and used as a base to compare future measurements. Power factor testing is extremely sensitive to weather conditions. Tests should be conducted in favorable conditions whenever possible. All tests are performed at 2.5kV or 10kV. If these values exceed the rating of the winding, test at or slightly below the rating.

- Follow the test sequence of the Two-Winding Transformers Test Connections in Section 3 Table 3 of the Delta 2000 manual. Tests 1, 2 and 3 can be completed without a lead change. Record the results.

- Test 4 is a calculation subtracting the capacitance and watts results in test 2 from test 1. The results should compare with the UST measurement for the CHL insulation

- Reverse the test leads for tests 5, 6 and 7. Test voltage should be at a level suitable for the secondary winding of the transformer. Record the results.

- Test 8 is a calculation by subtracting test 6 from test 5. Results should compare with the UST measurement in test 7 for the CHL insulation.

- Record all the nameplate information of the transformer.

- Note any special or unusual test connections or conditions.

- Record ambient temperature and relative humidity and a general indication of weather conditions at the time of the test.

- Record actual test voltage, current, watts, power factor and capacitance. Correct current and watts to a standard test voltage such as 2.5kV or 10kV.

- Correct the power factor readings of the transformer to 200 C from the top oil temperature. (Refer to the chart for Temperature Correction Factors for Liquids, Transformers, and Regulators, Appendix D in the Delta 2000 manual).

- Identify each set of readings of the transformer bushings with a serial number. Record manufacture, type or model and other nameplate ratings. Especially be aware to record nameplate C1 capacitance and power factor values if available. Correct the power factor readings on the bushings to 200 C using the ambient temperature. (Refer to the chart for Bushing Temperature Correction Factors in Appendix D in the Delta 2000 manual).

TEST RESULTS

Power factor results should always be compared to manufacturers' tests, or to prior test results if available. It is impossible to set maximum power factor limits within which all transformers are acceptable, but units with readings above 1% at 200C should be investigated. Bushings, if in poor condition, may have their losses masked by normal losses in the winding insulation Therefore, separate tests should be applied to them.

Increased power factor values, in comparison with a previous test or tests on identical apparatus, may indicate some general condition such as contaminated oil. An increase in both power factor and capacitance indicates that contamination is likely to be water. When the insulating liquid is being filtered or otherwise treated, repeated measurements on windings and liquid will usually show whether good general conditions are being restored.

Oil oxidation and consequent sludging conditions have a marked effect on the power factors of transformer windings. After such a condition has been remedied, (flushing down or other treatment) power factor measurements are valuable in determining if the sludge removal has been effective.

Measurements on individual windings may vary due to differences in insulation materials and arrangements. However, large differences may indicate localized deterioration or damage.

Careful consideration of the measurements on different combinations of windings should show in which particular path the trouble lies; for example, if a measurement between two windings has a high power factor, and the measurements between each winding and ground, with the remaining winding guarded, gives a normal reading, then the trouble lies between the windings, perhaps in an insulating cylinder.

THREE-WINDING TRANSFORMERS

Testing of three-winding transformers is performed in the same manor as two-winding transformers with the additional tests of the tertiary winding.

In some cases, transformers are constructed so that the interwindings are shielded by a grounded electrostatic shield or a concentric-winding arrangement. This could provide test results that capacitance is almost non-existent or even a negative power factor. The transformer manufacturer should be contacted to verify the existence of a shield or a concentric-winding arrangement.

AUTOTRANSFORMERS

In the design of an autotransformer, the secondary winding is actually part of the primary winding. For a given power output, an autotransformer is smaller and cheaper than a conventional transformer. This is particularly true if the ratio of the incoming line voltage to outgoing line voltage lies between 0.5 and 2. Generally all three-phase autotransformers have a tertiary winding.

Compare test results to previous tests on the same transformer.

To power factor test the autotransformer, both primary and secondary bushings are shorted together and the tertiary bushings are shorted to each other. The autotransformer is then tested as a two winding transformer. Individual tests should be performed on each bushing if they are equipped with a test tap.

TRANSFORMER EXCITATION CURRENT TESTS

Transformer excitation current tests are helpful in determining possible winding or core problems in transformers, even when ratio and winding resistance tests appear normal. Excitation tests should be conducted routinely along with power factor testing.

TEST CONNECTIONS

- Transformer excitation current tests are performed on the high voltage winding to minimize the excitation current. Problems in the low voltage windings will still be detected by this method.

- The secondary windings are left floating with the exception of a wye secondary. In this case, the X0 bushing remains grounded as it is in normal service.

- Refer to Section 3 Table 5 for test connections for Single Phase, Three Phase High Side Wye and Three Phase High Side Delta transformers.

- Single Phase: The transformer is energized from the H1-H2 bushings. Test connections can be reversed for additional data, but test results should be the same. H2 may also be designated as H0.

- Wye – Wye: Observe that the ground wire is removed from the H0 bushing for testing, but remains connected on the X0 bushing.

TEST PROCEDURE

- Test voltages should be as high as possible without exceeding the rating of the line-to-line voltages on delta connected transformers and line-to-ground on wye connected transformers.

- Test voltage should always be the same as prior tests.

- All transformer excitation current tests are conducted in the UST test mode.

- For routine testing, transformers with load tap changers should have tests performed in at least one raise and one lower position off of neutral. The no-load tap changer should be in the normal in service position.

- For new transformers, excitation tests should be performed in every tap position for both the load and no-load tap changers.

- The more information that is recorded at the time of testing will ensure the best comparison of results at the next routine test.

- Record test voltage and current. Corrections are not applied to transformer excitation current tests.

TEST RESULTS

Compare test results to previous tests on the same transformer, or to manufacturers' data if available. Tests can also be compared to similar type units. It is essential that identical test voltages be used for repeat tests on a transformer. Fluctuation in the test voltage will produce inconsistent current readings. Three phase transformers should have the indi-

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Infrastructure

Continued from Page 6

pricing model that is not included in most budgets. And in the world we live in today, reliability issues associated with using a public infrastructure exist—remember the blackout discussed earlier? Anyone on a cellular system was unable to communicate.

Using a long-range, high-speed solution that supports fixed and mobile applications is the answer. Long range and high speed - with data rates up to 512 Kbps and a range of many miles - means less infrastructure needed in your wireless network, which translates into dramatically lower costs.

In addition, a license-free 900 MHz radio means no licensing or frequency usage costs, and minimal costs associated with installation and setup in comparison to a wired network solution.

Rugged, industrial-strength radios that are simple to install requiring virtually no set up will mean little downtime and few disruptions in workflow. A solution that can withstand harsh elements such as cold, heat and the rough-and-tumble environment of a utility truck, is crucial to the success of a system.

An Internet Protocol (IP)-enabled network allows users to take advantage of new applications such as voice and video as well. Voice over IP (VoIP) is an ideal application in an emergency situation or remote location when other means of communications are limited or non-existent. Video over IP is also growing in popularity for surveillance as a security feature. Some electric utilities are working to install cameras in vehicles to obtain slow-frame video for accident and incident reports, as well.

LAST BUT NOT LEAST… SECURITY

Because electric utility networks are carrying mission critical data, the security of the network is paramount. An IP network comprised of an access point and remote radios that offer encryption, dynamic key rotation, provision lists, authentication, and a level of transmission security, such as frequency hopping spread spectrum, will provide the most secure network.

In addition to building security measures into your wireless network, every organization should have an enterprise-level security plan in place to safeguard their corporate network. For example, a firewall can be implemented to protect a network and restrict data from users outside of the network.

CONCLUSION

Every industry is being forced to do more with less these days, and nowhere is that more true than for electric utilities. Consolidation and deregulation in the industry means mobilizing large field forces to keep up with customer demand and maintain customer satisfaction.

The ability to leverage one private wireless infrastructure for both fixed and mobile services enables substation and distribution automation, and SCADA systems, as well as field service dispatch, outage restoration and asset management.

Empowering your field force by providing real-time information using a long-range, high-speed mobile data solution means more efficient operations, lower costs, reduced response time and satisfied customers.

Testing

Continued from Page 22

vidual windings energized at both ends if the original test appears abnormal. Transformer excitation current tests on the high voltage winding should detect problems in the secondary winding if they exist. Winding resistance testing in addition to the excitation tests could be helpful in isolating either a core or winding defect.

Test results on three phase transformers, especially wye-connected windings, could produce high but similar readings on two phases compared to the third phase. This is the result of the low phase being wound around the center leg of a three-legged core. The reluctance of the magnetic circuit is less for the center leg of the core resulting in a lower charging current.

SHUNT REACTORS

When electrical energy is transmitted at extra high voltages, special problems arise that require the installation of large compensating devices to regulate the over-voltage conditions and to guarantee stability. Among these devices are shunt reactors. Shunt reactors are composed of a large coil placed inside a tank and immersed in oil. They can be single phase units or three phases in one tank. In both cases each phase has its own neutral bushing.

TEST CONNECTIONS

- For all tests, the line and neutral bushings for corresponding phases must remain shorted.

TEST PROCEDURE

- Record test results on the test form for Miscellaneous Equipment Capacitance and Power Factor Tests, located in Appendix C in the Delta 2000 manual.
- Test voltages are at 10kV. If 10kV exceeds the insulation rating, test at or slightly below the insulation rating.
- For single phase units only one overall ground test is performed in the UST mode.

