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Transmission & Distribution

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JUDGING THE EFFICIENCY OF LOW NOISE POWER TRANSFORMERS

By Christoph Ploetner, Peter Heinzig, Harold Moore and Donald Chu, Siemens Power T&D Inc.

The emitted noise of transformers increases with the power rating and loading and can easily lead to a loss of quality of life for neighboring residents. Because of that, the specified noise levels for transformers have obviously decreased within the last several years. By using classical transformer design, it is often impossible to fulfill the requested noise levels, so special measures have to be applied for a suitable noise reduction. Because of the already achieved reduction of the no-load noise, the lowering of load noise becomes necessary and increasingly important.

1. Origin, transmission and radiation of transformer noise

The physical mechanism of transformer noise generation is well known in principal today . Two components form the total transformer noise. The first component is the magnetically-based noise (core noise, winding noise) and the second component is the noise of the cooling equipment when cooling fans are used. This paper deals only with magnetically-based noise because the cooling equipment can be seen as an external transformer element and its noise therefore understood and handled separately.

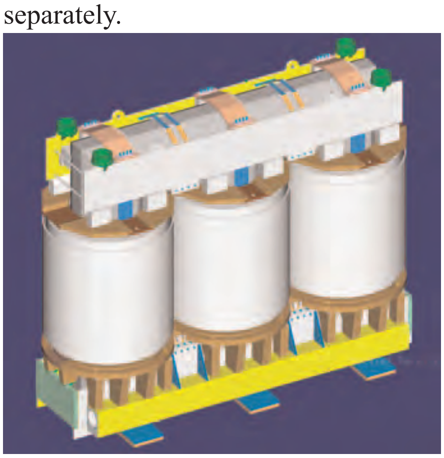

Fig. 1: Active part of a 318 MVA transformer

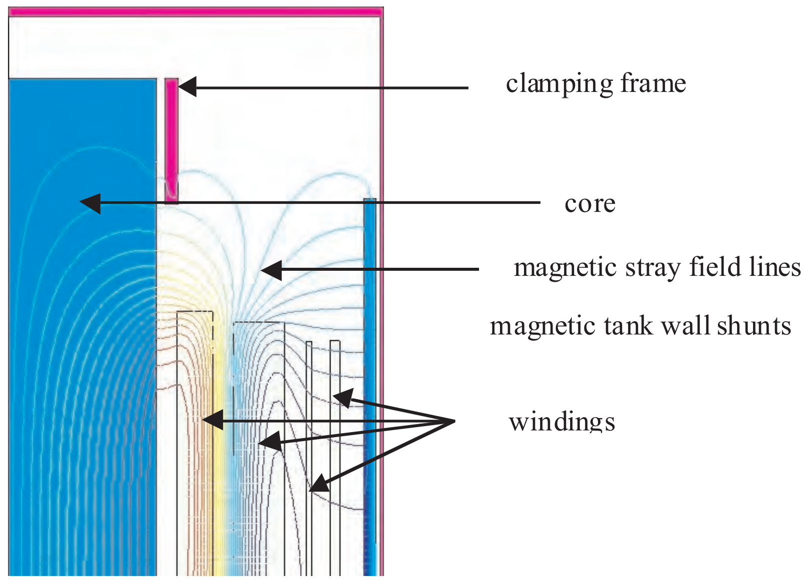

Fig. 2: Stray field in the upper area of a transformer

1.1 Origin of the noise

The source of magnetic noise is the active part of the transformer (Fig. 1). The active part (a.k.a. core-and-coil assembly) consists mainly of the core, windings and clamping parts. Noise formation is caused by mechanical oscillations of the mentioned elements of the active part in response to magnetic flux or fields. Because of the different associated mechanisms, the magnetic noise is advantageously separated into no-load noise and load noise. Both noise components can be measured separately with good accuracy and afterwards summarized to the total transformer noise.

a) no-load noise

As soon as voltage is applied to a transformer winding and the transformer is operated in no-load condition, there will be a magnetic alternating flux in the core. This flux causes a periodic shape variation (expansion and contraction) of the core laminations due to magnetostriction, resulting in oscillations of the whole transformer core at double the power frequency . Because of the nonlinear characteristic of magnetostriction there are also higher harmonic oscillations.

b) load noise

As soon as the transformer transfers real or reactive power , the associated magnetic stray fields due to the current flow generate electromagnetic forces on different parts of the transformer which excite these parts to mechanical oscillations. The main source for the load noise is normally the mechanical spring-mass system consisting of the windings and their clamping parts. The mechanical excitation for this system is provided by axial and radial winding forces caused by the winding currents and the stray field (Fig. 2). The characteristic frequency for the load noise is double the power frequency because of the almost sinu-

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LOW NOISE

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soidal current waveshape. Harmonics of minor magnitude occur due to some non-linear elastic modules of parts of the mechanical spring-mass system.

Further noise sources are oscillations of the tank walls and of the magnetic shunts mounted on the tank walls. Maxwell forces due to the radial stray field component, especially in the area of the winding ends, are the cause of that oscillation.

1.2 Noise transmission and radiation

Transmission of the vibration of the active part to the tank is primarily through the insulating liquid (oil) and, to a smaller extent, through the physical attachments of the active part to the tank base and cover . The vibration energy is transferred through the insulating liquid nearly non-damped and it excites the tank walls to oscillate. Lack of any appreciable damping is due to the incompressible characteristic of liquids and the relatively small distances between the active part and the tank walls.

Fig. 3 shows a measured 100 Hz oscillation mode of a single tank wall of a 340 MV A single-phase generator step-up transformer.

Fig. 3: 100 Hz oscillation mode of a transformer tank wall

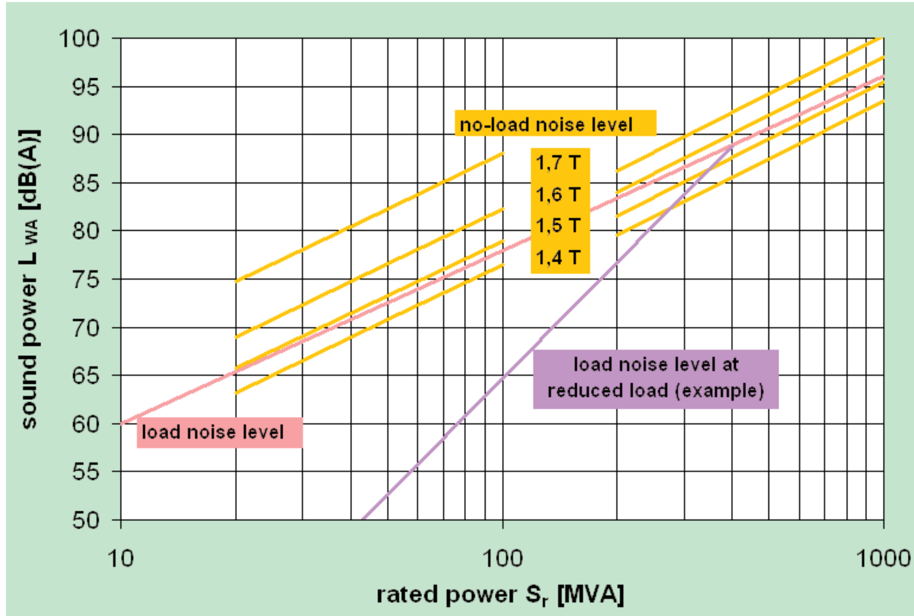

Fig. 4: Emitted A-weighted sound power of modern 50 Hz transformers

2. Typical values of the emitted sound power of transformers

By improvements of materials (for example the introduction of high permeability electrical steel - HiB), by using optimized design parameters, and by the permanent improvement of the transformer design (for example the introduction of step-lap core technology), over the past several decades it became possible to reduce transformer no-load noise on request as much as 12 dB without making the transformer uneconomical by a high increase of material cost or a lar ger transformer physical size.

Until the introduction of high permeability electrical steel and step-lap core technology, load noise of transformers was generally not of concern; it was considered as negligible in comparison to no-load noise. This has changed with the introduction of the mentioned material and technology . For transformers operating with induction values lower than 1.6 T (Tesla) to 1.5 T, the load noise is becoming more important and may easily become the dominant transformer noise.

Fig. 4 shows the average emitted sound power (not sound pressure) of 50 Hz transformers under no-load condition (yellow curves) and during the load test over the rated power (magenta curve). These curves are only typical because manufacturer-specific design measures are not introduced here. Therefore, for specific individual transformers a deviation from the curves of up to ± 5dB is possible. The noise levels for 60 Hz transformers would be increased by about 3 dB over the values shown.

For the calculation of transformer no-load noise, manufacturers have theoretically derived and statistically adopted design rules. The basis for the calculation of A-weighted load sound power (LWA) was empirically investigated and introduced by Reiplinger [1] and is now also discussed in international (IEC) standards [2], although the IEC formula gives typically too low noise levels. More realistic average levels can be simply calculated with equation (1).

Equation 1

$$L_{WA} = 42 + 18 \, Log_{10}[S_r / S_0]$$

Sr – rated power of the transformer
S_0 – power base (1 MVA)

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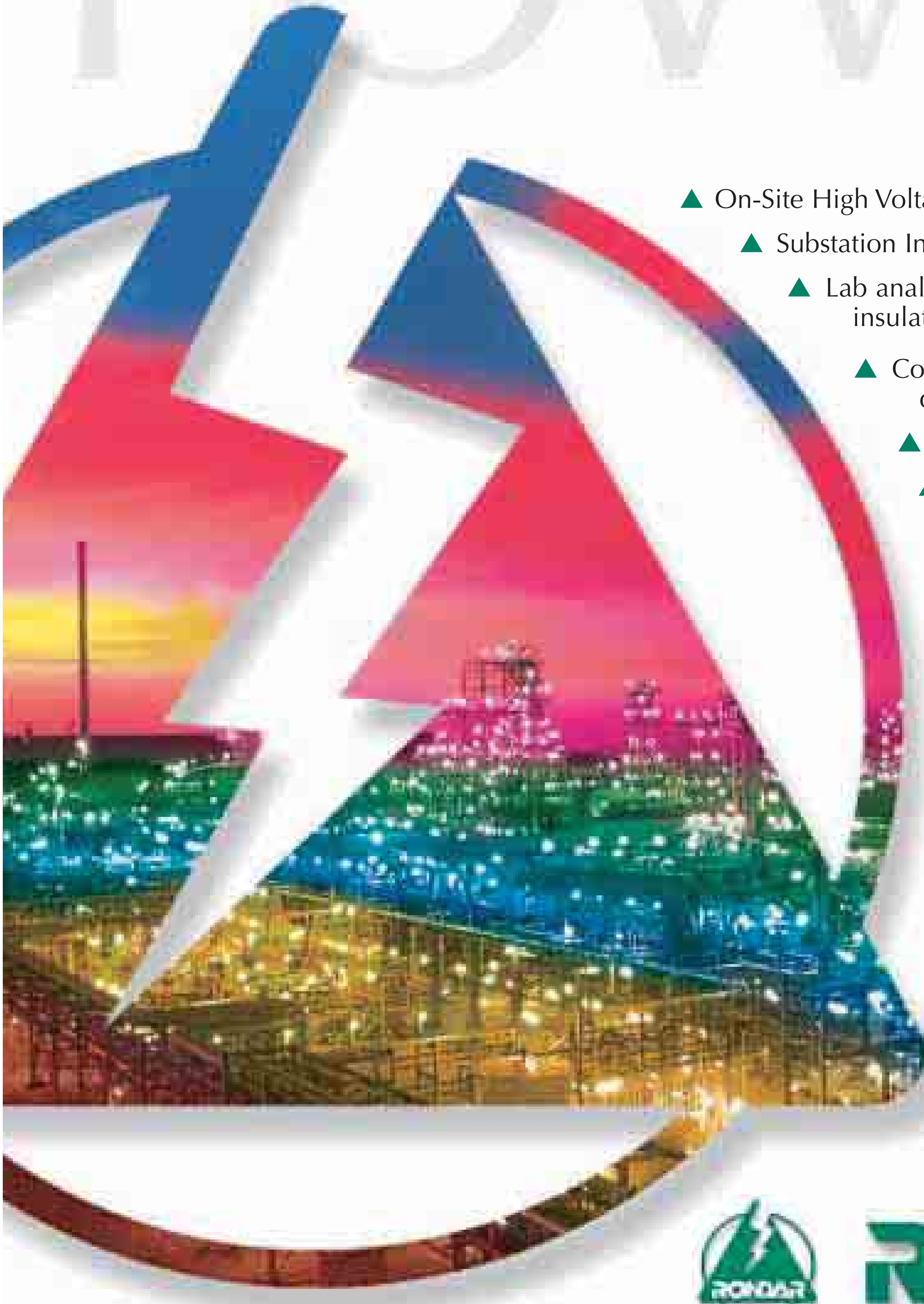
OUR KNOWLEDGE IS POWER



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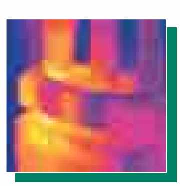

LOW NOISE

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Equation (1) is graphically shown also in Fig. 4.

A transformer is normally energized at a voltage at or near its rated value, but the MVA loading is typically well below the nameplate rating, with full load occurring only rarely, possibly only during failure contingency situations. This has the advantage that the load noise also only rarely reaches its full level, so the transformer noise level is determined by the no-load noise most of the operating time. This also explains why, up to now, load noise considerations have not had the importance of no-load noise considerations. Equation (2) shows the behavior of the load sound power related to the actual transformer load.

