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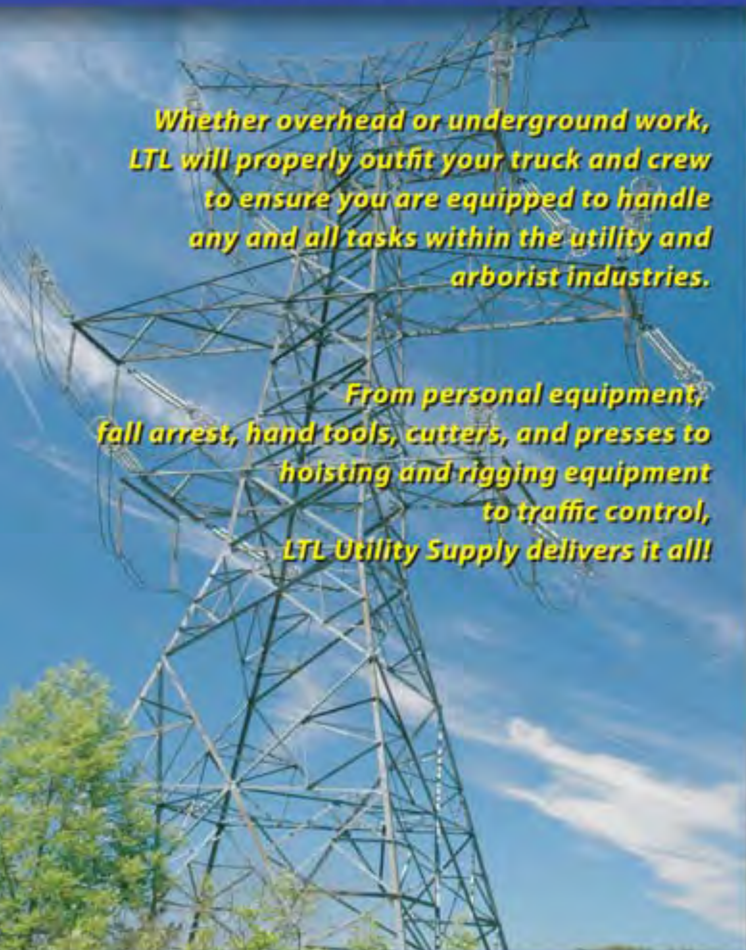

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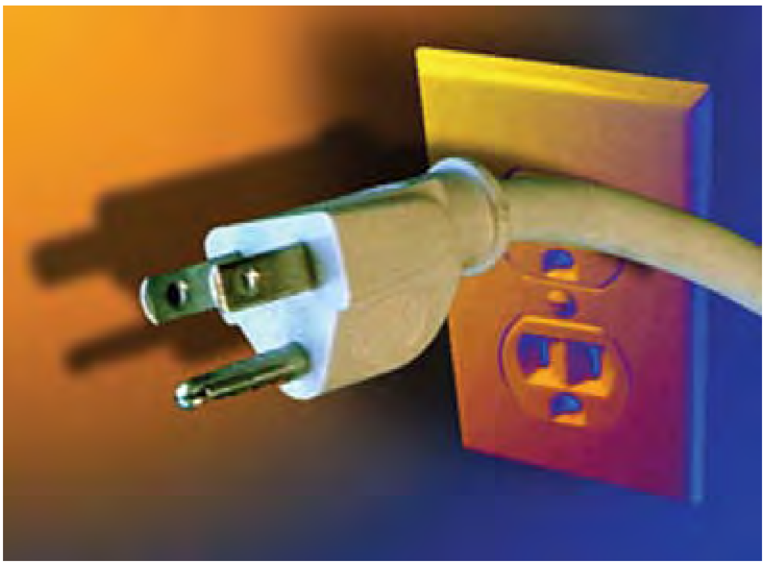
BALANCING THE BOOKS WHILE BALANCING HUMAN LIFE

By Don Horne

The road to hell is paved with good intentions – for Marvin Schur, a device known as a service limiter led the way to his death.

The elderly Bay City, Michigan man froze to death inside his home during a cold snap in January, unaware that the electric heat he depended on to stay alive was a mere flip of the switch away.

Mr. Schur was forced to have the limiter installed at his home because he owed the local utility more than $1,000 in unpaid electric bills. The limiter automatically shut off the flow of electricity to Mr. Schur's home once the preset limit was reached. But like most limiters, the flow of electricity could be resumed if Mr. Schur had manually reset the limiter himself.



Whether Mr. Schur was unaware or unable to reset the switch is moot. He remains just as dead. It remains unknown whether anyone had explained to Mr. Schur – a veteran of the Second World War – how the device worked.

According to the coroner, the death of the 93-year-old was slow and painful. When neighbours found the body, there was frost on the windows and icicles hung from the faucet. He lay dead on the bedroom floor, wearing a winter jacket over four layers of clothing.

It would be easy to point the finger of blame at the utility. If it comes out that Mr. Schur received no instruction from the utility on how to use the interrupter, certainly they bear the brunt of his death. When you consider Mr. Schur's age, coupled with the considerable back debt he had incurred in unpaid utility bills and the bitterly cold temperatures sweeping across Michigan during those dark days in January, it should come as no surprise that it should end in tragedy.

The utility and Michigan have immediately taken steps to avoid any future tragedies of this kind. The service limiter is a piece of technology that, when operated properly, manages to punish the delinquent homeowner while maintaining a minimum of heat and light to survive the winter. But a machine is only as good as the person operating it.

Utilities are placed in the impossible position of attempting to collect money for a vital service. No matter how many thousands of dollars a customer may be delinquent, the utility is forced to continue to provide that service – as was the case with the Michigan utility in January – so that the customer can survive until warmer weather arrives.

If any other businessman was told he must sell his wares to a customer with no guarantee of payment for months on end, he would laugh you out of the room. Sadly for utilities, this is the position they are placed in, and when something goes wrong – horribly wrong – they are branded little better than heartless fiends.

Although nothing can be done for Mr. Schur now, it seems his death may help prevent a rewriting of the rules governing the use of service limiters in Iowa.

Currently, the technology has advanced enough so rural co-ops can now use service limiters on delinquent customers. Some utilities refuse to use them, but others see the limiters as a way for customers who have fallen too deeply into debt to manage their power consumption.

With the death of Mr. Schur, those utilities pushing for the limiters state that they would only employ them on a case-by-case basis, and would ensure that any customers unable to take care of themselves would not be subjected to a limiter.

States like Minnesota and Vermont prohibit the use of limiters during winter months.

With the recession spreading wider and deeper than anyone has witnessed since the 1930s, devices like interrupters may become commonplace as customers find themselves out of work and out of cash.

The introduction of smart metering is a better, friendlier way of allowing the utility and customer to work together in lessening power usage, but that sense of camaraderie quickly evaporates when a family is faced with either paying the utility bill or putting food on the table.

The Obama administration is promising a massive infusion of stimulus dollars to fund infrastructure development, new nuclear generation and green grid expansion. Although the federal stimulus package will come as too little, too late for Mr. Schur – a man who lived through the Depression only to see his life end in a new millennia Recession – it may help utilities upgrade and adapt without placing the burden of debt on a customer base that really can't afford to support it.

don@electricityforum.com

RTD ENHANCES PROTECTION, REDUCES MAINTENANCE AT VITAL HYDROELECTRIC FACILITY

By Ed Sullivan

Reserve hydropower is an important support to the power grid during system emergencies. Ensuring that this standby power source is available can depend on small but powerful Resistance Temperature Detectors (RTDs).

After almost 25 years of service, the generator and transformer protection systems at the hydropower plant of a western U.S. dam and reservoir were upgraded, including the replacement of electromechanical relays with microprocessor-based relays from Schweitzer Engineering Laboratories, Inc. (SEL).

Originally designed for flood control on a major river, the multipurpose project now also provides irrigation water to a major agricultural area, enhances water quality, supplies domestic and industrial water, enhances fish and wildlife habitat, creates recreational opportunities, and generates electric power.

Hydropower, such as that produced at this project, provides stability to the power grid and helps avoid outages due to the loss of a base-load power plant. This reserve hydropower, which can be brought online within a few minutes, provides standby electric generation that keeps the power grid stable. Such plants help compensate for fluctuating power generation and transmission flows that occur during emergencies.

The dam is an earth-and-rock-fill structure, more than 600 feet high and 1,500 feet wide at the crest. Located above ground at the dam site, the power plant houses two 150 MW turbine hydrogenerators that produce more than 360 million kilowatt-hours of electricity. The power generated at this peaking plant supports the requirements of the nearby area, with remaining energy marketed through the grid to customers located outside the area.

Major components of the upgrade project include two SEL-387E Relays installed for comprehensive protection, metering, and event reporting of the power plant transformers. Generator protection is provided by two SEL-300G Generator Relays, which also provide important metering and events reporting/recording capabilities plus thermal protection in conjunction with RTDs.

Figure 1. The dam is an earth-and-rock-fill structure, more than 600 feet high and 1,500 feet wide at the crest.

Historically, the system used analog transducers (12 per hydrogenerator) to convert RTD measurements into scaled analog quantities. These transducers required annual calibration, using considerable technician time in the process.

