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ELECTRICITY Transmission & Distribution TODAY

THE ELECTRICITY FORUM

May 2008
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Making your Transformer Environmentally Friendly

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ELECTRICITY TODAY

Volume 20, No. 4 May 2008

in this issue

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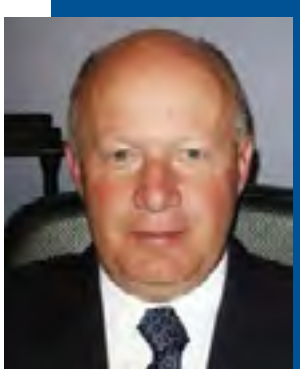

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Mr. Campbell holds the position of Vice-President, Corporate Relations & Market Development. In that capacity he is responsible for the evolution of the IESO-administered markets; regulatory affairs; external relations and communications; and stakeholder engagement. He has extensive background within the electricity industry, having acted as legal counsel in planning, facility approval and rate proceedings throughout his 26-year career in private practice. He joined the IESO in June 2000 and is a member of the Executive Committee of the Northeast Power Coordinating Council. He has contributed as a member of several Boards, and was Vice-Chair of the Interim Waste Authority Ltd. He is a graduate of the University of Waterloo and Osgoode Hall Law School.

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David O'Brien is the President and Chief Executive Officer of Toronto Hydro Corporation. In 2005, Mr. O'Brien was the recipient of the Ontario Energy Association (OEA) Leader of the Year Award, establishing him as one of the most influential leaders in the Ontario electricity industry. Mr. O'Brien is the Chair of the OEA, a Board Member of the EDA and a Board Member of OMERS.

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SCOTT ROUSE, Managing Partner, Energy @ Work

Scott Rouse is a strong advocate for proactive energy solutions. He has achieved North American recognition for developing an energy efficiency program that won Canadian and US EPA Climate Protection Awards through practical and proven solutions. As a published author, Scott has been called to be a keynote speaker across the continent for numerous organizations including the ACEEE, IEEE, EPRI, and Combustion Canada. Scott is a founding chair of Canada's Energy Manager network and is a professional engineer, holds an M.B.A. and is also a Certified Energy Manager.

DAVID W. MONCUR, P.ENG., David Moncur Engineering

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

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DOUBLE WHAMMY

By Don Horne

Just when the coal lobby thought it couldn't get any worse, it did.

New coal generation plant construction took a double hit when the U.S. Department of Agriculture's Rural Utilities Service (RUS) announced it was suspending its low-cost loan program for financing new coal-fired generation facilities.

This comes on top of exploding construction costs that have been fueled by a global building boom, pricing the normally inexpensive plants out of the reach of most rural electric utilities.

One rural utility in Missouri has canceled its proposed power plant in the wake of the RUS announcement. Another coalition of utilities, the Southern Montana Electric Generation & Transmission Cooperative (SME) is scrambling to raise money from private lenders for its generating station.

The numbers against coal generation are piling up.

Since 2006, more than 30 coal-fired facility projects have been canceled due to political and economic pressures. The climate of regulatory uncertainty and rapidly rising construction costs has made utilities shy away from new coal generation.

Despite all of this, more than 25 coal plants are in various stages of construction across the United States. But that number pales before the some 30 coal-fired plants that have been built each year in China since 2005.

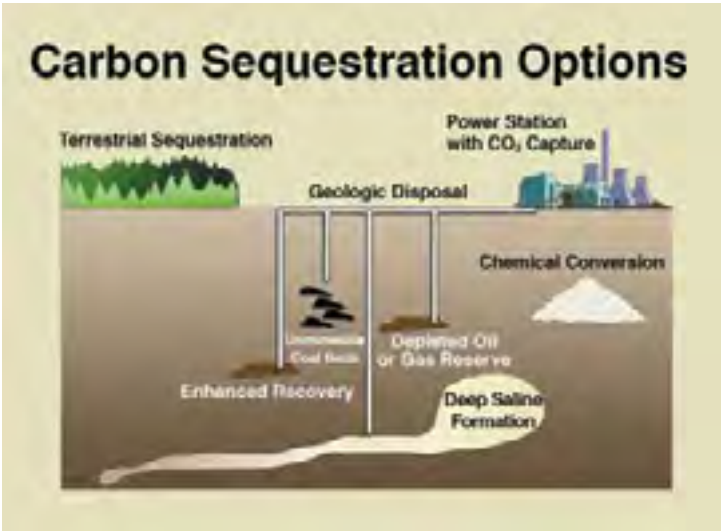
It is that massive increase in construction around the world that has pushed construction costs through the roof, creating a dearth of materials, labor and planners for projects back home.

The increase in costs is considerable:

- the 250-megawatt Highwood plant was $450 million; now it is $790 million;

- a 1,000-megawatt AMP Ohio facility was $1.2 billion; now it's $3.3 billion.

And the numbers do not even take into account the expected taxes on the greenhouse gas emissions the coal plants will produce.



For government budget planners, it makes no sense to subsidize the very plants that they will be taxing.

But if the government took a different view of how the money is spent, it could make a lot of sense to reinstate the loan program.

Although clean coal has been dismissed as window dressing by the environmental lobby, a clean coal plant does produce considerably fewer emissions than an older plant.

And a plant that sequesters its emissions introduces no pollutants into the atmosphere at all. And it is technology like this that should be rewarded with federal loans and subsidies.

To create an analogy with the auto industry, there is a progression from combustion engines to all-electric, zero emission vehicles. Currently there are no serious plans on the books to penalize internal combustion engines overnight in favor of electric vehicles.

No. Instead hybrid vehicles are being slowly introduced, allowing for an infrastructure to be put in place to accommodate electric vehicles 10 to 20 years from now.

New fuels, like ethanol, have been developed to help vehicles burn cleaner – but that has been recognized as a short-term solution to a long-term problem. And that fact hasn't dampened the millions and billions being poured into ethanol development and subsidization (Not to mention the massive harmful environmental side effects of harvesting crops to be converted into ethanol.).

Why not show the same largesse to clean coal as is doled out to ethanol? Rewarding wind and solar technologies with tax breaks and incentives is necessary and should be encouraged, as any nascent projects need a helping hand to get started until the economies of scale can be created to help them become viable.

But penalizing coal is shortsighted.

Yes, coal plant emissions are harmful to the environment. But shouldn't we be rewarding the development of cleaner coal now, at least until future wind and solar energy storage technologies are able to carry a substantial load on the grid?

The alternative is what many rural utilities are now facing – a power crisis.

The utilities are trying to replace aging generation and meet rising demand with new construction. If they cannot do this, the only option is to purchase more expensive power on the open market.

Certainly improved demand-management systems and more efficient distribution networks will forestall the need for new generation, but that is only a stop-gap measure.

And rural utilities need cost-effective solutions now.

don@electricityforum.com

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MAKING YOUR TRANSFORMER ENVIRONMENTALLY FRIENDLY

By Scott Weyker, Senior Product Specialist, Three-Phase Pad-Mounted Transformers

The Envirotran EF transformer program launched in May 2004 with single-phase transformers, stimulating the use of Envirotemp FR3 fluid in transformers becoming the first step in creating a strong movement toward biodegradable fluid.

Envirotemp FR3 fluid has gained visibility and acceptance from utilities, legislation, soybean boards, consultants and the public. A number of rural electric cooperatives have converted to Envirotemp FR3 fluid and have held media events promoting their environmental and safety consciousness.

GROWING ON SUCCESS

The success of single-phase Envirotran EF transformers has prompted the recent introduction of the three-phase pad-mounted Envirotran EF transformer.

This addition allows Cooper Power Systems to offer a full line of Envirotran EF distribution transformers. Envirotran EF transformers offer an environmentally responsible, high-efficiency, and safer choice for our customers. All units are optimized around the properties of Envirotemp FR3 fluid and NEMA TP1 minimum efficiency levels.

ENVIRONMENTALLY RESPONSIBLE

Envirotemp FR3 fluid is derived from 100% edible vegetable oils. Specially formulated with performance-enhancing food-grade additives, this non-toxic insulating fluid is the first truly green fluid. The fluid biodegrades quickly and completely in the environment. As a soybean-based fluid, it is eligible for current and future regulatory relief plus alternative spill response procedures may be possible. Schools, parks and ecologically sensitive locations are just some of the applications that are benefiting from the positive environmental characteristics of Envirotran transformers.

The Envirotran transformer has won several awards for environmental stewardship and product innovation.

IMPROVED FIRE SAFETY

Envirotran EF transformers are safer for people and the buildings they serve.

Envirotemp FR3 fluid's high fire point (360°C) and flash point (330°C) are more than twice that of mineral oil, virtually eliminating the risk of transformer fires and reducing liability concerns. Over 1,000 mineral-oil-filled transformers per year are destroyed by fire, with insurance claims estimated at over $50 million per year. Cooper Power Systems high-firepoint, fluid-filled transformers have had a flawless safety record for over 30 years.

This includes over 35,000 Envirotemp FR3 fluid-filled transformers currently in service. Based on electrical fire code regulations and nationally recognized testing laboratory certifications, Envirotran EF transformers can be installed indoors and outdoors, adjacent to buildings and walkways, or on rooftops, typically without additional safety requirements.

LONGER LIFE

The Envirotran EF transformer coil design has been optimized to maximize Envirotemp FR3 fluid benefits and to minimize the first cost of this new technology. The fluid has superior water absorption characteristics, helping to draw out retained moisture and the moisture generated by insulation paper degradation. It chemically helps prevent the paper fibers from severing when exposed to heat. This attribute enables the fluid to significantly reduce the aging rate of transformer paper and, consequently, helps extend transformer insulation life. Under standard loading, the Envirotran EF transformer insulating paper exhibits over seven times the normal life of mineral-oil paper. Due to Envirotemp FR3 fluid's unique properties, units can be overloaded up to 14% without causing loss of transformer insulation life (subject to temperature limitations of the IEEE Standard C57.91 loading guide). This means that Envirotran EF transformers are more durable than comparable mineral oil-filled transformers. "The soy-based oil provides benefits beyond improved protection for the environment," Stoughton Utilities Director Robert Kardasz said.

"The new oil will help extend the life of our transformers by improving their ability to safely handle high power demands experienced on hot summer days."

The Standard in Efficiency Utilities constantly face the challenge to reduce costs. In a competitive, de-regulated environment, there is constant pressure to cut capital, operating, and maintenance costs — often by purchasing distribution transformers with reduced efficiency. At the same time, most companies recognize that reducing immediate costs comes at a trade-off with efficiency, and reduced efficiency costs more long term.

In 1996, the National Electrical Manufacturers Association (NEMA) published an industry standard, NEMA TP 1, Guide for Developing Energy Efficiency for Distribution Transformers. The basis used to establish NEMA TP 1 standards was economic payback. Using typical electricity prices, transformer load factors, common transformer design technologies, and costs, the standards were set at levels that would typically result in a three- to five-year payback.

The standard, which was revised in 2002, lists the minimum efficiency levels

Continued on page 10

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Transformer fluid

Continued from Page 8

for single-phase and three-phase liquid-filled transformers. Efficiencies are referenced at 50% load and losses are referenced to temperatures of 55°C (Load Loss) and 20°C (No-Load Loss).

By meeting NEMA TP1 efficiency levels, Envirotran EF transformers approximate contemporary prices for a more highly evaluated ($3.00/$1.00 formula) mineral-oil unit. Cooper is also able to provide Envirotran EF transformers that meet higher efficiency levels.

FM APPROVED

INSTALLATION FLEXIBILITY

Three-Phase Pad-Mounted Envirotran EF transformers can be specified as Code-Listed FM Approved, which offers a practical and more dependable solution for installations near commercial or industrial complexes, office buildings, educational and health institutions and other fire safety sensitive areas. The high fire point of Envirotemp FR3 fluid enables it to meet the requirements for recognition as a fire safeguard by Section 15 of the National Electrical Safety Code and also meet the National Electrical Code Section 450-23 requirements for use as a listed less-flammable liquid. Typically, there is no need for a fire vault, automatic sprinklers, or special clearances.

The FM Approved transformer designs come with a special nameplate listing the transformer's protective devices and other compliance requirements, so the on-site inspector can easily and quickly verify code compliance for both indoor and outdoor installations.

EARLY ADOPTERS

Wisconsin Public Power Inc. (WPPI) is a regional power company serving 48 customer-owned electric utilities in Wisconsin, Michigan, and Iowa. By partnering with WPPI's Joint Purchasing Group, municipally owned utilities gain advantages of size, scope, and expertise in purchasing distribution transformers and other distribution goods. Since the Envirotran EF transformer was introduced to the members of WPPI, many have adopted it for all their transformer needs. Others find it vital for particular applications.

Evansville Water & Light is one WPPI member utility that has fully adopted the product. Evansville is the fastest growing community in Rock County, located south of Madison, Wisconsin.

"The Evansville community is committed to helping the environment by using the new biodegradable oil in as many applications as possible," stated John Rasmussen, Evansville Water & Light Line Foreman. Evansville was the first WPPI member to purchase the three-phase pad-mounted Envirotran EF transformers.

The WPPI member community of River Falls, Wisconsin, recently passed a resolution implementing "Lead by Example," a community-wide initiative to promote energy efficiency, conservation, and renewable energy resource development efforts. According to River Falls Municipal Utilities Superintendent Chuck Beranek, "The community will purchase only EF transformers from this point forward."

Bruce Folbrecht, superintendent of Jefferson Utilities and chairman of the advisory group overseeing WPPI's Joint Purchasing program, stated, "WPPI members are committed to working towards a full catalog of EF transformers.

The transition and implementation of the three-phase pad-mounted Envirotran EF transformer program is exciting, and is welcomed."

As of this printing, six WPPI members have purchased the new three-phase EF transformers: Cuba City, Evansville, Oconomowoc, River Falls, Stoughton, and Waupun.

PRODUCT SCOPE AND AVAILABILITY

Any three-phase pad-mounted transformer in Cooper's product scope can be specified as an Envirotran EF transformer.

This includes KVA ratings from 45 to 10,000 kVA with primary voltages up to 46 kV and secondary voltages up to 15 kV. In order to fulfill immediate demand for this product, Cooper has also been stocking common ratings, which can be delivered in as little as two weeks.

Envirotran EF three-phase transformer.

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THE ROLE OF DISTRIBUTED TEMPERATURE SENSING IN SMART GRID IMPLEMENTATION

By Kent Kalar, CEO of SensorTran

Smart Grid is a major transformation of the existing electrical infrastructure. As electric utilities across North America, Europe, and the rest of the world implement Smart Grid, cost effective monitoring tools will be required to optimize circuit and feeder loads.

Initial Smart Grid efforts have primarily been focused on system nodes related to the management of power generation and storage elements. However, with the shift from distant to localized renewable power generation and the need for the Grid to accept power injections from many types of energy resources, the reliability, efficiency, and usable capacity of the power cables between the nodes must also be properly managed.

