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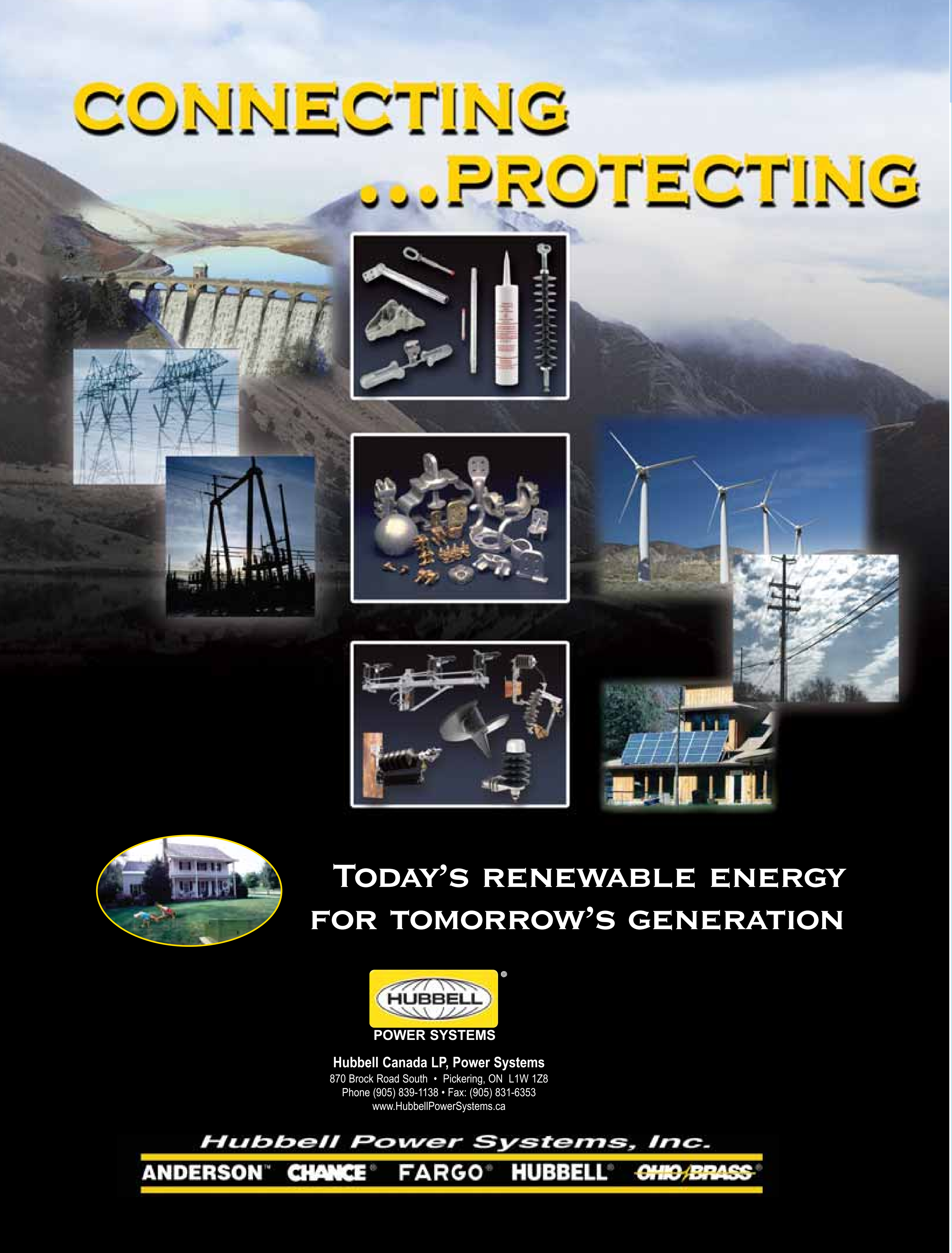
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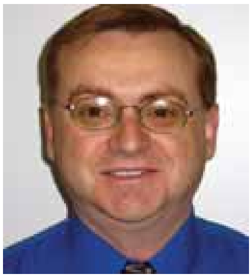

MANY BASKETS MAY BE THE BEST SOLUTION FOR ELECTRICITY RATES

By Don Horne

Some 80 cities in Texas have formed CAPP (Cities Aggregation Power Project), a coalition of municipalities that are hoping to reduce electric bills over the next decade.

The bulk buy - which would consist of a 10-year contract with a coal plant to supply electricity to these communities - would have CAPP issuing a bond to pay the upfront costs with the member municipalities reimbursing CAPP.

This comes on the heels of recent studies showing that Texans are now paying among the highest rates for electricity since that state adopted deregulation.

As support for CAPP grows (currently of the 85 members, the majority support the plan), it is anticipated that an agreement with a coal plant would take effect in October of next year, specifically, Sempra Generation's Twin Oaks CFB coal plant in central Texas.

Although large, long-term purchases are nothing new in other U.S. states, this is a precedent for Texas, the home of readily available cheap generation.

That is, until the price of natural gas began going through the roof.

For example, the city of Watauga spent $271,819 on electricity in 2005, up from $181,753 in 2001. In kilowatt costs per hour, the increase has gone from 0.04 cents per kilowatt hour in 2002 to 0.1186 cents in 2006.

And according to the local utilities, it is the volatile price fluctuations of natural gas that have caused this dramatic increase, citing coal as a more price-stable fuel.

Of course there are misgivings about a 10-year commitment, and the very reason for entering the contract (a volatile market) is underscored to stay out.

But aside from the length of the contract, the real benefit that these communities should examine is broadening their generation base. Having all of their eggs in the natural gas "basket" of generation has placed them in this current predicament. If nothing else, committing to coal will provide these communities with flexibility.

Flexibility from a 10-year commitment? Ironically, yes.

Unlike other states Texas' electricity grid has limited interconnection with its neighbours. Because of this isolation Texas is not able to connect its electricity

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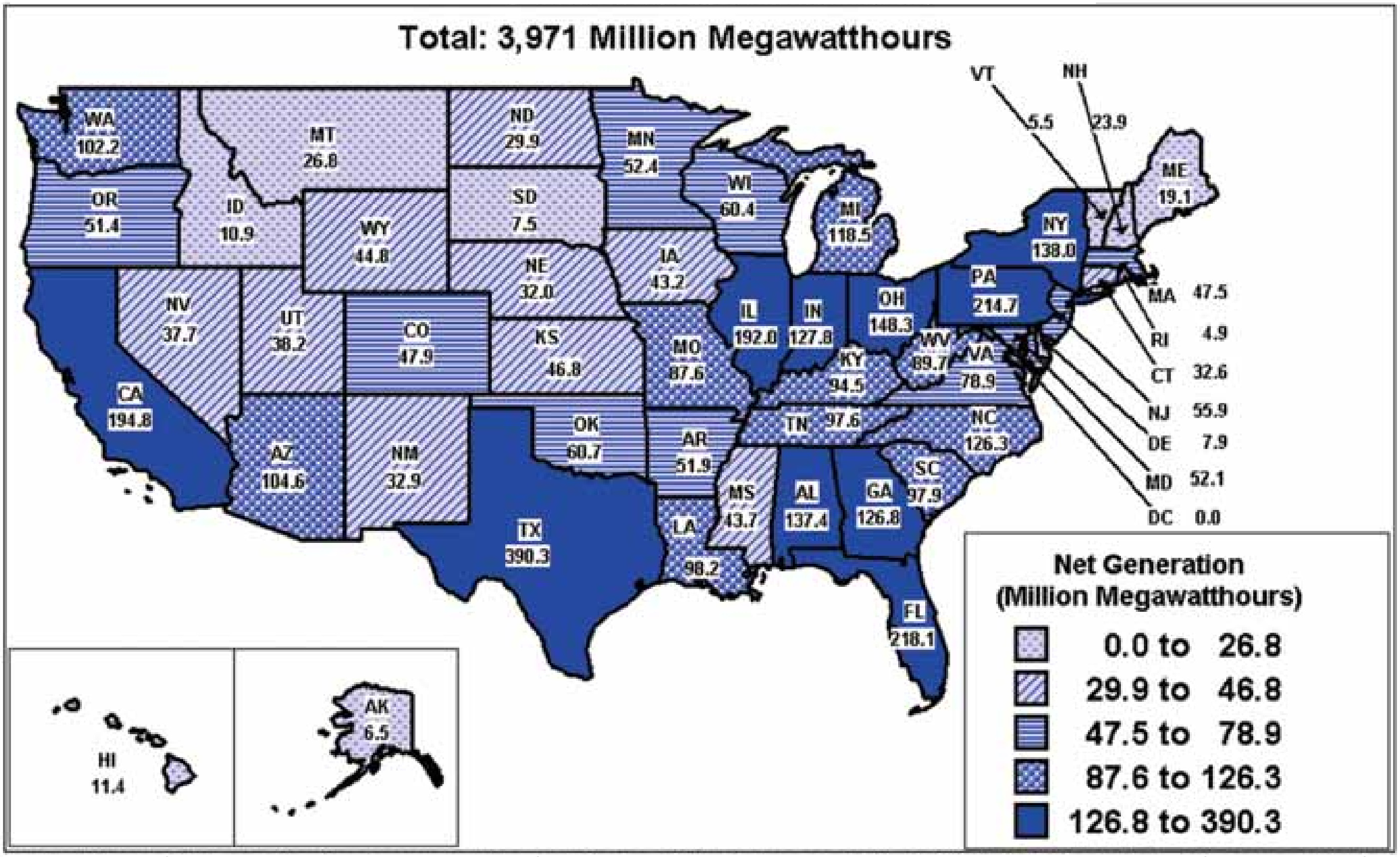
Figure 1.1 U.S. Electric Power Industry Net Generation by State, 2004 (Million Megawatthours)



Note: Figure information is shown by 5 groupings of 10 States and The District Columbia. The Presented range moves from the values for the lowest 10 States to the top 10 States.
Sources: Energy Information Administration, Form EIA-906, "Power Plant Report" and Form EIA-920, "combined Heat and power Plant report".

many baskets

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beyond its own borders. So when wholesale utility deregulation went into effect in 1995 and retail utility deregulation went into effect in January 2002, they were pretty much on their own.

In 2000, 46 percent of electricity in Texas came from natural gas-fired plants, 41 percent coal and lignite fired plants, and 13 percent from nuclear, all of which are non-renewable resources. Under the retail utility regulation bill, where investor-owned utilities will be required to develop 2000 MW of new renewable based power by 2009, a standard of three percent of renewable electricity for utilities would be achieved.

Texas is the fifth largest producer of coal in the United States, and leads the nation in coal consumption by a wide margin.

Flexibility? For Texas, the flexibility is either natural gas or coal; and coal has proven itself to be by far the more stable in price.

In California, the ISO Director of Market Monitoring, Keith Casey has gone on record endorsing the diversification of generation.

"Fuel diversity is also important. Too much reliance on power plants fueled by natural gas can create significant cost exposure to higher natural gas prices," says Mr. Casey.

Until there is greater interconnection with neighbouring states' electrical grids, a long-term investment in coal-generation does seem the best path for the members of CAPP.

The reliance on coal, compared to other regions and states, is considerable.

Not surprisingly, the New England states (Maine, Massachusetts, Connecticut, New Hampshire, Rhode Island and Vermont) have all dropped their reliance on coal (except for Massachusetts). Indeed, with the exception of states rich in coal (West Virginia, Kentucky, Georgia, Ohio and Texas), there has been a concerted move away from coal-generated electricity - mostly due to pressure from Environmentalists and the always-present Kyoto Protocol.

But coal - by far - remains king.

In terms of generation, Texas leads the nation. In 2004, a total of 390.3 million megawatt hours were generated, with Florida coming in a distant second at 218.1.

Looking at the numbers, a 10-year commitment to coal generation is anything but risky - but for Texans long accustomed to finding their energy coming from a well-head, it can be seen as a leap of faith. **ET**

CAPACITIVE VOLTAGE TRANSFORMERS: TRANSIENT OVERREACH CONCERNS AND SOLUTIONS FOR DISTANCE RELAYING

By Daqing Hou and Jeff Roberts, Schweitzer Engineering Laboratories, Inc.

Capacitive Voltage Transformers (CVTs) are common in high-voltage transmission line applications. These same applications require fast, yet secure protection. However, as the requirement for faster protective relays grows, so does the concern over the poor transient response of some CVTs for certain system conditions.

Solid-state and microprocessor relays can respond to a CVT transient due to their high operating speed and increased sensitivity. This paper discusses CVT models whose purpose is to identify which major CVT components contribute to the CVT transient. Some surprises include a recommendation for CVT burden and the type of ferroresonant-suppression circuit that gives the least CVT transient.

This article also reviews how the System Impedance Ratio (SIR) affects the CVT transient response. The higher the SIR, the worse the CVT transient for a given CVT.

INTRODUCTION

Poor CVT transient response and the distance element overreach it causes are a serious concern for high-speed line protection.

For faults that cause very depressed phase voltages, the CVT output voltage may not closely follow its input voltage due to the internal CVT energy storage elements. Because these elements take time to change their stored energy, they introduce a transient to the CVT output following a significant input voltage change. In this paper, we define the duration of CVT transient as that time period during which the CVT output voltage does not match the ratio input voltage.

CVT transients reduce the fundamental component of the fault voltage. This decrease in the fundamental voltage component results in a decrease in the calculated impedance. If the fundamental voltage reduction is great enough, Zone 1 distance elements undesirably pick up for out-of-section faults.

If a fault is within that portion of line protected by a Zone I element, the resulting distance calculation decrease due to a CVT transient is tolerable; the protective relay should operate. However, if the fault is located outside of that portion of line protected by the Zone 1 element and the CVT transient causes the Zone 1 element to pick up, then this CVT transient is not tolerable.

One solution to the CVT-transient-induced distance element overreach problem for out-of-section faults has been to reduce the Zone 1 element reach. However, the CVT transient response for some applications requires such a reduction of the Zone 1 distance element reach that the Zone 1 element is no longer effective protection. Another solution is to delay all Zone 1 distance element operations. This delay prevents the distance element from producing a trip output during the CVT transient. The later solution is undesirable in that close-in fault clearance times are penalized unnecessarily.

This article addresses the following questions:

WHAT IS THE STRUCTURE OF A CVT, AND HOW CAN WE DETEMINE ITS TRANSIENT RESPONSE?

The first section of the paper describes the components that make up CVTs. This section discusses how some key CVT components, such as coupling capacitors and ferroresonance suppression circuits, relate to the CVT transient performance.

HOW DO CVT TRANSIENTS AND OTHER SYSTEM PARAMETERS AFFECT THE PERFORMANCE OF DISTANCE RELAYING?

The second section of the paper discusses CVT and relay models. We use these models to study the performance of distance relays during CVT transients, under different SIRs, and for a variety of CVT loading conditions.

What are the possible solutions to the distance element overreach problem?

The last section compares different techniques of solving the distance element overreach problem due to CVT transients and proposes a new method.

CAPACITIVE VOLTAGE TRANSFORMER COMPONENTS

A CVT (Figure 1) consists of the following components:

- Coupling capacitors (C1 and C2)
- Compensating reactor (L)

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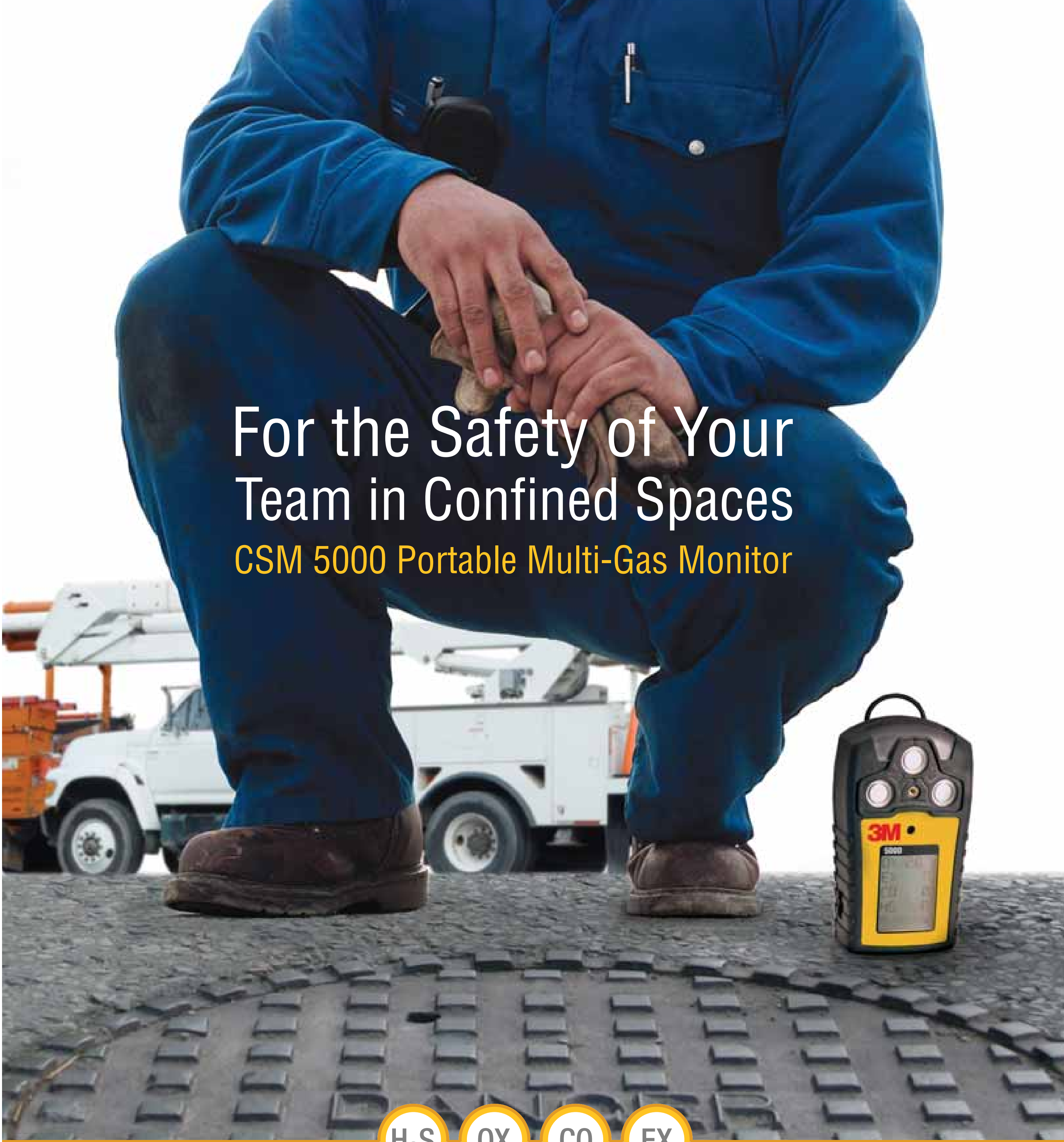
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EX

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- Step-down transformer
- Ferroresonance-suppression circuit

When equipped with a communication carrier, the CVT has an additional drain coil, choke coil, and carrier switch that are not shown in Figure 1.

The coupling capacitors of the CVT function as a voltage divider to step down the line voltage to an intermediate-level voltage, typically 5 to 15 kV. The compensating reactor cancels the coupling capacitor reactance at the system frequency. This reactance cancellation prevents any phase shift between the primary and secondary voltages at the system frequency. The step-down transformer further reduces the intermediate-level voltage to the nominal relaying voltage, typically $115/\sqrt{3}$

The compensating reactor and step-down transformer have iron cores. Besides introducing copper and core losses, the compensating reactor and step-down transformer also produce ferroresonance due to the nonlinearity of the iron cores. CVT manufacturers recognize this ferroresonance phenomenon and include a ferroresonance-suppression circuit. This circuit is normally used on the secondary of the step-down transformer. While this circuit is required to avoid dangerous and destructive overvoltages caused by ferroresonance, it can aggravate the CVT transient. Whether or not this suppression circuit aggravates the CVT transient depends upon the suppression circuit design. We discuss suppression circuits later in the paper.

When a fault suddenly reduces the line voltage, the CVT secondary output does not instantaneously represent the primary voltage. This is because the energy storage elements, such as coupling capacitors and the compensating reactor, cannot instantaneously change their charge or flux. These energy storage elements cause the CVT transient.

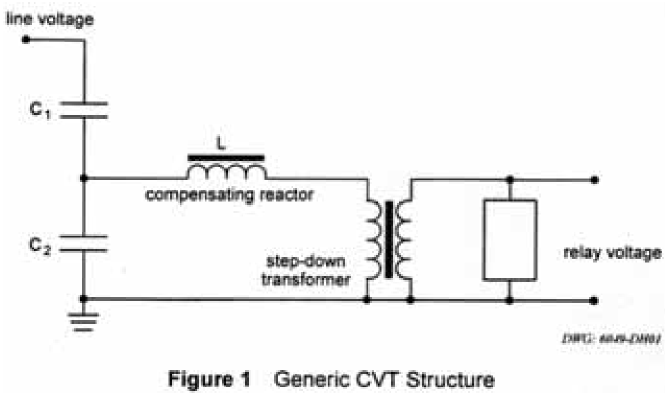

Figure 1: Generic CVT Structure

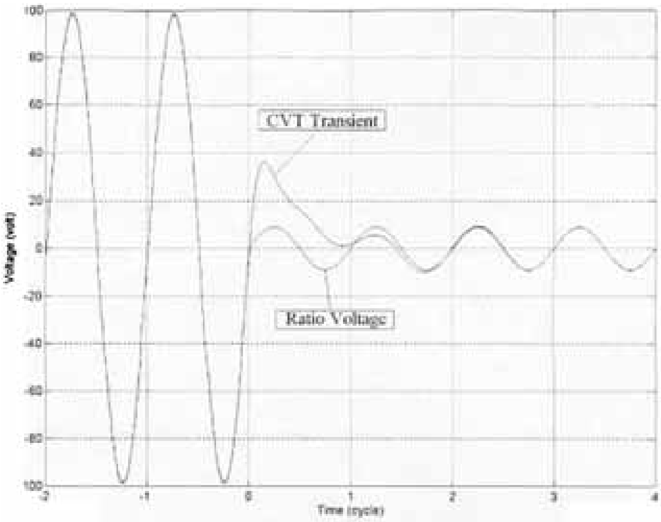

Figure 2: CVT Transient with Fault at Voltage Zero

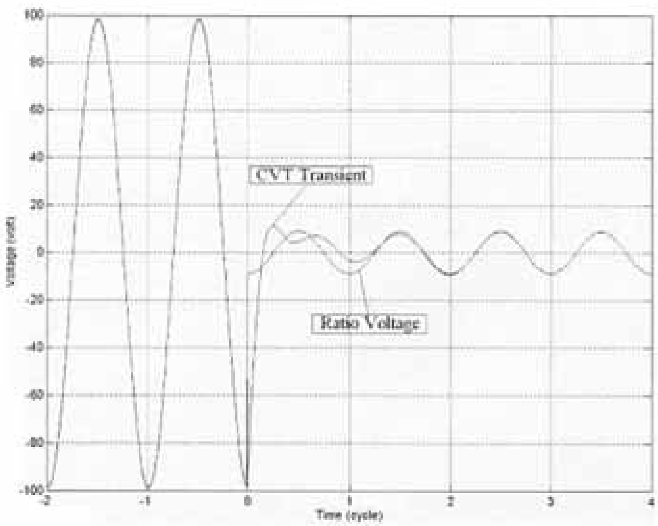

Figure 3: CVT Transient with Fault at Voltage Peak

CVT transients differ depending on the fault point-on-wave (POW) initiation. The CVT transients for faults occurring at voltage peaks and voltage zeros are quite distinctive and different. Figure 2 and Figure 3 show two CVT transients for zero-crossing and peak POW fault initiations. For comparison, the ideal CVT voltage output (ratio voltage) is shown in each figure. Figure 2 shows a CVT transient with a fault occurring at a voltage zero. Also, notice that the CVT output does not follow the ideal output until 1.75 cycles after fault inception.

Figure 3 shows the CVT response to the same fault occurring at a voltage peak. Again, the CVT output does not follow the ideal output. The CVT transient for this case lasts about 1.25 cycles. The CVT transient response to a fault occurring at points other than a voltage peak or voltage zero take a wave shape in between those shown in Figure 2 and Figure 3.

Each CVT component contributes to the CVT transient response. For example, the turns ratio of the step-down transformer dictates how well a CVT isolates its burden from the dividing capacitors C_1 and C_2. The higher the transformer ratio, the less effect the CVT burden has on these capacitors. The different loading on the CVT coupling capacitors due to different transformer ratios changes the shape and duration of CVT transients.

Next, we discuss how two key CVT components affect the CVT transient response: the coupling capacitors and ferroresonance-suppression circuit.

COUPLING CAPACITOR VALUE AFFECTS CVT TRANSIENT RESPONSE

A CVT is made up of a number of capacitor units connected in series. The number of capacitor units depends on the applied primary voltage level. The CVT capaci-

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tance is represented by two values: one for the equivalent capacitance above the intermediate voltage point (C_1) and the other for the equivalent capacitance below the intermediate voltage point (C_2). The Thevenin equivalent capacitance value (C_1 + C_2) is different from the total capacitance C_1-C_2/(C_1 + C_2) normally given by CVT manufacturers. C_J + C_2 is approximately 100 nano-farad (nF) for the CVTs studied in this paper. Some CVT manufacturers differentiate CVTs as normal-, high-, or extra high-capacitance CVTs.

The high capacitance value in a CVT decreases the CVT transient in magnitude. See this by comparing the CVT transient plots of Figure 2 and Figure 4 for a fault initiated at a voltage zero.

Figure 4 shows the transient response of a CVT with four times total capacitance of that shown in Figure 2.

Distance elements calculate a fault apparent impedance based on the fundamental components of the fault voltage and current. The fundamental content of the CVT transient determines the degree of distance element overreach. Figure 5 shows the fundamental components of the same CVT outputs shown in Figure 2 and Figure 4. We obtained the fundamental magnitudes by filtering the CVT outputs using a digital band-pass filter. Notice that the fundamental component of the higher capacitance CVT output voltage is closer to the true fundamental magnitude than that of the lower capacitance CVT. Therefore, any distance element overreach caused by a transient output of a higher capacitance CVT is much smaller than that caused by the transient output of a lower capacitance CVT.

Increasing the CVT capacitance value can increase the CVT cost but decreases the CVT transient response. Thus, protection engineers must strike a balance between CVT performance and CVT cost.