Due to maintenance requirements and some heating issues on one generator, a more economical and reliable RTD technology was considered. The initial approach was to take advantage of the capability of acquiring and transmitting temperature data with an SEL-2600A RTD Module.

"The customer chose the SEL-2600A RTD Module because it requires no annual calibration or maintenance and resulting simplification of RTD wiring. A single fiber-optic interconnection between the SEL-2600A and SEL-300G Relay provides all needed temperature data for the alarm and protection capabilities within the SEL-300G Relay," explains Greg Rauch, SEL application engineer.

"They had heating issues with one of the hydrogenerators. Up until the SEL relay installation, they only had alarm and protection functions on one RTD for each generator. The customer later found that the RTD used for this purpose was not located at the hot spot of the generator. The hot spot was located at the end-caps of the generator stator winding, and the heat radiated toward the RTDs locat-

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ed above. There were no data gathering capabilities with the relay-connected RTD, so they had no information as to what was happening with that RTD. The customer considered changing the RTD being monitored by the existing relay, but decided, instead, to install the SEL technology, which can give alarms and tripping on all RTDs simultaneously," Rauch explains.

The original SEL-2600 RTD Module was installed and tested. However, the RTD-connecting cables were not shielded, and the existing RTDs have a much lower signal-to-noise ratio tolerance; therefore, the module could not overcome the noise from the RTD wiring while the generator was under load.

To deal with the noise problem, SEL developed a new RTD module, the SEL-2600A. Designed for use with transformers, generators, electric motors, and other power system apparatus, the SEL-2600A operates with four types of RTD inputs, including 100-ohm platinum, 100-ohm nickel, 120-ohm nickel, and 10-ohm copper. The SEL-2600A is a fully compatible replacement for the SEL-2600 and provides new-generation, patent-pending noise rejection technology. Fiber-optic links eliminate expensive cable pulls and provide electrical noise immunity and ground isolation between devices.

"We redesigned our standard SEL-2600 RTD Module and launched a new product to handle all types of situations," says Rauch. Using this process, "We've made the product compatible with all common RTD types used in many applications. It also works well for upgrading older installations that use the 10-ohm copper technology."

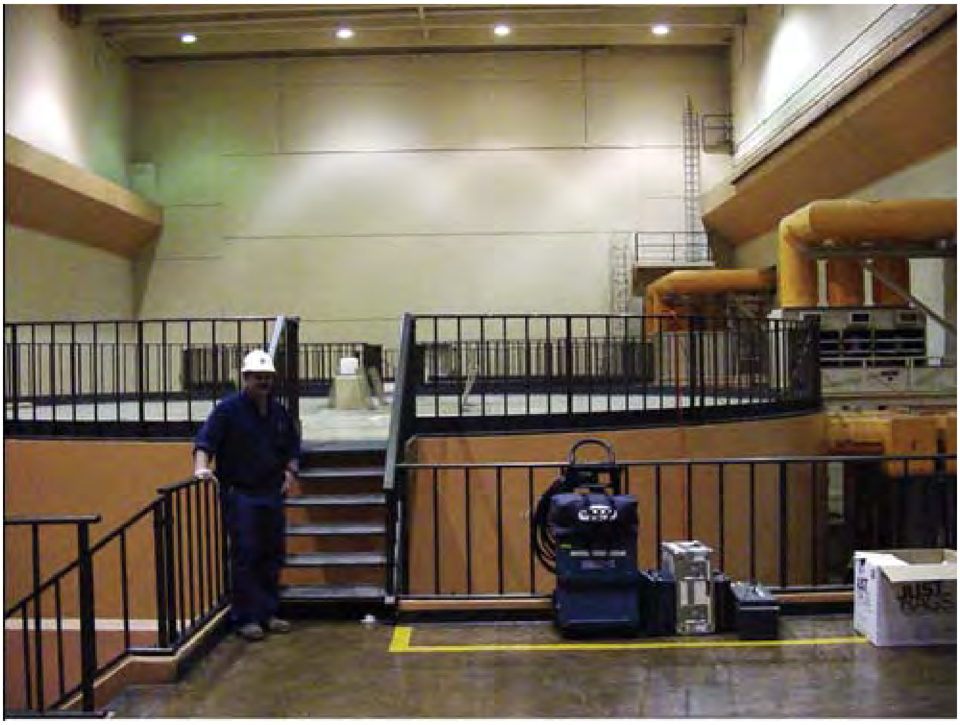

Figure 2. Located above ground at the dam site, the power plant houses two 150 MW turbine hydrogenerators.

Figure 3. The hydroelectric power plant transformers are protected and monitored by SEL-387E Current Differential and Voltage Relays.

Another benefit of the installation is that a single fiber-optic strand runs to the control room where the generator protection relay is located and handles data that come from the SEL-2600A. "This eliminates several control wires, which are susceptible to electromagnetic interference and other noise sources. Because this product eliminates the use of transducers altogether, it frees additional space in cable trays and wiring junction boxes," adds Rauch.

The SEL-2600A temperature monitoring scheme at the dam and power plant is used for alarm and trip functions in

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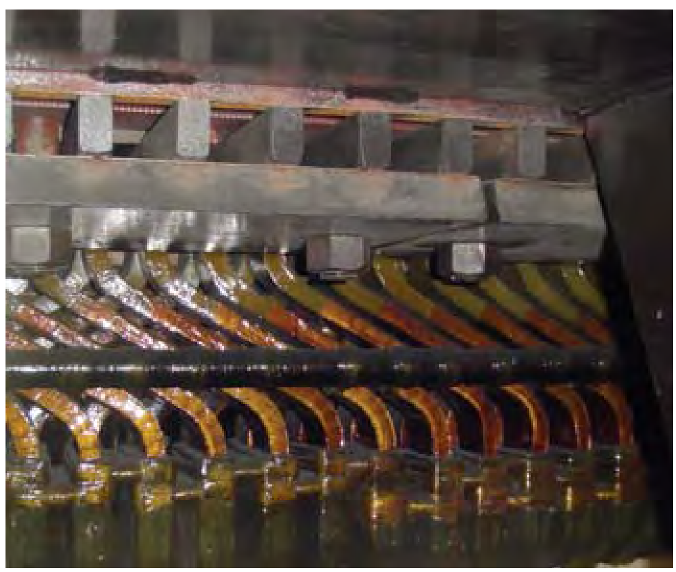
each SEL-300G. Temperature data are passed to the plant data control system via Modbus communications from the SEL-300G to the plant remote terminal unit. Stator temperature data are available locally and at the main control center located more than 60 miles away.

Figure 4. Two SEL-387E Relays are installed to provide comprehensive protection, metering, and event reporting of the power plant step-up transformers.

To date, the new power plant protection system is operational and error free. Thermal data are now transmitted from 12 different RTDs in each hydrogenerator. The RTDs are virtually maintenance free, which frees up technical support personnel. The project engineer felt that the project was a highly worthwhile experience. “I was very entrenched in the entire upgrade project, but enjoyed tackling the generator heat monitoring problem in a creative way that made a lot of sense,” he says.

Figure 5. Shown here (above) is the 150 MW turbine hydrogenerator.

Figure 6. The hot spot (shown right) was located at the end-caps of the generator stator winding, and the heat radiated toward the RTDs located above.



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ON-LINE PARTIAL DISCHARGE DETECTION IN TRANSFORMERS

By N. H. Ahmed and N. N. Srinivas, Detroit Edison Company

This article describes an on-line partial discharge (PD) detection technique applicable to distribution transformers.

This technique uses a spectrum analyzer with a high-frequency preamplifier and high-frequency current probes.

The PD measurements normally are made on each of the primary and secondary windings with a high-frequency current transformer clamped around the cables below the bushing of each winding. This technique is capable of detecting PD activity in the range of l00kHz to 200 MHz.

The on-line PD detection technique was used alongside the Dissolved Gas Analysis (DGA) technique to check the insulation integrity of several transformers. This article describes the results of these test methods applied on seven 300kVA transformers. These transformers show different levels of deterioration with the DGA concentrations in the range of 44 to 5,042 ppm and PD activity ranging from 15 to 1,800 pC.

INTRODUCTION

PD pulses generate electromagnetic waves, acoustic waves, local heating and chemical reactions. Detecting these phenomena possibly would indicate a PD defect. Chemical reactions produce dissolved gases in a transformer's insulating oil. For many years, DGA helped indicate the presence of serious defects in the insulating system.

Normally, DGA does not provide information about the present conditions of the transformer since gas formation is a cumulative process. DGA data collected over a period of time is required to assess transformer conditions.

Since the early 1960s, acoustical detection frequently was used to detect PD sources in power transformers [l-3]. The main problem with locating PD defects is the ability of acoustic waves to propagate equally in all directions [2]. Onsite PD detection was achieved by installing fixed acoustic sensors at different positions inside the transformer tank [3].

Most PD electrical detection in power transformers is performed with a classical discharge detector according to IEC Publication 270. Location methods are based on the analysis of the measured time resolved signals at the transformer terminals [4-61. Electrical PD detection and location normally are conducted on new or newly refurbished transformers at the manufacturer's facility. Performing these measurements onsite requires the removal of the transformer from service. It also requires, besides the PD detector, additional high-voltage components like a test-voltage supply and a coupling capacitor, which are heavy, expensive and not very suitable for on-site tests. On-line electrical PD detection is reported in reference [4]. This was accomplished by equipping the transformer with PD sensors (high-frequency current transformers) at different bushings (high voltage, low voltage and neutral terminations). This article describes an on-site PD measurement technique. The on-line technique can detect PD in distribution and sub-transmission transformers.