TEST RESULTS

Power factor and capacitance results should be recorded in the same manner as for oil filled power transformers. Temperature correction should be to the top oil temperature. Compare test results to previous tests or tests on similar units. Additional bushing tests should be performed if test results are suspect.

POTENTIAL TRANSFORMERS

Potential transformers are installed on power systems for the purpose of stepping down the voltage for the operation of instruments such as voltmeters, wattmeters and relays for various protective purposes. Typically the secondary voltage of potential transformers is 120 volts, so power factor testing is performed on the primary winding.

Potential transformers are typically single phase with either single or two bushing primaries. Single bushing primaries have one end of the high voltage winding connected to ground. Secondary windings are normally three wire and dual identical secondary windings are common.

TEST CONNECTIONS

- Ensure that the potential transformer is disconnected from the primary source before testing begins.
- Remove any fusing on the secondary circuits to prevent any type of back-feeding to the secondary.
- Ground one leg of each secondary winding for all tests on two primary bushing transformers, for dual secondary transformers it is typically X1 and Y1.
- Ensure that the case of the potential transformer is securely grounded to a system ground before testing begins, this also includes testing of spare transformers.

TEST PROCEDURE

- Ensure the test set is securely grounded.
- Record all tests results. Power factor tests should be corrected to ambient temperature.
- Compare test results to prior tests on the same or similar equipment.

CURRENT TRANSFORMERS

Current transformers are used for stepping down primary current for ammeters, wattmeters and for relaying. Typical secondary current rating is 5 amperes.

Current transformers have ratings for high voltage and extra high voltage application. The higher voltage classifications can be oiled filled, dry type or porcelain construction. Current transformers that are donut or window type are normally not tested for power factor.

Tests on two bushing primary currents transformers are performed by shorting the primary winding, grounding all secondary windings and test in the GST mode. Some current transformers in the high voltage classifications have test taps similar to bushings. Tests can be performed on units equipped with a test tap for the C1 insulation and the C2 tap insulation. Refer to the application guide for Bushing Testing.

Assure that the unit under test is grounded before testing. Record all test results and correct the power factor readings to the ambient temperature at the time of the test.

VOLTAGE REGULATORS

Regulators are generally induction or step-by- step. The induction regulator is a special type of transformer, built like an induction motor with a coil-wound secondary, which is used for varying the voltage delivered to a synchronous converter or an ac feeder system

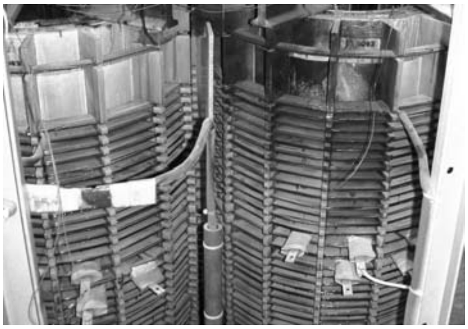
The step-by-step regulator is a stationary transformer provided with a large number of secondary taps and equipped with a switching mechanism for joining any desired pair of these taps to the delivery circuit.

Voltage regulators may be single or three phase. Single phase regulators consists of three bushings identified as S (Source), L (Load) and SL (Neutral). The

Continued on Page 32

DON'T NEGLECT MAINTAINING YOUR TRANSFORMERS

By Paul Eichenberg, Richard Pickering and Sandra Smith, RONDAR INC.



Transformers require less care and attention than almost any other kind of electrical apparatus. This, however, is not a reason for neglecting them. Transformers not only represent considerable investment but they are essential in maintaining the continuity of electric service. Failure of a transformer can cause a great deal of consequential damage to associated apparatus, therefore, it is important that transformers be kept in serviceable condition and that some protection given them against conditions which may cause failure.

There are two general types of transformer - Liquid Filled or Dry Type.

Liquid filled transformers are filled and cooled with one of the following insulating fluids:

- Mineral Oil
- Silicone Fluid
- Other Flame Retardant Fluids (examples):
- Askarel (PCB)
- R-TEMP ™
- Perchloroethylene

Either externally mounted radiators or internally mounted water coils accomplish cooling of the transformers. Cooling may be through natural convection and circulation or may be augmented with forced air through the addition of fans or forced oil utilizing pumps in the water-cooled application.

Dry Type transformers are usually either a varnish or epoxy insulation system. Cooling will be from either natural air convection, forced air or by an insulating gas.

GENERAL MAINTENANCE

Although transformers are highly reliable and efficient devices, routine inspections performed by the equipment owner can identify potential problems in their early stages. Most transformers are equipped with basic indicating devices that, when routinely monitored and recorded, will indicate a change from normal operation conditions. In addition to the information provided by various gauges and relays, physical inspections should also be performed to identify problems such as:

- Oil leaks
- Cracked or chipped bushings
- Damaged radiators
- Damaged cooling fans
- Deteriorated paint
- Rust
- Foreign debris
- Plugged breathers
- Depleted silica gel
- Defective Auxiliary Devices

Daily Checks

1. Ambient Temperature
2. Liquid Temperature
3. Winding Temperature
4. Load Currents
5. Voltages
6. Liquid Level – Transformer and Liquid Filled Bushings

Monthly Checks

Cooling Fans and Pumps

SPECIALIZED MAINTENANCE

The maintenance procedure that is best for your transformers will depend on the conditions that they operate under and will determine the frequency that they should be inspected. The ideal time to start a maintenance program is when a new transformer is being installed. At this time, pre-installation tests should include:

1. Insulating Fluid Analysis
2. Insulation Resistance
3. Voltage Ratio and Polarity Tests
4. Winding Resistance
5. Function Testing of Auxiliary Devices

The results of these tests should be recorded for future comparative purposes in determining the condition of the transformer. Usually after the first few inspections, a defined schedule can be set up based on the existing conditions.

INSPECTION

Scheduled inspections on a liquid filled power transformer include the following checks:

Insulating Fluid Analysis
1. Standard Analysis
2. Gas-In-Oil Analysis
3. Power Factor
4. Water Content
5. Furan Analysis

Mechanical Inspections
1. Liquid Level
2. Paint Finish
3. Cooling Equipment
4. Breathers
5. Alarm and Control Circuits
6. On-Load and Off-Load Tapchangers
7. Bushings
8. Auxiliary Devices

TRANSFORMER TESTING

Transformer testing in the field is usually limited to the following:
1. Ratio and Polarity
2. Insulation Resistance
3. Capacitance and Dissipation Factor (liquid filled only)
4. Winding Resistance
5. Core Ground Test (if applicable)

RATIO

This test establishes that the HV and LV windings have the correct turns.

If there is a tapchanger, the ratio should be checked on each tap position. The ratio should, first of all, be calculated using the nameplate voltages as a basis for the calculation.

In taking the actual ratio measurement, polarity is important in order to obtain the correct results.

Ratio error allowed = 0.5% between calculated and measured test value.

INSULATION RESISTANCE TEST

The purpose of the insulation resistance test is to determine the insulating capability of the insulation. If the insulation is contaminated with moisture, carbon, etc., its ability to insulate between the coil layers, turns and end turns will be limited.

This is a 3-part test.
Test 1- HV - LV & GRD
Test 2 - LV - HV & GRD
Test 3 - HV & LV - GRD

The results you obtain will be in megohms. (millions of ohms).

The values obtained should be corrected to 200C.

Note: never perform an insulation resistance test on a transformer under vacuum as winding failure may result.

DIELECTRIC-ABSORPTION TESTS

Dielectric-absorption testing is a refinement of the standard insulation resistance test method and tends to offset the effects of temperature and lack of previous records.

The ratio of the insulation resistance readings taken at 10 minutes after the test to the one-minute readings is called the polarization index. The values given in the following table may be used to evaluate the condition of liquid immersed transformers.

Polarization-index guide for evaluation of the condition of liquid filled transformers:

A polarization index of less than 1.0 may indicate excessive moisture or carbonized paths in or over the surface of the insulation.

CAPACITANCE AND DISSIPATION FACTOR (POWER FACTOR) TEST

The purpose of this test is similar to that of the insulation resistance test and is performed using a Capacitance and Dissipation Factor Bridge. The measurement of insulation power factor is the measurement of insulation dryness.

A complete analysis of the total insulation system, phase to phase, phase to ground and turn to turn can be evaluated when insulation resistance and insulation power factor results are combined.

TEST PROCEDURE

Following the instructions supplied with the bridge, take the following capacitance and dissipation factor readings:

- HV - LV
- HV - GRD
- LV - HV
- LV - GRD
- LV - HV + LV - GRD
- LV - LV + HV - GRD

All readings should be corrected to 20°C.

RESISTANCE

This test establishes that there are no improperly welded or bolted connections in the coil and checks the overall integrity of the coil.

Testing is performed using a Kelvin Bridge.

Note: Generally there is less concern

Polarization-index guide for evaluation of the condition of liquid filled transformers

Condition	Polarization index (10/1 min. Ratio)
Dangerous	Less than 1.0
Poor	1.0 - 1.1
Questionable	1.1 - 1.25
Fair	1.25 - 2.0
Good	Above 2.0

for the actual values of resistance than for the similarity of the resistance. The resistance of each LV coil should he similar as should he the resistance of each HV coil. If the resistance from coil to coil varies more than 1.0%, the reason for the variance should be determined.