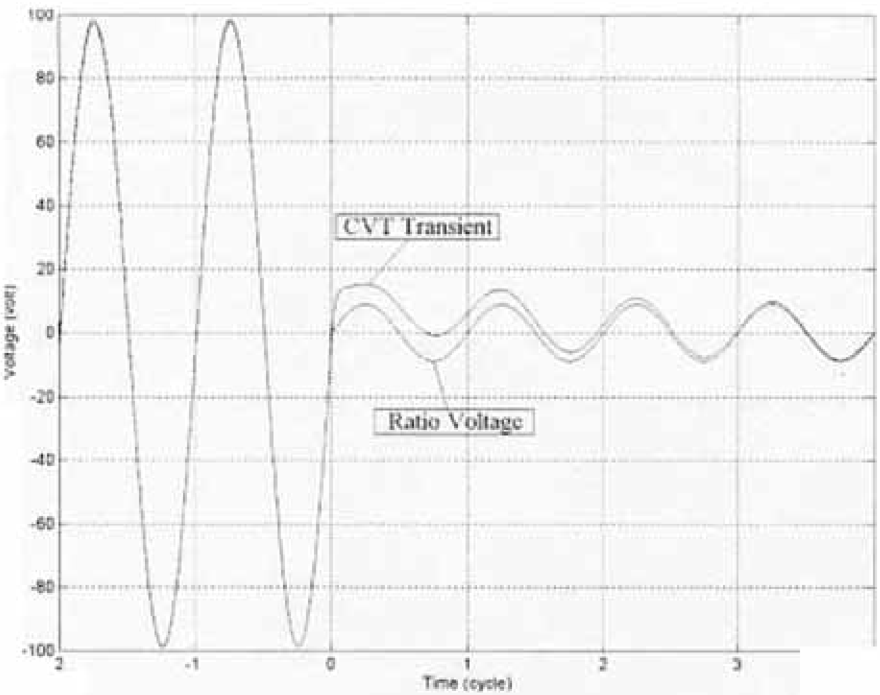

Figure 4: Transient response of a High-Capacitance CVT

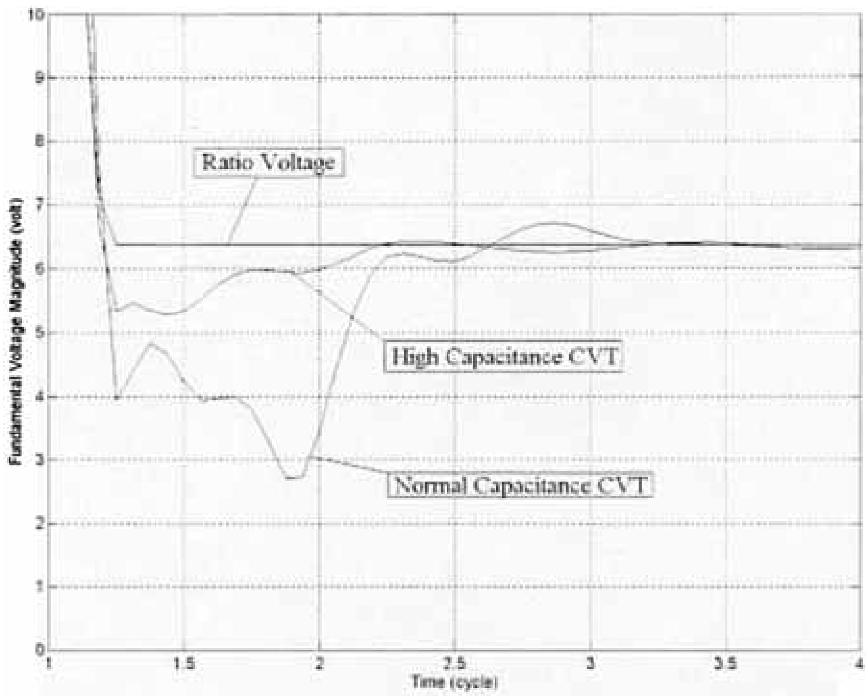

Figure 5: Higher Capacitance CVT Causes Less Reduction in the Fundamental Voltage Magnitude

FERRORESONANCE-SUPPRESSION CIRCUIT DESIGN AFFECTS CVT TRANSIENT RESPONSE

Figure 6 shows two types of ferroresonance-suppression circuits.

ACTIVE FERRORESONANCE-SUPPRESSION CIRCUITS

Active ferroresonance-suppression circuits (AFSC) consist of an LC parallel tuning circuit with a loading resistor. The LC tuning circuit resonates at the system frequency and presents a high impedance to the fundamental voltage. The loading resistor is connected to a middle tap of the inductor to increase the resonant impedance of the circuit. For frequencies above or below the fundamental frequency (off-nominal frequencies), the LC parallel resonant impedance gradually reduces to the resistance of the loading resistor and attenuates the energy of off-nominal frequency voltages.

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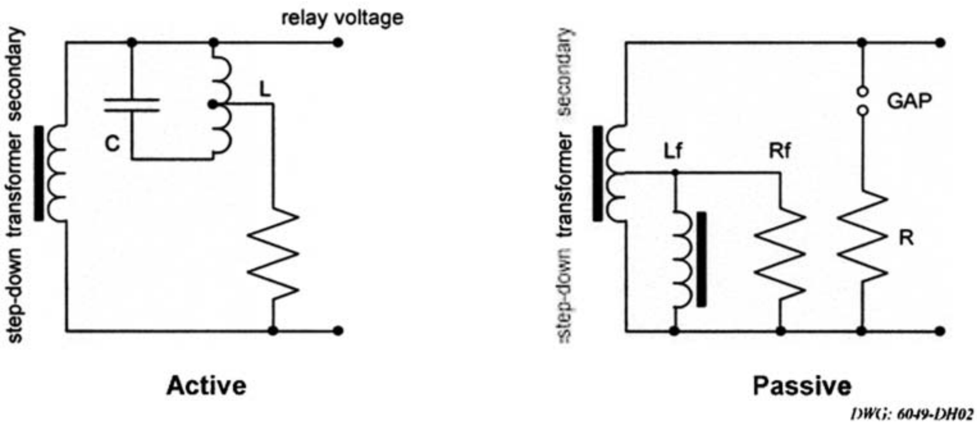

Figure 6: Active and passive Ferroresonance-Suppression Circuits

PASSIVE FERRORESONANCE-SUPPRESSION CIRCUITS

Passive ferroresonance-suppression circuits (PFSC) have a permanently connected loading resistor Rf, a saturable inductor Lf, and an air-gap loading resistor R. Under normal operating conditions, the secondary voltage is not high enough to flash over the air gap, and the loading resistor R has no effect on the CVT performance. Once a ferroresonance oscillation exists, the induced voltage flashes over the gap and shunts in the loading resistance to attenuate the oscillation energy. Lf is designed to saturate at about 150% of nominal voltage to further prevent a sustained ferroresonance condition.

FERRORESONANCE-SUPPRESSION CIRCUIT EFFECTS ON CVT TRANSIENT PERFORMANCE

The AFSC acts like a bandpass filter and introduces extra time delay in the CVT secondary output. The energy storage elements in the AFSC contribute to the severity of the CVT transient.

In contrast, the PFSC has little effect on the CVT transient. The majority components of the circuit are isolated from the CVT output when ferroresonance is not present. Figure 7 shows the difference of the CVT secondary outputs for a CVT with an AFSC and a CVT with a PFSC for the same fault voltage. Note that the CVT with a PFSC has a better, less distorted transient response than the CVT with an AFSC. This less distorted transient results in a fundamental magnitude that is closer to the true fundamental magnitude as shown in Figure 8.

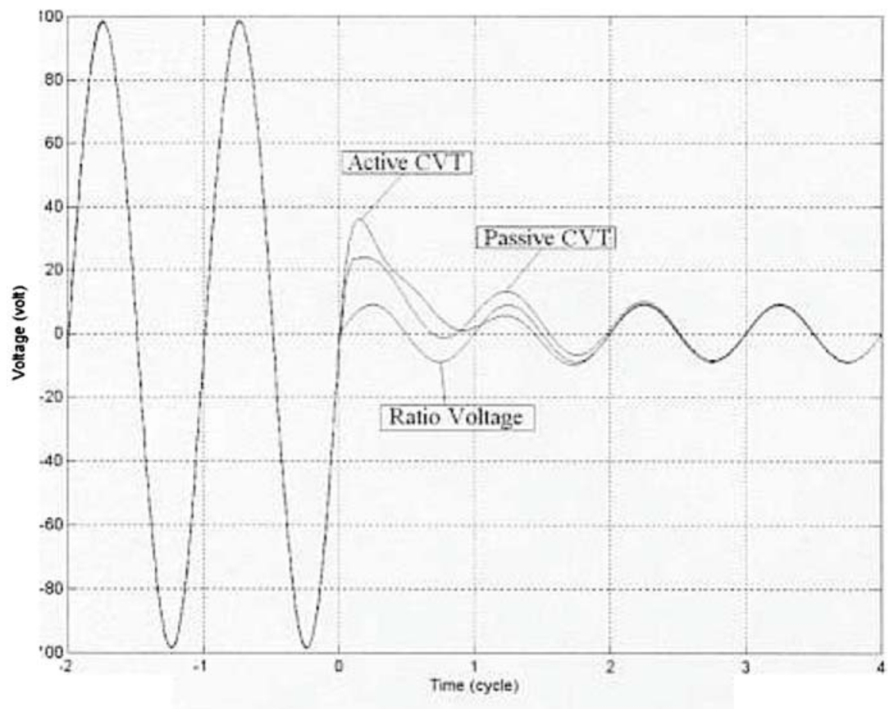

Figure 7: CVT Transients of AFSC and PFSC

The PFSC has a permanently connected resistor, which increases the VA loading of the intermediate step-down transformer. For the same burden specification, the CVT with PFSC requires a bigger intermediate step-down transformer.

DISTANCE RELAY PERFORMANCE

We modeled a simple power system, CVTs with AFSC and PFSC, and a generic distance relay to determine the performance of distance relays during CVT transients. The evaluation system is shown in Figure 9.

POWER-SYSTEM MODEL

Figure 10 shows the simple power-system model. It is a single phase, radial system with fixed line impedance and variable source impedance. The difference between pre-fault and fault voltage levels heavily affects the CVT transient magnitude and duration. This voltage difference is determined by SIR values, fault locations, and fault resistance (Rt).

CONCLUSIONS

- Faults occurring at voltage zero-crossings generate the worst-case CVT transient.
- The transients produced by CVTs with PFSC are much less than those produced by CVTs with AFSC.
- Distance element overreach due to CVT transients is not

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a problem for low SIR applications.

This statement is true for CVTs with either AFSC or PFSCs.

- High-capacitance CVTs reduce distance element overreach because the transients they produce have a lower magnitude as compared to lower C-ratings for CVTs.

- Reducing the CVT burden also reduces distance element overreach. The resistive burdens found in microprocessor-based relays cause less CVT transients than the inductive burdens found in electromechanical relays.

- The proposed CVT transient detection logic is superior to past detection methods for the following reasons:
  - It does not require special user or factory settings.
  - It introduces minimum delay for in-zone faults.
  - It optimizes automatically the voltage and current thresholds for each application.
  - It uses m-smoothness calculations to bypass any unnecessary time delay for close-in faults.

Daqing Hou received BS and MS degrees in Electrical Engineering at the Northeast University, China, 1981 and 1984, respectively. He received his Ph.D. in Electrical and Computer Engineering at Washington State University in 1991. Since 1990, he has been with Schweitzer Engineering Laboratories, Inc., Pullman, Washington, USA, where he is currently a research engineer.

Jeff Roberts received his BSEE from Washington State University in 1985. He worked for Pacific Gas and Electric Company as a Relay Protection Engineer for over three years. In 1988, he joined Schweitzer Engineering Laboratories, Inc. as an Application Engineer. He now serves as Research Engineering Manager.

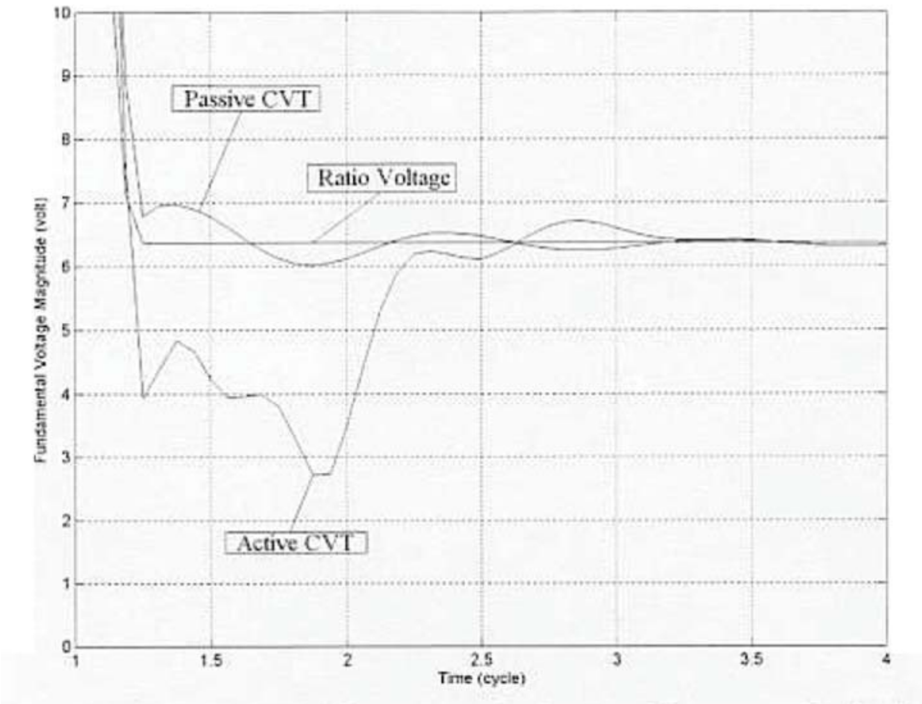

Figure 8: CVT with PFSC Causes Less Fundamental Component reduction

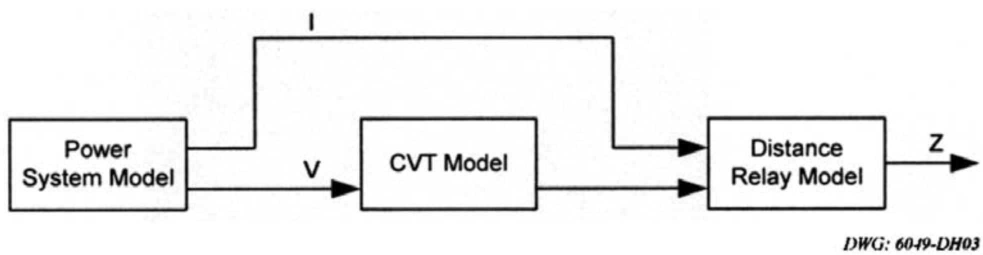

Figure 9: Distance Relay Evaluation System

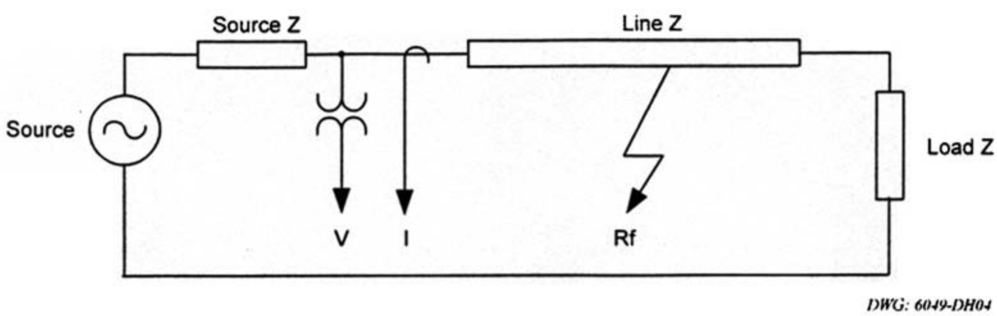

Figure 10: Power-System Model

BOOK OF THE MONTH WINNER FROM DOBLE CONFERENCE

Michel Larouche

Michel Larouche, was our Book-of-the-Month Club winner at the recent Doble Conference in Boston, Massachusetts.

Mr. Larouche is an electrical technician who has worked for Alcan primary metal Quebec since 1976 and has been at the Laterrière plant since 1988. The Laterrière aluminum smelting plant has two pot lines with a substation that consumes 410 megawatts in power. He has been happily married for 30 years and has one daughter and twin sons.

Mr. Larouche is the lucky winner of 12 technical handbooks from the Electricity Forum.

Congratulations. **ET**

You said it…

Edward Fatherly, Senior Electrician with the U.S. Army Corps of Engineers in Russellville, Arizona writes:

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Leslie Field, Senior Product Engineer with General Electric Company in Anasco, Puerto Rico writes:

"I would like more articles on protective relaying, switchgear and control systems."

James McLaren, Maintenance Supervisor at Bear Creek Consulting in Charlton, Ontario writes:

"I have read Electricity Today over the past several years and have found it a useful source of information and contacts. I also have read your new publication, Electrical Source and believe that I will find it even more beneficial. Keep up the good work."

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STATIONARY FUEL CELLS FOR POWER GENERATION - PART I

This article describes a policy strategy to expedite the commercial development of stationary fuel cell electric power generation that is consistent with the Texas' newly restructured electric market. Based on its knowledge of the electric industry, the commission makes the following recommendations with regard to fuel cell commercialization.

1) The state should seek to develop fuel cells as a grid-connected, economically viable distributed generation (DG) option, as this is the most likely way for fuel cell developers to achieve economies of scale and subsequent cost reductions.

Incentives for fuel cell distributed generation (FCDG) should be paid per kWh of output metered by the independent system operator (ISO).

2) The state should also seek to develop residential, off-grid and other small-scale applications of fuel cells, as declining costs for FCDG applications should enable similar cost reductions for small-scale applications. Incentives for small-scale applications should be paid as a lump-sum rebate once the fuel cell is activated.

3) Incentives under both programs:

A) should be larger for "early adopters", decline over time, and reach zero at a specific date;

B) should be adjusted automatically to account for federal fuel cell subsidies if and when such subsidies are created; and

C) should include a trigger that reduces the incentive if the market proves robust enough to be self-sustaining.

4) The incentive programs should reflect the state's expectation that fuel cell developers will aggressively reduce costs as the technology matures.

5) The incentive programs should be funded in a way that leverages the objective of encouraging fuel cell development. Those who bear the cost of the program should be relieved of part of that burden if they install and use fuel cells.

BENEFITS

As a stationary source of electric generation, fuel cells offer a number of benefits both to individual users and to society as a whole. The social benefits – less air pollution, reduced transmission congestion, and the ability to add new generation capacity within an area not in attainment with federal clean air standards – provide the main rationale for public efforts to accelerate fuel cell commercialization. The public benefits are discussed at length by the State Energy Conservation Office in its report to the Legislature on fuel cell commercialization.

The private, owner-specific benefits help identify the quickest and least-cost path to commercial viability, as they constitute elements of built-in value that need no subsidy.

The relative importance of each kind of benefit will vary from one customer to the next, but generally speaking, they include:

- Secure back-up power in the event of grid failure;
- Efficient power production;
- Cushion against natural gas price spikes (less fuel required to produce a kW of power);
- Fewer kWh purchased off the grid;
- Lower peak kW usage and lower demand charges;
- Heat cogeneration; and
- The potential for revenues from sale of ancillary services.

Table 1: Emission rate comparison

	Average emission rates (pounds per net MWh generated)		
	NO_x	*SO_2*	*CO_2*
Distributed generation technologies			
Fuel cells (solid oxide)	**0.01**	**0.005**	**950**
Natural gas powered microturbine	0.44	0.008	1,596
Diesel generator	4.7	0.45	1,432
Texas generation from natural gas (1998)	2.18	0.007	1,144
Texas generation from coal (1998)	4.06	9.90	2,349

Sources: Regulatory Assistance Project/National Renewable Energy Laboratory, workpapers for Distributed Resource Emissions Collaborative (http://www.rapmaine.org/DGEmissionsMay2001.PDF); U.S. Environmental Protection Agency, E-GRID 2000 database.

SIGNIFICANT OBSTACLE

Of all the obstacles to the widespread economic deployment of fuel cells, cost is by far the most significant. Without significant cost reductions by fuel cell developers, no large-scale economic deployment of stationary fuel cells will be possible.

ELECTRIC RESTRUCTURING

State fuel cell policy must be cognizant of and congruent with the changes brought about in the electric industry by Senate Bill 7 (76th Legislature), and should aim to find market solutions to address known challenges.

• Renewable energy as a study of success. Senate Bill 7's Goal for Renewable Energy has been so successful that it is being used as a template for similar federal legislation. Simply cloning the Goal for Renewable Energy and the Renewable Energy Credit Trading Program would not be a good idea, however, because there are important differences in the economic maturity of fuel cells and that of renewables – specifically wind power, which is driving the success of renewables in Texas.

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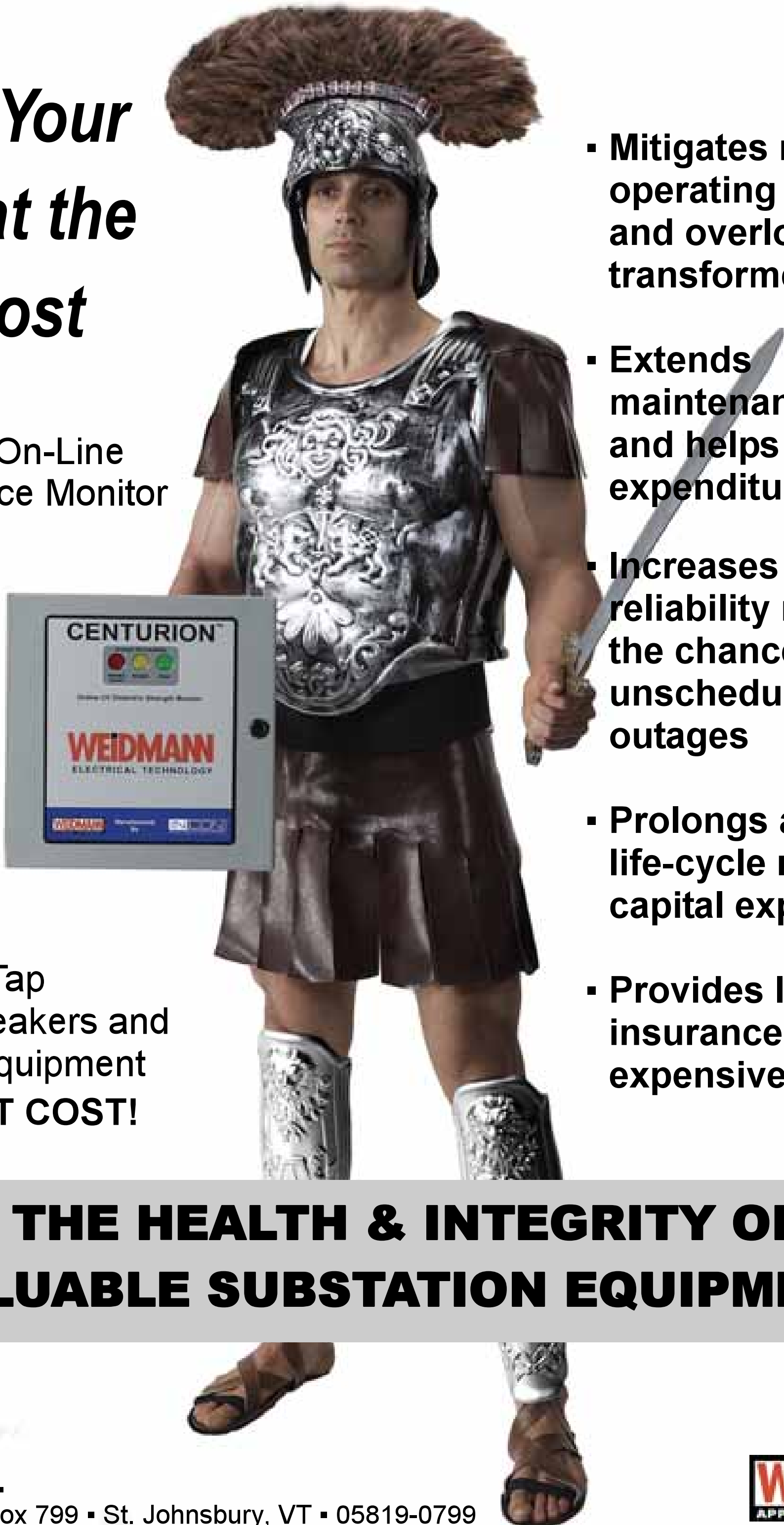

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fuel cells

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Nevertheless, lessons can be learned from the success of renewables that, if properly understood and applied, would increase the chances of a similar success with fuel cells.

• Importance of entrepreneurial effort. Sustainable commercialization cannot happen without entrepreneurial effort. Financial incentives should therefore reward efficiency and should be designed in such a way as to prevent subsidization of unused or overpriced equipment.

• Distributed generation. Large FCDG installations would have a natural market in non-attainment airsheds such as Dallas-Fort Worth and Houston, where reliable electric power is needed but is limited by air quality standards and transmission constraints. For some large customers, FCDG could provide additional flexibility to respond to wholesale power price signals and participate actively in the ERCOT market for ancillary services.

Table 2: Distributed generation interconnections reported by utilities

	Number of facilities	Year-end 2001 MW	Most common fuel
Oncor (TXU)	47	154.5	Diesel
Reliant	18	35.1	Natural gas
AEP	7	18.0	Natural gas
Rest of Texas	2	5.0	Natural gas
Total	74	212.6	

Source: Utility reports pursuant to P.U.C. Subst. R. 25.211(n) on applications received for interconnection and parallel operation of distributed generation.

PROPOSED LEGISLATIVE MEASURES

• Production incentive. The FCDG incentive would be paid over a ten-year period on the basis of kWh metered and delivered to the grid. The incentive rate for fuel cells installed during or before the first year of the program would be determined in a proceeding at the commission the year before the incentive was to be available. The commission would set the rate according to the following formula:

incentive rate = average FCDG market cost – price to beat – federal incentives

The price to beat rate would be the average general service rate and fuel factor in effect at the time of the commission proceeding, converted to a per kWh equivalent and averaged across all affiliated retail electric providers (REPs). The subsidy level would then decline and would phase out by 2010.

• Rebate for residential and other small-scale applications. The small-scale incentive would be paid on the basis of kW capacity. The initial rate would be determined in a manner similar to the per kWh production incentive, except that cost, price to beat, and federal subsidies would be converted to kW equivalents.

• Goals for new fuel cell capacity. The goals would represent benchmarks for self sustainability in the fuel cell market. If the goal for any year were exceeded, the production incentives and rebates would be reduced.

• Funding. Economic activity within the electric sector should be used to finance the state's fuel cell program. Funding mechanisms should be designed so that those who install fuel cells have a smaller obligation to pay for the program. Possible approaches include an emission-based dispatch fee, a flat-rate dispatch fee with credits for fuel cell generation, System Benefit Fund, awarding tradable emission reduction credits for fuel cell generation, and redirecting transmission congestion charges towards fuel cell generators located at points that ease transmission congestion.

I. WHY FUEL CELLS?

Fuel cells generate electricity by combining hydrogen and air. This electrochemical process is more thermally efficient than burning fuel to spin a turbine, although some advanced natural gas technologies such as microturbines and modern combined cycle gas turbines have efficiencies comparable to fuel cells. The main byproducts are water vapor and trace amounts of nitrogen oxides, although carbon dioxide can also be released depending on the process used to obtain the hydrogen.

Fuel cell technology lends itself to decentralized, consumer-owned generation ranging in scale from single-home use to larger distributed generation applications. Power generated by the consumer's fuel cell can reduce or replace power that otherwise would have been purchased from a retailer. As a stationary source of electric generation, fuel cells offer a number of benefits both to individual users and to society as a whole. The social benefits constitute the main rationale for spending public funds to accelerate fuel cell commercialization. The private, customer-direct benefits help identify the quickest and least-cost path to commercial viability.

SOCIAL BENEFITS

• Less air pollution. Fuel cells produce power with significantly less NOx and particulates than is the case with conventional combustion power plants. Table 1 compares emission rates for three distributed generation technologies and Texas averages for total generation.

• Less transmission congestion. Fuel cell units are small and relatively easy to site near consumers inside a power distribution area. By reducing the reliance on power imported from outside the area (from West Texas to Dallas-Fort Worth, for example), mass deployment of fuel cells can reduce costs incurred at the wholesale level due to transmission congestion, thereby reducing overall power costs for all customers within a transmission congestion zone.

PRIVATE BENEFITS

• Security. Like other types of distributed generation, fuel cell distributed generation (FCDG) provides an electric consumer with insurance against grid failure or power curtailment. Hospitals and other emergency services, for example, own distributed generation back-up because of their must-run power requirements. Companies that depend on uninterrupted communication or continuous operation of equipment may also invest in backup power.

• Efficient power production. Fuel cells produce more power from the same quantity of natural gas than do most conventional combustion power plants.

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• Cushion against natural gas price spikes. Because they require less natural gas to produce a kilowatt-hour of electricity, fuel cell generators are less vulnerable to the kind of natural gas price volatility that drove electric bills up in 2000 and 2001. Upswings in natural gas prices result in smaller upswings in total electricity costs for fuel cells powered by natural gas.