MEASUREMENT TECHNIQUES

In power transformer insulation, partial discharges generate high-frequency electromagnetic pulses that travel along the windings, bushings and

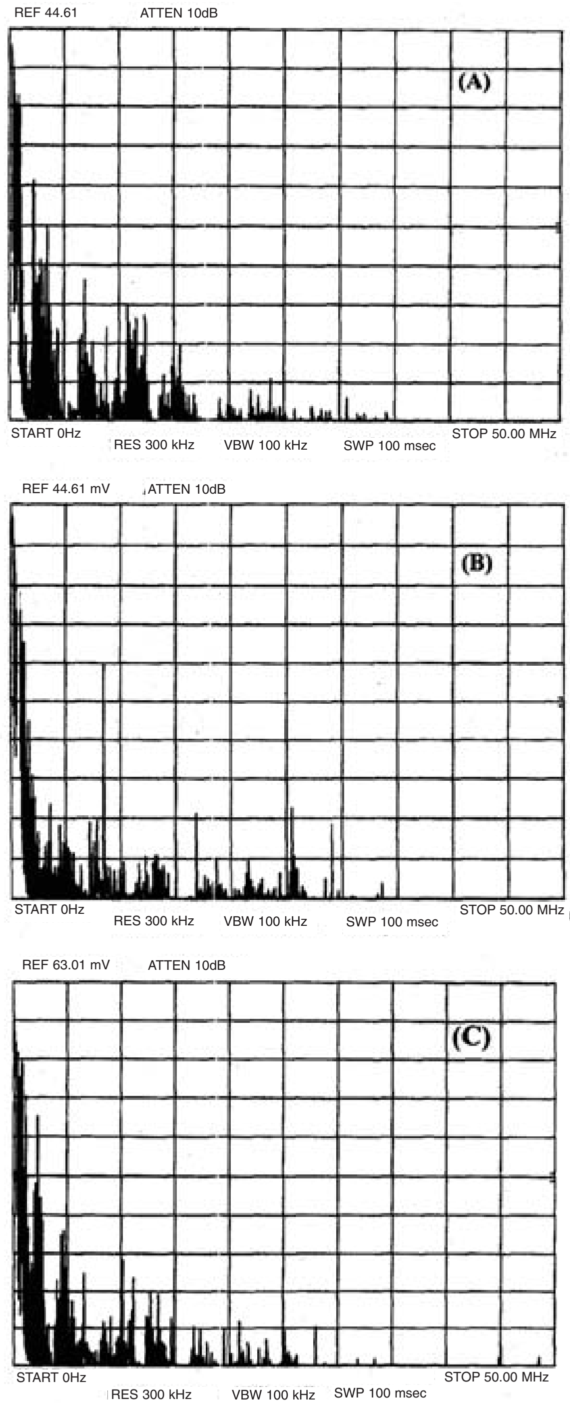

Figure 1: Signal detected from the primary windings of transformer #l. (A) X-phase (B) Y-phase (C) Z-phase.

the cable feeding the transformers.

During testing, these pulses are collected via a clamp-type high-frequency current transformer attached to the cables below the bushing of each winding. The high-frequency current probes used in this technique are made in two equal halves. One end of each of the halves is hinged and the other end butts together when clamped. The mating faces at both ends are machined flush to reduce air gaps to an insignificant amount. This ensures that the permeability of the toroid, and not the air gap, is the limiting factor in concentrating the magnetic field and reducing the overall path reluctance. It should be noted that the size, number, and deployment of the coupling turns of wire around the toroid determine both the circuit inductance and parasitic capacitance. The maximum usable frequency is limited to a value below self-resonance.

Transformer Number	Dissolved Gas Concentration (ppm)						Possible Defects
	H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	CO	
1	3,784	422	9	69	1	757	Corona
2	300	1,066	1,886	280	65	507	Arcing
3	14	254	558	1,776	145	37	Arcing
4	593	62	17	11	1	419	Corona
5	178	62	139	12	162	263	Arcing
6	0	0	17	5	0	130	-
7	11	0	4	0	0	28	-

Table 1 DGA data of 300 kVA transformers.

Thus, it is evident that any current probe can be designed to cover only a limited range in the frequency spectrum. Five current probes were used in the present investigation. Each consisted of a ferrite core with eight-coupling turns. These probes are sensitive to a frequency range of l0kHz to 200MHz.

The detected signals are coupled to a spectrum analyzer by a preamplifier. The characteristics of the spectrum analyzer used in this investigation are: frequency range from 100 Hz to 1,500 MHz; amplitude range from -135 dBm to 30 dBm; frequency span of 100 Hz to 1,500 MHz plus zero span; resolution bandwidth of 10 Hz to 3 MHz; video bandwidth of 1 Hz to 3 MHz; and sweep time of 20 ms to 1,500 s. A dual-channel preamplifier was used. The frequency range of the first channel was 0.1 to 1,300 MHz with a gain of 25 dB, while the frequency of the second channel ranged from 0.001 to 50 MHz with a gain of 28 dB.

It should be noted that the high-frequency components of the partial discharge spectrum are attenuated more rapidly than the low-frequency components. This behavior is used to locate the PD source.

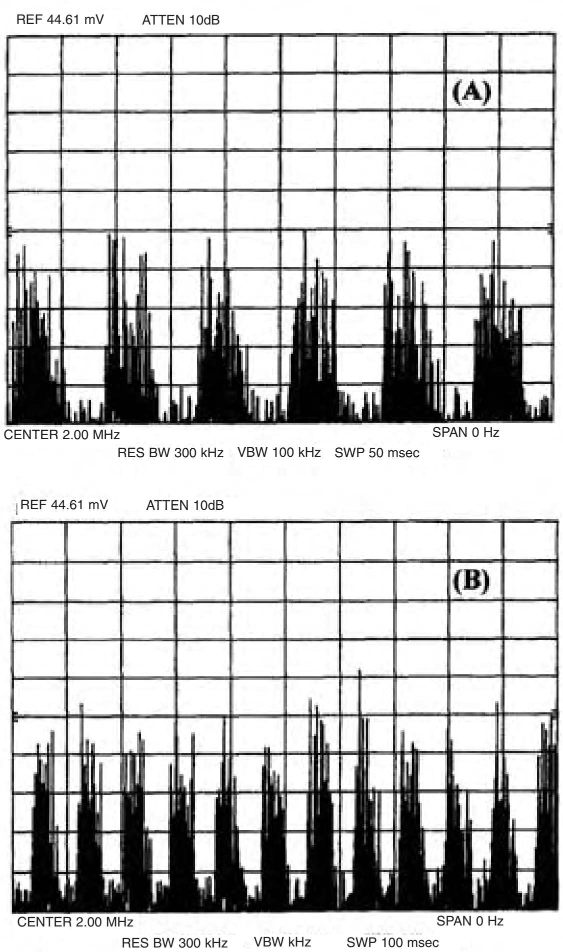

Figure 2: Zero-span spectrum of 2-phase, transformer #1. (A) 3-cycles (B) 6-cycles.

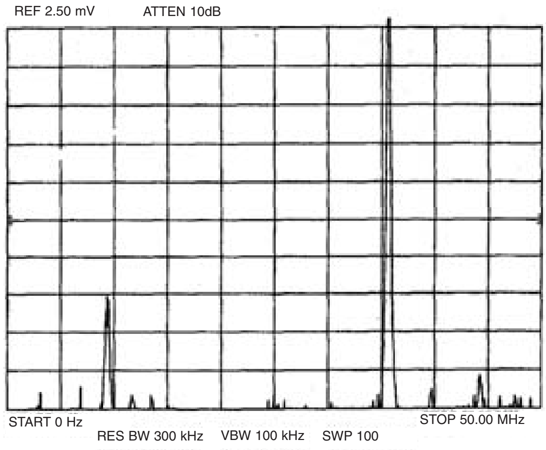

Figure 3: Signal detected from the secondary winding of transformer #1.

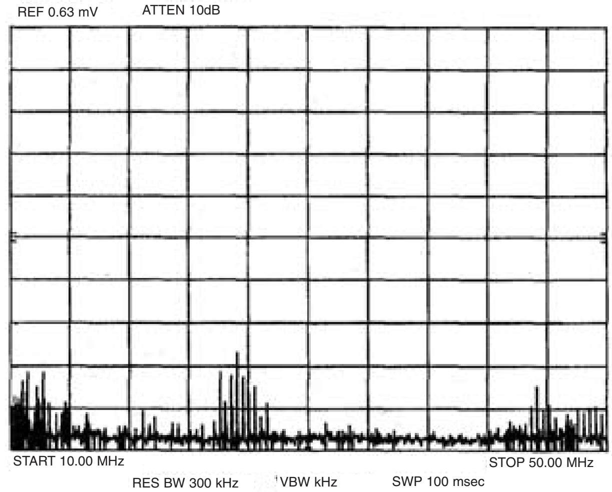

Figure 4: Signal detected from the primary winding of transformer #7, Y-phase.