The retooling of the electricity infrastructure in Europe and North America is expected to occur within the next 30 years. Such a large changeover comes with a unique set of challenges, such as standardization of technologies and protocols, synchronization of cross-border regulations, and major decisions regarding interfaces between old and new systems.

Continuous, cost-effective monitoring of these interfaces within the new Grid structure is essential to the successful implementation of Smart Grid.

The Smart Grid initiative is a major undertaking that the European Commission Directorate-General for Research has compared to the leap the Internet has made into the Web 2.0 age. In a similar manner that Web 2.0 features user-generated content, Smart Grid incorporates user-generated power. As power begins to move throughout the Grid in multidirectional flows, it becomes more important to actively monitor all the power cables – not just the EHV transmission lines at the core of the traditional Grid system.

DTS AND THE SMART GRID

Distributed Temperature Sensing (DTS) technology is the leading technology available for power cable monitoring, as it enables rapid and dynamic collection of continuous, precise, and accurate temperature measurements across distances ranging from 1 to 40 km with 0.5m sampling resolution and temperature resolution below 0.1°C.

By continuously monitoring the cables themselves, DTS makes it easy to identify temperature events (hot spots, cable damage, over-current conditions, etc.) – reducing the risk of failure associated with operating above a cable's specified maximum temperature. Because the temperature is measured directly – rather than estimated based on load and environmental conditions – the usable capacity in monitored lines is maximized. Utilities today use conservative mathematical models to estimate the cable temperature for given load conditions, building in a "factor of safety" to ensure the cable does not overheat. While these models are effective at protecting the cables from failure, they are ineffective at maximizing the usable capacity of circuits.

Distributed Temperature Sensing (DTS) technology is the leading technology available for power cable monitoring, as it enables rapid and dynamic collection of continuous, precise, and accurate temperature measurements across distances ranging from 1 to 40 km with 0.5m sampling resolution and temperature resolution below 0.1°C.

Through DTS-based, real-time dynamic monitoring, the cable's temperature is empirically – rather than theoretically – obtained, allowing cable to operate close to its maximum capacity. Maximum capacity results in load shifting flexibility that is a key component in the realization of Smart Grid functionality.

HOW DTS WORKS

DTS is a temperature sensing solution that employs a standard telecommunications-grade fiber optic cable, functioning as a probe, providing temperature measurements at every half meter along that probe. DTS systems use the light source from a laser to record temperature traces, deriving the temperature information from backscattered signals.

The earliest installations of DTS for power cable monitoring were focused on identifying problem areas and hot spots. For Smart Grid, however, DTS serves a critical role in load management. As costs for DTS systems continue to decrease, utilities can now obtain and use real-time, dynamic temperature measurements across all circuits. With the injection of renewable energy and consumer-generated surplus power into the system, it is critical to control variable bi-directional flows of current in order to ensure efficient, failure-free Smart Grid operation. Using DTS, utilities can closely manage load balancing using actual rather than calculated temperature data.

Continued on page 14

DTS INSTALLATION

Recent technological advances in DTS technology have greatly reduced the time, energy, and expertise required to successfully deploy fiber optic-based monitoring systems. The latest DTS systems offer Active Plug & Play, enabling self-calibration, continuous verification of calibration, and auto-correcting calibration. These capabilities have greatly simplified DTS management, enabling field crews to set up and operate systems without needing to involve highly-skilled technicians. DTS operators can define zones and set alarms through a standard control panel. After configuration, systems alert the operator immediately when pre-specified temperature thresholds are approached and/or crossed (and communicate the various alarm conditions to the operator's SCADA system).

New DTS systems also provide the ability to view temperature and alarm information mapped to the actual asset being monitored – enabling both quick and intuitive data interpretation. For example, the SensorTran AssetViewer image below illustrates a system-wide view of a substation, including satellite imagery as well as a schematic representation of the actual substation facility.

To date, the vast majority of fiber deployments for power cables have been during new construction projects. In this situation, the fiber is placed inside the cable itself or externally bound/banded to the cable. If properly planned for by both the utility and installer, this type of deployment is straightforward and easily accomplished.

For situations where existing infrastructure is to be monitored, the fiber optic probe must be retrofit onto the cable or into the cable duct bank. DTS field tests have proven that fiber probes can be successfully retrofit into existing facilities without damaging the power cables, even in situations with sharp angles of up to 90 degrees. This ability to effectively retrofit fiber probes is one of the key elements that makes DTS a unique, cost-effective, and important contributor to realizing the full potential of Smart Grid.

FUTURE DTS ENHANCEMENTS

In addition to providing real-time distributed temperature data, many DTS software packages will soon include an Ampacity estimator. Using dense DTS temperature measurements made over time as inputs, SensorTran is developing a proprietary algorithm that will predict future cable conditions based on various load scenarios.

Because DTS software has access to actual measurements, the resulting estimate of heat transfer rates will be available in real-time and immediately actionable. This capability will be available without requiring any additional hardware, further enhancing the value of DTS deployments. The ability to use one cost-effective system to continuously assess a circuit's immediate condition and the implication of future loads makes DTS a critical technology in fulfilling the Smart Grid vision.

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- **ARC RESISTANT** (U.S), ANSI C37.20.7 – 2001, (KEMA Certified)
- **ARC RESISTANT** (Europe), IEC62271-200, 2003, (ASTA Certified)
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- **ROBUST**, Vibration Resistant, (TUV Certified)
- **ALL WEATHER**, NEMA 3/12 & IP65, (UL, CSA & SIRA Certified)
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A LOOK AT THE LATEST IN POLYMER TRANSMISSION INSULATORS

Known as the Quadri*Sil insulator for its unique four-point sealing system, the product addresses the problems of moisture ingress, corona cutting and brittle fracture.

Since polymer insulators were first introduced in 1976, the industry has grown increasingly reliant on these lightweight, durable products. Despite three decades of design improvements, brittle fracture failure of the fiberglass rod remains a small but pressing issue.

Brittle fracture is believed to be caused by water penetrating the seals and electro-chemically reacting with the fiberglass in the core rod. Although any breach of the weathershed housing may result in brittle fracture, the area most vulnerable is the triple point, where the polymer housing, fiberglass rod and metallic end-fitting come together. The juncture of these three materials increases the likelihood of failure.

Manufacturers have wrestled with the issue for years, creating newer and better models of polymer transmission insulators by improving the sealing systems and other design features.

ADDRESSING BRITTLE FRACTURE HEAD ON

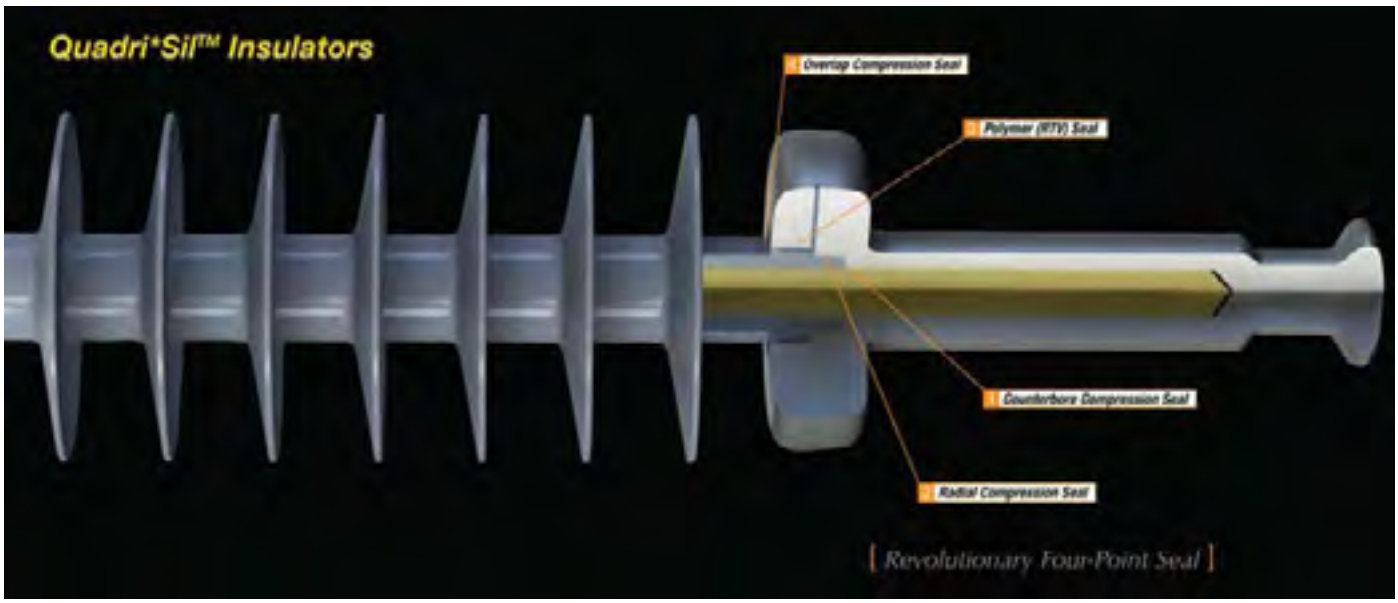
In 2005, Hubbell Power Systems and its Ohio Brass brand forged a team of seasoned engineers and scientists to design a new and improved polymer transmission insulator. Known as Quadri*Sil, it incorporates the company's century-long experience with transmission insulators. That includes more than 30 years of experience with the Hi*Lite insulator, the first commercially successful polymer insulator, which was introduced by Ohio Brass.

"Our goal was to create a polymer insulator that offered all the benefits of polymer, yet significantly reduced the risk of brittle fracture," says Jeff Thomas, business unit director for Hubbell Power Systems in Aiken, S.C.

Hot off the Press Operator Lonnie Richardson pulls a Quadri*Sil Insulator off the molding press.

A PROPRIETARY POLYMER THAT RESISTS ELECTRICAL TRACKING

While most manufacturers rely on off-the-shelf polymer compounds, Hubbell used its knowledge and experience to develop a proprietary compound



that offers superior resistance to electrical tracking. The compound was developed in the company's test lab in Wadsworth, Ohio, where Hubbell performs its research and development.

"We built on our long history with ethylene propylene diene monomer (EPDM) compounds to develop a silicone-rubber compound with the physical and chemical properties needed for high-voltage insulators," says Allen Bernstorf, Hubbell's principal engineer for insulators.

A SEAMLESS POLYMER HOUSING PROTECTS THE ROD

Quadri*Sil is not only made of an advanced polymer, that polymer is bonded to the fiberglass rod. "A chemical bonding agent is applied to the fiberglass rod, and then the polymer material is injected into a mold around the rod, so the polymer chemically bonds to the rod and creates a seamless housing. The resulting bond between the polymer and the fiberglass rod is stronger than the tear strength of the polymer. This greatly reduces the chances of moisture contaminating the fiberglass rod," says Thomas.

A UNIQUE FOUR-POINT SEALING SYSTEM KEEPS WATER OUT

Realizing that the best way to prevent brittle fracture is to stop moisture ingress, the team designed an innovative four-point sealing system. "The system is based on four individual seals that work together to stop moisture at the vulnerable triple point, where the housing, rod and end-fitting come together," says Thomas.

The molded shape of the end of the weathershed housing is designed to fit into a counterbore within the end-fitting with these four sealing points:

- Seal 1: The counterbore incorporates a butt seal at its blind end. This is a compression seal.
- Seal 2. A tapered cork seal. This is a circumferential compression seal.
- Seal 3. An internal room temperature vulcanate (RTV) back-fill. This is a chemical seal.
- Seal 4. A lip seal at the open end into which a raised lip on the housing fits. This is a compression seal that keeps the RTV inside the counterbore and protects it from moisture.

"Quadri*Sil insulators do not utilize RTV as an external seal between the rubber and end-fitting because long-time exposure to UV and other atmospheric conditions may negatively impact the effectiveness of RTV as an external seal," says Bernstorf.

The sealing system has passed ANSI's water penetration test (C29.13, clause 7.1), power arc tests (ANSI C29.13, clauses 7.5) and tests on interfaces and connection of end-fittings

(ANSI C29.11, clause 7.1).

SUPERIOR ELECTRIC FIELD SHIELDING AND GREATER MECHANICAL STRENGTH

Electric field gradients greater than 1,800 V/mm can generate corona in the air surrounding the insulator. As a source of intense and continuous ultraviolet energy, corona can expose the insulator's housing to energies capable of disassociating the bonds in the molecular backbone of the polymer material, accelerating aging and increasing the possibility of brittle fracture. Therefore, the design team incorporated a Corona Shielding Ring (CSR) into the new insulator to address corona cutting and water droplet corona on the unshielded insulator.

The team used electric field calculation software to determine the most effective CSR design. The software evaluated a variety of different diameter CSRs. Then modeling indicated that a 2.5" (63.5 mm) CSR would achieve an appropriate level of protection.

This CSR is positioned at the integral portion of the end-fitting closest to the polymer housing. This shield serves to smooth the electric field, thereby minimizing the gradients, or rate of change, of that field and reducing the probability of corona forming on the polymer.

Finally, the team used a circumferential crimp method to attach end-fittings. This more evenly distributes stress to maximize the available mechanical strength, creating a robust product built to withstand loading in the field.

MADE IN NORTH AMERICA

In bringing this product to market, Hubbell Power Systems made a substantial investment in North American manufacturing, as the company makes Quadri*Sil insulators at its 357,000- square-foot, state-of-the-art manufacturing facility in Aiken, S.C. The facility is certified to ISO 9001 standards.

By addressing the problems users may experience with non-ceramic composite insulators – brittle fracture, moisture penetration and corona cutting – Hubbell Power Systems and its Ohio Brass brand have created a lightweight, easy-to-install product that also offers durability, reliability and long life in the field, where it counts.

Made in the U.S.A. Employees in Aiken, S.C., are proud that Hubbell Power Systems has chosen its site to manufacture Quadri*Sil Insulators. The 357,000-square-foot, state-of-the-art manufacturing facility is certified to ISO 9001 standards.

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INTEGRATING MONITORING AND DIAGNOSTIC EQUIPMENT ON AGING TRANSFORMERS - PART II

By Byron Flynn, Application Engineer, GE Energy

III. CASE STUDIES

Case Study #1

Overall System Requirements

1. To gain remote control & monitoring of two Substations
   - By reducing outage times
   - By reducing operating costs
   - By reducing trips to the field
   - By catching problems before failures occur
   - By maintaining a healthy system.
2. To improve monitoring and load management
   - By balancing single phase loads
   - By monitoring underground for potential overload conditions
   - By managing the transformer loading and
   - By monitoring and controlling the voltage levels
3. To accommodate future SCADA System growth and to be expandable throughout the entire electrical system
   - Including the remaining substations
   - Including other distribution breakers and capacitors

The overall system installed is shown in the architecture drawing in Figure #1. The two dispatch centers communicate with the SCADA system via DNP 3.0 over IP on the SCADA System. Data Concentrators/RTUs were installed in the substations, which communicated with several Intelligent Electrical Devices (IE's). Additionally, communications equipment was installed to support the initial system. The new communications equipment utilized available channel space on the company digital microwave system.