• Demand reduction. For commercial and industrial customers, charges that are based on peak kW demand can be reduced to the extent that customer-owned FCDG operates when power usage is greatest.

• Heat cogeneration. Some types of fuel cells generate heat as they generate electricity. For electric customers who also need heat, a fuel cell can reduce the need to use grid power or natural gas to generate heat at the same time it is generating electricity for the customer's own use.

Table 3: Power demand, generation and transfer capacity in 2002

	DFW[a]	North Zone	Houston Zone
Peak demand (MW)	16,145	24,234	19,584
Available generating capacity (MW)	5,849	24,954[b]	16,524
Excluding plants older than 50 years	5,547		n.a.
Excluding plants older than 30 years	1,745		10,394
Total transmission capacity between major congestion zones at commercially significant constraints (MW)			
South to North (Sandow-Temple)		675	
West to North (Graham-Parker)		884	
South to Houston (South Texas Project-Dow)			758[c]

[a]Dallas, Tarrant, Collin and Denton counties.
[b]Another 2,647 MW is expected to be off-line.
[c]The South Zone is expected to have a generation surplus of about 3,600 MW, most of which will serve demand in the Houston zone via transmission lines that are not congested.

Note: Data are the most current used by ERCOT system planning staff as of this writing and are subject to change. These figures do not take into account plans by AEP and CenterPoint Energy to mothball about 7,000 MW of capacity in Texas. Updated data may be found at http://www.ercot.com/Participants/CSC/index.htm.

• Revenues from sale of ancillary services. This benefit would most likely be limited to large installations, or to loads acting as resources. FCDG capacity that is consistently greater than what the owner needs can be bid in the ancillary electric services market, where reserve capacity prices are typically between $5 and $15 per MW. Eventually, a large electric customer in ERCOT capable of switching between grid power and on-site FCDG will actually be able to bid part of its load on the ancillary services market. If the market price of power is high enough, a customer would be paid by ERCOT to use less grid power as needed to manage the reliability of the system. On-site FCDG could provide some large-use customers in non-attainment areas an additional degree of flexibility that could enable them to participate in these markets.

DISTRIBUTED GENERATION

Many of the benefits that an individual customer could obtain by operating fuel cells are the same as for most other distributed generation technologies. Indeed, the strength of the distributed generation market evident in Houston and in the Dallas-Fort Worth area demonstrates a robust market demand for small on-site generation units. (See Table 2.)

Distributed generation (DG) is self-generation. PUC rules define a distributed resource as "a generation, energy storage, or targeted demand-side resource, generally between one kilowatt and ten megawatts, located at a customer's site or near a load center, which may be connected at the distribution voltage level (below 60,000 volts), that provides advantages to the system, such as deferring the need for upgrading local distribution facilities." As customers use more DG, the less power they need to buy and the less power needs to flow through the grid.

Fuel cell technology makes possible a clean and highly controllable distributed generator. The controllable aspect means that it is possible for a fuel cell, with its inverter, to produce firm electrical capacity just as a large gas-fired combined cycle generating plant produces its capacity, but the fuel cell is not as complex. These attributes give FCDG great market potential. Customers who must have clean, dependable power would benefit from this technology to keep critical processes moving.

Large fuel cell installations are a natural for non-attainment areas such as the Dallas-Fort Worth area and the Houston area where clean, reliable electric power is needed.

A strong demand for distributed generation already exists in Texas. Moreover, this demand happens to be located in areas of the state with the worst pollution problems and significant transmission congestion. Pollution reduction and alleviation of transmission congestion constitute the two most significant public benefits that are likely to accrue from wider use of fuel cells for power generation. Consequently, a public policy that strategically targets distributed generation applications will coincidentally target the state's worst pollution problems and some of the most serious transmission problems.

The main constraint on future DG is the requirement that new generation meet air emission standards. Setting cost issues aside, these environmental requirements leave fuel cells (along with natural gas microturbines) as the preferred DG option due to its low emissions and high reliability. This would be especially true for DG applications that combine power generation with heat. The fact that it achieves all the benefits of distributed generation with negligible pollution gives FCDG a strong competitive advantage in the state's two most lucrative distributed generation markets: Dallas-Fort Worth and Houston.

The Texas Commission on Environmental Quality has put in place streamlined air permitting procedures that allow quick approval of FCDG power plants. For example, when municipally owned Austin Energy installed a 200 kW demonstration DG fuel cell, it received its state air permit in less time than it took to obtain the city building permits it needed.

ENSURING ADEQUACY OF ELECTRIC SUPPLY

Perhaps the biggest challenge facing the electric industry in the new world of competition is ensuring that the state's major metropolitan areas will continue to be served by an adequate amount of generation and transmission capacity well into the future. In-migration continues to drive growth in the DFW and Houston metropolitan areas. But installed capacity at major generation plants in these areas will remain virtually the same for many years to come due to the failure to attain air quality standards.

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The critical period for electric supply problems is the peak demand months, which in Texas occurs from June through September. The grid must have enough generation capacity to accommodate the one moment during the summer when the most air conditioners are turned on, the most number of refrigerators are running, and the overall demand for power is the highest.

As increasing electric demand pushes ever harder against the limits of nearby generation capacity, the transmission system also begins to press its operating limits at more locations more often. Transmission congestion makes it difficult to move power to everyplace it is needed, and makes it easier to manipulate local shortages and artificially drive wholesale power prices higher.

An effective strategy for staving off supply shortages combines three elements: less consumption, more generation, and more power imports from elsewhere in ERCOT.

FCDG is an effective means of reducing the use of grid power, and is one of the few ways of adding more generation in areas where emission standards limit the construction of new fossil fuel generating plants. The major benefits to the grid would include:

- Less need to import power from elsewhere in ERCOT;
- Fewer local distribution bottlenecks; and
- Fewer opportunities for market manipulation, as a market with many small decentralized resources is harder to monopolize than one with a few large resources.

Table 3 shows how tight demand, generation and transfer capacity are in the four county Dallas-Fort Worth region (which is part of ERCOT's north congestion management zone) and in the Houston area. ERCOT forecasts that local generators will provide only 36% of that DFW's 2002 summer peak demand. The rest will have to come from elsewhere. There will not be much slack across the north zone, however, as zonal demand is only slightly less than the capacity expected to be available. In addition, transporting power into the north zone is constrained at two points: near Temple to the south and near Graham to the west. Transmission into Houston from the South Zone is constrained on the line from the South Texas Project in Matagorda County to Brazoria County. (See Figure 1.)

Bidders have paid more than $45 million for the right to send power across the two transmission constraints into the north zone, and $30.2 million for rights to the constrained south-to-Houston line. This reflects the scarcity value of transmission into the zone generally, but it also suggests the market value of reducing peak demand through large-scale deployment of FCDG. Eventually, the $45 million will have to be paid by entities serving retail customers throughout the north zone, and these costs will not go away any time soon. Peak demand in the DFW area is expected to grow by 380 MW annually throughout the early part of the decade, but it will be difficult for the area to add new generation to replace its aging capacity. The Commission and ERCOT have identified priority transmission projects that are to be in service by the end of 2002, but a long-term solution needs to include aggressive conservation measures and capacity additions.

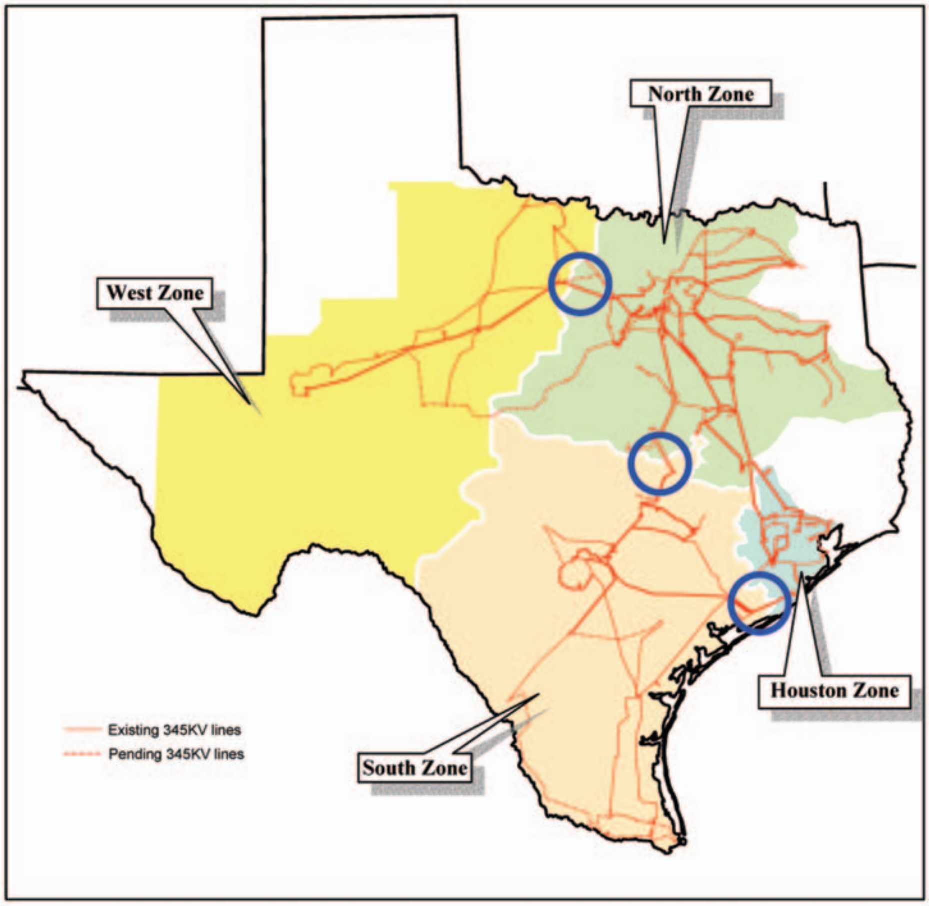

Figure 1: ERCOT major transmission lines and 2003 congestion management zones

FCDG can play an important role in ensuring adequate electric service for the state's metropolitan areas. For this purpose, it is not necessary for FCDG to replace large amounts of conventional generation, because the critical supply problems are most likely to occur at the margin. The incremental capacity that can be provided by FCDG could provide enough of a margin to help avert serious market problems.

See next month's issue for Part II, the Obstacles to Stationary Fuel Cell Generation.

TROUBLESHOOTING VACUUM BOTTLE FAILURE ALARMS

Vacuum interrupter failure alarms and lockouts can occur for a number of reasons, some are valid and the tap changer should not continue to be operated automatically. In the event a vacuum interrupter failure alarm occurs and cannot be reset, further attempts to operate the LTC in manual or automatic mode should not be attempted. If this happens follow the instruction manual provided by the original manufacturer. For random or intermittent vacuum failure alarms, the following information is intended to aid in troubleshooting the cause of the alarms. When this occurs, it is helpful to make note of the conditions at the time the alarm is indicated. The following information should be gathered, when possible:

a. How many operations has the tap changer seen before the first alarm and how many operations occur between alarms?

b. How frequently are the alarms occurring?

c. What is the range of taps the LTC is operating over?

d. Does the alarm occur while the LTC is operating in the raise direction, the lower direction, or both?

e. Does the alarm occur while operating in one direction or when the LTC reverses direction?

f. Does the alarm occur on a particular tap location every time?

g. Where, during the tap change sequence, does the alarm occur?

Once some or all of these questions are answered, resolving the false alarm may result in the need to perform an internal inspection of the LTC mechanism and possibly do diagnostic tests. The following is a list of possible causes for real and false vacuum interrupter failure alarms and details on how to investigate them.

1. Vacuum interrupters lost vacuum (insulation breakdown)
2. Internal clearance Between live parts less than required
3. Switching transients in station triggering sensing circuit
4. Interrupter mechanism fails to open/close
5. CT shorting switch not working properly

Fig. 1: Checking the interrupter bottle pre-travel

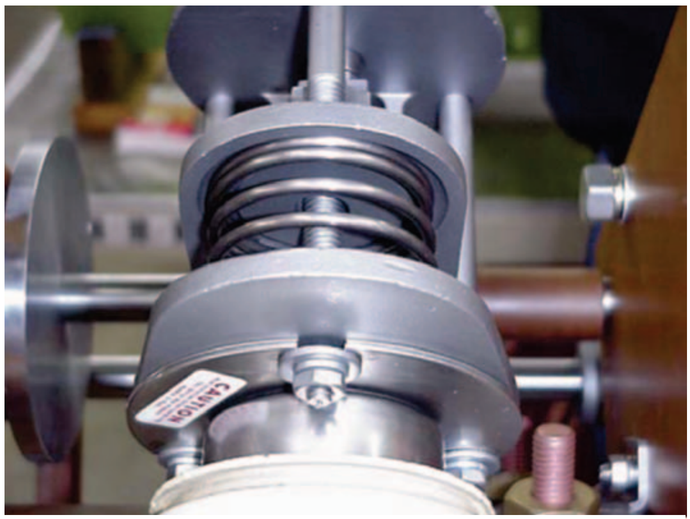

Fig. 2: Alignment of stud through upper actuator arm

DETAILED TROUBLESHOOTING

Vacuum interrupters lost vacuum (insulation breakdown)

The most probable cause for an interrupter failure alarm that cannot be reset is an actual failure of the vacuum interrupter itself. This is usually due to an interrupter losing some vacuum pressure or from heavy external contamination on the outside of the vacuum bottle. In either case, all three vacuum interrupters should be hi-pot tested per the installation instructions. Any interrupter that fails this test must be replaced.

Internal clearance Between live parts less than required

The minimum clearance required between any live potential on the LTC mechanism and ground or other potentials is 5/16". If this minimum clearance is not maintained between the vacuum interrupter and leads, electrical discharges can occur resulting in an alarm and lockout. Visually inspect internal clearances of all leads on the LTC and look for evidence of arcing between leads or from leads to ground. Visually inspect each vacuum interrupter for signs of arcing at the ends of the vacuum interrupter to any lead routed near it. This could result in an alarm that may or may not be reset.

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Fig. 3: Alignment of vacuum interrupter shaft through upper actuator arm

Fig. 4: Operating the vacuum interrupter assembly by hand

Fig 5 Checking Dashpot Baffle Plate Movement

SWITCHING TRANSIENTS IN STATION TRIGGERING SENSING CIRCUIT

Lockouts and alarms caused by this tend to be random in nature and easily correlated to switching events on the transformer or in close proximity to the transformer. A search for this should include checking all ground connections as well as control circuit connections to insure they are tight and the wiring is in good condition. A second cause of this could be the sensing circuit itself failing. If possible, a replacement sensing circuit can be installed to verify the circuit is operating properly.

One other possible fix is to replace the original silicon controlled rectifier (SCR) # 2N1595 in the sensing circuit with a new SCR # 2N682 that is less sensitive to transients. The 2N682 SCR is a stud-mounted device so it would require drilling a hole in the control circuit board to mount it. It is recommended that you consult with a GE service representative for further details before attempting this fix.

INTERRUPTER MECHANISM FAILS TO OPEN / CLOSE

A mechanical failure of the interrupter mechanism to open/close will typically result in an alarm that can be reset. This problem, even if intermittent, can usually be detected by visual inspection with the transformer de-energized and the LTC compartment open. The LTC can be operated both electrically and manually using a hand crank in the raise and lower directions while visually inspecting the operation of the interrupter assemblies. Obvious indications of problems include broken or binding parts associated with the vacuum interrupter assemblies, or arcing on the leading edges of the vacuum bypass blade and/or selector contacts. Other items to check here are as follows:

A. Verify the vacuum interrupter pre-travel by measuring the gap between the upper actuator arm and the drive nut (refer to Fig. 1). This gap should be .125” +/- .010” with the vacuum interrupter in the closed position. This insures the drive nut strikes the upper actuator arm with enough force to throw the vacuum interrupter open.

B. Carefully inspect the alignment of the hole through the upper actuator arm with respect to the 5/16” threaded stud going through it (refer to Fig. 2). If this stud is not centered in the hole of the upper actuator arm, the arm can bind on the threads of the stud and prevent the interrupter mechanism from operating freely. If this occurs the vacuum interrupter should be replaced.

C. Carefully inspect the alignment of the movable shaft on the vacuum interrupter where it passes through the hole in the upper actuator arm to insure there is no binding between the parts (refer to Fig. 3). If the vacuum interrupter is not centered through the hole in the arm and is binding during operation the vacuum interrupter mechanism should be replaced.

D. With the LTC off position and the vacuum interrupter open, release the latch block on the interrupter assembly with one hand while squeezing the upper actuator arm towards the interrupter mounting bracket to close the vacuum interrupter (refer to Fig.4). Do this on all three phases several times to insure the vacuum interrupter operates freely. Any signs of binding or slow operation should be investigated further and/or replacement of the suspect vacuum interrupter assembly be performed.

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A HOLISTIC APPROACH TO DISTRIBUTION NETWORK MODELING

By Bruce Seidel, JCMB Technology Inc. and Gary Smith, Sierra Pacific Power Company

Have you ever taken the time to inventory the number of applications you use to manage distribution operations? From new construction design to life cycle maintenance and equipment retirement, you'll find numerous applications that have been acquired over the years. Let's name a few:

- New construction design
- Engineering analysis
- Automated mapping or GIS
- Outage management
- Distribution SCADA
- Work management
- Mobile computing
- Network maintenance

This presentation deals with the fact that many of these applications require common data from the Distribution Network Model. Yet, when you analyze the manner in which these applications have been implemented, you find that the same exact data is being maintained separately in each application.

This observation has come from the fact that my company, a distribution network data specialty house, is almost always asked to consolidate a number of disparate data sources in the creation of a Distribution Network Model.

Let's have a look at the reasons why this has come to be.

It seems obvious that if you're going to maintain an accurate, single phase model of your distribution circuits, that it be done in one place only, in order to reduce errors and costs. As obvious as this may seem to us, we believe there are three main reasons for which this methodology is not being applied in most utility companies today.

1 - INDEPENDENT ACQUISITIONS

The distribution operations activity spans many departments with separate budgets and priorities. The design department, the operations department and the maintenance department acquire applications that are specific to their own needs, independently.

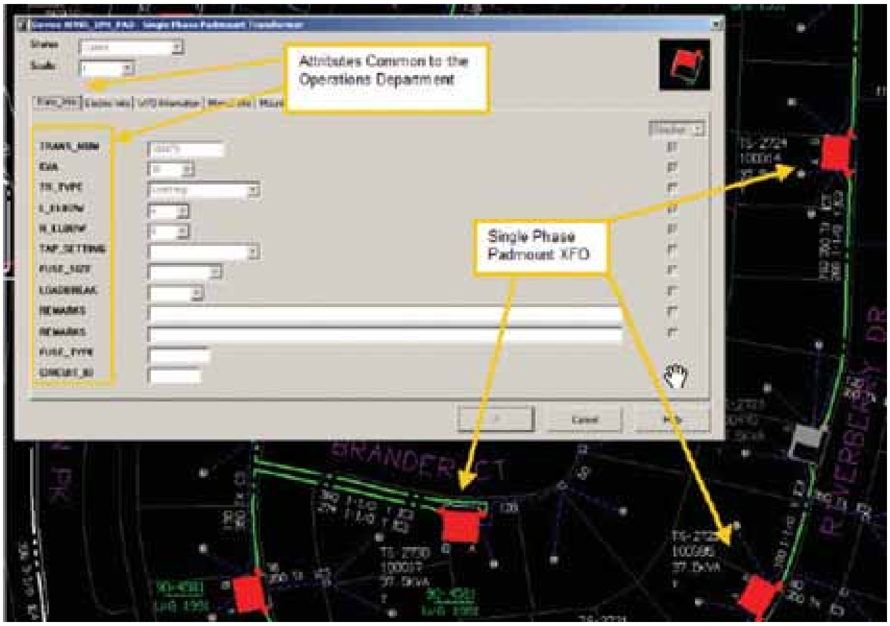
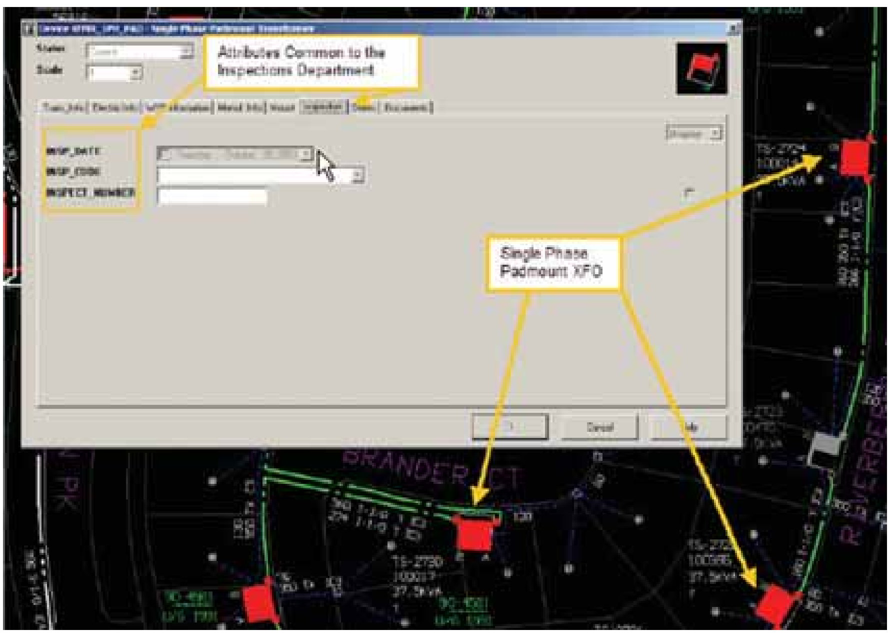


Figure 1 (above); Figure 2 (below)



2 - DEVICE ATTRIBUTION

If you analyze both the data requirements of a new construction design application and those of an outage management system, you will notice a common cross section of device attributes

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failure alarms

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E. Verify the wear indicator pin is centered in the hole of the wear indicator plate, and that it moves freely through the hole in the back side of the dashpot on top of the interrupter assembly.

F. Verify the dashpot baffle plate is not binding by inserting a small rod through the holes of the dashpot assembly and pushing down on the baffle plate (refer to Fig 5). If this plate is binding and not moving freely, sluggish operation of the vacuum assembly can occur, possibly resulting in vacuum failure alarms.

G. Verify the auxiliary cam and roller on the dual slope cam assemblies that control the opening and closing of the interrupter assemblies operate freely. Push/pull auxiliary cam with the LTC in position to insure it moves freely and the follower roller stays within the "V" shaped portion of the auxiliary cam (refer to Fig 6 & 7).

Binding of the auxiliary cam against the center cam can result in the interrupter not opening properly.

CT SHORTING SWITCH NOT OPERATING PROPERLY

The timing and operation of the CT shorting switch is critical to proper operation of the vacuum interrupter failure sensing circuit. During a tap change operation, the CT shorting switch should open just after the vacuum interrupters open and close just before the interrupters close.

If it opens prior to the interrupters opening or closes after the interrupters closing, a false failure alarm will occur. Proper CT shorting switch operation can be checked by using an ohm meter to indicate if the switch is opening and closing as expected.

Proper sequence of the CT shorting switch with the interrupters can be verified by visual observation. If the sequence of switching does not occur in the proper order, vacuum interrupter failure alarms can occur.

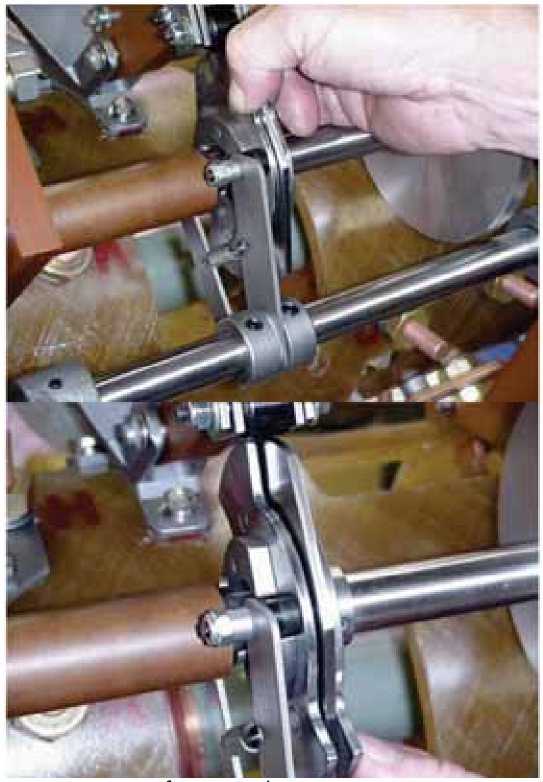


Fig. 6 & 7: Verifying auxiliary cam operation

COLLABORATIVE STUDY ON CORROSIVE SULFUR IN EARLY STAGES

By Paul J. Griffin and Lance R. Lewand, Doble Engineering Company

The problem of corrosive sulfur has reappeared after not being a significant issue for decades. In the past few years there have been a number of failures of very large power transformers and shunt reactors due to corrosive sulfur. This has occurred even though the electrical insulating mineral oils passed international standard test methods including ASTM D 1275 and DIN 51353.

The problem occurs because the corrosive sulfur reacts with copper conductors and silver contacts to form metal sulfides that contaminate the insulating paper. Since metal sulfides are conductive, the dielectric breakdown strength of the paper is reduced. Under some conditions, a breakdown occurs through the insulation between conductor strands on a disk or between disks.

In one example, there is evidence of discharge activity on the paper-wrapped conductor strands facing the center axis of this four year old transformer winding. This discharge activity ultimately leads to apparatus failure. Although the number of failures has been small, the value of assets lost has been substantial. Problems have been reported from many countries. Doble has organized a research program to investigate this problem. The details are available using this link:

http://www.doble.com/content/services/IM_03_Investigating_Copper_Sulfide_Contamination_Lewand_Paper.pdf

More than 25 companies have joined the collaborative study including transformer oil refiners, apparatus manufacturers, utilities, and an insurance company. This is an industry problem that needs to be resolved through improved specifications, a better understanding of the corrosion process, and methods for detection and mitigation.

Although copper sulfide cannot be removed there are methods that might greatly reduce further formation of conductive metal-sulfur compounds in problem units. Researching this problem as a group, representing a cross-section of the industry, provides substance and can help accelerate changes required to detect and mitigate.

Evidence of Discharge Activity on a Disk From a Failed Transformer

WHAT TRANSFORMERS AND REACTORS ARE MOST SUSCEPTIBLE?

Transformers with oils that do not meet the Doble modified corrosive sulfur tests are more susceptible to this problem.

The most recent revision of the Doble Transformer Oil Purchase Specification includes important details. The problem with corrosive sulfur is both time and temperature dependent. The longer an apparatus operates at higher temperatures with an oil containing excessive amounts of corrosive sulfur, the greater the corrosion and formation of metal sulfides. Sealed transformers are more susceptible to the corrosive sulfur problem as oxygen reacts with copper and organo-metallic compounds which compete for reaction sites with the corrosive sulfur. This slows down the formation of the conductive metal sulfides but does not stop their formation. Lower voltage apparatus have can have an advantage if the copper conductors are coated with enamel insulation. The enamel creates a barrier preventing reaction with the corrosive sulfur. The various factors that can influence copper sulfide formation will be investigated in the collaborative study.

HOW CAN THE PROBLEM BE PREVENTED?

Standards organizations need to revise present specifications for a more rigorous evaluation for corrosive sulfur. At Doble Engineering Company, we have revised our insulating mineral oil specification requirements for corrosive sulfur by modifying the present ASTM method D 1275. The modifications include extending the duration of the test from 19 to 48 hours and increasing the test temperature from 140ºC to 150ºC.

