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Electric Energy T&D MAGAZINE

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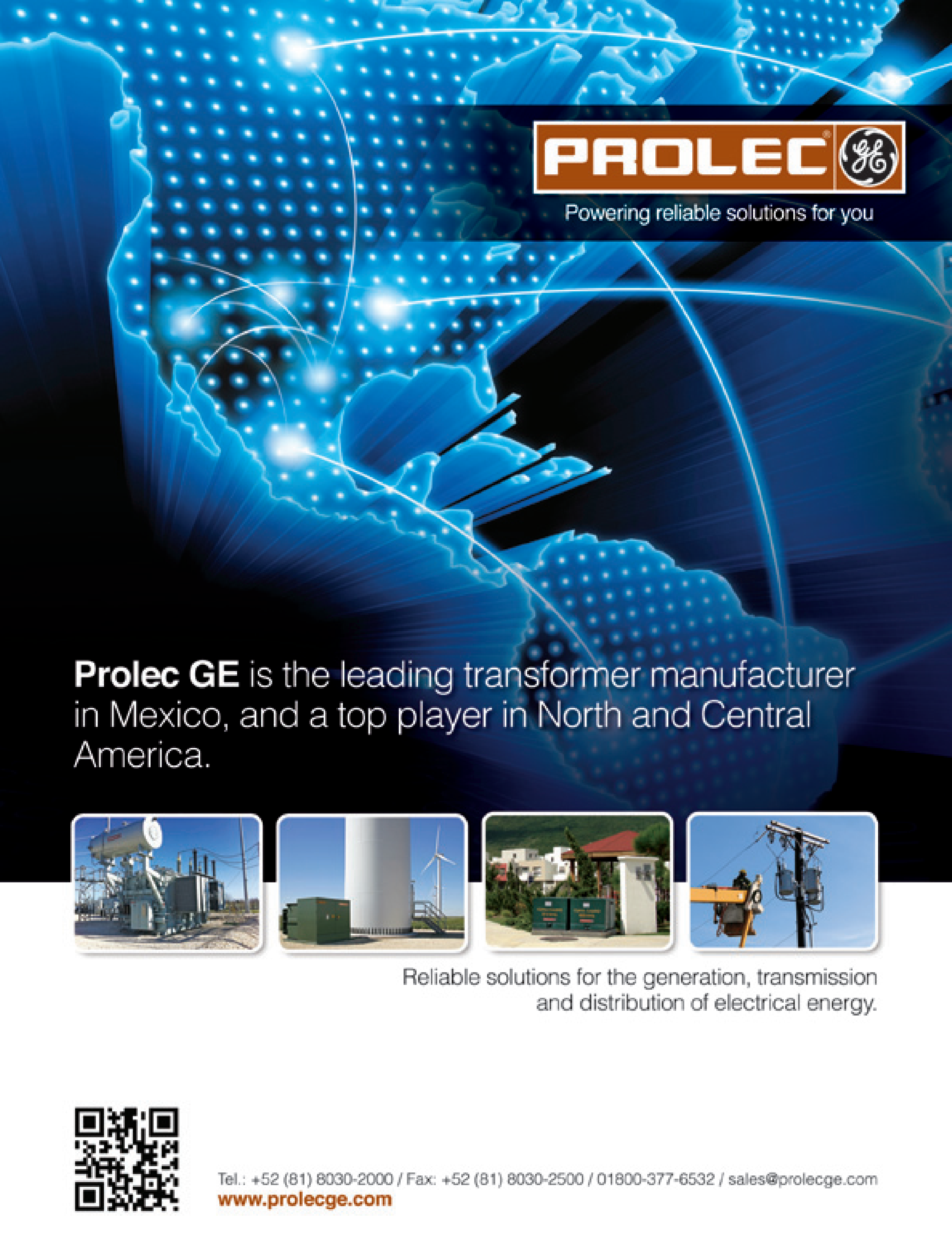
HOW UTILITIES CHOOSE THE RIGHT TECHNOLOGY

INSIDE 2016 BUYERS GUIDE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Electric Energy T&D
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Publisher:
Steven Desrochers:
steven@electricenergyonline.com

Editor in Chief:
Terry Wildman:
terry@electricenergyonline.com

Account Executives:
Eva Nemeth: eva@electricenergyonline.com
Murrae Gomola: murrae@electricenergyonline.com

Art Designer:
Anick Langlois: alanglois@jaguar-media.com

Internet Programmers:
Johanne Labonte: jlabonte@jaguar-media.com
Sebastien Knap: sknap@jaguar-media.com
Tarah McCormick: tarah@jaguar-media.com

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834 Montée Masson
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Tel.: 888.332.3749 • Fax: 888.243.4562
E-mail: jaguar@jaguar-media.com
Web: www.electricenergyonline.com

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POWERPOINTS

TERRY WILDMAN

On the Journey We Live, We Learn

I happen to think that I'm one of the luckiest men that I know. I have an awesome family, great friends, decent health, and an amazing career. The reason I bring this up is because they have all taught me and helped me to love and respect this planet and everything that calls it home.

Many years ago I remember watching my mum carefully removing the labels from cans, opening both ends and squashing the cans with the lids stuffed inside. That seemed to be the extent of conscious recycling in those days. Once a week, my mum and dad would drive to the recycling depot with a large box full of gleaming cans of all sizes to be deposited in a large bin. Good on them!

I recall that I learned to appreciate our land at a young age. Every summer vacation was a family camping trip in either Ontario or Quebec. Before we set up our tent, dad would have us kids make a rake out of twigs and branches and then sweep the entire camp site and pick up any garbage that was left behind. We went on every nature walk that was going being one with the natural habitat. When we struck camp, we swept again. I never knew my dad to be anything but dedicated to being a custodian of the earth.

The biggest influence on my love for this land came from my brother Rob. He taught me not to litter, even a gum wrapper. He used to keep the empty wrapper in his pocket so he had a place to put the spent piece of chew so it could be disposed of properly at a later date. No junk from fast food joints was ever to leave the car unless it was to get rid of it properly.

He taught me auto mechanics. He's truly a natural gear head and I still kid him about having wheels, gears, pullies and fan belts in his head fighting with the little grey cells. We would do our own maintenance on the family cars and he insisted we dispose of all scrap oil and rags at a certified depot. This included sweeping and keeping the garage floor pristine. He taught me how to wash the car using as little fresh water as possible. I helped him tear-down and rebuild from the ground up including the engine and gearbox of his 1954 VW Beetle. This didn't teach me about conservation per se but it further cemented the bond and admiration I held for him and only made me want to be more like him. To this day, he maintains the same principles.

Dad was never far from my psyche. He, Rob, and I loved car racing and there were many weekends spent at the major race track northeast of the city to watch the amazing Can Am Group 7 Sports Racing machines like McLarens, Chaparrals, Lolas, Porsches, and others. At the time they were the fastest cars on any track anywhere in North America. Even in the early sixties, these high-end racing teams were aware of emissions. In an interview at the time, the late Bruce McLaren said, "There are two very important areas where cleanliness is a must. The first is the fuel injection system. You've got to have clean fuel – that's all there is to it. The oil system's even more critical. The entire system inside and out demands strict cleanliness."

We slept in the car and dad insisted we take our own firewood, mostly offcuts and scrap lumber from one home reno job or another rather than take anything from nature. The three of us were so tall we had to sleep with our feet hanging out the open doors of the car.

As much as I loved the races and the rallying, I never saw any correlation between fuel-ravenous cars and the good of the planet. Was I wrong or was it simply not talked or thought about? I continued to be oblivious.