CORE GROUNDS

The magnetic circuit on transformers is usually insulated from ground, then grounded at one point to prevent a buildup of excessive voltages in the core. On smaller transformers, the connection to ground is often inside the tank where it is not readily accessible. Transformers have experienced failures because the magnetic circuit developed additional grounds. The multiple ground path for the flux through the steel members causes overheating in these steel parts. On modern power transformers with ratings of 10 MVA and above, the core ground connection is brought out to the outside of the tank where it is readily accessible for periodic checks.

The core insulation should be checked with a 1000-volt insulation resistance tester. Test between the core ground lead and ground.

Minimum acceptable values - 100 megohms at 20°C.

MECHANICAL INSPECTION CONSERVATOR TANK DESIGN

Transformers supplied with an expansion tank will have a head of oil above all the gasketed surfaces except the area of the expansion tank above the liquid level and the top half of the relief pipe. Therefore, any leaks below the oil level will be readily identified by the presence of oil around gasketed assemblies. Visual inspection of the relief pipe gasketed diaphragm assembly to ensure that it has not ruptured should suffice.

SEALED TANK DESIGN

Smaller transformers of ratings to 10,000 KVA are more likely to be subjected to frequently changing load conditions. If the transformer is a free breathing type with an expansion tank, the temperature cycling created by the varying load will likely introduce moisture and oxygen into the transformer in excessive amounts. This combination of moisture, oxygen and temperature is the major cause of high acidity levels and sludging of the oil.

Sealed tank transformers eliminate this condition as the sealed gas space above the oil prevents breathing under normal operating conditions. The tank is normally sealed at a temperature of 20-25°C and any change in temperature of the transformer from this level will create either a positive or negative pressure in the tank. A leak on this type of transformer can be disastrous if it is located in the area of the gas space and the unit is at a temperature below 25°C as moisture will be drawn into the transformer by the vacuum.

PAINT FINISH

Practically all transformers manufactured in Canada for outdoor applications are in painted steel tanks. The life of a well-designed paint system depends on the thickness of paint film and the quality of the paint. The industry standard requires a minimum thickness of 3 mil.

Any paint will weather in time. The rate of weathering depends on the operating environment. Painted surfaces should be carefully inspected annually and refinished as necessary. Rust should be removed from affected areas and bare metal coated with a suitable primer before applying a finish coat or coats of paint.

COOLING

Cooling on transformers is accomplished by means of oil to water heat exchangers or oil to air heat exchangers.

Oil to water heat exchangers have two basic designs:

1.) Internal Cooler mounted inside the transformer at the top oil level,

2.) External Cooler mounted outside the transformer with the oil piped from the top of the tank through the cooler and back into the bottom of the tank. Coolers usually require little or no maintenance for the first 10 years of service, however, the manufacturer's instructions should be followed regarding maintenance.

The oil to air heat exchanger is mounted outside the transformer either on the tank walls or on separate headers. Additional stages of cooling are available by the application of fans to the coolers and radiators and pumps to force the oil through the coolers.

BREATHERS

The most common type of breather is a simple opening in the expansion tank shielded to prevent the entry of water, and a screen over the opening to keep out bugs and debris. Inspections should be made to insure that the screen is clean and unplugged. The dehydrating breather consists of a container of silica gel piped to the expansion tank. Moisture in the air is absorbed by the silica gel as it passes through the breather. The addition of an oil seal to the breather provides a head of oil that the air has to lift before it can enter the breather, minimizing the amount of breathing resulting from minor temperature changes in the transformer. The oil seal will prolong the active life of the silica gel. Regular inspection of the breather is required to ensure that the silica gel is active and not saturated with moisture. If the normal blue colour has changed to pale pink, it should replaced with new silica gel.

ALARM AND CONTROL CIRCUITS

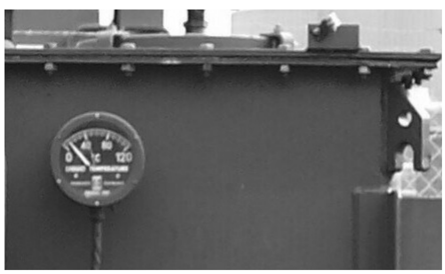
All power transformers are equipped with one or more protective devices, designed to initiate a warning or provide a trip signal to remove the transformer from the system in the event of a fault within the transformer.

Although frequently overlooked, periodic testing and maintenance of these devices are critical to your transformer maintenance program.

THERMOMETERS AND WINDING TEMPERATURE INDICATORS

The most common of these devices is the liquid temperature gauge. The liquid temperature gauge normally supplied on transformers usually has one set of contacts set to operate at 90°C. These contacts are usually connected to an alarm circuit to provide a warning that the maximum permissible operating temperature has been reached. Transformers equipped with forced air cooling will have additional contacts provided to operate at temperatures of 60°C and 75°C to switch on one or more stages of cooling.

Larger transformers will also have winding temperature indicators. These instruments indicate a simulated winding hot spot temperature and are generally supplied with three or four sets of contacts to switch on one or more stages of cooling and alarm circuits.



LIQUID LEVEL GAUGE

The correct liquid level on a transformer is essential to maintain its dielectric capability and its cooling requirements. On the conservator tank design, a gauge mounted on the end of the expansion tank indicates the liquid level. Most of these gauges will be equipped with a set of low level alarm contacts. Periodic inspections of the actual oil level in the expansion tank should be made to ensure the gauge is indicating correctly. On sealed tank design transformers, the liquid level gauge is mounted on the tank wall. The normal level at 25°C as indicated on the gauge will be approximately halfway up the opening of the top cooler header. A low liquid level in this type of transformer will result in overheating, as no liquid will be circulated through the coolers. The liquid level gauges on sealed type transformers are similar to the ones used on the expansion tanks, however, they may not be supplied with alarm contacts and should be inspected regularly.

EXPLOSION RELIEF DEVICE

The explosion relief device is provided on transformers equipped with expansion tanks. This device consists of a large diameter flanged steel pipe bolted to the transformer cover. The pipe has an elbow at its top end and is of sufficient length to allow the oil to rise to the maximum level in the expansion tank without flowing over the elbow portion.

A thin diaphragm of either Melinex or Kapton is placed between the relief pipe flange and tank cover and a Teflon diaphragm is used at the top to prevent moisture and foreign matter from entering the explosion relief device.

MECHANICAL RELIEF DEVICE

The Mechanical Relief Device is usually mounted on the tank cover and acts to relieve the pressure in the tank if this pressure exceeds a certain value. Usually it operates at 8 PSI although there are units available that operate at lower values.

Its construction is simple, comprising of a heavy coil spring inside the housing. The device will operate to relieve the tank's internal pressure, then self-closes to keep out water and other contaminants. It can also be supplied with contacts for alarm or trip circuits.

Mechanical Relief Devices are maintenance free and should never be dismantled in the field. The large spring inside is compressed at all times and could cause serious injuries.

VACUUM/PRESSURE GAUGE

This gauge measures the degree of vacuum or pressure present in the tank and is mounted in the gas space. The gauge usually has a range from -10 PSI to +10 PSI and can be supplied with contacts that will alarm or trip at some predetermined values. A regulator can also be installed to control the degree of vacuum or pressure in the tank. This regulator will, under certain conditions, allow the transformer to breathe, and therefore compromises the sealed tank principle.

The importance of vacuum/pressure gauge is not in whether it reads positive or negative, but that it reads something other than zero, indicating the transformer remains sealed. If, over a 24-hour period of varying loads and ambient temperatures, it always reads zero, you may have a leak in the tank that could allow the entry of water and the risk of a transformer failure.

SUDDEN PRESSURE RELAY (SPR)

This relay is mounted on either the transformer cover or tank wall and acts only on a sudden rise of pressure. Its response time is directly related to the rate of rise of pressure within the tank. The faster the rate of rise, the faster the bellows within the unit move to operate the microswitch. It is designed so that a gradual rise of pressure will not operate the device.

The relay is factory sealed and not field repairable.

GAS DETECTOR RELAY

There are several types of gas detector relays used on transformers. They are usually mounted on the transformer cover or pipe connection between the expansion tank and the transformer tank. The relays have two sets of contacts, one set operates by the slow accumulation of gas and the second set operates through a sudden increase in pressure, as would be the case when a heavy arc occurs inside the transformer. These relays will accumulate the gas evolved in a chamber where it can be collected and analyzed. The information gained from this analysis may identify the cause of the failure. When a transformer equipped with a gas relay is initially filled with oil, air released from the oil and trapped in the windings will collect in the relay and give an alarm. This condition may persist for intervals up to three months. If this condition persists beyond this period, it is likely that a fault in the windings, bad joints, faulty contacts, or overheated conductors may be the source of the gas. The transformer should be checked to establish the source of the gases.

ON-LOAD TAPCHANGERS

There are many designs of on-load switching devices with each device being designed to meet a specific range of voltage and current requirements. These tapchangers will all have a set of selector switches that select the appropriate tap on the transformer winding. Some selector switches will be exposed to arcing as they move from tap to tap, however most are equipped with a set of load break switches that divert the load current while the selector switches move from tap to tap. Switches exposed to arcing will be contained in a separate compartment of oil isolated from the main transformer. In general, these contacts can be operated through 100,000 operations between inspections. Always refer to the manufacturer's instruction book for information on specific tapchangers.

OFF-LOAD TAPCHANGERS

Most off-load tapchangers provide a wiping action on the contacts when moved from position to position. Industry standards recommend that tapchangers be operated through their range at least once a year to clean the contact surfaces. The operation of the tapchanger should be combined with turns ratio testing performed during annual maintenance to verify proper operation.