Some added precautions are taken to minimize the oxygen content in the test oil. In testing to date, we have found that the oils from failed transformers with evidence of copper sulfide formation did not pass this modified test, but did pass the present ASTM method. As additional research is performed, it is likely that new methods will be developed. Part of the collaborative study is to evaluate test methods for detecting the corrosive sulfur. However, to help prevent this problem from becoming widespread immediate use of Doble more rigorous test method is recommended.

See the Doble Transformer Oil Purchase Specification as revised January 1, 2006 for details. TOPS can be downloaded from the following link:
http://www.doble.com/services/lab_services_transformer_oil_specs.html

HOW CAN THE PROBLEM BE DETECTED IN EXISTING EQUIPMENT?

All failures have occurred without prior evidence of an incipient fault. This makes the problem difficult to detect and manage. The failures have occurred after from one to several years of apparatus being in service. The corrosion process appears to take this time to form critical amounts of conductive sulfides. Dissolved gas-in-oil tests are routinely used to detect developing problems from over-heating, partial discharge activity, or arcing. To date dissolved gas-in-oil has not given any indication of partial discharge activity or arcing in these units, even when a sample was taken one day before the failure. Although there can be an in increase in the insulation power factor, this test has not been found to routinely detect this problem when performed in the standard fashion. Some laboratory investigations using power factor have been shown to detect copper sulfide in paper under some conditions. More research is needed to determine if this can be applied to apparatus in the field. As part of the collaborative study electrical tests will be evaluated to see which might be able to detect significant contamination of the cellulosic insulation.

RESEARCH EFFORTS AND POTENTIAL SOLUTIONS

It is likely that there is a substantial amount of oil in service in large power transformers that can cause the sulfur corrosion problems. Although these oils with excessive amounts of corrosive sulfur represent a very small percentage of the total oil volume in service, it is still important as copper corrosion and sulfide formation cannot be reversed. It is possible to mitigate against further significant corrosion.

Possible methods include removal of the corrosive sulfur compounds, oil replacement, partial oil replacement, and passivation using metal deactivators. No simple means for removing corrosive sulfur compounds from the oil has been developed. Depending on the size of the problem this may be an area for future research. Preliminary studies at the Doble Laboratory have shown that mineral oils can have considerable differences in the temperatures at which they will begin to form copper sulfide under test conditions.

Further studies will be performed. Mixing higher corrosive sulfur content oils with those having very low sulfur content can significantly improve the former's characteristics well beyond acceptable limits. Another method that has been employed is the use of a passivator that binds up some of the active sites on the metal surface retarding reactions with corrosive sulfur. More research is need and will be performed as part of the collaborative study, to better understand how well these methods will work and the long-term benefits. For the immediate future these methods appear to be promising and could help mitigate developing problems.

Some companies have already started using these approaches; and we will be monitoring and evaluating the effectiveness as part of our study.

How do I Join? Contact Paul Griffin by emailing him: pgriffin@doble.com

Please don't hesitate to share your thoughts on this article. Send your opinions and comments to: DobleExchange@doble.com. We are always interested in Doble-Tested case studies and field photographs from the Client Community.

SUBSTATION RELATED AUTOMATION AND INTEGRATION PROGRAM SPENDING ON THE RISE WORLDWIDE

By Eric Leivo and Chuck Newton, Newton-Evans Research

According to recently published research, the current annual global spending for substation automation and integration programs is pegged at about $550-600 million, with an overall potential market size of nearly $40 billion.

More Than 80% of Global Utility Respondents Claim to Have Substation Automation and Integration Programs Underway

Findings from a newly published four volume research series entitled: The World Market for Substation Automation and Integration Programs in Electric Utilities: 2005-2007 compares the current round of research findings with earlier studies conducted by Newton-Evans Research.

Additional Observations:

• The years 2002-2004 were slow growth - or no growth - years in most categories of intelligent electronic equipment sales related to the modern, increasingly digital, electric power substation. Few retrofit programs were undertaken except for the most critical of substations.

• Increasingly, it is becoming more difficult to separate substation product classifications as manufacturers tout their platforms as “multifunctional” and the product positioning of many electronic devices now cuts across multiple product classifications.

• Newton-Evans further estimates that only about 12% of utility operated substations have been fully automated and integrated by year end 2005. Most of these are, in fact, newly or recently constructed substations.

• Most substation equipment manufacturers (mid size and smaller companies) and integrators surveyed in the second half of 2005 have indicated some moderate-to-good growth market conditions within their utility sales sectors, resulting in sales that are as much as 5% to 15% higher than 2003 or 2004 sales levels.

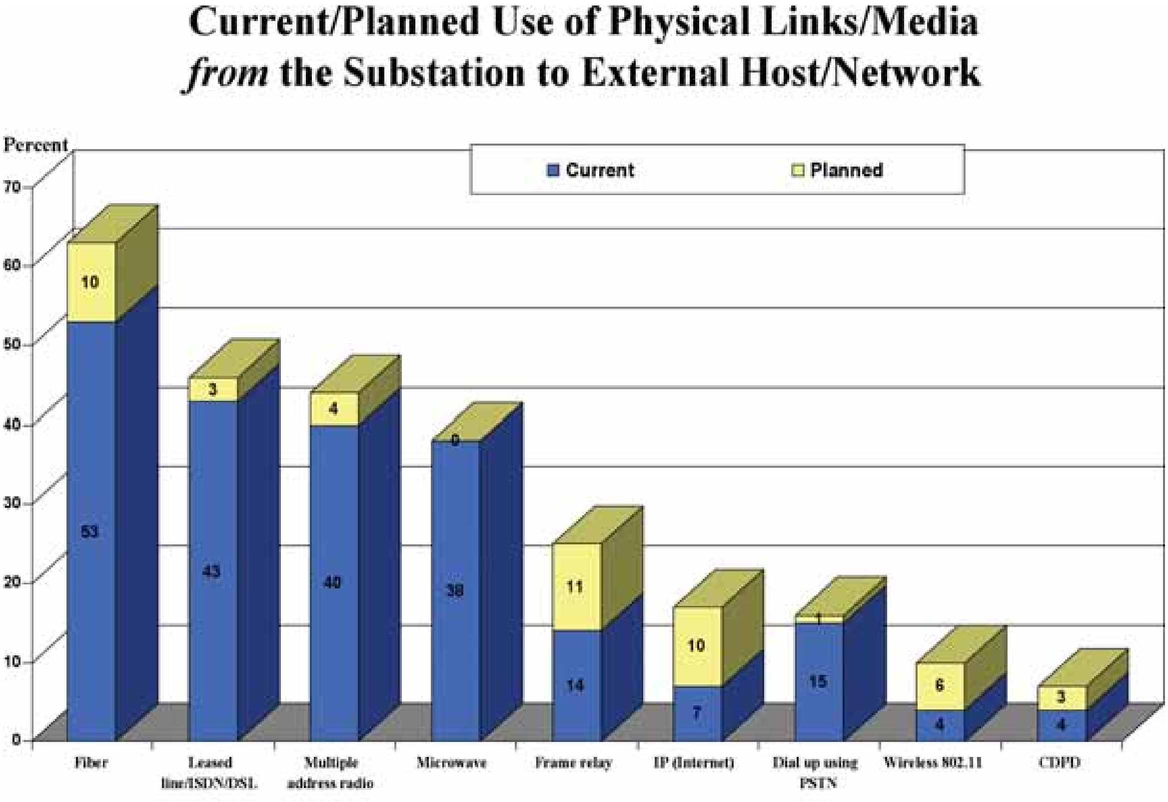
• Economic growth has continued in many electricity dependent sectors. In turn, this spurs demand for increased electric power, and increasingly reliable power. This results in internal planning for infrastructure and automation programs.

• There remains some concern in the industry about the dearth of skilled engineering resources due to retirements and layoffs. This may further impact the ability of technology supplier companies to engage utilities for other than short-term requirements. However, third party engineering and integration service firms are now making significant strides in winning substation automation-related business from planning to design to construction.

• If distributed generation activities continue to increase across the world, there is some positive benefit that will occur for the substation automation, integration and retrofit business, as utilities become more involved with distributed generation (DG) efforts.

• In summary, retrofit substations will be upgraded as warranted, based on load growth, criticality to customers, and development of DG programs. New substations will increasingly be designed and constructed as integrated and automated remote assets for the utility.

• Protocol use and plans among North American electric power utilities continue to differ from the trends among utilities in the international communities. North American utilities continue to strongly support DNP 3, and will likely migrate to a LAN version of this protocol. See the comparative charts at



the end of the release.

• International utilities tend to use IEC protocols. Currently, the 60870-5-103 protocol is popular, especially in Europe, while migration to IEC 61850 is underway in Europe, the Middle East and Africa, and among some of the largest utilities elsewhere. Nonetheless, Latin American and Asian Pacific utilities report strong use of Modbus and Asia-Pacific utilities tend to align themselves more with DNP 3 at the present time.

The four volumes of reports comprising the 2005-2007 series on substation automation and integration have been published by Newton-Evans Research during the first quarter of 2006:

• Volume One is the North American market study of more than 100 participating electric utilities.

• Volume Two contains information on the international substation automation marketplace, based on study participation from 53 utilities in 36 countries throughout the world.

• In Volume Three of the study, nearly 50 suppliers of substation automation systems, equipment and services are profiled.

• Volume Four is an assessment of the North American and international substation automation market

Additional topics being covered in the series of substation studies include cyber and physical security practices, voltage ranges used to power substation automation equipment, external systems linkages to the substation, preferred equipment suppliers, and an assessment of where the world's electric power substations are positioned along a five-phase path to complete automation.

For more information on the "Worldwide Market for Substation Automation and Integration Programs in Electric Utilities: 2005-2007", you can contact Newton-Evans Research Company at www.newton-evans.com.

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acquired by both, as well as specific device attributes required by only one application.

Does the operations department really care about accurate span length? Yet, all departments are concerned with unique device IDs.

3 - DATA EXCHANGE

Given the fact that these applications come from numerous vendors and that the technology behind these applications evolves quickly, I am afraid to report that the majority of application data exchange strategies we've seen thus far, either limp along or are abandoned completely.

Let's have a look at these three issues in a little more detail.

All of our customers have acquired some of the applications I mentioned earlier, over a number of years and through separate departmental initiatives.

For instance, if senior management has mandated a reduction in the per customer hook up charge in a given budget year, the new construction design department would most likely have acquired and implemented design engineering applications. Likewise, if the push was on outage restoration, the operations group would have been purchasing an outage management system.

If you stretch this phenomenon over a twenty-year period, you end up with multiple applications each having their own databases and data sources, and each being maintained by separate departments.

The opportunity here is that the required distribution data is often common among the various applications. If the majority of the data is common, you can reduce the costs and errors associated with maintaining it.

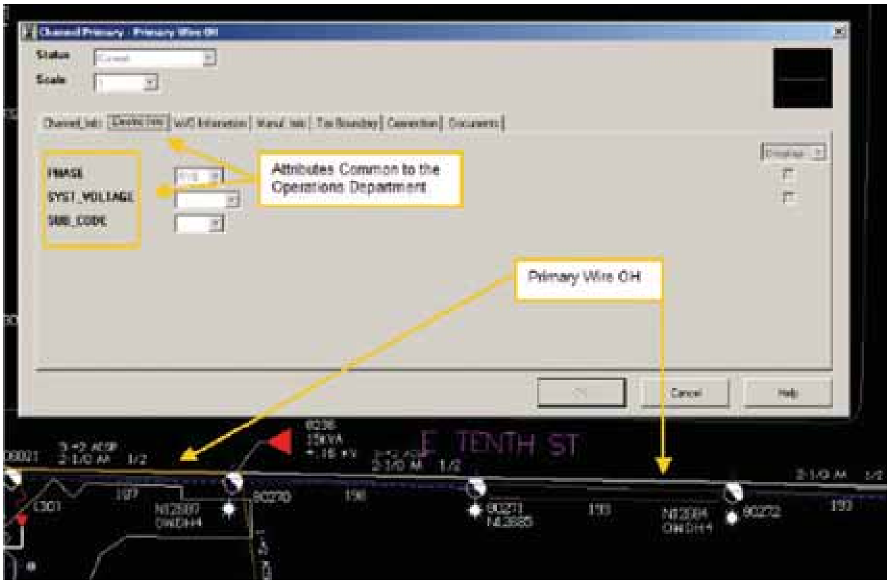
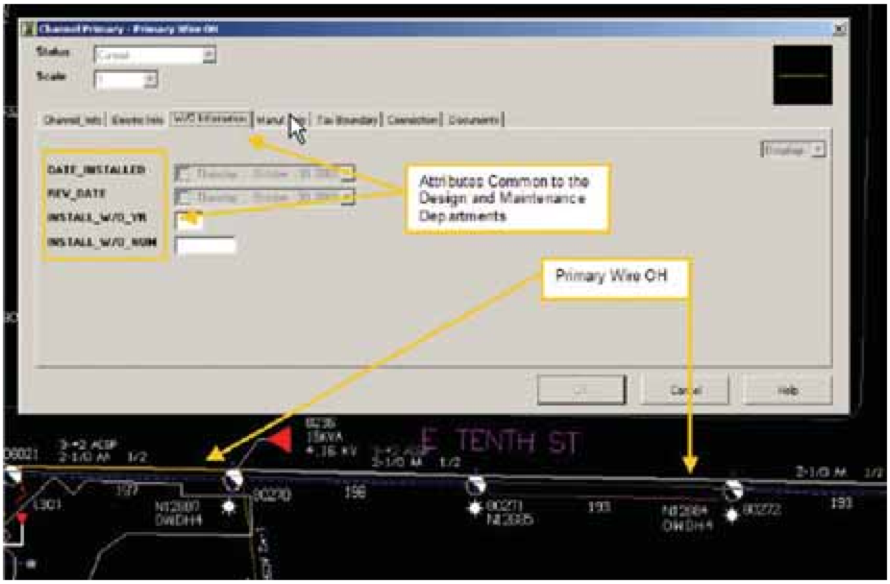


Figure 3 (above); Figure 4 (below)



DEVICE ATTRIBUTION

We define device attribution as all of the data details associated with a given distribution entity such as a conductor, transformer or switch. These attributes can be displayed and maintained in a database or deduced from the connectivity relationships of equipment.

The interesting observation here is that most of the applications used in distribution operations share roughly 70% of these attributes. As a result of independent applications and departments, these common data attributes are maintained in as many as four or five different databases. The result of course, is the opening for errors and data conflicts as well as the additional cost of maintaining multiple databases.

DATA EXCHANGE

Given the fact that most of these applications already exist (and therefore their databases exist), the obvious answer is to create data exchange mechanisms between applications. Over the last five years, we've seen several utilities combine new construction design data with GIS and Outage Management. Most of these initiatives haven't worked out primarily because the data models and proprietary applications made the data exchange inaccurate or untimely.

As an application designer, if you did not take into consideration data exchange when you built your application and its data model, extracting and importing data from another environment is very difficult. The result is that our customers end up with standalone applications and data models and they often struggle to find custom ways of exchanging data.

EXAMPLES

We'll take a closer look at two of our favorite devices that contain common and unique data attributes.

First we will look at a typical pad mount transformer and its attributes. We've highlighted those attributes that are common between applications and the ones that are unique.

Next we will examine a typical distribution conductor.

The span length and birth date are of little interest to the Operations department but are of vital importance to both Design and Maintenance, whereas the phase attribute of the conductor is of tremendous importance to Operations and of little value to Design and Maintenance.

Another general observation is that the X, Y position of the device is far more important to the design and network analysis functions, but of less interest to operations; this is simply due to the fact that the crew does not require a precise location in order to perform its job.

CUSTOMER RECORDS-ANOTHER IMPORTANT COMPONENT TO CONSIDER

Very few Distribution Network Models today include customer records as part of the model.

Since the Customer Information System (CIS) typically includes customer records and their service meter or transformer, does the customer record belong in the model?

We think so.

We believe that customer records belong in both the CIS and the Distribution Network Model. The primary reason for this vision is that GIS Mapping systems allow dispatch and control center operators to visualize the relationship between electrical equipment and customers.

What we want to achieve, is a visual appreciation for the number and type of customers affected by planned or unplanned outages. In addition, providing operations personnel with customer data allows them to communicate with customers and we believe, ultimately improve the quality of service they are able to offer.

The concept of including customer records within the Distribution Network Model requires forethought in the specification and implementation of CIS and GIS systems, starting with the data first.

DATA SERVICES CONCEPT

The first step is to assume that over a ten to twenty year-period you will be acquiring and implementing the following applications, in order to keep up with your competitors.

- Design
- Network analysis
- Automated mapping GIS
- Work management
- Outage management
- Mobile computing
- Customer Information Systems

The next step is to predict the Distribution Network Model data that is both critical and common to these applications - a sort of inventory of your data.

The questions to ask are:

- Where is the data today?
- Are there multiple sources?
- Are the multiple sources current?
- Do I have access to these sources?

The last step is to go one level deeper - since as we all know, "the devil is in the details"! It is insufficient to say that the device entities themselves are common. We need to actually analyze the individual data attributes pertaining to each device.

It is insufficient to say that the device entities themselves are common. We need to actually analyze the individual data attributes pertaining to each device.

Sounds painful? It is.

It is also time-consuming and expensive, since this task requires input from many departmental experts. However, we believe that equipment attribution analysis made upfront ultimately saves tens if not hundreds of thousands of dollars per year. A worthwhile investment.

OUR VISION

What we are suggesting is that you start with a data centric approach to all of the applications you believe will be used in

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RF PROPAGATION CHARACTERISTICS AND THEIR IMPACT ON AMR SYSTEMS

By Dan Merritt, Badger Meter Inc.

The vast majority of Automatic Meter Reading (AMR) systems installed in water utilities use radio frequency (RF)-based communication systems.

Radio transmitters are also widely used in utilities for applications such as voice communications with two-way radios, wireless SCADA systems, and the ubiquitous cell phone. An AMR transmitter, or transponder, is located at or near the utility meter and transmits the meter reading and other meter information. A receiver located in a utility vehicle traveling the neighborhood or carried by a utility employee walking nearby streets, will receive the information and store it for later downloading into the utility billing system. Alternatively, a utility might employ a "fixed network" solution, in which the meter data is transmitted directly via radio relay units to a computer at the utility central office, instead of using "walk-by" or "drive-by" methods. Regardless of the data collection method, a radio frequency signal is utilized for the communications link in these types of AMR systems.

RADIO PROPAGATION - SENDING DATA THROUGH THE AIR

The radio signal is actually an electromagnetic wave caused by electrons vibrating, or oscillating, at the transmitting antenna. The movement of the wave leaving the transmitting antenna into the air is called RF propagation (RFP). The behavior of the RF signal can be difficult to predict due to a variety of physical phenomena. RFP is also dependent on environmental conditions, both constant and temporary, that exist around and between the transmitter and receiver. Since the quality of the communications link between any given transmitter and receiver is affected by these phenomena and environmental conditions, installers and users of AMR systems should understand the basics of RFP to make the optimum use of this technology.

The frequencies typically used by utility AMR systems (450 MHz licensed band or 900 MHz non-licensed band) are often referred to as "line of sight" communications. That is, ideally the transmitter and the receiver are located so that they "see" each other, with the radio waves passing through the air unimpeded between the two antennas. But this ideal condition is rarely found in AMR applications. Clear line-of-sight conditions are often hindered by obstructions such as trees and vegetation, buildings and other structures, vehicles, and uneven terrain between the two antennas.

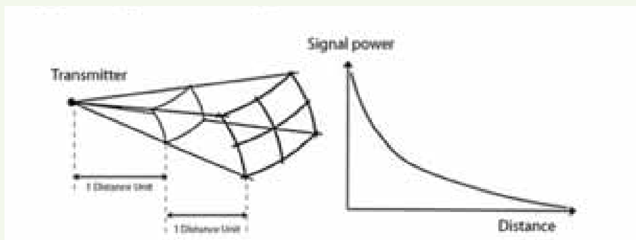

Figure 1. Radio energy is dispersed over larger areas as the distance from the source increases. This results in the wave weakening, or attenuating, as the distance from the source increases. For the change of one distance unit, the signal is only one quarter as strong.

Table 1.
Some factors affecting line of sight communications:

• Free-space attenuation	• Scattering
• Absorption	• Transmitter power
• Reflection	• Receiver sensitivity
• Diffraction	• Antenna design & configuration

RFP, and the resultant maximum distance between transmitter and receiver, is a function of the environment the two devices operate in at any given moment, which includes the effects of free-space attenuation, absorption, reflections, diffraction, and scattering. It is also a function of the design of the equipment itself, the transmission power level, and antenna configuration. See Table 1.

THE IDEAL SCENARIO AND FREE-SPACE ATTENUATION

Ideal conditions exist when the two devices have an unobstructed line of sight between the antennas and there are no nearby buildings, trees, and other objects that might influence the RFP. The radio signal behaves like light in free space. As the radio energy expands outward from its source, the energy is dispersed over an increasingly greater area. However, this dispersion causes the radio waves to weaken as they travel away from the transmitter. The weakening, or attenuation, grows rapidly with distance; in fact, the signal weakens with the square of the distance traveled. For example, if the distance between transmitter and receiver is increased 10 times, the signal will only be 1/100 as strong (1 divided by 10-squared).

Free-space attenuation is a significant factor governing strength of an AMR transponder signal. Refer to Figures 1 and 2.

Figure 2. Ideal conditions include unobstructed line of sight between the transmitter and receiver.

ABSORPTION

RF energy is also lost to absorption when radio waves travel through media other than a vacuum. Any non-conducting objects between the antennas of the transmitter and receiver will absorb some of the signal. In particular, large dense objects such as thick concrete walls (especially with no windows), houses, trees and other foliage all tend to significantly absorb AMR signals.

In pit applications, a composite pit lid itself can absorb some of the signal of transmitters mounted below the pit lid. The RF signal of a pit transmitter may also be hampered by absorption by water in a flooded pit.

From day to day and season to season, any particular installation may have changing absorption characteristics. During the summer, trees will have more absorption due to foliage. Wet trees absorb more than dry trees; pine trees absorb more than leafy trees. Thick fog and torrential downpours absorb RF signals. Snow buildup around a remotely mounted transmitter causes some degradation. Debris on pit lids, such as grass, dirt, and bark will also absorb the signal. And absorption characteristics for a specific installation can change permanently due to additions and removal of various objects in the area, such as new or renovated buildings, landscaping changes, etc.

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AMR systems

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It is important to understand that the more absorption that occurs in a specific situation, the closer the receiver may need to be to the transmitter to receive the signal. See Figure 3.

Figure 3. RF energy is absorbed by non-conducting objects between the transmitter and receiver, thereby reducing the effective range.

REFLECTION

At frequencies used by AMR systems, RF signal reflections occur from a variety of conducting objects, such as metal structures, aluminum siding, walls with metal lathe or rebar, chain link fences, cars and trucks, metal pit lids, water towers, etc. Objects such as a large truck parked over or near a pit transponder can cause temporary signal degradation due to reflections in undesired directions. Radio signals traveling over relatively smooth ground or bodies of water can also experience “ground reflections”. Other sources of reflections can be sides of buildings, especially in urban areas. Reflections can severely impact line of sight communications but they might also result in reception of the signal in unanticipated locations. See Figure 4.

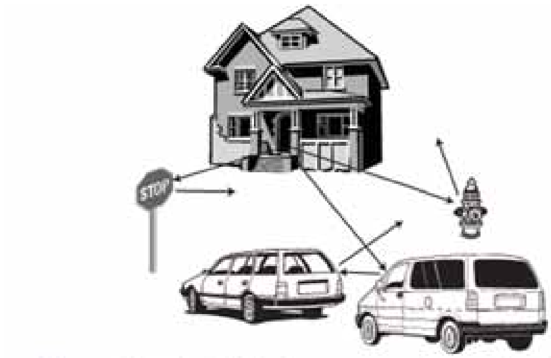

Figure 4. RF signal reflection can occur with a variety of conducting objects. Multiple reflections make predicting signal strength at a given location difficult.

DIFFRACTION

Radio waves can also pass behind solid objects with sharp edges, by knife-edge diffraction. Abrupt changes in nearby terrain can lead to diffraction, as can the sharp edges of buildings. Diffraction is a common natural phenomenon that affects light, sound, radio, and other coherent waves.

Knife-edge diffraction allows the potential of communication even though the line of sight is entirely obstructed. See Figure 5.

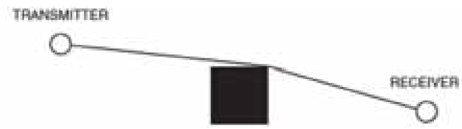

Figure 5. Diffraction occurs when a radio signal encounters a surface with sharp edges, resulting in a bending of the radio wave.

SCATTERING

The direction of radio waves can also be altered through scattering. The effect seen by a beam of light attempting to penetrate fog is a good example of light-wave scattering. Radio waves are similarly scattered when they encounter randomly arranged objects of wavelength size or smaller, such as masses of electrons, water droplets, or even some vegetation. See Figure 6.

Figure 6. Radio waves are scattered when encountering particles such as rain or fog that are equal to or smaller than the wavelength of the signal.

ANTENNA ORIENTATION

The AMR transmitter has an integral antenna that radiates the radio waves and the receiver has an antenna that collects the wave. The designs of the antennas are optimized by the manufacturer to the specific equipment and include a particular orientation of each antenna with respect to the other. Maximum signal strength between transmitter and receiver occurs when both antennas are using identical orientation, or polarization; manufacturer's installation instructions will indicate the proper installation guidelines of both the transmitter and receiver antenna to achieve proper polarization.

Significant signal degradation can occur if there is a misalignment of the two antennas. For example, a handheld receiver typically is designed to have the antenna pointed vertically with respect to the ground. Pointing the antenna/receiver at the transmitter can negatively affect its performance Figure 7). Alternatively, a pit transmitter that is simply dropped in the bottom of the pit rather than properly mounted through or below the lid will suffer poor performance due to misaligned antennas (as well as a high degree of RF absorption by the surrounding soil and any water in the pit).

Antennas are also affected by whatever is near them, especially metal objects very close to the antenna. This situation can lead to signal distortion

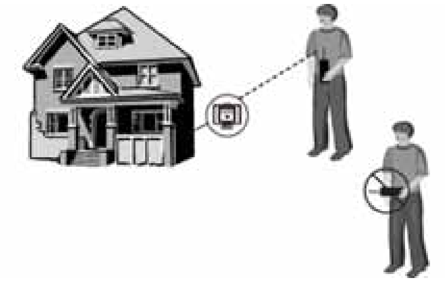

Figure 7. Proper orientation of both transmitter antenna and receiver antenna is defined by the manufacturer to achieve maximum strength. Pointing the receiver antenna at the transmitter negatively affects reception.

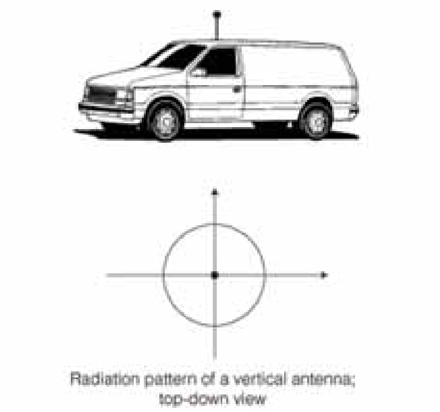

Figure 8. Omni-directional antennas, often used in AMR applications, radiate power as well as receive equally in all directions.

which might negatively affect signal strength.

While most AMR transmitters utilize omni-directional antennas which radiate RF energy equally in all directions (See

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AMR systems

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Figure 8), utility staff may be familiar with directional antennas, such as those used by wireless SCADA transmitters. Directional antennas send the RF energy out in a narrow beam rather than in all directions to provide better signal strength at a fixed receiver location to which the antenna is pointed. As a result, directional antennas exhibit "gain", although this simply means the signal is stronger in the desired direction and weaker in the undesired directions.

Directional antennas, typically larger and more expensive, are not normally used in AMR applications. See Figure 9.