RESULTS

On-line partial discharge measurements and DGA were made on seven 300 kVA, 13.2kV/480V/227V transformers feeding a busy shopping center in Metropolitan Detroit.

DISSOLVED GAS ANALYSIS

The DGA data are given in Table 1. The quantity of primary combustible gases of transformer #1 is about 5,042 ppm. The hydrogen concentration is elevated (about 15 times higher than normal) indicating possible corona problems.

Transformer #2 also shows a high concentration of combustible gases (4,105 ppm). The elevated concentration of acetylene (five times higher than nor-

Transformer #	DGA (ppm)	PD (pC)
1	5,042	1,800
2	4,105	1,250
3	2,784	600
4	1,102	300
5	816	500
6	152	30
7	44	20

Table 2 The quantity of the combustible gases and the maximum PD signals detected in 300 Kva transformers.

mal) indicates arcing is occurring inside the transformer. As in transformer #2, elevated concentration of acetylene also was found in transformer #3 indicating possible arcing. The hydrogen level of transformer #4 is about twice the normal value pointing indicating possible corona. All combustible gases, except acetylene, are below the normal values of transformer #5.

Acetylene concentration is about 15 times the normal level.

This elevated value of acetylene might be because of electrical arcing in the transformer. Gas concentrations found in transformers #6 and #7 are either undetectable or well below the normal values.

ON-LINE PD MEASUREMENTS

In each transformer, PD measurements were made on all primary and secondary windings. The PD highest level is detected in transformer #l. A significant amount of PD activity was observed in all three primary windings. (see Figure 1.) Pulses in the frequency range of 2 to 30 Mhz were detected. The PD level of Z-phase was the highest, more than 1,800 pC. These PDs occur at both the negative and positive cycles of the operating voltage. Figures 2a and 2b show the 2-MHz PD-component occurred during three and six cycles of the operating voltage, respectively. This was obtained by running the spectrum analyzer in the zero span mode. The center frequency is tuned to the frequency where the PD level was the highest (2 MHz). Zero-span examinations also were made at center frequencies of 4.8, 7.5, 12.4, 20.3 and 28 MHz. The zero-span spectrums at these frequencies were similar to those conducted at 2 MHz. No PD was observed in the secondary windings. (see Figure 3.)

This is true for all the transformers.

Partial discharges on the order of 1,200 pC were detected from transformer #2 with X-phase showing the highest readings. Moderate PD activity ranging from 300 to 600 pC was observed in transformers #3, #4 and #5. Partial-discharge pulses with magnitude below 30 pC were detected from transformers #6 and #7. The frequency of these pulses ranged from 22 to 26 MHz compared with a range of 2 to 30 MHz in transformers #1 through #5. (see Figure 4.)

PD normally produces pulses with

frequencies ranging from few hundreds kHz to few hundreds MHz. The attenuation of these pulses is a function of frequency. The higher frequency components will be rabidly attenuated as they travel alongside the windings of the transformer. This behavior can be utilized as a means of locating the source of PD. For instance, the detection of high frequency components (up to 200 MHz) indicates that the PD likely originates in the winding turns next to the transformer bushing.

ON-LINE PD TESTING VERSUS DGA

The results of both the DGA and PD measurements have been summarized in Table 2. In cases of severe insulation deterioration, PD results fully agree with the DGA data.

However, when small to moderate defects are present such as those found in transformers #5, #6 and #7, electrical PD detection is more accurate than DGA in identifying the extent of the deterioration.

CONCLUSION

On-line PD detection techniques using a spectrum analyzer capable of detecting PD activities in distribution and subtransmission power transformers are presented in this article.

The technique is very attractive to utility engineers in assessing integrity insulation of power transformers since it is not a destructive technique and it does not require the system to be de-energized. It also is inexpensive when compared with other detection methods since no heavy equipment is needed.

The suitability of this technique was checked against DGA.

In severe insulation deterioration, PD results fully agree with DGA data. However, the PD measurement technique was more effective in detecting small defects. DGA does not provide information about the present condition of the transformer since gas formation is a cumulative process.

DGA data obtained over a period of time is required to assess the transformer's condition. On the other hand, PD technique provides information about present conditions and does not interfere with the operation of the transformers. It also provides information about the location of defect.

REFERENCES

[1] H. Ogihara, "Detection and Localization of Corona in Oil Immersed Transformer with Corona Detector", IEEJ, Vol. 9, pp. 12-21, 1964.

[2] M. Beyer, H. Borsi and M. Hartje, "Some Aspects about Possibilities and Limitations of Acoustic Partial Discharge Measurements in Insulating Fluids", 5th ISH, paper 41.04, Braunschweig, Germany, 1987.

[3] O. Cohard and P. Luccioni, "Location of Partial Discharge in Transformers: Results of Tests Carried by EDF over the Period 1980- 1991", Second Volta Colloquium on Partial Discharge Measurements, Como, Italy, 1992.

[4] J. Fuhr, M. Haessig, P. Boss, D. Tschudi and R.A. King, "Detection and Location of Internal Defects in the Insulation of Power Transformers", IEEE Trans. On Electr. Insul., Vol. 28, No. 6, pp. 1057-1067, 1993.

[5] F.H. Kreuger, E. Gulski and A. Krivda, "Classification of Partial Discharges", IEEE Trans. on Electr. Insul., Vol. 28, NO. 6, pp, 917-931, 1993.

[6] H. Borsi, "The Relation between Thermal and Electrical Stress and the PD Behavior of Epoxy-Resin Transformers", IEEE Trans. on Electr. Insul., Vol. 28, No. 6, pp. 1007-1015, 1993.

FOR PIN INSULATORS, POLYETHYLENE PUTS PORCELAIN IN ITS PLACE

Material differences between polycoating on the conductor and the porcelain insulators was causing tracking around the insulators

Porcelain is excellent for bathroom sinks, dolls and dishes. But when it comes to pin insulators, it is not nearly as effective or reliable.

This is the conclusion reached by many professionals working in the utilities industry. Specifically, Warren Hadley, a senior engineering technologist at Northeast Utilities, agrees with this assessment. Working for New England's largest utility system and serving more than two million electric and natural gas customers in Connecticut, Western Massachusetts and New Hampshire, Hadley has seen the superior performance of polyethylene insulators versus porcelain – firsthand.

"At Western Massachusetts Electric Company and Connecticut Light and Power, we use the Hendrix Vise Top insulators almost exclusively," said Hadley, who works in the company's standards department, specifying materials and construction standards for overhead construction. "There are a few instances where we're using porcelain insulators with bare wire, but even with bare wire we've started to use the molded Vise Top (polyethylene) insulators with aluminum inserts."

According to Hadley, the decision to move primarily to polyethylene insulators (supplied by Hendrix Wire & Cable, one of the premier providers of high-quality overhead and underground power distribution products), was made in the mid-1980s, based on research that Northeast Utilities conducted at that time.

"Back in 1984, we were having problems with tree wire burndown caused by lightning," Hadley said. "It was an issue at the time for most utilities, and there were a large number of manufacturers trying to solve the issue. Our engineering department conducted a research study and found that because of the material differences between the polycoating on the conductor and the porcelain insulators, we were getting tracking around the insulators."

"At the time it was more expensive to use a molded polyethylene Vise Top insulator," he added. "But we conducted further study and found that, by using aluminum inserts in the jaw for bare wire application and plastic inserts for covered conductor, it was possible to save substantial time during the installation. This helped us recover the additional cost of using the molded insulator products."

As a result, Northeast decided to go forward with the molded Vise Top insulators. By the late 80s, the company was using them for all covered-wire installations. According to Hadley, other manufacturers were developing a tie wire made out of polyethylene that they believed might help to solve the problem. At that time, it was a matter of trying a little bit of everything to see what worked best.

The new insulators are more resistant to vandalism from gunfire.

Hadley added that in the past, Northeast might have still employed porcelain insulators with radio free tops for a bare wire installation. But it has gotten to the point that the company linemen prefer the molded insulators because they don't have to go through the tedious process of wire tying; it's now just a matter of using the right Vise Top product for the type of conductor being used.

"You just screw it down and tighten the breakaway bolts," he said. "The Vise Top uses sheer bolts that are torque sensitive and it's done in minutes. So they use them now even for running bare wire. The porcelain versions are just used for certain repairs."

Obviously, putting up new wire is the optimal application for molded insulators. That's when it's most cost effective, because that's where the labor cost can be substantially reduced by virtue of being able to pull the conductor through

Porcelain is excellent for bathroom sinks, dolls and dishes. But when it comes to pin insulators, it is not nearly as effective or reliable.

the insulators using the Hendrix VTST-1 tool and then have them all in place. Retrofits can be time-consuming and expensive; still, Northeast has gone back to older circuits and replaced the insulators with polyinsulators because of the problem with the conductor covering breaking down.

Without question, the polyethylene Vise Top insulators – the kind that Northeast Utilities purchases from Hendrix on a large scale each year – offer superior performance as measured by virtually any criterion you can name.

Take vandalism, for example. Every year utilities report property destruction among the causes of service disruptions. The fragility of porcelain, as well as the fact that porcelain insulators can be easily shattered on impact, makes them attractive targets for stones, balls or projectiles. Conversely, the impact resistance of high density polyethylene (HPI) insulators makes them the natural choice in vandal deterrence. If hit by a ball or stone, there is no shattering.