BUSHINGS

All bushings should be physically inspected annually. The insulators should be cleaned and inspected for cracks, chips, and faulty gaskets. Liquid levels on bushings with sight glasses or liquid level gauges should be verified. Power factor and capacitance on condenser style bushings with a capacitance tap can be tested and compared to the value on the bushing nameplates. Bushings without the capacitance tap require one reading between the conductor and ground. Changes in capacitance and power factor may indicate the presence of water and/or the deterioration of the condenser.

The power factor test is not valid for bulk type bushings, as defects will not be detected.

DEGRADATION OF OIL

The desirable properties of insulating liquids degrade in

service as a result of contamination and deterioration. Water is perhaps the most common and most dangerous since it reduces the dielectric strength. Dirt (for example, fibers) is a common contaminant and affects the electrical properties adversely, especially when water is present.

The most common type of deterioration is oxidation brought about by exposure to air and high operating temperatures. The oil is oxidized to organic acids, which may react later to form a sludge that will settle out on electrical elements, lowering their electrical resistance. Sludge may also plug tubing in coolers reducing oil circulation. Water is also formed in the oxidation process and when combined with the acids and sludge, lowers the dielectric strength and promotes corrosion of metal components. Certain metals, such as copper, catalyze oxidation.

EVALUATION OF OIL

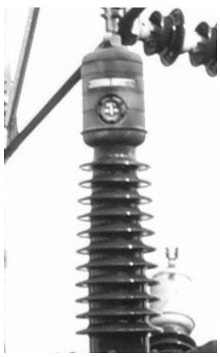
The properties of an insulating oil may be determined by suitable laboratory tests and the results of these tests can be used to decide whether the oil is safe for further operation or whether it should be reclaimed or replaced with new liquid. Some of the more important tests done and their significance are described below:

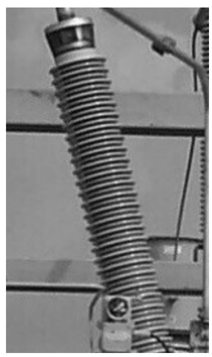
TRANSFORMER INSULATING FLUID TESTING

"Standard Analysis" is the minimum regular quality testing that should be performed on transformer fluid at least once per year. This should include dielectric breakdown, neutralization number, interfacial tension*, specific gravity, visual condition and colour. Power factor and dissolved water content tests can be added to these results, to give a more detailed picture of the fluids physical and chemical properties. (*on mineral oils only)

Regular testing of the inhibitor content is quickly gaining wide acceptance. Monitoring and keeping the inhibitor content at acceptable levels will help increase the service life of your transformer oil.

Internal transformer faults break the oil down into several gases. The detection of these gases by Dissolved Gas Analysis (DGA) can determine if the oil or insulation is being subjected to thermal faults, or if corona or arcing is occurring. There are various diagnostic techniques to interpret the fault type including Key gases, Doernenburg or Rogers ratios. Regardless of which diagnostic method used, gas generation rates will determine the severity of the fault. Regular DGA will help detect potential faults in your transformer, without taking it off line. Most problems and repairs can then be dealt with and worked into convenient scheduling, rather than an emergency situation arising due to your transformer suddenly going off line. DGA should be done on a regular schedule, the size criticality of the transformer will





determine whether this should be on an annual or more frequent basis.

If the DGA indicates the insulation has been subjected to above normal temperatures, it should be verified with a furan analysis. As with DGA, the rate of furan generation can be more important than the actual level. For this reason, monitoring the furan level over time can indicate if the paper is being subjected to heat stress. Furans can be directly correlated to the degree of polymerization of the paper; however, the history of the transformer must be taken into consideration, a reconditioning or replacement of the oil resets the furan level.

During transformer faults, metal particles are generated. Analysis of the insulating oil for certain metals can help pinpoint the location of the fault. The type of metals found indicates the possible source areas within the transformer.

The Environmental Act requires that all transformers with PCB contamination greater than 50 ppm, must be so identified, and all sample and material wastes generated from them must be handled, stored, or transported in the manner prescribed in the Act and its accompanying Regulations. Knowing the PCB content of your transformer and having an official record of it can also save valuable time and money, in cases of leaks, spills, or other transformer related emergencies. Most transformer servicing requires that the PCB content to be known before maintenance begins. The PCB content should always be verified after any oil treatment, or internal tank work has been performed, to ensure that no contaminants have been added.

OUTLINE OF LAB TESTS DIELECTRIC BREAKDOWN

This test is important as a measure of the ability of the fluid to withstand electrical stress without failure. It serves primarily to indicate the presence of contaminating agents such as water, dirt or conducting particles in the oil. A low dielectric test result can be caused by the presence of one or more of these agents.

In North America two methods are primarily used for dielectric testing. Historically ASTM Standard Method D877 has been used on most transformers. This standard was originally published in 1946, however it is not very sensitive to dissolved water in oil under 80% saturation. A newer dielectric test ASTM Standard Method D1816 is more sensitive to the effects of moisture in solution especially when cellulose fibers are present in the oil. For this reason ASTM D1816 is recommended for all new filtered, degassed and dehydrated oil and for power transformers above 230 kV. ASTM D877 should be used for acceptance test on oil received from vendors in tank cars, tank trucks, or drums.

NEUTRALIZATION OR ACID NUMBER

Transformer fluid acts as a cooling medium and helps insulate against electrical voltage. Oxidation products, sludge and water are all detrimental to electrical properties and can cause corrosion, impair cooling and accelerate the breakdown of the winding insulation material. An elevated neutralization number indicates acidic compounds which are a product of oxidation along with sludge and water. Build-up of acidic compounds precedes the formation of sludge which deposits on windings and cooling ducts, impairing heat transfer which increases temperature and increases the oxidation rate of the oil. The acid also directly weakens the paper insulation.

INTERFACIAL TENSION

Interfacial Tension (IFT) measures the polar contaminants in the oil and is therefore very sensitive to oxidation products. This measurement done on mineral oils in conjunction with the neutralization number, is a monitor of sludge development.

SPECIFIC GRAVITY

Transformer fluids perform a very specific task and therefore it is necessary that certain physical and chemical properties be present for that task to be performed properly. To that end, the specific gravity test tells us that the insulating fluid conforms to standards and has not been substituted with any other fluid.

VISUAL CONDITION

Visual examination of the fluid provides non-quantitative assessment of undesirable contaminates such as sediment, free water or carbon particles. The visual appearance of clear or cloudy is also reported. Visual inspection can help pinpoint causes of poor test results.

COLOUR

The colour of insulating mineral oil is determined by transmitting light through the oil and comparing it to a series of colour standards. Using ASTM D-1500, this is then expressed by a numerical value, ranging from 0.5 for a light yellow to 8.0 for dark amber. Oils tend to darken with age due to presence of contamination or oxidation products. Silicone and Askarel should be clear and colourless. Any colouration indicates contamination by another product, or leaching of pigments from paints etc.

DISSOLVED WATER CONTENT

Free water may be observed as droplets in the sample container, or as suspended particles causing a cloudy appearance. Dissolved water, however, cannot be detected by visual examination of the fluid; ASTM D-1533 uses the Karl Fisher coulometric method to detect dissolved water in the low parts per million range.

The maximum limit for dissolved water is 35 ppm for voltage classes up to 69 kV and 25 ppm for voltage classes above 69 kV through 288 kV for mineral oils, 60 ppm for Askarel and 100 ppm for silicone. Above these levels dissolved water can result in decreased dielectric strength and contributes to oxidation and fragmentation of paper insulation.

POWER OR DISSIPATION FACTOR

Small particles and fibers, polar contaminates and water all help to transmit, instead of insulate against, applied voltage. ASTM D-974 measures the percentage of dielectric losses in an electrical insulating fluid subjected to an energy field. Therefore, the lower the number, the better the fluid.

INHIBITOR CONTENT

Inhibitor is added to insulating mineral oils at the manufacturing or refining stage. Type I oil contains 0.08% and Type II oil 0.3% inhibitor.

Inhibitors help slow the aging process of oil by combining with oxidation byproducts and stop the spread of the oxidation reaction. When the inhibitor has been depleted from the oil oxidation byproducts - acids and free radicals - will start to significantly affect the oil properties. Analysis can easily check the level of inhibitor present in the oil. If the concentration is found to be less than 0.02%, the oil should be reclaimed and inhibitor added to the oil as soon as possible.

PCB CONTENT

It is advised that an owner should know the PCB levels of all insulating oils in his control, from a liability standpoint, as well as to comply with M.O.E.E. legislation. A PCB level greater that 50 ppm identifies equipment as being classifiable as a PCB article. PCB levels between 0 and 50 ppm are classified as non-PCB. The level determines how wastes, samples and the equipment will have to be handled.

FURAN ANALYSIS

In dissolved gas analysis, increasing levels of carbon monoxide and carbon dioxide as well as their ratio has been used to determine if a transformer's insulation is deteriorating. Unfortunately, these gases are also produced in high quantities from pressboard and some transformers have been carbon dioxide blanketed at one time. To determine if the insulation is actually involved, a Furan Analysis can be performed.

When the paper insulation has been damaged by heat, it produces glucose which, in turn, degrades to furans. There are several different types of furans produced, however Furfurol is specific to Kraft paper, and Furfuraldehyde is specific for thermally upgraded paper. Caution must be used and previous history of the transformer taken into consideration, as Fullers Earth treatment, or vacuum processing, removes almost all of the furans from the oil.