Equation 2

$$\Delta L_W = 20 \log_{10}[I / I_r] \leq = 20 \log_{10}[S / S_r]$$

I – actual current
I_r – rated current

S – actual power

The fast decline of the noise level can be seen from equation (2) when loading the transformer with a lower than rated power (current) and is exemplarily shown in Fig. 4 also for a transformer with a rated power of 400 MVA.

The total (no-load and load) emitted sound power level of a transformer can be calculated by a logarithmic addition of the sound power levels obtained during the no-load test and the load test with rated power. This is valid only by general agreement because the magnetic flux and field distribution inside the transformer is different during the real transformer operation with rated voltage and current in comparison with those given during no-load and load test, although this influence is normally small.

3. Possibilities for the reduction of transformer noise

Progress to date regarding no-load noise of modern state-of-the-art transformers is considerable. However, it is obvious that noise restrictions are becoming more severe and some are now also taking the load noise into account. Without special measures those noise levels cannot be fulfilled.

Over the years, a lot of different noise reduction measures have been proposed with varying success. In general, there are two groups of noise reduction measures: passive and active.

The most effective passive noise reduction measure is still the total enclosure of a transformer by a separate so-called sound house, with which it is possible to achieve 20-25 dB noise level reductions. The total cost for a sound house can easily be 10-20% of the transformer cost and also the additional space needed is considerable.

Proposals for active noise reduction have been used only very rarely and would not be expected to be successful in the future. Active anti-noise methods include, for example, anti-sound generating devices for noise cancellation and electromechanical or piezo actors attached at certain points on the tank walls to reduce the tank wall vibration. Both methods need a highly sophisticated microprocessor controlled algorithm.

To fulfill a certain noise level besides making the proper choice of some design parameters, it is also possible to apply different passive noise reduction measures which can be realized with an acceptable effort and at a reasonable cost and noise reduction levels of 8-10 dB can be achieved.

Because of the different origins (physical mechanisms) for no-load and load noise, the noise reduction measures have to be considered separately. Only measures related to the tank apply for both noise components.

The proper choice of the core induction level (flux density) and the grade of core steel is most important for the no-load noise, and the kind of core stacking (e.g. step-lap construction) and the kind and magnitude of core pressing will also strongly influence the no-load noise. In addition one must consider the mechanical natural frequencies of the core, which must not equal the exciting frequency.

According to equation (1) the load noise at rated load is primarily a function of the transformer rated power. Empirical investigations have further shown that different winding types and their arrangement on the core influence the load noise. Also the winding tightness plays an important role for the load noise. This tightness will be provided by having proper conductor tension during manufacturing of the windings and using pressing elements for the winding production, by applying a suitable drying treatment process for windings and active part, and by applying an adequate method of securing and pressing the windings within the active part. Furthermore, mechanical winding natural frequencies in the vicinity of twice the power frequency should be avoided since, in this case, the resonance excitation of the winding would cause a noise increase of up to 5 dB.

The influence of Maxwell forces on the tank walls and the tank wall shunts caused by the magnetic stray field are not significant as long as the shunts have a proper design and size and are properly attached to the tank walls.

To minimize vibration transmission from the active part to the tank, it is important to provide the placement and attachment of the active part within the tank such that it is almost totally isolated from oscillation vibration.

Another important noise reduction measure is the enclosure of the tank walls with special damping panels. The construction, the materials used, and the size of the covered tank surface determine the damping effectiveness. A normal noise level reduction value is 4 dB but reductions of up to 8 dB are

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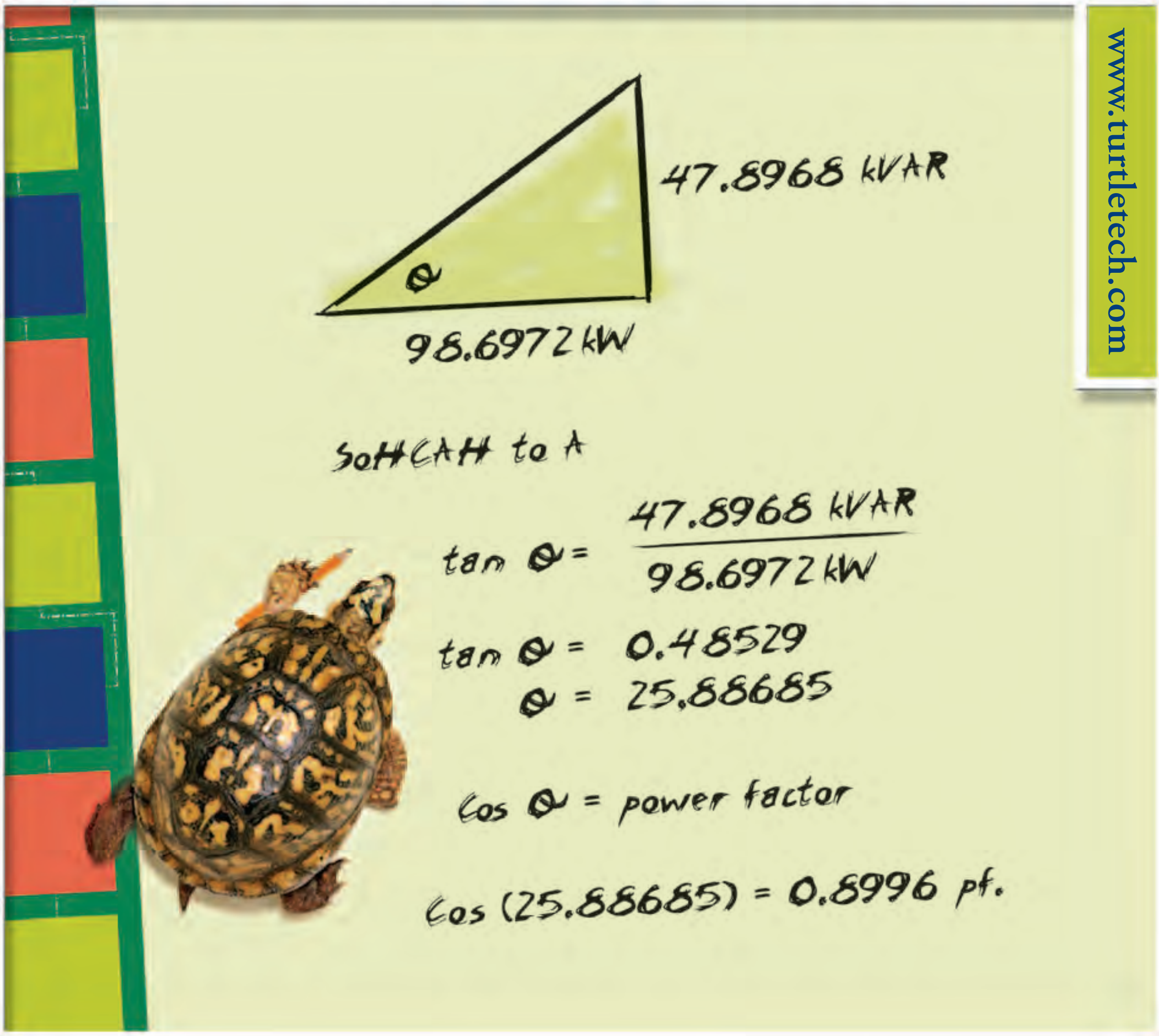

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RELIABILITY AND THE HUMAN FACTOR

By Bob Fesmire, Communications manager at ABB

With the energy bill moving to the front burner in the U.S. Congress, attention in the industry is being focused once again on the issue of reliability. That reminded me of something I learned almost twenty years ago. Let me explain.

When I was in college, my engineer roommate took a course called Human Factors. Today it's more commonly known as ergonomics, but when I think about what really makes the grid reliable, I keep coming back to that phrase: human factors.

With the rapid advance of technology, it's easy to forget how critical people are in keeping the lights on. Technologies such as wide area monitoring systems (WAMS) offer real benefits and are moving the grid toward becoming a more autonomous entity. But though these systems are already commercially available, it will likely be several years before their full potential is realized. As sophisticated as our monitoring and control systems have become, human judgment is still the most important factor in preventing blackouts.

Over the past several years, a number of trends have made it increasingly difficult for the power industry to preserve reliability. From an organizational standpoint, restructuring has created boundaries between operations that were formerly part of a single vertically integrated utility. Now, generation, transmission and distribution functions are controlled in many regions by groups that are required by law to be separate.

On the regulatory front, one need only look at a map showing the various stages of restructuring across North America to see that the end state of this transition is still very much unclear. As a result, the question of who is ultimately responsible for reliability remains largely unanswered.

Then, there is the issue of demographics. As has been widely reported, the "knowledge base" of the electric utility is aging, and there are not enough young engineers coming up in the ranks to take the place of those who are retiring. Add to that the fact that utility jobs — long viewed as some of the most stable anywhere — are no longer a guarantee of employment, and you have an increasingly complex power system being managed by less experienced people, who come and go from their jobs at a much higher rate than in the past. As a result, the exchange of knowledge is being thwarted and the institutional memory of the utility is in danger of being compromised.

In addition to the "human factors" within the industry, there is another kind playing havoc with reliability: politics. The August 2003 blackout is a distant memory for most ordinary people, who understandably assume that sufficient corrective action has been taken to prevent such a large outage from happening in the future. Those of us in the industry know better. The fact is that eighteen months after the largest outage in decades, we still do not have mandatory reliability standards in place, and much needed investment is still not flowing into the transmission infrastructure. This is due in large part to the failure of our elected officials to pass legislation that would put the necessary framework in place to allow more widespread improvements.

It is a sad irony that the near universal agreement over the need for mandatory reliability standards (and an accompanying enforcement regime) is, in fact, the very thing that keeps them from becoming a reality. Grid reliability is political bait, you see. Embedded in the energy bill, reliability rules act as a "sweetener" to encourage negotiations over more contentious issues such as drilling in ANWR or regional price increases brought on by open power markets. Take the reliability title out of the bill and you get a legislative pill that's harder to swallow, but considering what is at stake that may be the most expedient path to establishing reliability standards.

Uncertainty is investor kryptonite, and without a clearer understanding of who is responsible for what with regard to grid reliability, the resources needed to strengthen our electric power infrastructure will remain elusive. Mandatory standards won't solve the problem on their own, but they are a necessary and fundamental first step.

There is little we can do in the short term to mitigate the aging of the utility workforce and the other institutional reactions to a changing industry landscape. There is, however, much that can and should be done to make reliability safe for investment, and it starts with clear standards and meaningful enforcement. If for the current session of Congress that means relegating issues such as production tax credits to some committee backwater in order to pass the reliability measures separately, so be it. You can't build a better wind turbine if your assembly line isn't moving.

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

HYDRO-QUEBEC LINE CREW RETURNS HOME FROM HAITI

By Don Horne

The 14-member Hydro-Quebec line crew and support group that left last November to re-establish essential services in Haiti returned home recently.

The work - mostly carried out in the city of Gonaives and along the national highway between Saint-Marc and Gonaives - was conducted in concert with Electricité d'Haiti (EDH). The some 90 sites that were worked on, including the villages of Johanisse and Bois Blanc and the city of Estère, saw the Hydro-Quebec team installing 400 poles, 10 kilometres of conductors and 85 transformers.

The Hydro-Quebec team routinely put in 16 hour days, six days a week, with Canadian and Haitian lineworkers benefiting from the shared knowledge on each project on which they worked.

The fruits of their labour were shown in the restored service to water pumps crucial for field irrigation, and restored power to La Providence and Raboteau hospitals, a centre housing Doctors without Borders, a CARE distribution centre, and convents and schools run by Canadian and Italian nuns.

In addition, the installation of street lamps at strategic points allowed lighting to be restored in several districts of Gonaives.

With the help of a $500,000 contribution from the Canadian International Development Agency, Hydro-Quebec was able to prolong the mission in Haiti and purchase more poles and transformers. The total budget for the project - of which Hydro-Quebec was the only company to come to the aid of the EDH - was $4 million.

Standing (back): Jean Alain, Chief Lineman; Pierre Bernèche, Technician; Claude Bolduc, Chief Lineman; Robert Beaupré, Chief Lineman and Dominique Thériault, Chief Lineman; Jean-Paul Poissant, Foreman, Robert Guindon, Chief Lineman, André Lauriot, Chief Lineman; Claude Jacob, Chief Lineman; Hortense Lessard, Clerk.
Sitting (front): Réjean Gosselin, Chief Lineman; Raynald Bonneau, Chief Lineman; Alain Brodeur, Logistician, Philippe Nault, Chief Lineman and Gilbert Paquette, Mission leader.
Missing from the picture are Lyne Brousseau, clerk and Carl Guimond, Chief aerial maintenance.

At left, the crew works on stringing new lines.

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possible.

4. Example: 65 MVA low noise transformers produced for Consolidated Edison

Consolidated Edison Company serves New York City, with a power peak load of 12,200 MW, and operates about 350 power transformers in its system. These transformers are almost standardized regarding power, voltage and voltage control and are classified in 10 types. The smallest substation power transformer type is the 65 MV A transformer with a voltage ratio of 132 kV± 5% (DETC) to 13.8 kV±12% (OLTC) with the high voltage winding delta connected and the low voltage winding wye connected. Many of these 65 MVA transformers are located in substations in close proximity to residential and business buildings within New York City.