Further evidence of HPI Insulators' near indestructibility can be gleaned from ballistics tests, showing that even with damage from rifle or shotgun fire, these insulators are still able to operate. Using the HPI Insulator is analogous to putting up a fence around a pool or taking a ladder down around the house when not in use – it mitigates the "attractive nuisance" factor that is characteristic of porcelain.

Hendrix maintains that porcelain insulators should not be used with a covered conductor. This is due to the inherent dielectric incompatibility between the two materials (polyethylene and porcelain).

HPI insulators also require less maintenance than porcelain insulators in the same environment. What's more, high density polyethylene is naturally hydrophobic, meaning that it is water repellent, i.e., water will bead up rather than penetrate and will leave dry spots between the water beads. This phenomenon is similar to a newly waxed car; the lack of stickiness, along with wind and rain, allows for a natural cleaning. This property, along with the HPI's superior track resistance and design in increased leakage offers excellent resistance to polluted or salty environments.

The aforementioned features and benefits help to explain why polyethylene insulators give a utility company such as Northeast Utilities an advantage over a competitor using porcelain insulators. Hendrix Wire & Cable's HPI Insulators have proven to be an effective alternative solution for Northeast Utilities—and that's putting porcelain in its place, or in this case, polyethylene on the system!

MAKING THE MOVE TO SMARTER TECHNOLOGIES

By Cathy Tough

Canadian utilities are undergoing a fundamental change. Similar to what telephone companies went through in the 1980s and 1990s, they need to deal with a shrinking workforce while looking to optimize costs, reduce environmental impact, and deliver more and differentiated products and services to an educated and sophisticated customer base.

At the same time, the "consumerization" of energy is becoming a growing trend in utilities with the increased concern for the environment. Consumers are becoming more active participants in the energy delivery network by engaging in energy efficiency programs and deploying renewable distributed energy resources, sometimes regardless of the financial incentives to do so. In fact, Gartner estimates that 35 per cent of new and 15 per cent of existing residences in North America will participate in energy efficiency programs by 2015.

Utilities also need to contend with aging infrastructure, which has increased the demand on information technology (IT) to better monitor, diagnose and report on the performance and reliability of existing assets.

With the current volatile economy, it is important for utilities to incorporate smarter technologies – such as advanced metering infrastructure (AMI), mobile workforce management, customer self-services and intelligent network management – into their corporate and operational infrastructures and better manage increasing regulatory demands from a variety of sources. These technologies help deliver cost reductions that may be passed back to consumers and also help utilities enhance environmental stewardship.

Take AMI as an example. AMI solutions are expected to bring the utility industry one step closer to one of the most important technological challenges it faces over the next decade – implementing and integrating smart meter technology to provide energy more intelligently and efficiently.

AMI automates the transfer of energy and event data and enables bi-directional communication between utility back-office systems and utility assets in the field. Utilities can read meters remotely on demand, eliminating incorrect readings and reducing travel time and costs.

AMI moves along the increased adoption of services-oriented architecture (SOA). Previously siloed business and operational applications can now be seamlessly integrated to deliver end-to-end business process enablement. This move towards a process-centric organization can help utilities improve efficiency and lower the total cost of IT by eliminating costs associated with maintaining disparate and often redundant applications to perform similar functions.

> As the economic turmoil continues, utilities will have to learn to do more with less.

In addition to the operational efficiencies AMI presents, AMI enables utilities to provide improved and flexible self-service customer service options, such as pay-as-you-go and time-of-use rate tariffs, by delivering greater transparency to the consumers' energy usage and price of that usage.

Ultimately, the reduction of IT costs and increased efficiencies and flexibility AMI delivers can help utilities to increase bottom-line revenues while improving customer service.

To take advantage of smart technologies such as AMI and meet the increased demands in customer billing processes, Canadian utilities need to look into another important technology – the customer information system (CIS). A CIS is a very large and integral enterprise application for utilities that primarily supports customer-facing functions, including account maintenance, order processing, billing, credit and collections, and accounts receivable. Sophisticated and extensible CISs support integrated business processes that span across various enterprise systems, including work and field service management, outage management, and asset management systems.

While cost is a major consideration for utilities in moving forward with infrastructure projects, and CIS represents a significant chunk of a utility's IT investment, Canadian utilities are increasingly looking to invest in CISs to strengthen their operations and deliver improved services. A recent poll by U.S.-based UtiliPoint International revealed that 60 per cent of the Canadian utilities surveyed plan to replace their current CIS in the next four years, with 34 per cent planning no replacement before 2013. Many said they needed to make the switch to simplify their IT, better manage risk or because their current system was reaching end of support life. Almost half (49 per cent) noted their principal reason to switch to a new CIS was to support new product and service offerings. The study polled 40 Canadian utilities of all sizes, both private and publicly-owned and providing one or more commodity – electricity, water and/or natural gas.

In addition to pursuing CIS projects, Canadian utilities will be putting their efforts into renewing other legacy business systems such as enterprise resource planning, workforce management, enterprise asset management and geographic information systems over the next few years. Utilities will also focus on integrating customers' AMI assets with back-office systems and improving enterprise and operational data consolidation and reporting.

As the economic turmoil continues, Canadian utilities will have to learn to do more with less. While Canadian utilities have always been conservative in their spending due to the public regulatory

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YOU SAID IT…

"Always enjoy your magazine."
Ashley LeBel, Hydro One Networks Inc., Peterborough, Ontario

"I just have to commend you on a fine journal. Your articles have been most informative, especially all those detailing trends and new alternative power technologies. Keep up the good work and many thanks."
David Mayzes, Electrical Systems Officer, Fleet Maintenance Facility CB, Malahat, British Columbia

"Electricity Today magazine has a lot of information and keeps me updated. Thank you."
Oscar Rojas Pinon, Control Panel Designer, Enerflex Systems Ltd. – Syntech Division, Calgary, Alberta

"Your publication is invaluable in keeping abreast of current products and associated information."
Michael Shea, Electrical Safety Officer, City of Victoria, Victoria, British Columbia

"Thanks for a great magazine. It is an important way for me to keep informed on industry developments. I especially like reading the editorials about the future of the electrical generation industry."
Mel Smillie, Project Engineer, Bruce Power, Tiverton, Ontario

"Quality magazine. I cover Fort McMurray (all industrial based)… every electrician I visit has a copy of your magazine on their desk."
Douglas Baker, Senior Service Technologist, Eaton Power Quality, Ft. McMurray, Alberta

"Your articles are very informative. Great Job!"
Sonny Punzalan, Power Engineer, City of Roseville Electric Department, Roseville, California

"I enjoy your magazine, and find the articles very informative and relates to our industry."
Daryl Shonaman, VP of Engineerng Operations, Saint John Energy, Saint John, New Brunswick

Smarter Technologies
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review process in place in most provinces, capital spending towards modernizing aging energy infrastructures will undergo even greater scrutiny by the utility management boards and public utility review boards. To justify any new capital spending on technology or business applications, the technology will need to be leveraged across the enterprise to achieve the expected rate of return. Leading utility vendors recognize this shift in decision-making and are focusing their efforts on solutions that address the business needs of various business groups within the utility – creating greater integration and lowering total cost of ownership across utility processes and systems.

Adopting new-generation solutions may seem to require a lot of resources, but these systems deliver long-term benefits that justify the investment. These systems can help utilities achieve end-to-end process transparency, integration across the enterprise and enable easy, cost-effective adoption of new technologies such as AMI. With the significant cost reductions and improvements in customer service expected from these smart technologies, utilities can increase their responsiveness to customers' changing needs and become successful utilities of the future.

Cathy Tough is National Director, Utilities, at Toronto-based SAP Canada Inc., which provides business software, consulting and educational services for utilities of all sizes in Canada and worldwide. For more information on the SAP® for Utilities solution portfolio, visit www.sap.com/canada/industries/utilities.

CONDITION ASSESSMENT OF ELECTRICAL EQUIPMENT IN POWER PLANTS

By Nagu Srinivas and Dr. Oscar Morel, DTE Energy Technologies

INTRODUCTION

Power cable and electrical equipment such as motors and transformers must operate as long as possible within reliability and safety standards. Critical plant equipment must be monitored and maintained without sacrificing plant availability. A critical component is one whose failure could endanger plant safety, could cause an extended forced outage, or has a long lead time. An influence component is one whose failure would probably not result in an extended outage, would not endanger plant safety, and is unit specific. In a power production plant, cable and station main transformers are critical components.

Electrical systems do not last forever. At some stage, Plant Operations personnel must decide when to replace cable components, electrical equipment, or an entire electrical system. This is a difficult and potentially costly decision. Wholesale refurbishment of an electrical plant is too costly to be a practical economic option. Common practices used to schedule electrical system maintenance are as follows.

• Operate until the electrical system fails.

The least involved practice is to operate the electrical system without any preventive maintenance and repair when the cable fails. Replacement is scheduled when repair costs become more expensive than replacement.

• Replace based on specified failure rate or life span

Replacing equipment when the failure rate reaches a pre-established level or replacing the cable system after a certain life span is still widely used. This assumes that cable and equipment age uniformly, which is not the case. Different segments of the cable system often age non-uniformly along its length. If Plant Operations has the means to identify only the components that need replacement, significant savings can be achieved.