RECEIVER SENSITIVITY

The sensitivity of a receiver defines the minimum signal strength that must be received at its antenna before the signal can be detected and amplified. A more sensitive receiver (usually meaning more expensive) can detect a signal of lower strength. This means, for example, that a less sensitive receiver might not pick up a signal while a more sensitive receiver might detect the signal, even though the two receivers are adjacent to one another.

TRANSMITTER POWER

The transmitter power level is dictated by modern transmitter design, cost objectives, and battery life and capacity considerations. Power levels are also regulated by the Federal Communications Commission (FCC), with limits based on frequency used, licensed versus non-licensed operation, and transmission techniques employed.

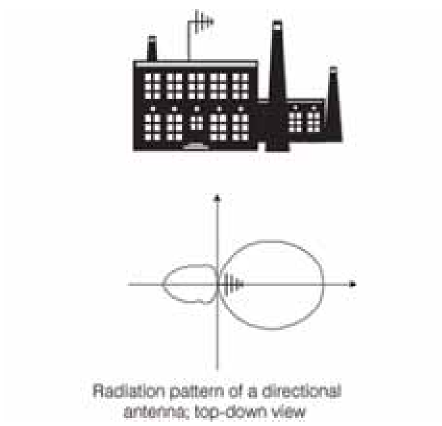

Figure 9. Directional antennas, often used in SCADA systems but rarely in AMR applications, shape the signal to radiate most of the energy in one direction while minimizing radiation in other directions.

REALISTIC SCENARIOS

While the "direct" or "line of sight" signal might be blocked or absorbed by a large dense object, the signal still might be received at a given location as a result of a reflected signal. However, multiple reflections arriving at a given location might cancel each other out due to the varying path lengths of the direct and reflected signals, resulting in the receiver not sensing a signal. As a practical result, there may be a "null" or a "dead zone" at a given location, where a signal cannot be sensed due to the various propagation impairments.

But at a nearby location there may be a "sweet spot" that does not suffer significant propagation impairments. Often,

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- **5 mA output current provides fast charging and testing of capacitive loads**
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10 kV Insulation Tester

A 10 kV Insulation Tester that's ideal for rotating machinery

The new S1-1052 10kV insulation resistance tester is designed specifically to assist the user with the testing and maintenance of high voltage equipment. It offers an increased measurement range to 35 TΩ in order to provide trending values for the best of insulating materials used on higher capitalized equipment.

This model also features an expanded test voltage range from 50 V to 10 kV in 10 V increments and 1 kV to 10 kV in 25 V steps.

- **Line or battery operated**
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- **Noise rejection (2 mA rms @ 200 V and above), for use in high voltage substations and switchyards**
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- **Model MDP3 also records waveform capture and harmonics (used to perform harmonic analysis out to the 32nd harmonic)**
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AMR systems

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simply moving the receiver a slight distance may result in moving from a dead zone to a sweet spot, resulting in signal reception. See Figure 10.

Fixed network AMR systems utilize data collectors and/or repeaters are typically mounted permanently at selected locations. Often they are mounted on street light poles, rooftops, or water towers. Since obstructions that cause attenuation and reflection affect the receiver performance of these units, the guideline is to attempt to locate these units as high as possible to improve the clear line of sight between the repeater/data collector antenna and the various transmitters. See Figure 11.

THE BOTTOM LINE

The RF signal from an AMR transmitter is affected by a variety of phenomena that are often unpredictable. Therefore, careful attention to good installation practices and data collection practices are critical to optimizing the overall performance of the AMR system.

A good installation will strive for a clear line of sight between the transmitter and expected location of the receiver. Installations that include significant obstructions may require testing signal reception at potential reading locations; relocating the transmitter and/or the receiving location might be

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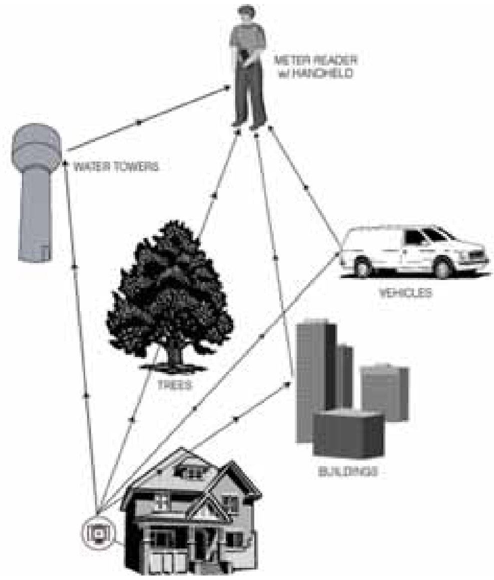


Figure 10. The transmitted signal is affected by propagation impairments, including free space attenuation, absorption, reflections, diffraction, and scattering. Multiple transmission paths may occur, possibly reducing signal strength at the receiver, or even creating a dead zone.

AUTOMATED METER READING: A FLEXIBLE, SCALABLE INVESTMENT

Itron customers recently added the 30 millionth Encoder-Receiver-Transmitter (ERT) to their installed base of automated meter reading (AMR) equipment. That's a big vote of confidence from utilities around the world. While a large installed base can sometimes become unwieldy to manage as new technology appears, Itron designed their ERT technology with the versatility for long-term viability, including the ability to work with multiple data collection methods. Utilities can choose, mix, and match their data collection methods depending on their growing and changing needs to collect and apply data throughout their organization. This versatility ensures that investing in ERT technology today will continue to provide utilities with strong benefits reaching beyond automated meter reading. This article describes the versatility of using ERT technology and how energy utilities can adapt and scale their systems from one reading technology to another as and when their business needs change.

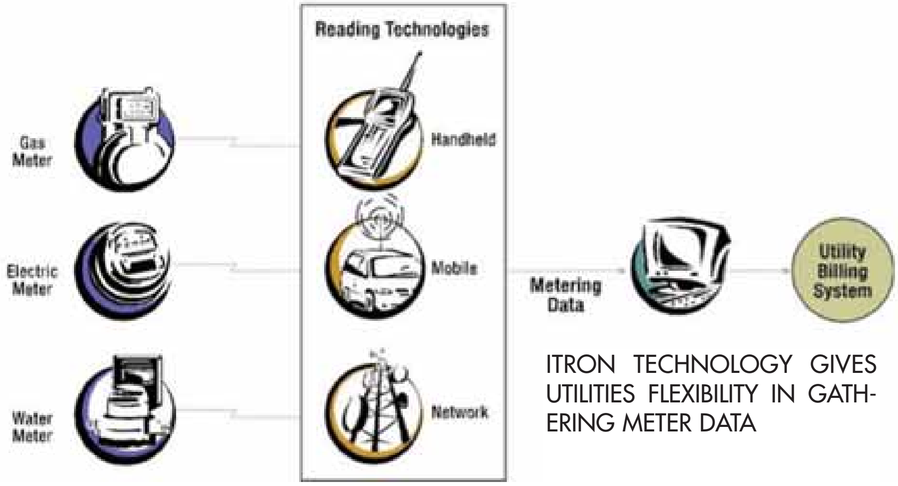
ERT TECHNOLOGY: A VERSATILE FOUNDATION

Itron's ERT design works on well-established 900 MHz radio standards and remains a dynamic and beneficial technology. Using the 900 MHz frequency provides customers with data transmissions that are easily deployed, require no licensing, and remain reliable for years.

Itron has continuously invested in ERT technology to enhance it for the increasing business needs of the utilities of the future while ensuring that customers can economically leverage their investments for a long time. Just since 2001, Itron has launched eight new ERTs for electricity, gas, and water, along with new handheld, mobile, and fixed network data collectors. Electric ERTs are now embedded in solid-state meters. Current Itron customers continue to find new benefits and business uses for their investment in over 30 million ERTs.

Basing a metering platform on ERTs gives a utility several long-term benefits:

- Increased speed, accuracy, and frequency of meter reading;
- Reduced liability for meter readers;
- Increased accuracy;
- Improved customer service;
- Eliminated estimated reads and re-reads.



ITRON TECHNOLOGY GIVES UTILITIES FLEXIBILITY IN GATHERING METER DATA

READING YOUR ERTS

From their beginning, Itron ERTs have been designed for flexible data gathering. Data from ERTs can be gathered in several ways:

- Meter readers on foot with handheld, radio-equipped computers;
- Mobile data collection vehicles equipped with rugged, portable computers and radio transceivers;
- A fixed communication network with radio transceivers.

In each case, either a radio signal from the collection system "wakes up" the ERT and requests it to transmit its data as a 900 MHz radio signal, or the ERT is broadcasting its readings automatically every few seconds. Once the data is transmitted and received, the ERT returns to its standby state.

A utility's choice of reading technology depends principally on its required or desired business applications. Some utilities project their current and future needs, and then choose a reading technology that will meet their requirements for many years. Others start by choosing a technology which satisfies their immediate business needs and plan to adopt other reading technologies as their business expand.

Some people see ERTs as being useful only for reporting monthly consumption. But as a utility increases its frequency and efficiency of data collection, it also increases its ability to improve and expand its business based on that additional data. Only ERT technology from Itron provides this flexibility in designing, deploying, and adapting automatic meter reading to serve the various and growing needs of energy and water businesses.

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AMR systems

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needed. The maximum distance between the transponder and the receiver will vary for each individual meter and is dependent on the environment between the two devices. It is important to note that this environment continually changes, due to weather, season, growth of vegetation, movement of vehicles, new buildings, modifications to existing buildings, etc.

INSTALLATION TIPS

• Carefully follow manufacturer's installation guidelines, especially regarding the mounting and orientation of the transmitter.

• Attempt to achieve a clear line of sight between transmitter and receiver.

• Locate transmitter to minimize obstructions, especially metal and large, dense objects, in the line of sight path.

• Consider a remote transmitter mounted in basement joists or outside of the building as alternative to a transmitter integral to the meter.

• Mount remote transmitters as high as possible.

• Pit applications must have the transmitter mounted through the lid or positioned properly just below the lid per manufacturers instructions; a transponder simply dropped in a pit will likely exhibit poor performance.

METER READING TIPS

• Attempt to have a clear line of sight between receiver and transmitter.

• Walking/driving at slower than normal speed might improve results of hard to read transmitters.

• Being closer to the transmitter is not always better due to the effect of reflections.

• Try different angles of approach if the transmitter is hard to read.

• Keep the receiver antenna pointed vertically; pointing the antenna at the transponder is not recommended.

• Use reader notes to make note of the best spots to receive transponders that are particularly challenging.

• Note that change of season, increasing vegetation, building construction and remodeling will all contribute to changing the signal strength over time.

• Keep pit lids free of dirt, grass, and other debris to minimize signal absorption.

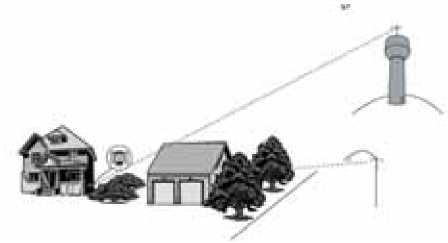

Figure 11. Fixed network repeaters and data collectors that are located at permanent locations, in general, should be as high as possible, providing improved line of sight with fewer attenuation and reflection variables. For example, the antenna on the top of the water tower offers better line of sight than a repeater located on the street light pole.

flexible investment

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DATA COLLECTION BY HANDHELD COMPUTER

Itron integrates radio transceivers with existing handheld computers used by field workers. This lets meter readers gather data from meters equipped with ERTs without directly accessing the meter or the premises. The same handheld computer can read any combination of electric, gas and water meter modules as the meter reader walks the route. Back at the office, meter readers plug their computers into the utility's network for automated uploading of gathered data and downloading of the next day's routes.

A meter reader using a radio-equipped handheld computer can read anywhere from 600 to 1000 meters in a typical day, significantly more than with a system based on manual data entry. Utilities switching to automated meter reading with handheld computers can see cost reductions coupled with more accurate and timely billing, which helps with revenues. This method works well for small- to mid-sized utilities and those planning a slower transition away from completely manual meter reading.

DATA COLLECTION BY MOBILE COLLECTOR

For larger-scale automatic meter reading, utilities can equip vehicles with Itron's rugged portable computers and radio transceivers to read ERT-equipped meters. The speed of a car or van, compared to a meter reader on foot, dramatically improves meter reading frequency. That increased frequency gives utilities more possibilities to use data for saving costs and improving operations.

While the meter reader drives the mobile collection vehicle along its route, the radio transceiver gathers data from ERT-equipped meters within a radius of up to 1,000 yards. At the end of the day, the gathered data are uploaded to the billing system for bill generation and the next day's route downloaded. Mobile data collections systems now come with state-of-the-art GPS mapping systems that let users "see" their data collection process and analyze any missed readings before leaving a route. Once the route has been completed and the meter reader has returned to the office, the system administrator can then play back the route that was driven to identify opportunities to optimize routes and improve meter reading.

Mobile data gathering excels in a variety of environments. A single transceiver will read an average of 10,000 to 12,000 meters in an 8-hour shift with a single service, depending on meter density and system use. With this speed of reading, mobile systems enables utilities to collect more off-cycle meter reading without adding special staffing or routing.

That extra data can also be used throughout the organization to help make system operations more reliability and cost-effective.

Mobile collection can also save time and costs in rural and industrial areas where meters may be too distant, difficult, or dangerous to reach effectively on foot. Some utilities using mobile data collection even earn additional revenues by reading the meters of other adjacent or overlapping utilities for a fee.

Mobile collection works well for utilities of nearly any size. According to industry data, a majority of the automated meters are being read through mobile collection.

READING ERTS BY FIXED NETWORK

For unparalleled meter reading capabilities, utilities install a fixed network of Itron central collection units for automatic meter reading. A central collection unit consists of a radio transceiver mounted on a pole, tower, or building gathering data from the meters within its radio reception range. Phone lines, IP, broadband, cellular, or other data connections provide communications with the utility.

This permanently-installed data collection equipment gives utilities incredible opportunity and flexibility, including:

- Reading multiple types of meters, such as both gas and electric meters, in a given area;
- Reading meters daily, hourly, or even on demand, thereby generating very granular interval data;
- Delivering quality customer service in densely populated areas where customers move in and out frequently;
- Identifying electric service outages and restoration.

Some utilities use a fixed network in more densely populated urban areas where high energy consumption and high account turnover in multiple-occupant buildings makes on-demand meter reading desirable.

Other utilities install a fixed network in their service area when they need to gather very frequent readings to help with operational improvements. Once they see the uses and benefits of a fixed network, they can then deploy it across the board.

The amount of data that fixed networks can generate only truly becomes useful with the right data management and knowledge applications to analyze that data. Itron's Enterprise Edition Meter Data Management suite of solutions offers utilities the right tools to take full benefit of a fixed network's capabilities.

Applying those solutions to the data generated by a fixed network can revolutionize designing, planning, forecasting, rate structuring, distribution asset optimization, and system operation throughout a utility.

ERT TECHNOLOGY: MIX AND MATCH FOR OPTIMUM RESULTS

With this ERT technology as the foundation of their meter-reading strategy, utilities are free to mix and match reading strategies and technologies to meet their changing business needs without any need to revisit meter sites.

This adaptability bolsters the confidence of utilities to invest how much they want, when and where they want, to achieve their business objectives and provide superior customer service.

Itron is committed to ensuring that any utility investing in ERT technology will continue to benefit from reliable, adaptable, scalable technology as their business grows.

Itron is currently collaborating with a major electric utility to showcase how Itron solutions, including ERTs, help create the utility of the future.

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support of distribution operations. Start with a corporate data mart dedicated to mimicking the Distribution Network Model in the field; it should be as close to reality as possible.

The applications therefore should not drive the data requirements; rather, the data model should become a service to the applications. If you discover that a data attribute is not available in your data model for a given application, it simply means that the data model must be expanded to serve the application. Naturally, this expansion implies additional costs; as well, a business decision needs to be made in order to balance the cost of capture and maintenance of the data, versus the benefit that the application will bring to the company.

How do you build the Data Services Concept?

There are three major considerations:

- Common Attributes
- Accuracy of Attributes
- Timeliness (refresh/update)

CONSIDERATION #1 - COMMON ATTRIBUTES

What are the common attribute opportunities and how can we share the cost of maintaining them across departments?

This presents a considerable opportunity to obtain a reduction in both costs and data errors. If we can achieve the "buy-in" and commitment of separate departments to "co invest" in common attributes, this will certainly lead to a significant reduction in errors and data conflicts.

A great example of this concept would be to have field personnel really believe that data errors they detect in the field will actually be corrected promptly through the use of mobile computing, instead of encountering the same uncorrected data error again in a couple of years!

CONSIDERATION #2 - ACCURACY OF ATTRIBUTES

The accuracy of the attributes significantly affects the cost of data services. A great example of this is the decision related to GPS location of distribution network facilities.

Is it worth it? Does it become more compelling when the cost is shared across departments?

CONSIDERATION #3 - TIMELINESS

Of the three issues to think about when considering a data services concept, my personal favorite would be the timeliness of the data updates; this is simply due to the fact that there is a price tag associated with the timeliness of the updates.

The question here is how often do I need to update a specific attribute. A great example is the timeliness of a meter read on a new service installation.

How much revenue is lost based on the latency of entering a new meter set in the Customer Information System.

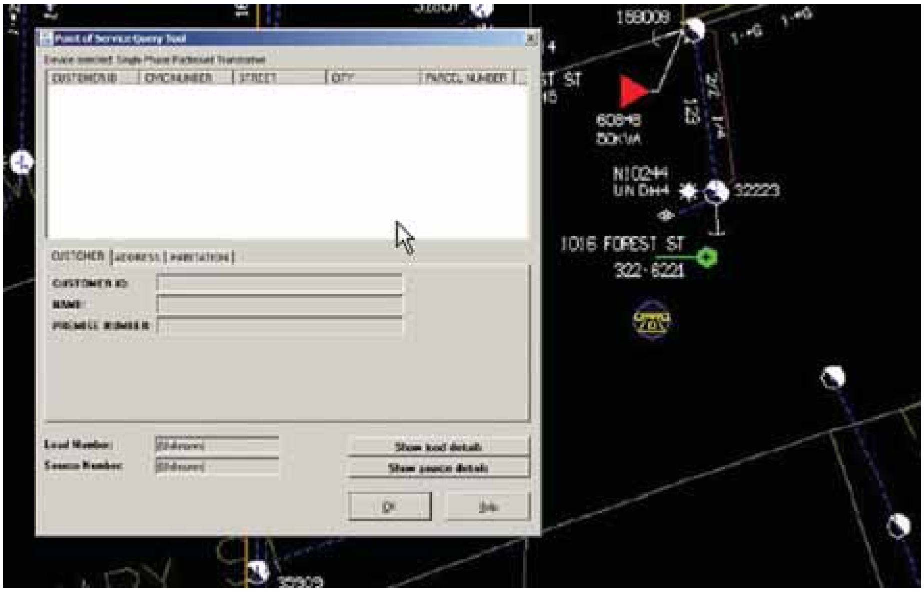

Figure 5

What data attributes need to be "real-time" and what attributes will rarely be updated through the life cycle of a device? Moreover, even if a device must be updated in "real-time", perhaps a particular field within the device does not require such costly updates.

POINTS TO PONDER

Coming from a Distribution Network Model data specialist company, I can tell you that most of our revenues are derived from consolidating or correcting the situations I have described. If our customers would have taken a more data centric approach over the last ten years, I can tell you that JCMB's revenues would be lower!

Following, are a few points to think about when considering the data services concept for your company:

Point 1

Can you identify today's applications that maintain distribution network databases with common attributes?

Point 2

If you were to build the perfect Distribution Network Model, can you identify the data sources you would need to consolidate?

Point 3

Do you believe that with accurate and timely data attribution you could provide more effective applications to your user community?

COMMANDMENTS

To conclude, we would like to provide you with a set of five "commandments" that you should abide by, when building your Distribution Network Data Model.

- Data model requirements come first, application second.
- All departments must become co-investors in common data.
- Capture and maintain data attributes in ONE place.
- Expect to publish and share your data.
- Inform data custodians and users about the true cost of data attribute accuracy.

USING OBJECT-ORIENTED TECHNOLOGIES TO SOLVE SUBSTATION AUTOMATION DILEMMAS

By Jim Y Cai, Member, IEEE, and H. Lee Smith, Life Senior Member, IEEE

Traditional Substation automation/integration systems involve huge numbers of man-hours to commission and maintain, even for similar systems. Using object-oriented technologies can reduce this commissioning time by approximately 80%. This has been demonstrated by field experience. The real-time information processing objects are composed of interaction-GUI parameters, real-time data, and functional processing. The defined objects – classes can be re-used among all the projects. Commissioning a new project is just to create instances of classes by "drag and drop". No further individual point/tag definition or verification is needed. These steps were done once, when class was created. Changes made to class will change all its instances automatically. The classes can be inherited from, referred to, and embedded into others classes.

Simple naming convention makes data usage instances link to data source instances automatically.

The traditional real-time processing system is built on point/tag concepts; each point/tag represents a basic real-time information item in the system. Based on this concept, the first step to building a real-time application substation integration system or a control center SCADA master is definition and creation of the real-time database. Most of us are familiar with this task of defining each point/tag of each I/O type of every IED/RTU and the virtual/calculated points, then creating interactive part GUI to database – graphics with correct real-time data linkage, in addition to using some special tools to build the calculation/control logic definitions. After all this creation, the major task is still ahead: to verify all point/tag definitions one at a time are correct and have the correct dynamic linking to the graphics. One possible way to simplify this database

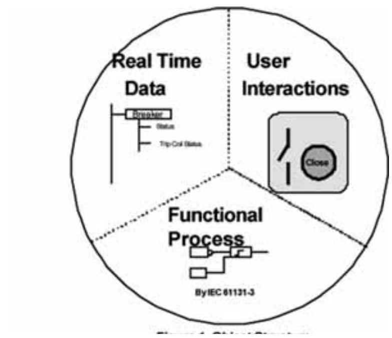

Fig. 1. Object Structure for Real-time Information Processing

definition procedure is to use some type of spreadsheet or text file editing with import capability to avoid typing the similar text over and over. For graphics creation, some basic components can be grouped together in a template to save time.

An object-oriented approach might be the better way to go. As we all know, there are no completely identical projects in the world. But, in most cases, we do have similar projects with similar elements. For example, in substation automation/integration applications, each power company will want all the breakers with the same voltage level to behave in exactly the same manner: same alarming logic, same graphical representation, and same operator prompt to trip/close. So, conceptually, we want to treat this breaker as a basic object or brick.

II. OBJECT STRUCTURE FOR REAL-TIME INFORMATION PROCESSING

We may get really confused and frustrated if we try to exactly define an object-oriented system/software package. As real-time information processing application engineers, what we look for is re-use or duplication. These basic tested objects can be re-used in the same project, in different projects individually without testing being required in new projects.

This paper presents an object-oriented real-time information processing solution implemented on Linux that is already in operation in the field.

A. Generic Object Structure

Let's first clarify some terms we use. The term "object" is a generic term as a concept. "Object" in this paper or our solution does not specifically have any strict definition. We use the term "object" to describe the implemented approach.

Each object has three basic elements, data, method (functional processing), and interaction to the GUI (graphic user interface). We use "class" to represent an object or the strict definition of objects. The term "class" has the same definition as in C++ language. Or you can say class is a template.

The term "instance" is the utilization of a class. The instances are composed of partially real-time information/database. So "object" here refers to class and instance.

As we mentioned above, the object is composed of three parts: real-time data, functional processing, and user interaction.

The real-time data are values and definitions of analog, digital, etc. By "drag and drop", you create an instance of the object, which is identical to creation of a traditional real-time database. Then the values and attributes of analogs, digitals will be updated accordingly.

B. real-time Data

A class could have hundreds of instances in a project. In some instances, some data could be shared with all instances or the whole system. Some data specific in each instance can't be shared among other instances. We call the shared data server data. The non-shared data is called client data. In the class builder tool, there are two panels for each

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class: one is titled "server data" and the other is titled "client data".

Both server and client resource members can be all kinds of data types including elementary data types like integer, class type, reference type, and alarm type.

Server data has access authorization levels to make data variables private, friendly, and global. Addressing format for the variable is xxx.yyy. . .vvv. The first xxx is the instance name of this object, which must be unique system-wide. The last vvv is variable name. Between the two are the names of class or referred instance. So we can address a breaker status in a substation by Sub1.Bay1.Breaker.status1. All the characters in the names can be in different language character sets.

C. User Interaction - GUI

User interaction defines how the object is displayed on the screen including static background. The dynamic update rate and how the object reacts to operator action by clicking or pressing some key are also defined.

D. Functional Processing with IEC 61131-3

Functional processing may be:

- Interlocking logic for a breaker operation,
- Alarming for breaker status,
- Simulation logic for testing and/or training purpose,
- Special calculation,
- Or algorithms.

Functional processing can be created by following IEC61131-3 ladder logic language and/or by using the system proprietary scripting language. The functional processing can be executed continuously or on demand.

This feature is also called soft PLC (Programmable logic controller) function and the system will guarantee that all the continuous logic execution finishes in a timely manner.

III. IMPLEMENTATION

Real-time information processing always consists of real-time data acquisition, and real-time data presentation. The real-time data acquisition provides interface to field devices – IEDs, while the real-time data presentation provides user interaction interfaces and displays. Objects that provide interfaces to IED are data source objects. Data usage objects are objects that provide user interaction interfaces. An example is used to explore the idea in the following section. There is one 220KV bay in a substation, which has a breaker and switches with one multi-function protective relay IED. There are two data source objects for this bay, one for the bay controller IED and one for the protective relay. And there is one data usage object - the bay object, which may be derived from the breaker and switch class. The object defines the graphics display, the pop-up windows, interlocking, alarming, etc.

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A. Data Source Objects – IED definitions

Data Source Objects contain basically three functions:
Protocol interpretation;
IED interface control, settings, and diagnostics;
Data point definitions.

Protocol interpretation is a special processing function of the object to interrupt the communication message by following the defined architecture. For each IED interface, GUI is definitely needed to control, monitor and diagnose the interface such as start/stop polling, reset the channel, etc. The point list will define variables associated with all the points as well as data types. Obviously, those data are server data so the other objects can access them accordingly.

For the above protective relay IED, a class is created which will share the same protocol interpretation function with the other classes. The protective relay classes could have their own GUIs (like using IED picture/LEDs as its own background). The IED point list will include, for instance, OC_Activated, Breaker_Trip, Breaker_Status, Breaker_Trip_Coil, GroundingSwitch_Status. All the points can be imported via a text file which could be generated by IED configuration tool. Definition file in the future IEC61850-6 substation configuration language could be used. When an instance BAY1_IED is created from the protective relay class, then I/O points can be addressed as

```
BAY1_IED.OC_Activated,
BAY1_IED.Breaker_Trip,
BAY1_IED.Breaker_Status,
BAY1_IED.Breaker_Trip_Coil,
BAY1_IED.GroundingSwitch_Status.
```

Classes for different I/O configurations of IEDs with the same protocol can be easily created by only editing the I/O definition text file.

Also, all the engineering scaling, ranges can be defined in the class. When a data source class is created in house, full testing and documentation can be done in house. The class encapsulates all the information needed. Then the class can be used across projects with peace of mind.

B. Data Usage Objects – One-line Diagram

A substation bay on a one-line diagram consists of breakers and switches. The basic requirement is that the dynamic text and graphics should be updated automatically. It should have appropriate pop-up/prompts for the operator's interaction, alarming when analog values go out of limits and digital status changes state. The object definition should also include event logging associated with the bay, bay level interlocking which monitors and controls operates breakers and switch operations.

