North American Policies and Technologies

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THE ELECTRICITY FORUM

October 2006
Volume 18, No. 8

Interest in Smart Metering Project surprises Utility, IBM

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ELECTRICITY TODAY

Volume 18, No. 8 October 2006

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Electricity Today Magazine is published 9 times per year by The Electricity Forum [a division of The Hurst Communications Group Inc.], the conference management and publishing company for North America's electric power and engineering industry.
Distribution: free of charge to North American electrical industry personnel who fall within our BPA request circulation parameters. Paid subscriptions are available to all others.
Subscription Enquiries: all requests for subscriptions or changes to free subscriptions (i.e. address changes) must be made in writing to:
Subscription Manager, Electricity Today
215-1885 Clements Road,
Pickering, Ontario, L1W 3V4
or on-line at www.electricityforum.com.

Canada Post - Canadian Publications Mail Product Sales Agreement 40051146
ISSN 0843-7343
Printed in Canada.

Member of:
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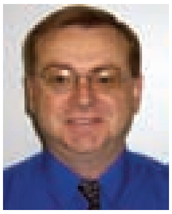


POWER NEEDS OF MINOR APPLIANCES A MAJOR CONCERN FOR THE GRID

By Don Horne

A recent load forecast discussion paper by the Ontario Power Authority estimated that the equivalent power of two nuclear reactors will be needed to meet the growth needs of minor appliances.

These minor appliances encompass everything from plasma screen TVs, DVD players, toaster ovens and iPod chargers — all the gadgets that fill residential households and represent the single largest contributor to residential energy growth in the next 20 years.

Gone are the days when there was one television per household. Now, TVs can be found in almost every room – and in many cases households have more than one computer.

The load forecast from the Ontario Power Authority (OPA) predicts the energy consumed by minor appliances will grow to 20.32 terawatt-hours in 2025 from 12.71 terawatt-hours in 2005, an increase of 7.61 terawatt-hours.

Put into perspective, it's the annual output of two Pickering A nuclear reactors — 1,000 megawatts.

However, those forecasted numbers are being questioned by the Pembina Institute as being artificially high, not taking into account improvements in technology to make more energy-efficient appliances. And as most small appliances have a short life-cycle, those upgrades would come at a fast pace.

The David Suzuki Foundation also questions the rate of growth estimates set by the OPA, pointing to recent annual consumption rates coming in below 1 per cent.

OPA's figures are based on the number of households growing 1.2 per cent annually (with commercial floor space growing 1.9 per cent), with the total consumption for commercial, industrial and residential sectors weighing in at 35.6 per cent, 33.4 per cent and 30.9 per cent respectfully by the year 2025.

The Pembina Institute is an independent, not-for-profit environmental policy research and education organization. The David Suzuki Foundation is a group dedicated to finding ways for society to live in balance with the natural world, following the principles laid out by its namesake, Dr. David Suzuki.

The Pembina Institute argues that such forecasts have been wrong before, pointing to the 1970s when the government of the day predicted significant economic growth and began massive spending on several nuclear and oil-fired facilities. The growth never materialized, and many facilities ended up being delayed or mothballed altogether.

The rate of residential consumption growth can be argued either way – be it a full percentage point a year or a fraction thereof; but there remains the inescapable fact that Ontario is in desperate need of more – much more – generation capacity.

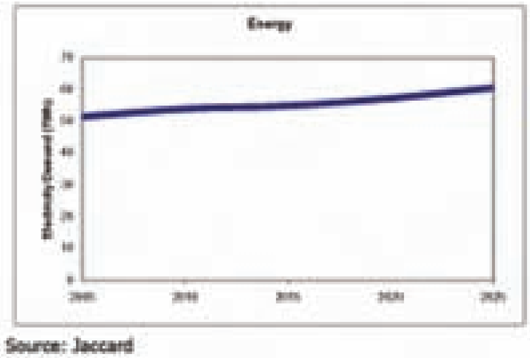


Figure 4.4 – Growth in Residential Electricity Use, Energy, 2005 – 2025

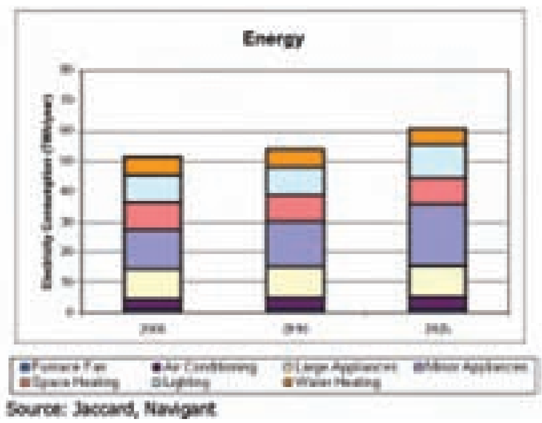


Figure 4.5 – Electricity End-Use in 2005, 2010 and 2025, Residential Sector: Energy

The arguments raised by the Pembina Institute and the David Suzuki Foundation that the OPA's figure may be artificially high do have merit, but certainly if the OPA is to err, it should be on the side of too much rather than too little.

Ontario has transformed from a province of exportable generation to that of a net importer. The discussion paper – which makes a direct analogy between nuclear power and future load requirements – is a not-so-subtle argument for new nuclear construction.

But the reality is that for a dramatic increase in generational capacity, nuclear is the best route to take.

Renewables do play a crucial role in contributing to the grid, but they lack the flexibility and brute capacity that nuclear can produce, and fossil fuel generation is ironically going the way of the dinosaur.

The decision to go nuclear is certainly one that will be predicated on public support – and every study, forecast and discussion paper endorsing its use will win that backing. But the OPA should be mindful that today's consumer has come a long way from the one TV per household mentality, and won't be willing to swallow facts and figures whole without taking into consideration every side of the equation.

INTEREST IN SMART METERING PROJECT SURPRISES UTILITY, IBM

By Don Horne

When Hydro Ottawa and IBM took on the smart metering pilot project, they couldn't have imagined the kind of positive response from the public.

"We sent out 1,800 letters to people who already had smart meters to see who would want to participate in the pilot project," says James Strapp, project manager. "We were looking for a 10 per cent response, typical for any utility mailouts. Instead we got a 30 per cent response – 525 people.

"That kind of involvement rate has been a surprise – a very positive surprise."

Mr. Strapp, who works for IBM, is not new to metering projects.

"I've managed similar projects in the United States, and it has given IBM a sense of how to attract people to participate, form focus groups and conduct surveys."

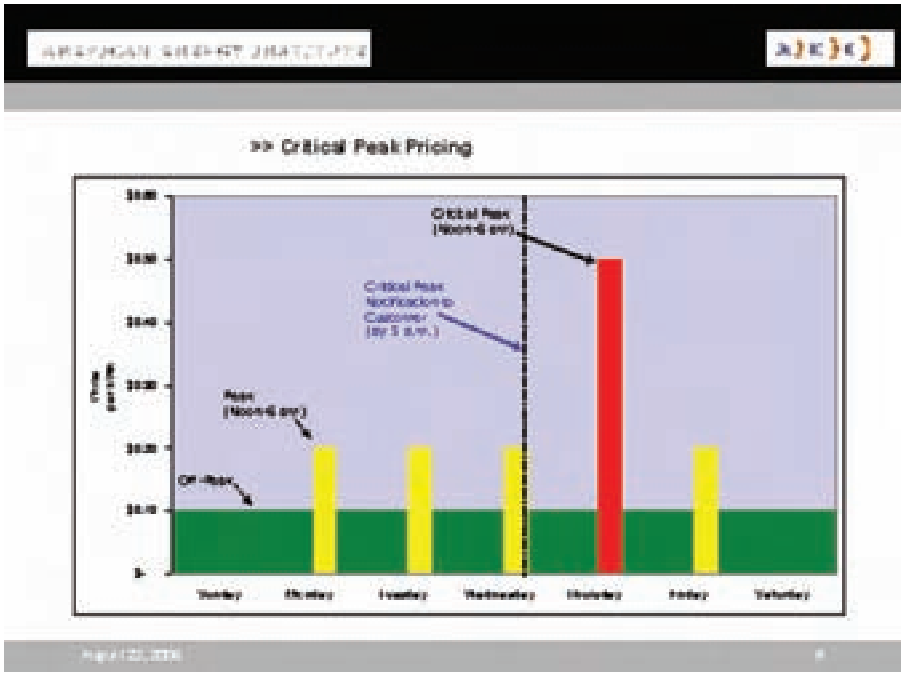
The project features 375 participants, broken down into three groups of 125 to look for potential consumption differences between those charged according to:

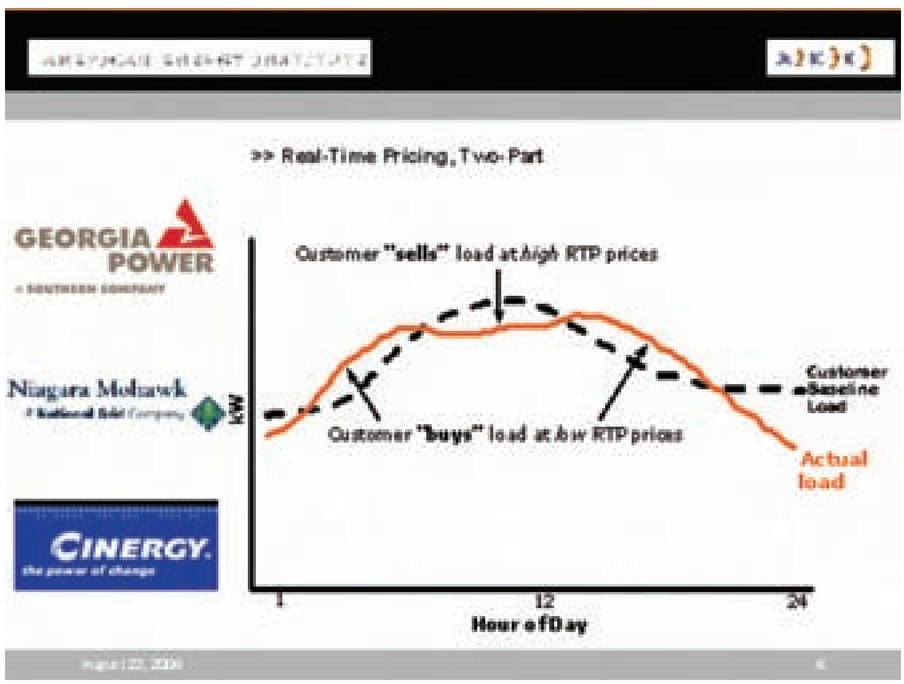
- standard TOU (Time Of Use) pricing where rates change in relation to periods of Off-peak, Mid-peak and On-Peak demand;
- TOU with critical peak pricing (CPP), and;
- TOU with critical peak rebates (CPR).

The Ontario Smart Price Pilot project will run for approximately five months with results to be presented in January of 2007.

"It will provide some very detailed energy information about usage, how much is off peak, on peak and critical peak," says Chris King of eMeter, who is providing consulting on the project.

"From what we've seen in the past, people respond very quickly once they are able to monitor their energy usage, and they modify their behaviour."





Ontario plans to have all homes and small businesses on smart meters by 2010.

In the United States, the prolonged

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smart meters

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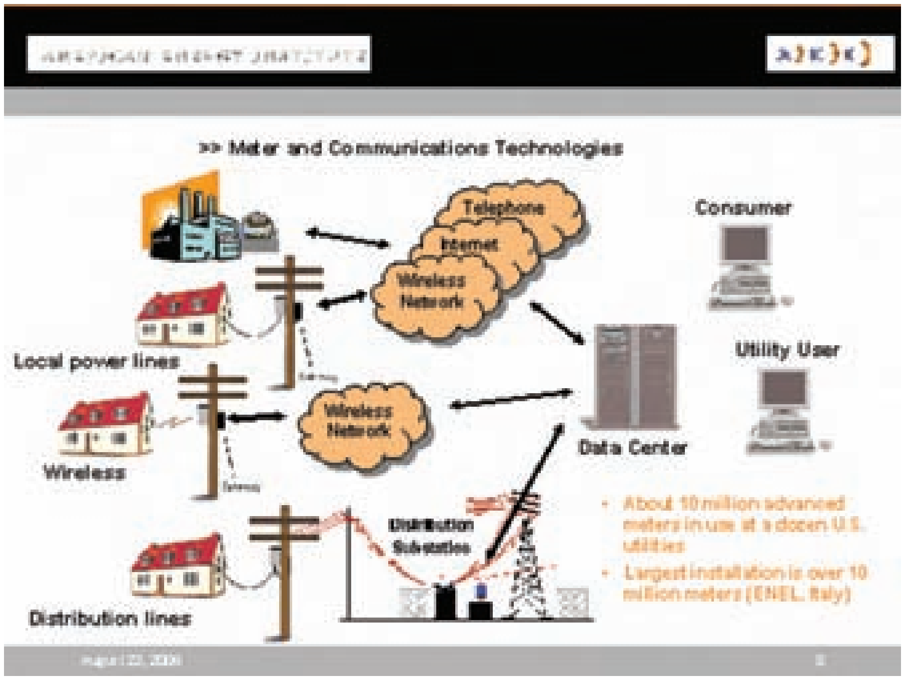

heat wave that enveloped much of the country this summer placed record demand for electric and water services in affected areas. High seasonal demand, coupled with the initiatives suggested under the "Smart Metering" Section 1252 of the Energy Policy Act of 2005 (EPAct), have placed conservation, balanced resource use and customer responsiveness to the top of many utilities' priorities.

Smart metering is a term that describes an enabling technology for demand response and for time of use (TOU) rate schemes. Demand response is the management of customer energy use at times of elevated demand to help address system-wide reliability. For customers, TOU plans establish rates based on the time of day a resource is used or

"The demand for the monitors has been very positive. I think northern Ontario customers are enthusiastic about a device that can help them to monitor their electricity consumption and conserve. We all like to save money."

on overall demand during critical periods. Section 1252 of EPAct suggests that states investigate the implementation of time-of-use rates reflecting the true cost of providing electricity during critical, high demand occurrences.

Through mid-July, AMRA has tracked at least 10 states that have begun their examinations of smart metering and advanced metering. In June, the California Public Utilities Commission approved a $1.7 billion statewide plan to replace 9 million electric and gas meters with advanced meters to deal with its climbing electric demand, address balanced resource use and better serve its residents.

In northern Ontario, customers of Hydro One have ordered 10,000 electricity monitors that the utility is giving away for free.

In total, 30,000 units are being made available on a first come first served basis to Hydro One residential customers in northern Ontario.

Danny Tuff, CEO of Blue Line Innovations commented on the program saying: "The demand for the monitors has been very positive. I think northern Ontario customers are enthusiastic about a device that can help them to monitor their electricity consumption and conserve. We all like to save money," he says.

Northern Ontario Hydro One customers are the first in the province to be offered the free monitors.

Called the PowerCost Monitor, the device is simple to install. The homeowner attaches the sensor unit to the hydro meter on the outside of the home and it reads the meter. It then sends a signal to a small companion display unit, which can sit atop the kitchen counter or in any other room in the house.

The display unit shows the homeowner how much money is being spent on electricity from moment to moment. There are no wires used to connect the sensor unit to the display unit in the home.

Research results from an earlier year-long Hydro One demonstration project with 500 Ontario homeowners showed that real time electricity monitors can help homeowners reduce their consumption of electricity by up to 15%.