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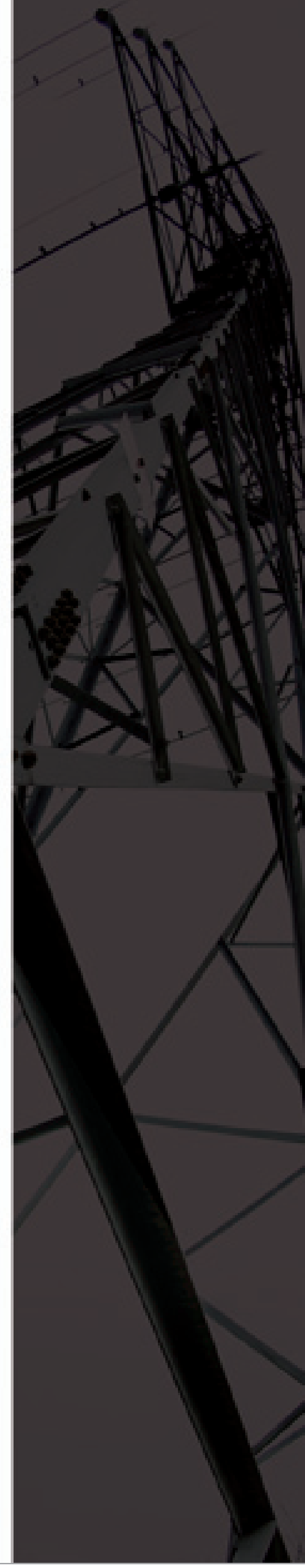
POWER POINTS



After graduating high school, I spent time at the Ontario College of Art working towards a degree in English, Art History, Two and Three-D Design, Museum Studies and Drafting. One weekend, hundreds of OCA students gathered along the banks of the Don River that flows through the east end of Toronto. We were there as part of a burial session for the overly polluted river by offering up flowers and chanting goodbye. I'm glad to say that today, after years of concerted clean-up the Don now boasts a thriving ecosystem.

Then I grew older, married an awesome lady and had a boy and a girl. I started my journey to teach them the stuff I had learned and the things I was so passionate about. We still love camping and I took every opportunity to teach my little ones about how important this earth is to them. How precious life all around them is.

We had a fantastic family dog – an Airedale. He was like a built-in baby sitter. Nobody got near our kids when Dougal was on the job. He never balked at the opportunity to go for a family walk and never failed to be the family protector. I know he taught the kids and me to think about nature and what was real in the world around us. They put all of their faith in his being there at all times. Today, each of my grandchildren enjoy the fun and beauty of having their own family pets. My grandson has and studies his ball python, king snake, waxy monkey tree frog, rescued alley cat, frilled lizard and the most beautiful and charismatic Boston terrier I've ever met. My granddaughters in the Maritimes enjoy their Chesapeake Bay retriever and a fluffy pussy cat. My son-in-law is one of a handful of people registered with the Canadian Government as a trapper/conservationist. Not long ago he was sent to the west coast to cull over 700 ducks that were invading and threatening the very being of a resident population of ducks. Killing sounds cruel I know but it was for the good of the entire flock and to ensure their future.

I landed one of the most incredible jobs I could ever hope for. I became a photojournalist/brochure designer for an aircraft manufacturer here in Toronto. I was sent half-way around the world and then some in search of story material and photos of the company's fantastic lineup of STOL (Short Take Off and Landing) airplanes. All of the trips were fantastic but one has stayed in my mind over the rest. I spent twelve days in Greenland where the population rely on the various helicopters and fixed-wing aircraft of Air Greenland. When I was there the name of the airline was Greenlandair. I had the advantage of being in the jump seat between the two pilots on every flight so the photos I got were awesome. Many of the villages were accessible only by helicopter which was the beating heart of the village and surrounding area.

Most people lived the way their ancestors had for millennia – mostly fishing and whale and seal hunting. One of the highlights of a trip took us along the coast of a fjord and the pilots dropped the helicopter to mere metres off the water. All of a sudden several bowhead whales came to the surface and started swimming in step with the chopper. Apparently they hear the chop of the rotors and turn the flight into a game of 'catch me if you can.' This, as you can imagine, was a delight to the passengers.

After the leviathans peeled off we continued along the coast and I witnessed the most primeval sight I have ever seen. Several Inuit hunters were in their tiny boats and had surrounded a bowhead whale. The native peoples were hurling harpoons into the hapless victim. The water was red as the hunters overcame their prey. Seeing this made me at once sad and thankful that I could witness people who live off the land were securing their future as short as it may be but taking a majestic creature from the sea in order to do so. With these thoughts in my mind and as my travels through this magnificent land continued, I felt a real bond with the people and only hoped their futures were secure. What I found interesting after being told by the pilots was the gulf that exists between those who have and those who have not. Hundreds of miles north of where we saw the whale slaughter, companies were capturing glacial meltwater to drive huge generators to supply the north western region of Greenland with electrical power. What a contrast – hunting game with archaic tools to implementing hi-tech equipment and methods to provide electric power in a northern area of the country. Where is the middle ground? I want to think that I'm aware of the difference but continue to look around me and see what I've learned with regard to saving this planet and where the bottom of the equation lies.

My hope is that I and all of my family and friends will continue to follow their roots and keep the same regard that I have learned for the environment and show the same drive to ensure our planet and, by extension, our lives, will have an awesome future.

Today, as editor-in-chief of *Electric Energy T&D* magazine, I have the pure luxury of spending my time associating with some of the greatest minds in the electrical industry including renewable energy on line and at conferences and expositions. The sheer magnitude of intelligence amongst these industry players boggles my mind and from these people I draw strength to continue my conservation efforts through the efforts made by everyone in the industry.

I also produce a weekly online column called *Global Renewable New*. This gives me a chance to learn more and more about where we are going and how we are getting there with regards to saving our planet. I don't think it could get any better. The efforts that are trailblazing the pathways with alternate fuel sources and renewable energies are truly worthy and encouraging. I don't think it could get any better – nourishing my need to save and protect – and actually getting paid to do so.

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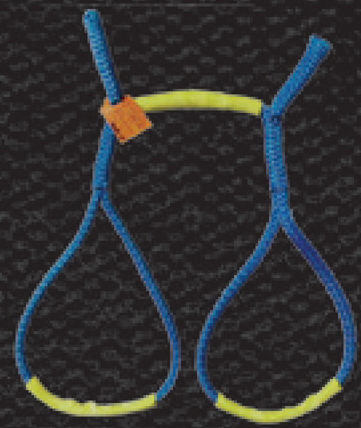

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Itron Announces Patent Litigation Settlement

July, 2016

Itron, Inc. (NASDAQ:ITRI) announced that it has reached an agreement to settle patent litigation claims brought by TransData, Inc. against Itron and certain Itron customers.

The parties have mutually agreed to dismiss all litigation claims related to TransData's patents. Itron and Itron's customers will not be subject to any further infringement claims in connection with these TransData patents. Financial terms of the settlement were not disclosed. Itron previously recorded a financial reserve in 2015 for estimated settlement costs related to this matter and will record adjustments to the amount in 2016 to reflect the final agreement.

Itron provided the following statement regarding the agreement: "Itron has a long track record of innovation, including more than 1,000 patents issued and pending. We are pleased to have reached a resolution to this matter on mutually agreeable terms and look forward to continuing to serve our customers as a leader in designing smart communicating meter systems."

About Itron

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Appalachian Power re-energizes its utility inspection program

July, 2016

A multi-million dollar investment by Appalachian Power to inspect and maintain 60,000 wooden power poles, more than 20,000 underground electrical structures and nearly 10,000 miles of overhead electrical line by the end of the year is underway across the company's three-state service area.