New Dispatch Centers

The SCADA software was configured nearly identically at the two masters. The only other difference with the two dispatch center systems is the master stations have different IP and DNP addresses. This allowed the two systems to be operated independently. System analog and status changes and control signals are communicated to both masters over the same communication line. This is possible because the system operates over Ethernet communications. This also provided the ability to dispatch for the entire system from either master, providing additional coverage during busy times or a secondary master station if a problem occurs. The similarity of the two

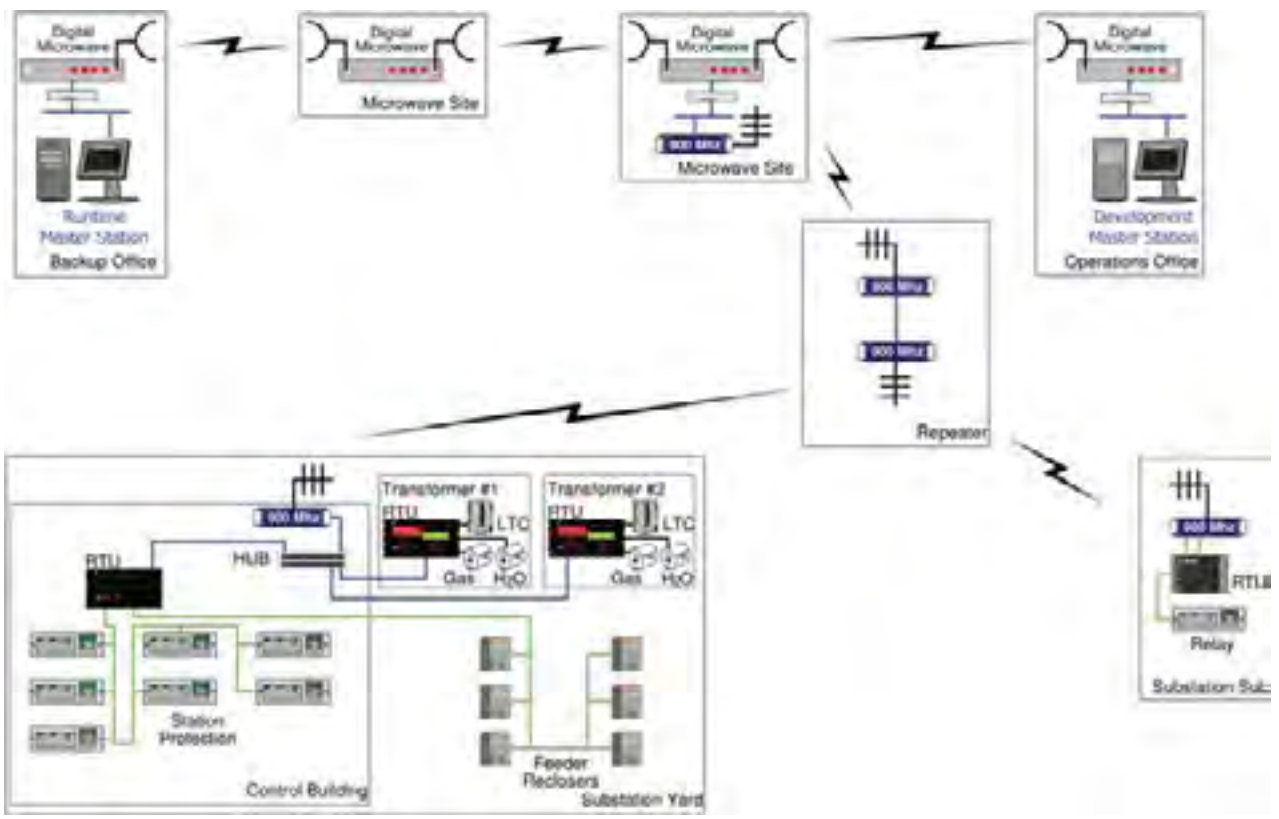

Figure #12: Case #1, System Architecture

Master Stations simplified software configuration of the masters and the RTUs.

The communications system will be discussed in further detail in a subsequent section.

Integrated Transformer Monitoring

Two monitoring systems were installed on the two 120 MVA transformers and integrate into the system using DNP 3.0 protocol over IP. The monitoring and diagnostic (M&D) systems contain smart RTUs, which form the foundation for the diagnostic system.

These RTUs integrate data from several sensors and the transformer monitoring IEDs and perform the diagnostic models. These IEDs consist of a LTC monitor, and sensors which monitor combustible gases and moisture of the oil in the main tank. The M&D RTUs then analyze the data using several of the diagnostic models. It is important to operations and maintenance personnel that the transformer monitoring system reduce the amount of raw data provided. All the intelligent models described in the previous section were implanted which provided information regarding the health of the transformers. These models focused on three main areas; the main tank, the cooling system, and the Load Tap Changer (LTC).

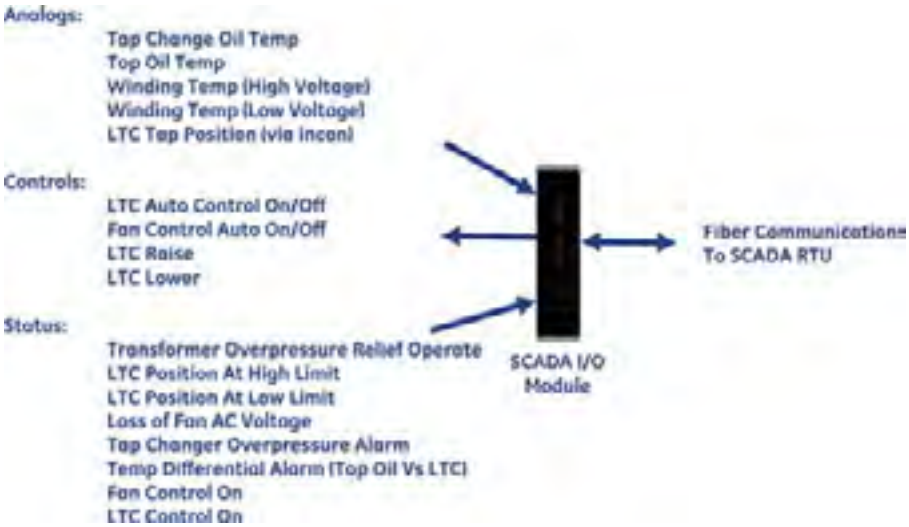

Figure #13: Case #2, System Architecture

Case Study #2

This system utilizes on-line monitoring with no on-line diagnostics. It provides an inexpensive method to capture data from the transformer and assist in

off-line diagnosis of transformer problems.

Distributed I/O

This system is based on distributed SCADA I/O modules communicating back to an RTU in the control building. The I/O modules have on-board digital status, analog and control allowing the transformer monitoring system to be integrated into the SCADA system.

Analogs – the following values are used to detect problems with the LTC or the main tank. Indication of the LTC position is also provided, which can be used to determine operation of the LTC and potential problems such as LTC hunting or subsequent tracking of the number of operations of each tap between maintenance intervals. These values include:

Tap Change Oil Temperature – to detect problems with the LTC

Top Oil Temperature – can detect problems with the tank or cooling system

Winding Temp (High Voltage)
Winding Temp (Low Voltage)
LTC Tap Position

Controls – provides on/off control of the LTC and Fan automatic systems. In addition, remote control of the LTC is also provided. The points included are:

LTC Auto Control On/Off
Fan Control Auto On/Off
LTC Raise
LTC Lower

Status – The status points monitored include indication of the control points and on other transformer alarm points. The Top Oil vs. LTC temperature alarm is a primary alarm indication of LTC problems whenever the LTC tank temperature exceeds the top oil tank temperature. The status points include:

Transformer Overpressure Relief Operate
LTC Position at High Limit
LTC Position at Low Limit
Loss of Fan AC Voltage
Tap Changer Overpressure Alarm
Temp Differential Alarm (Top Oil Vs LTC)
Fan Control On
LTC Control On

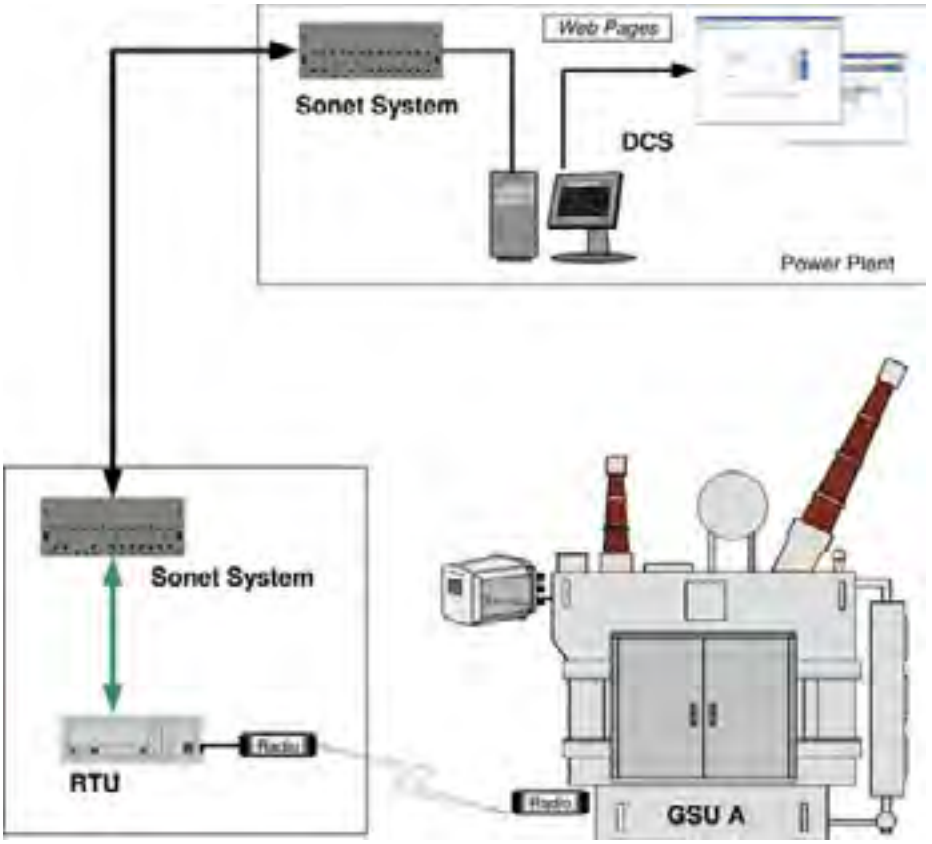

Figure #14: Case #3, System Architecture

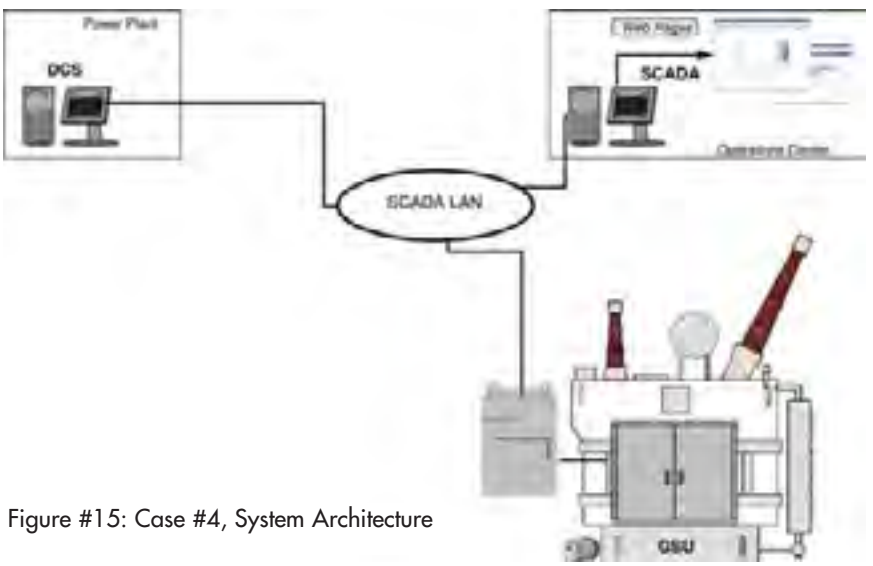

Figure #15: Case #4, System Architecture

Case Study #3

This system is installed on a power plant Generator Step Up (GSU) transformer. From manual oil samples collected from the transformer, it was found that this GSU was gassing above normal operational parameters. The transformer was taken off line in mid-October of

2006 for maintenance. On-Line monitoring is critical for this transformer, as failure could result in a loss of revenue exceeding $100K per day.

The customer flushed and filtered the oil and inspected the transformer for any potential problems. A continuous on-line gas PPM monitoring was installed to provide the Power Plant operations indication of combustible gases in the oil

System Description

This system uses an on-line gas monitor integrated into station RTU which feeds data to the DCS system using Modbus over IP. The on-line gas monitor reports the following data:

- PPM value of composite combustible gas measurement
- Short term and long term rate of change of PPM value of composite combustible gas measurement
- Relative saturation (humidity) of moisture dissolved in oil (%RH)
- Hourly average of %RH and PPM of water in oil
- Computes the PPM water content in oil
- Computes the water in oil condensation temperature

Monitoring these parameters at the plant will help reduce the potential of an unexpected outage due to failure of the transformer.

Figure #16: Case #5, Transformer Photos

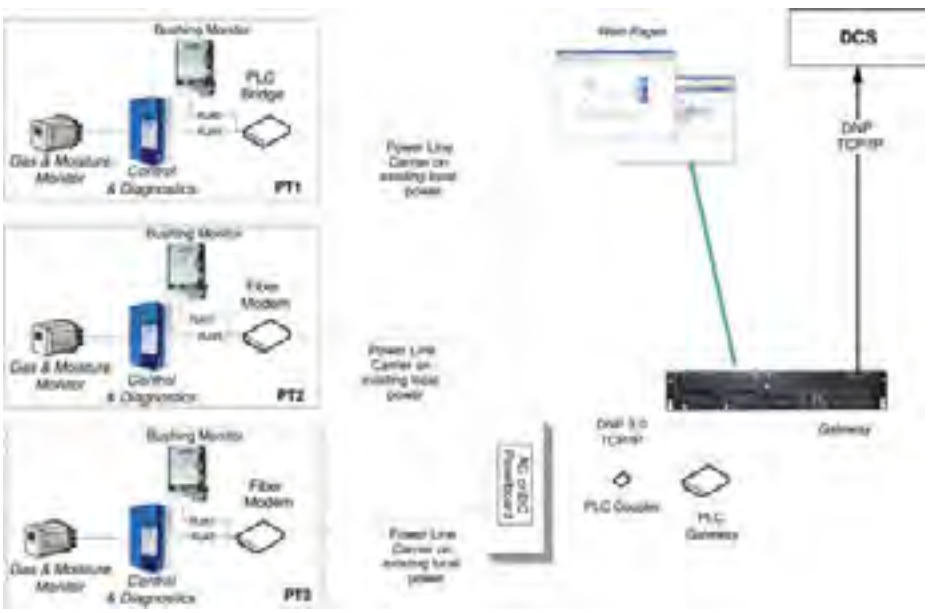

Figure #17: Case #6, System Architecture

Case Study #4

This system is installed at another utility on a series of power plant Generator Step Up (GSU) transformers. This utility had similar concerns about the potential revenue lost from unexpected GSU failure. Much of their fleet of GSU transformers is over 30 years old. This utility was also looking for a method of reducing maintenance costs and loading on limited maintenance resources by moving to a condition-based maintenance system. On-Line diagnostics was installed to provide real-time information to the plant control operators on their DCS systems and to their SCADA system.