GUIDELINES FOR EMERGENCY RESOURCE PLANNING FOR OVERHEAD TRANSMISSION LINE ASSET OWNERS

A question that each Asset Owner should ask is "Do we have a clear emergency response policy? Is there an organizational structure to respond effectively to emergencies?" However, the question that is most frequently asked by asset managers is "Why do we need all this material in inventory?" Does this sound familiar?

Tower failure due to mudslide

Let's pose these questions differently. Ask, "What is the responsibility of the asset owner to minimize network outages?" or "How much can the asset owner or the economy afford to lose due to a failure?"

The latter question rings true if one considers that the major impact on the asset owner (in terms of unavailability or revenue lost) is marginal when compared to losses incurred by society, which is affected most through loss in productivity and affected public and health care services.

Tower failure due to high winds.

It can be seen that the question on inventory is internally focused on the needs (and more specifically financial considerations) of the asset owner with little regard for other stakeholders. There are no quick answers to this question, but certain guidelines can be provided to ensure that the Asset Owner has the proper resources. It is imperative to recognize that these resources cannot be established without considering the overall emergency preparedness plans that the asset owner has put in place.

Less stock may be required if the asset owner is properly prepared to deal with emergency situations. However, the logistics and constraints imposed during emergencies could render any level of emergency resources useless without a detailed plan as to how to overcome anticipated problems to ensure adequate utilization of the resources when they are required.

Again, the questions which need to be raised are, "Does the asset owner have a clear emergency response policy? Is there an organizational structure to respond effectively to emergencies?"

These are the questions which will be considered in this article.

1.0 PURPOSE STATEMENT

The purpose of this article is to help asset owners develop their own emergency response plan for their overhead transmission lines (OHTL). The implementation of the plan should result in adequate material, manpower and equipment resources to address identified emergency situations.

2.0 RESPONSE PLAN DEVELOPMENT

The key to the development of an adequate emergency response plan is for the asset owner and senior management to commit to a proactive long term plan for responding to anticipated emergency situations, and the formulation of a corporate policy on how the utility will respond to emergencies.

This policy will involve the commitment of significant resources. The first commitment is the establishment of an Emergency Response Organization.

RTE is the French transmission system operator created after the storms of 1999 (a GIP Priority Action Group).

This rapid reaction force consists of seven teams spread throughout France. It is activated by the crisis management unit for the purpose of analyzing the problem and proposing feasible solutions which can be implemented in less than 5 days to re-establish power supply on network facilities. RTE objective is to have 17 km of 400 kV overhead restoration lines.

BC Hydro, after a major ice storm in 1972, created a stock of material for emergency repair and set up the predecessor of the present transmission emergency response organization. The emergency response organization is managed centrally by a joint BC Transmission Corp and BC Hydro team.

The BC Transmission Corporation planned level of preparedness provides for material and plans for emergency erection of up to 10 km of each voltage level of line.

Emergency Response Structure

2.1 Emergency Response Organization

The Emergency Response Organization is led by a senior manager and includes appropriate internal experts. The Strategic Planning Team of this organization will identify risks, evaluate restoration scenarios and develop the response plan which will be implemented by the Opeational Restoration Team.

Tower destroyed by mud slide

2.1.1 Senior management accountability and support

The responsible individual in the corporation for implementation of this policy should be a senior manager, vice president or higher, because of the requirement for commitment of significant resources. Also, this raises the profile of this program for the people in the organization.

The first job of the responsible senior manager is to assemble a team of in-house experts and appoint a Strategic Planning Team leader, who may also be the Operational Restoration Team manager. Typically this team would consist of skilled individuals in fields such as system operation, engineering, environment, field construction, materials and logistics and communication with the public.

2.1.2 Strategic Planning Team

The Strategic Planning Team will produce practical implementation plans for the stated corporate policy as follows:

- Identify potential risks to the asset owner
- Develop various restoration scenarios for identified risks
- Choose scenarios consistent with the corporate policy
- Structure membership of the operational restoration team
- Operational liaison with external emergency response organizations
- Operational liaison with news media (make sure a technical representative is available to explain technical aspects)
- Develop a training program consistent with the policy
- Conduct post event evaluations and implement continuous improvements

2.1.3 Operational Restoration Team

The Operational Restoration Team will restore the damaged transmission line following guidelines set by the strategic planning team. The structure and membership will vary with each organization; however the following key functions need to be addressed:

- Team Management
- System Operations
- Engineering
- Field Construction
- Materials coordination
- Safety Coordination
- Logistics, Transport and communications

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- Communication Coordination
- Contract Management
- Property Issues
- Financial Coordination

Typical responsibilities for these team members are given in Table 1.

TABLE 1: Operational Restoration Team Member Responsibilities

Team Manager • Overall project manager • Reports directly to senior management • Mutual aid agreements • Governmental authorizations • Coordination with Distribution utilities	**System Operator** • Determines circuit restoration priorities • Provides input for circuit restoration plan • Coordinates protection • Returns circuit to service
Engineering • Damage assessment • Provides design specifications • Approve field modifications • Construction inspection • Revise design criteria • Recommends restoration priorities following damage assessment • Approves material substitution • As built drawings	**Field Construction Manager** • Damage assessment • Planning & scheduling • Coordination and supervision of restoration • Site safety, protection and isolation procedures • Site environmental compliance • Communication with Operational Restoration Team • Returns line to system operator for service. • Coordination of all external work crews
Materials coordinator • Material expediting • Procurement • Quality control • Issuing & packaging • Recycling & disposal	**Safety Coordinator** • On site safety • Site first aid • Compliance with safety regulations for all personnel • Worker qualifications
Logistics • Shipping & receiving • Travel, accommodation & meals • Equipment & tools • Permits • Customs & immigration • Transport • Telecommunication equipment • Site security **Contract Management** • Verifying contractor activities • Negotiating contracts	**Communication Coordinator** • Internal & external communication • Coordination of site visits • Provide feedback from outside stakeholders **Property Issues Coordinator** • Owner contact & access permission • Right of way issues • Property damage & restoration **Financial Coordinator** • Funding approval • Purchase orders • Cost control

2.2 Identify Risks

The first and most important activity of the Strategic Planning Team is to identify potential failure events. The following should be considered:

- Identify historical failure events experienced by the asset owner.
- Current condition of the lines being considered
- Potential natural events (storms, floods, landslides, fires, etc.)
- Man made failures (vandalism, aircraft, automobiles, etc.)

The predicted frequency, extent and severity of the event is estimated as well as the potential for multiple simultaneous events. Also, with the identified events will come a set of conditions (e.g. poor site access, ground conditions and hostile environment), to be considered.

The basic design withstand criteria of the lines (cascading towers, ability to withstand identified event loads) should be evaluated to project the scope and extent of the damage under the event.

The political and economic consequences of the identified failure events are quantified. The extent of consequences of the OHTL failure may cause monetary losses to the OHTL asset owner, its customers and local or national governments. The cost of unsupplied energy is the most common term used to quantify these losses.

- The consequences arise generally at different levels within the company. Each case is different, however, in most cases, these costs of consequences can be connected either to the company as a whole, or to the system operations division (i.e. electricity commerce division), or to the transmission line division. (Reference technical bulletin No. 175 for the calculation of risk)

The combination of probability of failure and consequences will quantify the risk, and the appropriate level of resources to be committed, consistent with the company policy.

2.3 Estimate the Aggregate of all risk events

Evaluate the probability of the occurrence of multiple simultaneous events or very large scale single events, in order to estimate the amount of resources required. For example, is material required for a single event, or is material required for simultaneous events (very large area storms, multiple sabotage events are examples of simultaneous events)? Note key suppliers located in the affected area

2.4 Restoration Scenarios

The Strategic Planning Team determined the risk of identified events. Probable events can be prioritized from this assessment. It may be possible to reduce some of these risks by taking proactive measures, for example: agreements with major customers to curtail demand in emergency situations and reinforcement of specific structures.

The Strategic Planning Team will determine what resources are required to restore the line within a specified time frame. This typically requires consideration of possible system reconfigurations to address the problem as well as an estimation of Material, Manpower & Equipment requirements, Logistics. Support Services, Communication for each identified event and restoration scenario. Material and resources to be considered in preparing the estimated requirements for each scenario are summarized in Table 2. These estimates will be the basis for the response plan.

3.0 RESPONSE PLAN

The risk assessment and scenario review can be used as the basis for establishing the level of event or events for which the asset owner will be prepared. When that level is established relative to the emergency response policy the response plans can be prepared. This

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HOW A TIME-TESTED THEORY BENEFITS FORWARD-LOOKING UTILITIES

By Eric Murray, VP, Sales & Business Development, Tantalus Systems Corp.

Back in the late 19th Century, Vilfredo Pareto developed mathematical proof for something he called "The Law of the Unequal Distribution of Results". Pareto, an engineer turned economist, established that 80% of the land in his native Italy was owned by just 20% of the people.

It's doubtful that Pareto's name would have lingered on had he not been an avid gardener. One day, while tending to his vegetable patch, he observed that 20% of his peapods yielded 80% of the harvest. Hence Pareto's eureka moment. Thus was born a theory that has proved remarkably resilient for over a century, even under heavy-duty empirical scrutiny and in a wide variety of situations.

If you know it at all today, you know it as Pareto's Law or the 80/20 Principle. You've likely seen it applied to customer complaints (80% of complaints arise from 20% of customers), or business results (80% of revenue comes from 20% of customers), or even to environmental studies (80% of traffic pollution is caused by 20% of vehicles).

Simply put, "a few account for most". The numbers may vary from study to study – 70/30 or 82/18 – but there typically is a misdistribution of a particular quality among a group. Some refer to this as the separation of the vital few from the trivial many.

All that's well and good, but how does Pareto's Principle – or the 80/20 rule – apply to metering? Simple answer: business case strategy. By applying Pareto's Law to AMR deployment, you can focus on those specific customer service issues or business priorities that have the greatest impact on your utility. As a result, your chances of deploying a winning solution improve significantly.

The better you are able to target AMR installation with significant payback – by focusing on the 20% that bring about the most results – the more likely you are to develop a winning business case, and more importantly, deliver value to the utility and your customers.

The difficult part is to determine which 20% will deliver 80% of results and address these customers first (only).

Traditional AMR deployments are infrastructure and deployment intensive. For a full deployment, the average utility spends a lot of money on installations that deliver no return. Following a regimented deployment plan makes the deployment easier, but increases the costs and delays the benefits. Maybe grandma said it best when she said: you've got to kiss a lot of frogs before you find a prince.

For a utility, a one-size-fits-all approach to problem solving can result in higher costs to achieve minimal benefit. Critical problems often remain unsolved and the sheer scope of a mass deployment can prevent other worthy projects from progressing due to the drain on staff, resources, and budgets.

The beauty of an end-to-end wireless RF network approach is that you do not need to follow lockstep with a systematic deployment in order to reach the desired endpoints and implement the most appropriate solution(s) – whether the goal is to resolve chronic service issues or improve revenue opportunities. A utility can go where needed, when needed, and where the business case is most compelling. After all, customer types or operational challenges don't always congregate in convenient local groupings.

The goal is to implement advanced functionality according to business priorities, not deployment logistics or network layout. Solution specific installations enable a utility to fast track high-value service rollouts such as installing advanced meter reading in hard-to-read locations, monitoring capabilities in areas experiencing orphaned outages or fluctuating power, and implementing remote connect/disconnect in high turnover areas or those with many delinquent accounts.

It can paralyze even the most rational mind trying to correct the myriad of problems in a large, complex system. And a utility is nothing if not a large, complex system. Improving processes or solving significant problems usually requires much more time and effort than you can probably afford.

Rather than spending time, energy and money in an effort to correct everything in one fell swoop, it's wise to concentrate on those few, select variables that will likely deliver the bulk of the benefits.

That's Pareto's Principle in practice.

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planning will be the basis for emergency spare material stocks and sourcing, manpower and equipment plans, emergency organization structure and responsibilities and the training necessary to implement the plan. Most of the key elements of the plan are addressed here.

When these plans are implemented, it is critical that they be reviewed by the Response Planning Team on a frequent basis to insure the validity of the plans and external agreements.

It is essential that documentation and inventory of material and resources be kept up-to-date at all times.

3.1 Level of Emergency Response

The plan will vary with the asset owner and its circumstances, but it should be structured to deal with three levels of emergency:

• First level is of a size and impact that it can be managed by a local manager

• The second is of a size and impact that it will be managed by a senior manager

• The third is a size and impact that restoration will be managed by a senior manager, as part of an inter-agency emergency recovery program

While the size and scope of the problem is different, the basic organization structure and plan elements are the same.

3.2 Rapid Response

Implementation of emergency response plans can be expedited by Early Warning Systems and rapid identification of the damage location and scale. The Operational Restoration Team and resources can be put on standby when risk factors increase due to weather forecasting information, political or special events or terrorist events. When a failure does occur, equipment and means of quickly locating the failure need to be available.

3.3 Emergency Material

Whether the Utility chooses to retain emergency stock or not, it is essential that there be a plan to address material needs. The better the risk identification and the response plan, the more likely it is that essential material will be available. This may not require very large investments in material, but rather investment in the right material. Some of the more commonly used approaches for emergency response material are:

TABLE 2: Material and Resources to be Considered in Planning Restoration Scenarios

Material (for permanent and/or temporary construction) • Suspension & tension structures (including foundation materials and anchors) • Conductor • Splices, terminations & hardware • Insulators • One of a kind structures & conductors (crossings) • Emergency response agreements with key suppliers. • Stock emergency restoration structures • Basic material ready for fabrication • Suitable long-term storage to avoid deterioration. • Standardized replacement insulator & hardware kits **Logistics and Transport** • Transportation requirements (special loads & permitting, helicopter loads) • Clear understanding of security and location of emergency material. • Location of Mutual aid material (other utilities, suppliers) • Housing, food, transport to job site • Site first aid facilities • Communications equipment	**Manpower** • Skill level required • Numbers required • In-house and external availability and agreements • Training (Workers & management) • Special construction techniques & work methods • Engineering Expertise **Equipment & Tool Requirements** • Heavy equipment (cranes, specialized stringing equipment) requirements, availability & maintenance. • Helicopters • All-Terrain Vehicles and other special man transport needs • Specialized small tools (compressors, splicing dies, night-lights, etc.) • Appropriate rigging tools • Conductor tie-off equipment **External Communications** • Media relations • Public information • Information to local governments • Impacted stakeholders
Support Services • Human Resource services • Payroll & banking • Clerical support • ROW & property • Environmental • Safety Officer	**Alternative Responses** • Temporary Generators • Temporary re-configuring of circuits • New temporary feed • Re-examine the need for the line

3.3.1 Segregated emergency stock

This material may be intended for temporary repair, like-for-like replacement, or both. It should attempt to standardize as much as practical. The stock should have very tight control with decisions to release this material for non-emergencies, to be made by the senior manager responsible for emergency response.

3.3.2 Non-segregated emergency stock

Minimum stock levels are set with the intent that this material always be available somewhere in the system. This allows the stock to turn over. This approach might be used for less critical, readily available material or material which deteriorates with age.

3.3.3 Mutual Aid Agreements

These agreements establish understanding between neighboring asset owners or pools of owners, under emergency situations. The group may pool interchangeable emergency stock as well as provide access to individual emergency out-source agreements. It is very important that all parties understand the intent and rules of such an agreement. However, during large storms or multiple failure events, mutual assistance between neighboring asset owners may have its limitations.

After the storms of 1999, RTE signed mutual aid agreements with several European utilities to facilitate the interventions of other transmission system operator teams with their own equipment.

3.3.4 Out-Source Agreements

Agreements can be established with vendors ranging from priority access to material, to commercial agreements to retain emergency stock for the Utility.