As the paper insulation is subjected to heat stress, it loses its strength and becomes brittle, however, left undisturbed it will still act as electrical insulation. The problem is, if it is subjected to any mechanical stresses, it could fall away from the metal it is insulating, with

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Testing

Continued from Page 24

windings in the regulator cannot be effectively separated, so one overall power factor test is performed. All the bushings are shorted together and tested in the GST test mode. Tests should be conducted with the tap changer moved to some position off of neutral. Additional Hot Collar tests may be conducted on bushings of suspect units.

Excitation tests may also be performed by energizing terminal L with the high voltage lead and the low voltage lead on SL in the UST position. Terminal S should be left floating.

Power factor results should be corrected to top oil temperature on regulators just taken out of service. Ambient temperature should be used for those that have been out of service for any length of time. Power factor results should be compare to previous tests on the same equipment or similar tests on similar units.

DRY-TYPE TRANSFORMERS
TESTING NOTES

Test voltages should be limited to line-to-ground ratings of the transformer windings. Insulation power factor tests should be made from windings to ground and between windings.

Temperature at the time of testing should be at or near 200C. ANSI/IEEE C57.12.91 - 1997 recommends correcting results other than 200C. However, there is very little data available for temperature correction of dry-type transformers. Repeat tests should be performed as near as possible, in the same conditions as the original test.

Higher overall power factor results may be expected on dry-type transformers. The majority of test results for PF is found to be below 2.0%, but can range up to 10%. The insulation materials necessary for dry-type construction must meet the thermal and stress requirements.

If power factor results appear to be unacceptable, an additional test called a Tip-Up Test can be performed if a 10kV test set is used. This test can be performed to evaluate whether moisture or corona is present in the insulation system. The applied test voltage is varied starting at about 1kV and increased in intervals up to 10 kV or the line-to-ground rating of the winding insulation. If the power factor does not change as the test voltage is increased, moisture is suspected to be the probable cause. If the power factor increases as the voltage is increased, carbonization of the insulation or ionization of voids is the cause.

REFERENCES

Theodore Wildi, Electrical Machines, Drives, and Power Systems
Waukesha Electric Systems, Instruction Manual #V 2.1 REV 12/95 9300
Terrell Croft, American Electricians' Handbook
ANSI/IEEE, C57.12.80-1979, Terminology for Power and Distribution Transformers
C57.12.90-1987 Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers
C57.12.91-1979 Test Code for Dry-Type Transformers

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Transformers

Continued from Page 31

possible devastating effects.

DISSOLVED GAS ANALYSIS

Dissolved Gas Analysis is probably the most important test that can be performed on a Power Transformer. It checks for various gases that are produced in the event of internal faults of corona, thermal faults, arcing, and insulation breakdown. It involves utilizing Gas Chromatography to measure the concentration expressed in parts per million of the following gases:

Oxygen + Argon (O_2 + A), Nitrogen (N_2), Carbon Dioxide (CO_2), Carbon Monoxide (CO), Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4), Ethane (C_2H_6), and Acetylene (C_2H_2).

A limited amount of gas generation, under normal operating conditions occurs in all transformers. If the transformer is under electrical or thermal stress, the level of gasses or the rate of combustible gas generation will be abnormal. The rate of increase in conjunction with the size of the transformer can give an indication of fault type and severity.

SUMMARY

The information provided in the previous text provides the equipment owner with basic information regarding the maintenance requirements of power transformers. Industry standards recommend transformers be tested annually in addition to the daily and monthly inspections suggested.

While the equipment owner can perform daily and monthly inspections, annual testing should be performed using a Professional Service Specialist trained and experienced in transformer testing and evaluation. Specialized laboratories with personnel experienced in providing detailed interpretation and recommendations of the test results should also be utilized to perform the Transformer Fluid Analysis.

Sandra Smith received her Bachelor of Science degree from Guelph University in 1985. She is the Manager of Rondar Inc.'s Fluid Analysis Laboratory and has 13 years of experience in transformer fluid analysis and interpretation, assisting customers in their maintenance decisions.

Richard Pickering is Customer Account Representative with Rondar Inc. His twenty eight years of experience in the electrical service industry includes a wide range of commissioning, testing repair and maintenance of electrical power systems for industrial, marine and utility customers.

Paul Eichenberg is a professional electrical engineer with a B.Sc. from Queen's University in 1978. He is a Service Engineer with Rondar Inc., with broad experience in Canada and Overseas in power system design, protection, commissioning, maintenance and project leadership.

TRANSFORMER TRIPPED? FIGURE OUT ITS SAFETY LEVEL BEFORE ANYTHING ELSE!

By Tony McGrail, Doble Engineering

No one enjoys the stressful and time-consuming problem of having a transformer that has tripped off line. There are a number of reasons why it could have tripped, and many tests that can be done to determine what went wrong. Where to start?

Before the testing begins, the most important issue is safety: of the transformer, of the work space, and, above all, of personnel. Figure 1 shows a transformer, which tripped when in service. Looking at the transformer, it isn't obvious that there is anything wrong with it. This visual inspection may not show much. Regardless of its appearance, it's imperative to keep in mind the safety of the transformer.

Safety is the key concern, taking priority over the bottom line. It might make good economic sense to try and return a questionable transformer to service, but do you want to be held accountable for the risk involved? A catastrophic failure of the unit could occur.

In order to make a rational decision on how to handle the transformer, reliable information about the dielectric and mechanical state of the transformer is needed. Dielectric information shows the ability of the insulation to withstand voltage. Mechanical information shows whether the transformer has suffered winding damage, which could lead to dielectric breakdown.

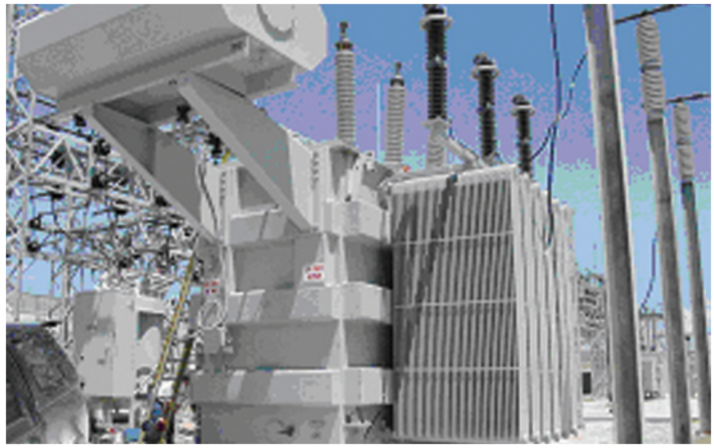

Figure 1: A transformer, which tripped out while in service.

DECISIONS, DECISIONS

The first item that needs to be addressed is the cause of the transformer tripping while on-line.

In order to do so, some initial questions must be answered:

- What does the protection tell us?
- What where local weather conditions at the time of the trip?
- Is this related to something internal or external to the transformer?
- If the cause of the trip was internal– what are the symptoms?
- If the cause was external to the transformer– has any internal damage resulted?
- What past test data is on file?
- What further tests are needed to accurately determine the transformer's viability?

This is also the time when a general visual inspection and review of the transformer history is typically performed. To do this effectively, requires knowledge of the transformer design, problems and likely weak spots.

The next step is doing an efficiency assessment to evaluate which tests are required so that the transformer can be returned to service with confidence. It is important to find out the transformer's viability before putting it back into service.

In order to determine the transformer's viability, we should differentiate between the general testing of transformers that confirms viability during regular maintenance, and the focused testing of transformers that demonstrates viability after a fault. A suspect dissolved gas analysis result during routine maintenance may have less weight than one produced after a transformer trip.

Determining the transformer's viability is the reason the SFRA (Sweep Frequency Response Analysis) is a key tool for assessing transformer health and safety.

GENERAL TESTS FOR TRANSFORMER HEALTH

The general tests performed on a transformer are power factor and capacitance testing or dissolved gas analysis of oil (DGA). These tests give a broad indication of the health of the transformer. Power factor testing indicates the dielectric strength of the transformer, while capacitance testing is related to the construction of the windings.

After the transformer is out of service, a closer inspection of the dielectric and mechanical aspects of the transformer should be done. The DGA signature should be paid close attention to determine what key gases are present and how their proportions have changed since the last sample.

Years of research by Doble Laboratories have shown that DGA is a powerful indicator of problems within a transformer and can often identify the cause of the fault. However, DGA is an integrating diagnostic: the results are for the transformer as a whole and it is difficult to pin down a particular part of the transformer as being the problem.

SWEEP FREQUENCY RESPONSE ANALYSIS — RECORDING THE TRANSFORMER'S SIGNATURE

SFRA is a tool for investigating the mechanical integrity of a transformer. SFRA provides a fingerprint, for every winding on each phase of the transformer. The fingerprint is provided in the form of an SFRA trace. These traces are plotted as a response, in dB, to an input signal that varies in frequency from 20 Hz to 2 MHz. An example of this is shown in Figure 2.