System Description

This system uses an on-line diagnostic system integrated into station DCS using Modbus over IP. All the diagnostic models described in Section II were installed and integrated into the DCS critical data was also provided to the SCADA system via web pages from the DCS system. The on-line diagnostics system was installed because the models reduced the amount of raw data being handled by the operators and the value of calculated output data which then generates an alarm when the model detects a problem. Over 150 gas monitors and 40 diagnostic systems have been installed to date. The utility plans to install an additional 40 units over the next three years.

Case Study #5

This case study describes a system installed on two large 400MVA station transformers.

The utility decided to install a diagnostic system because of the critical nature of these transformers and the costs of an unexpected failure. The diagnostics systems for these transformers, shown in these photos, were installed late in 2002.

System Description

This system includes the diagnostics capabilities similar to the previous example but also integrated bushing monitoring. The following listing contains the values being monitored in this case study.

Functions:

- Monitor all critical parameters
- Top Oil Temp
- Ambient Temp
- Bottom Oil Temp

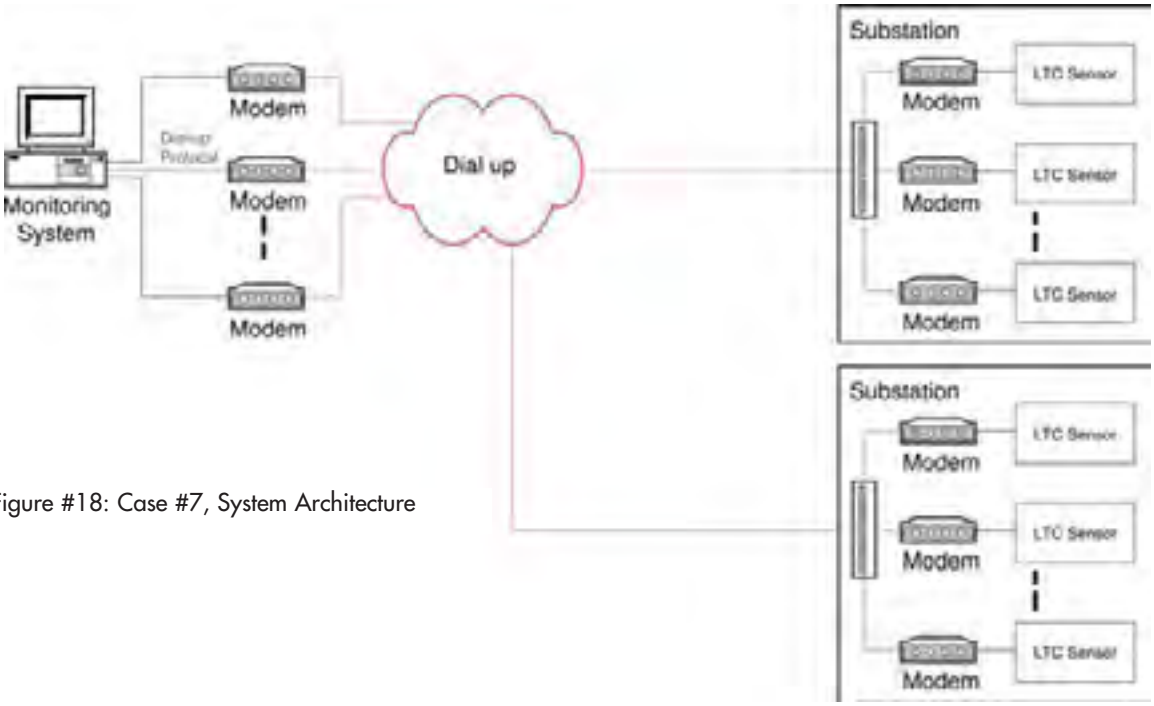

Figure #18: Case #7, System Architecture

- Dissolved gas in oil
- Moisture in oil
- Load current
- Voltage
- OLTC position
- OLTC remote control
- HV & LV Bushings

The Bushing monitor sensors are installed on the high- and low-voltage bushing on each phase. This allows the system to monitor the leakage current on each bushing and detect potential problems.

This system communicates directly with the SCADA system via DNP 3.0.

Case Study #6

This system highlights a few additional communications and functional capabilities.

First this system provides the diagnostic and monitoring of previous systems, including bushing monitoring.

The communication system between the transformers and the control building consists of a DNP IP communications over the local power line carrier system. It utilizes a secure PLC (Power Line Carrier) system that allows low-voltage wiring into an intelligent highspeed broadband networking platform. This system is useful when there is no economical method of adding communications between the transformer and the control building. This system also includes a smart gateway which has a DNP connection to a DCS and Https web-based server access by authorized users.

Figure #19: Case #7, LTC Sensor Installation

Case Study #7

The following system consists of a LTC monitoring system which communicates via dial-up modems. This system provides monitoring on the transformer and the LTC's condition including monitoring the LTC tap operations, tap operation counts, LTC tap wear factors, the temperature difference between the transformer tank and the LTC compartment, the operational characteristics while operating through the various tap positions (LTC Controls), and monitoring the drive motor current and motor index. The utility using this system now performs condition-based maintenance on their LTCs.

They also have credited this system with averting over 30 failures.

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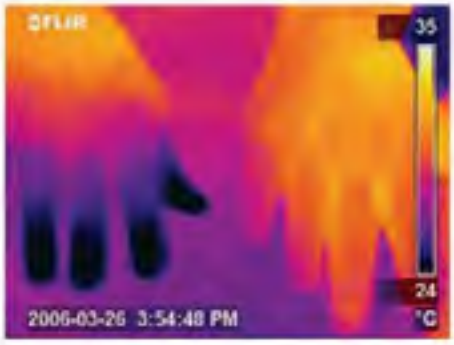

	Date	Course	City
May	05	Level I	Monton
NEW!	05	Level I	Vancouver
	12	Level I French	Montreal
NEW!	12	Level I	Greater Toronto Area
NEW!	15	Reporter Template Design	Greater Toronto Area
	21	InfraQuebec	Mt. Tremblant, QC
NEW!	26	Level I	Edmonton
	29	Reporter Template Design	Edmonton
June	03	InfraCanada - East	Niagra Falls, ON
	16	Level I	St. John's
	19	Reporter Template Design	St. John's
July	07	Level I	Saskatoon
	10	Reporter Template Design	Saskatoon
	14	Level I	Ottawa
	17	Reporter Template Design	Ottawa
	28	Level I	Calgary
	31	Reporter Template Design	Calgary
August	05	Level I	Greater Toronto Area
	08	Reporter Template Design	Greater Toronto Area
	11	Fugitive Emissions	Greater Toronto Area
	14	Building Investigations	Greater Toronto Area
September	03	Level III	Greater Toronto Area
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PROTECTION, CONTROL AND AUTOMATION FOR A MULTISTATION LOOPED DISTRIBUTION SYSTEM - PART II

By David Charles, ESCO Engineering and Testing; Ryan McDaniel and Michael Dood, Schweitzer Engineering Laboratories, Inc.

VI. IMPLEMENTATION

Breaker 16 is responding in kind, and both receive the GOOSE permissive to trip and isolate the fault. The entire process takes about 11 cycles with a 1-cycle delay on the definite overcurrent element, less than 5 cycles for GOOSE messaging, and 5 cycles for the breakers to open. Breaker 8 is undergoing the same crisis as breaker 4, but both backup 51S1T elements drop out before timing out.

That all worked well enough, but what if one breaker is already open? GOOSE messaging also lets breaker 15 know if breakers 16 and 17 are open or closed, and an open state is used as a permissive to trip breaker 15 for a reverse fault condition. Since the loops are relatively small, an added layer of protection is provided by backup definite time-overcurrent settings enabled for a reverse fault condition that persists beyond 30 cycles. These elements are coordinated with the backup time-overcurrent settings in the loop supply breakers to allow a remote breaker to operate before a bus breaker.

The control schematic for breaker control at the remote substations can be seen in Fig. 9.

The trip logic and relay bit assignment within the GOOSE message can be seen in Fig. 10.

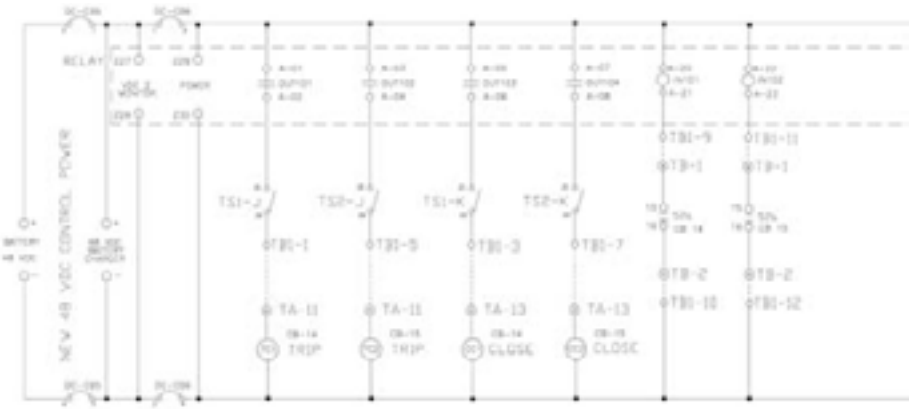

Fig. 9. DC Breaker Control Schematic

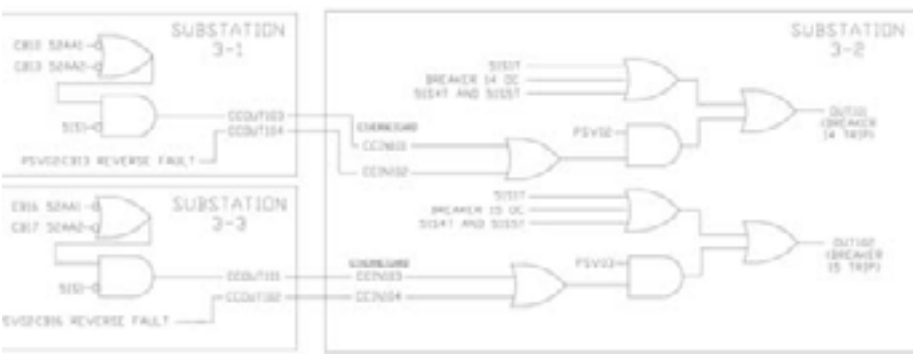

Fig. 10. Breaker Trip Logic

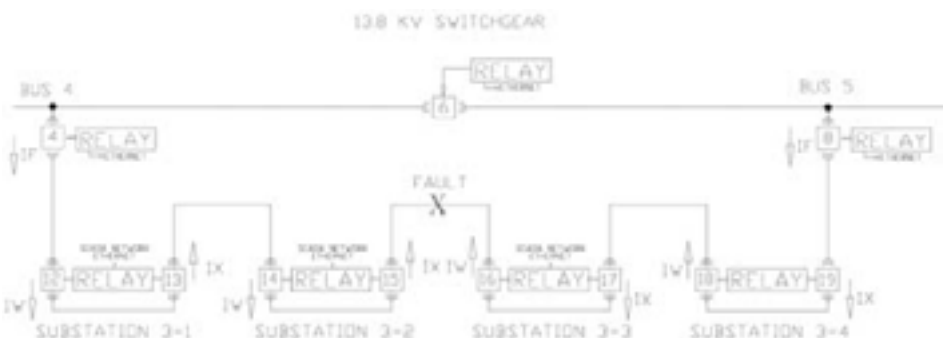

Fig. 8. System Fault

Note that the CCOUT word bits are set with logic statements similar to relay outputs and the CCIN word bits are assigned by addressing. The word bits updated on a change of state only.

Word bits used in Fig. 10:

- 51S1T: Transformer time-overcurrent protection
- OC: Serial port open command issued
- 51S4T and 51S5T: Line protection time-overcurrent backups

The final installation will have an outdoor enclosure with the relay mounted with test switches, shorting blocks for

Continued on page 28

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Continued from page 26

existing instrument current transformer circuits, and fuses for existing potential transformer circuits. Control power will be provided by a sealed battery and charger and utilize the relay alarm function for low DC voltage. An interposing relay will be provided for trip and close circuits for the existing circuit breakers at the remote sites. Synchronism check will be provided by the relay by a contact wired in series with the close output. A local/remote switch function is provided by the programmable operator buttons. Up to 12 programmable pushbuttons are available as well as a trip/close control switch that is independent of the relay power and logic as shown in Fig. 11.

Fig. 11. Local Breaker Control Panel

VII. SUBSTATION U SWITCHGEAR

The substation 13.8 kV switchgear installation is different from the remote sites since only one circuit breaker is controlled by the relay using a standard one-breaker configuration. However, the main and tie-breaker relays are also used to implement an automatic transfer scheme.

The main breakers have time-overcurrent settings coordinating with the time-overcurrent settings of the loop breakers and an instantaneous setting to detect bus fault conditions. The bus fault condition is used to supervise the autosource transfer of the bus-tie breaker so that the tie is never allowed to close into a bus fault. When the generator breakers are closed, additional settings are enabled in the main relays for under/overvoltage, under/overcurrent, and reverse power.

The automatic transfer scheme is implemented using the logic available in the relay as well as using relay-to-relay communications. The local control of the scheme is accomplished through the programmable pushbuttons on the relay as shown in Fig. 12.