3.4 Manpower

Manpower plans follow a very similar structure to the material plans. Whether internal workforce and equipment are used or external resources, or both, it is essential that there be a viable plan. Questions such as how many staff are required for standby, short term availability or long term availability must be answered by the plan.

With RTE emergency reaction organization, 300 RTE operators and 600 specialists from outside companies can be called up in half a day.

As soon as an intervention action is triggered, a major chain of different specialists such as electrician and mechanical engineers, topographers, linesmen, logistic managers, helicopter pilots and telecommunication experts is activated.

3.4.1 Internal Work Force

What level of work force is required, what skills, how many are on standby? All these questions need to be answered and plans in place to address them in the event of an emergency.

3.4.2 External work forces

If the decision is made to use external contractors either exclusively or as supplements to internal forces, commercial agreements or understandings are essential. The criticality of these agreements increases with the level of dependence on the contractors. Regular review of these agreements is essential.

3.4.3 Mutual Aid Agreements

This is an agreement between asset owners or among a pool of owners to share resources in the case of emergency. Again it is important that the intent and rules of the agreement are clearly understood. Regular review of these agreements is critical.

3.5 Logistics

It is essential that the material requested by the field is clearly communicated to the emergency stores. Pre-assembling kits and pre-packaging of material and tools are useful ways of expediting this process. Also, the mode or modes of transportation and transport availability need to be closely managed. The person responsible for logistics must be able to expedite the material, communicate needs clearly to the stores and have transport arrangements suitable to the location and urgency of the field need. One practice followed by some asset owners is to have special trailers and containers pre-packaged with key material and tools. Other preparations which can be made are special transport needs (load limits, wide loads, etc.) and permitting. If it is anticipated that helicopter transport will be used then packaging should take into account the load limits of the helicopters likely to be available.

One of the most critical aspects of emergency restoration is effective communication between all of the parties involved. One of the most important pieces of equipment is communications equipment such as satellite phones and portable radios and battery charging facilities.

3.6 Equipment

Either the asset owner's equipment such as: puller pilot winder, all wheel drive bundle bull wheel tensioners and fiber optic bull wheel tensioners (for pulling overhead ground wire and fiber optic cable) should be maintained, or agreements with owners of such equipment established. This equipment must be maintained in good working order for effective emergency response. In addition, other specialized equipment suitable for various terrains found along the OHTL right-of-ways (such as: all terrain rubber track vehicles for working in snow conditions, and all wheel drive trucks with front winches) should also be maintained by the asset owner, or be readily available under special agreements.

A major piece of equipment for emergency response is helicopters for: transportation of men and materials to remote job sites, staging materials in rough terrain, and as safety standbys for construction personnel at job sites. During transmission line emergency restoration, they are used to locate the damaged site and find the actual trouble location.

3.7 Communications

3.7.1 Internal Communications

One aspect of planning, crucial to the successful handling of an emergency, is communication between the various units of the emergency response team. A "single point contact" concept can be used during emergency situations to insure that all communication between each unit is direct and that the responsibilities are clearly defined.

Using this concept, a single individual within each unit is assigned to handle all intra-company contact in any major functional area. In addition, once a task is assigned to an individual, it becomes the obligation of that individual through completion - thus establishing a clearly defined path of responsibility. This approach can improve the efficiency of the intra-company communications in the hectic emergency environment. An emergency centre where the Operational Restoration Team members can gather is important. At this centre there will be network diagrams, communication equipment, telephone directories with contact details of contractors, suppliers, customers etc. and pre-planned emergency documentation.

3.7.2 External Communications

The responsible person has an important role to communicate the plan and schedule of restoration to the news media,

Continued on Page 36

REVERSE ENERGY AUCTIONS CHANGING ENERGY PURCHASING

By Stephen V. Gerrard, Juhl Communications

The combined forces of the Internet, deregulated energy markets and one of the oldest trading models known to man are changing energy procurement. Government organizations, and commercial and industrial businesses – even utilities – are using reverse online energy auctions for strategic spend and overall all supply management.

While auctions have been around since roughly 500 B.C., the advent of the Internet has turbocharged their acceptance as one of the most effective means of price discovery – to the point where today over 4% of all corporate spend is sourced via on-line auction. The engine behind this growth – the reverse auction – brings buyers and sellers together in an environment designed to extract the lowest possible price for the buyer.

Energy was tabbed early on in the adoption of the Internet as an ideal commodity to take advantage of on-line auctions. In its 2002 report, analyst The Meta Group identified several companies that burst onto the online energy procurement scene in the late 90s and early 2000s as emerging leaders – including World Energy. In 2006 retail energy analyst, KEMA Inc. named World Energy as the industry's leading retail energy channel partner, and noted that energy market intermediaries such as World Energy are responsible for between 40 and 70 percent of energy volumes transacted today in U.S. retail markets.

Since entering the online reverse auction marketplace, the World Energy Exchange reverse auction platform has been used to procure 24 billion kilowatt (kWh) hours of electricity and 52 million decatherms (dth) of natural gas supplies.

EARLY ADOPTER

The Maryland Department of General Services (DGS) was an early adopter of reverse auctions for its spend-management efforts. DGS is responsible for procuring energy supply for some 8,000 separate accounts.

DGS' Carl LaVerghetta, director of procurement, points out that deregulation presents a complex set of challenges, ranging from documenting facilities and supply requirements to educating team members and agency heads on the evolving DGS spend management philosophy.

In March 2004, DGS became the first state agency in the country to conduct a reverse online energy auction. Maryland's initial 2004 auctions for purchase of electric supply for 660 accounts resulted in cost avoidance savings of more than $12 million. Savings are a measure of cost avoidance realized through the online reverse energy auction compared to the published utility rates in various service territories.

As a result of this auction, Maryland won three awards at the joint National Association of State Chief Administrators (NASCA) - National Association of State Facilities Administrators (NASFA) annual event, including the "Outstanding Program" Award for the most effective cost-saving program of any spend category in any state.

DGS' most recent May 2 auctions were for 3,212 accounts with contracts valued at $78.2 million. DGS estimates some $7 million in cost avoidance savings from that auction.

"The World Energy Exchange auction platform allowed DGS to test a variety of supply parameters, such as green energy mix", said LaVerghetta. "We conducted 38 auctions five minutes apart to determine the price point at which there would be no premium for buying green energy as a portion of our electricity supply. As the bids came in, we were able to evaluate the results in real time. We found that we paid no premium for buying green at the five percent mark.

"In addition, because we were able to contract immediately following the auction, suppliers did not include risk premiums in their bids as is normally the case with delays in contracting in the paper process. On top of these benefits, World Energy was able to attract new suppliers to the auction which we had no knowledge of previously," said LaVerghetta.

NOT JUST FOR THE BIG GUYS

Online reverse energy auctions aren't exclusive to large organizations like DGS. They can be effective in delivering benefits to companies that are comparatively smaller. The Saunders Hotel Group is one example of a commercial customer that is using reverse auctions for supply management.

Saunders is a family-run company that, for over three generations, has owned and managed hotels in the Boston area, including historic properties Copley Square and Lenox. Saunders also owns other hotels in Boston, the surrounding New England area and Virginia, including a Comfort Inn and Suites, a Hampton

Continued on Page 21

QUICK-TRIP™

ARC FLASH REDUCTION SWITCH

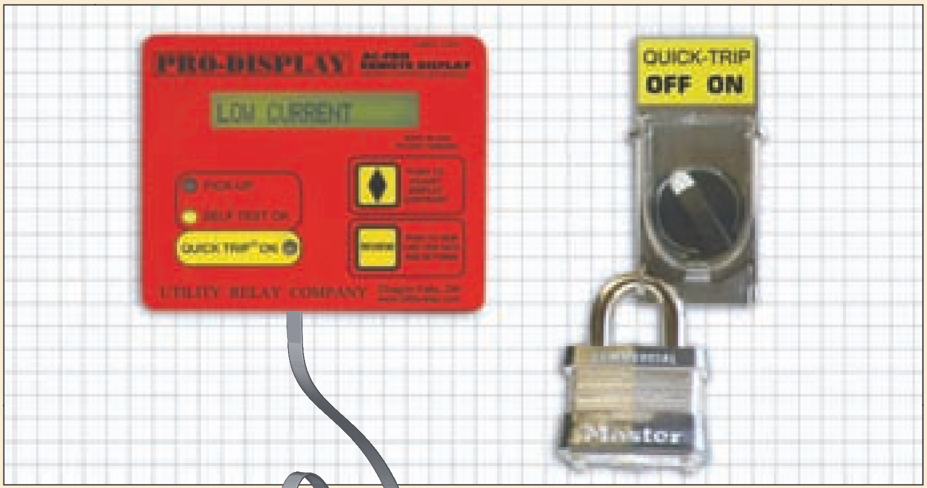
Providing a safer working environment for people working on energized electrical equipment

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.

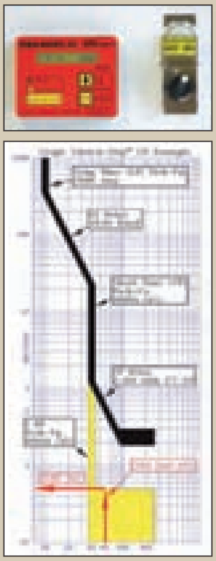
Given that: **F = 12kA** and **D = 18 in.**

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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PUSHING THE ENVELOPE IN MITIGATING OUTAGES

By Dominic Tarascio, Manager Engineering Services, HPS Canada

NFLD & Labrador Hydro (Hydro) is a utility which owns and operates facilities for the generation, transformation and distribution of electricity to utility, industrial and residential customers in the Province of Newfoundland.

Two (2) of Hydro's 230 kV transmission lines, TL202 and TL206, extend approximately 141 km long from its major hydroelectric plant at Bay D'Espoir to the Sunnyside Terminal Station. They are on separate towers, sharing the same right-of-way and spaced about 40 meters apart (center-to-center). These lines are the major transmission facilities and the major source of power servicing a large portion of the power system load for the Avalon Peninsula, which includes the City of St. Johns and surrounding vicinity. The lines are of a lattice steel (guyed and self-supporting towers) construction and are unshielded (i.e. there is no overhead ground wire), making them particularly susceptible to lightning-caused flashovers. Both lines have experienced approximately ten (10) simultaneous double circuit faults along with 77 single circuit faults as a result of lightning strikes within the last 25 years. These double circuit faults are presumed to be due to large magnitude lightning currents that flashover not only the stricken circuit, but also cause a backflash of the parallel circuit due to its close proximity and grounding.

As a result of studies conducted by an external consultant, the installation of lightning surge arresters was recommended as a means to mitigate these outages and decrease the double circuit simultaneous outage rates that have plagued these lines. The Hubbell/Ohio Brass Protecta*Lite Arrester System proved to be the answer to some very difficult questions and required results.

The required results are as follows:

(1) The installation of such an application must be carried out so as not to compromise the present daily operations and reliability of the line.

(2) A rate of one (1) double circuit outage in every 35 years is sought through the use of station class varistor blocks - 60 mm in diameter.

(3) The lightning arresters are to be fitted to one of the line's structures only - TL206.

(4) A total of 365 Structures, 3 phases each, were fitted with lightning arresters over a period of just over one (1) year.

The upgrade of TL206 represented a significant technical challenge in order to meet the long-term performance improvements required. The Hubbell Team, including Hubbell Canada Inc.,

The Ohio Brass Company, Harris & Roome and various consultants tracked this project with great interest through various stages of investigation and analysis. The project had also been scheduled on a fast track basis requiring delivery of complete arrester assemblies in order to facilitate an April installation. The actual timeline proceeded as follows:

(1) The first phase of the project spanned a period of four months, which included the tender review, award of project, supply of complete arrester assemblies and installation.

(2) The first phase of installation included 50% of the arrester assemblies that amounted to 560 assemblies.

Newfoundland & Labrador Hydro had to balance the cost of the solution against the desired improvement in line performance. With the assistance of the superior staff at Newfoundland and Labrador Hydro and the contracting group J&J Line Construction, all site specific installation challenges were quickly overcome, and the project proceeded within budget and to critical timelines. The initial feedback concluded that the line had not experienced any outages through the first lightning season.

reverse energy auctions

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Inn, a Marriott Residence Inn, a Holiday Inn and a Hawthorn Inn and Suites. In addition, they own the building occupied by a Jurys hotel. Saunders has invested millions in renovation of its facilities and has won awards from the EPA for its ongoing commitment to environmental efficiency. The company also received the 2006 Skal International Eco-Tourism Award. Skal is the largest travel and tourism organization in the world.

Frank Healey, director of property operations, said Saunders has been buying energy in the competitive market since 2002. “We did better than if we’d stayed with the utility, but we always felt that we could save more. The process was paper driven. We’d get an offer and then negotiate for a lower price. Scale didn’t matter at all. We’d have one rate for the Lenox and another for Copley Square, which is a hundred feet away,” said Healey

“The procurement process for multiple properties was time consuming, requiring about two hours a day. And we still had doubts that we were getting the best possible price,” he said.

“Our consultant would recommend locking in at a price and then the next day, the price would be lower. We felt that we had to find a way to take advantage of our scale and make the process work to our advantage,” said Healey.

EcoLogical Solutions, Inc., a Saunders subsidiary company headed by founder and President, Tedd Saunders, began to investigate reverse online energy auctions, said Healey. EcoLogical Solutions focuses on environmental efficiency to reduce operating costs. This search led to the World Energy Exchange reverse auction portal.

“Now, rather than spending two hours a day collecting supply information, we provide account numbers to World Energy and they manage the information online prior to and after auctions. Supply management now takes about two hours a month,” said Healey.

In August, Saunders conducted reverse auctions to procure 4.4 million kWh of electricity. Their supply strategy focuses on short-term three-month contracts. This allows them to test the volatile energy supply market via the portal’s flexibility, said Healey. Saunders estimates its savings from the August auctions will be nearly 11 percent below what it would have paid from local utilities.

“After the cost savings, the biggest benefit is the time savings factor,” said Healey.

WHAT ABOUT LOCAL UTILITIES?

Open competition has changed the historic relationship between local utilities and their customers. Many organizations are taking advantage of the choice option by going to other suppliers. So do utilities have a play in the reverse auction marketplace?

Austin Energy is a community-owned electric utility and a department of the City of Austin, TX. The company will shut down its 358 megawatt Holly gas-fired power plant in 2007 and must find replacement supply for 2008-2010.

Roberto Delgado, an energy marketer with Austin Energy, said, “We historically used a paper RFP process. From beginning to end we would spend four months,” said Delgado. “By the time we got through the paper process, the market had changed.

“We needed something that was faster, more market sensitive and more transparent that allowed suppliers to bid at the same time,” he said.

On September 12, Austin Energy conducted a series of eight auctions on the Exchange for up to 150 MW of 5x16 replacement supply for May through September weekdays in 2008-2010. “During the last two minutes of each auction, suppliers became very aggressive in their bidding.” Delgado said the cost avoidance savings from the recent auction is expected to be a little over five percent compared to market benchmarks.

“In a reverse auction, every supplier gets a fair shake. It’s completely transparent,” he said. Bidder identities are not revealed during the reverse auction, he noted.

Delgado cites a number of key benefits from reverse online energy auctions. “The auction is pertinent to what is going on in the market, it derives highly competitive pricing and it is happening in real-time. Transparency is a key aspect. There is no risk for the supplier due to time delays and market changes as with a paper process. Contracts are awarded within hours of the close of an auction. Finally, a complete audit trail is created online from the beginning of the RFP process to post-contract management,” said Delgado.