Until recently, the noise level requirement for these transformers was specified as 60 dB(A) to 66 dB(A) sound pressure level in relation to ANSI/IEEE standards, i.e. only for no-load operation so the sound power levels would have to be 82 dB(A) or 88 dB(A) depending upon the transformer location. The new noise requirement now specifies a 78 dB(A) sound power level and in addition there are specified maximum sound levels for eight octave bands up to 8 kHz to limit tonal frequencies.

In a major change from the previous specification, for all new transformers the emitted sound level now must be fulfilled not only for no-load condition at nominal voltage but also for full load operation with maximum line voltage in a tap position which implies additionally an over-excitation. The reason for these new requirements is a revision of the New York City noise regulations and the observation on the already installed transformers that the emitted noise under load conditions increased significantly as compared to noise under no-load conditions. On-site sound measurements on some installed transformers of different manufacturers have shown sound power levels under full load condition between 82 and 88 dB(A).

A special characteristic of these particular transformers is voltage control by load tap changer on the low voltage side which, because of the large current and specific requirements for the impedance voltage over the tap range, results in the application of a booster (series) transformer. Therefore two active parts, main and series, are placed in the transformer tank.

In addition, other special characteristics such as the high impedance voltage of 25% at rated power and a separate compartment for the load tap changer make this a special transformer. Consequently, the normal rules for noise determination can be used only in a limited manner.

An external sound house application for noise reduction was not feasible because of space and other restrictions, but damping panels on the tank walls were permitted. The restrictive space requirements did not allow any significant reduction of the core induction, resulting in a larger active part. For the same reason, thick damping panels were also not applicable.

The following average sound power levels for the four transformers were obtained by careful matched application of the above described noise reduction measures:

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Fig. 5: 65 MVA low-noise transformer after successful final test in the factory

INDUSTRY LEADERS LOOK TO DOBLE, METERING AMERICA CONFERENCES

By Don Horne

April spells not only the arrival of spring showers, but the annual Metering America Conference and the International Conference of Doble Clients from April 10-15.

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The 6th Annual Metering America Conference in Las Vegas will be at the focal point of next-generation technologies for energy management and revenue expansion.

Attended by leading international and national associations, such as NETA, PLMA, PLCA, the Canadian Electricity Association and NASEO, Electricity Today is proud to be a participant of this conference and exhibition.

The unique international perspective comes from James Lau, Principal of GSL Consulting in China, as he examines opportunities in the Chinese metering market. The Automatic Meter Management project in Italy will be discussed by Matteo Codazzi, Sales Executive of Enel Distribuzione and Michele Marzola, AMM Business Leader for IBM, Italy.

Just a few of the exhibitors offering vendor briefings include Peace, Sungard, Itron, Coronis Systems, Analog Devices, and Carina Technology Inc. Welcoming everyone on Day One will be Craig Goodman, President of NEMA, DC for the keynote address from Dick Burdette, Energy Advisor to Governor Guinn and Director of the Nevada State Office of Energy.

As Metering America is all about looking ahead, the remainder of the morning will include a live discussion of the good, the bad and the ugly of what is going on in the industry. Although the discussions have proven hard-hitting and critical in years past, the discussions have always been based on a desire to improve - constructive debate so that everyone can become better.

In the same vein, Eric Cody, President of Cody Energy Group, will lead a discussion on Future shock: What market upheaval will mean for metering, billing and CRM, followed by a round-table discussion on the top three metering and customer service needs of utility professionals.

During the late morning and early afternoon, smart metering comes to the forefront with the Senior Strategic Manager of the SPi Group Brent Williams looking at how to implement standards to overcome obstacles and issues of a smart meter initiative, followed by a close look at Ontario's move to smart metering with the focus on leveraging the consumer benefits from the competitive provision of energy services.

The afternoon discussion groups turn to networking and how the grid of the future will look, from wireless mesh and peer-to-peer networks to the value of IDRs to data aggregators for competitive power procurement.

The problems of billing, as it relates to managing cash flow, the advantages of prepayment and the pros and cons of flat and complex billing, will be chaired by Warren B. Causey of Georgia.

Examining asset optimization will be Jim Nolan, Residential Load Control Manager of Nevada Power. A wide range of topics from route optimization to manage the transition to AMR, the future of mobile computing for field workforces and an application of SCADA in feeder automation systems for medium voltage distribution networks in Istanbul, Turkey will be on the agenda.

Day 2 continues in the same vein, with a multi-level look at metering, from demand response to revenue assurance. A special forum (by invitation only) will be directed by Jan Peeters, President of Olameter Ontario, on the evolution of chief information officers within the utility industry. The four major groupings of today's modern CIO:

- Traditional CIO: Strategic role focusing on shaping top-level business needs and expectations across the enterprise and would not be responsible for delivering on implementation.
- Chief Technology Officer/Chief Infrastructure Officer: Responsible for ensuring that the technology-based services are delivered cost-effectively and responsibilities include exploiting sourcing opportunities.
- Technology Opportunist: Heavily

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ELECTRICAL WORKERS UNVEIL PUERTO RICO TRAINING CENTER

The International Brotherhood of Electrical Workers unveiled the first multi-employer electrical apprenticeship training in Puerto Rico in March, the crucial first step in achieving a uniform skill level for the island's construction electricians.

The educational center offers Puerto Rico's electricians the opportunity to upgrade their abilities to meet the highest standards in electrical construction.

"This is an historic moment in the IBEW," said IBEW International President Edwin D. Hill. "For the first time in Puerto Rico, contractors, builders and all users of construction will have a benchmark by which to judge the abilities of electricians. Soon, everyone in the Puerto Rican business community will know that IBEW means the most experienced, best qualified electricians in construction."

The training center is a co-operative effort of the IBEW, the National Electrical Contractors Association (NECA), a group of 70,000 electrical contractors, and the National Joint Apprenticeship and Training Committee (NJATC), a model educational partnership of IBEW and NECA that spends $100 million annually to develop the work force of the future.

The three-story, 8,700-square-foot facility in Dorado will also serve as the administrative offices of newly chartered IBEW Local 950. Featuring conduit-bending and transformer labs, theory classrooms and eight jobsite-comparable evaluation stations, the educational center will be staffed by NJATC-certified instructors. Former Colegio De Peritos Electricistas (Puerto Rico electrical trade association) President Juan Pagán is the education director. The center opened on March 1.

A key component of the instruction at the educational facility will be English as a Second Language classes. All training material is in English, and for the sake of safety and uniformity, IBEW members must have basic proficiency in English. Most instructors will be bilingual.

One of the first tasks of Local 950's charter members will be to adopt the IBEW Fifth District's Code of Excellence, a written commitment to demonstrate to customers that IBEW members perform the highest quality of work, utilize their skills and abilities to the maximum, and exercise safe and productive work practices.

To maintain the uniformly qualified work force, potential IBEW members must take evaluations that test the full scope of skills required to install electrical components and systems. Before workers can become journeyman electricians, they must undergo a five-year, full-time apprenticeship program that covers a full range of instruction that includes digital electronics, structured cabling system, basic math, transformers, DC theory, motors and more. Adhering to strict performance standards, each IBEW journeyman wireman is required to spend 1,000 hours in the classroom and 8,000 hours on the job. By graduation, IBEW members are qualified to perform everything from delicate fiber-optic installations to large construction projects.

The IBEW is an international labor organization that has trained the most qualified electricians in the trade for more than 110 years. With approximately 750,000 members in the United States, Canada, Puerto Rico, Guam and the Republic of Panama, the IBEW has members in construction, utilities, manufacturing, telecommunications, broadcasting, railroads and government.

AREVA T&D WINS DE-ICING CONTRACT IN QUEBEC

AREVA's Transmission and Distribution (T&D) division has been awarded a 25-million euro contract in Canada to build the world's first HVDC-based de-icing and power quality system for Hydro-Québec.

During the ice storms that struck Quebec in the winter of 1998, hundreds of kilometers of high-voltage transmission lines and thousands of transmission towers collapsed due to an accumulation of ice, leaving millions of people without electricity. To optimize the security of its power grid, Hydro-Québec has contracted AREVA T&D to build and install HVDCice™, a transmission line de-icing system based on high-voltage direct current (HVDC) technology.

Kurt Hakansson, Executive Vice-President for AREVA's Systems Business Unit, said: "AREVA T&D's system will ensure maximum electrical efficiency and guarantee a secure supply of electricity, in line with Hydro-Québec's sustainable development principles. This is the second important HVDC-based project awarded to AREVA T&D in the last 18 months, which demonstrates our commitment to breaking into this market. This latest success is due to our ability to combine existing technologies in an innovative way".

AREVA's HVDCice™ will generate up to 7200A of direct current in the transmission lines, which will increase their temperature in order for the ice to melt and fall off. The HVDCice™ system will be implemented at the Lévis substation, a major connection point for the transmission lines of the province.

When not in use for de-icing purposes, AREVA's innovative HVDCice™ system will act as a Static Var Compensator (SVC), to improve the power quality of the transmission network in a metropolitan region of Quebec. The SVC will stabilize the voltage on the 735 kV power grid, which can fluctuate depending on the amount of electricity being consumed.

DOBLE, METERING AMERICA

Contniued on Page 16

involved in stimulating new business opportunities because of grasp of emer ging technologies and the business directions of the enterprise.

- Information Manager: Runs significant business unit, focusing on combining supply-and-demand roles within the business unit while responsible for delivering on specific business-unit-level services.

A speaker at last year's Doble conference.

During the same week, the 2005 International Conference of Doble Clients meets for the 72nd year in Boston.

The annual conference is highly regarded as the most valuable event in the world for the electric power industry . It is here that maintenance engineers and other utility representatives from around the world gather to exchange knowledge and experience in the vital sector of electrical apparatus ownership, operation and maintenance.

The 2005 Conference will mark the 72nd year that Doble Engineering has organized and hosted what is recognized as the industry's premiere event.

One of the most unique aspects of the Doble Conference is the fact that the agenda is designed exclusively by and for the benefit of the electric utility and testing company delegates. The Conference program is created by nine Client Committees, each having unique expertise in a particular area.

See related story on Doble International on Page 24

For example, discussions on arresters, capacitors, cables and accessories will include Skip Hicks of Emerson Process (ETI) talking about On-Line Partial Dischar ge Testing of Medium Voltage, and recent research that questions whether DC hipot testing is ef fective and whether it might damage extruded cables.

Long Pong of Doble Engineering examines a specific case of capacitor bank failure and the possibly related subsequent failure of two bushings installed on a voltage regulating transformer, and the analysis and field-testing of the unit afterwards.

Jon Hilgenkamp and David Myers of S&C Electric Company talk about getting the most out of older circuit-switchers, and the challenges faced by workers in maintaining reliability in utility and industrial electric substations. Tips on inspection and rebuilding selective parts offer considerable savings compared to service time outs or installing entirely new devices.

Some of the exhibitors at this year's conference include AREVA T&D, Cannon Technologies, FLIR Systems, General Electric, Siemens Power T&D, The VON Corporation and Velcon Filters Inc.

The Doble Conference will be held at the Westin Hotel Copley Place, Boston Massachusetts. Metering America is at the Rio Suite Hotel & Casino in Las Vegas, Nevada. Both conferences run from April 10 through to the 15.

SEALING THE LEAK TO REDUCE GREENHOUSE GAS EMISSIONS

By Gary Lee Brown and Jim Hackett, COLT Power Services

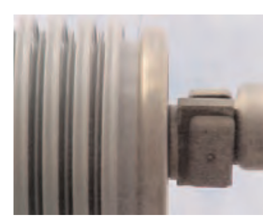
COLT Power Services recently attended the SF6 & the Environment Conference in Scottsdale, Arizona. An estimated 100 people, including Environmental Protection Agency and international government officials, attended.

A T-Fitting leaking on SF6 Gas. A special T-Enclosure can be fabricated, installed and then injected with our sealant for a seal.

Discussions centered on the potential greenhouse effects of SF6, or sulphur hexafluoride, and how to reduce gas leakage. SF6 is an insulating gas used in modern electrical switchgear and was identified in the Kyoto Protocol as one of six greenhouse gases targeted for reduction. Nearly 80 percent of all SF6 gas produced is used by the electric power industry.

A typical T-Enclosure made out of aluminum.

COLT Power Services has long been involved in the reduction of SF6 gas leakage, utilizing time-proven techniques to repair SF6 gas leaks on various components. These repairs can, and are, made while the system is under pressure and leaking, not requiring the evacuation of gas.



A 345kV Breaker Bushing Terminal End. These are notorious for leaking where the porcelain goes into the aluminum terminal end.

A few examples of some typical repairs are depicted above:

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SELECTING A SURGE GENERATOR FOR MAXIMUM EFFICIENCY

By Tom Sandri, Megger

The surge generator or ‘thumper’ is one of the oldest and most widely used tools for locating failures in underground power cable. The origin of the surge generator dates back to the mid/late 1940s when the James G. Biddle Company introduced the first commercially available underground fault-locating instrument to the world. The instrument used a technique known as capacitor discharge and was used to both trace and pinpoint underground cable failures. Today the surge generator serves as the backbone of many cable fault locating techniques and systems. Before discussing surge generators and how to select a proper unit, it is important to first understand cables and cable faults.