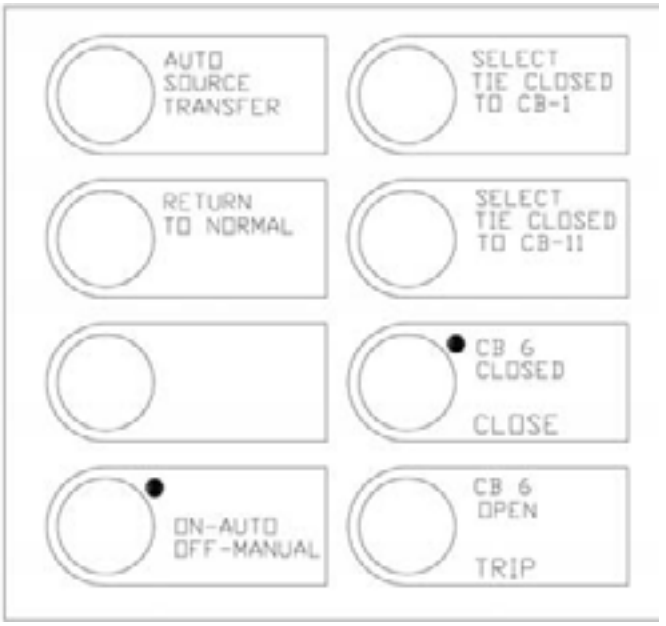

Fig. 12. Automatic Transfer Pushbuttons

The following items describe how the pushbuttons are used in the automatic transfer scheme:

• Auto/Manual Mode

When the scheme is in Auto mode, closed transition bus-tie operations are enabled and breaker close pushbuttons are disabled. When the scheme is in Manual mode, all automatic and remote operations are blocked, however, manual closing of breakers via pushbuttons are allowed.

• Automatic Operations

The following operations can only be performed when the scheme is in Automatic mode:

- Automatic Source Transfer

An automatic source transfer occurs when one utility source becomes unhealthy for a configurable amount of time while the other utility source is still healthy. Once the source is determined unhealthy, the associated main opens to isolate the facility from the failed source. Once the relay determines the associated bus is dead, the tie will close. All load at the complex will be fed via one utility source in the transferred state.

- Return to Normal

For a retransfer to the normal state, the failed source must become healthy for a configurable amount of time. Once the source is healthy, operator action (press the Return to Normal pushbutton) is used to close the main and then open the tie. The relay determines that the source is healthy and in sync before the main is closed.

- Utility 1 Source Transfer

This pushbutton allows the user to transfer the entire load at the facility over to Utility Source 1 on CB-1. The tie breaker will close to parallel both sources if they are in sync and then CB-11 opens to remove the Utility 2 source. This operation is blocked if a generator breaker is closed. The scheme can be reconfigured to the normal state by pressing the Return to Normal pushbutton.

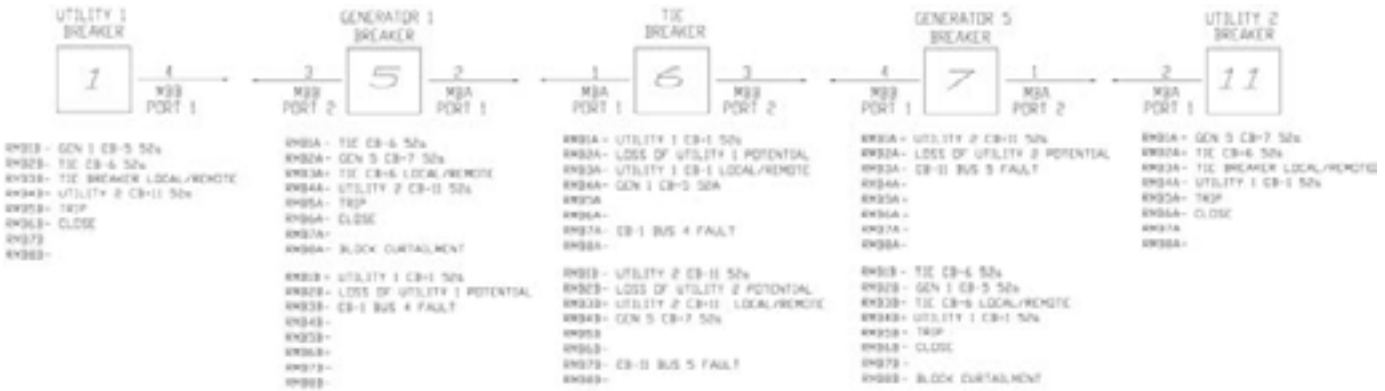

Fig. 13. Automatic Source Transfer Logic

- Utility 2 Source Transfer

This pushbutton allows the user to transfer the entire load at the facility over to Utility Source 2 on CB-11. The tie breaker will close to parallel both sources if they are in sync and then CB-1 opens to remove the Utility 1 source. This operation is blocked if a generator breaker is closed. The scheme can be reconfigured to the normal state by pressing the Return to Normal pushbutton.

Due to installation constraints, MIRRORED BITS communications protocol was used for the autotransfer scheme. Fig. 13 shows the MIRRORED BITS communications scheme that was used to exchange status and control between the 13.8 kV switchgear to implement the autosource transfer.

As can be seen from the diagram, all the information needed to perform or block transfers is transmitted so each relay can determine when operation is necessary.

The proposed installation is to have new door panels manufactured with cutouts for the relay, test switch, and generator controller for the generator breaker cubicles. The new door panels will be wired off-site. Installation on-site will require removing the existing doors and wiring back to terminal strips, installing the new door panels on existing hinges, and wiring current, potential, and control circuits.

Each loop breaker can be done on one bus while remote sites are powered from the other bus. The bus-tie can be closed, and a source interconnection breaker can be retrofitted. The tie breaker will be done last. All relay settings and control programming have been developed and tested in advance of the installation.

VIII. GENERATOR CONTROLS

The same relay used in the loop scheme and main breaker protection also provides the generator protection and control logic for selecting modes of operation. Because the relay does not have the ability to supply an analog output for driving a governor signal, ESCO initially had thought of using a programmable automation controller with analog outputs. This concept was abandoned in favor of using a generator controller that provided preprogrammed functionality. The generator protection relay provides the operator interface and hardwire interconnects to drive the Woodward GCP, as shown in Fig. 14.

The digital controllers start the engine, parallel the generator to the 13.8 kV bus, and drive the governor for load control. The digital controller loads the engine up to the generator rating as determined by operator input for parallel operations. The digital controller provides generator protective functions, alarming, and monitors currents and potentials. The relay selects the operating mode and operates the utility breakers accordingly. The relay also provides generator protection including a differential circuit (not shown) that wraps the gen-

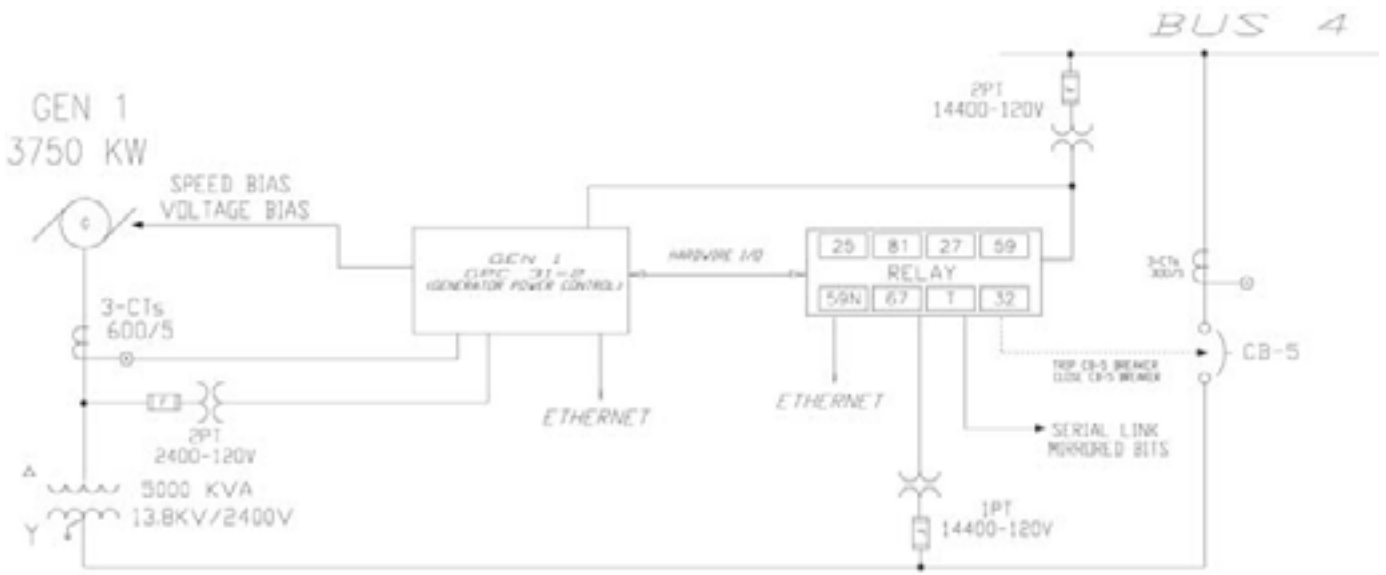

Fig. 14. Hardware Interconnections for Generator Controls

erator, step-up transformer, and circuit breaker.

Operating modes for the system are as follows:

• Standby: Normal operating mode where a loss of source potential or condition other than a bus fault causes the main breakers to open — both have to open to instigate a standby condition. The loop breakers open to isolate loads from the bus and the tie breaker closes to form a generator bus so all generation capacity is available for load pickup. The first generator breaker closes to the bus and the second is paralleled to the first. The loop breakers are then closed sequentially. If the load on each main was greater than the generator capacity right before the outage occurred, one loop is not given the permission to reclose after the generators restore bus voltage. The loop that is left last to close is selectable, and the last loop closure also has underfrequency settings enabled for an outage operation that will trip if the generator frequency is pulled down for longer than two seconds.

The maximum previous load is stored in the main breaker relays using math variables, and an inequality statement in the logic is used to determine if the last loop should be closed. When the source returns, the generators parallel to one utility source and that breaker is closed, then the other utility breaker is closed. The tie breaker is opened and the generators are soft unloaded and the generator breakers open.

• Isolate: Operator-selected mode will start both generators in parallel with the utility sources. The tie breaker is closed and the load is transferred to the generators. When the power flow across the utility is zero, the utility circuit breakers open. When the operation is cancelled, the combined bus is synchronized to one utility source in the same manner as a return from Standby.

• Base Load: Operator-selected mode will start both generators in parallel with the utility sources. Both generators will be loaded to the operator-set value up to the rating of the generator. When the operation is cancelled, both generators will unload and open the generator breakers.

• Curtailment: Operator-selected mode will start both generators in parallel with the utility sources. Both generators will be loaded to reduce the imported power to the set demand level. When the operation is cancelled, both generators will unload and open the generator breakers.

Again, the generator relay has sufficient programming capabilities to implement these operations. The programmable operator pushbuttons are used as the manual interface, with the same control interface available from the HMI.

IX. COMMUNICATIONS SYSTEM

Even though there is only one multifunctional relay that is being used for all these schemes, there are four different communication protocols being utilized within it to accomplish all the necessary functions. These protocols and their functions are:

• DNP3 LAN/WAN is being used to provide data to the SCADA system

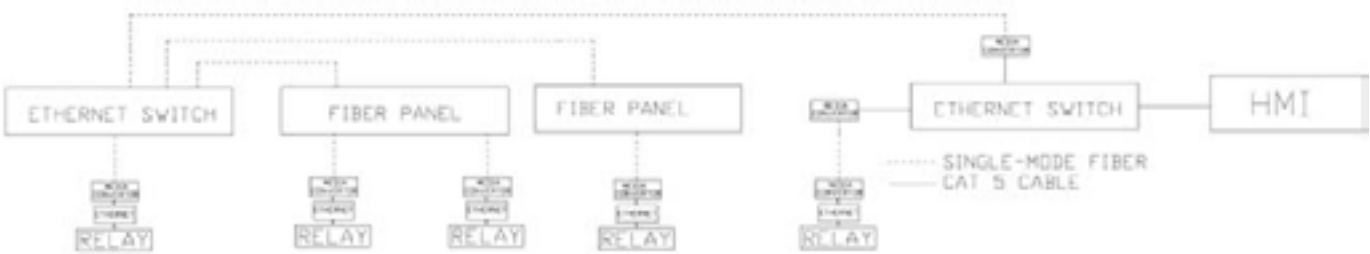

Fig. 15. Ethernet Communication Network

• GOOSE is being used for high-speed communications between relays for the pilot protection scheme

• Telnet is being used for providing terminal access to any of the multifunctional relays

• MIRRORED BITS® communications is being used for the automatic transfer scheme DNP3 LAN/WAN is a SCADA protocol, which was developed for use in telecontrol applications. The protocol has become popular for both local substation data collection and telecontrol. DNP3 is one of the protocols included in the IEEE Recommended Practice for Data Communication between Remote Terminal Units and Intelligent Electronic Devices in a Substation [4].

Rather than wiring individual input and output points from a station Remote Terminal Unit (RTU) to the station Intelligent Electronic Devices (IEDs), DNP3 is used to convey this same measurement (binary and analog) and control data directly to the SCADA master via data communications. This reduced the equipment and wiring requirements. In turn, this reduced installation, commissioning, and maintenance costs while increasing remote control and monitoring flexibility.

The multifunctional relay chosen for this project supports both serial and LAN/WAN implementations of DNP3.

LAN/WAN was selected because using the Internet protocol suite as a transport mechanism for DNP3 provides seamless integration of the SCADA LAN to the customer's WAN. It permitted use of existing backbone equipment with minimal need to install additional equipment or wiring. Plus it is highly scalable for future growth of the network. One of the big advantages of using Ethernet is the ability to support multiple protocols over the same communication media. Thus, DNP3 LAN/WAN, GOOSE, FTP, and Telnet are all supported using the same communication equipment and wiring. The growth of the Internet has stimulated the large availability of networking equipment and technology, which has proved that the IP protocol suite is capable of transporting tremendous quantities and types of data.

The GOOSE capability of exchanging binary data very quickly between multiple devices in a multicast method made it very attractive for doing the POTT communications in this project.

Telnet is part of the TCP/IP protocol suite. Telnet can establish terminal access to a remote device. A Telnet connection provides access to the user interface of either the host or the Ethernet card. Host user interface access is similar to an ASCII terminal connection to the front port of an IED.

Since the relay configuration software supports Telnet connections, this was a big advantage to the customer. This software not only supports settings, it also has a built in HMI that is very useful in commissioning and troubleshooting. It also has tools that allow the user to send commands, display event histories, and retrieve event reports. Using the built-in event waveform view allows engineering to quickly analyze fault records and relay element response. With the facilities' communication network, all of this can be done from anywhere on the complex.

MIRRORED BITS communications protocol is used for the automatic transfer scheme. With this protocol, protective relays and other devices can directly exchange serial information quickly and securely without the need for any external equipment. This protocol accomplishes the reliable exchange of critical data using a simple and effective method to communicate the state of eight logical bits of information between IEDs. This protocol is also capable of transmitting up to seven analog values between IEDs. This protocol also supports comprehensive diagnostic messages. Thus, when there is a communication issue, that issue is reported to the remote operator almost instantaneously. There are also extensive communication logs available to easily troubleshoot the communication issue.