GeoForce, Osmose Utilities and UC Synergetic were hired to complete Appalachian Power's revamped inspection program. In late April, contract workers from the three companies fanned out across Tennessee, Virginia and West Virginia to begin a visual inspection of Appalachian's utility poles, overhead and underground distribution facilities.

This is a multi-year plan. With more than 600,000 poles in the Appalachian Power system that qualify for the program, the pole inspections will take at least ten years to complete. The company's oldest poles are among the 60,000 that will be inspected this year.

To assess the company's overhead and underground equipment is expected to take five years. There are nearly 50,000 overhead line miles identified for inspection and more than 115,000 underground structures that qualified for review.

To date, several thousand wooden poles, hundreds of overhead line miles and thousands of underground structures have been inspected. The underground structures consist mostly of above-ground transformers and pedestals involved in the distribution of power to customers.

Once an inspection is completed, workers enter the results in mobile computers from the job site. If power poles or other equipment are in need of immediate repair or replacement, the company is quickly notified and an Appalachian crew is dispatched to the location.

"This is a proactive investment on the part of Appalachian Power," said Phil Wright, vice president distribution operations. "We're not only identifying electrical equipment that needs to be fixed or replaced, but we've also revamped our inspection program to include money for preventive maintenance that will extend the life of our equipment and make it safer for the public."

A chemically-safe treatment to guard against insect and weather damage is applied to the inside and outside of each wooden pole inspected and deemed in good condition. By protecting and strengthening the poles, they are expected to last longer and be less likely to topple during storms, thus improving overall safety and electric service reliability for customers.

Workers completing the overhead line assessments are primarily inspecting the utility hardware located atop the wooden poles and cross arms. Contractors are asked to look for missing or damaged equipment and tree limbs touching or at risk of falling onto the equipment.

Safety and service reliability are also the focus for inspectors surveying the company's underground structures. This process involves looking for exposed underground power cable and broken or missing locks on transformers and pedestals. If safety labels are old or missing, new labels are applied to the equipment. Crews also ensure the numbered stickers on the equipment are visible and correspond with the number that is on record with Appalachian Power. Numbers that differ could delay repairs and restoration times when service is interrupted.

An Appalachian Power video that explains each of the company's responsibilities is available on YouTube. The link is https://youtu.be/OGpdgC74RtY.

"This is an outstanding program and investment that will benefit our customers and the company now and in the future," said Wright. "I'm extremely pleased with the results so far, and we're just getting started."

Appalachian Power has 1 million customers in Virginia, West Virginia and Tennessee (as AEP Appalachian Power). It is a unit of American Electric Power, one of the largest electric utilities in the United States, delivering electricity and custom energy solutions to nearly 5.4 million customers in 11 states. AEP owns the nation's largest electricity transmission system, a more than 40,000-mile network that includes more 765-kilovolt extra-high voltage transmission lines than all other U.S. transmission systems combined. AEP also operates 223,000 miles of distribution lines. AEP ranks among the nation's largest generators of electricity, owning approximately 31,000 megawatts of generating capacity in the U.S.

INDUSTRY NEWS

U.S. Department of Energy Announces Up to $15 Million to Help Improve the Security and Resilience of the Nation's Power Grid

July, 2016

As part of the Obama Administration's commitment to protecting America's critical infrastructure, U.S. Deputy Energy Secretary Elizabeth Sherwood-Randall announced new funding to strengthen and protect the nation's electric grid from cyber and physical attacks. The Energy Department will provide up to $15 million, subject to congressional appropriations, to support efforts by the American Public Power Association (APPA) and the National Rural Electric Cooperative Association (NRECA) to further enhance the culture of security within their utility members' organizations.

"As our definition of energy security and the cyber threat landscape evolve, we continue to help our partners strengthen the ways in which they protect critical infrastructure," said Deputy Secretary Sherwood-Randall. "This funding is another important step in improving the resiliency of our power grid and our ability to respond quickly and effectively to threats in today's dynamic environment."

Over the next three years, Energy Department funding will be used by APPA and NRECA to develop security tools, educational resources, updated guidelines, and training on common strategies that can be used by their member organizations to cultivate an improved cyber and physical security culture. Activities to bolster their members' security capabilities will include exercises, utility site assessments, and a comprehensive range of information sharing with their members. Approximately 26 percent of the nation's electricity customers are served by municipal public power providers and rural electric cooperatives.

The Energy Department has a long history of working closely with federal and private partners, including the Department of Homeland Security on critical energy infrastructure cybersecurity. All of DOE's cybersecurity efforts align with the September 2011 release of the Roadmap to Achieve Energy Delivery Systems Cybersecurity, which was developed by industry and facilitated by the Energy Department. For the past seven years, through the Office of Electricity Delivery and Energy Reliability' Cybersecurity for Energy Delivery Systems (CEDS) program, the Department has invested more than $210 million in collaborative cybersecurity research and development projects among industry, universities, and our national labs. Today's (7/12) announcement is another important piece of DOE's overall commitment to cybersecurity research, engagement with energy sector stakeholders, and the drive toward an end goal of practical use.

For more information about DOE's efforts to ensure a resilient, reliable, and flexible electricity system, visit Energy.gov.

THE GRID TRANSFORMATION FORUM

Envisioning the 21st Century Grid

How Utilities Choose the Right Technology

We are in discussion with Stéphan Lelaidier, Chief Engineer for Grid Solutions Business, a GE and Alstom joint venture.

EET&D: Technology advancements have had a huge impact on our everyday lives across multiple industries. How has it already transformed the energy industry – and how will it continue to do so?

Lelaidier: When you think of how technology has already impacted our everyday lives, you may think of services and products that help us save time, money and energy. These savings bring welfare to the world and, being more efficient, help preserve the resources of our planet.

Technology has the same potential to make the energy industry more productive, taking care of scarce sources of energy and minimizing impact on our environment. Some advancements in the energy markets already exist today, including electric vehicles, unconventional gas, solar PV and wind turbines, to name a few. However, to continue to meet growing energy demands worldwide, the energy grid must continually adapt to technological changes and advancements. Tomorrow's technology innovations can bring more affordable options to consumers, such as battery storage, clean generation and distribution alternatives, and increased digitization of the grid.

For example, today's home energy management platforms (HEM) – from solar to storage to electric vehicles – provide consumers with residential utility demand response programs, home automation services, personal energy management, data analysis and visualization, auditing and related security services. With a breadth of services at their fingertips, HEM platforms give consumers direct choice over technology for the first time, changing the rules of the games for incumbent utilities.

In addition, consumers are moving toward an off-grid approach by utilizing battery storage, which further affects utilities' bottom lines. But while off-grid solar energy may be great for consumers with low energy consumption, battery storage is ultimately finite, making it an unreliable source of consistent energy. Utilities have a huge challenge, but also an opportunity: how to best incorporate this energy advancement into existing offerings to provide affordable, multi-faceted solutions for its customers.

EET&D: What should utilities keep in mind to stay on top of technology advancements that will help them serve their customers?

Lelaidier: Utilities must recognize these advancements as opportunities to enhance their network operations.

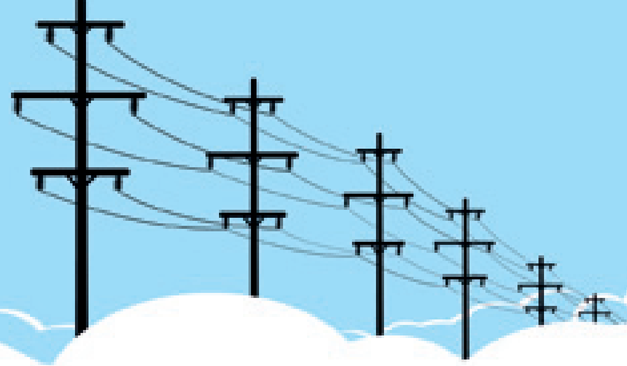
At the transmission level, the increase of large renewable generation (wind farms) and the preoccupation of improving optimization of generation investment across frontiers will require more HVDC optimized connections, interacting with AC networks.