Stephen V. Gerard is an Executive Consultant with the Colorado-based market communications firm, Juhl Communications.

CALCULATIONS ON THE MECHANICAL SAFETY AREA AT TRANSMITTER TOWERS

By Wolfgang W. Scherer

The transmitter towers for telecommunication are normally from 200 ft (ca. 60m) to 350 ft (ca. 100m) high and, in some cases even more, depending on the local elevation. To accommodate the construction, a site is required, being a square with a side length of about twice the towers height.

However, if available properties in desired locations are not big enough to accommodate this, in an area with lower wind activity the steel ropes (guys) that hold the tower in place are set at a steeper angle requiring a smaller area for construction, thus the square size is reduced allowing the use of a smaller piece of property. In higher wind load areas, where a steeper angle may not secure the tower safely, a big enough site must be found.

But according to the local office of Industry Canada, the above-outlined square size is not regulated and since those towers are considered utility structures, local building codes do not apply.

The size of the square depends only on the area needed for the actual construction of the tower with the anchors. Furthermore, the size of the security area (fence) is set to protect the site from outside hazards, and not to protect the public from hazards caused by the installation.

This distance by itself is, therefore, inadequate as a safety zone because it does not give a safe area in case of a serious mechanical failure at the tower. This is a serious flaw in the site selection process.

The following calculations are based on a worst case scenario to determine the area endangered in such a situation by mechanical failure at the tower. We assume for a worst-case scenario a total mechanical failure that can be caused by stress, extreme overload, defect in material, fatigue, corrosion, poor workmanship, insufficient maintenance, and sabotage, as well as any combination of these factors.

In the following calculations the letter h represents the height of a given tower.

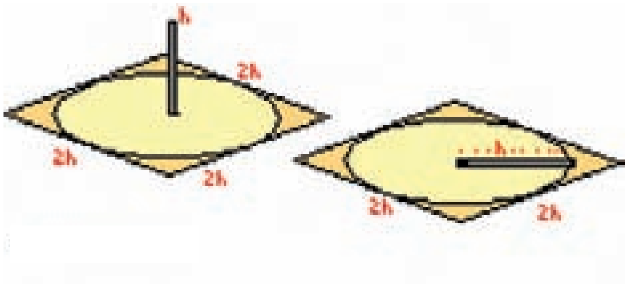

Figure 1 – Case A

CASE A) THE TOWER FALLS OVER

For a rigid structure (e.g. a pole or even a tree) the endangered zone is a circle with a radius of the structure's (tower) height, that is twice the height in diameter, it is accommodated by a square with such a side length, that is 2 x h. Most sites have exactly this size and are therefore declared sufficient by the operating company.

However, most of these towers are not single pole structures; they are cage element structures secured with steel ropes (guy wires) to ground anchors. The possible hazards of these wires add to the endangered area. The upper ones of these wires are reaching up to at least about 90% of the height of the tower; that is 0.9 h. They are secured to an anchor in the ground that is positioned within the square. For the calculations, the anchors are assumed to be at a distance equal to 90% of the height from the center of the tower; that is also 0.9 h. The length of the highest reaching wires calculates then to about 1.27 times the height of the tower, that is 1.27 h.

(Apply Pythagorean Theorem: guy wire length = square-root of { (0.9 h) + (0.9 h)} = 1.27 h)

CASE B) THE GUY WIRE SNAPS AT THE TOP - LASHING OUT.

The whip-lashing and falling steel rope endangers an area with a radius given by its length around the anchor. The guy anchors are assumed to be located at 90% of the height; that is 0.9 h, from the center of the tower. Therefore, the endangered zone is 0.9 h + 1.27 h = 2.17 h reaching 1.17 h outside the normal tower site (a 2 h square).

With tie wires, this risk could be reduced, but a tie wire may give way under such conditions too. The theoretical distance endangered by such a wire is therefore 2.17 h from the tower center. Taking into account bends in the falling wire and obstructions in the path, a reasonable reduction of this distance by 10 % can be made. The real danger zone for mechanical failure is, therefore, 90% of this distance, that is 0.9 x 2.17 h = 1.953 h, rounded to 2.0 h, from the center of the tower. The danger area is a circle with 4 h in diameter.

Therefore, only if the site is a square with a side of at least 4 times the height of the tower, it encloses the danger zone in case of severe mechanical failure!

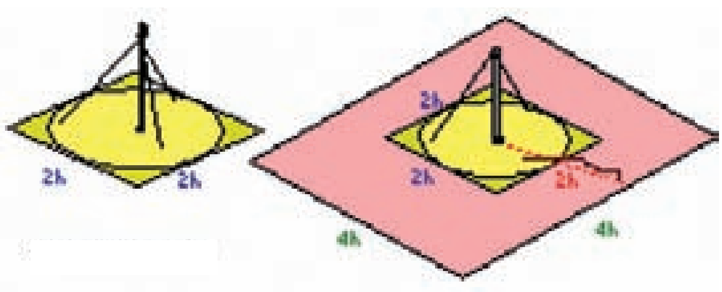

Figure 2 – Case B

CASE C) THE WIRES SNAP AT THE ANCHOR, AND THE TOWER FALLS.

The falling tower causes the guy wires to whip out in the direction of its fall. The longest wire is connected at 90% of the tower's height. Hence, the calculations have the same numbers and the result as in case B.

The distance of danger is 2 x h from the center of the tower. The radius of danger is given by this distance = 2 h. The area is a circle with 4 h in diameter

Again here, only a square with a side of 4 times the height of the tower encloses the danger zone.

CASE D) THE TOP WIRE SNAPS AT ONE ANCHOR, THE TOP CAGE ELEMENT BREAKS OFF AND LASHES OUT TIED TO A REMAINING ANCHOR.

The total mechanical length is 2x wire length plus anchor distance from center that calculates to (0.9 + 2.54) h = 3.44 h applying bend and drag reduction, the safe distance in this case easily calculates to 0.9 h + 0.9 x 1.27 h + 0.4 x 1.27 h = (0.9+1.143 + 0.508) h =2.551 h. The safety zone is a circle with about 5 h in diameter requiring a square of this side length.

The 40% drag-lash length is a favourable assumption - applying the full length of this "debris" 3.44 h from center would require a square of about 7 h to ensure 100% safety.

The fenced area may be smaller, depending on regulations, but the tower must then be removed from a neighbouring property by the above calculated lengths to be at a safe distance.

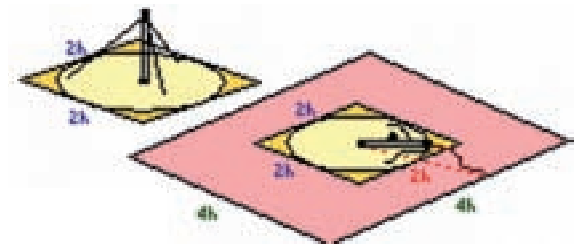

Figure 3 – Case C

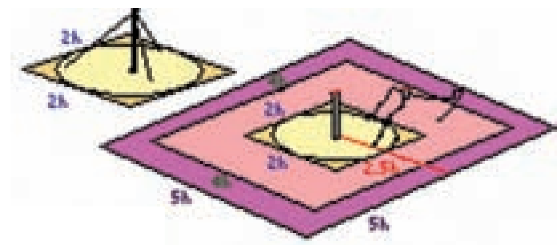

Figure 4 – Case D

Therefore, it is best that any such tower should be distanced at least twice the height (better two and a half times) the tower's height from any neighbouring property line.

You said it

Robert Webb, President of Power Choice, Inc. in Austin Texas writes:
"Your magazine has been useful in helping our sale and installation of distributed generation in Texas."

Charlene Anderson, HR/Safety Coordinator for Tri-County Electric Cooperative, Inc. in St. Matthews, South Carolina writes:
"Great information. Many of our employees love to look through this."

Gina Melson, Sales Engineer with Indus International writes:
"I look forward to receiving this publication."

Thomas Matusiak, Engineering Specialist with Fm Global, Washington operations, writes:
"Your magazine is one of - if not the most - valuable trade publication I receive; there has not been a magazine where there wasn't at least two articles I found beneficial."

DYNAMIC THERMAL RATING SYSTEM RELIEVES TRANSMISSION CONSTRAINT

By Jerry Ausen, Bernard. F. Fitzgerald, Member, IEEE, Ernest A. Gust, Member, IEEE, Daniel C. Lawry, Member, IEEE, John P. Lazar, Member, IEEE, and Randall L. Oye, Member, IEEE

Dynamic thermal line rating can optimize transmission operation by capturing previously unutilized line capacity while simultaneously improving system reliability. This article will introduce a new system for dynamically determining the thermal rating of an overhead line. The article will focus on a case study by describing how the system was used to relieve a transmission line constraint for a wind farm in the mid-western United States. A description of the particular constraint will be presented, followed by a discussion of the installation of the dynamic rating system and the integration of the dynamic rating data into operations. Results from the first summer of operation of the system will also be presented.

Figure 1 – System Map

I. NOMENCLATURE

Thermal rating – the maximum current or MVA that can be transferred over a transmission line without exceeding the specified maximum operating temperature of that line.

Static rating – the thermal rating of a line as determined by assumed weather conditions. A line may have multiple static ratings (e.g. summer, winter).

Dynamic rating – the thermal rating of a line that is determined in real-time using actual weather conditions.

Transmission line constraint – a situation where a line transfer is limited by either normal system flow or post-contingent flow (flow that would result if a failure occurred somewhere in the system) exceeding the rating of the line.

II. SUMMARY

According to the American Wind Energy Association (AWEA), wind generation is the fastest growing energy source in the United States, with 2500 MW installed in 2005 and another 3000 MW expected in 2006. The rapid growth of wind generation and its location many miles from the large load centers have created significant challenges to the transmission providers. These challenges require innovative solutions, since it is not always possible, or cost-effective, to build new, or upgrade existing, transmission lines in time to provide outlet for the wind generation.

Xcel Energy learned this first-hand in 2005 when the wind generation growth in Southwestern Minnesota's Buffalo Ridge area was straining transmission outlet capacity. Xcel Energy needed to quickly increase the outlet capability of one of the lines leaving the area, or be forced to curtail wind generation. The line could not be taken out of service to be rebuilt because of reliability issues, and there was not enough time to construct a new line, so Xcel Energy and Marshall Municipal Utilities, the owner of the line, chose to dynamically rate it. Their choice of equipment was Shaw Energy Delivery Services' (EDS) dynamic line rating solution, the ThermalRate System.

The ThermalRate System was chosen because of the many advantages it offers over other dynamic line rating equipment. The major advantage is it does not need to be physically connected to the line, which simplifies installation and maintenance.

Since its commissioning in June 2005, the ThermalRate System has allowed Xcel Energy and Marshall Municipal Utilities to increase the LYC-MSH line rating and recognize previously unused capacity. The recognition of this capacity has allowed higher steady state and post-contingent flows and eliminated the need to curtail Buffalo Ridge wind generation.

III. BACKGROUND

Buffalo Ridge runs along the border between Southwestern Minnesota and Eastern South Dakota and is an ideal location for wind power generation because of the area's strong, steady

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transmission constraint

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winds. Wind generation development at Buffalo Ridge has grown dramatically during the last 10 years and now includes over 600 wind turbines capable of generating over 500 MW.

Xcel Energy completed a number of transmission upgrades at Buffalo Ridge in late 2004 designed to allow an additional 165 MW of wind generation. Upon completion, Buffalo Ridge had three 115kV interconnections to the 230kV and 345kV bulk transmission system; Lyon County – Marshall (LYC-MSH), Lyon County – Minnesota Valley (LYC-MNV) and Pathfinder – Split Rock (PAF-SPK) – See Figure 1.

During construction, it was determined that during times of high wind generation output, the LYC-MSH line could exceed its summer rating following certain transmission contingencies – which is not allowed. Unless the LYC-MSH line rating were increased, Buffalo Ridge wind generation would have to be curtailed beginning in May of 2005, when summer ratings take effect.

Rebuilding the LYC-MSH line was not a good option, since there are only two sources feeding the city of Marshall and the risk of taking one out for a long period of time was considered too great. Similarly, building a new line was also not considered a good option, due to the cost and time needed to complete the process.

The post-contingent loading on LYC-MSH is only a concern during periods of high Buffalo Ridge wind generation.

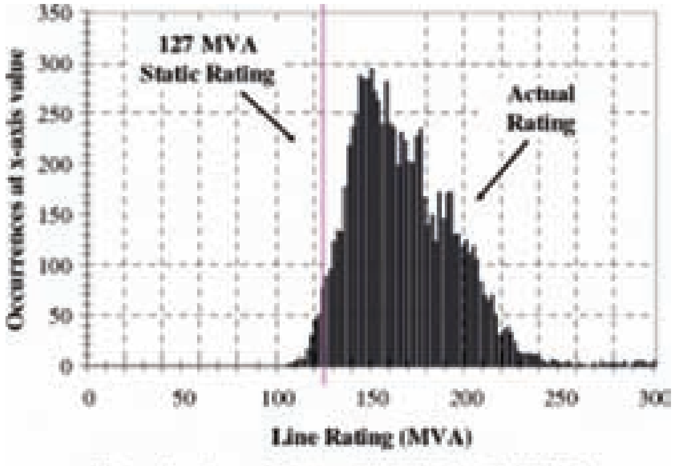

Figure 2 – Actual Ratings, 7/17/2005 to 8/17/2005

Marshall is located near the ridge, and historical weather data showed a consistent wind pattern between the ridge and Marshall. The actual wind effect on the LYC-MSH conductor was likely greater than was assumed when calculating the 127 MVA static summer rating for the line.

Xcel Energy and Marshall Municipal Utilities made the decision to dynamically rate the LYC-MSH line and identified the ThermalRate System as the best solution. The ThermalRate System was preferred because of (1) ease of installation, since the line did not need to be taken out of service; (2) simplified maintenance, since it is not attached to the line; and (3) accuracy, since it simulates the actual condition of the conductor.

IV. THERMAL RATING

The thermal rating of an overhead transmission line is the maximum current that the line can transfer without overheating. The line rating is a function of the weather conditions seen along the line, including wind speed, wind direction, air temperature, sun, and other secondary influences such as precipitation and indirect solar radiation.

The thermal rating of most lines is calculated based on sag.

As electrical current increases through an overhead conductor, the temperature increases, the conductor elongates, and the line sags. The thermal rating is the maximum current that can be transferred on the line without causing the line to sag past the minimum clearance to ground.

The sag, and therefore the thermal rating, is a function of weather conditions which, in most cases, are conservatively chosen using industry guidelines. Common weather assumptions are full sun, 40 Celsius (104 Fahrenheit) air temperature, and 2 ft/s (1.4 mph) wind speed perpendicular to the conductor.

Conservative assumptions must be used for safety reasons, but experience shows the actual line rating is usually much higher than the static rating. Therefore, using a static rating can underutilize a line's thermal capacity.

The actual (dynamic) rating of the MSH-LYC line during the period 7/17/2005 to 8/17/2005 is shown in Figure 2. It can be seen that the actual rating exceeded the static rating over 96% of the time.

There are a number of methods to increase the capacity of line, such as raising structures, reconductoring, or retensioning. An alternative to these more costly approaches to measure and monitor the true rating of the line during all system conditions. Dynamic rating is an approach which harnesses unused capacity by monitoring the status of the line and/or weather conditions and calculating the actual rating in real-time. By using actual, rather than assumed, weather conditions, dynamic rating can simultaneously increase both capacity and reliability.