• Conduct laboratory diagnostics

Another way of assessing cable condition is to perform a laboratory evaluation on cable samples removed from field. The diagnostic tests conducted in the laboratory may reveal valuable information about the condition of the removed sample but the results have to be extrapolated to the rest of the system. High voltage DC (Hi-pot) and VLF tests are sometimes used to identify the cable components that are on the verge of failure. However, these are destructive tests.

• Perform Diagnostics testing.

Of all the diagnostic methods available today; condition assessment diagnostic testing provides the most detailed information about the performance of an electrical system, down to individual components. Condition assessment provides early identification of weak components of the cable system. It locates degraded components and determines the extent of degradation. This is essential to maintain system reliability. Cost savings can be realized by prioritizing the replacement of weak sections of a circuit. Condition assessment is often more expensive than other diagnostic methods. However, the value of the detailed test results and the savings achieved far exceed the cost of condition assessment.

Nomenclature
EPR Ethylene Propylene Rubber
PD Partial Discharge
PILC Paper Insulated, Lead Covered
XLPE Cross-Linked Polyethylene
PD Partial Discharge

DTE ENERGY TECHNOLOGIES ONLINE CONDITION ASSESSMENT

On-line, in-situ testing to estimate future performance of operating cable systems and electrical equipment represents an advance in diagnostics technology for the cable industry. This advance is possible due to novel technology developed and patented by DTE Energy Technologies (DTECH), including advances in signal processing and interpretation. Of several diagnostic methods available today, the Cable/Wise condition assessment diagnostic testing is most effective, as it provides early identification of weak components of the cable system while the system remains energized. It can locate degraded components of the system and determine the extent of degradation. This is essential to maintain system reliability. On average an 80% cost reduction in cable and equipment replacement costs can be realized by DTECH condition assessment.

The overall objective of diagnostic testing, of course, is to identify defects that could cause a system failure, and estimate the time remaining before these defects progress to failure and cause an outage of the electrical system. The test should be economically justified and should not cause additional degradation to the system under test. Hence, testing performed at over-voltages is always of some concern.

Diagnostic test methods that detect partial discharges (PD), which are active during the time of testing, can only detect defects or imperfections that produce partial discharge greater than the sensitivity of the test method. Cable accessories such as splices and terminations are most likely to fail because of PD that causes degradation. For cables, not all degradation phenomena are associated with PD.

Power cables are used to supply power to plant equipment, such as large motors, auxiliary transformers, precipitators, and back-up diesel generators. These cables are rated from 2001V to 15 kV and are single conductor or three-conductor cables, shielded or unshielded construction. Before 1970 power cables were insulated with extruded dielectrics, such as XLPE, and butyl rubber. In some cases PILC cable was also used.

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EFFECTIVE RESEARCH CAN MAKE A BIG DIFFERENCE IN THE PLANNING PROCESS

Market research that gives utility companies a clear sense of what their customers are thinking provides valuable information for planning and strategy development, but all too often decision-makers shoot in the dark based on gut instincts.

That's one of the messages delivered to attendees of the American Public Power Association's Customer Connections Conference held earlier this fall in Nashville, Tenn. During a presentation moderated by Mark McNeely, senior partner of Nashville-based McNeely Pigott & Fox Public Relations, panelists emphasized the importance of quantitative research.

Surveys are essential tools in determining how well a utility is communicating with its customers and other stakeholders.

"Many company executives and managers develop plans based on what they think they know, and sometimes that works out," said McNeely, whose firm represents Nashville Electric Service and has coordinated hundreds of surveys in various regions of the country. "But they are often wrong."

"Doing a scientific telephone survey is the most cost-effective way to quickly gauge general attitudes of your customers, whether it's on how they view you versus competitors or about specific programs," McNeely said. "Survey results give you a real sense of your strengths and weaknesses – they let you know if you need to shore up communications in certain areas."

Alan Carmichael, a partner in the Knoxville, Tenn., public relations firm Moxley Carmichael, agreed, saying surveys are essential tools in determining how well a utility is communicating with its customers and other stakeholders.

"If a utility is rated low on value, or on how well the vegetation management program is going, the first thought that comes to mind should be about how to do a better job of communicating," said Carmichael, a former vice president of communications for the Tennessee Valley Authority whose firm represents the Knoxville Utility Board.

Also on the panel were Deidre Malone of The Malone Group, a Memphis public relations firm that's worked with Memphis Light, Gas & Water, and Dan Lockman, senior technology consultant with Atlanta-based Apogee Interactive, a provider of online services to energy utilities across the country.

Among the key points made by the panelists:

Customer surveys should be done on a regular basis – preferably every year but at least every two years. An initial survey establishes a benchmark, with subsequent tracking surveys providing results that can spot emerging trends or validate communications strategies.

Web-based surveys provide a quick and inexpensive way to gather customer feedback; but they are self-selecting, so the results may not be as accurate as those of a survey of a randomly selected base of customers.

Surveys are a good way to test messages prior to the launch of a campaign. For example, asking survey participants how strongly they agree or disagree with certain statements about the need for vegetation management programs can identify the most effective ways to communicate with customers about the program.

It's important to accurately analyze the results and to not overreact to small fluctuations in the results from year to year that are within the surveys' margins of error.

It's important for utilities' communications specialists to be actively involved in the development and analysis of surveys because the results are a direct reflection of their jobs.

— *Electricity Forum*

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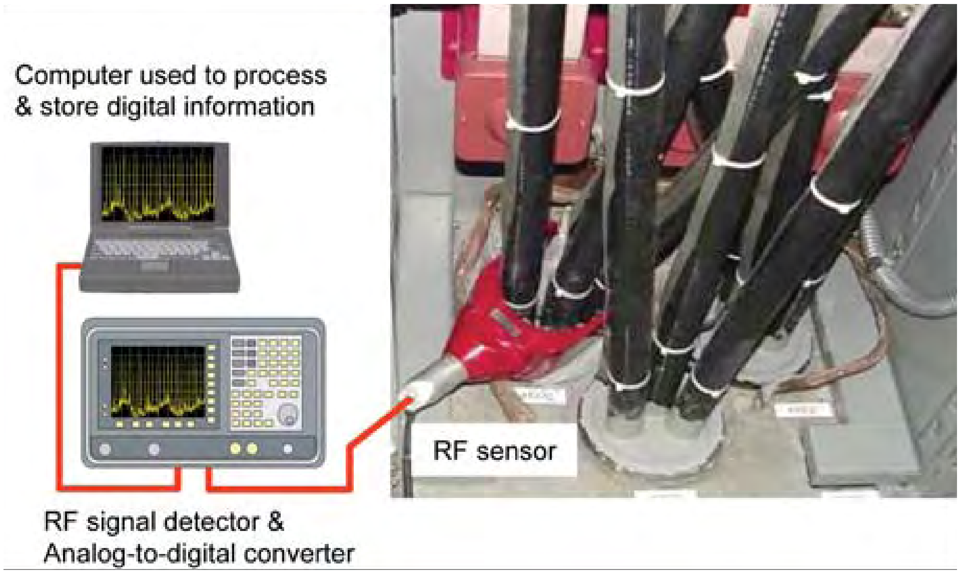


Figure 1 Data acquisition setup

The majority of cable failures in an extruded cable system are related to water treeing, which fail the cable when they progress to electrical trees. Once a water tree progresses to an electrical tree, the time to failure normally is very short because the initiated electrical tree propagates rapidly through the already weakened dielectric. Thus, the only window for detection is during the conversion process. Under normal operating conditions, such conversion is caused by prolonged activity in cavities created in the water tree channel as the result of heat generation caused by ionic current.

In PILC cables, failures are commonly associated with moisture ingress, which normally fails the cable through thermal runaway. Moisture in PILC cables increases the dielectric losses resulting in localized heat generation that thermally degrades the paper insulation and normally leads rapidly to a cable failure. PD may only be present at advance stages of such degradation.

An integral method that provides detection, location and condition assessment of both PD and water content is needed to ensure reliable cable system operation. Any PD testing technique that requires a cable system or equipment to be isolated will require shut down coordination to switch off and isolate the equipment under test, and reroute power to other equipment not under test. This may not always be convenient or economical. Also, critical circuits remain in service while being tested. In contrast, the Cable/Wise (DTECH) technique is capable of detecting and locating PD and moisture content while the entire system remains energized.

Note that measuring only the magnitude component of PD does not provide enough information to reliably assess the cable condition. The severity of the PD condition depends on the:

- Insulation material in which PD occurs;
- Environment in which the cable system is operating;
- Type of defect producing the PD;
- Location of the PD within the insulation wall.

Hence, any specific reported PD value diminishes in significance as that activity is further removed from the conductor shield.

DTECH TEST METHODOLOGY - CABLE

As noted above, when cables and accessories age, the resulting changes do not take place uniformly along the system length. Hence, for any diagnostic tool to provide truly meaningful information, one must be able to assess the cable system by length. Non-uniform aging may be due to one or more of many factors; manufacturing issues, localized contamination leading to weak boundary layers at an insulation-contaminant interface, water migration to high stress sites, loose shields at discrete locations, microcracks produced by mechanical fatigue, and so forth. Of great significance is the exact location of the defect within the cable insulation wall.