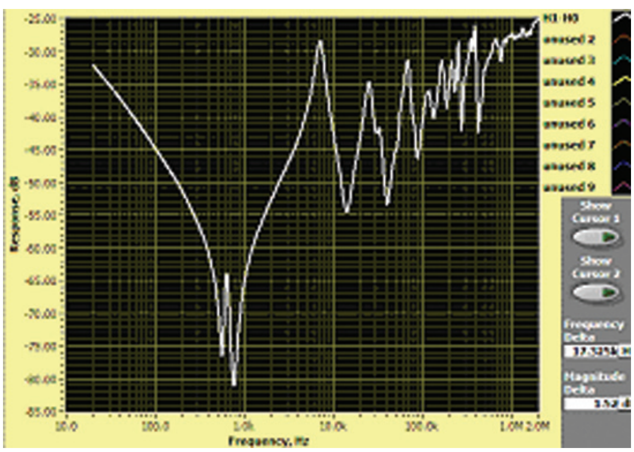

Figure 2: Example SFRA Trace

The peaks and valleys in the trace are resonances that relate to impedance (specifically, inductance and capacitance) within the transformer. The values of this impedance are strongly determined by the transformer construction and geometry. It is the variation in the SFRA responses that provides evidence of winding movement or damage.

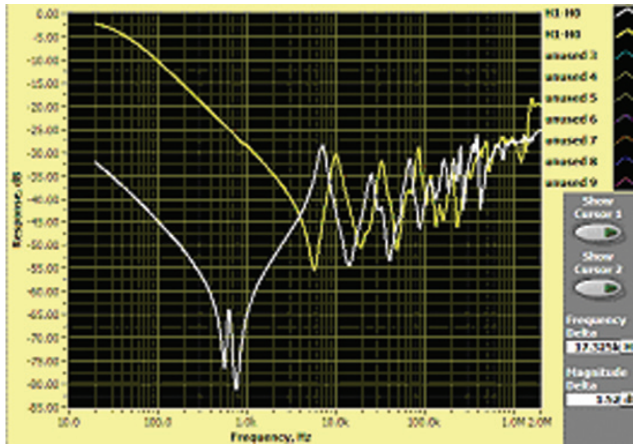

Figure 3: SFRA variation before and after a shorted turn within a transformer

Variations in the SFRA traces (Figure 3) are a clear indication of a turn within a transformer that has shorted out. In this case, the initial results of Figure 2 are overlaid by a subsequent response after a close in fault. The initial trace shows the characteristic 'dip' or first resonances around 1 kHz. The subsequent trace shows the effects of the short circuit: a resonance missing and a low dB response at low frequencies. After seeing this type of variation once, it is relatively easy to make this diagnosis in future.

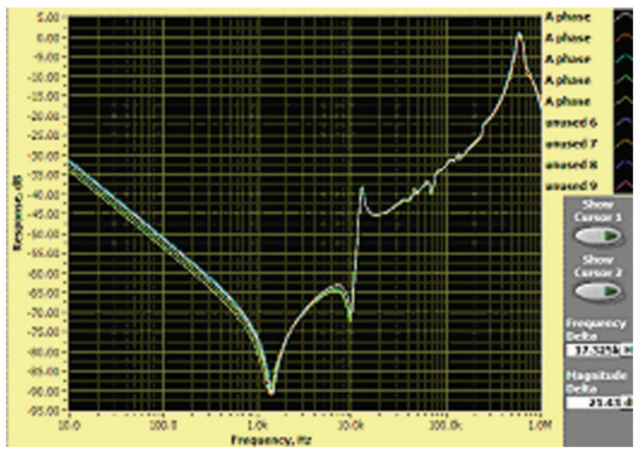

Figure 4: Null result – SFRA measurements taken in 1994, 1997, 1999, 2000 and 2002

Even without reference results, there are certain characteristic shapes expected from a SFRA trace. (i.e. the core resonance is around 1 kHz, and the main winding responses is below 100 kHz.)

Conversely, a null result, where there has been no change in response, is strong evidence that nothing has changed within the transformer. Figure 4 shows FIVE successive SFRA traces from one winding of one phase of a Generator Step-Up

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(GSU) transformer taken in different years. Small variations at low frequency relate to the state of core magnetization when the transformer was switched out of service. Overall, it is clear that the main resonances have not changed.

These results give strong evidence that there has been little significant winding movement or distortion over the past five tests. In this case, the SFRA test demonstrates there has been no degradation in the mechanical integrity. For this transformer, the only step needed is to 'reset the clock' for reference results during a routine maintenance outage.

THE TRANSFORMER MAY BE 'BENT' BUT NOT BROKEN

One of the benefits of SFRA is that it can indicate non-fatal damage within a transformer that will need to be addressed in the future. A case story presented at the 2004 Doble Client Conference concerned a 28 MVA mobile transformer that became suspect due to rising DGA results. This transformer was tested using SFRA, resulting in a clear diagnosis of hoop buckling (compressive deformation) on the X1 winding. The open circuit SFRA results, shown in Figure 5, show a shift left for one phase at a key frequency area.

The short circuit SFRA results shown in Figure 6, show increased impedance for the same X1 phase.

Using reference results from a sister unit and analysis of results from the Doble Knowledgebase, it was possible to make a definitive diagnosis without the costly de-tanking and internal inspection of the transformer.

By performing the SFRA testing and comparing the results, the question remains on the level of safety of the transformer.

In this case, the transformer is safe, but there is a warning that the transformer is 'bent'. The transformer has been damaged by a fault, which compromised its mechanical strength: making it much less likely to withstand another close-in fault.

The unit was returned to service for six months and performed well, providing a vital service up until it could be safely taken to a workshop for repair. The 'bent' diagnosis was confirmed during the repair, as shown in Figure 7.

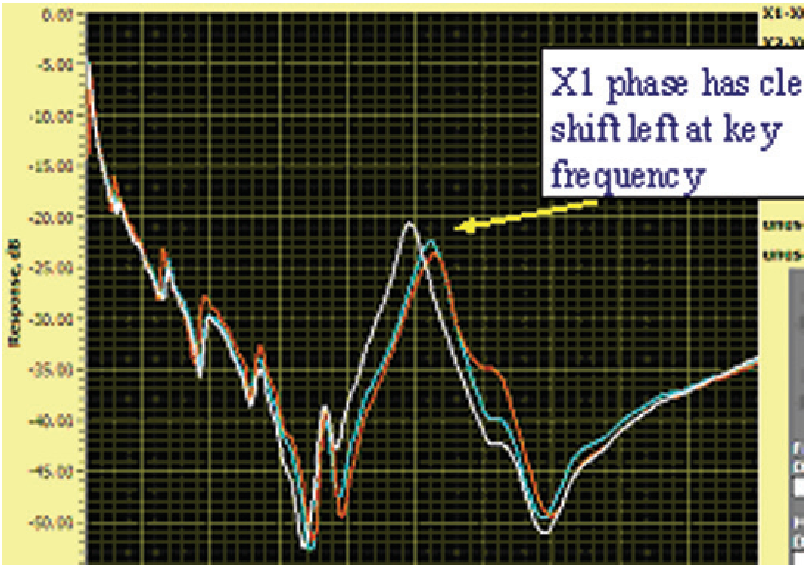


Figure 5: Open Circuit SFRA traces

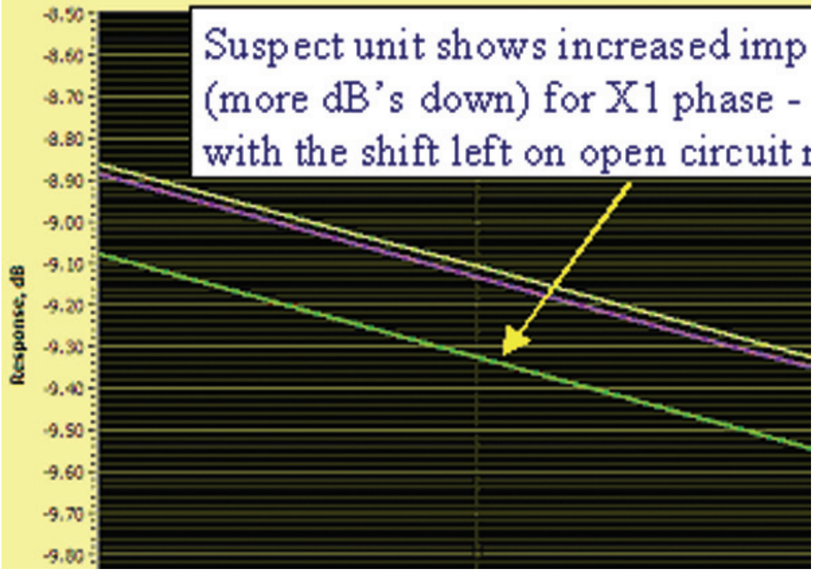


Figure 6: Short Circuit SFRA traces

REPEATABILITY - THE VALUE OF SFRA TESTING

The true value of SFRA testing is the repeatability of results. Experience over the years has shown that a Sweep system is the only way to extract that value from the results. The 'Null result' showing no movement in Figure 4 would be lost if the measurement was not repeatable to within +/- 1 dB.

SFRA identifies damage within a transformer and indicates the location and extent of damage without the need for costly de-tanking or internal inspection.

SFRA - REDUCING UNCERTAINTY

When making decisions relating to transformers, the most important factor is reducing uncertainty about the test results. With SFRA, better decisions, more effective asset management, and the confidence of re-energization can be made. SFRA is the only tool that provides the Range, Resolution and Repeatability ensuring that the data is useful for improved decision making.