V. THE THERMALRATE SYSTEM

The ThermalRate System is a dynamic line rating approach that uses the patented ThermalRate Monitor TRM) to determine a line's rating by measuring how actual weather conditions heat and cool a conductor. The TRM includes two conductor replica sections which are similar to the actual conductor in material, size, and surface (see Figure 3). Each of the replica sections includes an embedded temperature sensor, and one of the replica sections contains an electric heater.

Figure 3 – TRM Conductor Replica Section

The TRM's internal microprocessor measures the two replica temperatures to determine the effective wind speed and solar effects (direct and indirect) seen by the TRM. The heater power is constant, so increased effective wind causes the heated replica's temperature to fall nearer to the unheated replica's temperature. The relationship between conductor temperature and wind is identified by IEEE-738, "IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors." The effective wind speed also takes into account the various forms of precipitation. The TRM then calculates the actual rating of the line by again using IEEE-738 with the effective wind speed and the parameters of the line conductor.

A ThermalRate System consists of one or more ThermalRate Monitors (TRMs). Each TRM includes a sensor mounted at approximate line height, a controller mounted somewhere below the sensor, an antenna for radio communication, and an optional solar power supply for installations where AC power is not available. TRMs are installed at critical locations along the line, and the lowest TRM rating is used as the rating of the line. The system components are shown in Figure 4.

The TRM Controller includes a microprocessor which controls the measurements, stores information about the actual conductor, calculates the line rating, and supports DNP3 communications so the line ratings can be easily reported to SCADA.

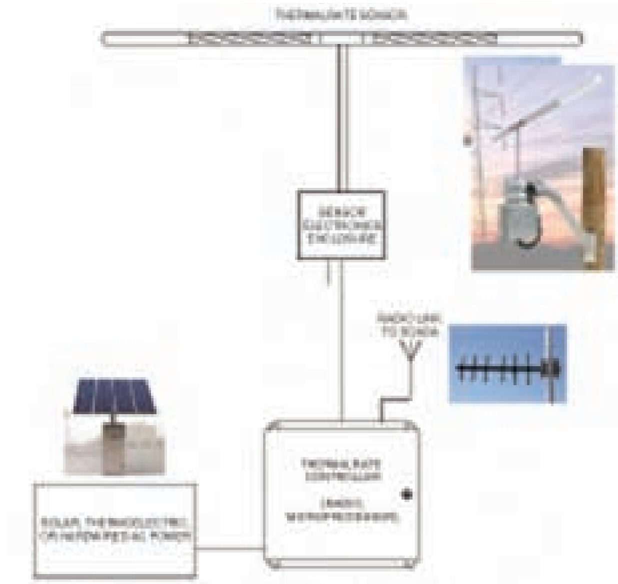

Figure 4 – ThermalRate Monitor Components

VI. SYSTEM INSTALLATION

The MSH-LYC line is a 4.1-mile long, 115 kV line between Marshall and Lyon County substations located east of Marshall, Minnesota. The land in this area is flat, with fields, few trees, and frequent wind. The line consists of Penguin T2 397.5 kcmil conductor with the exception of the slack span at Marshall, which uses Hawk 477 ACSR. The line runs East-West, except for the Marshall slack span and a single span near LYC, which run North-South. A diagram of the line is shown in Figure 5.

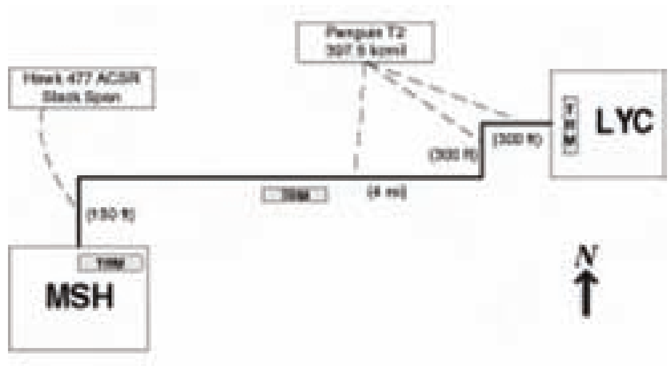

Figure 5 – Line Configuration and TRM Locations

Personnel from Marshall Municipal Utilities, Xcel Energy, and EDS selected TRM locations based on line orientation, ease of installation, and availability of AC power. Three TRM locations were selected along the MSH-LYC line, one at Marshall Substation (MSH), one at Lyon County Substation LYC), and one at the approximate line midpoint (MMT).

The TRMs at the substations are powered by DC station power, while the midpoint TRM is solar powered.

Each TRM (Sensor and Controller) is installed on a wood distribution pole set for this purpose. The TRM Controllers are installed near ground level for easy access as shown in Figure

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Figure 6 – TRM Controller at Lyon County Substation (LYC)

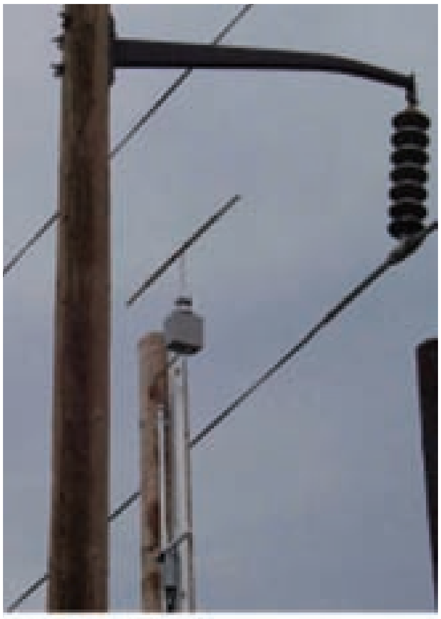

Figure 7 – TRM Sensor at Midpoint (MMT)

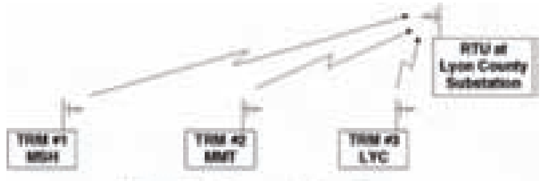

Figure 8 – Communications Diagram

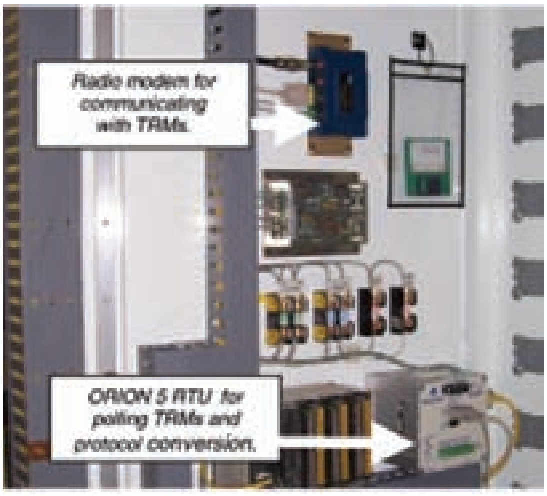

Figure 9 – RTU at Lyon County Substation

6. The TRM Sensors are installed at a height of 30', so that they experience the same wind conditions as the line itself. The 30' elevation was chosen because it is the average height of the lowest conductor under maximum sag conditions. An installed TRM Sensor is shown in Figure 7.

The TRM Sensors are oriented in the same direction as the line being monitored. The TRMs at MSH and MMT are East-West to monitor the main length of the line. The LYC sensor is North-South to monitor the single span at LYC sub. The span of Hawk ACSR at Marshall Substation has a higher rating than the North-South span at LYC and does not need to be monitored.

Each ThermalRate Controller includes a spread-spectrum radio modem for communicating the rating information to SCADA. The communication scheme is shown in Figure 8.

Each TRM responds directly to DNP3 protocol SCADA requests from an RTU at Lyon County Substation. The primary RTU at LYC supported only Modbus protocols, so an inexpensive NovaTech Orion 5 RTU was provided to convert DNP3 protocol information to Modbus. The RTU includes communication failure detection logic as well as logic to report the lowest of the three TRM readings. Figure 9 shows the communications equipment installed in an existing cabinet at Lyon County Substation.

VII. OPERATIONS

The ThermalRate System communicates the LYC-MSH normal and emergency ratings to Xcel Energy's SCADA system. Xcel Energy Control Room Operators monitor steady state and post-contingent loading on LYC-MSH and compare the results with the normal and emergency dynamic rating provided by the ThermalRate System. Exceeding either of the dynamic ratings would require curtailment of wind generation on Buffalo Ridge.

VIII. RESULTS AND CONCLUSIONS

The ThermalRate System was installed beginning in May of 2005, was commissioned in June, and has been in service since that time. The actual ratings measured by the ThermalRate System are generally much higher than the static rating, as can be seen in Figure 10. This is primarily due to the actual wind speed, which is typically stronger than the assumed 2 ft/s wind. The rating spikes are likely due to precipitation.

Figure 11 shows the ratings and the LYC-MSH loading over a two-day period around July 20, 2005. While there appears to be a large margin between the

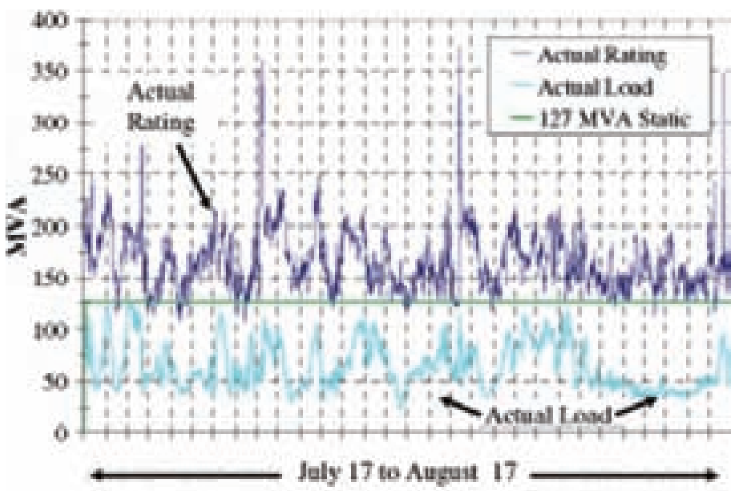

Figure 10 – Ratings for 1 month period

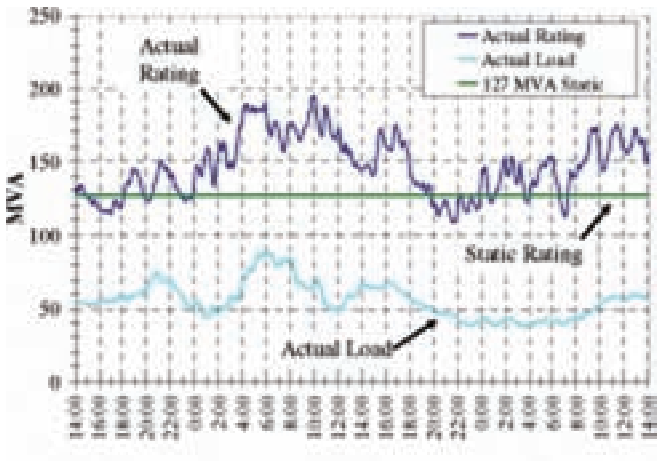

Figure 11 – Ratings for 2 day period

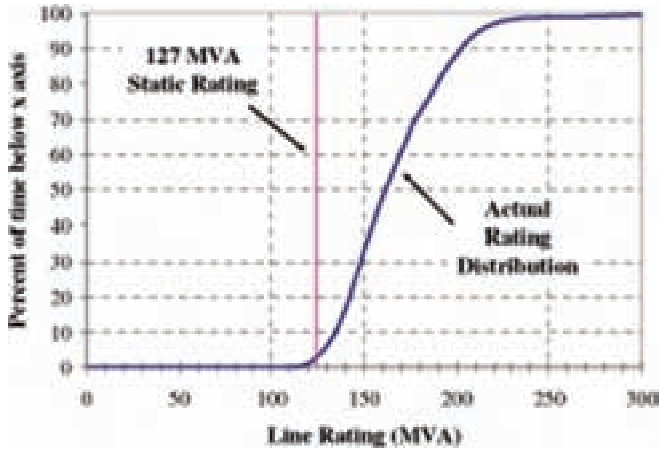

Figure 12 –Cumulative Line Rating, July 17 – August 17

actual load and the static rating, the line is constrained due to post-contingency loading. In other words, while the actual load on the line is shown in the figure, the more pertinent value is the post-contingent load, i.e. the load that would appear on the line if there were a loss of another line in the system. Post-contingent load is continuously calculated and displayed in the Xcel Energy Control Room. Post-contingent load is not recorded so it cannot be included in the figure, but at no time during this period did the actual load exceed the post-contingent load.

Figure 11 also shows short durations where the dynamic rating was less than the static rating due to very low wind speed. This figure illustrates how dynamic rating is particularly effective in wind generation applications – at times when wind generation is high due to strong winds, those same winds are typically providing line cooling and increased rating. Conversely, the periods of low rating occurred when wind generation was low, so full line capacity was not required.

Figure 12 provides a cumulative distribution of line rating.

Notice how the actual line rating is above the static 127 MVA static rating 96% of the time.

Figures 10-12 illustrate how the ThermalRate System allowed Xcel Energy and Marshall Municipal Utilities to increase the LYC-MSH line rating and recognize previously unused capacity. The recognition of this capacity has allowed higher steady state and post-contingent flows and eliminated the need to curtail Buffalo Ridge wind generation.

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Bernard Fitzgerald has a BSEE from Rensselaer Polytechnic Institute and a MSEE from Union College. He has worked for Shaw Energy Delivery Services since 2005 and has over 20 years experience designing instrumentation and control systems for electric power system applications.

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Dan Lawry has a BSEE degree from Clarkson University. He has worked for Shaw Energy Delivery Services and Power Technologies, Inc. since 1993 in the area of thermal uprating of overhead lines and other outdoor power equipment.

John Lazar has a BSEE from Marquette University and is a registered Engineer in Minnesota, Wisconsin and Illinois. He has worked for NSP/Xcel Energy since 1970 in the areas of Distribution Standards, Transmission Engineering and Sourcing with emphasis on Distribution Standards and overhead and underground line design.

Randall Oye has a BSEE degree from North Dakota State University. He has worked for Xcel Energy since 1997 and has over 20 years experience in the electric utility and power generation industries.

WORKING LIVE CAN BE MANAGED SAFELY

By Dave Kenney, Chatham-Kent Hydro

Working live is a necessity for all utilities. No matter how brief, power interruptions inconvenience customers and are a source of lost revenue for utilities. No matter what the task at hand, or the type of pole a lineman is working with — wood, steel, concrete or fiberglass — the rules remain the same: safety procedures should always be followed to the letter.

We at Chatham-Kent Hydro ardently agree with this mindful approach to live line maintenance and distribution maintenance in general. Our company, which supplies power to 34,000 customers in Chatham-Kent, an urban area in the Canadian province of Ontario, has a health and safety committee which assists with the development of a full range of live-line maintenance procedures.

The group includes linemen and management to ensure that installation protocols take into account all aspects of the task at hand, from equipment to manpower. One of the committee's assignments has been to develop installation and live-line protocols for steel poles. Chatham-Kent Hydro first purchased steel distribution poles in 1996 when looking for an alternative to wood poles and an answer to the environmental issues that surrounded their disposal.

BASIC RECIPE FOR INSTALLATION

Chatham-Kent Hydro's line crews follow the same basic procedures for wood and steel poles.

We stress two things in all live-line maintenance: second point of contact and concentration. We also have an emergency plan in place and practice CPR and rescue operations at least twice a year. Ongoing safety training is also an important part of our safety regimen.