Photo 1. Water tree in an extruded dielectric

What is a Cable Fault?

The most common electrical cable fault occurs as a breakdown between one of the system phases and ground. Typically, this breakdown results from a process known as ‘treeing’. In the case of extruded dielectric cables, the treeing results from water ingress within the cable and is commonly referred to as ‘water treeing’ For laminated cables, treeing results from the burning of insulating paper thus leaving carbon tracks or ‘carbon trees’ in the insulating material. Regardless of whether the fault begins as a water tree or a carbon tree, a simplified diagram of this failure can be represented by resistance R in parallel with a spark gap G as shown in Figure 1. Resistance R, as it exists in the fault, may vary in value from a bolted solid short circuit to a very high resistance due to surface leakage. The spark gap G is likely to be a jagged hole in the insulation caused by the fault current. Its spacing may range from near zero to larger than the original thickness of insulation, and the gap space may be filled with air or other gas, water, oil, or the burned remains of insulation. Cable faults display a wide range of values for R and G. The basic strategy of all fault location is to determine where R and/or G differ from normal. In the technique of capacitor discharge, applying a high enough voltage to flash over the gap G creates a detectable audible ballistic event.

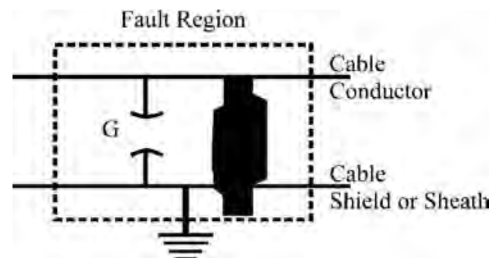

Figure 1. Simplified Diagram of a Cable Fault

Breaking down a Cable Fault

The capacitor discharge technique is performed with a surge generator. This device converts line power into high voltage, unidirectional, impulses that are transmitted into a faulted power cable. A simplified circuit of a surge generator connected to a faulted cable is shown in Figure 2. Capacitor C charges to the voltage of the power supply. When switch S1 closes, the capacitor C discharges into the cable under test in the form of a high voltage impulse. The red curve of Figure 3 depicts the way that time affects the voltage at which a gap will flash over. The gap G in Figure 1 will behave in this manner. Applying successively higher voltages to the gap and plotting the time lag until it sparks over develops the curve. The curve shows that:

1. The higher the applied voltage, the shorter the time lags before flashover occurs.

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Photo 2. Carbon tree in a laminated cable

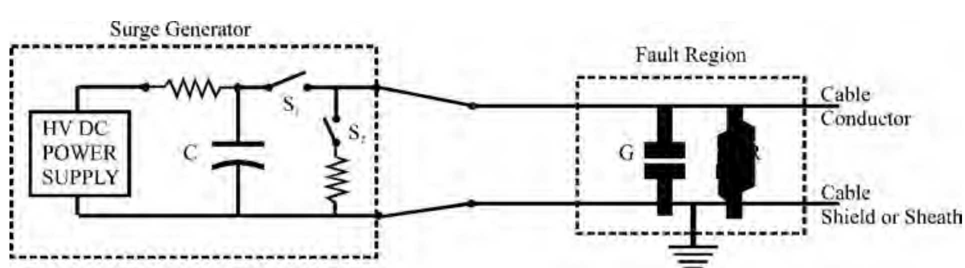

Figure 2. Simplified circuit for a surge generator connected to a cable fault

2005 ITC CANADA TRAINING SCHEDULE LEVEL I, II, III

April

25 - 28*	Level I	Vancouver

May

9 - 12*	Level I	Montreal
16 - 19*	Level I	London
30 - 2*	Level II	Moncton

June

7 - 10	Level II	Edmonton
14 - 17	Level III	Burlington
20 - 23*	Level I	Halifax

July

18 - 21*	Level I	Saskatoon

August

8 - 11*	Level I	Burlington
15 - 18*	Level I	Sudbury
22 - 25*	Level II	Quebec

September

12 - 15*	Level I	Windsor

October

17 - 21	InfraMation – Las Vegas	
24 - 27*	Level I	Regina

November

7 - 10*	Level I	Moncton
14 - 17*	Level II	Burlington
21 - 24*	Level I	Edmonton

December

12 - 15*	Level I	Burlington

*** 1/2 day software course in the afternoon of the last day of course**

2005 ITC CANADA TRAINING SCHEDULE APPLICATION COURSES

April

4 - 5	Law Enforcement	Burlington
7 - 8	Roofing	Mississauga
12 - 15	Building Science	Burlington
18	Building Science	Vancouver
19 - 20	Roofing	Vancouver
21 - 22	Law Enforcement	Vancouver
29	Operator	Vancouver

June

3	Operator	Moncton
24	Operator	Halifax

July

25 - 26	Electrical	Calgary
27 - 28	Mechanical	Calgary

August

2	Operator	Burlington
3 - 4	Mechanical	Burlington
5	Building Science	Burlington
19	Building Science	Sudbury

September

19	Operator	Vancouver
20 - 21	Mechanical	Vancouver
22	Building Science	Vancouver

October

11	Operator	Burlington
12 - 13	Electrical	Burlington
31	Operator	Moncton

November

1 - 2	Electrical	Moncton
3 - 4	Mechanical	Moncton
25	Operator	Edmonton
29 - 30	Mechanical	Burlington

December

1 - 2	Electrical	Burlington

SURGE

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2. There is always a minimum time lag, as indicated by the 'Minimum Breakdown Time', under which the gap will never flash over.

3. There is a minimum voltage, shown by the 'Minimum Breakdown Voltage', below which a gap will not flash over within a typical test period of several minutes.

The curve demonstrates that for breakdown to occur in any particular cable fault the applied impulse must reach a particular voltage and it must last for a definite period of time to flash over.

Figure 3 also shows three different fault-locating impulses applied to a spark gap. Note that the rise times are short and, after reaching a controlled peak, their amplitudes decay at varying rates. Impulse (a) has sufficient voltage and duration to cross the bold curve at a point A and cause flashover. Impulse (b) has sufficient peak voltage but is too short in duration to intersect the bold curve and will not flash over; impulse (c) has the same peak amplitude as (b) but is long enough in duration to cross the bold curve at point C and achieve flashover.

Although the shape of the flashover characteristic curve is typical of all such gaps, the actual curve will vary with each cable fault and will be unpredictable. To locate a fault with the capacitor discharge technique, the surge generator must be capable of generating an impulse of sufficient voltage and time duration to create flashover. Performance of a surge generator is based on its output voltage and energy capability. As mentioned earlier, when switch S1, of Figure 2, closes, the capacitor C discharges into the cable under test in the form of a high voltage impulse. The larger the value of capacitor C, the greater the amount of available energy for discharge into the fault. The greater the probability of intersecting the characteristic flashover curve of Figure 3, the greater the signal level at the fault.

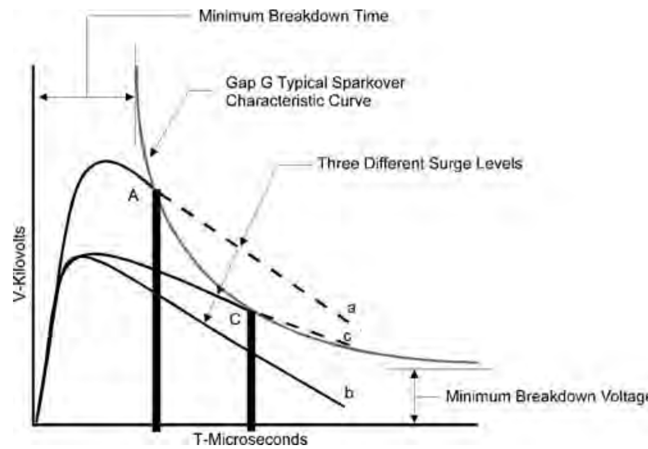

Figure 3. Typical Flashover Characteristics of Gap G.

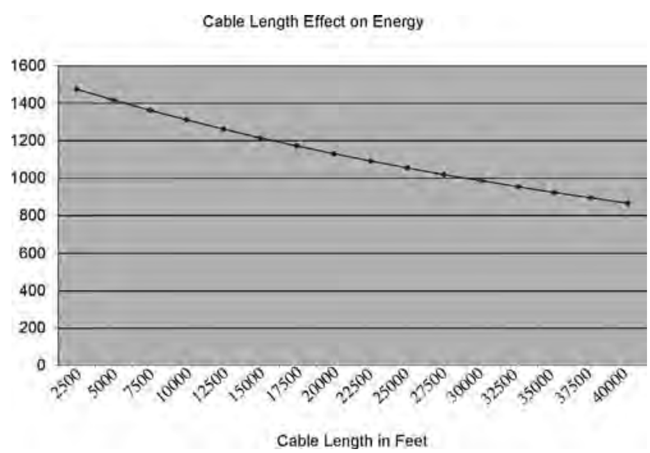

Figure 4. Effects of cable length on stored energy

Effects of Cable Length on a Surge Generator

The length of the cable will affect the peak amplitude of the voltage that reaches the fault. Cable capacitance will vary and is calculated based on unit length.

The typical application for a surge generator is to find faults that have occurred during service. The vast majority of faults that occur within a cable typically breakdown at voltages lower than 8 kV, however there may be situations where higher voltages are required. As a general rule, the voltage capability of the surge generator should be equivalent to the cable system's peak operating voltage to ground to obtain maximum efficiency in fault locating.

As an example, if a cable system were rated at 15 kV phase to phase, the effective range of maximum performance for a 16 kV surge generator would be 40,000 ft. (12.2 km) based on Figure 4.

At 40,000 ft. (12.2 km) Figure 4 shows effective voltage to be 12.2 kV. Beyond this distance the effective voltage reaching the fault will be below the peak operating voltage, phase to ground, of the circuit. This is not to say that the surge generator is incapable of breaking down a fault beyond this distance, it merely points out that efficiency will begin to degrade. The stored energy of a surge generator is also affected by cable length. To accomplish a maximum level of efficiency in fault location, the surge generator should offer a sufficient capacitance to overcome the capacitance of the cable under test. Sufficient energy provides strong arcs used by detection equipment such as cable radar, acoustic and electromagnetic detectors. Figure 4 shows the effects of cable length on a surge generator equipped with a 12 mF capacitor . The applied voltage in this example is 16 kV and cable capacitance is given as 100 pF per foot.

Summary

The surge generator or thumper serves as a critical element in cable fault location. The device's voltage and energy capability determine the efficiency at which faults can be broken down and located. When selecting a unit, consideration must be given to the type of cable and overall length being tested.

Tom Sandri is a Senior Application Engineer, Cable Fault Locating, with Megger. Contact him at tom.sandri@megger.com

DOBLE'S STRENGTH LAY IN ITS INTERNATIONAL EXPERTISE

By Don Horne

Although Doble is best known in North America for its venerable Client Conference in Boston, it may surprise many to know that the company has made great strides to be the source for apparatus know-how and diagnostic training worldwide.

Having established itself in Europe through the EuroDoble Colloquium, now managed by Doble's European companies, Doble PowerTest UK and TransiNor in Norway, the Colloquium has allowed Doble to provide the European electric power community with an event that suits their unique local needs.

Doble's United Kingdom office Doble PowerTest (DPT), successfully completed Doble's first project in the Kingdom of Saudi Arabia last year with a condition assessment project involving Westinghouse generators. Part of DPT's business portfolio is its expertise in testing and condition assessment of Transformers and Generators, including High Voltage Diagnostics and special tests, such as Back Energization of Transformers.

"Doble is uniquely positioned in the international marketplace," says Jerry Jodice, Vice President of Strategic Development for Doble Engineering, "In the last four years we've made a more concerted effort worldwide to be the major source of apparatus maintenance and asset management knowledge."

Based in Boston, Massachusetts, USA, Doble is internationally recognized as a leader in products and services to maximize the safe and efficient delivery of electric power. And while Doble has been in business for over 80 years, it's what the company is doing right now that's truly exciting. Since Doble does not manufacture or market utility assets such as transformers, circuit breakers, insulators and bushings, they have always been in a position to act as the "honest broker" of information related to the performance of these system compo-

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SEALING THE LEAK

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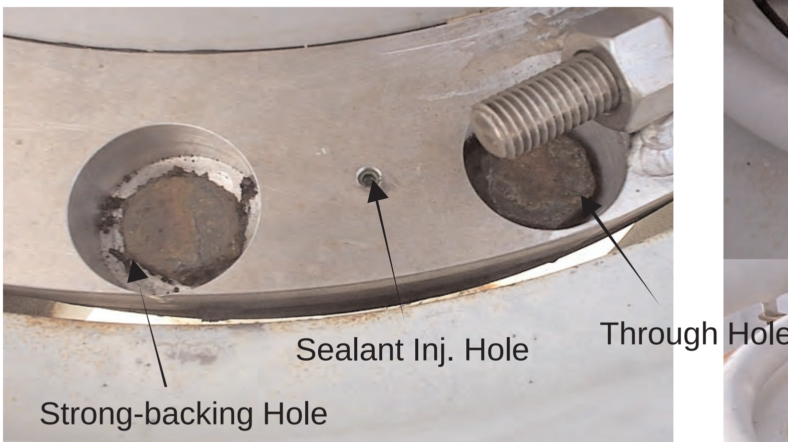

The picture (above right) shows a 345kV Breaker Bushing that has a SF6 Gas leak between the porcelain bushing OD and the aluminum flange ID (see arrow). The picture (at right) shows an aluminum hub clamp installed and sealed for the solution to this problem. The photo above shows the use of existing flange bolts in pulling the clamp down for obtaining the hub seal. Hence, strong-backing is the term. The hub seal is located on the inside face of the clamp. It is activated after pulling it down tight up against the existing flange outside face. Note: A total of 6 bolts were used for strong-backing. Through holes on the clamp were used to accommodate the other bolts. Other style clamps can be fabricated to seal SF6 Gas leaks. Trained technicians take appropriate measurements on many different component configurations so special hardware can be designed & fabricated for installation.