Signal and partial discharge detection in the field is significantly different from partial discharge testing of extruded cables shortly after manufacture. The objective of the latter is to detect manufacturing defects (voids, shield-interface imperfections) as a result of the extrusion process. This testing is intentionally performed at an over-voltage. Testing in the field requires suitable sensors, a noise filtration system and signal detection and processing capability. The DTECH approach (Cable/Wise) provides this at operating voltage, hence eliminating the need for a system shutdown and deleterious effects caused during off-line testing.

Due to defects, all cable components emit signals during operation, but the nature of those signals changes depending upon the cause (i.e., the defect type, as noted above); for example, loose shields yield different signals than do internal defects. The Cable/Wise totally passive technique utilizes the (RF) emissions to provide an assessment of the remaining life of the cable sections, splices, terminations, and other electrical equipment connected to the circuit.

One challenge is to be able to measure such small signals and transmit the information, and another is to be able to interpret them (relative to type and location). DTE Energy Technologies has been able to perform this and relate the information from such signal detection to future reliability in operation. The signals measured are generally due to small conventional partial discharges; however, DTECH has been able to measure other age related signals also.

The signal developed during aging induces a current flow in the cable shield and conductor; this consists primarily of high frequency components of the signal. The magnetic field resulting from the current flow is measured. The DTECH method couples energy from the magnetic field of the signal pulse into the measurement system (Figure 1). The sensors, developed and constructed by DTECH, are designed to pick up the magnetic field and are capable of detecting signals in the high frequency range. The readings are taken at intervals of several hundred feet along the cable. This is preferred since, as noted above, cables age unevenly and knowledge of the aging condition of the system over discrete sections is desired. It is to be emphasized that this testing is performed while the system remains energized. Noise reduction is accomplished through signal processing in the frequency domain. The non-destructive test procedure is not limited by cable length, operating voltage, insulation type, cable construction, or branching of the system. A significant feature of Cable/Wise technology is that it can distinguish between cable and accessory degradation activity.

The development of an extremely fast, affordable digital signal oscilloscope and waveform digitizer, and recent advances in signal processing and computer technologies have led to better understanding of the role and significance of individual partial discharges and related signals in degrading insulation systems.

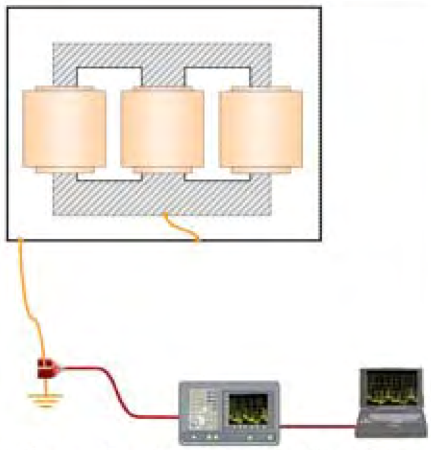


Figure 2 Data acquisition for a station or unit transformer

Frequency domain testing

Key to Cable/Wise technology is Frequency domain testing. Frequency domain testing has several major advantages over time domain testing, including:

1. PD can be detected, characterized, and located without having to trigger on the first pulse.

2. Since the frequency domain testing is usually carried out in service, and the PD is detected at various points along the cable, the cable between the point of detection and the cable termination acts as a high frequency filter which removes much of the noise which interferes with sensitive PD detection.

3. Since the PD detector is closer to the PD source and much of the interfering noise is filtered out by the cable, the bandwidth of the PD signal at the sensor can be used to judge location, and very sensitive PD detection is possible (Figure 5).

4. If the analyzer is triggered synchronously with the power frequency, the analyzer display becomes a phase/frequency fingerprint of the PD signal.

5. Because PD detection is undertaken in service, one can assume that any PD source which could be active is likely to be active. As explained above, if the cable is taken out of service to do off-line PD testing, the voltage must be raised to 2 pu in order to assure that all PD sources which could be active will be active.

Thus PD testing at 2 pu off-line is roughly equivalent to testing at normal operating voltage in service.

Since the signal magnitude cannot be used by itself to assess the significance of the detected signal, condition levels have been assigned to the signal information. A description of each level is provided below.

Level 1: The system is not degraded. No action needs to be taken.

Level 2: There is a small amount of aging related signals in joints and terminations. This amount of signal is normal and thus, no action needs to be taken. However, in extruded cables, retesting is recommended within the next two years.

Level 3: The system has a low probability of failure within the next two years. Consider retesting at a one-year interval.

Level 4: The system has a medium probability of failure within the next two years. Consider replacement.

Level 5: The system has a high probability of failure within the next two years. Consider immediate replacement.

Phase resolve studies of signals from several hundred thousand feet of cables (PILC, XLPE, EPR) over the past six years have enabled DTECH to ascertain patterns from the data developed, which, in turn, facilitates estimation of future performance.

Test Methodology - Electrical Equipment

The condition of electrical equipment such as transformer, switchgear, and motors connected to power cable can also be assessed with Cable/Wise technology. Again, no shutdown of equipment is required while taking readings (Figure 2).

Measurements are taken while the equipment is operating at operating voltage under normal conditions.

Throughout the life of a transformer several operating and physical conditions degrade the transformer cellulose and oil insulation system.

• High temperature and high load currents (above name plate rating)

- Moisture inside the transformer
- Oxygen – oxidation of cellulose and oil
- Voltage surges, lightning
- Physical damage due to moving/re-locating

As cellulose and oil ages, their insulating properties degrade, and produce gases that can form voids in the insulating oil. These voids, in turn, are sites for partial discharge.

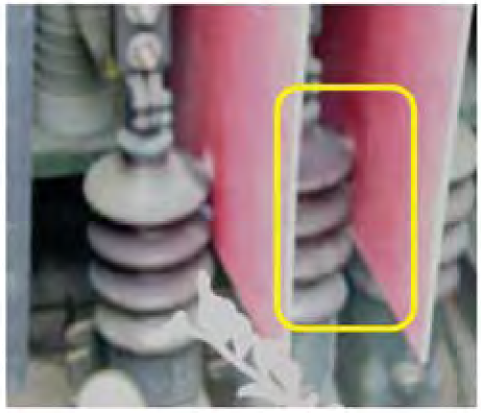
Cable/Wise detects partial discharge in these sites. Aging can progress to a level that will eventually fail the transformer, most commonly in the coil structure.

In addition to insulation aging, the laminated core of a transformer can degrade.

Discharge may take place between laminations at locations where the lamination insulation (usually a metal oxide layer) has broken down. Core discharge can take place over a long time period, but usually does not lead to catastrophic failure of the transformer. Transformers typically fail in the core structure. Cable/Wise can discriminate between core and transformer insulation discharge.

Transformers, motors, and switchgear operate with some level of internal discharge, even when new. A single test can indicate the presence or absence of discharges as well as their relative intensity. The discharge intensities and patterns measured in the initial test are unique to that motor only.

TP#	Date	From	To	Feet	Insltn	Yr	Jacket	Phase	Cable	Accessory	Comments
19	7/11/2002	MH 4219 17S	SW 1008/591		LC		Yes				
								A	Level 2	Level 4	Level 4 for switch 591. Discharges in this unused switch confirmed with parabolic corona detector. Hot points observed with IR camera
								B	Level 2	Level 4	
								C	Level 2	Level 4	



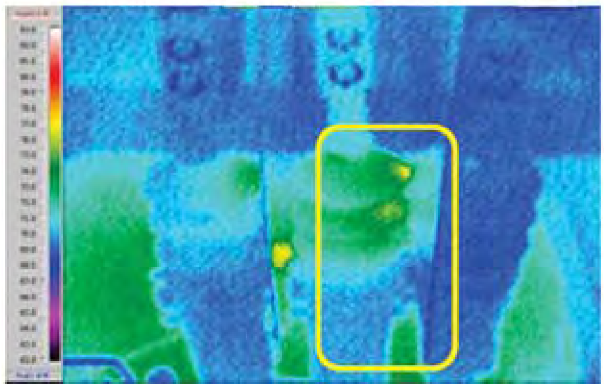
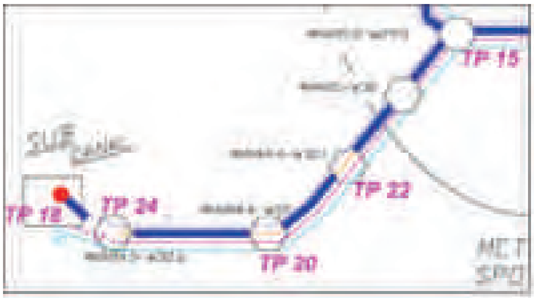


Figure 3 Surface discharge detected in a pad mounted switchgear

Length (ft)	Insltn	Jacket	Vntg	Phs	Diagnosis Cable	Diagnosis Accessory	Comments
100	XLPE	No	1984	A Parallel	Level 2	Level 5	Level 5 for cable terminations due to strong tracking discharge signals(Figure1)
100	XLPE	No	1984	AB	Level 2	Level 5	Level 5 for cable terminations due to strong tracking discharge signals(Figure1)
100	XLPE	No	1984	B Parallel	Level 2	Level 5	Level 5 for cable terminations due to strong tracking discharge signals(Figure1)
100	XLPE	No	1984	C	Level 2	Level 5	Level 5 for cable terminations due to strong tracking discharge signals(Figure1)
100	XLPE	No	1984	C Parallel	Level 2	Level 5	Level 5 for cable terminations due to strong tracking discharge signals(Figure1)

Figure 4 Analysis of 15-kV terminations

More than one test within a certain period of time is necessary for an accurate diagnosis, with the period of time between tests depending on the intensity of the discharge. Trend analysis of such a series of tests is a method that provides an accurate assessment of the condition of electrical equipment. This also applies to transformers.