Theoretically, there is no difference in installation procedures between wood and steel. Our staff was concerned about the use of steel, so we developed stricter procedures for steel pole installation. These procedures include more cover-up on the lines, more clearance from steel to live conductors and grounding the pole to isolate the line in the event of a accidental contact with an energized circuit.

With a typical live-line job, the linemen at Chatham-Kent Hydro work in teams of three, with two of the crew in the bucket truck. Each wears rubber gloves to handle the line safely. The third lineman is on the ground as an observer: first to make sure that installation protocol is followed; and second, for rescue if needed.

Chatham-Kent Hydro replaces some 250 poles per year. Approximately 100 of these replacements are steel poles.

STEP BY STEP

This is our guide for steel pole installation on a 27,600 volt circuit with a 4,000 volt underbuild. By its very nature, live line and utility maintenance overall is a dangerous undertaking. Proper safety precautions are required at every step of the process, with every type of pole. The crew will complete a job plan and tailboard conference and obtain a hold-off on the circuits.

(Note: RIV nut on bottom section must be in line with the overhead line [vertical & semi roll] and across to the overhead line [A-frame construction].)

PREFERRED METHOD OF INSTALLATION:

1. Check adjacent structures (porcelain wood pins).
2. Install protective cover up on underbuild that will allow movement along phases while steel pole is being raised.
3. Spread underbuild on approved temporary conductor support.
4. Install a minimum of three lengths of cover up on top circuit.
5. Using a double bucket truck, untie and lift center phase or top conductor approximately six feet.
6. Install adequate approved cover up on steel pole that is to be installed.
7. Install temporary ground to base of top section to bond truck and pole to system neutral.

8. Install ratchet binder cant hook at lowest of point of attachment on top section to be raised.
9. Mark friction point on bottom section to allow a 21" to 27" overlap of top section (check manufacturer's specifications).
10. Raise top section of steel pole with radial boom derrick truck using approved web sling. Make sure to continue maintaining safe limits of approach.
11. Align welds on top and bottom section of pole to allow ease of friction fit.
12. Put a slight down pressure on boom to ensure sections are joined properly.
13. Tie in top or center phase conductor.
14. Relocate remaining phases.
15. Secure pole. With cover up in place, remove old pole.
16. Remove cover up, starting with furthest phase.
17. Disconnect temporary ground.
18. Surrender hold-off.

BENEFITS OF STEEL WITH LIVE LINE

Steel distribution poles help utilities keep distribution systems intact and lines live, according to George Manning, formerly a chief executive of Energy Cooperative, a utility holding company based in Ohio. "If a wood pole is hit by an automobile, there's a good chance it will shear and fall down, bringing down other poles in the distribution line. This almost always causes a power outage," said Manning.

He continued, "In the same situation, a steel distribution pole will only dent. Since no other steel poles are downed or damaged, there is no power interruption. The lineman can work live to replace the dented pole during regular hours. With steel poles, labor and equipment costs are reduced. And, we don't lose revenue because of unforeseen power outages."

As Manning testified, keeping electric power flowing to customers is of great importance. That's why most utilities have made live line maintenance a common practice. Working live allows a utility to avoid power outages, increase system availability and enhance service reliability. Live-line maintenance is mandatory when it is not possible to transfer or shut down electrical power. Working live is preferred for installing switches, replacing insulators or installing a distribution or transmission pole.

Dave Kenney is president of Chatham-Kent Hydro and can be reached at 519-352-6300 or davekenney@ckhydro.com.

A PROBLEM OF POWER SUPPLY OF MICROPROCESSOR-BASED PROTECTIVE RELAYS IN EMERGENCY MODE

By Gurevich Vladimir, Ph.D., Israel Electric Corp., Central Electric Laboratory

This article discusses a problem for power supply of microprocessor-based protective relays with AC and DC auxiliary voltage on substation in emergency mode.

As is known, both auxiliary AC and DC voltages are used at power substations. Use of DC auxiliary voltage increases the essential reliability of relay protection due to use of a powerful battery, capable of supporting the required voltage level on the crucial elements of the substation at emergency mode with the AC power network disconnected. However, this increase of reliability comes at the cost of an essential rise in price of the substation and its maintenance. On the other hand, electromechanical relays of all types do not demand an external auxiliary power supply for proper operation, as their operation requires input signals only. There may be some problem when it is necessary to energize the trip coil of the high-voltage circuit breaker at loss of auxiliary voltage in the emergency mode, but this problem has been solved for a long time and simply enough through use of a storage capacitor. It is constantly charged at the normal operating mode from the AC auxiliary power supply through a rectifier and provides a power current pulse to the trip coil on operation of the protective relay in the emergency mode.

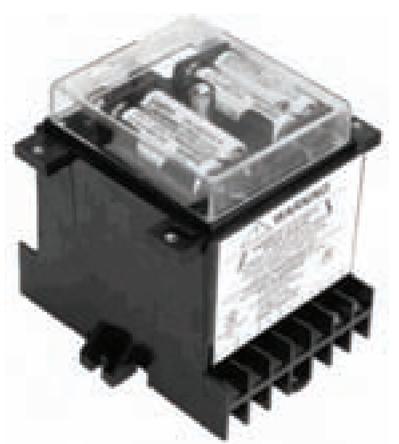

Fig. 1. One of the modern capacitor trip unit providing accumulation and long storage of energy for a feed of trip coil of circuit breaker at absence of an auxiliary voltage.

A modern capacitor trip unit contains, in addition, little nickel-cadmium cells and a low-power solid state inverter for an output voltage of 250V, through which the main capacitor is constantly recharged from a battery while auxiliary voltage is disconnected.

The power capacity of the inverter makes mill watts which are spent only for compensation of self-discharging of the capacitor. Such compact devices (Fig. 1) are issued by many companies and allow keeping the capacitor charged for several days. Clearly, in such conditions, sufficient reliability of relay protection, even on an operative alternating current, is provided. For this reason, the operative alternating current is applied very widely.

The situation began to change with the introduction of microprocessor-based relays and the mass replacement of electromechanical relays by them. To the many problems caused by this transition, one more problem was added. As is known, the internal switching-mode power supply, admitting use as auxiliary AC and DC voltages, has an overwhelming majority of micro-processor-based protective relays (MPR). Therefore, at first sight, there should be no reason to interfere with the use of an auxiliary AC voltage on substations with MPR. The problem arises when there is not enough power for normal operation of an overwhelming majority of MPR and only the presence of corresponding input signals (for electromechanical relays) requiring a feed from an auxiliary supply. How will the MPR behave at loss of this feed at failure mode when the hard work of the microprocessor and other internal elements is required? How will the complex relay protection (containing some of MPR, incorporated in the common system by means of the network communication when there are also losses of auxiliary feed) function? How will the MPR behave during voltage sags (brief reductions in voltage, typically lasting from a cycle to a second or so, or tens of milliseconds to hundreds of milliseconds) during failure? We shall try to answer these questions.

The internal switching-mode power supply of the MPR contains, as a rule, a smoothing capacitor of rather large capacity, capable of supporting the function of the relay during a short time period. According to research which has been conducted by General Electric for various types of MPR, this time interval takes 30-100 ms. In view of this time of reaction, the MPR for emergency operation lays in the same interval and depends on this type of emergency mode, it is impossible to tell definitely, whether the protective relay will have sufficient time to work properly. At any rate, it is not possible to guarantee its reliable work. It is a specially problematic functioning of protection relays with the time delay, for example the distance protection with several zones (steps of time delay, reaching up to 0.5 – 3.0 s). Also it is only possible to guess what will take place with the differential protection containing two remote complete sets of the relay, at loss of a feed of one of them only.

Voltage sags are the most common power disturbance. At a typical industrial site, it is not unusual to see several sags per year at the service entrance, and far more at equipment terminals.

These voltage sags can have many causes, among which may be peaks of magnetization currents, most often at inclusion of power transformers. Recessions and the rises of voltage arising sometimes at failures and in transient modes are especially dangerous when coming successively with small intervals of time. The level and duration of sags depend on a number of external factors, such as capacity of the transformer, impedance of a power line, remoteness of the relay from the substation transformer, the size of a cable through which feed circuits are executed, etc. MPR also have a wide interval of characteristics on allowable voltage reductions. As mentioned in, various types of MPR keep working capability at auxiliary voltage reduction from the rated value of up to 70-180 V. Thus MPR with a rated voltage of 240 V supposes a greater (in percentage terms) voltage reduction than devices with a rated voltage 120 V. It is also known that any microprocessor device demands a long time from the moment of application of a feed (auxiliary voltage) to full activation at normal mode. For a modern MPR with a built-in system of self-checking this time can reach up to 30 sec. It means that even after a short-term failure with auxiliary voltage (voltage sag) and subsequent restoring of voltage level, relay protection still will not function for a long time.

What is the solution to the problem posed by the experts from General Electric? Considering that existing capacitor trip devices obviously are not sufficient to feed MPR, as reserved energy in them has only enough for creation of a short-duration pulse of a current and absolutely not enough to feed MPR, the author comes to the conclusion that it is necessary to use an uninterrupted power supply (UPS) for feeding the MPR in an emergency mode. The second recommendation of the author - to add an additional blocking element (a timer, for example, or internal logic of MPR; will prevent closing of the circuit breaker before the MPR completely becomes activated. Both recommendations are quite legitimate. Here only usage UPS with a built-in battery is well known as a solution for maintenance of a feed while in an emergency mode. This solution has obvious foibles and restrictions (both economic and technical). Use of blocking for switching-on of the circuit breakers can be a very useful idea which should be undoubtedly used, however, it does not always solve the problem, as failure of voltage feeding connected to operation of the circuit breaker is always a possibility.

In our opinion, a more simple and reliable solution to the problem is use of a special capacitor with large capacity connected in parallel to the feed circuit of every MPR instead of UPS usage. High-quality capacitors with large capacity and rated voltage of 450-500 V are sold today by many companies, see the table below.

Use of such capacitor for auxiliary voltage of 220 V AC requires, naturally, a rectifier and some more auxiliary elements (Fig. 2).

Capacity, μF	Rated Voltage, V	Dimensions (diameter, height), mm	Manufacturer and capacitor type
6000	450	75 x 220	EVOX-RIFA PEH200YX460BQ
4700	450	90 x 146	BHC AEROVOX ALS30A472QP450
10000	450	90 x 220	EVOX-RIFA PEH200YZ510TM
4000	500	76.2 x 142	Mallory DuraCap 002-3052
4000	450	76.2 x 142	CST-ARWIN HES402G450X5L
6900	500	76.2 x 220	CST-ARWIN CGH692T500X8L

Table 1.
Parameters of capacitors with large capacity and rated voltage of 450-500 V.

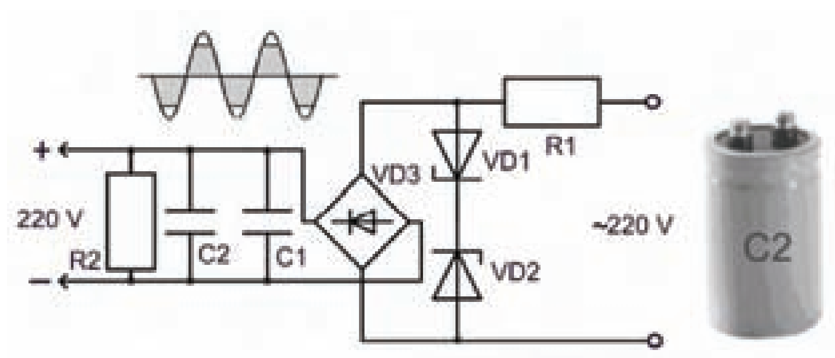

Fig. 2. The device for reserve feed of MPR at emergency mode with AC auxiliary voltage.

In this device, a capacitor of large capacity is designated, such as 2. The C1 auxiliary - not electrolytic - capacitor with capacity in some microfarads serves for smoothing pulsations on electrolytic capacitor C2. It is possible to include also in parallel to C1 one more ceramic capacitor with a capacity of some thousand pico-farads, for protection of C2 against the high-frequency harmonics contained in mains AC voltage. A R1 (200-250 Ohm) resistor limits the charging current of C2 at a level near 1. The same resistor also limits pulse currents proceeding through back-to-back connected Zener diodes VD1 and VD2. Resistor R2 has high resistance and serves to accelerate the discharging capacitor up to a safe voltage at switching-off of the auxiliary voltage. Zener diodes are intended for the maximal value voltage limits of capacitor C2 at a level of 240 V. Without such limitations on the device, output voltage would reach a value of more than 300 V due to the difference between r.m.s. and peak values of voltage. That is undesirable both for MPR and for C2. The Zener diodes slices part of a voltage sinusoid in which amplitude exceeds 240V, forming a voltage trapeze before rectifying. As powerful Zeners for rating voltage above 200 V are not at present on the market, it is necessary to use two series connected Zeners with dissipation power of 10 W and rating voltage of 120 V, as each of Zeners (VD1, DD2 - for example types 1N1810, 1N3008B, 1N2010, NTE 5223A, etc).

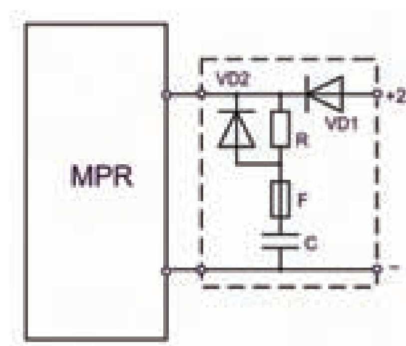

Fig. 3. The device for reserve feed of MPR at emergency mode with DC auxiliary voltage.

As further research of this type of situation clarified, the problem

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of maintenance of reliable feed MPR is relevant not only for substations with AC auxiliary voltage, but also for substations with DC voltage. Many situations where the main substation battery becomes switched off from the DC bus bars are known. In this case nothing terrible occurs, as the voltage on the bus bar is supported by charger. However, if during this period an emergency mode occurs in a power network, the situation appears to be no better, since use of an AC auxiliary voltage as charger feeds from the same AC network. Usually an electrolytic capacitors with high capacitance for smoothing voltage pulsations is included on the charger output. Since not only many MPRs but other devices are connected to a charger output it is abundantly clear that this capacity is not capable of supporting the necessary voltage level on the bus bars during the time required for proper operation of the MPRs. Our researchers have shown that such high capacitance as 15,000 µF doesn't provides proper functioning of MPRs at consumption from charger reaches up to 5 – 10 A.

For maintenance of working capability of MPRs in these conditions it is possible to use the same technical solution with the individual storage capacitor connected in parallel to each MPR feeding circuit. Now the design of the device will be much easier, due to a cut-out from the circuit diagram of Zeners and rectifier bridge (Fig. 3). The resistor R (100 Ohm) is necessary for limiting the charging current of the capacitor at switching-on auxiliary voltage with a fully discharged capacitor. Diode VD1 should be for a rated current of not less than 10. High capability quick blow fuse F (5A/1500A, 500V) is intended for protection of both feeding circuit of MPR and the external DC circuit to avoid damage of the capacitor.

The prototype of such device with the capacitor 3700 µF, fig. 4, has shown excellent results at tests, with the various loadings which simulate MPRs of various types with different power consumption, fig. 5.

Fig. 4. The prototype of the device for reserve feed of MPR.