CONCLUSION

On oil and nitrogen repairs that have a grooved or recessed area where the O-ring or gasket lies is a perfect spot to penetrate using a drill-and-tap technique. By intersecting this grooved area, there is a channel where sealant can travel around creating a seal.

On other repairs, such as SF6 gas, COLT technicians create a barrier (fabricate a clamp) around the leaking component and inject the cavity of that piece of hardware to obtain a seal. This special hardware allows for sealant to be injected under pressure.

Orange & Rockland Utilities Inc., a wholly owned subsidiary of Con Edison, has been conducting a study using COLT's service. This study began over two years ago and involves having COLT repair various types of oil leaks and then monitoring the results. To date, Orange and Rockland have been happy with the repairs completed and plan to continue to use Colt for these repairs.

COLT credits their success to repairing oil, nitrogen and SF6 gas leaks to the dedication and experience of their employees.

Gary Lee Brown and Jim Hackett are with COLT Power Services. They can be reached Toll Free at (866) 572-5325 or email: colt@coltonline.com

Jean Guay

ABB is pleased to announce that Mr. Jean Guay has been appointed Vice-President, Sales and Marketing, for the Power Technologies (PT) Division in Canada, effective January 2005. In this role, Mr. Guay will be responsible for the PT front-end sales organization in Canada.

Mr. Guay has acquired a wealth of local and international expertise since joining ABB in 1989. He has held successively senior positions, both in Canada and Switzerland, in the areas of project management and sales of various power system applications. Prior to this appointment, he was Vice-President for Drives and Motors in Canada, and for Power Electronics in North America.

Mr. Guay holds a bachelor's degree in Physics Engineering from the École Polytechnique de Montréal, and is a member in good standing of the Ordre des ingénieurs du Québec (Quebec Order of Engineers).

ABB (www.abb.com) is a leader in power and automation technologies that enable utility and industry customers to improve performance while lowering environmental impact. The ABB Group of companies operates in around 100 countries and employs about 102,000 people. In Canada, ABB employs about 2,100 people in 25 locations from coast to coast.

ABB

NEW KALAR MTS TO MEET PEAK ELECTRICITY NEEDS IN NIAGARA

By Don Horne

A new, state-of-the-art Kalar MTS (Municipal Transformer Station) facility is now providing electricity to meet the current and future needs of the growing City of Niagara Falls.

The $8 million Niagara Falls Hydro Kalar MTS receives electricity from Hydro One's high-voltage transmission lines and then transforms the power to the appropriate voltage for distribution to residences and business in the city. At full capacity, the Kalar MTS can feed the peak electricity needs of approximately 3,800 homes or 50 large hotels.

"This significant investment by Niagara Falls Hydro is important for economic development in terms of matching the growth in both our residential and commercial sectors with a secure and reliable supply of electricity," said Niagara Falls Mayor Ted Salci.

The Kalar MTS serves the southwest section of Niagara Falls and provides relief to the Murray Street and Stanley Avenue Transformer Stations. Construction of the Kalar Road facility began in September 2003.

"We have seen growth in the city's electricity load of approximately 2.5 per cent per year," said Brian Wilkie, President, Niagara Falls Hydro. "The Kalar MTS has an available capacity to handle that rate of growth for the next 15 years. Half of that capacity is connected now and the other half will come on line when required."

The huge transformers on the site, located inside a compound surrounded by high block walls, feature the latest technology for safety and security. The equipment located inside the Transformer Station is state-of-the-art and is operated within and remotely by a sophisticated computer and SCADA system (Supervisory Control And Data Acquisition).

"I'm also pleased to note that the Niagara Falls Hydro property adjacent to the facility, which is used for the new home for girls' soccer, will continue to be available for community use," added Wilkie.

RURAL MISSISSIPPI UTILITY GOES TO AUTOMATIC METER READING

By Don Horne

In a place best known for producing cotton and blues musicians, Delta Electric Power Association is introducing automatic meter reading (AMR). This rural co-op, based in west central Mississippi, recently committed to deploy the Turtle® System from Hunt Technologies to its nearly 25,000 members.

"We wanted AMR, first and foremost, to get daily meter reads," says Harold Pittman, chief engineer at Delta Electric. "We chose Hunt Technologies because their power line carrier system had more going for it and was clearly the most cost efficient system we looked at."

Delta Electric is on schedule to install the entire system in about two years. So far, the co-op has deployed about 7,000 endpoints. The co-op began an initial deployment of 2,600 endpoints in early 2004, and is on pace to complete installation at a new substation every other month.

Based in Greenwood, Delta Electric serves residential, commercial and agricultural accounts in parts of 13 counties. It averages 4.3 meters per mile of line, and doesn't directly serve any large towns or cities.

Two-thirds of the utility's service area lies within the Mississippi delta, a diamond-shaped area along the Mississippi river known for its rich topsoil. Most of the electricity provided to this region powers irrigation pumps and aerators for an emerging catfish farming industry. The "hill area" in the eastern third of the co-op's service territory, on the other hand, is primarily residential.

"IT'S LIKE OPERATING TWO DIFFERENT SYSTEMS," PITTMAN SAYS. "THE AGRICULTURAL AND COMMERCIAL CUSTOMERS ARE MOSTLY 480V THREE-PHASE SYSTEMS. THE OTHER PART OF OUR SYSTEM IS PRIMARILY SINGLE-PHASE RESIDENTIAL."

"It's like operating two different systems," Pittman says. "The agricultural and commercial customers are mostly 480v three-phase systems. The other part of our system is primarily single-phase residential."

Pittman said Delta Electric is using the GE kV2c meter with the factory-installed TS2 endpoint for its three-phase meter applications. In the future, he said, the utility may consider using the load control capabilities of the Turtle System to remotely control loads to irrigation pumps and other agricultural equipment.

Another benefit of the Turtle System is the interface between the Command Center™ operating software and Partner Software System that Delta Electric already had in use.

ANALYZING ELECTRIC UTILITY NO_X EMISSION ALLOWANCE TRADING STRATEGIES

By Frank Selker, Decision Management Associates LLC

Figure 1: NOx Decisions. Risk managers will need to focus on evaluating the need to buy and sell EAs to manage compliance risk (bold oval).

In 1999, many Northeastern electric utilities faced a brand new and uncertain commodity market required for operations: the nitrous oxide (NOx) emission allowance (EA) market. This new market poses a serious constraint to utilities, with the potential to substantially increase total power production costs and to force plant shutdowns if emissions exceeded limits. The challenge was compounded by the uncertain function and behavior of a brand new market.

This market was created in response to the 1990 Clean Air Act Amendments, with the goal of cost-effective reduction in summer ozone levels. A consortium of Northeastern states formed the Ozone Transport Commission (OTC) and agreed in 1994 to allow interstate trading of NOx credits over an 11-state region — the OTR — including the District of Columbia. The OTC's Budget Rule affects major electric utilities, independent power producer, and industrial sources operating boilers with heat inputs in excess of 250 MBtu per hour, or electric generators with output greater than 15 MW. Over 450 sources in the Northeast are receiving an allocation of NOx allowances to cover their NOx emissions during the May to September period.

EA uncertainties create real risks

Like power markets, the NOx EA market can show substantial volatility and EA price risk. For example, a late summer heat wave or nuclear outage could boost emissions when there is little time for offsetting NOx reductions, sending NOx prices skyward. Also, the NOx EA market has compliance risk — with a fixed supply of EAs, certain combinations of weather, planning, and plant outages could lead to OTR emissions exceeding the EA supply. As a result, some utilities would be out of compliance for the season, bringing penalties, public criticism, and reductions in future EA allocations. The experience of the New England Power Pool in 1997, when various unit outages and high electricity demand resulted in high ozone-season NOx emissions, illustrated this possibility.

NOx market participants face a series of tasks before and during each NOx season. Aside from short-term plant control changes, risk managers will be evaluating the need to buy/sell EAs to manage compliance and price risk (Figure 1).

It is primarily the specter of an NOx EA supply shortage that creates a challenge. Decision-makers must answer questions such as:

Since there could be shortages in the NOx EA market, holding an inventory of EAs may be wise. How large should it be in each week of the ozone season?

Should NOx EA options be bought or sold to reduce risk?

How would an EA shortage affect power purchases and sales, and generation operations?

How can effective price and risk management strategies be developed?

Model simulates costs and outcomes

With the NOx market's real-world complexities, closed-form analyses of risks are not practical. However, Monte Carlo simulation of market outcomes is feasible, particularly with the use of a spreadsheet add-in such as Crystal Ball®. Such a spreadsheet implementation requires more computing power than a programmed model, but makes the model transparent to users and allows for inexpensive customization

Continued on Page 30

DOBLE INTERNATIONAL

Continued from page 24

nents. For decades, Doble has been collecting and storing what is now an incredible treasure trove of valuable apparatus maintenance data. Simply put, there exists no comparable knowledge base of information for this industry. Doble has been, and continues to be, the electric utility's "librarian".

> "GENERATION IN CHINA IS GROWING AT THE RATE OF 6% PER YEAR - THAT INCLUDES HYDRO, NUCLEAR AND FOSSIL, " SAYS MR. JODICE, "THAT LEVEL OF GROWTH WILL REQUIRE THE CONSTRUCTION OF HUNDREDS OF NEW SUBSTATIONS OF ALL VOLTAGE CLASSES EVERY YEAR, NOT TO MENTION THE THOUSANDS OF KILOMETERS OF LINES WHICH NEED TO BE ESTABLISHED!"

Just last year, Doble held over 50 seminars worldwide, with each seminar tailored to the clients' unique needs in each region.

In 2004, Doble opened an office in Vadodara, India, in order to provide after-sales technical support in India and Asia.

"When we started to do training events in India, we brought our employees and our presenters," says Mr. Jodice. "Now it's like Doble (conferences) in the U.S., with local clients making presentations on subjects of local interest. It is the same approach that we will be taking in China later this year."

"In Latin America, Doble provides conferences and training seminars – in Portugese for Brazil and in Spanish for Mexico. We had 200 delegates turn out for the recent Mexican seminar and 150 in Brazil. That says a lot."

Doble's reputation as a "knowledge provider" throughout the industry makes it unique insofar as the seminars they hold.

"I don't know any other company who talks about apparatus technology and insulation equipment without pushing their own product," says Mr. Jodice. "With Doble's conferences, people know they are getting substantive information and expertise, not a product pitch."

In addition to Doble events in India, Australia, Singapore, Mexico, Brazil, the UK and Poland was their participation in CIGRE Paris 2004, where Doble staffers participate in study committee activities for Insulation and Transformers. In IEE and IEEE, Doble staff are members of standards-making committees, helping to guide the latest industry advancements.

And it is this wealth of expertise and knowledge that Doble hopes to bring to the vast, mostly untapped market of China, where a new Doble office has recently opened in Beijing.

"Generation in China is growing at the rate of 6% per year - that includes hydro, nuclear and fossil, " says Mr. Jodice, "That level of growth will require the construction of hundreds of new substations of all voltage classes every year, not to mention the thousands of kilometers of lines which need to be established!"

Doble hopes to work with the Chinese power community to provide training and knowledge to support this rapid growth. Their engineers can benefit by benchmarking new equipment, establishing standardized test practices, and begin collecting data in preparation for future needs and analysis.

Doble provides their clients with an On-line Center, giving them access to a vast database of information via the web. Clients have always counted on their relationships with their Doble Client Service Engineers - these engineers work in close partnership with customers, analyzing test data and handling service issues, providing a wealth of knowledge and expertise. Now that interaction is also available on-line, enabling the round the clock support that is so critical in today's fast-paced global marketplace.

As Doble continues its international marketing efforts, the Doble library will be enhanced by the addition of technical presentations, test results and knowledge from other countries. Doble's ultimate goal is to develop its library into a truly international resource, with information provided in different languages.

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of inputs, system parameters, and outputs. This flexibility and transparency is a crucial advantage, especially in an industry that is changing as fast as the electric power industry is today.

A simulation must evaluate thousands of market scenarios to reliably estimate costs and risks, representing combinations of EA prices, power prices, plant operation and outages, and EA market conditions and transactions for each week of the NOx season. A complete picture of risks can then be developed by compiling the scenarios' costs (power generation, power transactions, EA purchases and sales, option purchase and exercise) and NOx compliance outcomes.