CASE STUDIES

Pad mounted switchgear

Surface tracking in a pad mounted switchgear was located by the RF sensor located 200 feet away in an manhole (Figure 3). The switchgear was not part of the original condition assessment contract. However, after notifying the client about what was detected, the switchgear was investigated further. The switchgear was opened and a parabolic corona detector was used to confirm that the RF signals appeared to be emitted by surface contact between cable terminations and barriers inside the switchgear. The discharge also registered as heat in a thermal image of the terminations.

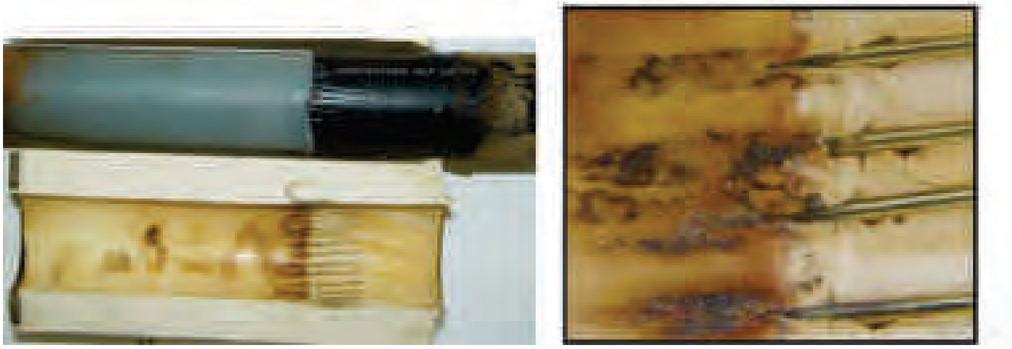


Figure 5 Dissection results of 15-kV terminations

15-kV Distribution Feeders

RF measurements were taken at the base of six terminations of a double cable distribution feeder circuit at the substation end of the cables. The terminations had been in service for 20 years. Analysis of the signals indicated that all six of terminations had an advanced degree of internal tracking (Figure 4). It was recommended that the client replace all six terminations as soon as possible. The client replaced the terminations and the existing cable. The client shipped the terminations, each with a 25 ft length of cable attached, to DETCH.

Laboratory RF measurements confirmed the results of the field measurements. The terminations were then dissected (Figure 5). Heavy tracking was observed in the bore of each elastomer stress cone in all six terminations. Discharge activity eroded some the elastomer at the embedded wire stress cone area. Some of the metal components inside the terminations were heavily corroded, an indication of moisture entry over a long period of time. Silicone grease was found at the termination of the cable semiconducting insulation shield in all six terminations. The grease in some of the terminations had begun to wax, an indication that discharge activity

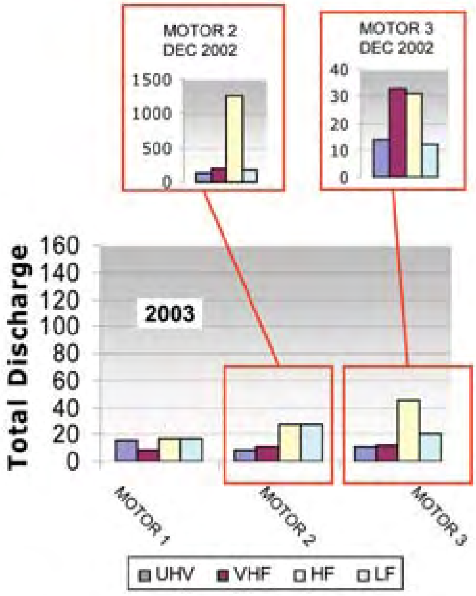


Figure 6 Trend analysis in motors

was in progress at the end of the shield. In one termination a double impression in the elastomer stress cone was evidence that the cable had moved 1/4" inside the termination.

It was concluded that although these terminations did not fail in service, they certainly were near end of life.

Motors

A motor operates with some level of internal discharge, even when new. A single test can indicate the presence or absence of discharges as well as their relative intensity. The discharge intensities and patterns measured in the initial test are unique to that motor only.

More than one test within a certain period of time is necessary for an accurate diagnosis, with the period of time between tests depending on the intensity of the discharge. Trend analysis of such a series of tests is a method that provides an accurate assessment of the condition of a motor.

In Figure 6 two motors in a refinery facility had high levels of RF discharge as measured in 2002. Maintenance was performed on the motors based on the 2002 measurements. The same motors had significantly less discharge when retested in 2003 as shown Figure 6.

On-line Discontinuity Locator (ODL)

ODL is used to detect direct buried splices and neutral corrosion in cables. The technology used for the tests is DTECH (proprietary) On-line Discontinuity Locator (ODL). A small pulse signal is injected into a cable by a sensor. The signal reflects back to the sensor at changes in the cable impedance. The reflected signals are picked up with the same sensor. The pulse reflection shape indicates impedance changes along a cable. Neutral corrosion, cable faults, both open and short circuit (short circuit, open circuit), and insulation damage, can be detected and located by analyzing the reflected signals.

Figure 7 shows an example of severely corroded copper shield tapes located by ODL in a nuclear power plant.

Figure 7 Neutral corrosion

25 kV Rated, Heat Shrink Joints

Cable/Wise testing was performed on a 24 kV cable system in two utilities. The less than 20 year old, XLPE insulated, direct buried systems exhibited a significant number of sites with elevated levels of degradation. The source of degradation was identified to be the cable splices. The customer elected to remove 12 joints with a 10-meter cable section attached and sent them to the laboratory for visual inspection and tests. The splices exhibited degradation levels 2 through 5. The splices were identified as A through L.

The laboratory evaluation included RF detection, AC breakdown, thermographic and visual examination. The results are given in table 1. The laboratory evaluation confirmed the field data. In addition a correlation was observed between degradation levels and ac breakdown.

Table 1 25-kV Splices

Splice Identification	PD Level Laboratory	Splice/Cable Temperature (%)	Ac Breakdown Voltage (kV)
B	Level 2	107%	120
E	Level 2	115%	130
A	Level 3	110%	105
G	Level 3	135%	110
J	Level 3	140%	95
D	Level 4	125%	90
F	Level 4	122%	85
K	Level 4	155%	80
C	Level 5	140'/°	50
H	Level 5	160%	55
I	Level 5	115%	70
L	Level 5	130%	70

15 kV rated Butyl Rubber Cable

Partial Discharge measurements were performed in the field on 15 kV rated butyl rubber insulated, armored/PVC jacketed cable installed at a production facility. Visual observation of the cable revealed various degrees of jacket cracking from light to severe cracking (In some places there was no outer jacket at all). Subsequently, the 250 meter section of cable, which showed discharges of high level distributed uniformly throughout the length of the cable, was removed from service. This section was then cut into ten-meter long samples and brought to DTECH for further examination. The samples were subjected to various electrical and chemical tests in the laboratory. The samples exhibited a breakdown strength in the range of 8.0 to 16.00 volt/mm. Chemical testing also indicated a uniform thermal degradation both radially and longitudinally. This indicates that the cable had degraded along its entire length, independent of the condition of the jacket.

15 kV rated Submarine Cables

Condition assessment was performed on two circuits of submarine cables (rated at 24 kV and operated at 13.2 kV). Each circuit consisted of three single conductor, 4/0, EPR insulated, armor cables. The circuits were in service 12 years. A small portion of the circuits was installed on land, while the majority was in 150-meter deep water. A system overload condition lead to thermal degradation of the cables. Both circuits suffered several failures within one week. As a result, the circuits were tested by the DTECH system. Data from testing revealed that the land portion of the cables at both shores had degraded completely.

The data also showed that the water portion of the cables was still usable due to the cooling effect of the water. The land portions of the cables were replaced, and the circuit returned to service. This action saved the remainder of the tourist season for the island. The cables were completely replaced the following year prior to the tourist season.

CONCLUSION

Cable/Wise online condition assessment has a proven track record of being a cost effective, timely, and versatile diagnostic tool that assesses the condition of each component of an energized electrical system, including all sections of cable, cable accessories, transformers, motors, and switchgear. It can increase electrical system reliability, and avoid unplanned outages and power plant electrical problems.

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ELECTRICAL SAFETY FOR NON-ELECTRICIANS

Industrial plant managers, supervisors, building owners and health and safety coordinators are all responsible for the welfare of their workers.

For several years now, the Electricity Forum has offered countless electrical safety and arc flash awareness courses for electricians and electrical engineers. Now there is a course tailored specifically for the non-electrical worker.

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- Wearing of protective clothing;
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- Metrification of all measurements.

For more information on these upcoming courses, you can go to this link:

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