To create this bay class, the class variables are defined as:

```
$Instance_IED.OC_Activated,
$Instance_IED.Breaker_Trip,
$Instance_IED.Breaker_Status,
$InstanceIED.Breaker_Trip_Coil,
$Instance _IED.GroundingSwitch_Status.
```

Here "$Instance" is a substitution command. When an instance gets created with this class, it will be replaced with the instance name. Please note that the class variable names are the same as in the IED class. By using those variables, the dynamic update, interlocking logic can be implemented. By using the class builder tool, graphics as well as all the pop-ups/prompt can be created. Using the built-in function block classes compatible with IEC61131-3, interlocking logic is easily implemented. During this creating process, the source of the variables is ignored.

Then by drag and drop, the bay instance by name is created with name Bay1. The system will automatically link the bay variables to the IED variables.

C. Objects Linking – Naming Convention in Class Building

Still we need naming convention to accomplish automatic linking between the data source and the data usage objects.

Variable name of both data source and data usage classes must be the same so all the instances created with the classes can be automatically linked.

D. Object Reuse

Reuse is the method for reducing the commissioning effort.

Object reuse is accomplished through:

- Classes and instances,
- Inheritance-type embedded classes,
- Instance referencing,
- Mirroring instances.

Class and instances is basic reuse architecture. Each class can contain fully tested and field proven data definitions, function processing and GUIs, documentation as well as class version information. The class is a fully encapsulated element.

When class is being copied among projects, it keeps all the information and relationships intact. In most cases, a modification to the class will automatically apply to all the instances.

The Inheritance-type embedded class feature makes the class more powerful and easy to manage. For example, bay class can be built up from switch and breaker classes. When you create an instance of a bay class, the switch and breaker instances will be created automatically.

Instance referencing is a linkage to other instances and a mechanism of accessing objects.

The mirroring function makes sure that the same instance can be viewed at several places or on multiple screens without creating multiple instances.

E. Project Implementation Procedure

Object modeling analysis is the first step of the project implementation. The analysis can be at the industry/application level to define generic objects for substation integration/automation. The analysis can be at the project level to define generic objects for specific projects or customers. For substation integration/automation application, the following classes identified:

Data usage objects: single pole and three pole switches, single pole and three pole breakers, bay classes, bus classes, and transformer classes. Note only one switch class is needed for single pole switches to cover switches for all voltage levels, no matter what color and position orientation,

Advanced application classes (automatic transfer, load shedding, voltage/reactive control, etc.),

Data source objects: Protective relay IED classes, bay controller classes and meter IED classes.

As substation integration/automation system providers, several class libraries have been built:

1. IED class libraries to cover most commonly used IEDs like XJ's transmission line protection devices,

   a. WH801, transformer protection

   b. WBH801, bus protection WMH801,

   c. GE UR's T60, D60, L60

   d. SEL-421, etc.

These IED classes can be used almost in all projects witout any customization.

2. One-line display class libraries. Usually, each customer has his/her unique requirements for the GUI and processing functions. Therefore a library must be maintained for specific user/utilities along with the baseline;

3. Advanced applications libraries. In most cases, these classes can be re-used without any customization.

Again, all the classes can be built and fully tested in-house with supporting documentation. For a specific project, the classes from the class libraries can be re-used to create, test and document the project. If customization is needed, the class build tool is used to provide a built-in version control feature to track all the modifications.

F. Operating Experiences

As an example, consider a 220KV substation with two 220KV lines, ten 110KV feeders, twenty 10KV feeders, two three-winding transformers. About 50 classes are used. About 30 of classes are IED classes, 15 one-line diagram classes, and several advanced application classes. Approximately 100 turnkey substation integration/automation systems are delivered worldwide each year. Approximately 80% of the traditional commissioning time has been saved using the object definition approach.

Jim Y Cai graduated from the Shanghai Jiao-Tong University, China and received a B.Sc. and M.Sc in 1983 and 1985 respectively.

H. Lee Smith , PE (LSM)BSEE, MSEE, PE in PA is an author of more than 40 technical papers and articles including IEEE/PES Tutorial on Automation Systems, chapter on Remote Terminal Units.

INVESTIGATING COPPER SULFIDE CONTAMINATION IN A FAILED LARGE GSU TRANSFORMER

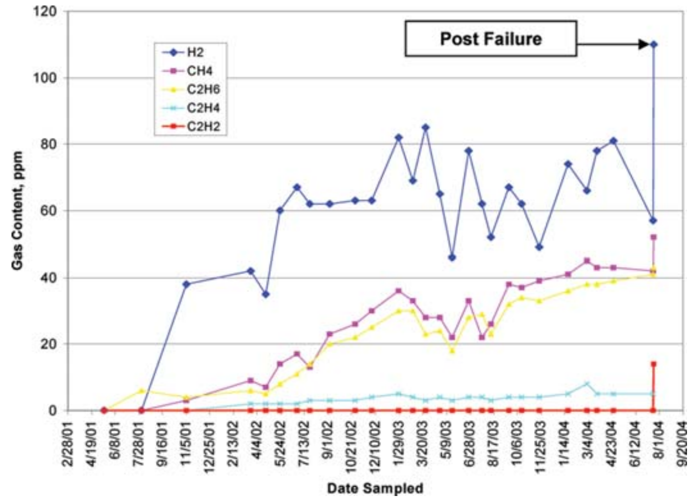
By Lance Lewand, Doble Engineering Company

Let's examine the details of the teardown and laboratory investigation of a failed GSU transformer. The failure involved sulfide contamination of the copper conductor and copper sulfide in the associated paper insulation in the upper third portion of the failed winding. The theory is put forth that a combination of time and temperature and corrosive sulfur in the oil created conditions to exist in the transformer that caused this problem despite the oil having passed the standard test criteria for corrosive sulfur. Although the mechanism is still unclear, copper ions migrate to the insulating paper adjacent to the conductor, react with corrosive sulfur compounds, and cause a reduction in dielectric strength. At some point, the voltage being carried by the conductor exceeds the insulating capacity of the paper insulation and BIL rating of the transformer. The result is arcing between two or more disks and a subsequent burn through (failure).

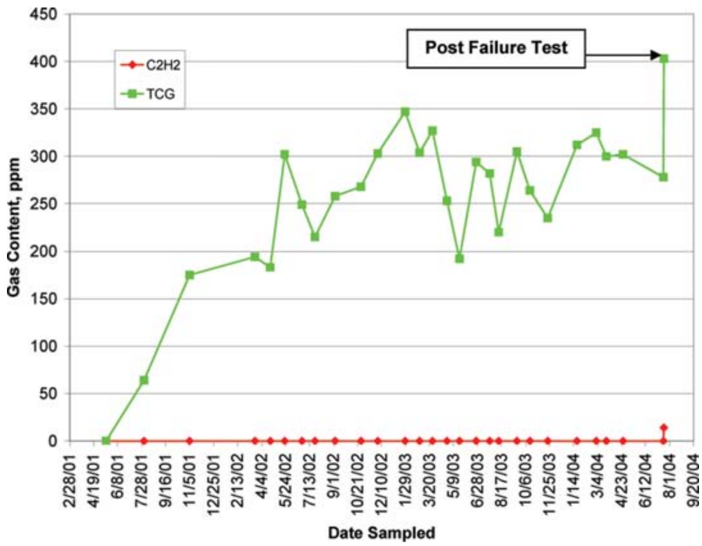
FAILURE EVENT AND HISTORY

Without notice, a large GSU transformer failed in July of 2004. In reviewing the operating history of the transformer including loading, transients and other operating parameters there was nothing noteworthy or unusual in its 4 years of service. A review of the historical oil quality data showed that the oil was in good condition and the unit was very dry. Dissolved gas-in-oil analysis (DGA) was performed routinely over the course of its in-service life and there was no indication of an impending failure. The DGA results were so normal in fact, that even though the unit was sampled the day before the failure (7/19/04), totally by coincidence, there was no indication of impending failure as shown in Figure 1.

The gassing pattern is a typical one for GSUs in that there are some heating gases present but not of sufficient concentration to raise any alarms or take remedial action. A sample taken the day before the failure actually shows a slight decrease in combustible gases (Figures 1 and 2) and still significantly far below any level that would be of concern. The acetylene content of 14 ppm would be of concern but that was only present after the failure occurred.



Gassing Trend of GSU Transformer. FIGURE 1



Total Combustible (TCG) and Acetylene (C2H2) Gas Content

TABLE 1
Results of the Furanic Compound, Phenol and Cresol Compound Analysis

Compound	Results
5-hydroxymethyl-2-furfural	<1 ug/L
furfuryl alcohol	<1 ug/L
2-furfural	4 ug/L
2-acetyl furan	<1 ug/L
5-methyl-2-furfural	<1 ug/L

Compound	Results
phenol	<10 ug/L
m-cresol	<10 ug/L
o-cresol	<10 ug/L
2,3-dimethyl phenol	<10 ug/L
2,6, dimethyl phenol	<10 ug/L
2,3,5-trimethyl phenol	<10 ug/L

TABLE 2
Results of the Various Sulfur Tests

Elemental Sulfur	Total Sulfur	Corrosive Sulfur ASMT D 1275	Doble Modified Corrosive Sulfur Test
<1 mg/kg	886 mg/kg	Non-corrosive	Corrosive

Picture of Bucholtz Gas Relay (Found half filled with Gas) FIGURE 3

continued on page 66

CCA-PA poles are climbing in lineman popularity

Introduction

Arch Wood Protection, Inc. (a US-based firm which specializes in wood preservatives), in partnership with Hydro-Québec, has developed a polymer-based additive which, when injected into CCA-treated wood poles, gives them a degree of climbability comparable to that of poles treated with pentacholorophenol (PCP).

Chromated copper arsenate (CCA) is used extensively in commercial and industrial applications. Over the last decades, the popularity of CCA treated poles has increased significantly in North America; they are now widely accepted by utility pole engineers and linemen. Despite all this there are still concerns expressed about CCA poles being harder to climb and to work on compared to oil-borne treated poles such as penta and creosote.

CCA poles also change somewhat upon aging. For instance, the wood tends to harden, requiring line workers to use more force to dig in their gaffs. This makes linemen feel more constrained in their movements, especially when having to move laterally while working higher up on the pole. With the increased use of bucket trucks, climbability is less of a concern, but there is still a need to climb a pole when using the trucks is not feasible.

After reviewing new gaff designs and tests done on the climbability of various CCA additives such as wax, polyethylene glycol and light oils, it was concluded by Hydro-Québec that no individual item provided a satisfactory solution, until the development of a polymer-based additive (PA), which created the CCA-PA Pole.

The CCA-PA Pole

In 1998 an R&D partnership was initiated by Hydro-Québec with Arch Wood Protection, which resulted in the CCA-PA pole.

The CCA-PA pole offers the complete benefits of a CCA-treated wood utility pole: *clean, dependable, and environmentally preferable,* plus,

- *a degree of climbability comparable to that of poles treated with oil-borne wood preservatives*
- *it is easier to saw drill and nail than a CCA pole, and*
- *there is nominal storage maintenance -- no need to rotate pole during storage.*

Photo courtesy of Hydro-Québec

The Polymer Additive

The polymer-based additive is water-soluble in its initial state. It is part of a patented mixture that is injected under pressure into the wood being treated with CCA. This process takes place in a plant using large horizontal cylinders. The wood is heated and the additive is polymerized to form a three-dimensional network that is water-insoluble.

Testing

In February 2000, a series of tests was done as a final part of a 20-month research and testing campaign. During that time a group of control poles were monitored to determine additive retention, pole hardness, the degree of climbability and the washing out of preservatives.

Two series of climbing tests were carried out at Hydro-Québec Research Institute (IREQ) pole testing site. In February 2001, twelve Hydro-Québec line workers conducted field tests on 18 red pine poles divided into three groups of six, which were treated with PCP, CCA or CCA-PA. The line workers were not aware which of the CCA-treated poles had the polymer additive in it. The temperature at the time was minus 14°C and followed a few days of mild and wet weather, which were ideal conditions for the tests. Each worker climbed onto each pole in turn and assessed the hardness of the wood and the level of comfort experienced, then assigned a climbability rating. The line workers' psychophysical assessment was compared with objective data collected by instruments on the ease of penetration of the spurs in each pole. It was concluded that in summer conditions, the CCA-PA poles were more accepted than the PCP-treated ones, whereas in winter conditions, their acceptability was just slightly below that of PCP.

Photo courtesy of Hydro-Québec

Where is the CCA-PA Pole Now?

The polymer additive has been approved by Hydro-Québec and Bell, and CCA-PA treated wood utility poles are currently used in service.

The CCA-PA pole has also recieved CSA approval under O80.207-05.

For more information...

For more information on CCA-PA treated wood poles, please contact Arch Wood Protection Canada Corp in Mississauga, Ontario at 1-800-387-8349, or visit

www.wolmanizedwood.com

GSU transformer

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INSPECTION AFTER FAILURE

Besides tripping the circuit, there were no outward signs of transformer failure except for the Bucholtz relay. A visual inspection of the Bucholtz relay mounted on the transformer did indicate a major event occurred in that the relay was half filled with gas (Figure 3) which in service, should be completely filled with oil.

INVESTIGATION AND TEARDOWN

After failure, the transformer was transported to a transformer repair facility where it was un-tanked. The failure investigation isolated the failure to one phase and the teardown of that phase began (Figure 4). The actual failure was isolated to disks 95 through 97 (starting from the bottom). This area represented the upper third of the winding, (see Figure 5). The failure consisted of a puncture that left a hole through the inner most portion of the disk (Figures 6 and 7).

During the teardown investigation, a black or grayish coating was found on some of the copper, paper insulation and spacers. Scanning electron microscopy, energy dispersive X-ray (SEM/EDX) analysis showed this material to be copper sulfide.

LABORATORY ANALYSIS PERFORMED BY DOBLE

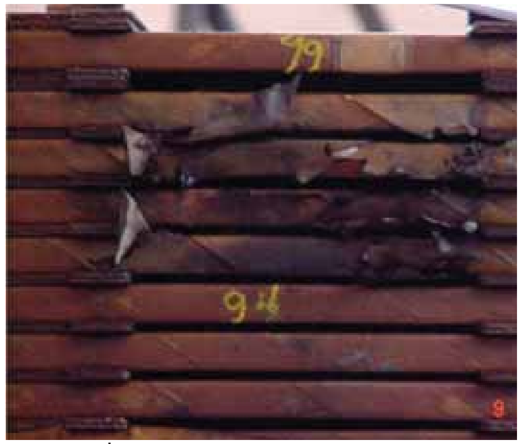
At the request of the transformer owner, Doble performed a variety of tests to assess the condition of the oil and paper insulation. Some of these tests included furanic compound analysis, phenol and cresol compound analysis, total sulfur content, elemental sulfur content, sulfur speciation, corrosive sulfur by ASTM D 1275 and a Doble modified corrosive sulfur method. The results of the testing are shown in the Tables 1 through 5.

In addition, several additional tests were performed on the paper insulation. One of these tests consisted of testing the copper content of the paper insulation. Paper samples were taken from individual conductor turns at different regions and depths along the failed high voltage winding as shown in Figure 8.

Table 6 and Figure 9 catalogs the copper (Cu) concentration and illustrates its distribution throughout the paper layers of three turns on the 130th disk. This

Removal of Failed HV Winding. FIGURE 4

Area of Failure. FIGURE 5



Disks 95-97, Burnt Regio. FIGURE 6

Hole in Disk 96. FIGURE 7

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DATA SHEET

QUICK-TRIP™

ARC FLASH REDUCTION SWITCH

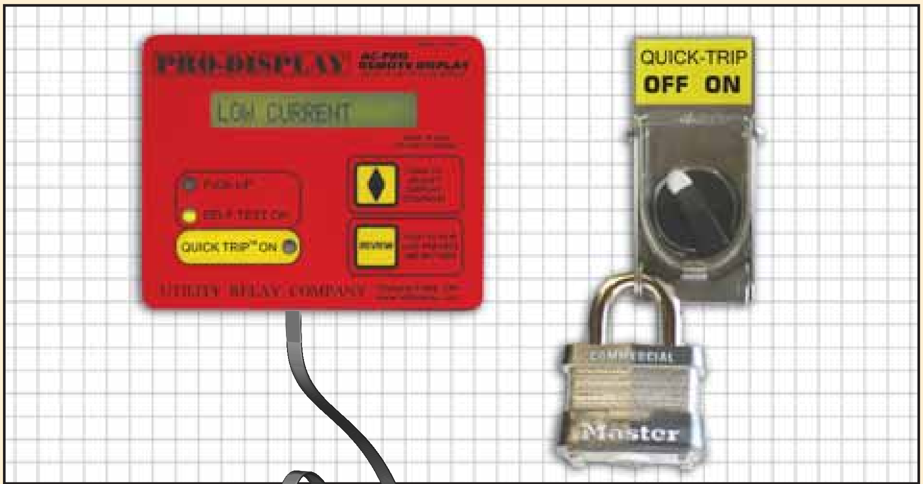
Providing a safer working environment for people working on energized electrical equipment

Since arcflash potential is directly related to breaker clearing time, the QUICK-TRIP system provides an easy and safe method to reduce fault-clearing time without opening a cubicle door to reprogram the trip unit.

The QUICK-TRIP system is activated by means of a padlockable selector switch. When enabled, two additional settings are activated in the AC-PRO trip unit to provide enhanced protection:

- ❑ QT Instantaneous
- ❑ QT Ground Fault

These two individually programmable settings are designed to provide faster clearing times in the event of a fault.



System Features

The QUICK-TRIP system is as easy to use as it is to install, with the additional personnel safety features:

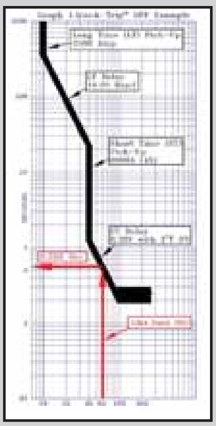
- ❑ Installation uses standard punches.
- ❑ Wires in minutes without cutting into existing wiring harness.
- ❑ QT settings are only active when the selector switch is in the ON position (during maintenance).
- ❑ Reduction in arc flash incident energy levels may permit lower PPE clothing for maintenance personnel.
- ❑ Padlocking switch can be incorporated into a lock-out tag-out procedure.
- ❑ QUICK-TRIP ON LED confirms operation.
- ❑ SELF-TEST LED verifies trip unit operation.
- ❑ PICK-UP LED indicates overcurrent situations.
- ❑ QUICK-TRIP settings can be reviewed on the external PRO-DISPLAY.
- ❑ Last Trip Data and all settings can be reviewed on the PRO-DISPLAY.
- ❑ 3-phase currents are displayed continuously on the PRO-DISPLAY.
- ❑ The system is fully powered by the trip unit's CTs. No aux power or batteries.
- ❑ Extra contacts on the selector switch are available for external annunciation.

Practical Example

A technician needs to rack out a feeder breaker for maintenance. In so doing, he is the minimum 18" away from any potential arc flash source in the cubicle. As the breaker is being racked out, a 12,000 amp arcing fault occurs inside the cubicle. The 2000A main breaker sees the fault and trips, subsequently clearing the fault in the feeder breaker cubicle.

The two graphs below illustrate the dramatic impact that arc-clearing time has on incident energy levels.

Given that: **F = 12kA** and **D = 18 in.**

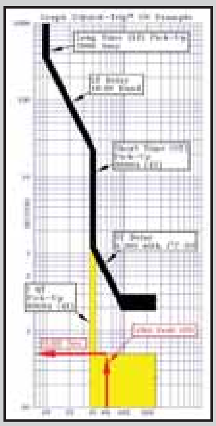


Graph 1:
QUICK-TRIP: **OFF** shows the trip time characteristics of the main breaker.

- ❑ The AC-PRO will cause the main breaker to clear the 12kA fault in .556 seconds (based on a Short-Time Delay of .20 seconds with I^2t ON). The resulting arc duration will be: **t = .556**
- ❑ The resulting incident energy is: $\mathbf{E_I}$ **= 25.8022**
- ❑ The Hazard Risk Category is: **4**

Graph 2:
QUICK-TRIP: **ON** shows the trip time characteristics of the main breaker.

- ❑ The AC-PRO will now cause the main breaker to clear the 12kA fault .05 seconds (based on the Instantaneous QT or I QT Pick-Up setting of 8000 amps). The resulting arc duration will be: **t = .05**
- ❑ The resulting incident energy is: $\mathbf{E_I}$ **= 2.3203**
- ❑ Hazard Risk Category reduced to: **1**



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GSU transformer

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disk is located near the very top of the winding.

Removal of the paper insulation from the turn to perform the copper analysis on the paper also exposed the copper conductor. Significant discoloration of the copper was visible as shown in Figure 10. The copper turns in Figure 10 represent some of the 29 turns in Disk 130. This discoloration is different forms of copper-sulfur compounds.

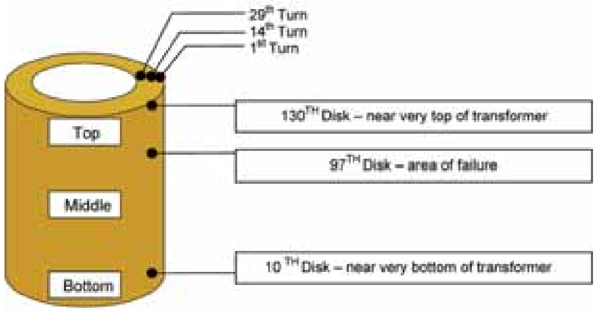
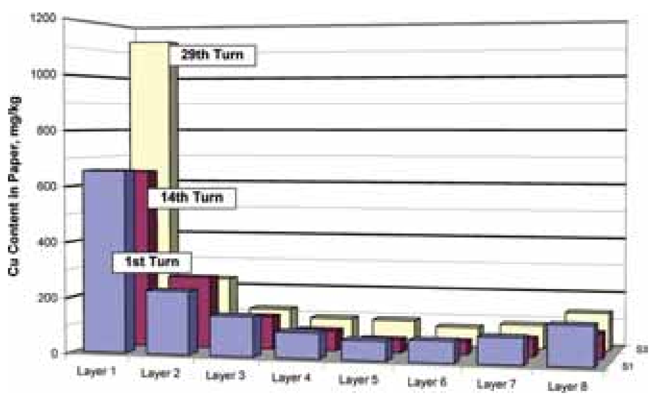


Diagram of Failed High Voltage Winding. FIGURE 8

Removal of one piece of copper from this disk shows just how extensive some of the contamination really was. This is shown in Figure 11.

Table 7 and Figure 12 lists the copper (Cu) concentrations and shows its distribution throughout paper layers of three turns on the 97th disk. This disk was located in the direct vicinity of the failure. Figure 12 has been depicted on the same concentration scale as Figure 9 for comparison.



Distribution of Copper in Paper in Winding Disk 130. FIGURE 9

Table 8 and Figure 13 catalogs the copper (Cu) concentrations and illustrates the distribution throughout the paper layers of the three winding turns on the 10th disk. This disk was located close to the bottom of the transformer. Figure 13 depicts the same concentration scale as Figure 9 for comparison.

TABLE 3
Results of the Sulfur Speciation Test, ASTM D 5623

Compound	Result	Compound	Result	Compound	Result
hydrogen sulfide	<1 ppm	n-butyl mercaptan	<1 ppm	benzothiophene	<1 ppm
carbonyl sulfide	<1 ppm	dimethyl disulfide	<1 ppm	methyl benzothiophenes	<1 ppm
methyl mercaptan	<1 ppm	2-methyl thiophene	<1 ppm	dimethyl benzothiophenes	<1 ppm
ethyl mercaptan	<1 ppm	3-methyl thiophene	<1 ppm	trimethyl benzothiophenes	<1 ppm
dimethyl sulfide	<1 ppm	tetra-hydro thiophene	<1 ppm	tetra-methyl benzothiophenes	<1 ppm
carbon disulfide	<1 ppm	ethyl methyl disulfide	<1 ppm	dibenzothiophene	8 ppm
isopropyl mercaptan	<1 ppm	2-methyl-tetra-hydro-thiophene	<1 ppm	4-methyl dibenzothiophene	26 ppm
ethylene sulfide	<1 ppm	2-ethyl thiophene	<1 ppm	3-methyl DBZT + 2-methyl DBZT	42 ppm
tert-butyl mercaptan	<1 ppm	2,5-dimethyl thiophene	<1 ppm	1-methyl dibenzothiophene	31 ppm
n-propyl mercaptan	<1 ppm	3-ethyl thiophene	<1 ppm	4,6-dimethyl dibenzothiophene	27 ppm
ethyl methyl sulfide	<1 ppm	2,4 & 2,3-dimethly thiophene	<1 ppm	dimethyl dibenzothiophenes	109 ppm
thiophene	<1 ppm	3,4-dimethyl thiophene	<1 ppm	trimethyl dibenzothiophenes	88 ppm
sec-butyl mercaptan	<1 ppm	methyl ethyl thiophenes	<1 ppm	tetra-methyl dibenzothiophenes	10 ppm
isobutyl mercaptan	<1 ppm	trimethyl thiophenes	<1 ppm	Unidentified volatile sulfur	545 ppm
ethyl sulfide	<1 ppm	tetramethyl thiophenes	<1 ppm		

TABLE 4
Results of the Total Metals Analysis, ASTM D 5185 (ppm = mg/kg)

Compound	Result	Compound	Result
Iron	<1 ppm	Titanium	<1 ppm
Chromium	<1 ppm	Silicon	14 ppm
Lead	2 ppm	Sodium	<1 ppm
Copper	<1 ppm	Magnesium	<1 ppm
Tin	<1 ppm	Calcium	<1 ppm
Aluminum	<1 ppm	Barium	<1 ppm
Nickel	<1 ppm	Phosphorous	<1 ppm
Silver	<1 ppm	Zinc	<1 ppm
Molybdenum	1 ppm	Vanadium	1 ppm

TABLE 5
Results of the Particulate Metals Analysis, Doble Test (ppb = ug/L)

Copper	Lead	Iron	Zinc	Aluminum	Silver
15 ug/L	<1 ug/L	<1 ug/L	2 ug/L	2 ug/L	<1 ug/L

TABLE 6
Copper Concentration of Paper Layers in Winding Disk 130

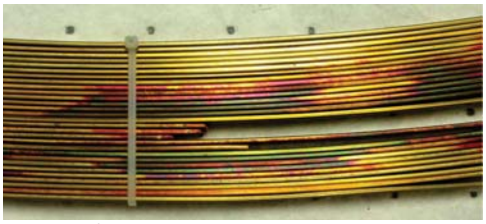
Paper Layer	Turn 1 Cu Result, mg/kg	Turn 14 Cu Result, mg/kg	Turn 29 Cu Result, mg/kg
Layer 1, next to Conductor	656	647	1136
Layer 2	227	257	233
Layer 3	143	117	122
Layer 4	92	72	92
Layer 5	70	47	91
Layer 6	77	47	71
Layer 7	95	63	86
Layer 8	143	89	136

DISCUSSION OF LABORATORY RESULTS

The results of the furanic, phenol and cresol compounds do not indicate any advance or abnormal aging of the cellulosic insulation. Even though there was a clear indication of failure (Figure 7), the amount of material involved in the failure was very small and would not have increased the byproduct concentration significantly.

The tests for total sulfur, elemental sulfur and corrosive sulfur by ASTM Method D 1275 also indicated that the oil was satisfactory for use. However, Doble employs a modified corrosive sulfur test which is more severe than the ASTM test, and in this analysis, the oil was found to be clearly corrosive.