I created the "NOx Assessor" simulation model with funding from the Electric Power Research Institute (EPRI) in collaboration with Dr. Gordon Hester, the EPRI Project Manager. The model is fundamentally a spreadsheet model of an electric utility's operations, with sections devoted to:

Demand for electric power
Costs of power generation
Long-term power contracts
Plant outages
Emission rates
Power and NOx price behavior
NOx market behavior

There are uncertainties (Crystal Ball "assumptions") in most sections. There are also correlations among several variables – for example a hot summer will increase both power demand and power cost. These correlations are critical to the behavior of the model, and so require careful attention in setting up runs. Ideally, they are estimated from historic data, which is relatively plentiful in the electric power industry.

The NOx EA price during the season is a key uncertainty and is modeled as following geometric Brownian motion (a.k.a. an "Ito process"), which is a common way to model stock market prices. Unlike a typical stock market model, however, volatility may be specified as varying by week. Another key uncertainty is how the NOx market will behave when a shortage occurs that prevents trading. To model this the user can:

Specify a probability of market shutdown by week of the season,
Specify a specific time at which a shutdown occurs, and most realistically
Specify price bounds which trigger a market shutdown

For most runs, one or two variables are identified as Crystal Ball "decision variables." These are varied over multiple simulations with the decision table tool, with (1) NOx inventory levels at one or two times during the season, and/or (2) NOx option purchases or sales at one or two times during the season. A typical analysis allows a comparison of the risks and costs associated with several inventory level and/or option purchase choices.

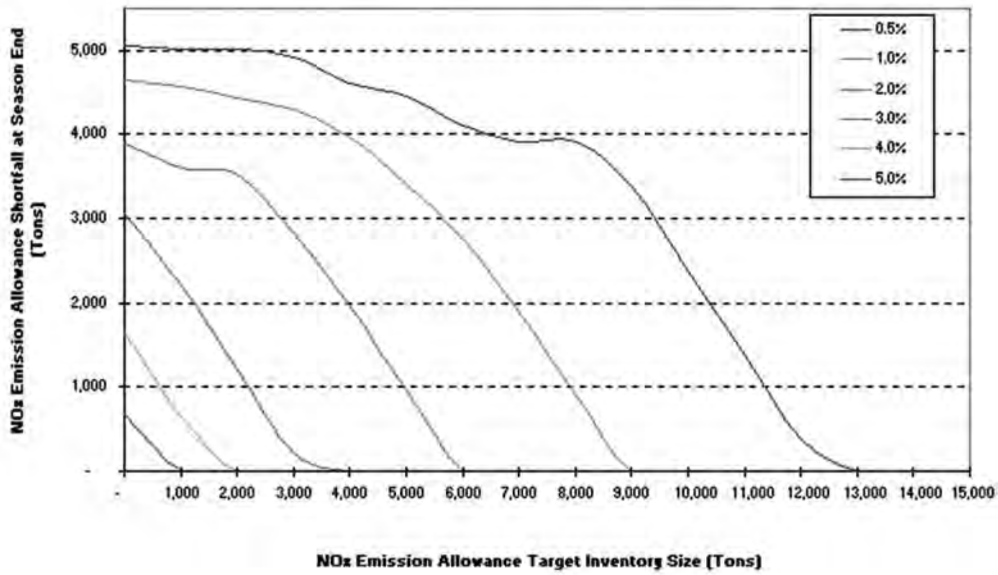
One advantage of spreadsheet modeling is that any variable of interest (a Crystal Ball "forecast") may be monitored during runs to assess the realism of the model. For example, the production of each plant, fuel consumption, up- and downtimes, and various costs can be monitored and checked against experience and historic data.This lets modelers identify data or modeling errors and build confidence in the model's realism.

The spreadsheet model is about 1.4 MB in size and takes about one quarter of a second for each recalculation on a Pentium II 400 MHz computer . A typical run might include ten decision variable values and 5,000 iterations, or 50,000 recalculations, taking about four hours. If two decision variables are varied (e.g., to evaluate interaction of inventory size and use of options) over five values each, the run is complete in about ten hours. While a minimum of 2,000 trials was required per scenario, a minimum of 5,000 trials was preferred since extreme outcomes are of great importance. For example, the risk of a NOx market shutdown just when NOx EAs are needed is a possible scenario that must be accounted for in the model.

By analyzing alternative strategies, price and compliance, risk can be balanced against expected costs. For example, the model can evaluate two major NOx risk management decisions: (1) the value and timing of NOx EA inventory buildup, and (2) the use and pricing of various types of options. The model can also be used to explore how other uncertainties af fect outcomes – for example, the occurrence of a steep decline in EA prices if it becomes apparent during the NOx season that there will be no shortages.

Finally, the model can be used in an optimization mode (using OptQuest, the crystal Ball optimization program) to search for strategies that minimize or maximize selected variables while meeting specified constraints – for example searching for the inventory size that minimizes cost while keeping noncompliance risk below a specified likelihood.

Figure 2. Likelihood of NOx Emission Allowance Shortfalls for Various Target Inventory Levels (Hythetical utility)



How Big of an EA Buffer do You Need?

EA inventory acts as a buffer, covering emissions for a time even if EA shortages develop. Bigger inventory provides a greater buf fer and lower risk of noncompliance However, a large inventory can also be expensive – particularly if everyone is trying to build them, driving EAprices up. Figures 2 and 3 are example outputs of hypothetical analyses using the author 's simulation to explore risks of alternative inventory policies for a lar ge NOx emitter – note that these results could change dramatically for different generation mixes and other assumptions.

Figure 2 shows compliance risk for various tar get inventory sizes at a hypothetical utility . The y-axis is the projected season shortfall, that is, the number of tons by which emissions exceed allowances at the end of the NOx season. The x-axis is the tar get inventory level, i.e., the number of EAs that are held in excess of emissions during each week of the season. It is a "target" because a shortage of EAs may make them unavailable in the market, reducing inventory below this target.

Each curve in Figure 2 corresponds to a likelihood of the shortfall level for the inventory levels. For example, the shortfall has only a 2% chance of exceeding the 2% curve. No curves above 5% appear because, in this analysis, there was only about a 5% chance of shortfall even with no inventory. As inventories increase, the size of shortfalls decreases, with each curve falling to the x-axis (zero shortfall) when the chance of a shortfall is less than the likelihood of that curve. For example, a 13,000 ton target inventory reduces the risk of a shortfall to less than 0.5% and a 9,000 ton inventory brings the shortfall risk to less than 1%.

But what about cost? Figure 3 shows how the net cost of buying/selling allowances during the NOx season (y-axis, including penalties for shortfalls), varies with inventory level (x-axis). Each curve represents a likelihood, in Figure 3 showing the likelihood that compliance costs will exceed various amounts.

As inventory levels increase from zero inventory , the risk of high-cost scenarios declines, since shortages and penalties are less likely. For example, with a tar get inven-

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NERC 1300 MADE EASIER

By Ron Lepofsky, ERE Information Security

NERC 1300 (draft version 1.0, Sept 15, 2004) is the latest security standard along with revisions, proposed by the North American Reliability Counsel for North American electricity local distribution carriers and power generators. This proposed new standard is intended to supplant the NERC 1200 standard, and will place onerous demands upon the complying agencies to upgrade policy, documentation, training, and technology. Power companies are already expressing concern about how to minimize time to implement, once executive committees commit to the standard.

Clearly, implementers will need some help. Implementers could investigate third party expertise to minimize the time to implement, by outsourcing authorship of policies, procedures, and documentation, which are specified in each of sections 1301 through 1308.

As well, outsourcers can jump start the deployment of sophisticated technology such as 24 hour per day , 7 day per week Intrusion detection, retention of system logs, and ensuring the integrity of the security perimeter of the cyber assets.

Outsourcers can also accelerate training, which inevitably allows the power company to see what deliverables are actually meaningful to them from a new technology or a new documentation process. In essence, the outsourced services provide a quick “proof of concept” to the power company, who may then decide to modify their requirements, retain the outsourced services, or use their acquired knowledge to redeploy in-house.

Power companies may consider time and cost saving ideas indicated below by subject.

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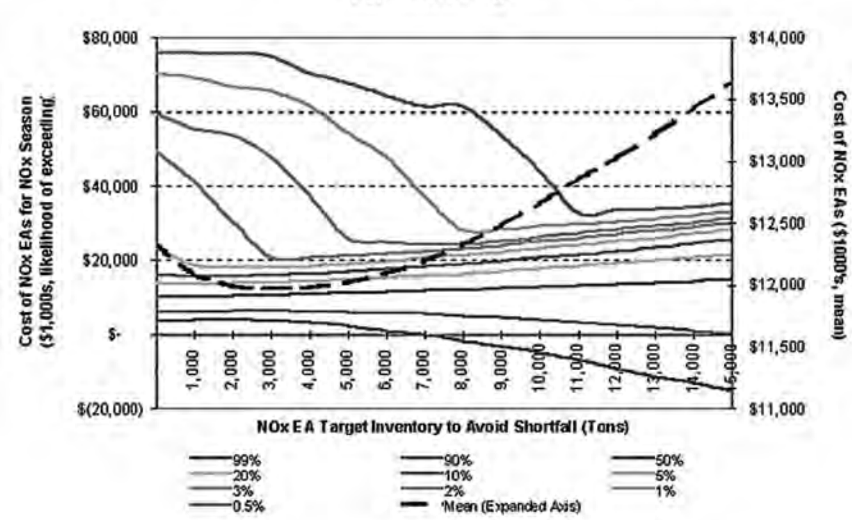
tory of 4,000 EAs the risk of costs exceeding $40 million drops below 2% for the hypothetical utility . However, costs begin drifting back upward with increasing inventory, reflecting the risks of holding excess allowances at season end, which must then be sold at a discount or held for the next season.

Since NOx costs will be a small part of utility operating costs, some price risk may be acceptable, and the mean or expected cost should be considered. The mean cost is shown with a heavy dashed line in Figure 3, scaled to the expanded right hand axis. Mean cost is not highly sensitive to inventory level, varying by about 10% from its minimum at an inventory of 3,000 tons to it' s maximum at 15,000 tons.

Given the modest cost impacts in this hypothetical analysis, compliance risk (Figure 2) should probably be the primary determinant of inventory level. For instance, if a 1% chance of noncompliance is acceptable, then the tar get inventory level should be 9,000 tons. Although this level adds about $500,000 to expected compliance cost (mean cost of $12.5 million versus the minimum mean value of about $12 million with 3,000 tons of inventory), it keeps compliance risk below 1% (Figure 2), and also keeps the chance of costs exceeding $30 million below 1% (Figure 3).

Figure 3. Likelihoods of EA Costs for the NOx Season for Various Target Inventory Levels (Hypothetical Utility)



Black-Scholes Is Not Adequate

Purchasing options to buy allowances of fers another hedge against NOx EA shortage and noncompliance Valuing such options can be tricky , given particular option costs, exercise prices, exercise dates, inventory decisions, generation plans, and so on.

A Black-Scholes analysis captures ef fects of volatility assuming asset prices follow a geometric random walk with uniform volatility. While this may be appropriate for stock prices, it is inadequate in a market that may experience shortages, where prices are correlated among interacting commodities (e.g., power and EA prices), and where there are compliance issues – essentially non-symmetric, nonlinear costs of various inventory levels at season end. Simulation offers the most practical approach to valuing options when such conditions violate assumptions needed for closed-form analysis.

To illustrate this difference we recently analyzed a realistic NOx call option using both the Black-Scholes formula and a full simulation. The Black-Scholes formula gave a value of about $125/option, while the simulation revealed an actual value of about $400/option, in part due to reduced risk of noncompliance fines. Simulation also allows exploring the cost and risk tradeof fs of various combinations of options and inventory, revealing the mix giving the best risk and cost performance.

Figure 4 shows the 1% noncompliance risk (analogous to 1% curve in Figure 2) for another hypothetical example

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NERC

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SCADA and Corporate IT Security Create a Joint NERC 1300 Task Force

The corporate IT infrastructure could certainly benefit by complying with NERC 1300, even though the standard basically ignores corporate IT. A higher degree of security for corporate IT could reduce downside costs resulting from liabilities such as identity theft, contravention of privacy legislation, and non-compliance with Sarbanes-Oxley (SOX) for public corporations listed on US stock exchanges.

As well, corporate and SCADA security compliance groups certainly need to cooperate on the matter of securing the electronic perimeter of the key cyber assets. Issues of connectivity of servers on both sides of the perimeter such as email and billing servers, and end-user access to Internet for browsing, are areas of common concern to both IT groups.

Shared resources of two groups may substantially decrease the time to plan and to deploy.

Time and cost saving recommendation:

SCADA and corporate security compliance groups form a joint NERC 1300 task force.

Foresight: Compliance to the Highest Standard or Jurisdiction

The adage of “measure twice, cut once” applies here. It is often less expensive and painful to investigate and combine the best of all relevant standards and recommendations prior to implementing any one standard. For instance, the US Department of Energy and ISACA publish recommendations for SCADA cyber security and a prescriptive standard for IT Controls for SOX compliance respectively.

Time and pain saving recommendations:

1. The NERC 1300 task force should investigate the recommendations for securing SCADA which are provided in the document titled “21 Steps to Improve Cyber Security for SCADA Networks,” published by the (US) Department of Energy and the President’s Critical Infrastructure Protection Board.
2. For corporations with SOX compliance requirements and who have created a joint SCADA/Corporate Joint NERC 1300 task force, investigate ISACA’s suggestions for SOX requirements which are provided in the document titled “IT Control Objectives for Sarbanes-Oxley”.