As we move toward more distributed generation, it will become more challenging to estimate generation needs. With renewable integration on the rise, the mix becomes increasingly complex and utilities are challenged to have proper forecasting tools to help meet demand.

Utilities can optimize demand energy resources (DER) available to enhance the grid, providing more resiliency against system-wide disruption. By involving the end user – who is now the prosumer – we can make electricity more available and affordable.

THE GRID TRANSFORMATION FORUM

Envisioning the 21st Century Grid



EET&D: Are there specific technology upgrades that all utilities should be implementing? How do they choose the right technology?

Lelaidier: With the complex mix of generation, it's more important than ever for utilities to provide reliable future forecasting and real-time analytics. This is not only increasingly important to optimize distribution, but also to lower impact on the environment – not solely on increasing renewables, but also by creating grid equipment and solutions with a lower carbon footprint and accurately predicting and extending the life of a product. Of course, reducing the environmental impact directly using new technologies on grid equipment is also a key enabler. The use of new gases with drastically reduced GWP, as Green Gas for Grid or g3, is one example.

GE helps utilities with this mission by digitizing substations – what we call our intelligent digital substations. Substations help convert electricity to different voltage levels, switch power to different branches of the grid and guarantee continuity of service. By digitizing this technology, utilities can control and protect their substations with greater convenience and flexibility. It also guarantees dynamic adaptation, as all operational information – including electrical parameters and status of the primary, secondary and auxiliary equipment – is digitized and transmitted to the substation's control room. This helps manage the network to limit losses and optimize production.

EET&D: How has GE helped utilities navigate the technology landscape to upgrade their systems and facilities?

Lelaidier: GE continuously listens to the needs of our customers and focus on outcomes. By partnering with the customer, we help them prepare and customize technology and standards of the future.

One way we are accomplishing this is through our digital twin technology, a collection of algorithms and models that builds a digital representation of machines and equipment to test outcomes before physically implementing changes, which allows utilities to grow and create new business and service models through the Industrial Internet. Our industrial platform PREDIX is at the heart of this digital twin technology, paving the way for big data management.

Until the beginning of the 21st century, the only way to obtain detailed information about industrial equipment was to physically inspect it. Today, utilities can virtualize maintenance and upgrade tasks by creating a digital representation to create, test and build in a virtual environment. Only once the digital twin meets performance requirements do engineers physically implement new procedures or manufacture product upgrades. For example, manufacturing simulations can determine whether virtual designs can realistically be built using the machines available, and real-time data feeds from sensors can predict the exact state and condition of an operating asset. An accurate digital representation of a physical asset not only cuts prototyping and construction costs, but also enables utilities to quickly predict failure, reducing both maintenance costs and downtime.

One example of how GE utilizes the digital twin is through our digital wind farm, where we test the configuration of each wind turbine prior to procurement and construction. Once the farm is built, each virtual turbine receives data from its physical environment and software helps optimize power production by adjusting turbine-specific parameters like torque of the generator or speed of the blades. This process aims to generate 30 percent gains in efficiency.

EET&D: What else should utilities consider to prevent their facilities from becoming outdated?

Lelaidier: At the end of the day, we cannot ignore the possibilities new technologies provide. Utilities must be open to testing, piloting and integrating new technologies to stay ahead of the curve in the energy industry, particularly as we see more regulation and desire for renewable energy sources.

We are at the eve of a big transformation in the energy world. We will experience a new wave of major technical innovations driven by a convergence of digital and physical technologies. More than ever, the partnership with utilities will be of paramount importance, so that energy brings welfare to the world and allow the whole process of energy generation and transmission to be more and more efficient in order to save the resources of our planet.

EET&D: We can't thank you enough Stéphan for taking time out of what I'm sure is a very busy schedule to talk with us.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GREEN OVATIONS

Innovations in Green Technologies

Managing the Operational Challenges of the Distribution Grid

By Dr. Farrokh Albuyeh

The distribution grid in the United States is aging and dates back to the early days of the 20th century. Today it is still being designed, planned, and operated using the same methods and procedures that were used to accommodate the consumption patterns of yesteryear. With the proliferation of renewable and distributed sources of energy (such as solar PV) at both the distribution grid level and at customer facilities, as well as the end-use consumers' ability to alter and manage their demand and consumption patterns, distribution grid operators are facing increasing challenges to operating the grid. The increasing number of electric vehicles and fast-charging stations at the commercial level and at private residences also adds to the problem. Reversal of power flows, equipment overloading, phase imbalances, increased losses, and voltage fluctuations are just some examples of the challenges that grid operations personnel are facing.[1]

Most Distributed Energy Resources (DERs) and Demand Response (DR) capabilities are located in the secondary and tertiary parts of the grid where operators have little or no visibility. This is because most conventional Distribution Management Systems (DMS) rely on analytical tools, such as three-phase power flow calculation engines and state estimation methods, which were originally designed for analyzing balanced transmission networks using mathematical models of the grid equipment. Since the data to properly model the distribution grid (especially in the secondary and tertiary circuits) may not be readily available, these tools have become ineffective. As such, the majority of DMS installations provide visibility only to distribution substations, feeders, and primary circuits. In these installations, the grid operators manage only the visible parts of the grid and rely on autonomous operations of grid equipment downstream in lower parts of the grid.

Another problem often seen at a typical distribution operations center is the existence of many data silos, which are designed for various activities, with little or no exchange of data among them. Examples of such data silos include DMS, Outage Management Systems (OMS), Customer Information Systems (CIS), Geographical Information Systems (GIS), and Meter Data Management (MDM) Systems, among others. Often, the same data is duplicated and managed independently in two or more data silos.

Advanced Metering Infrastructure (AMI) Systems, when properly designed, can offer great sources of data and information from the deepest parts of the grid, the customer-side of the meter, and grid-edge assets. However, in most AMI implementations, the focus is on customer metering and billing and many of the advantages offered by the AMI go unused.

Addressing the Challenge

When coupled with new analytical techniques, new sensing, communications, and control technologies can provide the opportunities and tools needed to assist operators in properly managing the grid. These technologies give grid operators the ability to use the very same DER and DR assets that are causing operational issues as tools to address them. In addition, the emergence of smart inverters offers another set of tools and capabilities to assist in grid operations. A smart inverter can provide support for grid operations by connecting generation and storage assets in a variety of control modes to address local and system-wide operational and reliability issues.

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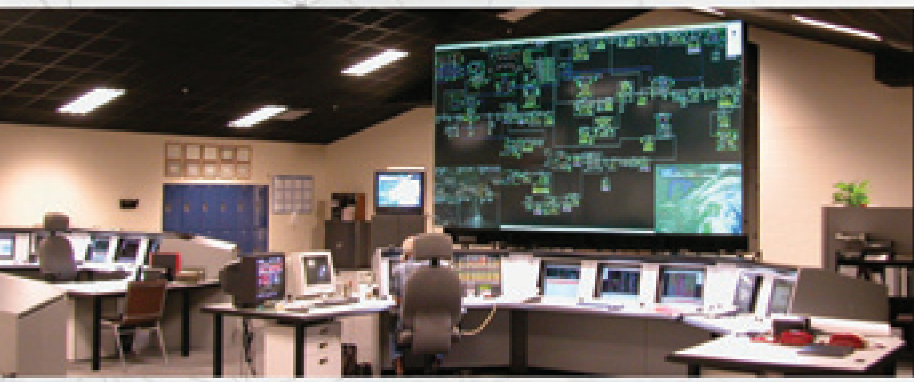

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Changes for the Better

The proper management and coordinated scheduling of DER and DR assets, in conjunction with other conventional resources, is the key to addressing grid operational issues. In order for these initiatives to be successful, grid operators must have complete visibility and situational awareness to these assets, the ability to analyze their impact on the grid, and the capability to manage and control these assets in near real-time. This, combined with the analytical capabilities to optimize and coordinate the scheduling, dispatch, and control of all DER and DR assets (in conjunction with other conventional assets), will enable the operators to utilize all of the capabilities provided by grid-connected and customer-side assets to maximize the return on their investments.