The multifunctional relay specified in this project has a built-in Ethernet processor that supports many protocols including DNP3, GOOSE, Telnet, and FTP. The Ethernet interface processes incoming GOOSE messages and delivers them to the relay quickly so that word bit state changes are processed in milliseconds. GOOSE messages are published when the contents change or to verify channel integrity to the other peers on the network. Ultimately, each device processes only the messages it is configured to use. Configuration parameters allow configuration of the system to manage GOOSE traffic and processing burden.

The customer's backbone fiber system is a single-mode fiber system consisting of several 24-fiber bundles. The electric department allocated one 24-fiber bundle. Six fibers are assigned to the SCADA network and those are extended to each remote site by installation of six strand, single-mode, direct bury fiber from existing splice points. The proposed arrangement is shown in Fig. 15. At the time this system was developed, the Ethernet interface only supported multimode fiber-optic compatibility, so a media converter was used to connect to the network.

The trial devices were supplied with a network port 10/100BASE-T option using a CAT 5 cable and an RJ-45 connector to the media converter. To simulate the actual SCADA network conditions, the media converter was connected to a single-mode fiber, which was connected to a fiber panel, then to another fiber which, in turn, was connected to an Ethernet

switch. From the Ethernet switch, fiber was used to connect to another Ethernet switch using a media converter. In lab tests over this network, 30 cycles were shown more than sufficient to exchange all the POTT-required GOOSE messaging with six relays in a multicast group.

X. HUMAN MACHINE INTERFACE (HMI)

The supervisory HMI package selected was from Wonderware. This is the software package that provides capability to develop customized screens to allow the remote personnel to monitor and control the power system. In addition, a DNP3 I/O Server from Imperious Technologies was used to gather the information from the various multifunctional relays using DNP3 LAN/WAN and converting the data to Suitelink. Suitelink, in turn, interfaces to Wonderware. A Dell tower computer was selected as the platform of choice, because the client uses the same machine in other HMI applications and feels the computer can be changed as the technology changes without sacrificing much of an investment. The greater cost is in the software license, screen development, and programming, all of which are transportable to some degree or can be upgraded over time. A 3000-tag license was selected to allow for further development beyond the initial installation, which consumed almost 1000 points. Because both master control stations were to be placed in control room environments and because none of the functions in the HMI were deemed critical, no "hardening" was felt to be necessary. The software application can be loaded on another machine in minutes, and with two control stations at different locations, both failing simultaneously is not expected. The HMI is not critical to the operation of the system, and all HMI functions can be performed locally at the relay location.

DNP3 has many features that help it obtain maximum possible message efficiency. These features optimize the use of bandwidth and maximize performance. DNP3 event data collection eliminates the need to use bandwidth to transmit values that have not changed. Event data are records of when observed measurements changed. For binary points, the remote device logs change from logical 1 to logical 0 and from logical 0 to logical 1. For analog data, the remote device logs a change only when that value exceeds a dead-band limit.

DNP3 remote devices collect event data in a buffer that the master can either request or the relay can send to the master without a request message. Data sent from the remote to the master without a polling request are called unsolicited data.

The multifunctional relay allows the development of custom DNP3 maps, so that the amount of polling is even further reduced by looking at a smaller subset of all the information available. The concern was to keep routine communications traffic at a minimum for coordination messages. The general consensus during development was DNP3 is much faster than Modbus.

The intent of the HMI is to show, at a glance, the current state of all the breakers and if each line section has voltage.

The HMI also allows remote control of circuit breakers and provides metering information. Additional information, such as currents, voltage, kW load, alarms, and fault event data, is available through accessing additional screens. An overview screen of the whole system similar to Fig. 1 is the default HMI display. Clicking on an object drills down to the control elements and data displays. Operating breakers requires two distinct operator actions including entering an employee number assigned by the customer. Present alarms show up at the bottom of any page and are archived in an alarm summary.

The operator control screens mimic the front panel of the relays. Trending is a popular application of Wonderware, so additional screens track voltage profile and power usage. The generator controls have a separate screen. Event and waveform analysis software is used to access individual relays one at a time.

The HMI provides an operator interface for generator mode control and loading control, as well as generator information and operating alarms. Generators may be started and stopped from the HMI, and the mode of operation selected remotely.

The standby function may be enabled or blocked remotely.

Further development may take advantage of the Ethernet capability of the Woodward devices to set control parameters and obtain alarms.

The view-only licenses offer access from a server connected to the SCADA network that is provided an IP address. The view-only access is limited to five connections and can be password pro-

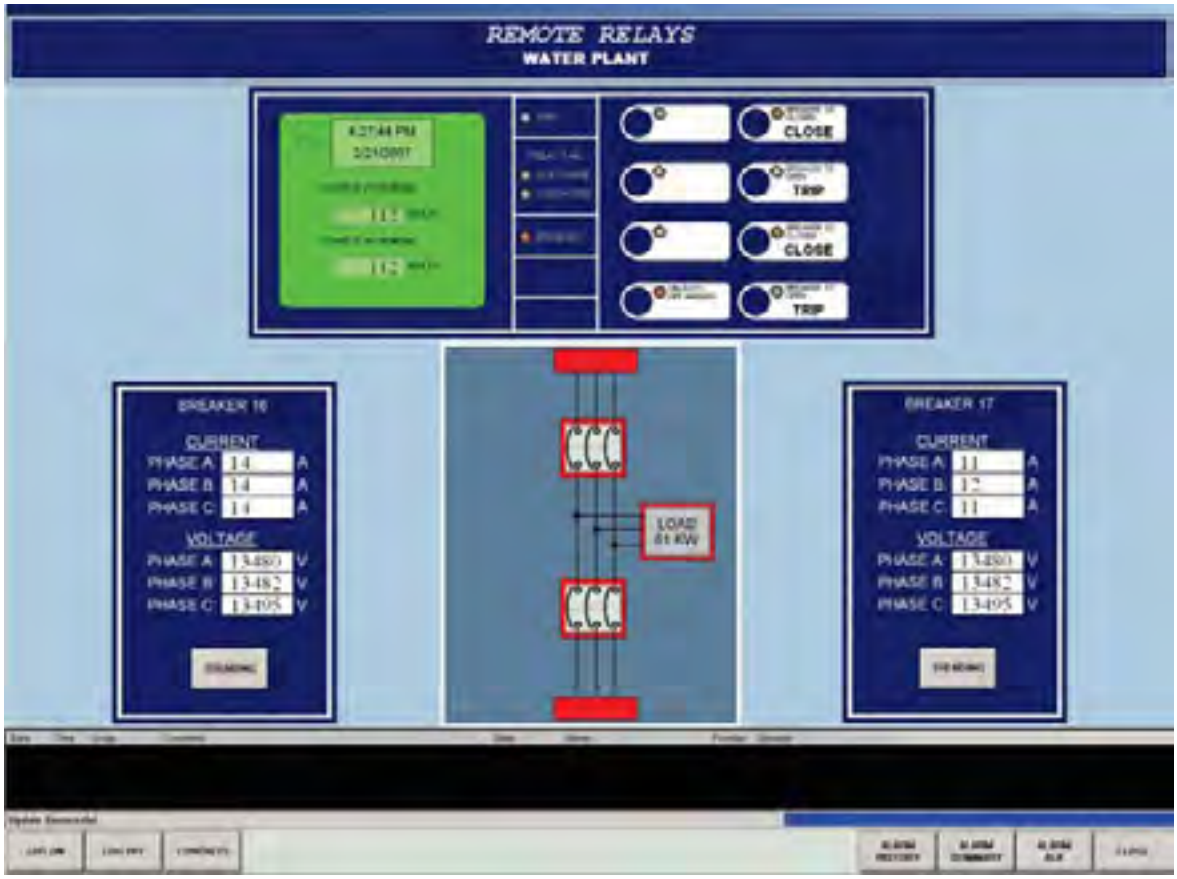

Fig. 16. Example SCADA HMI Screen

tected to prevent unauthorized use.

The view-only access does not allow circuit breaker control.

Other control actions allow resetting the meter functions and remote resetting of targets. The system is not manned, but intended for checking system status, responding to system events, fault analysis, and periodic metering functions. The computers running the HMI application are actually used for other applications.

Fig. 16 shows what the HMI screen for a remote substation looks like.

XI. CONCLUSIONS

The customer is very happy with the results of this project.

The use of a single, multifunctional, microprocessor-based relay resulted in a dramatic reduction in the number of discrete devices. Utilizing this relay, along with the communication scheme, greatly improved the protection of this system and allowed them to install a very powerful SCADA system for very little cost. They believe that the new design will greatly improve the overall reliability of their system because of the significant reduction in individual devices that were converged with one device. They expect a reduction in maintenance requirements as a result of these changes as well.

The system is also a lot more flexible because changes can be easily made in logic rather than adding components and wiring.

Due to the flexibility of the relay and analog logic available, one relay was able to protect two lines in a POTT scheme as well as protect a transformer at each distribution station. This type of protection would traditionally require three separate relays. For the 14 distribution installations in this network, using one relay instead of three led to purchasing 28 fewer relays and a significant cost savings.

The SCADA system provides much more measured information about the power system than the customer ever had previously. Not only does the customer now have the capability of remotely monitoring this/her power system, but he/she can now reconfigure and restore power remotely resulting in manpower savings and reducing outage time. The customer was not aware of the functionality, the amount of information available, and the simplicity of operations by having the remote operator interface match that of the local operator interface.

Another benefit that is being used is the ability to get engineering access data, for example, fault event reports, from anywhere on their communication network. They are using the information from the multifunctional relays to ensure that their protection and automation schemes and settings are correct.

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CYBER SECURITY FOR GREATER SERVICE RELIABILITY

By Peter Vickery, N-Dimension Solutions Inc.

Transmission & Distribution executives strive to continuously improve the service reliability they deliver to their customers.

While high service reliability has always required that T&D operators challenge themselves and invest wisely in new technological advancements, the task of operating a reliable Transmission & Distribution grid is becoming even more challenging. In today's environment, service reliability is threatened not only by equipment failure, harsh climactic conditions, natural disasters, a vastly increasing demand for electricity, but also by malicious computer hackers whose goal is to disrupt service by illegally accessing T&D resources.

Furthermore, as organizations that provide part of our critical infrastructure, T&D operators are also threatened by cyber terrorists, well-equipped and well funded adversaries, capable of forging ties with industry insiders who are well aware of the vulnerabilities inherent in service control systems.

The U.S. Department of Homeland Security confirms that cyber attacks represent an ever-evolving risk category which is particularly relevant for Power & Energy (P&E) organizations and that such attacks could result in massive outages. Additionally, following the August 14, 2003 North American blackout, the US-Canada Power System Outage Task Force confirmed the existence of cyber vulnerabilities in the electric system. The vulnerability of SCADA systems is also underlined by Cox News Service which reports that "a major comprehensive study... shows that major companies in the U.S. and four other nations have recorded about 135 SCADA security incidents over the past 4 1/2 years."

It is, therefore, essential that a T&D operator's service reliability strategy include a strong cyber security plan. Operators must ensure that cyber security risks are well identified and that appropriate measures are put in place to address those risks. Let us review the various elements to be considered by the T&D organization whose goal is to reduce risk and improve service reliability by using cyber security to protect the integrity of its operational systems.

THE ENVIRONMENT

Attacks against T&D operators' computerized resources have become increasingly sophisticated as new blended cyber security threats have emerged. Spyware, botnets, malware, vulnerabilities, intrusion attempts, and denial of service are today's reality against which organizations need to be protected. At the same time, the T&D operator's increasing reliance on system automation has introduced multiple new weak points in the service reliability environment: remote terminal units (RTUs), intelligent electronic devices (IEDs), distributed control systems (DCSs), programmable logic controllers (PLCs), intelligent field devices, intelligent meters, substations, SCADA systems, and back doors to these systems for remote access procedures.

> NERC specifies that a vulnerability assessment should be conducted and that this process and its results should be well documented.

Furthermore, while most service control systems were originally built as networks that were completely separate entities, today an increasing number of "interconnection" points exist between an operator's service control systems and external systems, including corporate systems as well as outside parties such as Geospatial Information Systems (GIS), internet, and other utilities. As these new systems and communication tools have brought great improvements in overall effectiveness and efficiency in the T&D environment, operators need to find ways to preserve these new advanced operating methods while at the same time ensuring that service reliability and the integrity of corporate resources are protected. This is why the establishment of an all-encompassing, robust cyber security strategy is crucial.

Operations management teams tend to focus on ensuring that operational systems are in place and that the processes are efficient. Cyber security concerns have not traditionally been a part of those teams' planning.

Furthermore, when attempts have been made at addressing cyber security, T&D operators have found it difficult to identify effective and easy-to-use tools that would detect cyber intrusions and that would deliver the necessary reporting routines. Ensuring the security of T&D cyber assets is further complicated by the numerous and disperse locations that form the service grid and by the presence of both legacy systems and new open protocol-based equipment. Finally, as with any other industry, the T&D sector must also ensure that protection against vulnerabilities introduced by its employees form a part of the cyber security strategy.

PRACTICAL CYBER SECURITY GUIDANCE

In order to ensure service reliability, the cyber security efforts of T&D organizations should be guided by the North American Electric Reliability Council's standards (NERC CIP), by cyber security best practices, as well as by the directives issued by the U.S. Department of Energy, the U.S. Department of Homeland Security, and the Canadian Energy Infrastructure Protection Division. NERC has set up a phased compliance program which is now in effect. At present, this program emphasizes the need for monitoring, audits, logs, and reports. It should be noted that the NERC standards represent minimum requirements and that pro-active T&D operators may

benefit from expanding their cyber security efforts beyond these compliance measures.

As covered by NERC standards, a large number of factors need to be considered when formulating a robust cyber security strategy.

NERC CIP 001 to 009 requirements are:

- CIP-001: Sabotage Reporting
- CIP-002: Critical Cyber Asset Identification
- CIP-003: Security Management Controls
- CIP-004: Personnel & Training
- CIP-005: Electronic Security Perimeters
- CIP-006: Physical Security
- CIP-007: Systems Security Management
- CIP-008: Incident Reporting & Response Planning
- CIP-009: Recovery Plans for Critical Cyber Assets

As the cyber security challenge is multi-dimensional, the NERC CIP standards state that T&D Operators must adopt a Defense-in-Depth approach to cyber security that includes: security measures at and within the electronic security perimeters, access control, internal intrusion detection and malware monitoring, and application security.

NERC specifies that a vulnerability assessment should be conducted and that this process and its results should be well documented. The T&D Operator must also formulate a detailed cyber security strategy.