Documentation and Policy Requirements throughout the Standard

Since many power companies will be tackling documentation process, and since many consulting companies have expertise in creating such documentation, it would be simple and useful to confer with other power companies and consultants, in order to find a template which most closely matches an implementer’s requirements.

Time saving recommendation:

Confer with associates at other power companies, during industry conventions, and consultants, about the availability of templates of documentation.

Self Certification Requirements throughout the Standard

Self-certification of compliance monitoring processes has several drawbacks, as follows:

1. Self certification or auditing does not employ a basic security fundamental of impartiality.
2. Power company employees may not have the expert skills or experience for auditing security infrastructure and policy.
3. Auditing is time consuming
4. Senior executives and certainly partnering organizations favor the opinion of third party auditors over audit results presented by in-house employees.
5. Most in-house certification or audit reports do not convey the recommendations both in terms of procedural actions and in terms of ROI benefits, which senior executives can understand and act upon.

Time saving recommendation:

Consider outsourcing certification or auditing to third-party experts, particularly those with expertise in conveying recommendations in ROI terms.

1304 Electronic Security and 1306 Systems Security Management

Several of the technology recommendations are time consuming to implement.

For instance, intrusion detection (IDS), which is specified in paragraph (a) (3) of 1304, may be simple to initially install, but requires considerable expertise and time to “tune” the service in order to make it useful. If the IDS is not properly tuned, it may overload the host network with nonsensical data, and may not clearly indicate actual or attempted intrusions.

Similarly, paragraph (a) (4) of 1306 specifies integrity software such as anti-virus, anti-Trojans etc, all of which are relatively straightforward to implement. However, they generate large event logs, which need to be reviewed.

In fact, the issue of event logs is specified in paragraphs (a) (6) and (b) (6) also of 1306. Event logs are large, arcane, constantly produced documents. Event logs are produced by all security and data servers, including SCADA servers. In order to comply with the requirements to review logs of critical cyber assets 24 hours per day, 7 days per week, the implementer would require automated event log analysis.

In order to comply with the spirit and intent of the paragraphs, the implementer would require automated event correlation technology, which would compare the vulnerabilities identified across all the logs, and look for risk patterns.

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SAFETY ARTICLES SPARK READER'S INTEREST

From Tim Parks, Electrical Utility Maintenance Supervisor for the City of Ashland, Ohio:

"I find the magazine very informative and look forward to receiving it each month. I enjoy the safety articles. Can you start an 'It happened to me' section each month about near misses or accidents others have had so we can learn from? Just a thought. Thanks.

Jerry Tang-Kong, a Certification Engineering for CSA International in Toronto, Ontario says:

"Articles are very informative."

Terry Ogden, P.Eng., Territory Manager of PBW High Voltage Ltd., wanted to express his gratitude to one of the speakers at a recent forum we held:

"Mr. Pablo Diaz (of Grounding Systems Technologies), I enjoyed your Seminar in Toronto and will definitely be able to utilize the information provided."

We are always looking for comments from our readers. You can reach the editor to share your views at:
don@electricityforum.com

LOW NOISE

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no-load sound power level at 15.6% over -excitation in guaranteed tap position: 59 dB(A)

no-load sound power level at 15.6% over -excitation in extreme tap position: 71 dB(A)

load sound power level at 65 MVA: 73 dB(A)

Since the no-load noise level in the guaranteed tap position is quite low the total transformer noise is almost identical to the load noise. The maximum deviation of the measured noise levels for the four identical units is ±2 dB.

5. Summary

More severe restrictions for noise emission require a further reduction of the transformer noise, so the load noise becomes more and more important in comparison to the no-load noise.

Starting with the physical principles of noise development, the paper discusses and evaluates general possibilities of noise reduction. By application of some of these noise reduction measures on four identical transformers for Consolidated Edison Company, delivered by Siemens Transformatorenwerk Nürnberg, Germany, the efficacy of these measures could be proven. In comparison with a transformer delivered in 1991 with identical electrical parameters the noise level was reduced by 9 dB. The relevance of load noise for low-noise transformers is demonstrated by the measured sound power levels; load noise is clearly dominant in comparison with the no-load noise in the guaranteed tap position.

CLASSIFICATION OF ELECTRIC SHOCK HAZARDS NEEDS RE-EXAMINATION

By V. Myasnikov, Electrical Engineer, Ukraine

The variety of technical solutions providing protection to operators of electrical engineering product (EEP) against electric shock isn't reflected in the current standards of the IEC (International Electrical Commission), by indexation of EEP with classes of electrical safety by protection method. Nowadays, such technical solutions are based on the following methods of operator protection corresponding to the following IEC safety classes:

- Protection by insulations – main, dual, reinforced (strengthened). Protection by main insulation is covered by IEC class 0. Protection by either dual or reinforced (strengthened) insulation is covered by IEC class II;
- Protection by insulation in combination with grounding of metal non-conductive parts is covered by IEC classes 01 and I;
- Protection by safe super low voltage of power supply is covered by IEC class III.

Existing IEC classification of electrical safety by protection method (further throughout this text – IEC classification) doesn't cover operator protection emergency switch-off devices, appropriate casing, interlocks preventing physical contact with EEP conductive parts, and the circuits galvanic separation. It does divide the method of electric shock protection – grounding – into two independent classes (01 and I) which is illogical, and at that point, for example, neither of these classes covers one more method of grounding. The supporting (mounting) surface contacting the metal base that is grounding without the element for grounding widely used in EEP of different designs. One more important point is that the above different methods of EEP safety design provide different protection levels for the person/operator which is absolutely missed by existing IEC classification.

However, these classifications cover the following methods of person/operator protection:

- protection through main insulation,
- protection through dual (doubled) or reinforced(strengthened) insulation,
- protection through grounding of non-conductive metal parts,
- protection through the means of emergency switch-off devices (upon overload and/or short circuit; upon leakage of a current over insulation) and/or appropriate casing, interlocks, galvanic separation of circuits, all of them combined with the above listed methods,
- protection using safe super low voltage of power supply.

In the classification of EEP grounding methods, the different levels of insulation (main, dual or strengthened) of metal non-conductive parts from conductive ones are combined with different types of grounding (single or dual grounding). It is supposed that the reliability of the dual grounding is higher than that of a single grounding. As a result, the whole diversity of EEP grounding methods is reduced to three groups with the greater group number corresponding to the higher safety level of the operator.

The following different levels of operator safety can be provided with regard to the protection methods:

- standard (A),
- reinforced (B),
- increased (C),
- high (D),
- maximum (E).

These suggested combinations of protection methods with provided safety levels of the person/operator are ultimately the classes of EEP electrical safety according to suggested classification: more differential, informative and comprehensive than ones used at the current IEC classification. Thus the suggested classification of EEP electrical safety includes the following eleven classes: 1A, 2B, 3B, 3C, 4B, 4C, 5B, 5C, 5E, 6C, 6E.

The pattern of codes of these classes characterizes the adopted technical solutions on protection methods, and the level of safety for the person/operator.

It should be pointed out that the level of safety provided to the person-operator must be adequate to the severity of EEP usage conditions - the more severe they are the higher the level of provided safety. For example, dual grounding improves operator safety during the exposure of operated EEP to the mechanical impacts because of the impossibility of simultaneous disruption of two independent grounding circuits.

It is important to note that, for the customer ordering specified EEP using hereby suggested classification, it is sufficient in many cases just to indicate the required EEP safety level; at that point the designer will be free to choose the protection method meeting the customer's requirement who is free to choose the appropriate class of EEP electrical safety.

The discussion of advantages and disadvantages of the suggested classification of EEP electrical safety by the experts can become a subject of debate on the pages of professional publications, and could precede the probable proposal to introduce suggested classification into status of International Electrical Commission's (IEC) standard document.

Vitaliy Myasnikov earned his BSc.EE from Kharkov Politechnical Institute, Kharkov. Since 1973 he has worked in an electrical laboratory as part of the product design department specializing in low voltage electric apparatus and safety figure evaluation. He is currently lead engineer working on product certification in regards to compliance to safety standards.

For example, intrusion detection logs may not alarm on sporadic, unsuccessful attempts by an IP address (person) to access a variety of servers. However, event log correlation technology might identify that in fact the same IP address (person) over an extended period of two weeks, had, in fact, unsuccessfully attempted access to several SCADA-related servers. This would certainly qualify as a security risk meriting investigation.

Once again, log event correlation technology is sophisticated to install and to tune, taking considerable time to successfully accomplish, plus its price tag is $500,000 - $1,000,000 for a network with many servers.

Time saving and cost saving recommendation:

Implementers should seriously consider evaluating outsourced technological solutions, even if only for one year "proof of concept" periods, and in order to minimize time to comply.

"Delta Reporting": A Missing Link

While the standard specifies monitoring and alerting on intrusions and security events, the standard does not give a prescriptive definition of how to create meaningful, action-oriented reports from the mass of data that will be created from the monitoring, alert, and event log data.

The key here is to summarize all the security data into "delta" or change reports, which identify new security events and recommend how to deal with them. This action oriented information is important for dealing with potential or actual crisis.

The underlying voluminous data is also important for analyzing trends, forensic investigation, evidence, and for attestation.

Without a process or technology to create "delta" reports, the ROI on the underlying capital investment in technology is close to zero %.

Time Saving and ROI preserving recommendation:

The implementer should give serious consideration to acquiring a process or technology which will summarize all their new monitoring, alerting, and event log data into useful action-oriented, "delta" reports. The two most important features are identification of new security events and recommendations on how to deal with them.

1307 Incident Response Planning (IRP) and 1308 Recovery Plan (DRP)

Best practices for IRP and DRP plans involve creating thick, verbose documents, which are dif ficult to use during a crisis. In comparison, spread

ELECTRICITY FORUM TRAINING INSTITUTE'S COURSE SCHEDULE

Electrical Safety In The Workplace

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These Cross-Canada Forums will focus on recent code revisions from NEC and NFPA regarding electrical safety, specifically arc flash hazards. As well, electrical inspectors from each province will make special presentations about electrical safety codes and standards. CSA will be making a special presentation on how the Canadian Electrical Safety system works and how CSA standards are integrated into it. Also, various Flame Retardant clothing manufacturers will discuss the wide range of options available when it comes to protective clothing and safety equipment.

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For detailed information visit our web site at
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With your forum participation, you will receive the NFPA 70E - Electrical Safety in the Workplace Book.

Early bird registration fee is $599.00 + $41.93 GST. (8 days prior to the course start date).

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The objective of this course is to build confidence in the student by providing him/her with useful information and practical hands-on exercises that demonstrate the relevance of the course material. This course is recommended for electrical engineers, technicians, designers and electrical maintenance personnel responsible for VFDs.

For detailed information visit our web site at
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This course is designed to enable participants to:

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ON-SITE CONDITION ASSESSMENT OF MEDIUM VOLTAGE CABLE

By Vern Buchholz, P.Eng., Powertech Labs Inc.

Utilities and industrial plants make extensive use of medium voltage (5 to 35 kV) power cables. In many cases these cable are approaching or have exceeded their design life. In this article the available methods of on-site cable condition assessment or diagnostic testing are covered.

Condition assessment testing does not mean simply "proof" or "high-pot" testing. Condition assessment testing, although it should find serious defects, is not a simple go/no-go test, but is designed to provide a ranking of the cable system and assist in prioritizing future cable maintenance and replacement. No cable tests have yet been discovered which will determine the "remaining life" of a cable. The ultimate purpose of cable condition assessment is to improve system reliability and minimize long-term cost.

Most modern cables have a polymeric insulation, either polyethylene (PE) or Ethylene-Propylene Rubber (EPR). Older design medium voltage cables were Paper - Insulated Lead-Covered (PILC). Any diagnostic testing must take into account the cable design.

When doing cable condition assessment testing the work can be broken into five parts:

- Metallic shield or neutral
- Jacket – on some cables
- Accessories – splices and terminations
- Local environment and operating conditions

The tests used in each of these parts may differ depending on the design of the cable. The tests available for each of the five basic parts with reference to the two designs of cable will be discussed further.

Insulation Testing

At present there is no standard condition assessment test for cable insulation. In fact no one test is yet a clear leader or will tell everything about the insulation. Table 1 lists tests that are now available for insulation evaluation on the market in North America. They are divided into "general health tests", which look at the condition of all the insulation and cannot locate problems, and "partial discharge locators", which can locate partial discharges that are signs of incipient faults along the cable system. Most of these tests are relatively new to cable diagnostics, being developed in the last 10 or so years. Each provides information about insulation "quality" and will give indications of degraded insulation. The results of a test are subject to interpretation.