To this end, a Distributed Energy Resource Management System (DERMS) is required with the following functionalities:

Data Acquisition and Control: Requirements for a modern and cost-effective system include two-way communications and control functionality, the ability to monitor all grid-edge and DER/DR assets, and the ability to exercise control. Public or private internet provides the communications platform. Where existing broadband internet capabilities are lacking, cellular technologies may be used to establish the required communications and control capabilities. It is also important to consider cyber and physical security issues, as every grid-edge device presents another entry point for malicious activities and unauthorized intrusions.

Distribution Grid Modeling and Analysis: The distribution grid, as well as all load and generation resources, will need to be modeled in detail. Most DER/DR and grid-edge devices are connected at the customer-side of the meter or in the last miles of the distribution grid. As electrical characteristics of last-mile and tertiary circuits may not be readily available, the conventional model-driven network analysis tools – such as three-phase state estimators and power flows—will not work. New data-driven network analysis tools that utilize a wealth of data from AMI and other sources to model the distribution grid and all assets will be required. These tools enable system operators to analyze the impacts to the grid of grid-edge devices and will allow them to develop operating schedules and dispatch instructions that take the limitations imposed by the grid into consideration.

Breaking Data Silos: To enable DER/DR and other grid-edge devices to participate in the operation of the system, a single and consistent system of record containing all grid, customer, and asset data is required. This capability can be provided by breaking various data silos and collecting and managing all data in one system.

Forecasting, Scheduling, Dispatch, and Control Functions: These functions require the ability to forecast the availabilities and capabilities of all grid-edge devices. The forecasting function must take into consideration exogenous parameters such as time of day, solar irradiation, or temperature, as well as the technical capabilities of all assets. The ability to schedule, dispatch, and control all assets is also a required capability of the system. These schedules can be determined ahead of time and executed automatically or based on event triggers. They can also be developed ad hoc and executed manually.

Optimization: In order to get the most out of all conventional and renewable sources of energy and DR, scheduling and dispatch needs to be coordinated and optimized. Optimization may include operational as well as economic objectives. The optimization process will also need to take various grid and asset capabilities and constraints into consideration, in order to arrive at practical and implementable schedules.

Asset Monitoring and Performance Analysis: As most DER/DR and grid-edge devices reside at the customer side of the meter, the ability to monitor their performance and adherence to control instructions is required. Performance data can also be used as a part of forecasting functions, as well as for billing and invoicing purposes.

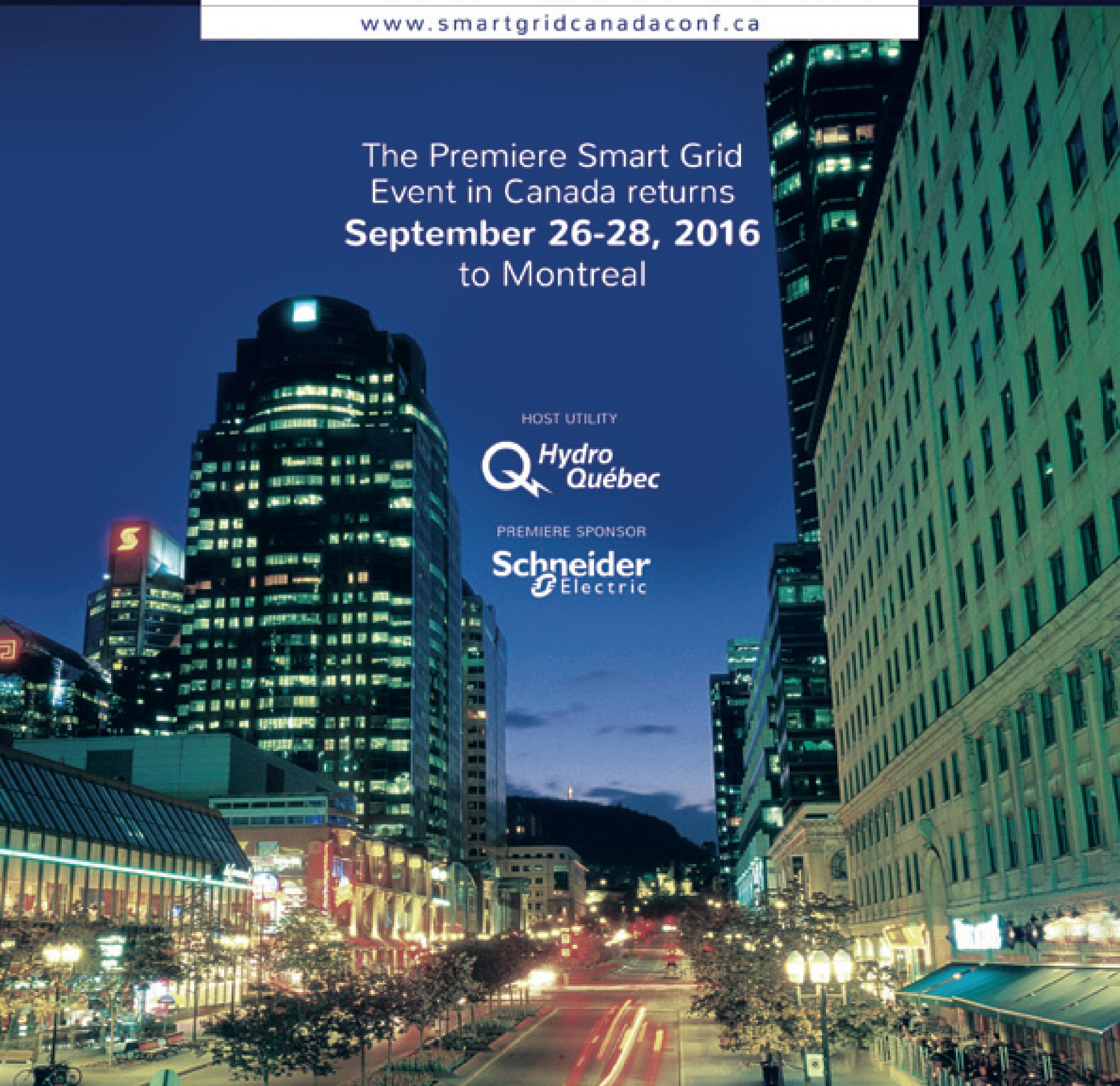
System Heartbeat Monitoring: Given the number of interconnection points and the multitude of legacy and third-party systems involved, monitoring the health of various systems and communications links is important. A heartbeat monitoring system will continuously observe all systems and communications facilities and will alert the operator of any malfunctions.

By properly integrating all field data from various sources, breaking silos of data, forecasting and optimizing the operational schedules of all assets, and analyzing the state of the grid and the impacts of DER/DR operational schedules on the grid, distribution utilities can provide better power quality for their end-users. At the same time, distribution grid operators will have access to a wide set of tools and resources to effectively operate the grid and to address operational issues.