While SFRA is an important tool, it should be used in conjunction with other electrical and diagnostic tests to paint a complete picture of transformer health.

For further information and case studies, please visit the Doble web site: (www.doble.com).

Tony McGrail is the M5100 SFRA Product Series Manager with the Doble Engineering Co., based in Watertown, MA, USA. Prior to this, Tony was a Transformer Engineer with the National Grid Co. in the UK. He is a Chartered Engineer in the UK, holds a Ph.D. in Electrical Engineering and a Masters in Instrumentation.

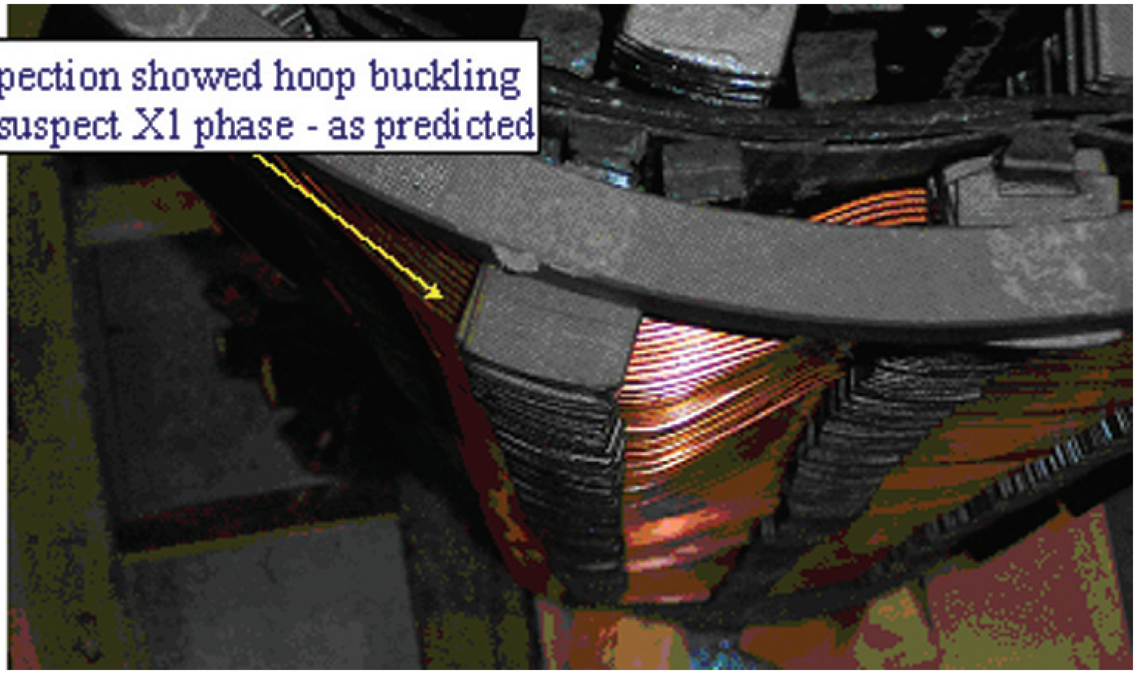


Figure 7: Hoop Buckling of Transformer Winding

'DC TIE' ELECTRICAL POWER TRANSFERS BETWEEN MEXICO, TEXAS GRIDS APPROVED

Sharyland Utilities announced that it has obtained a Certificate of Convenience and Necessity (CCN) from the Public Utility Commission of Texas (PUCT) to build an electrical interconnect between the Texas and Mexico power grids.

This cross- border tie will be the first of its kind to support both emergency power and commercial business activity in Texas and Mexico. The 150-megawatt High Voltage Direct Current Tie ("DC Tie") will allow two-way electricity transfers between completely independent power grids, which supports economic development and increased reliability of both grids.

Prior to approving the CCN, PUCT Chairman Paul Hudson issued a memo expressing his "strong belief that reliability from both instantaneous capability and reserve (electrical power availability) perspectives support the investment". He also emphasized Sharyland Utilities' commitment to operate the DC Tie as an open-access connection. This means that all electricity market participants, including Mexican industrials and utilities on both sides of the border, can sell and/or purchase power to the mutual benefit of both parties.

"We are grateful to the State of Texas for approving this project," said the Honorable Norbeto Salinas, Mayor of Mission, Texas, where the DC Tie converter will be located. "The technological and economic benefits of this tie will be felt not just in Mission, but throughout the Valley and in northern Mexico. On behalf of the City of Mission, I look forward to working with Sharyland Utilities to make this project a reality as soon as possible."

"The always-on feature makes the DC Tie quickly accessible during an energy crisis, and the addition of competitive Mexican power prices creates an interesting alternative in Texas' energy price-shopping environment," said Mark Caskey, general manager of Sharyland Utilities. "Strengthening the reliability of our state's electric systems remains a priority for us. This project emphasizes our commitment to the infrastructure in South Texas and the consumers who call the Valley their home."

With construction planned for early 2006, the 20-month DC Tie project is expected to be completed in the first quarter of 2007.

Sharyland Utilities is the first Greenfield electric utility in the United States since the Reedy Creek Improvement District was created to serve Disney World in the late 1960s.

ET

CANADA'S WIND POWER CAPACITY JUMPS ALMOST 25 PER CENT

Canada's wind-power capacity, already the fastest-growing form of electricity generation in Canada, took another significant step forward recently with the announcement of funding for two new wind-power projects in Murdochville, Quebec.

Together, the 60 turbines at the Mount Miller and Mount Copper wind farms provide 108 megawatts of wind-energy capacity, lifting Canada's total wind-power generation capacity from 444 to more than 550 megawatts, an increase of nearly 25 percent.

The new wind farms were developed with the support of the Government of Canada's Wind Power Production Incentive (WPPI), which will contribute more than $36.5 million to the two projects over the next 10 years. The WPPI is administered by NRCan (Natural Resources Canada).

"To address climate change and maintain a strong and growing economy, we need a reliable supply of competitively priced, clean energy," said Minister Jacques Saada.

Funding to the WPPI has been increased to more than $900 million, with a goal of adding 4,000 megawatts to Canada's wind-energy capacity by 2010.

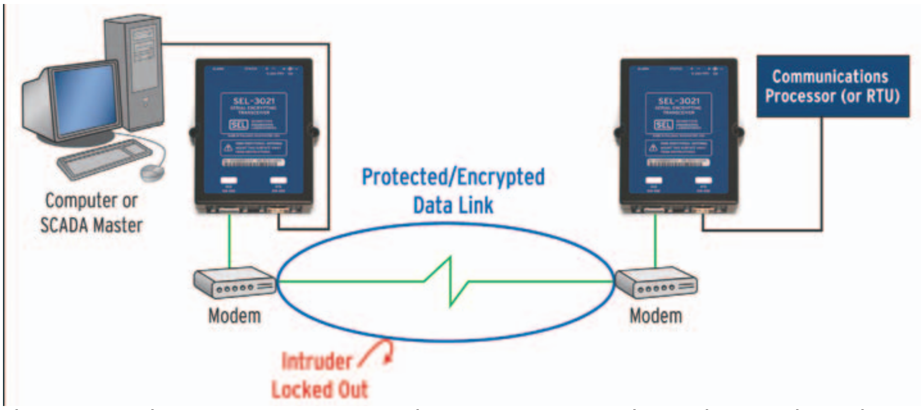
"Wind power is a perfect example of how we can do good for the environment, and do good for business at the same time," said Mr. Robert Vincent, President of 3CI, Incorporated, co-developer with Northland Power of the Mount Miller wind farm and co-developer with Creststreet Power Holdings of the Mount Copper wind farm.

"The price of wind-generated electricity is becoming more and more competitive, and the Wind Power Production Incentive is playing an important part in accelerating its competitiveness."

Under the WPPI, eligible recipients, such as independent power producers, utilities and cooperatives, can receive an incentive of approximately one cent per kilowatt-hour (kWh) of production for electricity generated by their wind farms. Payments to eligible recipients are made over ten years and begin once a wind farm is commissioned or operational. Typical large-scale wind turbines have a life expectancy of about 20 years.

Including the wind farms commissioned, Canada's total wind-power capacity is now 552 megawatts. Through the WPPI, the Federal government has contributed to the development of almost 60 percent of that capacity. ET

PROTECTING VITAL COMMUNICATIONS FROM CYBER ATTACKS WITH SERIAL ENCRYPTION



The SEL-3021 Serial Encrypting Transceivers secure vital communications to protect electric grids against cyber attack.

Instrumentation and control systems operate and monitor critical infrastructure components. Today there are real threats of malicious physical and cyber attacks on these systems, making their protection and security more important than ever.

An attacker, for example, can secretly monitor sensitive information on data links, or send messages to operate equipment or change settings. Attackers could steal data that would identify biggest customers, usage patterns, delivered power quality, and production rates, or to identify physical targets. Worse yet, imagine the problems they could cause by commanding breakers to open or close, machines to stop or start, and gates or valves to open or close.

The Federal Energy Regulatory Commission (FERC) and electric utilities are concerned about attacks on the

Continued on Page 42

METERING PROGRAM APPLAUDED

McKenzie Bay International Ltd applauded the voluntary statewide net metering program approved by the Michigan Public Service Commission (PSC).

The net metering initiative is the result of a consensus agreement signed by 11 utilities serving customers in Michigan. As a result of the decision Michigan customers will be able to generate renewable energy for on-site use with McKenzie Bay's next-generation WindStorSM wind power system. The decision also empowers Michigan customers to further maximize savings by transmitting excess power into the public grid. In exchange for the power generated by the customer the utility will issue a credit to that customer commensurate with the power metered.