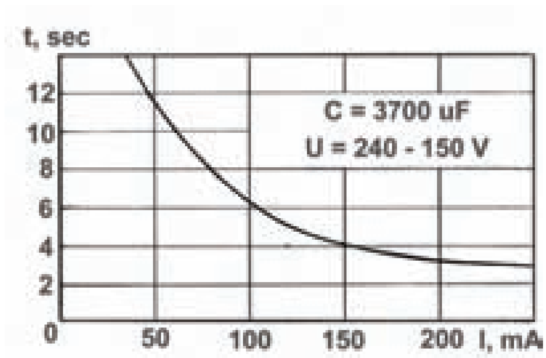

Fig. 5. Relation between consumption current of MPR and prolonging the reserve feeding with capacitor 3700 µF, at discharging from 240 to 150 V.

One more variant of the solution of this problem for substations with DC auxiliary voltage is to not use an individual capacitor for each MPR, but rather a special "supercapacitor" capable of feeding a complete relay protection system set together with conjugate electronic equipment within several seconds. Such supercapacitors can already be found on the market under brand names such as: "supercapacitors", "ultracapacitors", "double-layer capacitors", and also "ionistors". There are electrochemical components intended for storage of electric energy. On specific capacity and speed of access to the reserved en-ergy they occupy an intermediate position between large electrolytic capacitors and standard accumulator batteries, differing both from one and the others in their principle of action, based on redistribution of charges in electrolyte and their concentration on the border between the electrode and electrolyte. The capacity of modern supercapacitors reaches hundreds and even thousand of Farads, however the rated voltage of one ele-ment does not exceed, as a rule, 2.3 - 2.7 V. For higher voltage separate elements connecting among themselves in parallel and series as consistent units (Fig. 6).

Fig. 6. Internal design of high-voltage (ten voltages) supercapacitor, assembled from number of low-voltage elements

Fig. 7. High-voltage supercapacitors made as single module and main parameters of the ESCap90/300 type capacitor.

Unfortunately, supercapacitors are not easily incorporated among themselves as ordinary capacitors, demand leveling resistors at series cells connection and special electronic circuits for alignment of currents at parallel cells connections. As a result, such units turn out to be rather "weighty", expensive and not so reliable (there could be enough damage to one of the internal auxiliary elements to cause failure of the entire unit). For example, combined supercapacitor manufactured by NessCap, with a capacity of 51 F and voltage of 340 V, weighs 384 kg! One unique company known to us which produces individual modules (that is not containing too many low-voltage cells inside) for high voltage, fig. 7, is the Canadian firm "Tavrima". Its ESCap90/300 type supercapacitor (see table below) serves our purpose quite well.

At use of supercapacitor SC, the feeding circuit of the protective relays should be allocated into a separate line connected to the DC bus bar through diode D (Fig. 6).

Due to the large capacity of the supercapacitor, the voltage reduction on feeding input of MPR at emergency mode (with loss of an external auxiliary voltage) will occur very slowly, even after passage of the bottom allowable limit of the feeding voltage. From the personal experience of the author, cases of false operation of the microprocessor systems have been known to occur at slow feeding voltage reduction, below allowable levels.

This can be explained by the existence of different electronic components of a high degree of integration serving the microprocessor, having different allowable levels of voltage feeding reduction and stopping the process of voltage reduction serially, breaking the internal logic of the MPR operation. If such equipment is found in the MPR, used on the given substation, in parallel to the supercapacitor, it should be connected to a simple voltage monitoring relay KU, which disconnects the supercapacitor at a voltage reduction below the lowest allowable level, for example, lower than 150-170 V.

Rated Voltage, V	300
Capacitance, F	2.0
Max. Power, kW	75
Max. Energy, kJ (at 300 V)	90
Internal Resistance, Ohm	0.3
Dimensions, mm	Dia. 230 x 560
Weight, kg	35
Temperature, °C	-40 +55
Price per Unit (for 2006), $	1000.00

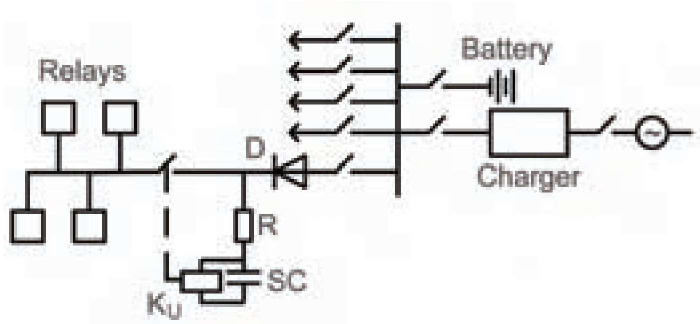

Fig. 8. Example of usage of the supercapacitor as group power supply for protective relays at emergency mode with DC auxiliary voltage.
KU - voltage relay; SC - the supercapacitor

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the public, other service organizations, and both Government and non-government agencies. It is essential that this person be part of the Operational Restoration Team in order that current information can be provided to the external parties and also that the team be made aware of outside issues and the message being sent.

This person should be the only channel for dissemination of information externally.

4.0 Training

An organization can only build confidence and competence in its emergency preparedness through regular training. This includes training of the organization to know its emergency response plans. Training of all members of the Emergency Response Team, including senior management, through regular simulated (mock) training exercises is recommended. This should be conducted on a regular basis, and based on the emergency response plan set out by the organization.

Line crews should receive regular classroom and field training to better prepare for emergency response. Crew training can also be on-the-job training, if in-house crews perform jobs, such as build towers and string conductor, transmission line modifications, fiber optic installations as well as normal maintenance including live line maintenance. If in-house line crews do some, or all, of these jobs, they will stay familiar with the equipment and tools that are available to them because they use them on a normal, daily basis.

Without this normal use of the construction tools and equipment, some material might not be operable when required in emergencies. A free flow of ideas should be encouraged from the line crews on new tools and equipment, to improve response time.

If there is significant reliance on contractors, they must be included in the training exercises.

5.0 Continuous Improvement

After every incident, the Strategic Planning Team needs to re-evaluate restoration plans through a post-event evaluation, in order to make the required adjustments and/or improvements. Also, the data to be collected following a failure should be gathered as outlined in TB No. 175 Chapter 2.

Another important source for internal improvements is the evaluation of emergency restoration response of other OHTL asset owners.

6.0 Conclusion

An effective emergency response plan requires a clearly-stated corporate policy. This policy is the basis for detailed risk assessment and planning of an appropriate response. The asset owner can then evaluate whether this plan falls within the policy and financial constraints. This may lead to iterations of the policy and restoration plan.

Implementation of the plan will result in adequate material, manpower and equipment resources to address identified emergency situations consistent with the corporate policy. Due to the changing utility environment, it is essential that the restoration policy and plan be reviewed regularly.

ANAHEIM DEDICATES NATION'S FIRST UNDERGROUND ELECTRIC SUBSTATION

Anaheim Public Utilities, in a partnership that included the city's Community Services Departments as well as some of the nation's top energy contracting and consulting firms, today dedicated Park Substation, the first underground electric substation in the United States. Adding to the uniqueness of the substation is the fact that it sits below Roosevelt Park, a two-acre facility that serves the East Anaheim neighborhood.

The electric distribution station has the capacity to serve 25,000 current and future residential customers. It uses state-of-the-art technology in substation design with Gas Insulated Switchgear (GIS), which reduces the required space for the substation to approximately 30 percent of a conventional station design. The use of this technology is more common in Europe and Japan.

"I am pleased to see Anaheim continue its transformation into a city of the 21st century with the completion of this innovative project," Anaheim Mayor Curt Pringle told an audience of more than 100 invited guests that included city and utility leaders, project team members, as well as local residents and business owners. "With this new technology, we will be able to build substations closer to where we need them, in spaces that are considerably smaller than their predecessors and within enclosures such as buildings or underground."

The $19.5-million project is expected to be a benchmark prototype for other utilities, not only in California but across the nation. All circuits into and out of the station are underground, including 10 circuit miles of underground cable installed on Santa Ana Canyon Road, while anoth-

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Anaheim

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er 5 miles of existing overhead lines are being converted to underground. An additional 8 circuit miles are underground on other streets.

"In building this facility, our community leaders once again challenged us to fulfill our mission to deliver the affordable and reliable power that Anaheim needs now and into the future," said Marcie Edwards, general manager for Anaheim Public Utilities. "However, in doing so, we were also reminded that success requires solutions that work in concert with our neighbors and enhance the community."

Roosevelt Park will include open green space, walkways, seating and landscaping. It will complement the local surroundings and be within walking distances from the neighboring local residential and commercial areas. Even before its official opening, Park Substation and Roosevelt Park were officially recognized with a plaque for "its contribution to the civic beauty of our community" by Anaheim Beautiful, an all-volunteer non-profit organization composed of citizens and affiliated local organizations.

The design-build team for Park Substation is a joint venture consisting of three companies — Siemens, a worldwide supplier of GIS equipment; Turner Construction, a general contracting firm; and BETA Engineering, a highly experienced specialty electrical engineering firm. As a design-build project, the joint venture was responsible for engineering, procurement of the material and construction of the facility.

"While we knew Park Substation would be a first-of-its-kind facility for Anaheim, we were wise enough to know that it would have been foolish for us to take on the responsibility to build a $19.5-million facility as mere novices," Edwards said. "Due to the complex nature of the project, the city retained the construction management services of Sargent and Lundy, LLC." Headquartered in Chicago, Sargent and Lundy is a leading internationally renowned engineering firm with extensive experience involving GIS substations.

"This is the first of several new substations that we are building to update our electric system throughout Anaheim," Pringle said. "In the coming months, Anaheim Substation, located near City Hall, will be replaced using GIS technology. The new substation will be enclosed within an above-ground structure designed to fit in with the historical architectural theme of the surrounding downtown Anaheim neighborhood.

"Additionally, Vermont Substation, also in the downtown area, will not be far behind. It will also use GIS technology, but will have an open-air design in a very compact space."

DOES TIME-OF-USE CAUSE US TO LIMIT OUR POTENTIAL?

By James Madsen, Consultant, Conectisys Corporation

The Federal Government, State Governments and U.S. Utility companies are sorting through the "Goliath" of Automated Meter Reading. AMR concepts have grown into AMI, AIM and now AMM. The Federal Energy bill provided motivation and generic requirements; "Manage Energy, give the consumer control over their usage and reduce overall costs of energy consumption and energy generation."

Deregulation is driving the restructuring of the electric utility industry in the U.S.; this is providing the momentum for developing low-cost Automatic Meter Reading (AMR) solutions. The federal mandate requires reading meters more frequently, in turn making the manual meter reading techniques currently in use obsolete. Use of the existing infrastructure via modems or pagers costs substantially more than customers are currently paying for meter reading, creating an extensive barrier to AMR market entry. Therein lays the need for the new telemetry technology.

The utility world is being transformed with new legislation pushing forward the evolution of Demand Response, Open Access and Dynamic Pricing. The AMR eruption over the last ten years has caused a myriad of new terms, new approaches and new concepts. This demands an understanding of the market needs, the path that will achieve the greatest return for the investment and a technology that exceeds expectations.

Several Utilities are putting proposals before the PUCs of several states utilizing Time-of-Use technology. Time-of-Use technology time stamps the usage of energy with regards to pricing structures established against energy demand during certain time windows. The consumer then has the option of modifying their usage within these time windows to obtain certain pricing, if they know these time windows ahead of time. The consumer then analyzes their monthly bill to see if any reductions were gained using the TOU windows to reduce energy consumption and can adjust for the next month. The pricing structure can fluctuate with these time windows on an ongoing basis due to demand compared to the demand used to initially set up the pricing.

Several emerging technologies are already antiquating system designs presently installed in the field. A cost effective system, with meter reads every 15 minutes, outage monitoring, remote connect and disconnect, grid monitoring to virtually eliminate rolling brown outs and black outs and consumer interaction on energy consumption habits 24 hours a day. This is Real Time Smart Metering.

Real Time meter reading records the energy usage of a consumer as it is being used, and allows the consumer to view, over the internet, their usage and energy costs in a real-time scenario. At any given point in their monthly usage, they can view the accumulating energy bill as it is happening. Consumer awareness is the key in Real Time technology, to gaining energy efficiency and energy control, allowing the modification of the demand based on energy generation capacity. Consumer involvement at this level is paramount. TOU allows minimal interaction with the consumer as their energy bill is being accumulated.

The Energy Efficiency and Conservation Incentive Act of 2001

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AMR time-of-use

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allows consumers to ask the utilities to provide them with a meter that allows "consumers to manage their purchase, sale or use of electricity… in response to energy price and usage signals". The Energy Policy Act of 2005 only requires TOU pricing to be updated "at lease twice a year". The EECIA also allows reimbursement of the cost of the meter/installation of at least $30 per meter to the utility. The EECIA goes further to allow, "The price and usage signals are readable on AT LEAST a daily basis". TOU does not allow this aspect in a short response time window for the consumer.

Compare this to the Smart Metering Promotion Act of 2001. This goes further to define the requirements to be "interconnected in a manner that permits the reading of energy price and usage signals on AT LEAST AN HOURLY BASIS".

Let's compare this to a fuel gauge in your car. The fuel gauge shows you the fuel remaining as you are using it, and the tank of fuel cost you so many dollars. This gives you an idea of how many miles you can continue until the fuel (which cost you an average price per gallon) runs out. You know the energy required; you could watch its usage as you go up and down hills as the demand (cost per mile in miles per gallon) fluctuates, more on the uphill side, less on the downhill side. You can anticipate when the amount of fuel you have decided to use will last, and determine if you want to spend more for additional fuel to finish the trip. You are able to make decisions such as canceling the trip, modify your travels to eliminate the demand fluctuations of up and down hills to flatter routes, or shorten your trip to conserve fuel. You can make these decisions as you are driving, with up-to-date information. As you drive, you notice the price to refuel goes up or down depending on the price changes of fuel as you travel through different price locals.

Now envision the fuel prices changing as you drive and how this will impact your decisions, understanding the fuel supply is changing as others stop to fuel up. Oh, remember the fuel suppliers are making a profit off your decisions, and your awareness of this changing demand and price allows you to determine when to use the fuel as the price fluctuates. You can stop half way through the trip and wait until the price comes into your comfort zone, or choose to continue, because you know what the prices are at that time. Now, assume you tell the fuel suppliers ahead of time (and all other travelers do the same), based on your travel history, of how much fuel you plan to use. The fuel suppliers can arrange for better pricing and anticipate usage of all travelers to let their fuel generators know how much they will need ahead of time and pass this cost savings on to you. The opportunity for a bad decision using Real Time is very limited.

Compare this to Time of Use, where you don't plan your trip and route ahead of time. Without a fuel gauge, you plan when you will be going through the different fuel cost areas, analyze the landscape to determine whether your miles per gallon will be more or less than the base miles per gallon, depending on how hard your engine has to work to develop the power to navigate the hills and valleys. You have a determined amount of dollars you want to spend for fuel. The fuel prices can change from the base fuel price, but you don't know when or what they will be, because you don't know what the supplier is paying for the fuel you will buy. So you can plan your trip on general knowledge of mileage, pricing and usage, but you do not have any way to update your decisions as you go because you planned it all on pre-described time windows, usage in those time windows and fixed pricing within those windows. If there are several more travelers than anticipated, consuming more fuel than anticipated that drives the price of fuel up while you are driving and impacts the supply of the fuel, you may well run out of fuel or money to finish the trip or it will cost you more than you anticipated in an "excise" cost to make up for the difference, and another problem is the supply may not be there. Also, the average fuel used within those time windows limits the ability to predict usage to any degree by the fuel generators. Hindsight will determine if the decisions were either good or bad. All this WITHOUT a fuel gauge! Until you get your monthly fuel bill. Then you can modify your future trips, but all the disadvantages of the first trip still exist.