About the Author

Dr. Farrokh Albuyeh has more than 30 years of experience in the electric power industry, developing and implementing power system applications and systems, as well as managing and delivering projects. In his role as Senior Vice President of Smart Grid Projects at OATI, he is involved in the development and delivery of solutions and services for wholesale energy markets, applications for scheduling and managing DR and DER, as well as the development and delivery of solutions to support distribution grid renovation. Dr. Albuyeh has specific experience with technical analytical studies, application software development, providing consulting services, and managing and delivering large-scale projects.

[1] *Grid of the Future -Are we Ready to Transition to a Smart Grid?" A. Ipakchi, F. Albuyeh; IEEE Power & Energy Magazine, March/April- 2009, pp 52-62. (Reprinted in special IEEE PES Publication on Smart Grid in March 2010)*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From Research to Action

How to talk about utility standards and methodologies at your next barbecue

By Christine Hertzog

Standards and methodologies. Bring up these topics at your next barbecue and your guests may quickly find reasons to leave early or drink heavily. But nothing is more important to the reliable, resilient, flexible, secure transport and management of grid data than standards and methodologies.

Let's not rehash the typical messages about the drivers of change confronting utilities because the outcomes of change are what matter. A key outcome is *interoperability*. Interoperability is important because grids and their supporting network infrastructures can't be *built to last* as they were in the twentieth century. Advanced grids and networks must be *built to change*.

Serious about Standards

Designing agility is the right response to resolve the fragility of today's data-drenched smart grid infrastructure. Utilities need standards-based solutions that eliminate proprietary vendor lock-in, reduce risks of stranded equipment investments, and increase the scope and tempo of competitive offerings that accelerate the deployment of networks that support advanced grid operations.

Interoperability is based on standards. EPRI's Information and Communications Technology (ICT) team takes a leadership role in standards development organizations (SDOs) and industry associations with utilities in mind as these standards are developed. EPRI's team knows the ins and outs of standards making, and can rapidly assess the impacts of activities on utilities and make meaningful contributions to standards development efforts.

There are more than a dozen entities that address different areas of utility telecommunications, enterprise architecture, data management, meters, and communicating sensors—like phasor measurement units. These include the typical SDOs associated with grid activity like the International Electrotechnical Commission (IEC) and the Institute of Electrical and Electronics Engineers (IEEE). However, the list also includes organizations focused on the telecommunications functions supporting advanced grids, like the Wi-SUN Alliance, the Wi-Fi Alliance, and emerging areas such as machine-to-machine communications.

For instance, EPRI participates in SDOs that impact data management, an area of exponential growth and opportunity for utilities as communications-enabled meters and other advanced sensors replace existing gear. The common information model helps utilities create data definition and management approaches that eliminate data silos. EPRI also works with industry organizations addressing geospatial and meter data to reflect utility requirements and conditions.

Methodologies to the Rescue

Methodologies deliver common and proven approaches to critical infrastructure designs and upgrades. While just as "sizzling" a topic as standards, methodologies present opportunities for utilities to save time and money, and reduce risks. EPRI began work in 2000 on a methodology that could be used by utilities that were planning, designing, and implementing Smart Grid applications like advanced metering infrastructure. This methodology was ultimately published by the IEC in 2008 as the—*IntelliGrid Methodology for Developing Requirements for Energy Systems*, a publicly available document.

The timing could not have been better. Many utilities wanted to develop tactical plans to support strategic, smart grid planning. When they asked the question, "Where do we start?" the answer was, "You start with the IntelliGrid Methodology."

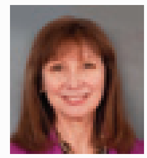
Even though utility strategic visions are like snowflakes (i.e., each one is unique), the methodology fits—it's a common approach to guiding each utility's advanced grid projects. There is a strong focus on principles related to architecture development, project planning, requirements definition (with use cases), and technology acquisition. Cyber security best practices are also highlighted.

In the ensuing years, an extension of the IntelliGrid Methodology was developed—the Smart Grid Roadmap Methodology (SGRM). It has been used by Investor Owned Utilities, Cooperatives, Municipal Electric Utilities, government agencies and Independent System Operators. The SGRM helps utilities address applicable business objectives and mitigate associated risks through the effective adoption and implementation of technologies, applications, and standards.

So maybe a better topic at your next barbecue is how to save money. It's the stealth way to insert standards and methodology topics into the conversation. Standard can remove the risk or future-proof technology designs and acquisitions. Standards promote interoperability, which minimizes threats of early obsolescence. Interoperability supports agility, which accommodates faster tempos of technology changes. Proven methodologies deliver common approaches to critical infrastructure projects, optimize technology planning, provide organizational direction, and deliver short- and long-term guidance on project governance.

As today's electrical grid evolves to advanced grid operations, the importance of reliable, resilient, flexible, and secure telecom infrastructures increases. Starting with a solid foundation based on standards and implementing based on methodologies like IntelliGrid and SGRM helps increase the odds of success for every utility.

About the author



Christine Hertzog is a Technical Advisor for ICT and Cyber Security R/D/D programs at EPRI. In this role, she works with utilities to ensure that EPRI's research programs reflect current and future-state needs and that results are effectively leveraged. She was previously the founder of a consulting firm focused on innovative grid solutions and has an extensive background in telecommunications hardware, software, and services with startups and international corporations. She authored the Smart Grid Dictionary and co-authored Data Privacy for the Smart Grid. She has also served in an advisory capacity to startups, industry associations, and publications. She has an MS in Telecommunications from the University of Colorado at Boulder.

Shedding Light on the Importance of Transmission Line Efficiency, Capacity and Reliability

By Dave Bryant

Following the Western Energy Crisis of 2000 and the Major East Coast Blackout of 2003, a group of engineers in California got together to design a new type of bare overhead conductor that could carry twice the current of a conventional conductor without exhibiting excessive conductor sag. The team essentially replaced steel core strands, used to strengthen most types of overhead conductors, with a composite core made up of high-strength carbon and glass fibers.

The composite core offered a coefficient of thermal expansion nearly ten times less than steel. This allowed the 'new' conductor to carry very high levels of current during peak load and/or emergency conditions without sagging into underbuilt lines, trees or other structures. To date, the new conductor has been deployed to more than 400 projects in 40 countries, primarily to increase the capacity of existing transmission lines.

Increasing line capacity offers several advantages. It can alleviate grid congestion allowing the grid operator to access the least expensive source of energy; it can improve grid reliability should an adjacent line fall out of service; and it can open up existing pathways to enable the distribution of renewable energy without having to build additional lines.

The downside is that this conductor type (ACCC) has been categorized as a 'High-Temperature, Low-Sag' HTLS conductor and engineers associate high temperature with extremely high line losses. And they are absolutely correct.

What is often overlooked, however, is the fact that this particular conductor design actually operates more efficiently than conventional or other HTLS conductors of the same diameter and weight under any load condition. The reason is quite simple. The composite core is so much lighter than its steel counterpart, that it allows the conductor to utilize 28 percent more aluminum without a weight or diameter penalty. The added aluminum content (and quality) reduces the electrical resistance of the conductor which serves to reduce line losses by 25 to 40 percent or more depending upon load level.

In North America, line losses are generally considered to be around 3 percent and the costs are simply socialized and passed through to the consumer. If you broaden the range of transmission to include sub-transmission and the higher end of distribution ~34.5 kV and above, the number may climb to 4 or 5 percent, but most people would still consider these to be very small numbers.

Stepping back for a moment, think about how efficiency is driving technical innovation in other industries. Boeing, for instance, developed the carbon fiber based 787 Dreamliner to reduce fuel costs, extend range, and increase airframe service life. BMW and other car companies are also using carbon fiber technology to improve performance and fuel efficiency. You may have also noticed that it's becoming increasingly difficult to find a bicycle or a pair of skis that doesn't utilize carbon fiber technology. Performance and efficiency go hand in hand.