Once again, NERC specifies that the strategy should be well documented and that the documentation should be kept up-to-date. The cyber security strategy must ensure that all cyber assets are protected, whether they are within the established electronic security perimeter or whether they form part of the network perimeter and control access points.

All access points must be monitored to detect intrusion attempts, and access logs must be reviewed periodically.

It is recommended that cyber security measures first address the requirements at the head end, and then at the remote stations.

For greater effectiveness and efficiency, Cyber security data should be presented to, and interoperable with the operator's SCADA system. Furthermore, while legacy systems were installed prior to the emergence of cyber security concerns, the operator's service reliability can be adequately protected only if legacy systems are included in the security strategy.

The emergence of new initiatives such as the deployment of the Advanced Metering Infrastructure also underlines the need for a robust cyber security strategy. When deploying smart metering/advanced metering infrastructure resources, the T&D organization is exposed to external as well as internal cyber security threats. It is therefore essential that cyber security considerations be an integral part of the planning for smart metering projects.

At the substation level, the T&D organization should ensure that its resources are well protected from cyber attacks while at the same time facilitating access to information for its field personnel.

At the substation level, the T&D organization should ensure that its resources are well protected from cyber attacks while at the same time facilitating access to information for its field personnel. It is therefore essential that cyber security monitoring be put in place. In addition, comprehensive audit logs and reports should be available to support compliance with industry-specific cyber security standards.

When T&D operators are challenged to deploy strong cyber security solutions while, at the same time, having to deal with limited budgets and the imperative of accommodating innovative business solutions and improved competitiveness, they should favour cyber security solutions that deliver: strong cyber security, flexibility, migration to new devices, integration with existing operational systems, compliance with relevant standards and regulation, reduced complexity, and cost-effectiveness.

As interconnection points between operational systems and corporate information systems increase, it is essential that a good working relationship exist between these two areas of responsibility. T&D operators should also ensure that any vendor they use truly understands the vast differences that exist between the cyber security needs of operational systems and those of corporate information systems. As an example, operational real-time controllers have crucial reliability and timing requirements that differ from those of corporate IS systems.

It is essential that senior management be involved in the establishment and on-going support of the organization's cyber security strategy as the responsibility assigned to management for the protection of corporate assets is clearly indicated by corporate governance guidelines and by compliance requirements with industry-specific standards.

Senior management's participation also ensures that all operational systems are considered, from the control centre to every substation and field device. Furthermore, senior management should commit to a periodic cyber security re-assessment program in order to keep up with constantly changing, ever more sophisticated cyber attacks that threaten the T&D operator's service reliability.

CONCLUSION

The reliability of the service that Transmission & Distribution operators can offer to their customers is threatened by computer hackers and cyber terrorists. It is therefore clear that a strong cyber security strategy is essential if Transmission & Distribution executives are to realize their goal of continuously improving service reliability. Today, T&D organizations can be guided by NERC standards and by best cyber security practices to deploy multi-featured, flexible operational systems while protecting the integrity of their corporate assets. To ensure the greatest positive impact of the cyber security strategy, senior management should fully support their organization's efforts to align their cyber security program with NERC CIP standards. Management should also ensure that the cyber security plan is put in place with a firm commitment to periodically re-assess its effectiveness, thereby managing cyber security as a process that leads to continuous improvements in service reliability.

N-Dimension Solutions Inc. designs, develops, and markets cyber security solutions that address the specific requirements of the Power & Energy industry.

THE UTILITY INDUSTRY AND MOUNTING PRESSURES - "WATT" TO DO?

The $400 billion energy utility market is undergoing significant changes resulting from rising energy prices, industry deregulation, pro-environmental trends, governmental mandates and ever-increasing energy demand. These changes are forcing Public Utility Commissions and other regulatory agencies to place an unprecedented amount of scrutiny on electric and gas utility operations and practices.

The need for such scrutiny is exacerbated by the fact that the electricity market is capacity constrained. In 2005, the world generated 17,350 billion kilowatt-hours of electricity – an amount that is predicted to rise to 30,116 billion kilowatt-hours by 2030. The United States alone will need 258 gigawatts of new capacity by 2030, which will cost $412 billion to build. Yet factors such as CO2 limitations will dramatically hamper and curtail traditional supply-side growth.

In states like California, highly publicized brownouts have resulted in legal mandates to accurately predict and control energy demand while minimizing the development of new, expensive and environmentally damaging power plants. Other states, such as Texas, have deregulated electricity generation, enabling greater competition for electricity services and providing businesses and consumers a choice of energy providers.

Meanwhile, utilities are experiencing increasing upward pressure on the demand-side as well from residential consumers, who represent the major growth in energy consumption on a per capita basis. A combination of rising energy prices, increased environmental awareness and the value of conservation are driving consumers to demand more information and control over their energy usage. Other dynamics such as shifting demographics and an exposure to service innovations in other industries are further heightening consumer expectations.

Both top-down and bottom-up pressures are forcing utility companies to continually look for methods to improve their day-to-day operations and customer service, which include activities such as performing monthly/cycle billing reads, providing flexible billing dates for consumers, capturing interval data for profiling data usage, implementing time-of-use billing, capturing peak demand, supporting critical peak pricing events, forecasting energy usage, and measuring, validating and controlling energy loads.

The overall result has been a flurry of activity among utilities, metering vendors and energy providers to define strategies and innovative approaches to better control and manage energy demand and improve service quality and value. Industry groups such as EPRI, IEC, ANSI, DRAM, SmartGrid, TAHI, DLMS, UtilityAMI and others are helping to create awareness and solve pressing market needs, and are focusing on the required infrastructure improvements needed by the utilities to help enhance areas where energy delivery assets are inadequate. They are also working to improve grid reliability, encourage more intelligent energy and resource consumption and help utilities conform to new local and national regulations.

One such landmark regulation came in the form of the US Energy Policy Act of 2005, which has spurred some of the market need and direction by outlining several energy management strategies including:

• Consumer access to energy use and price information

• In-Premise and In-Home energy and price responsive automation

• Communicating and Controllable Thermostats

Put another way, the Act mandated that utilities must investigate the possibility of providing improved demand response programs to end-user consumers.

DEMAND RESPONSE – POWER TO THE PEOPLE

Simply put, demand response programs put more power (literally and figuratively) into the hands of consumers by allowing them to better control their electric usage based on a variety of factors, including consumption patterns, price fluctuations, and incentives offered by utilities to reduce consumption during peak load periods and events. The US Department of Energy defines demand response in this way:

"Changes in electric usage by end-use customers from their normal consumption pattern in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

While demand response programs are by no means a new phenomenon, much of the onus has historically been placed at the doorstep of utilities rather than consumers due to relatively low consumer awareness, flat-rate pricing, and a paucity of enabling technologies. Traditional demand response programs simply did not provide consumers with enough choices or individual control.

But consumer awareness has heightened dramatically over the past several years, and new technologies are now emerging to empower utility consumers to voluntarily act to reduce costs, make smarter choices through greater information gather and achieve greater management and control – all while being good environmental citizens.

For their part, utilities are recognizing the tremendous business opportunities these emerging technologies represent, such as a greater ability to balance loads, reduce costs, operate more efficiently and achieve greater compliance with regulatory standards. In addition, new capabilities based on the latest technologies can be leveraged by utilities to attract cause-driven, loyal consumers – a formula that ultimately leads to increased profit margins.

In order for demand response programs to be truly effective (even attainable), two-way network communication

between utility companies and their consumers must be established. Utilities must be able to capture and leverage consumer information in meaningful ways, while consumers must be able to rely on intelligent energy management devices within the home to transmit critical information to and from utilities in order to achieve the increasing levels of control they desire.

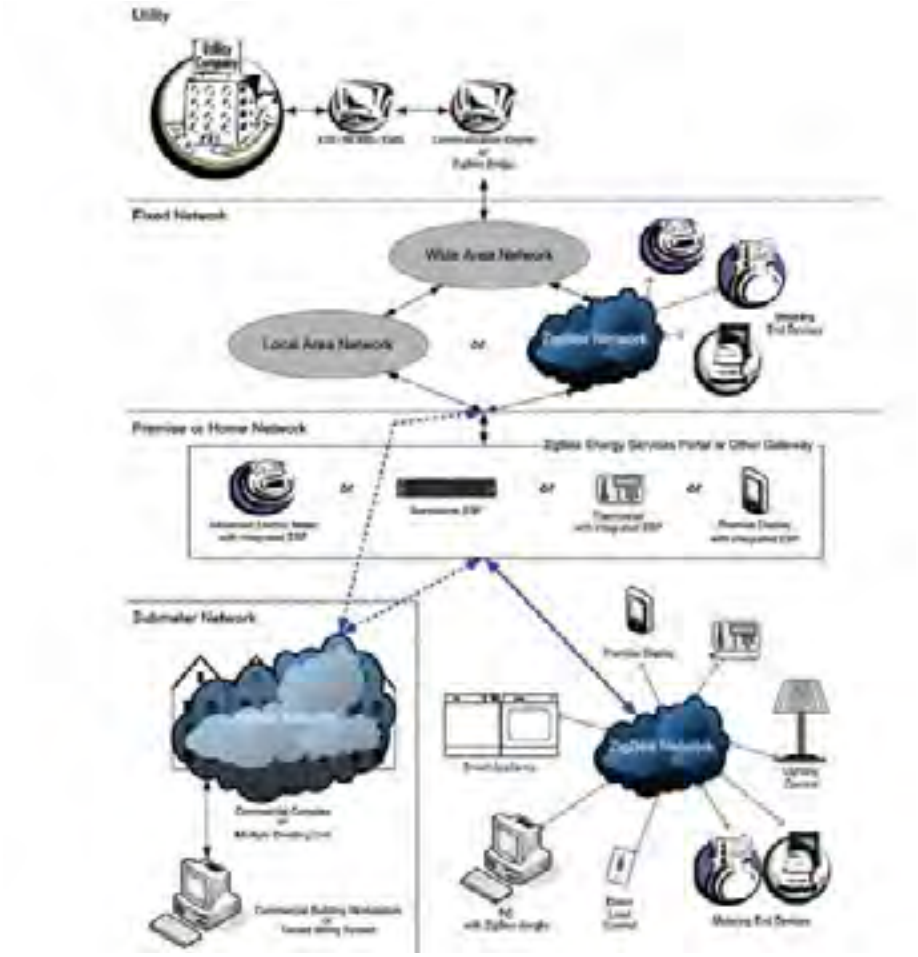
In other words, a technology ecosystem is needed that comprises the utilities, consumers and all critical intermediary players in order for next-generation demand response programs to be feasible and viable. These networks of cutting-edge technologies have come to be known as Advanced Metering Infrastructures.

ADVANCED METERING INFRASTRUCTURE – COMPLETING THE CIRCUIT

There is one main road leading to the more advanced iterations of demand response programs, and it's being paved by Advanced Metering Infrastructures, or AMI. AMI functions as a comprehensive network comprising both wide-area networks (linking neighborhoods to utilities) and neighborhood local area networks (linking energy meters to the WAN) – both of which carry information provided by Home-Area Networks connected to smart devices such as outlets, displays, thermostats and energy meters.

In contrast to the traditional automated meter reading (AMR) systems, AMI provides the information backbone that enables grid operators to measure power usage, remotely control usage, and diagnose and repair outages. AMI also enables energy delivery companies to provide advanced demand response solutions to encourage conservation and to shift the load to off-peak times. AMI typically consists of advanced digital meters, bi-directional automated meter reading networks and increasingly sophisticated software for aggregating and processing large amounts of near real-time information.

It might be tempting to assume that broad AMI adoption is a far-off aspiration, however, market data indicates otherwise. The AMI market currently consists of strong companies with combined annual revenues of more than $10 billion, and a dozen startups or private companies that have received nearly $1 billion in venture investment over the past few years. Of the 286 million meters in the U.S. alone, utility industry experts



anticipate that AMI contracts will be awarded for at least 30 million of them in the next 12 to 18 months.

The rapid AMI revolution is being fueled by the promise of providing a quantum leap forward in both supply-side and demand-side response capabilities, and includes powerful resources such as the:

- Ability to provide time-stamped interval data for each consumer at least hourly
- Option of conducting remote disconnect/connect for some or all meters
- Ability to remotely upgrade meter firmware
- Capability to remotely read meters on-demand
- Ability to diagnose outages and, in many instances, automatically reconnect stable portions of the grid.
- Inclusion of data warehousing systems
- Ability to extend AMI to multiple in-home appliances connected together as part of a Home Area Network (HAN).

In order to offer two-way, interactive demand response programs, utilities must be able to fully extend the AMI network deeply into the home. By deploying and utilizing "smart" appliances, HVAC and lighting control, residential utility consumers will be able to optimize their budgets through greater cost control and management while enjoying the widespread benefits of increased conservation and enhanced system reliability. This final link is all being made possible by the emergence of the Home-Area Network – a critical link in the much-heralded "smart grid".

CONSUMERS GET A HELPING HAN

Consisting of in-home information/control devices and smart meters, Home-Area Networks (HAN) facilitate near real-time communication between utilities and their consumers. Such devices are used to provide information to the consumer about electricity consumption and/or to control every type of electrical device, from thermostats and lighting systems to water heaters, pool pumps, ovens and refrigerators.

According to OnWorld, a leading research company that provides business intelligence on emerging wireless markets, there will be 122.8 cumulative (wired/wireless) two-way electric smart meters installed worldwide by 2012. Assuming there are 2.25 HAN devices installed per household on average, there will be a total possible global market of 276.3 million Home Area Network (HAN) devices at this time.

Several forces are hard at work creating support and momentum for this impressive rate of HAN adoption, including OpenAMI and OpenHAN. OpenHAN is a task force of the UtilityAMI working group, which operates under the auspices of the Utility Communications Architecture International Users Group (UCAIug)). OpenHAN is charged with addressing issues related to the utility/consumer interface for advanced metering – most notably for demand response programs that feature in-premise devices, real-time communication between the utility and consumers and dynamic pricing options.

Unlike traditional demand response initiatives, HANs deliver the right balance between utility control and consumer independence to deliver a win-win scenario that encourages widespread energy conservation and significant savings. EnerNex®, an electric power engineering and consulting firm specializing in the development and application of new electric power technologies, describes the benefits provided by HANs this way:

The biggest advantage to the HAN and HAN equipment is the ability for both utilities and consumers to coordinate the energy usage and demand limiting efforts. Utilities can focus on offering demand response programs that provide significant incentives for consumers to limit their demand during critical periods. This includes monitoring and control of heating, air conditioning, water heating, pool pumps, dryers and irrigation systems (of course, the latter has the double benefit of potentially optimizing water usage as well). Once the first has been offered, well-designed time-of-use rates can then provide the load shifting benefit for entertainment, cooking, clothes washing and dishwashing appliances.