"This program will encourage the development of on-site renewable energy sources such as WindStorSM. It will also take some pressure off the electrical grid and allow residential and small business customers to utilize green energy in a meaningful way while reducing their power costs," said McKenzie Bay President, Gary L. Westerholm.

Michigan-based McKenzie Bay subsidiary WindStor Power Co is the owner and developer of WindStorSM, a wind energy system designed to integrate distributed generation wind power installed on or near a building with grid power. WindStorSM will feature WindStor Wind Turbines, a proprietary system integrator and, if applicable, a battery.

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Fire Alarm Systems: Practical Applications	19-20 Saskatoon, SK 21-22 Winnipeg, MB			1-2 Toronto, ON 6-7 Vancouver, BC 8-9 Edmonton, AB
Industrial Electricity Efficiency	26-27 Toronto, ON	4-5 Vancouver, BC 6-7 Edmonton, AB 17-18 Saskatoon, SK 19-20 Winnipeg, MB		
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FOOD FOR THOUGHT AT THE POWER INDUSTRY FORUM

By Bob Fesmire, Communications manager at ABB

The 12th Annual Power Industry Forum was held May 11-13 in Washington, DC and featured panel discussions on generation, transmission, retail competition and industry recovery. The panels were made up of top-level executives from across the industry and the views presented were equally far ranging.

I was especially interested by the discussion of transmission issues, perhaps because that is my area of focus in my "day job", but also because transmission seems to be on everyone's mind, regardless of what sector of the industry they hail from. Since the August 2003 blackout, oceans of ink have been spilled as regulators and the industry grapple with how to prevent such an event from recurring. The Forum, hosted by Torys LLP, offered some interesting perspectives.

Michael Calviou, Vice President, Transmission Regulation and Commercial at National Grid, put the issue of underinvestment in perspective by noting that while transmission spending in real dollar terms has declined, it's even more alarming when you compare US investment with other countries on a dollars per gigawatt per year basis. Taking the UK as an example, Calviou noted that on this score our colleagues across the pond are investing three times as much as we are annually in their transmission infrastructure. The reasons for underinvestment are many, but what can be done to reverse the trend?

Several panelists pointed to changes in the structure of how transmission investments are made and regulated. Robert Mitchell, President of Trans-Elect New Transmission Development Company, suggested allowing market participants into the transmission segment as a way to make more capital available to transmission projects and offer those companies access to regulated (read: assured) returns. He noted that participants in competitive markets would have to be restricted to investing as passive partners in order to avoid market power issues, but the idea is worth considering.

Picking up on the issue of regulated returns, Rana Mukerji, ABB's Vice President of Electric Systems Consulting noted that the lack of transmission investments transcends the usual siting and other complexities that utilities have grappled with. According to Mukerji, the two main pricing options for transmission owners—regulated returns based on dollars invested or returns based on ownership of congestion rights—both have serious deficiencies. The first pricing mechanism involves recovering its embedded costs via a network access charge. The second involves entitlements to receive congestion revenue rights (CRRs). The first pricing mechanism is a traditional cost-of-service model, which does not allow a transmission company or ratepayers to capture the benefits of innovations in technology or managerial improvements. Given the costs, risks and complexity of building transmission projects, the regulated rates of return may not offer enough incentives for transmission investments. The second mechanism, which is based on congestion revenue rights (CRRs), provides incentives that are simply too little and too uncertain to be bankable. The fatal flaw in the CRR mechanism is that once the transmission corridor is upgraded the CRRs are worth less than when the congestion was in effect. Mukerji hopes that incorporating economic benefits of improved efficiencies and congestion mitigation into the regulatory calculus for transmission projects might allow for more attractive returns and thus draw more investment.

The rules governing who can invest in transmission projects and how those investments are recouped in particular markets are important issues, but there are also industry-wide considerations. In restructured regions, competitive markets might provide some of the answer to the transmission dilemma. MISO President James Torgerson noted that with the implementation of real-time and day-ahead markets and the systems that support them, MISO is now able to redispatch generation resources within ten minutes as opposed to the hour it took previously. Clearly, recent experience with restructuring in North America has made regulators less enthusiastic about the ability of markets to solve complex issues such as those surrounding transmission investment. But as the MISO example shows, there are at least some positive changes that are brought about with the implementation of a competitive energy market.

Questions about the capability of markets as a catalyst for improved reliability will remain, but there is a sense of inevitability beginning to take hold across the industry when it comes to transmission. National Grid's Calviou pointed out that there are presently over 450 entities that own transmission assets in the US. In the current business climate, consolidation seems increasingly likely, and could very well have a positive impact on the ability of transmission owners to undertake upgrades and expansion projects - larger, wealthier companies simply have more muscle to make transmission projects happen.

Central Vermont Public Service President and CEO Robert Young was confident transmission expansion would happen, he said, because it is so vital. He also posed the rhetorical question, what happens to generation owners when their plants are idle because of congestion? Obviously, transmission issues affect industry players of all kinds, but everyone has their own ideas about what should be done and who should pay for it.

Still, the discussions I heard in Washington gave me the sense that our industry knows that something has to give, that we need to find an answer to the question of who pays for transmission and, by extension, for reliability. If the energy bill making its way through Congress is passed and mandatory reliability standards become the law of the land, that will add to the pressure, but perhaps the bill will also provide some of the certainty that is needed to break the inertia of transmission investment.

The opinions expressed here are the author's own and do not necessarily represent those of ABB.

FUND BRINGS PUBLIC, PRIVATE SECTORS TOGETHER TO DEVELOP POWER GENERATION

By Don Horne

Developing new power generation in Ontario is more crucial than ever, and it is the Algonquin Power Venture Fund that is showing how the private and public sectors can work together to solve this problem.

Established as a Labour Sponsored Investment Fund (LSIF) to provide venture capital to support the development of independent power projects, the Venture Fund aims to provide LSIF investors with access to the predictable yield and long-term capital appreciation typical of the electrical power generation, distribution and infrastructure sector in Ontario.

For Algonquin Power it is a natural fit, as the group's two decades of experience in the engineering, environmental and regulatory fields (in addition to being an experienced developer and asset manager of independent power facilities), gives them the background and knowledge to make expert decisions on funding potential power generation projects.

"We have a proven track record and established industry contacts that enable us to place our investments on the low end of the risk scale for venture capital," says Jeff Norman, President of the Algonquin Power Venture Fund.

"For as little as a $1,180 (after tax credits and deductions), an investor can acquire a $5,000 investment in a LSIF. The LSIFs invest a high percentage of their assets in businesses with less than $50 million in assets (at the time of investment) with fewer than 500 employees. For a typical power project, this fits the requirements," says Mr. Norman.

For a venture capital project, the power generation sector is about as conservative an investment in risk capital as an investor will find.

The venture fund benefits from the managerial experience it shares with the Algonquin Power Income Fund (APIF), recognized as a leading consolidator in North America's deregulated electric power generation market since its inception. Boasting an SR-2 stability rating (Very High) on trust units by Standard & Poors, the APIF also has an A- rating on their bank debt.

Since 1987, Ontario Hydro has entered into long-term power purchase agreements with various independent power producers, with some 120 producers now operating within the province.

The need for the private sector to take on a greater role in Ontario's power generation needs is underlined by the commitment by Queen's Park to close the province's coal-fired facilities by 2007. This loss of 7,500 megawatts accounts for approximately 30 per cent of Ontario's generation capacity.

For the Algonquin Power Group, they are looking at developing co-generation, small hydro facilities and alternative power sources.

"The relative stability of the sector (and) our knowledge of the industry means we can make quick judgments," says Mr. Norman. "We know what we like and what we don't like…. We tend to invest in potential cash flow, not cash burn."

Looking outside of Ontario, Manitoba's first wind-turbine generating facility in St. Leon benefited from Algonquin Power's investment and venture fund, helping to get the 99 megawatt project off the ground in co-operation with the Canadian Renewable and Conservation Expense program.

"The legislation allowed the venture fund to invest in the wind farm project outside of the province as the wind farm was run from within Ontario," points out Mr. Norman. "We are looking at investing in projects in the wind sector, smaller, niche-market projects in hydro-generation, and also in the biomass and cogeneration areas of electricity generation."

With a diverse portfolio that includes power generation and infrastructure assets reaching across North America (47 hydroelectric facilities, five natural gas-fired cogeneration facilities, 18 alternative fuels facilities and 11 water reclamation and distribution facilities), Algonquin Power is proving that small-scale generation can be lucrative for those willing to invest.

For more information on the Algonquin Power Group, you can visit their website at www.algonquinpower.com or the Venture Fund at www.algonquinpowerventurefund.com. ET

Serial Encryption

Continued from Page 39

systems that monitor and control the electrical power grid. Serial Encrypting Transceivers, like the SEL-3021, protect critical infrastructure from attack and comply with industry requirements and recommendations. They use encryption and session authentication, and locks out unauthorized control, and are designed specifically to protect existing and new communications links between power control centers, electrical substations, and generating plants.

Systems that require time-critical communication, such as SCADA, metering, and protection, require low latency from serial encrypting transceivers. The "bump-in-the-wire" solution developed by Schweitzer Engineering Laboratories allows easy installation in existing links. ET

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