Returning to the discussion of electricity, let's consider investments made to improve the efficiency and performance of generators. Improved efficiency reduces fuel consumption, associated emissions and life cycle costs. It's generally easy to justify a few extra up front dollars for substantial long term performance gains. Transformers and other equipment also benefited from technical advancements. Again, improved efficiency and reduced life cycle costs justified higher upfront capital costs.

On the consumer side, substantial improvements have been made to improve the efficiency of appliances. In many cases, utilities offered incentives to consumers to use more efficient refrigerators, air conditioning units and light bulbs because of the difficulties associated with building new generation and transmission. An outsider might think it's a strange business model to pay customers to use less product, but all industries certainly have their share of issues.

In recent years, Smart Grid was envisioned. The idea here, simply stated, is to connect the 'generation brain' with the 'appliance brain' so they can work more efficiently. This might allow dishwashers, washing machines and other appliances (including electric cars), for instance, to tap the grid during off peak hours. This is all good.

But what about the wires themselves that connect everything? They essentially represent one-hundred year old technology and many of them have been in service for 50 years or more.

Getting back to the high capacity composite core conductor described above, let's consider its efficiency aspects on a 345 kV line upgrade – as was recently completed by one of the larger utilities in the U.S. Keep in mind that improving efficiency was not a first tier goal. Increasing capacity for a growing market and ensuring reliability in a highly corrosive and weather event prone area were the primary objectives.

How and Why ETESA is Working to Build the World's Most Efficient Electric Power Grid

Interview between Dave Bryant of CTO and Mr. Ivan Barria, CEO, Empressa de Transmision Electrica, S.A., (ETESA) Panama

Bryant: We understand that ETESA – the leading Panamanian Transmission Utility – is securing public financing via the Bond market to rebuild and expand the transmission infrastructure in Panama.

Barria: Yes. Over the last several years Panama's demand for electricity has grown at a rate of nearly eight percent annually. This has put tremendous pressure on our grid. Additionally, because we do not produce fuel locally, we are adding renewable generation resources to supplement our hydro facilities. We intend to export a percentage of the clean electricity generated to Costa Rica as well.

Bryant: What makes this Capital raise unique or different from other Government backed infrastructure projects?

Barria: In most cases infrastructure projects are paid for by consumers. While the cost of transmission represents a relatively small percentage of a typical electric bill, these costs do add up and we are often limited in what projects we can pursue – and in what timeframes – based upon cash flow constraints. By pursuing Bond financing we can accelerate project completion thereby providing improved services and reliability sooner rather than later, without overburdening the consumer.

Bryant: Where is the revenue coming from to support the financing and return on investments?

Barria: The agreement we have with the Panamanian government allows us to retain any excess revenue that is generated from efficiency improvements that drop system and line losses below four percent. By pursuing maximum efficiency we are able to show actual revenues and predicted revenues that are sufficient to cover the investment costs and provide good returns to Bond holders. We have currently secured $200 million with the help of the Bank of Nova Scotia.

Bryant: Will the funding of the Bonds have a detrimental impact on the electricity prices in Panama – are the rate payers accessed a premium to cover the loans?

Barria: Not at all. Improvements in efficiency, capacity, reliability and resiliency will not only reduce consumer costs, it will also allow us to deliver more power to our rapidly growing customer base. This will not only be reflected in lower electric bills, it will also help our society and economy grow and become more productive. Everyone wins, including consumers and investors.

Additionally, even though the higher performance products we purchase are more expensive than commodity products, we generally order products in bulk through multiyear contracts. We also use tenders to ensure we receive competitive bids. The bulk purchasing contracts not only help reduce our costs, they also help manufacturers plan their production strategies which can help them as well. Finally, leveraging zero to one percent financing via EXIM Bank, World Bank, and others in Japan, Korea and elsewhere, allow us to establish one year payment terms with our vendors so we don't have to actually pay for the products until they are in service and the vendor's don't actually have to wait one year for payment.

Bryant: That is a very creative strategy. Can you explain a little bit more about the role transmission and related equipment efficiencies have in your plans?

Barria: We only purchase the most efficient products and technologies. We recognize that many organizations focus on purchasing the least expensive components including transformers and commodity wires, but we are driven to reach the highest possible levels of efficiency. ACCC conductor, for instance. We know it costs nearly three times as much as ACSR or AAAC, but its efficiency gains – not to mention capacity gains – pay for themselves in months. And this is considering new lines. As it relates to upgrading existing lines there is no comparison and the cost savings are immediate - as we would otherwise have to replace structures at a much higher cost and over a longer timeframe.

Bryant: This appears to be a very unique strategy and your goals of having the most efficient and reliable transmission system on earth are very aggressive. How did you define the path to reach this goal?

Barria: It's simple. When faced with daunting challenges one must think outside the box. When I assumed the role as CEO at ETESA, there were a handful of people that couldn't understand this. Today, our team is now the most progressive group I have ever worked with. It's quite an exciting and dynamic time for us all which I'm sure others in our business can relate to.

Thank you, Mr. Barria. It seems you have developed a very impressive and practical business model for improving grid efficiency and reliability. Perhaps others will take note?

Shedding Light on the Importance of Transmission Line Efficiency, Capacity and Reliability

A line loss calculator using IEEE 738 methodology (and certain operating assumptions) estimates that the use of the composite core conductor will reduce line losses by 30 percent compared to the steel core conductor of the same diameter and weight that it replaced (Drake size). If we assume a 62 percent load factor and a peak capacity of 3,000 amps, the reduction in line losses would equate to 300,000 MWh per year.

As a basis for comparison, let's consider the energy savings offered by a 100 watt equivalent LED light bulb replacement. The LED reduces electrical consumption by around 80 percent compared to a standard incandescent light bulb. Translated, the use of 12.5 LED bulbs would save 1 kWh of electricity per hour. 12,500 LED bulbs would therefore save 1 MWh. If we assume a 4 hour per day / 365 day per year light bulb utilization, it would take 2,568,493 LED bulbs to save 300,000 MWh of electricity. At a cost of $20 per LED bulb, the energy savings would translate into a capital cost of $51,369,863.

The composite core conductor (3 phase, double bundled), on the other hand, would cost roughly $14,000,000 (not including hardware and installation costs). While these and other project costs would certainly add substantially to this figure, it would be safe to assume that the conductor would not have to be replaced every few years like the light bulbs. If the LEDs had to be replaced once every five years, the cost of the energy savings would climb well over $400,000,000.

From an environmental perspective, based on the average CO_2 emissions from all combined sources of electricity in the state where this project was completed, either investment choice would reduce emissions by approximately 200,000 metric tons of CO_2 per year. Considering that the average car in North America emits 4.75 metric tons of CO_2 per year, this would be the equivalent of taking 42,000 cars off the road for every one-hundred circuit miles of 345 kV conductor upgraded or every 2.5 million lightbulbs replaced. It appears that conductor replacement may be a significantly less expensive alternative.

Perhaps we should take a closer look at the wires themselves and consider how modern conductor technology and line loss reductions might cost-effectively help us reach a number of important environmental and policy objectives? If policy makers can find a way to incentivize the utilities that invest in these upgrades, everyone should win.

About the author

Dave Bryant is Director of Technology at CTC Global Corporation in Irvine, California. Dave was a co-inventor of the patented ACCC conductor and ancillary hardware components. His 35 year background as a design engineer focused on the use of advanced composite materials in numerous industrial applications which helped expedite the development, testing, and commercialization of the ACCC conductor.