ASTM Method D 5623 was also utilized. In this test certain sulfur species are identified and quantified by gas chromatography using a sulfur selective detector. Sulfur is present in crude oils used to make transformer oil. The refinery attempts to remove or convert the harmful sulfur species so a corrosive condition does not occur during use in service. Some sulfur compounds such as thiophenes can actually aid in the oxidation stability of the transformer oil and may also act as metal passivators/deactivators reducing the catalytic effect on oil oxidation in transformers. This analysis showed that



Picture of Copper Turns in Disk 130.
FIGURE 10

TABLE 7
Copper Concentration of Paper Layers in Winding Disk 97

Paper Layer	Turn 1 Cu Result, mg/kg	Turn 7 Cu Result, mg/kg	Turn 29 Cu Result, mg/kg
Layer 1, next to Conductor	478	222	731
Layer 2	94	62	215
Layer 3	64	92	114
Layer 4	51	55	77
Layer 5	46	70	61
Layer 6	44	75	57
Layer 7	56	79	79
Layer 8, some of it exposed as outermost	106	121	124
Layer 9, CREPE, outermost layer facing oil	116		

Picture of Copper Turn 11 in Disk 130
FIGURE 11

TABLE 8
Copper Concentration of Paper Layers in Winding Disk 10

Paper Layer	Turn 1 Cu Result, mg/kg	Turn 14 Cu Result, mg/kg	Turn 29 Cu Result, mg/kg
Layer 1, next to Conductor	181	243	1024
Layer 2	87	107	143
Layer 3	58	93	74
Layer 4	47	83	56
Layer 5	44	68	54
Layer 6	45	91	55
Layer 7	57	90	66
Layer 8	68	130	195
Layer 9, Crepe	206		

although there were numerous thiophenes present, there was a large amount of unidentified volatile sulfur compounds also present (Table 3) which may have contributed to the corrosive condition that was found.

The different types of metal analyses performed indicated the presence of a small amount of particulate copper and a considerable concentration of dissolved silicon. The low concentration of copper would not normally be of concern. It may indicate that the oil was involved in the transportation of copper ions throughout the transformer but it was probably a minor influence. Because the concentration of silicon was so elevated, the analysis was repeated to confirm the concentra-

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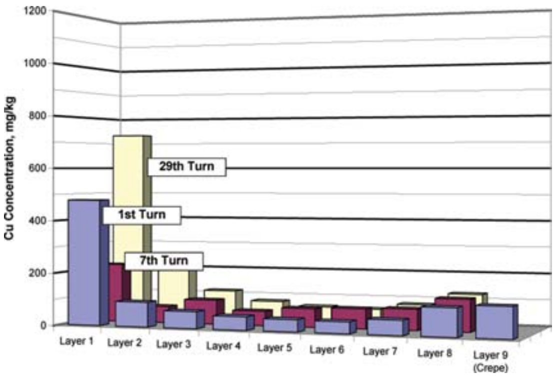
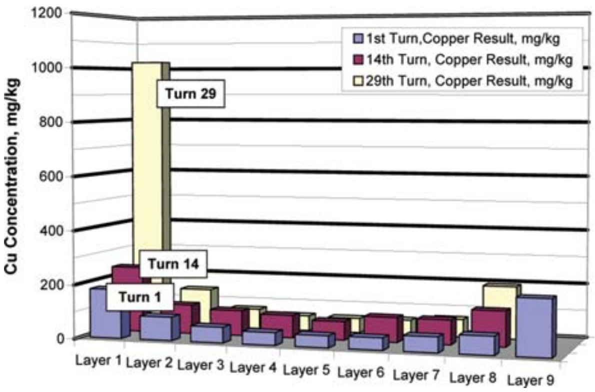


Distribution of Copper in Paper in Winding Disk 97
FIGURE 12



Distribution of Copper in Paper in Winding Disk 10
FIGURE 13

COMPETITIVE ELECTRIC POWER MARKETS AND GRID RELIABILITY: SOMETHING HAS CHANGED DURING THE PAST DECADE!

By Kellan Fluckiger, Executive Director, Electricity Division at the Alberta Department of Energy

Electric power's contribution to modern life is unparalleled. Electric power is pervasive in our society, permeating every aspect of the economy and affecting our daily lives both in business and at home. We depend on extraordinarily high reliability in electricity service; interruptions are limited to no more than a few hours per year and have far-reaching consequences when they occur.

This dependence on electricity is starkly evident as we recall the blackout in the eastern part of North America in the summer of 2003. Although the costs are still being sorted out, they are estimated in the billions of dollars. The aftermath of the blackout is fervent activity by public commissions; regulatory bodies; and federal, provincial, and state agencies to identify appropriate actions to prevent such outages in the future.

Not only are we dependent on electricity, but customers' expectations of reliability have changed. Consumers are demanding very high quality power in their homes for electronics and at work for industrial processes. Some industries have indicated that the tolerances of their processes require fluctuations of no more than a few volts and frequency distortions of less than a cycle. Higher quality does not come without a cost. The question is: who should pay these higher costs, the individual customer or society as a whole?

FUNDAMENTAL CHANGES

During the past few years, the way in which electricity is provided to customers in most jurisdictions has changed fundamentally. The changes do not speak to the physics of electricity or to how it is delivered in a physical sense, but they affect the institutions, pricing, reliability, and regulation of this essential service.

Previously, electricity was delivered by integrated electric utilities that directly served their customers and owned both generation and transmission. Restructuring has altered the rules that governed control, operation, ownership, and regulation of the industry so that the traditional integrated utility has been disaggregated. Regions across North America have embraced a market philosophy for generation, wholesale power trading, and retail electricity services. Generation is controlled or owned and operated by private, non-regulated companies. Electric energy costs, instead of being set by regulators, are priced by market fundamentals. Transmission, however, remains regulated as a natural monopoly to ensure open, nondiscriminatory access and to protect the public interest.

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GSU transformer

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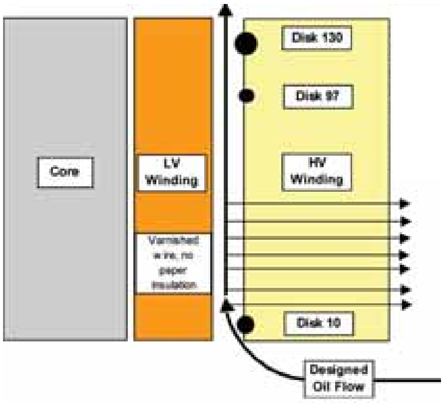

Diagram of GSU Transformer Winding
FIGURE 14
The oil flow lines in the HV winding take place in every disk just not those shown. The 3 black dots represent the turn with the highest copper found in the testing. The sixe of the dot indicates the relative concentration.

tion. In addition, a foaming tendency test was performed. The results from this test suggest that the fluid is contaminated with a silicone liquid or some other silicone based product. Although, part of the initial laboratory investigation, the presence of silicon and silicone probably did not contribute to the failure of the transformer.

The copper analysis on the paper insulation was a clear indication that copper was being transported from the conductor to the layers of paper surrounding the conductor with the highest concentration being found next to the conductor. Of even more interest is the distribution of copper in the layers. The copper concentration followed a distorted U-shaped curve from inside to outside with the lowest concentration being in the middle layers of paper wrapped around the conductor. This illustrates that paper is adsorbing copper not only from the conductor on the inside layers but from the bulk oil on the outside layers so it is being impacted from both directions. It also shows that copper ions are being transported through numerous layers of paper. In previous experiments performed at Doble, new paper received from the paper manufacturer only contained about 1 to 3 mg/kg (ppm) of copper in the paper.

What is also shown in these results is that the inner most turn (Turn 29), exhibits the highest concentration of copper of all the turns in a disk and it may be due to the oil flow that exists between the low voltage and high-voltage windings. Even in one of the bottom most disks (Disk 10), though the overall copper concentration was much less then the other two disks tested, the 1st layer of the 29th turn still exhibited a very high copper concentration. Another interesting fact is that the copper concentration in the paper also increases as the disk position increases in the winding. Basically, the top of the winding exhibited the highest overall copper concentration even though this was not the immediate area in which the failure occurred. As this was a core form transformer, it is thought that the copper distribution in other core form units or designs would be similar if a problem of this type should exist. Figure 14 provides an overall diagrammatic view of the transported copper distribution determined in this analysis.

CONCLUSIONS

This article discussed some of the details of the teardown and laboratory investigation of a failed GSU transformer. Teardown evidence and laboratory analysis showed that the failure was in part the result of copper and copper sulfide contamination of the insulating paper of the windings that led to a reduction in dielectric strength. Several analytical test techniques were used to make clear the reason for the failure and to understand the dynamics of the contamination. Testing for the copper concentration in the paper of the high voltage winding provided important information on the transport and distribution of copper as result of the corrosive sulfur condition and showed how the conductor and oil flow influenced the copper concentration in the transformer.

Lance Lewand is the Laboratory Manager for the Doble Materials Laboratory and is also the Product Manager for the Doble DOMINO, a moisture-in-oil sensor. The Materials Laboratory is responsible for routine and investigative analyses of liquid and solid dielectrics for electric apparatus. Since joining Doble in 1992, Mr. Lewand has published numerous technical papers pertaining to testing and sampling of electrical insulating materials and laboratory diagnostics.

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KEY ISSUES

In order to understand the relationship of industry restructuring and reliability, we first need to understand how generation and transmission and the interconnected network have changed as a result of restructuring. In view of those changes, we can then address the roles of the key players, such as the Independent System Operators (ISOs) who can affect reliability, and the key considerations that affect transmission in particular.

A NEW VIEW OF TRANSMISSION

Transmission systems are no longer overhead pipelines to move a certain amount of electric power from generator A to load B. The transmission system now connects many components, including millions of commercial transactions, into a gigantic synchronized machine. There is a greater strain being placed on the system because of the increase in supply and demand. Growth in the digital economy has increased the demand for diversity and higher reliability.

THE ELECTRICITY MARKET HAS CHANGED - FOCUS USED TO BE ON GENERATION

The transition from a regulated-utility model to a competitive-market structure is complex. This is particularly true for electricity because of its physical properties; electricity is not storable, it moves at the speed of light, and it has no substitutes. Moreover, because of the integrated nature of electricity service - generators, transmission, distribution, wholesalers, and retailers are all engaged in delivering the product to customers.

A number of changes related to the competitive market have changed the way that generation decisions are made. First, wholesale electricity costs are no longer regulated; prices are now set by supply and demand in a market context. And, second, generation owners no longer have their historic obligation to serve. As private, non-regulated market competitors, they make decisions based on their financial interest and must compete in the private capital market like any other high-cost, capital-intensive, long-lead-time investment.

In a competitive market, generation investment decisions are made based on future expectations of market performance. This means that the electricity market framework must provide signals that are predictable, understandable, and supportive of future investment in the electricity sector to underpin economic growth. Suppliers, too, need assurance that they can get their product to market, over a reliable transmission system, so they can have the opportunity to compete.

Finally, the framework for load must also be predictable and reflect market fundamentals.

Existing and future load customers must be able to make reasonable predictions about price to make informed choices. Load must be assured it will have access to needed electricity supply, including the required levels of quality and reliability. The cost of unreliability to customers, especially industry, is very high. In light of all these issues, a new view of transmission is needed.

ACCESS TO TRANSMISSION

To support the new market structure, transmission must be readily available and open to all supply and load customers in a non-discriminatory manner with sufficient capacity to constrain neither load nor generation. Transmission remains a regulated monopoly and is the foundation for reliable service. Transmission is now also the facilitator of the competitive market. The cost of transmission must be evaluated not only in light of its contribution to reliability and cost effectiveness but also its contribution to a smoothly functioning competitive market.

THE INTER-TIES

Transmission development must recognize that each region is part of, and connected to, the rest of the North American electricity grid. Inter-ties are an essential part of a competitive market and a reliable electricity system, both as a means to import power when needed and to export surplus energy, ensuring that the competitive wholesale market functions effectively. Inter-ties are essential to a well-functioning market. The transmission policy and regulatory environment must facilitate open access to larger markets while ensuring that regional needs are met.

TRANSMISSION – THE NEGLECTED PARTNER

Transmission is the foundation for reliability and a competitive market. The role of transmission has been amplified by the change to a market-based framework. Therefore, the value of transmission has changed and must be understood in light of transmission's new, broader role.

THE QUESTION OF RELIABILITY

Today, there are more transactions, players, and variability in system conditions than in the past. Demand for energy has increased year by year as most jurisdictions continue to grow. Suppliers and customers continue to expect predictable service without disruption. Balancing supply with demand has become more challenging as market forces influence when and if a generating unit operates. There are numerous examples of the impact of market forces. One example is that some services provided by generation resources, like power system stabilizers and automatic voltage regulation, which were previously taken for granted, must now be specified and paid for through contracts and agreements. Reliability has become more complex.

Today's transmission system must accommodate greater variability in power flows and system voltages than were true in the past. Energy is exchanged based on domestic and regional needs. All these factors increase the challenges of maintaining reliability of the transmission system.

TRANSMISSION DELIVERS BENEFITS

As the market facilitator, transmission facilitates new generation by providing nondiscriminatory and efficient transport to the market. Transmission must be robust and adequate to allow for a fully competitive and functioning market, or customers will not receive the benefits of competition. For generation competition to deliver benefits to customers, every single megawatt of electricity must be able to reach the market. Stranded generation is not in the interest of the customer or the producer.

CONGESTION IS NOT A GOOD THING

Transmission systems are vulnerable to periodic disruptions. Inadequate transmission creates bottlenecks that compromise reliability and undermine market efficiency. System constraints such as congestion foreclose, disrupt, and increase the cost of power delivery. Congestion on transmission systems creates "winners and losers" as some generators are unable to reach the market with their products. Congestion drives energy prices higher.

> ***We need to upgrade and make additions to the transmission system – fast.***

Lack of transmission investment is resulting in economic penalties: rising losses and constraints on more economic generators. When any congestion exists, even one megawatt, the cost for all energy in the market rises to the cost of the next megawatt that can be delivered. Transmission congestion is simply counterproductive to the interests of customers, and it costs money. Transmission congestion calls for action. Prevention is the cure for transmission congestion.

WE'VE GONE "SHORT" ON TRANSMISSION INVESTMENTS

The timeline for transmission is getting longer, which is exactly opposite to what markets need. The lack of transmission investment has been recognized as being costly relative to the potential benefits it will yield. Whether the costs are assessed in terms of increased line losses, reduced market efficiency, or degradation in reliability, transmission investments still deliver substantial benefits. Customers bear the direct cost burden of congestion, both in the short term by paying higher energy prices and in the long term in the form of costs of deferring transmission additions. Customers also bear the indirect, substantial costs resulting from disturbances or outages. Paying to remediate congestion, instead of building new transmission, is wasteful and not in customers' long-term interest.

A CALL TO BUILD

We need to upgrade and make additions to the transmission system – fast. Everyone everywhere is late to the party. Throughout the world, electricity systems face similar decisions to upgrade their transmission to meet growing demand. The lack of investment in new transmission facilities has produced detrimental effects including major widespread service interruptions and substantial economic losses. The impacts of the U.S.-Canadian Eastern outage in the summer of 2003 are well known. Other substantial service interruptions have also recently taken place in Italy, Denmark, Sweden, and England. Timely planning and development of transmission are integral to maintain reliability and prevent congestion.

THE TIMING GAP

Transmission additions are "lumpy" by nature and take considerable time to plan and build. Because transmission typically takes longer to develop than generation, it is understandable that generation developers may be reluctant to invest if they believe adequate transmission is not in place. Therefore, the insti-

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tutions responsible for transmission planning must look forward and make assumptions about load growth and generation development to ensure that a robust transmission system is in place in a timely manner. A forward-thinking transmission policy will declare that it is in the public interest to take ownership of the timing difference between generation and transmission additions.

The electricity industry continues to evolve to find the right set of policies, regulations, economic structures, and incentives to spur the transmission investment that is so sorely needed to ensure system reliability and handle the level of demand and the market forces that will affect the grid of the 21st century.

THE PLANNING VIEW

The power system is a huge interconnected, synchronous machine; an operation in one area can be felt throughout the entire system. In order not to adversely affect our neighbors, we must move from the myopic regional planning approach to a view of the wider interconnection. This is not easy and may not have been a fully functional strategy in the past; however, if we are to move forward with reliable power systems, integrated planning for the overall interconnection is essential.

> ***In the competitive environment, companies must attend to the need to maintain their facilities as well as to their bottom lines.***

PUTTING OFF MAINTENANCE

In the competitive environment, companies must attend to the need to maintain their facilities as well as to their bottom lines. The practice of deferring necessary maintenance, such as vegetation management, as a way to generate short-term profit must end; a single tree can cause a blackout.

ADVENT OF THE MERCHANT POWER LINE

Merchant transmission is an offshoot from traditional transmission projects built by utilities and approved by regulators on a cost-plus, rate-of-return basis. Despite the urgent need for new transmission infrastructure, investment in merchant alternating-current (AC) projects has been slow to materialize. Frustrating the industry is the conundrum that building a new transmission line erodes the very spread that the line was intended to capture.

Other challenges include the uncertainty of regulatory processes and investment recovery as well as the unpredictability of flow patterns in the bulk power system. Changes to underlying checks and balances, such as coordinated operations and planning, which have in the past been the foundation for the reliable operations of regional transmission systems, have also added to the complexities.

In Alberta, a framework, through legislation, has been created to allow merchant transmission projects to be developed, primarily for import or export. These projects are to be considered on a case-by-case basis. Pricing for such projects would normally be paid by the project beneficiaries that are the exporters/importers. However, if residual benefits to the internal grid, such as increased reliability, are demonstrated, consumers may fund system upgrades in a manner consistent with the benefits.

WHAT'S THE ANSWER?

The significantly larger number of energy transactions, more and more generation sources and congestion, and changing power flows that were never previously contemplated are evidence that competition has impacted reliability. The sheer volume of energy that the transmission system is being asked to accommodate has an impact. How can we reduce the risk of a blackout like the one in August 2003? The answer is to reinforce our transmission systems by building new and upgrading existing facilities and to improve the way we monitor, schedule, maintain, and operate the grid.

ROLES, RESPONSIBILITIES AND RELATIONSHIPS OF THE INSTITUTIONS – TO THE MARKET AND FOR RELIABILITY

The electric power industry must have in place effective institutions to address transmission's dual role of reliability and commercial market facilitation.

GUARDIAN OF RELIABILITY

Although it is tasked with many important responsibilities, first and foremost the ISO/regional transmission organization (RTO) must be the guardian of reliability. This responsibility and authority for maintaining the reliability of the power system needs to be given to the ISO/RTO through legislation.

THE ISO PLANS

The ISO/RTO is also responsible for planning the transmission system, including creating or implementing criteria, standards, and rules to ensure system integrity and adequate supply to meet demand. In planning the transmission system, the ISO/RTO must respect the fact that jurisdictions are not isolated from each other and that they must, therefore, adhere to the relevant operating standards and policies that govern North America's interconnected electricity systems. These standards and policies apply to every aspect of the physical delivery of electricity.

Established by the North American Electric Reliability Council (NERC) and Regional Reliability Organizations (RROs), the standards are intended to keep the lights on everywhere in the interconnected grid without operational behaviours that are detrimental to others on the system. The real-time and interconnected nature of electricity systems absolutely requires adherence to these standards so that neighbouring systems do not adversely affect others as happened on August 14, 2003. It is patently obvious that mandatory reliability standards are required.

PLANNING SUPPORTS THE COMPETITIVE MARKETS

ISO planning must also recognize the needs of the competitive market. Planning for a robust transmission system supports the competitive market in two important ways:

1. A robust transmission system facilitates development of new generation by allowing efficient transport of power to the market. Inadequate transmission is a deterrent to development of new generation. Investors want assurance they can get their

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product to market.

2. Robust transmission contributes to a level playing field. Non-discriminatory transmission access is fundamental to competitive generation. The transmission system should not determine "winners" or "losers." All generators, including intermittent sources like wind, should have equal opportunity to compete in the market. Only an adequate, open, non-discriminatory transmission system can facilitate this objective.

ISO OPERATES MARKETS

In some cases the ISO is the operator of the competitive wholesale market. In this role, the ISO must be independent and unbiased for the market to function competitively in a fair and open manner. Non-discriminatory operation of the wholesale market is as important as nondiscriminatory access to the transmission system. There is a nexus between a robust transmission system and the competitive generation marketplace that needs to be reflected in the duties of the ISO/RTO.

It is incumbent on policy makers and governments to be clear about the role of the ISO/RTO in ensuring reliability and about how the ISO/RTO is to work with other institutions in fulfilling its mandate.

ISO ROLE IN STANDARD SETTING

The ISO/RTO must be a full participant in the development of new or amended reliability standards and must monitor compliance with reliability standards and submit reports to the appropriate agencies.

In practice, the ISO/RTO, transmission facility owners, and others are expected to work cooperatively with the RROs and NERC on setting reliability standards. It is essential that mandatory and enforceable reliability standards become a reality sooner rather than later. Legislators need to be encouraged at every opportunity to enact such standards. In the Western Interconnection, participants have voluntarily entered into a Reliability Management System (RMS) Agreement with the Western Electricity Coordinating Council (WECC) that includes a contractual commitment to abide by WECC reliability rules. This contract approach works well and should be championed as a model for other regions. The RMS can be modified to incorporate mandatory enforcement requirements.

ROLE OF THE REGULATORS

Changes to the electricity industry have altered the role of the regulator. In the former integrated utility environment, regulators were asked to review proposals for new investment, taking need for generation and transmission into account together. There are often trade-offs between generation and transmission investments. Accordingly, transmission was evaluated as a portion of the overall tariff to be charged to customers. In that environment, it was acceptable to trade off generation and transmission because ratepayer dollars were used for both investments. In the wake of electricity industry restructuring, regulators need base their evaluations on the new industry framework, in which generation and transmission investment decisions have been decoupled. Generation has become a business decision for private investors vying to compete in the new marketplace. A "need" assessment for new generation is now a thing of the past. Trade-offs between transmission and generation are, therefore, no longer appropriate. Market forces determine generation additions and investors assume the risk of these decisions.

Transmission needs to be evaluated by the regulators in a new light consistent with the changes in the electricity market. Transmission remains regulated as a natural monopoly to assure both reliability and efficiency. The transmission system functions as a single entity and needs to be managed and regulated in a highly coordinated manner to ensure balance of supply and demand at all times. Building competing sets of wires across the same regions would result in unnecessary and costly duplication. Transmission systems built as a patchwork of control and ownership will never operate as reliably and efficiently as desired.

REGULATORS MUST TAKE A LONG-TERM VIEW

A long-term perspective on transmission development is required. It is necessary for regulators to assess and evaluate proposals for new transmission taking into account transmission's role as reliability agent and market facilitator. Regulators must also have regard for how a transmission upgrade or expansion contributes to: improving system reliability, facilitating a robust competitive market, improving system efficiency, improving operational flexibility, maintaining options for long-term development of the transmission system, fostering a desirable investment climate, and providing transmission access to other jurisdictions.

Although regulators must consider cost, reliability and operational flexibility must also be carefully addressed. Transmission is now both the provider of reliability and the highway for electricity commerce. Therefore, evaluations of new transmission must consider these complementary objectives, taking a broad and forward-looking view. The absence of appropriate regulatory mechanisms for cost recovery has led to an underinvestment in transmission in most jurisdictions.

ROLE OF THE POLICY MAKER

It is incumbent on policy makers and governments to be

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SMART ENERGY STRATEGIES: INTEGRATING SOLAR ELECTRIC GENERATION AND ENERGY EFFICIENCY

Alameda County successfully completed the fourth largest solar electric system in the world atop the Santa Rita Jail in Dublin, California. The Santa Rita Jail is the largest energy user of Alameda County's government buildings. This solar installation, the nation's largest rooftop system, was commissioned to help Alameda County reduce and stabilize future energy costs.

"Over the past several years, Alameda County has reduced electricity use by more than 30 percent…We are confident that solar energy is a very smart addition to our overall energy strategy"
– County Supervisor Scott Haggerty

This smart energy project reduces the jail's use of utility-generated electricity by 30 percent through solar power generation and energy conservation. Clean energy is generated by a 1.18 Megawatt installation consisting of three acres of solar photovoltaic panels.

Even before the entire installation was complete, the initial solar systems of 650 kW helped Alameda County weather the California state energy crisis by reducing the jail's monthly electric bill and replacing pollution-generating electricity with clean, on-site solar power. Improved building efficiency measures applied in tandem with solar electric power generation optimized Alameda County's investment in their own, on-site solar power supply.

BENEFITS TO ALAMEDA COUNTY AND CALIFORNIA

• Over 2.4 million kWh of annual electricity is no longer purchased from the power grid

• Avoided emissions of 38,000 tons of carbon dioxide and 24,000 lbs of nitrogen oxide, major contributors to smog, acid rain and global warming.

• Enhanced solar electricity generation facility with reduced need for maintenance

• PowerLight's solar PV tiles protect roof

• Lower operational costs

• Generates community goodwill and elevates Alameda County's status as a progressive energy leader

This case study presents the results of Alameda County's Santa Rita Jail solar electric power program, including system costs, savings, and performance, for the period of January 2001 through March 2002. The Santa Rita Jail solar installation was performed in three phases:

Phase I: This first solar project, installed in July 2001, consisted of a 519 kW photovoltaic rooftop system located on the top of six of the jail's eighteen housing units, a chiller replacement with variable speed drive, a cool roof and an energy management system upgrade. The primary motivation was to reduce high

System Specifications
System Size: 1.18 Megawatts
Annual Power Generated: 1,460,000 kWh
PowerLight Photovoltaic Roof Tiles 9,726
Solar Array Size (square feet) 130,000
Solar Array Size (acres) ~ 3 acres

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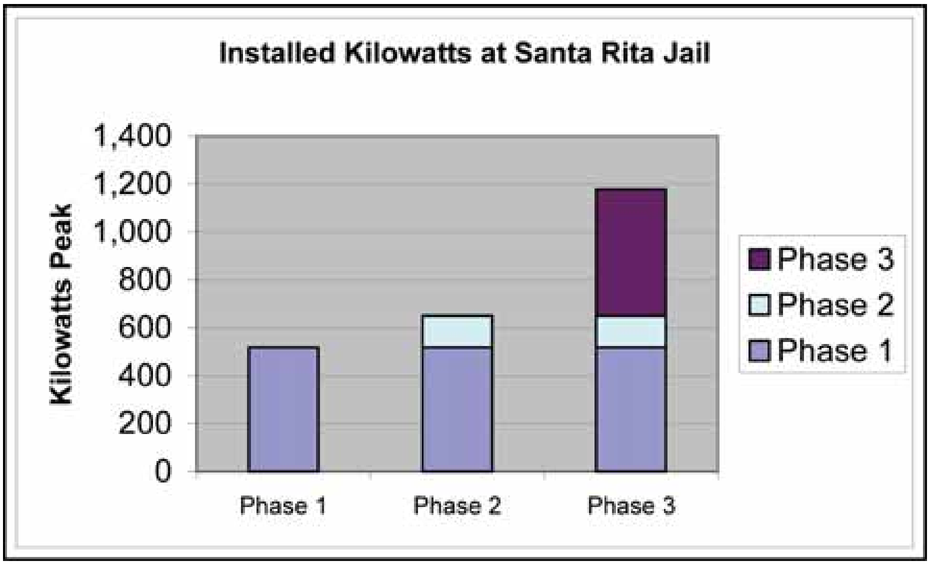
electricity costs because of the California energy crisis.

Phase 2: In October 2001, Alameda County took advantage of increased California state solar energy incentives and installed a second solar electric system of 131 kW on top of an additional two housing units.

Phase 3: After the successful implementation of the first two solar installations, Alameda County purchased a third solar photovoltaic system in April 2002 to further reduce operating costs and to demonstrate that large-scale solar power is feasible and economically attractive for a large energy user, such as the Santa Rita Jail. Fourteen of the jail's eighteen housing units now have solar photovoltaic systems installed on their roofs. A summary of the capacity of these projects is presented in the figure below:



BACKGROUND

For years, Alameda County has been a leader in smart energy strategies. This is a direct result of the vision and leadership from the County's Board of Supervisors and General Services Agency to reduce the County's annual overall energy usage and costs.