Can you develop a monthly budget for expenses based on average dollars per month, when you receive funds on a daily basis and are billed on a daily basis? Would you not need a daily budget in order to avoid not having funds (energy) to pay the daily requirements? So do the energy generators and energy providers. They must know the details in order to eliminate costly over purchases, under purchases, over and under demand with the cooperation of the consumer. Utilizing "hindsight" information does not give the needed planning and response windows necessary to effectively and efficiently plan from the generation side nor allow for energy usage modification from the consumer side.

Real-time meter records, not only show how much electricity is used, but also when it is used, as it is used. This provides a full array of energy services to the utility industry, including consumption reports, which will allow end-users the ability to view real-time data and give them the ability to instantly evaluate and provide cost savings. Actual usage data allows the utilities to better manage long term energy generation plans, energy purchases (overages and underage), as well as potentially eliminating rolling black outs and brown outs, such that have been experienced in California, New York and most recently, Denver. Why would you plan on using TOU when Real Time technology exists and in some cases, may be more cost effective?

Real Time improves the ability for the consumer to determine energy management, gives a greater ability to control energy generation needs and energy purchase requirements to the utility, increases awareness of energy conservation as well as a broader opportunity to make choices about energy consumption, all the while, allowing cost savings on the consumers' billing, and cost reductions by the utilities.

We, as a nation, cannot afford this time nor money, with the advent of Demand Response opening the doors to Direct Access and Open Access to begin the transformation to a nationwide transmission grid, where any consumer can define their energy sources, and affect the energy consumption and distribution nation wide.

The advantages of Real Time over TOU, in energy saving and energy conservation over the long term could easily translate into major savings to the consumer, increased awareness to the need for energy conservation by creating intimate involvement by the consumer, more accurate predictions of energy generation needs, reduced costs of added transmission grids and erection of generation facilities, accurate purchase quantities based on a modified demand history as well as reduced environmental effects of energy generation and eliminate black outs and brown outs.

Why would we, as a nation, go in the direction of TOU, when a more sensible, higher advantaged and cost effective option exists? Time-of-Use technology cannot match the Real Time technology in its short term and long-term benefits. How can we argue against available information that provides meter reads and reports on time electrical consumption data at 96 reads per day (15 minute meter reads) or 2,880 meter reads per month all with consumer involvement? The on time interval data is anticipated to play a key role in energy conservation, power distribution and on-time energy purchasing.

The Energy Bill of 2005 states that the utilities are required to offer you a fuel gauge (i.e. real time or near real-time information). Are we going to spend implementation dollars to use TOU and then switch to Real Time, when the Energy Bill timeline runs out for the utilities or wait until the apparent increased savings of Real Time are recognized? The time this takes will mean missed efficiency gains and lost cost savings. It makes sense to take a hard, honest look at the proposals and the technology available, in order to secure an energy efficient and energy conserving future for our country.

We need to move ahead with the best available technology, spend tax dollars and consumer energy rate dollars on the technology that makes sense in the long term. Shortsightedness in the proposed use of TOU may prove to be a mistake. Time will tell. We may have to reinvent the wheel once again, as real time technology proves itself. We, as a nation, cannot afford this time nor money, with the advent of Demand Response opening the doors to Direct Access and Open Access to begin the transformation to a nationwide transmission grid, where any consumer can define their energy sources, and affect the energy consumption and distribution nation wide.

DRY-TYPE TRANSFORMERS AND ENERGY SAVING FOR THE FUTURE

By Jean-Guy Boudrias, Senior Application Specialist, Hammond Power Solutions Inc.

	E-Source-1995	ORNL-1997	CADMUS - 1999
Annual Losses	60-80 billion kWh (based on discussions with researchers from ORNL)	80 billion kWh	17 billion kWh (Energy saving for low voltage only)
Annual Saving Potential	1 billion US$ per year	330-400 million kWh	350 million kWh
Load Factor	35%	35%	16%

Table 1 Opportunities/Savings Potential of Dry-Type Transformers
Sources : Barnes et al. 1997; E-Source 1995; Korn et al. 1999

On January 2005, a Canadian Federal law was passed that changed the definition of efficiency for dry-type distribution transformers. Of course like any new law, many interpretations developed causing some confusion and trepidation in the transformer industry on who was responsible for the implementation of this new standard in transformer efficiency.

The objective of this legislation is to save large amounts of energy or, for some, save on the escalating cost of energy while at the same time saving the environment.

This all started in approximately 1992 when the United States Department of Energy began studies on energy saving in transformers. One study by one of the DOE collaborators, the E-source Group in 1995, estimated that most of the transformers measured were only loaded at an average of 35% and since most dry-type transformer efficiencies were designed to be loaded at 100% of the name-plate capacity, they were not very efficient at the 35% level. The estimated potential for losses in this study was from 60 to 80 billion kWh, and with proper design the annual savings could be up to $1 billion per year.

Some further studies confirmed this and the latest one by the CADMUS Group in 1999 established that for low voltage only, the average loading was16% with estimated annual losses of 17 billion kWh and potential savings of 350 million kWh with proper designs.

TP1, ENERGYSTAR AND C802.2

In 1996 the National Electrical Manufacturing Association (NEMA) published for dry-type distribution transformers an efficiency standard called TP1. It was designed for use by industry manufacturers. The Department of Energy (DOE) soon after the TP1 publication, included this standard in their EnergyStar self Labelling Program for Transformers.

In an effort to harmonize the North American standard, CSA established its C802/2000 which became the C802.2, and in 2004 in the spirit of the Kyoto protocol the Canadian government passed a law which became in effect on January 01, 2005.

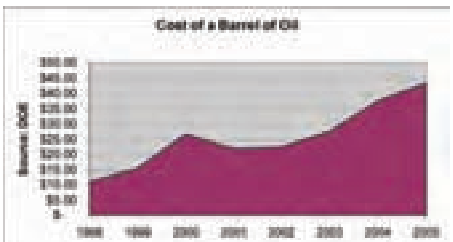
On that date, all 60 Hz dry-type distribution transformers installed in Canada must comply and meet the C802.2 efficiency standards in the following ranges:

- 1ph, 15-333 kVA, low voltage
- 1ph, 15-833 kVA, medium Voltage, 20-150 kV BIL
- 3ph, 15-1000 kVA, low voltage
- 3ph, 15 to 2500 kVA, medium voltage, 20-150 kV BIL

As expected, and in view of the complexity of the ruling, some were mainly looking for a possible loophole for immediate first cost saving, neglecting the major energy cost saving for the end user.

As an example to illustrate the savings, let's take a standard 75kVA and apply a 35% loading of linear load (e.g. heating). The savings over a year could be as high as $800. This would make a good investment for the client but more so, it would keep increasing the payback as the cost of electricity increases through the years.

ELECTRICAL SYSTEMS



All of the studies and rulings on transformer efficiency are, of course, for our North American 60Hz electrical systems. In addition, these efficiencies are calculated for the traditional resistive loads referred to as 'linear loads'.

When we say 35% average loading, it is expected the loads will sometimes be higher or lower. In fact the best efficiency of a dry-type transformer should not be at precisely 35% but in a window of 16% to 65%.

NON-LINEAR

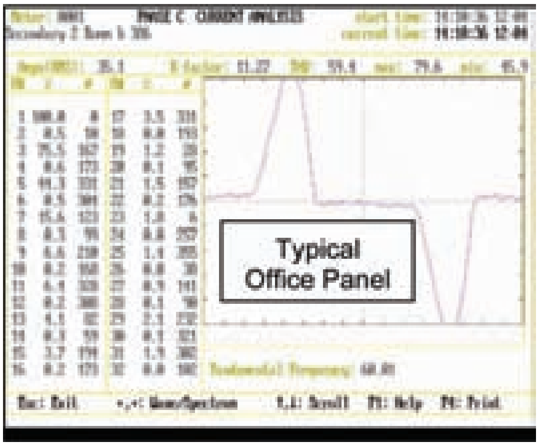
Motors became drives; ballasts became electronic devices and then began a proliferation of switching power supplies with the massive growth in the computer industry. Because of this, in a modern building one can expect to see up to 90% of the loads to be 'Non-Linear'.

The uses of non-linear loads are not new in the electrical world. They were introduced many years ago with the introduction of DC drives and rectifiers. The DC drive was the only way to regulate the speed of a motor and some equipment in the transport industry. This required the rectifier to produce DC voltage.

THE OFFICE BUILDING

The computer industry needed a better, more reliable and less susceptible method to control voltage fluctuations at a lower cost. This would produce DC voltage for computers.

The introduction of Switching Power Supplies (Three Pulses) changed the industry. These devices use the 60Hz current sine wave and, due to their design to produce DC current, they will distort



the current and because of the ohms law, distort the voltage. In other words, "it generates Harmonics on the AC system or THD (Total Harmonic Distortions)".

A Large proportion of the harmonics produced by this single-phase application (switching power supply), are 'triplet' harmonics (zero sequence harmonics). This is natural for single-phase switching power supplies.

These frequencies (triplet) are not cancelled on the neutral at the design phase shift of 120 degrees on the 60Hz North American electrical grid (3q). One of the consequences is that the neutral wire becomes overloaded, and this could start a fire on that fourth wire.

To control motors and save energy for ventilation and heating, we started using AC motors with a 6-pulse, 3-phase Converter Bridge and the "Pulse Width Modulation" technology. This produced substantial harmonics. But since it is a 3 phase application, it does not produce triplet harmonics. It does however produce (5th, 7th, 11th, 13th, etc.) harmonics on the primary side which distorts the voltage and produce losses on the 60Hz systems. These voltage distortions could damage some electric motors and/or resonate with power factor correction capacitors or detuned filters.

One important consequence of the current distortion is the voltage wave distortion. Current is load related, but voltage feeds every load in the system, thus affecting the overall efficiency of the loads in the system.

ENERGY SAVING FOR THE FUTURE

One important factor for the choice of utilizing "non-linear load technologies" is the energy savings. The fact that it uses energy at only a fraction of the full sine wave will save energy. As an example a good retrofit to an AC motor is to install a drive. It gives more flexibility to processing but it also reclaims some energy.

Now with electronic ballasts for lighting, computers, UPS, PLCs and for HVAC applications (electronic control, fan pump drives) just to name a few, it is clear that this is the direction of the future.

Because of their designs, the problem with non-linear loads is that they feed harmonics back into the system, and these are multiples of 60Hz, therefore are at higher frequencies.

As frequencies increase, and electricity travels through the wires, the current will travel more and more on the outside layers of the cables thus increasing the losses.

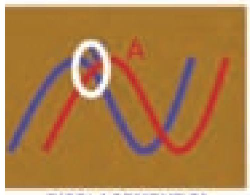
These energy losses will cause more heat and there is an energy cost in some cases to circulate this heat.

You will also have degradation on the efficiency of the system due to the poor Total Power Factor. This appears in the form of distortion power factor created by the distortions of the current and voltage sine wave.

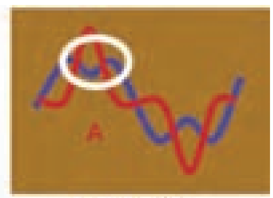
INSTALLATION

These factors should influence the installation protocol. If you look at a typical office panel connected to the secondary of a transformer, you will notice the biggest quantity of an order of harmonic is the 3rd (74%). The longer the cable is on the secondary, the greater the losses.

Since this current will be traveling on the outer layer of the cable it would be good practice to parallel the cable where the code permits. Using this same approach, you would have to install the transformer as close as possible to the loads.



DISPLACEMENT Pf



DISTORTION Pf

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dry-type transformers

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If you phase shift the transformers by 30 degrees, you will cancel the 5th, 7th… harmonic components and, in turn, will correct the total power factor. It will also cancel the harmonic components at very low impedance, minimizing the losses created by the frequency currents.

THE ADDED COSTS & SAVINGS UNDER OFFICE TYPE LOADS!

When we now compare the energy losses in this new environment, we realize the importance of looking closely at the dry-type transformer. Changes in design will often have a substantial influence on the energy usage.

Using the same previous example of a 75kVA, we will find that under an (non-linear) office load profile (NLL) of "K11" (K-Factor 11), a transformer loaded at 35% of its average name plate capacity and designed to conform to C802.2 efficiencies, will save up to $1,500. If we 'optimize' the design (a design that reduces the losses by up to 25% more than the C802.2 standard calls for), it will save up to $2,300 per year. In a large office building it could save up to $42,000 for C802.2 values and $125,000 if the transformer is optimized.

C802.2, MODERN LOADS AND DRY-TYPE TRANSFORMERS

With all this in mind, let's now have a look into how a transformer should be designed to maximize the energy savings. We will not consider a Delta-Delta connection since there is no need for this type of connection in distribution. It could also be dangerous if the system is not well grounded (floating) and could cause electrocution.

DELTA Y CONNECTION

This type of connection is the most common in a distribution circuit.

In Canada the most popular primary voltage is 600, and the most common secondary voltage is 208/120. You could connect three-phase loads and also single phase loads on the same secondary.

Delta Y connections can be designed for standard, C802.2 energy saving for linear loads, K-Factor for non-linear loads and K-Factor C802.2 energy saving for non-linear loads. It can also be optimized to reduce the losses by up to 25% more than the standard, which means it would retain its C802.2 rating even under a non-linear load profile of K-Factor 20.

The best performance, however, would be to keep C802.2 efficiency from 35% to 65% under linear or non-linear loads.

The biggest challenge with these designs is the fact that under a single phase non-linear load application the biggest harmonic component is the triplet (3rd, 9th etc.) and those triplets will circulate in the delta side of the transformer with the full impedance of the design. Achieving better performance under those conditions is difficult and the cost of the material

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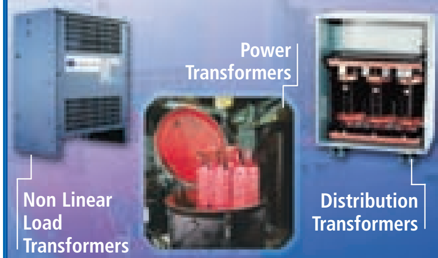

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increases immensely, however the payback is still very short compared to the traditional model (non C802.2).

The best efficiencies therefore can be achieved by using the Delta Y connection for three phase loads, three wires. What to do for single phase non-linear loads (e.g. computer)?

DELTA ZIGZAG CONNECTION

It's been around now for 15 years and was mainly used for Power Quality applications and phase shifting.

The secondary connections have one half of the phase connected to the other half of the second phase and so on. This means that if you divide 120 degrees, which is the angle between the phases, by two, you get a 60 degree phase shift. This is the right angle shift to cancel the triplets and is done at very low impedance, typically 0.95. This will minimize the losses and therefore save energy.

If you compare the Delta Y connection to the Delta Zigzag connection under single phase office loads, you get up to 20% less losses which makes this design very appropriate.

Energy Efficiencies at a C802.2 level are easily achieved when utilizing this kind of design. If you optimize this type of transformer, you can meet those efficiencies under all loading conditions of an office building from 35% to 65% of the rated nameplate capacity.

Furthermore, this design is very well suited for phase shifting as it is built with minimum cost difference to make a zero degree or a 30 degree phase shift with the primary.

You can also easily phase shift two loads for further cancellation of harmonics on the primary side at low impedance. This will improve your 'Total Power Factor'.

CONCLUSION

By applying energy saving approaches like the ones we have just discussed, you will save energy that will pay back your initial equipment cost quickly and, at the same time, will promote Power Quality by minimizing the voltage distortions.

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