HANs comprise a wide variety of devices, including meters, in-home displays, load control devices and gateways (connecting utilities' networks to metering and in-home displays), as well as everyday electrical devices such as lights, outlets, washers and dryers and hot-water heaters.

If AMI and HAN are gaining increasing momentum among utilities and are being seen as key enablers in providing next generation demand response programs for energy consumers, then low cost, robust wireless sensor networking based on open standards is making these market-changing demand response solutions possible.

WIRELESS SENSOR AND CONTROL NETWORKS

Wireless sensor networks (WSN) represent one of the most exciting technologies in the computing industry today because they build a bridge between the physical world and computing systems for the first time. There are extremely strong market drivers for WSN-based demand response, including new regulations, anticipated vendor strengths, industry standards, low threat from competing alternatives, low switching costs compared to other options (including the status quo) and potential for a strong return on investment.

Driven by these and other dynamics, utilities will spend $1.6 billion on WSN technologies for smart metering and demand response in 2011. Likewise, the WSN smart meter market is growing rapidly with 1.6 million wireless smart meters to be deployed (by 2007), up from tens of thousands a few years ago.

Regardless of the topology (P2P, P2M, star, mesh, hybrid), WSNs generally have the following three basic components:

1. Sensors/microcontrollers: monitor, detect, collect and send data about a wide range of parameters such as temperature, humidity, flow, pressure, etc.
2. Radios: collect and transmit the data between nodes and/or to a repeater or controller
3. Software: whether embedded in the node (module) and/or on a gateway or remote location, software ensures that the sensor data is collected and presented in a useful way for end-users.

The benefits of wireless sensor networks vary by application, but the following are the general benefits for the initial target applications emerging today:

1. Potential for applications that were not possible before, such as covering dangerous or unwired areas and monitoring/backing up equipment that could otherwise be done – such as a gas or water meter.
2. Reduced wiring installation costs (up to 80 percent less)
3. Reduced maintenance complexity and costs
4. Reduced overall costs by allowing users to collect information about their environment and giving them increased control over their equipment (e.g. heating and lighting are often wasted by industries/commercial buildings)

5. Cost – the industry is targeting a Bluetooth-scale price point within the next few years

Many factors converged in the beginning of the new millennium that created "the perfect storm" to energize the WSN revolution, including advances in nanotechnology (the rapid collapse in size and cost of semiconductors), the rapid proliferation of silicon-based, low-power radios and a growing need for national security. It was within this environment that the government issued a mandate to create an "invisible but reliable mesh" of data sensing points that could be deployed into an arena to monitor enemy activity.

This mandate led to academic and governmental research in the miniaturization of sensors, radios, microcontrollers and the local operating system software to control the radio. It also led to substantial research in the field of network protocols and routing mechanisms when dealing with such heavily-constrained devices – devices with only a few kilobytes of available memory, a cell-sized battery to operate the device for months or years and a tiny microcontroller.

Beginning in 2002, these research efforts led to other collaborations outside the U.S. government resulting in the spinout of several private startup companies, including the world's largest provider of ZigBee networking chips, Ember.

EMERGING STANDARDS AND THE ZIGBEE BUZZ

When the WSN market was in its early stages, the industry's main focus was on developing the underlying infrastructure. But for commercial users, it wasn't only a question of whether the hardware would work, but if it would work at a reasonable price point. As a result, the initial phase was followed by the next important step for the commercial enterprise – creating technology standards that would bring out multiple sources of technology and increase competition to keep prices low. Semiconductor controls and startup companies all came together to address this fundamental market problem, and the result was the formation of the ZigBee Alliance.

The ZigBee Alliance is an association of companies working together to enable reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard. The goal of the ZigBee Alliance is to provide the consumer with ultimate flexibility, mobility, and ease of use by building wireless intelligence and capabilities into everyday devices.

ZigBee technology is being embedded into a wide range of products and applications across energy, residential, commercial, and industrial markets worldwide. At last, companies have a standards-based wireless platform optimized for the unique needs of remote monitoring and control applications, including simplicity, reliability, low-cost and low-power.

The ZigBee Alliance has a four-pronged focus, which includes:

1. Defining the network, security and application software layers

2. Providing interoperability and conformance testing specifications

3. Promoting the ZigBee brand globally to build market awareness

4. Managing the evolution of the technology

ZigBee is based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). The relationship between IEEE 802.15.4-2003 and ZigBee is similar to the one between IEEE 802.11 and the Wi-Fi Alliance. The ZigBee 2007 specification was ratified in Q4, 2007, and is now available to all members of the ZigBee Alliance.

Critically, leading AMI vendors and utilities installing large-scale AMI solutions have chosen ZigBee as the primary element for their HAN technology for three simple reasons: 1) it's wireless and can be battery powered (dangerous to wire a gas meter!), 2) it's a global open standard which promotes competition and choice, and 3) it's inexpensive.

POWERING 21ST CENTURY ENERGY

ZigBee is now the utility industry's leading open and standards-driven wireless technology for enabling the interface between the utility AMI infrastructure and the HAN. The world's leading utilities have been working closely with ZigBee Alliance members to develop a Smart Energy Application Profile (ratified in January, 2008). The Smart Energy Application Profile enables two-way communications and control of ZigBee devices for the purpose of energy management inside the home, and serves as the entry point for advanced metering and demand response systems from the utility or energy management companies, such as time-of-use pricing programs, energy monitoring, pay-as-you-use and net metering.

ZigBee is an ideal candidate for utility industry applications because of the market demand for an open and interoperable standard that can provide a low-cost, sustainable "off-the-shelf" product paradigm for promoting efficient and responsible energy, gas and water usage. It is predicted that within five years, the ZigBee networking standard will be used for 30 percent of the smart meters used for the neighborhood utility Local Area Network (nLAN). It will be dominant for WSN devices used in emerging Home Area Network (HAN) systems and will make up 95 percent of the wireless HAN market in five years.

The reason behind the rapid adoption is that no other standard has the same type of ecosystem, adoption levels, scope and breadth of participating companies, and ability to solve key low-power wireless problems as ZigBee.

ENERGY MANAGEMENT SYSTEMS – DEPLOY, MONITOR, MANAGE, CONTROL

Utility industry initiatives such as AMI and HAN along with WSNs based on open-standard protocols like ZigBee are creating the means for truly automated methods of notifying, modifying and managing residential energy demand. With single-chip solutions from leading vendors now below $4 (with some announcing sub-$2 pricing soon) for semiconductor radio chips, almost every device can now have wireless communications.

As such, more and more traditionally-wired solutions can now be untethered to provide the flexibility, freedom and reduction in wiring costs that other wireless technologies (such as cell phones and Wi-Fi) have brought to the world. But even with the global focus on energy reduction, many of the devices that consume electricity are not networked. That prevents any active, efficient management of energy consumption, particularly the devices that are "energy hogs" such as, HVAC, washers and dryers. For these devices, ZigBee networks establish wireless connections that render them available for automated energy management, making it possible to achieve significant reductions in energy consumption.

But now that the basic hardware infrastructure has proven to be feasible, reliable and affordable, and common standards have emerged, the market is looking to address the larger issues of monitoring, managing, deploying and controlling the entire system. As a result, we now see the emergence of new, comprehensive solutions called energy management systems (EMS).

While some energy providers have been involved with EMS for many years, the advent of WSN, AMI, HAN and ZigBee are giving new meaning and dimension to the concept. When combined with the right software platforms, these initiatives will deliver unprecedented levels of management and control to utilities as well as consumers.

Deregulated utilities, like other mature consumer products such as telephones, have the same basic business problem: to reduce customer churn. By embracing residential EMS, such utilities have the unprecedented opportunity to more deeply engage their customers to build brand loyalty and realize additional revenue generating opportunities. Utilities in more regulated environments realize important benefits as well, including improved grid reliability, enhanced load shifting efforts and a greater ability to respond to regulatory pressures. Additional benefits to utilities include:

• Implementing direct load control and demand-response system through a single-source supplier.

• Accessing electricity consumption, temporal and appliance-specific information to better understand consumer behavior and to provide better modeling of energy demand profiles across neighborhoods, zip codes and municipalities.

• Delivering a secure and reliable connection into the home area network.

• Allowing consumers to see and react to price adjustments to shift their own consumption manually/voluntarily.

• Gaining greater stability and reliability of the electricity grid during times of extreme instability.

• Selling excess and/or reduced energy at profitable rates.

• Maintaining a tighter, more daily interactive relationship with consumers.

Residential EMS offers many unique opportunities for consumers as well, including the ability to:

• Effectively predict and manage peak load periods

• Control energy usage/lower consumption

• See and react to energy price adjustments

However, not all EMS are created equal, and utilities looking to implement a system should look for the following features and characteristics:

• **Back-office monitoring** – Ability to diagnose HAN devices from the EMS back office

• **Independent consumer access and control** – Provides consumers the ability to appropriate respond to non-utility-benefit time periods at anytime through a Web-based portal

• **Open, standards-based architectureat the device level** – A successful EMS must allow a consumer to walk into a retail outlet such as The Home Depot® and purchase ZigBee™ Smart Energy Profile device for the home that can be easily added into an EMS offered by a utility company. Closed systems will ultimately lack the price competitiveness and will not capitalize on white goods manufacturers' desires to network their appliances.

• **Open, standards-based architecture at the enterprise software level** – If utilities are to truly reap the benefits of residential EMS, the software needs to plug into existing back-office applications. A successful EMS system should therefore support accepted and published enterprise software integrations standards and methodologies.

• **Compliance with ZigBee Smart Energy Application Profile for true affordability and interoperability**

• **Support for different consumer categories** — Many utilities will need to accommodate consumers from different socio-economic levels and varying technological infrastructures. Early research suggests three consumer categories that a successful EMS must support:

- Homes with no broadband, no PC and no programmable thermostat
- Homes with a PC and programmable thermostat but no broadband
- Homes with broadband, a PC and a programmable thermostat

• **Rich consumer information access and usage modeling** – Consumers have shown a willingness to pay for real-time, rich, detailed and personalized access to electricity information if it provides them with the ability to manage their home energy consumption more effectively. An EMS must support this need for success with in-home deployments that utilities are undertaking.

• **Support for multiple WAN technologies** – Where use of the AMI system is possible, it should offer the lowest cost WAN technology. The EMS also should support broadband and other WAN technologies as a means of communication between the energy provider's infrastructure and the residence. This is a key requirement for utilities seeking a residential EMS for their rollouts.

• **Sustain load modeling** – At any time the EMS should be able to predict the likely effects that a given price change or Demand Response message will have on the energy load.

• **Fault/fraud detection** – Any useful EMS system must detect consumer fraud by comparing registered devices and program information against real-time device behavior and electricity consumption information.

• **Support for consumption benchmarking** – Analysts expect that consumers will want to benchmark their energy consumption against their neighbors.

• **Reasonable cost** – Any EMS must allow interested utilities a reasonable profit while providing consumers with the ability to reduce expenses through wise energy management.

• **Upgrade path for utilities from legacy AMR infrastructure to AMI** - As EMS grows, utilities will want to centralize more applications and infrastructure. The system architecture must support integration and upgrade of legacy systems.

• **Simple user self-installation** – For rapid adoption, the residential portion of the EMS needs to be easy to learn, easy to use and capable of quickly adding more smart devices to the network.

• **Compliance with the regulatory environment of each locale** – Every state and local utility is under specific regulatory requirements. For EMS success it must easily conform to different regulatory requirements.

• **Scalability that retains levels of demand response** – As the EMS system adds more consumers and capabilities, response time must increase proportionally to meet the every-increasing demands on the system.

• **Availability in three usage models** – Complete utility control, "hybrid" utility/aggregator control or a completely separate aggregator should be delivered.

This may seem like a daunting list of criteria. But unless a system is able to meet all of them, utilities and consumers will not experience and realize the full potential that a WSN-based residential EMS can provide.

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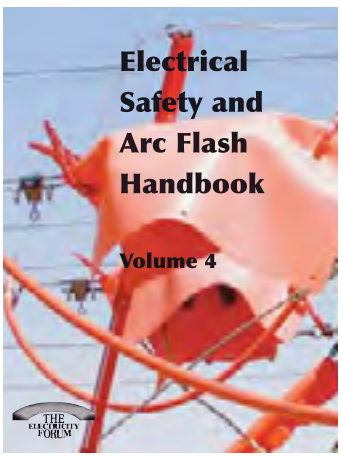

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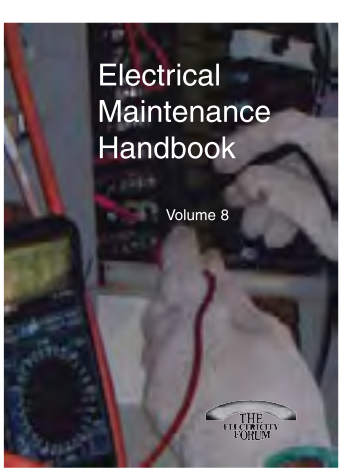

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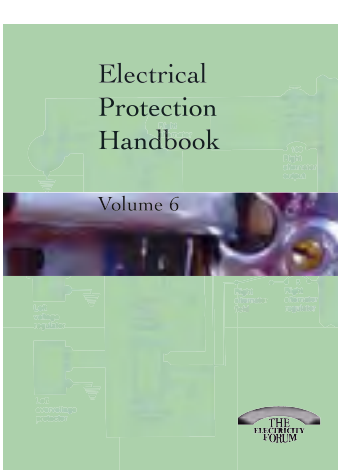

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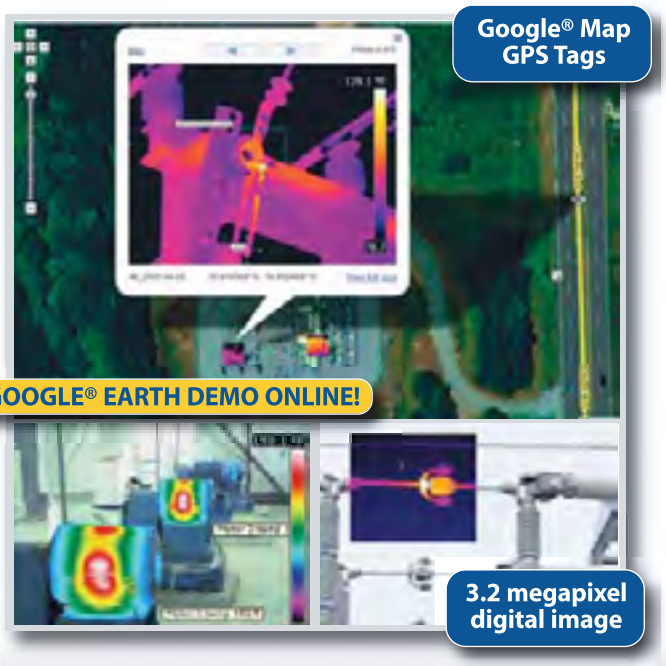

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