The Insulated Conductors Committee (ICC) of the IEEE Power Engineering Society has a working group to

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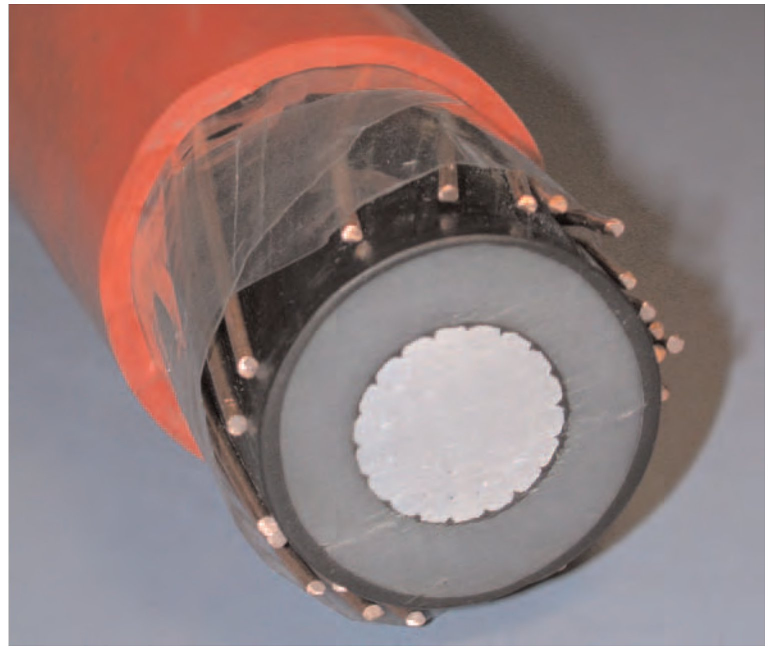
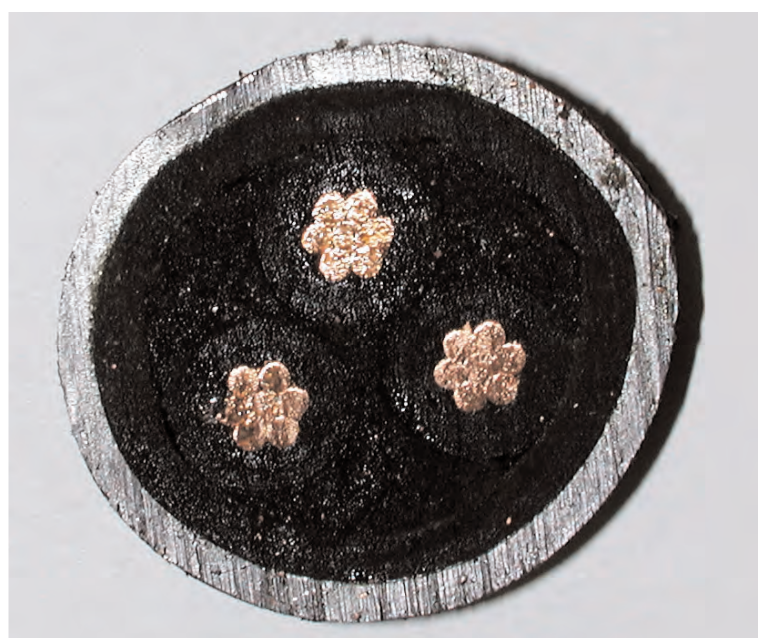


Modern XLPE Insulated Feeder Cable with copper shield/neutral and PVC Jacket



Older 3-Phase PILC Cable without Jacket. Note the phases are not individually shielded.

develop a series of guides on cable field testing. They have recently published the first guide in a series: IEEE Std 400-2001, "IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems."

At Powertech Labs we have been using a technology called LIpATEST. We developed LIpATEST and have been using it on XLPE over the last 10 years and more recently on PILC. The technique applies a stepwise increasing dc voltage from a highly regulated, very low ripple power supply. The leakage current is measured with a sensitive, highly filtered, dc pico-ammeter, which is fiber-optically coupled to the data acquisition system. The maximum voltage applied is settable and does not exceed 1.5 times normal voltage. The test is computer controlled and the test duration is less than 10 minutes per cable. The equipment is suitcase-sized and easily transportable.

Metallic Shield or Neutral Condition Assessment

Copper shields or neutrals over polymeric cables may suffer mechanical damage during installation, or over time from temperature cycling, particularly under cable clamps. The lead sheath on PILC may be subject to fracture and creep, resulting in cracks and breaks. Corrosion may also be a serious form of shield damage in both copper and lead, even in fully jacketed cables. Breaks in the metallic shield on polymeric cables may lead to points of high electrical stress, which may lead to local partial discharge and ultimate failure.

To determine the condition of the cable shield, an initial assessment is made with a dc resistance meter. If the resistance reading is high, Low Voltage Time Domain Reflectometry (LV TDR) can be used to locate the points along the cable where the neutral or shield is deteriorating. The LV TDR sends a low voltage, fast rise-time pulse down the cable, and an oscilloscope in the unit shows reflections when cable transmission characteristics change. Reflections show cable splices as well as shield breaks. The LV TDR test equipment is very small and easily transportable.

If the neutral or shield is damaged or corroded at many points along the length of the cable, a recommendation to replace the entire cable may be made. If the corrosion is isolated to only a few points, these locations may be cut out and new sections of cable spliced in place.

In the case of PILC cable, cracks or breaks in the lead sheath can lead to oil seeping away or water getting into the insulation. If the phase conductors are not individually shielded, the lead acts as the shield on a PILC cable, and lead breaks may cause high electrical stress points. An LV TDR check of the cable may show reflections at very large holes in the lead. In duct installed PILC, many lead breaks occur in manholes, at duct exits and around splices. A close visual inspection may locate problems in the manholes. To locate small cracks or incipient problems a metallurgical examination may be necessary.

Cable Jacket Tests

In jacketed cables, the jacket may be compromised during installation of the cables, or may age and crack, particularly when exposed to certain chemicals or soil conditions.

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evaluating certain call options that may be exercised in the last week of the NOx season. Either options or inventory are effective in reducing the likelihood of shortage to less than 1% (zero shortage), with about 2,000 tons of inventory required for the same risk reduction as 1,000 call options.

Figure 5 shows mean compliance cost (analogous to heavy curve in Figure 3) for another hypothetical example. Costs vary from about $11 million to $12 million over a range of choices. The minimum cost is achieved with little or no inventory and the purchase of about 4,000 EA call options. As above, options and inventory provide similar protection from expensive shortages, so fewer options are needed when greater inventory is held, and vice versa. This creates the diagonal valley in the figure.

Figure 4. EA Shortfalls for NOx Season for Various Inventory and Option Levels (Hypothetical utility, 99th percentile values shown)

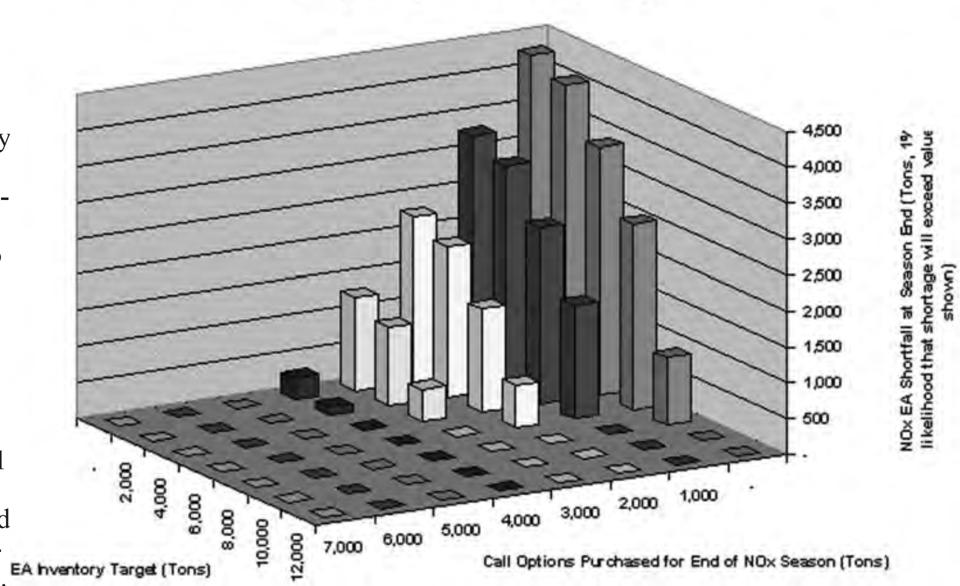
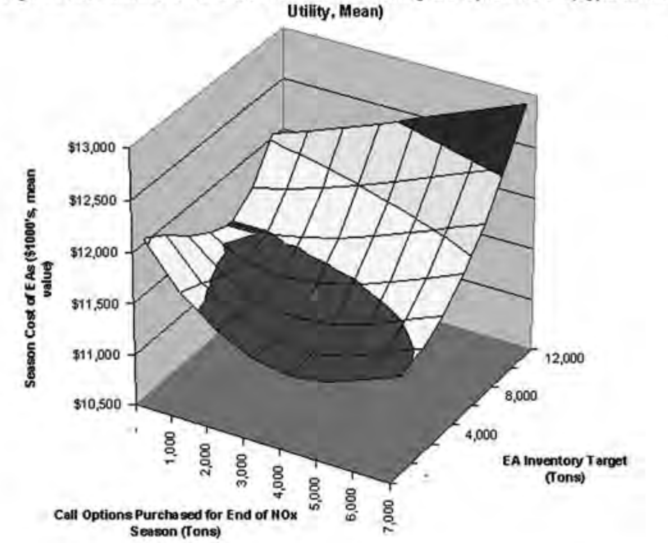


Figure 5. EA Costs for NOx Season for Various Inventory and Option Levels (Hypothetical Utility, Mean)



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Acknowledgments

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NERC

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sheet based, point form, simple crisis management documents are easier to understand, and can possibly also be used as actual "incident reports".

Spreadsheet templates are easy to tune and to update by their owners, particularly with volatile information such as employee information, references to technology, and vendor contact information.

Time saving recommendation:

Implementers should contemplate purchasing from third parties with expertise in IRP and DRP creation, spreadsheet-based templates, in order to meet their NERC 1300 compliance needs.

1303 Personnel and Training

Third party consultants and outsourcers often have training expertise for their service. Time saving recommendation: Consider single-sourcing both training and the underlying service.

Conclusion

NERC 1300, a much more specific and documentation demanding version of its predecessor NERC 1200, contemplates that power companies implement compliance thoroughly, but not necessarily by themselves. SCADA security implementers should consider collaborating with their corporate IT departments and their peers in other power companies, in order to reduce expense and time to deploy . They should also lever third-party expertise, which can provide template-oriented documentation and training-rich outsourced security technology services.

Ron Lepofsky is the President and CEO of ERE Information Security, who are information security and financial disclosure/privacy compliance auditors. ERE provides services to electrical distribution companies, large law firms, and to large publicly traded corporations.
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CABLE

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A damaged jacket is often a first indication that further problems may be encountered. To test a cable jacket, the cable must be de-energized and the shield/neutral grounds must be disconnected. A dc voltage check with a multi-meter between the floating shield and ground will indicate if the jacket is intact. A potential of several volts on the metallic shield indicates corrosion activity and a compromised jacket is likely. Switching the multi-meter to the micro-amp range and measuring the short circuit current, can give an indication of the magnitude of corrosion and jacket damage. If the jacket appears to be intact, the jacket insulation resistance should be checked with a Megger.

Cable Accessory Testing

Cable accessories, including splices or joints, and terminations or elbows, are some of the most vulnerable parts of an underground installation. Failure mechanisms in accessories are varied, but one of the most common causes of failure is improper installation. Often poor installation does not result in failure for many years. To determine the condition of accessories on-site, generally two symptoms are assessed: elevated operating temperature and presence of partial discharges.

Operating temperature is easily measured on an energized, current carrying accessory with a hand-held, infrared detector. The load current must be recorded during the temperature measurement and, obviously, the higher the current, the higher the temperature will be. In general, the surface temperature on a splice or termination should be lower than the surface temperature on the in-coming cable. If not, an accessory problem is indicated.

Partial discharges (pd) in accessories can be located using a number of off-line or on-line techniques as given under "Partial Discharge Locators" in Table 1. In addition, we have found that sonic or RF detectors are very useful in listening for pd in terminations or accessible splices. Non-contact sonic probes may find surface discharges which indicate contamination that may lead to a breakdown. A contact sonic probe or RF detector is required to detect internal discharges. Since cables must be energized for pd testing, contact probes should be electrically isolated from the person doing the test.

Corroded metal shield causing failure from outside in

Local Environment and Operating Conditions

A good deal of information that will help determine condition of the cable system can be had with simple observations or questioning site personnel during the testing. Always try to find out and record:

- Current loading and duty cycle
- Fault levels
- Previous failures
- Lightning levels and whether arrestors are installed
- Water table fluctuations
- Workmanship of the installation
- Surface contamination on accessories

An environmental test that may be helpful is one to determine the chemical composition of groundwater. This may be indicated particularly when surface deterioration is seen on accessories or jackets. One operating condition that can seriously affect cable life is elevated temperature. It may be possible to monitor cable-operating temperature by installing thermocouples at "hot spots" along the cable. The environmental assessment should be used in conjunction with the diagnostic tests to prioritize cable maintenance and replacement.

Conclusions

A cable condition assessment program should evaluate all parts of the cable system. Any test program must be designed to find serious cable defects requiring immediate attention, and to assist in prioritizing future cable maintenance and replacement. The ultimate purpose of a test program is to improve system reliability and minimize long-term cost.

Vern Buchholz has over 25 years experience in the electric industry. He came to Powertech Labs in 1984 from the Transmission Engineering Group at BC Hydro. He has been the Director of the Electrical Technologies Business Unit at Powertech Labs since 1994. Vern's projects include work on medium and high voltage cables and accessories, grounding apparatus, electrical connectors, commercial electrical equipment and high impedance fault detection.

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