A number of cost-effective energy efficiency programs were launched in 1993, when the County's General Services Agency hired its Energy Program Manager, Matt Muniz, P.E. One of Muniz's first projects was to retrofit over 12,000 fluorescent light fixtures with energy efficient T-8 lamps and electronic ballasts and install innovative lighting controls throughout the County's Santa Rita County Jail in Dublin, CA. Later Mr. Muniz's energy team replaced over 550 inefficient fractional horsepower exhaust fan motors with premium efficiency motors at a payback of less than one year. Both of these projects are part of Pacific Gas & Electric's (PG&E) "PowerSaving Partners" demand-side management program. As a Power Saving Partner, the County has received over $2.3 million in direct incentive payments and ultimately reduced electricity costs at the jail by one-third.

Charged with the task of achieving even greater energy savings at other Alameda County facilities, the County's energy program staff implemented a number of other energy efficiency measures that presently total over $4 million in annual cost avoidance savings. These measures included lighting retrofits in 95% of County owned-buildings, the installation of state-of-the-art building automation systems in 25 facilities, replacement of most chillers with energy efficient and CFC-friendly equipment, and installation of Variable Frequency Drives to the HVAC systems in County facilities.

Alameda County established the following goals at the inception of the solar program:

• Evaluate the feasibility of solar electric (photovoltaic, or PV) technology for the Santa Rita Jail and other Alameda County buildings.

• Reduce the Santa Rita Jail utility operating cost, and the risk of future fuel price volatility, in a cost-effective manner.

• Contribute to California sustainability and environmental preservation.

THE RIGHT PARTNER

Alameda County chose PowerLight Corporation, a Berkeley, California firm, to design, manufacture, install, and maintain their solar electric systems. PowerLight is the leader in delivering large grid-connected PV systems, and has developed and patented the solar mounting system technology used at the Santa Rita Jail.

The reason for choosing PowerLight's protective solar electric rooftop products was that they not only provided energy savings from solar electric generation, but offered additional benefits of HVAC savings through thermal building insulation and extended roof life.

"I thought that we had completed all the cost effective energy saving measures that were possible at the jail," says Matt Muniz, Alameda County's Energy Program Manager. "But with over a half-million square feet of unused flat roof space at the jail and the recent drop in prices for solar cells, PowerLight and I immediately saw that solar electricity was the perfect solution for further demand reduction."

CHALLENGE

How could Alameda County achieve its vision of becoming a leader in solar energy? Could the economics of large-scale solar photovoltaic systems be cost effective? How would such a large capital purchase be financed?

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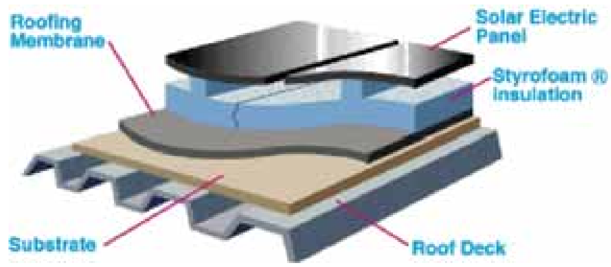
SOLUTION

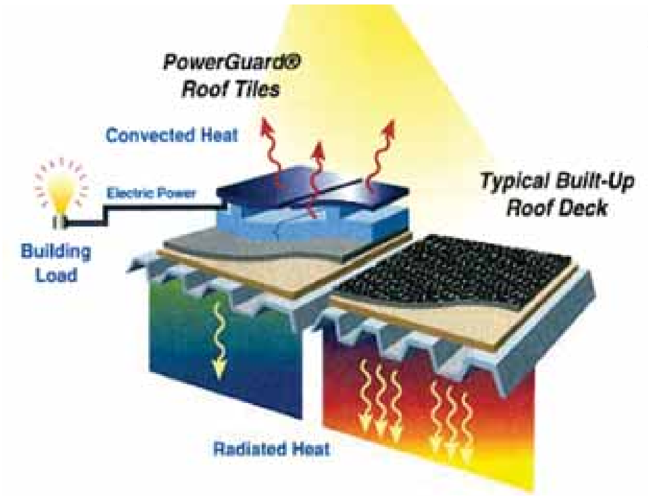
By leveraging one of California's most plentiful resources — the sun — and embracing renewable solar photovoltaic technology to generate clean reliable power, Alameda County significantly reduced its operating costs and helped to contribute to California's sustainability. The abundant solar electric incentives available in California, such as the California Energy Commission's Emerging Renewables Buy-down program, made the solar electric system affordable in its own right. However, an even more affordable idea was borne: to combine on-site solar electric generation with reductions in the jail's overall energy use by implementing energy conservation and sophisticated energy management measures.

PowerLight Corporation soon thereafter contracted with CMS Viron Energy Services, to showcase the synergy between the latest advancements in solar PV and state-of-the-art energy efficiency technology. CMS Viron is a 27-year old firm based in Overland Park, Kansas and a subsidiary of CMS Energy, a leading utility and diversified energy group based in Michigan doing business in 21 different countries.

Alameda County, PowerLight, and CMS Viron then crafted an integrated solar electric generation and energy efficiency plan with the goal of exceeding the County's 10% internal rate



Solar Photovoltaic (PV) Installation Provides Multiple Benefits: PowerLight's PowerGuard product is a patented photovoltaic (PV) roof tile assembly that delivers clean solar electricity to the building. PowerGuard tiles incorporate state-of-the-art PV cells backed with insulating polystyrene foam, turning the sun's free energy into usable power while increasing building thermal insulation and extending roof life. A key innovation of these roof tiles is that they can be installed on flat rooftops without penetrating the roof membrane.



Roof Protection and Energy Savings

PowerGuard technology offers unique characteristics of an insulating substrate that serves to protect and insulate the roof, as well as reduce the interior building temperatures. PowerGuard provides HVAC (heating, ventilation, and air conditioning) savings in several ways. The modules sit several inches above the surface of the building roof, effectively shading the roof like a huge umbrella. The shading reduces the peak temperature of the roof reducing both conductive and radiant heat transfer into the building interior. The illustration (right) compares the relatively low radiated heat internal to a roof covered with PowerGuard solar tiles with that of a typical built up roof deck without PowerGuard.

of return threshold for energy projects. This plan now serves as a model for other local governments and large commercial customers concerned about rising electricity rates, reliability, and the nation's increasing environmental concerns.

TECHNOLOGICAL INNOVATIONS

The Alameda County solar project offers proof that solar electricity and energy efficiency are a robust blend of technological innovations well suited to respond to California's stressed power grid. Linking Santa Rita Jail's solar electric installation with energy efficiency upgrades and state-of-the-art energy management software, Alameda County is able to reduce its peak power consumption at Santa Rita Jail by 30%.

By applying a "Cool Roof" reflective coating on the jail's existing roof, the roof area not covered by solar tiles now reflects 65% of the solar energy. This effectively reduces the roof's temperature during the hot summer months by 50 degrees Fahrenheit. Peak electrical demand reductions result from the reduced air conditioning requirement in the occupied spaces below.

Large electricity savings were achieved by replacing an old inefficient chiller with a new 850-ton high efficiency chiller that does not use CFCs that contribute to the degradation of the ozone layer. New variable speed drives attached to the new chiller, chilled water pumps, and cooling towers respond directly to the precise real-time cooling requirements needed to deliver chilled water instead of operating at 100% speed all of the time.

Implementation of UtilityVisionSM, a computerized energy management system developed by CMS Viron, automatically reduces peak power consumption during dips in solar-generated electricity. These dips may be caused by normal weather conditions such as cloud cover. For example, if clouds block the sun for five minutes on a summer afternoon, UtilityVisionSM will automatically reduce power consumption proportionately so that no additional purchases of expensive peak priced electricity are necessary.

Modified central plant cooling tower installation features an 850-ton high efficiency chiller

Solar Installation at the Santa Rita Jail consists of nearly 3 acres of Power-Light's roof top PV tiles.

ECONOMIC GAINS

The approach used by Alameda County demonstrates that integrating innovative solar electricity systems with energy efficiency and energy management technologies offer worthwhile economic benefits to end-users.

• The 1,178 kilowatt (1.2 MW) solar PV installation on top of the Santa Rita Jail consists of roughly 9,700 PowerGuard tiles mounted on fourteen medium and minimum-security housing units in Dublin, California. This solar array covers 130,000 feet, which is equivalent to approximately three acres of solar photovoltaic tiles.

• Total gross project costs for the solar photovoltaic system, cool roofing, and energy efficiency upgrades were approximately $9 million. State government incentives and loans from the California Energy Commission and the California Public Utility Commission that are available to all city and county governments, helped make the project financially attractive.

ECONOMIC BENEFITS

The solar project goals were to reduce the Santa Rita Jail's utility costs as well as contribute to California's sustainability and environmentally sound initiatives. In addition, this PV system also helped to offset the air conditioning loads of the jail by providing additional roof insulation.

The PowerGuard photovoltaic system on the Santa Rita Jail facilitates the generation of as much as 915 kWac at midday. Additionally, PowerGuard's special insulating properties have reduced the jail's peak roof temperatures, yielding HVAC savings. PowerGuard's PV tiles and protective membrane roofing system are designed to shield the roof from UV radiation and protect against thermal cycling — two environmental factors that greatly undermine a roof's life span. It is estimated that the roof membrane protection will increase the roof life to approximately 25 years while reducing air-conditioning loads.

Alameda County's solar electric power program had an

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internal rate of return of over 10%, which met their energy investment hurdle. Net savings to Alameda County in its first year of operation averages $410,000. These savings are based on February, 2002 Pacific Gas and Electric electricity rates. Gross savings to Alameda County over the 25 year life of the project will total $15 million.

BENEFITS TO ALAMEDA COUNTY AND CALIFORNIA

Over 2.4 million kilowatt-hours of annual electricity consumption are diverted from the power grid by the Santa Rita Jail project. These savings benefit all state consumers by reducing grid power purchases, most of which occurs on-peak – during times of the tightest supply and highest demand. Additionally, by supplying clean on-site power, the PV system will help defer costly transmission and distribution upgrades. This is an especially critical concern in the severely constrained Tri-Valley transmission line area.

ENVIRONMENTAL SAVINGS

Alameda County's solar-powered installations spare the environment from thousands of tons of harmful emissions, such as nitrogen oxides, sulfur dioxide and carbon dioxide, which are major contributors to smog, acid rain and global warming.

It is estimated that over the 25-year lifetime of the Santa Rita Jail's photovoltaic systems, the solar-generated electricity will reduce emissions of nitrogen oxides by 24,000 pounds and carbon dioxide by 38,000 tons. The environmental savings are based on the average California utility generation mix, calculated from values provided by the U.S. Department of Energy. These emission reductions are equivalent to not driving 126 million miles or removing over ten thousand autos from roadways.

SYSTEM PERFORMANCE

Accountability is a key component of this project. The project's performance data is posted on the Internet so that other local governments and commercial customers can review and analyze the performance of both the solar installation and the energy efficiency measures.

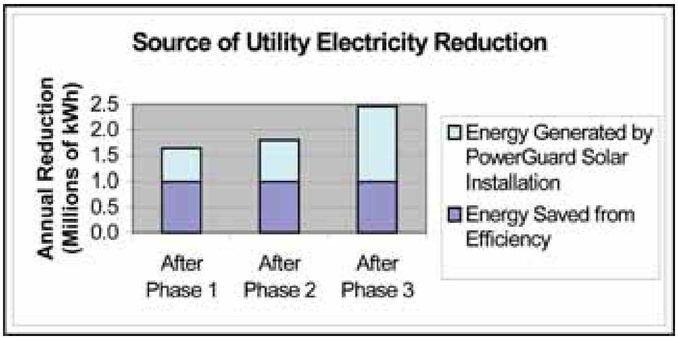
LESSONS FOR OTHER LOCAL GOVERNMENTS

Alameda County has shown that large-scale solar PV systems can indeed be a cost effective investment if available financing and subsidy mechanisms are fully leveraged, and even more cost effective if the system is integrated with the facility's energy management infrastructure.

PowerLight Corporation's PV System on the Santa Rita Jail generates as much as 915kWac at mid-day and simultaneously reduces the jail's air conditioning load.

COST MANAGEMENT

Another compelling aspect of this project was the purchasing and installation strategy. By purchasing multiple demand reduction measures through an integrated project with PowerLight under a single contract, administrative and management costs were lower than if the measures had been contracted separately.



Over 2.4 million kilowatt-hours of annual electricity consumption are diverted from California's power grid by the Santa Rita Jail solar project

Alameda County Solar Project	Predicted Energy	Offset Emissions 25 Years		Equivalent to Saving	
	Energy Production in kWh	Global Warming CO_2 (lbs)	Smog NOx (lbs)	Not Driving Miles	Removing Autos from Roadways
Santa Rita Jail	1,460,000	3,024,813	965	5,047,657	404
Total over 25 year life:	36,500,000	75,620,325	24,125	126,191,417	10,095

The environmental benefits linked to the 1,178 kilowatt solar PV system and energy efficiency improvements over the life of the Santa Rita Jail project are considerable.

ARC-FLASH HAZARD ENVIRONMENTS REQUIRE STRINGENT SAFETY MEASURES

By Bob Hill, FLIR Systems

Over the past two decades, the dangers of arc-flash events and the devastation they can cause have become fairly well understood. As the leader in infrared (IR) camera technology, FLIR Systems believes that perhaps less well understood are the precautions that should be taken to prevent such occurrences, or at least minimize their impact.

FLIR infrared cameras are often used to uncover potential arc-flash trouble spots, such as deteriorating electrical connections that may not be visible to the naked eye. Thermographers, electricians, and other workers at risk need to be familiar with all aspects of the arc-flash phenomenon: what it is, how and why it occurs — and how they can keep themselves out of harm's way anywhere this hazard may be present.

SHORT CIRCUIT, DEADLY FORCE

An arc-flash hazard is a dangerous condition associated with the release of energy caused by an electric arc. The arc consists of energized, ionized plasma that can, within a fraction of a second, reach some of the highest temperatures that occur on Earth — up to 35,000°F, a temperature at which all known materials are vaporized. Putting those figures into perspective, the surface temperature of the sun is approximately 9,900°F.

Arc-flash incidents can be triggered anywhere electrical systems are present and electrical equipment is being serviced or repaired. For example, a short circuit can result when a metal tool is dropped, momentarily reducing or bridging the electrical distance between energized components. Other causes include the careless removal of a metal cover plate; the failure of a circuit breaker as it is switched on; residual moisture in components; and voltmeter failure or a probe simultaneously touching phase and ground. Dust and impurities on insulating surfaces can provide a path for current, as can corrosion of equipment parts.

As with a bolt of lightning, the

power of an arc flash is almost beyond comprehension.

When it occurs, a massive quantity of concentrated, radiated energy explodes outward and simultaneously unleashes (1) expanding pressure waves of gas (an arc blast) that can damage hearing and turn loose metal objects into shrapnel hurtling through the air at velocities greater than 700 MPH; (2) a high-intensity flash that can damage eyesight or even cause blindness; and (3) a super-heated gas ball capable of vaporizing metal and severely burning anyone in the vicinity.

REAL-WORLD CONSEQUENCES

As the founder and principal engineer of an electrical power system consulting firm in Colorado, FLIR customer Bill Woods knows from long experience how devastating an arc flash can be. Yet even he was taken aback by the consequences of an arc-flash incident at a food plant, as captured on film by a security camera and shown at a recent industry conference.

"Three men were working on a deadline over a three-day weekend," he says. "They were hurrying to repair a transfer switch that had malfunctioned. One man had his hands up in the equipment, the second man was kneeling down next to him with blueprints, and the third man was the supervisor standing behind him and watching.

"The first man caused an arc, and he was pretty much incinerated," Woods continues.

"The man on his knees was engulfed in the fireball and badly burned. The supervisor — even though he was about 6'5" and at least 300 pounds, the shock wave was so powerful that it picked him up and knocked him back about ten feet."

One master electrician sadly recalls losing a colleague to arc flash when both were just starting out as journeymen many years ago. "It was in one of the local mills," he says.

"He was standing 15 feet away, but that wasn't far enough. You can still see the imprint of his shadow on a glazed tile wall over at that mill."

SOBERING STATISTICS

Arc-flash events are not at all infrequent; in the U.S., between five and ten occur every day that send their victims to a burn center and, according to one study, result in medical costs of $1.5 million for each episode. Those statistics do not include victims sent to regular hospitals and clinics, cases that go unreported, or cases in which no one was seriously injured. It is estimated that 80 percent of electrical injuries are caused by burns resulting from arc flash and igniting of inflammable clothing. Treatment can require years of skin grafting and rehabilitation, with no assurance that the victim will ever be able to return to work or a normal life.

The arc-flash phenomenon isn't new; it has been around as long as electricity has been distributed. Only since the late 1980s, however, has it been given the attention it deserves, spearheaded in large measure by the petrochemical

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industry. Today a number of organizations — both government and private-sector — provide regulations, policies, recommendations, and monitoring in order to minimize the possibility of arc-flash incidents and protect those who work in environments where arc flash is likely to occur.

OSHA

While not specifically addressing arc-flash hazards, OSHA's 29 CFR Part 1910, Subpart S, does set design safety standards for electrical systems. Included are standards for electric utilization systems, including all electric equipment and installations used to provide electric power and light for employee workplaces. Safety-related work practices and maintenance requirements, as well as safety requirements for special equipment, are also covered.

Paul Frisk, who covers all of Canada as a roving instructor for FLIR Systems' Infrared Training center (ITC), comments that OSHA mandates working in deenergized conditions except under special circumstances, such as when a problem can't be uncovered by troubleshooting the equipment in a deenergized state. "They want you to work on equipment that isn't energized," he says. "And yes, that would be ideal. But in order for our infrared cameras to work, the circuit has to be energized."

Although this situation might appear to be something of a Catch-22, there are solutions.

In particular, infrared windows — such as Hawk IR sightglasses — can be installed in cabinet doors or panels, enabling thermographers to do their job safely even in the presence of an energized environment.

REGULATIONS AND RECOMMENDATIONS

Four separate industry standards have been established that deal with the prevention of arc-flash incidents:

- Occupational Safety and Health Administration (OSHA), 29 Code of Federal Regulations (CFR) Part 1910, Subpart S
- National Fire Protection Association (NFPA) Standard 70, National Electrical Code
- NFPA 70E, Standard for Electrical Safety in the Workplace
- Institute of Electrical and Electronics Engineers (IEEE), Standard 1584, Guide for Performing Arc Flash Hazard Calculations

NFPA NATIONAL ELECTRICAL CODE

The NFPA's National Electrical Code was first introduced almost a century ago and has grown to almost 800 pages. Invariably referred to in the trade as "The Code," the NEC is the standard reference work for electricians and is mostly concerned with installation practices.

Over the years, the NEC has dealt with protection from fire, electrocution, and shock hazard. Recently, arc-flash safety has been moving into the picture as well. Of particular relevance is the NEC requirement that hazard warning labels be posted on switchboards, panel boards, industrial control centers, and motor control centers to warn workers of hazards that might cause serious injury or death due to arcing faults.

These labels must be located where they will be visible to qualified personnel before any examination, adjustment, servicing, or maintenance of the equipment is undertaken.

NFPA 70E

Although OSHA sets forth the legal requirements, it does not spell out how they are to be implemented. NFPA originally developed NFPA 70E, Standard for Electrical Safety in the Workplace, as a national consensus safety standard primarily to assist OSHA in preparing electrical safety standards. In effect, OSHA says what to do and NFPA 70E explains how to do it.

NFPA 70E guidelines provides requirements for Flash Protection Boundaries (FPB) related to electrical safety when working on energized equipment. An FPB is a distance from exposed or enclosed live circuitry within which a person could receive a second degree burn if an arc flash occurred. These boundaries specify safe distances from an energized component in which a worker can operate without the use of PPE such as clothing, gloves, tools, face protection, and glasses. A worker crossing such a boundary must be qualified and wearing appropriate PPE.

NFPA 70E further specifies the type of PPE to be worn by workers in the vicinity of energized circuitry. The nature and extent of this equipment varies with the potential calorie level of radiated energy. Although they are not responsible for selecting appropriate PPE levels, thermographers have to be aware that such a requirement exists. In fact, they need to be thoroughly familiar with all NFPA 70E guidelines because, in certain situations, covers must be removed to permit access so that an inspection can be completed.

Even though, strictly speaking, companies are not legally required to comply with NFPA 70E, they'll be expected to offer a compelling alternative if they choose not to do so. As Woods puts it, "You still have to follow the intent. You better be doing something that protects your workers." In short, compliance with NFPA 70E will ensure compliance with OSHA regulations.

Woods also notes that utility companies are currently exempt from many provisions of both NFPA 70E and the National Electrical Code. "This seems kind of strange," he says, "but apparently the idea is that if your job is to produce electricity, you ought to know something about it." He adds that OSHA is now proposing changes that may require utilities to comply with parts of NFPA 70E.

IEEE

IEEE's major contribution to arc-flash hazard safety is its Standard 1584, Guide for Performing Arc Flash Hazard Calculations. As the title suggests, this publication helps facility's personnel calculate the hazards of arc flash in different types of equipment in various power systems. It provides definitive calculation steps in support of NFPA 70E and outlines a method for calculating the expected incident energy level.

With this information, a facility owner can make an informed decision about the level of PPE that those who work on the equipment must wear. From the results of the analysis, Hazard/Risk Categories are established, and Flash Protection Boundaries calculated, by NFPA 70E. Although applying NFPA 70E and IEEE 1584 practices can't guarantee that a worker will not be injured by burns from an arc-flash incident, it has been shown that following these methods plus using appropriate PPE greatly reduces the possibility of burns.

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THE IMPORTANCE OF PPE

Personal protective equipment — such as clothing, gloves, tools, face protection, and Glasses — is intended to protect workers from the most destructive arc-flash events, mainly those that might cause potentially fatal burns to the head and chest.

NFPA 70E provides a table of PPE ratings, which are based either on voltage rating (gloves) or thermal rating (cotton and fire retardant clothing). Also included are PPE ratings for various kinds of apparel, chiefly shirts, pants, and underwear. PPE is improving at a rapid pace as new technology is developed and introduced.

Frisk offers another suggestion in his classes:
"Whether you have a sightglass or not, if you're planning to open the door, do the fireman trick. The fireman will always take his gloves off and put the back of his hand on the closed door to determine whether there's a high-heat source on the other side.
We can accomplish the same thing with our IR cameras. So as a safety precaution, always measure the temperature of that door."

REDUCING HAZARD CATEGORIES AND PROBABILITIES

A fundamental principle of reducing arc-flash hazard categories is to keep fault currents low. Unfortunately, this may be difficult to accomplish in existing plants owing to outmoded design practices of the past. These include installing oversized transformers to accommodate future growth that might never materialize; using transformers with the secondary side protected by a primary fuse; using bolted fault currents (currents with no impedance) for setting breaker trip points; and selectively coordinating overcurrent protection, which involves slowing down the circuit-breaker tripping time.

Engineering techniques exist that can address such problems. Once an Arc Flash Hazard Analysis has been completed, it is relatively easy to perform a study of overcurrent protective device coordination to ensure that all devices clear a fault as quickly as possible. And slow-acting protective devices can be replaced with faster ones.

The main circuit breaker should trip instantaneously when any fault current is detected.

This can be accomplished in several ways: The breaker can be set to instantaneous when work is to be performed. A maintenance switch, or a proximity or motion detector, can be installed on the breaker. An optical detection relaying system can be installed.

Finally, fuses and/or the transformer can be replaced.

As important as reducing arc-flash risk categories is reducing the probability that an arc-flash event will occur. A corporate-wide arc-flash hazard program should be implemented, one that includes hazard assessment, documentation, a PPE plan, development of procedures to minimize hazard, training for workers, and periodic safety audits.

Preventive measures that can be taken include keeping energized parts from being exposed, retrofitting exposed bus bars with insulated ones, and retrofitting terminal blocks with "finger-safe" components. Arc-resistant electrical equipment now on the market can redirect the forces associated with an arcing fault to a direction away from where an employee is working.

It should be emphasized that arc-flash hazard analysis and safety program development are still in the relatively early stages. A great deal more study and testing remain to be done. One electrician emphasizes that the best safety procedure is still the simplest and most obvious: "If you're not qualified, and you don't feel safe, and you don't have to be there — leave!"

ADDING SAFETY WITH INFRARED WINDOWS

As was stated earlier, OSHA regulations state that personnel should work on deenergized electrical circuits whenever possible. The operation of infrared cameras, however, requires that circuitry be energized so that thermographers can perform IR surveys of high- or low-voltage electrical equipment cabinets.

"FLIR infrared cameras can be fitted with telescopic lenses," comments Woods, "but someone still has to open up the cabinet. And we don't want the thermographer unprotected doing that."

An increasingly popular solution is to install infrared windows, such as Hawk IR sightglasses, so that inspection can be performed with doors and cabinets closed.

Hawk IR sightglasses provide thermographers with a direct line of sight for IR inspections and are also transparent to visible light. In addition, they eliminate the need for having a licensed electrician remove and replace doors and panels for inspections.

The results are significant increases in inspection speed and area coverage, and greater safety for workers.

Hawk IR sightglasses are available with either crystalline or mesh barriers. The "C" (crystalline) range sightglass can be used indoors or outdoors in either high- or low-voltage applications, while the "M" (mesh) range sightglass is suitable for indoor, low-voltage applications. UL-approved and easily retrofitted or installed in new equipment, both types provide an all-important physical safety barrier between the inspector's IR camera and the target. Hawk IR sightglasses are distributed in the United States by FLIR Systems.

SAFETY TRAINING FOR THERMOGRAPHERS

FLIR Systems is extremely concerned about arc-flash hazards and the dangers they pose to thermographers. Accordingly, in-depth information about arc-flash hazards is an integral part of the curriculum at the company's Infrared Training Center, where training is conducted by highly qualified international thermography instructors.

ITC instructor Paul Frisk advocates the "buddy system" to his students. "You have two thermographers on hand," he explains. "One is dressed in bulky PPE that almost makes him look like one of those robots from the '60s. There's no way he can possibly operate an IR camera. So, instead, he functions as the door opener, and the other does the thermography at a safe distance. One can keep an eye out for the other. After a certain length of time, they switch off."

FLIR Systems urges thermographers, electricians, and plant managers to thoroughly acquaint themselves with all of the various precautions that should be taken when working in a potential arc-flash environment. Whatever the job, safety comes first.

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clear about the role of the ISO/RTO in ensuring reliability and about how the ISO/RTO is to work with other institutions in fulfilling its mandate. Policy makers need to identify areas where the ISO/RTO role or responsibility is not clear and promptly enact legislation to resolve the lack of clarity.

ROLE OF THE WIRE OWNERS

The wire owners, both transmission and distribution, have a responsibility and need to maintain their systems at a level that ensures safe, reliable, and economic delivery of electricity. This includes all aspects of operation, maintenance, construction, and practices for the assets under their control.

WORKING TOGETHER

The industry has complementary functions that call for effective interaction and cooperation. The goals need to be closely aligned. Their common objectives necessitate that participants share a consistent vision to achieve the best outcome for the interests they serve, both public and private.

The reliability of the power system and the competitive electricity market that has been established are a benefit to participating customers. For these benefits to continue to accrue, we all need to be cooperatively and diligently working together.

CONCLUSION

Transmission is a small cost and well worth the investment to secure the significant benefits of an unconstrained market. Competitive generation markets will not work with an inadequate transmission infrastructure.

As the market facilitator, transmission enables new generation by ensuring non-discriminatory and efficient transport to market. Policy makers need to take the initiative to fill any and all policy gaps that are barriers to reliable transmission systems and robust, vibrant electricity markets. It must be very clear which institutions are the guardians of reliability, and these institutions must be given statutory authority to carry out their responsibility.

We are all in this together, and we have to make it work!

Kellan Fluckiger is the Executive Director of the Electricity Division with the Alberta Department of Energy. Kellan joined the department in July 2003. He brings 27 years of experience at all levels in the electric power industry to this position. His major responsibility is policy development related to Alberta's electricity sector.
During the last 27 years, Kellan has become a leading expert in all phases of electricity restructuring and the synthesis of technical, practical and political perspectives.

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