Integrating DA with AMI May Be Rude Awakening for Some Utilities

By John D. McDonald

The many benefits of distribution automation (DA) - visibility, fault detection and isolation, energy efficiency, and asset management - are creating a "second wave" of smart grid investments and integrations, following the widespread adoption of advanced metering infrastructure (AMI). Currently, in fact, the business case for DA is better than for any other single system in the phased steps of grid modernization.

In those phased steps, typically AMI comes first, followed by DA. In fact, DA relies on AMI's end-of-line sensors, a.k.a. "smart" or interval meters, to enable its benefits. The hitch in this picture lies in the fact that the fundamental AMI system must accommodate DA functionality.

Utilities that adopted AMI as an end in itself, without a well-considered technology road map, may be rudely surprised to learn that their AMI choices of a few years back were not made with future integrations in mind. We need an industry standard that spells out the architecture of communications infrastructure within the meter so it can send 'last gasps' to the outage management system (OMS), voltage data to the distribution management system (DMS) and serve other functions to systems other than AMI. But because there is no such industry standard with respect to AMI systems, the endeavor remains very much a caveat emptor situation.

Some AMI systems simply do not lend themselves to DA integration and may require replacement or a laborious, expensive, inefficient workaround. For utilities that have not yet embarked on an AMI implementation, looking ahead to future systems integration can avoid duplicative efforts and costly mistakes. In fact, a successful DA integration with AMI unlocks the value in both systems. In addition, the creation of a technology road map and adoption of these and other technologies should drive organizational change toward a more holistic approach to smart grid. De-siloing will bring efficiencies and further unlock the value in technology adoption, something that regulators will increasingly demand as they scrutinize cost recovery and rate cases.

The market and the business case

Of the approximately 48,000 distribution substations in the U.S., fewer than half have any sort of automation. Substations with some automation and those without automation typically connect to feeders with no automation or monitoring whatsoever. Today, very few distribution feeders send any kind of real-time information upstream. This creates large areas of, shall we say, "unobservability." We just don't know what's happening on the system.

The imperative to learn what's happening on the system will only grow stronger, and the need to support a variety of data streams from the field and route them efficiently is only going to grow exponentially in the near future. As more distributed, renewable energy is integrated into the grid, and as the utility copes with two-way power flows, the utility will face new safety and protection challenges. Add to that the additional, two-way data flows that will accompany dynamic pricing and the interaction of that signal with a home energy management system. When the peak price of electricity moves customers to shed load, the utility will want to understand precisely how much load is being shed, individually and in aggregate. Ideally, these data flows, like those for AMI and DA, would use the same communication network: the AMI support infrastructure.

All of these considerations are driving utilities to implement a DMS to manage complexity. But the DMS is only as good as the information coming from the field. These factors explain why distribution automation or distribution optimization, if you will, currently represents the most cost-effective step and the best business case of all smart grid solutions.

The substations and feeders without automation in the U.S. pose an enormous challenge - not coincidentally, a huge addressable market for vendors and a cost-effective route with big operational and organizational payoffs for utilities. The thinking I'll outline here is designed to assist both parties in making the best products and the most cost-effective investments.

First, break down the walls

The holistic approach to smart grid, in particular, and grid modernization, in general, requires a strong dose of executive leadership due to entrenched interests that have persisted in power utility culture. For instance, AMI implementations typically fall under the purview of a metering group inside the utility, while DA is under a distribution engineering group in operations. The two systems share a need for service-territory-wide communications systems. Too often, a siloed utility builds two systems, side by side, when a single, well-vetted system could be built to serve both purposes. That results in redundant efforts, duplicative expense and two separate data streams that would serve the organization far better if they were integrated.

The simplest way to avoid this misstep is to have executive leadership, sometimes aided by a third party, bring together the metering group and the distribution engineering group to jointly determine their mutual, functional requirements for a common communication network. And don't stop at accommodating DA functionality, because as I've mentioned, demands on that network will only grow with time.

Cooperation leads to a stronger business case for both systems in this example. Indeed, a general rule of thumb for a technology road map and resulting utility investments is to develop them with a horizontal organizational structure that results in cost-effective investments and integration-friendly systems. As this becomes a more widely recognized best practice in the smart grid era, regulators will come to expect this approach and conceivably may base decisions on whether it's being implemented.

Integrating the acronyms

Many AMI technologies are designed for meter-related data output only - those 15-minute interval readings that flow upstream to the network management system (NMS), which manages the communication network aspect of AMI and also feeds the data to the meter data management system (MDMS). The MDMS stores that data and feeds it to applications, such as generating customer bills, analyzing usage patterns and so forth.

The interval meter's so-called 'last gasp' when an outage occurs isn't metering information; that signal needs to be routed to the OMS, where it can be analyzed to determine the cause and extent of an outage. Some AMI systems cannot split off that last gasp to the OMS. Similarly, another distribution automation function - voltage data coming back from the end-of-line sensor, in this case the meter, needs to be routed to the DMS to ensure that the utility is achieving the 114v to 126v ANSI standard at the customer premise. That is not easily accomplished with some AMI systems. Note that one doesn't need the voltage readings from every meter, just those at strategic points at the ends of selected feeders.

An AMI system is the glue between the meter and the utility. Functionality in the meter needs to be matched to functionality in the supporting systems, the 'infrastructure' in 'advanced metering infrastructure.' That means the communication network, among other things. Thus, an AMI system needs a certain flexibility to integrate properly with DA functions, such as routing meters' last gasps to the OMS and steering voltage information to the DMS.

For utilities that have installed AMI, this underscores the need to evaluate the underlying systems with DA integration in mind. A utility may have had the foresight to develop a carefully thought-through road map and be in a good position to reap the benefits of DA. If that foresight was lacking, the consequences can be laborious and expensive. It's technically true that AMI data can be routed through the NMS and the MDMS to reach the OMS and DMS, but that's a cumbersome route that challenges bandwidth and latency. A well-architected system would avoid that scenario.

Further, as meters gain functionality, they may well be upgraded or swapped out for more advanced ones. What a utility wants to avoid is ripping and replacing the underlying infrastructure - again, the 'I' in 'AMI.'

The AMI system needs to have enough flexibility to support the metering information going to the NMS and MDMS, but also support other data outputs on the smart meter and be able to route that to other systems. I've mentioned routing last gasps to the OMS and sending voltage data to the DMS, but as time goes on, deriving value from more functionality in the meter requires having the functional-ity to route those data streams to other systems and destinations over a common communication infrastructure.

Vetting the DMS

The DMS contains the network model manager, which is a critical piece of software. Utilities would be wise to look closely at this functionality during the procurement process. The DMS must interface with the utility's geographic information system (GIS), so it is imperative to know whether the particular DMS in question will, in fact, integrate easily with the utility's particular GIS. The DMS must know what data to pull from the GIS, how that information is stored and how to retrieve the needed data for building the network model.

A DMS that works well with a GIS is important because, as the data in the GIS changes, incremental updates inform the network model in the DMS and keep it up to date. The OMS also has a network model for outage analysis that depends on the GIS, as well.

The network model

Think of the network model as two major sets of information. One is the power system connectivity information, which includes the electrical characteristics of grid assets. For instance, that includes transformers, the model of each transformer and its connection information - is it YY, is it ΔΔ, is it ΔY grounded? Power system connectivity information also includes the branches, nodes and capacitor banks connected on the distribution feeders to ground.

The second set of information in the network model is the real-time information about the network, the operational information - the voltage, current, real and reactive power flows, statuses of switches and circuit breakers, and so forth.

DA functions, up close and personal

When we talk about DA, we're talking about three primary functions: improving reliability with fault detection, isolation and restoration (FDIR) for optimal feeder reconfiguration; reducing losses with VAR control; and managing load or demand with voltage control. (Voltage is directly proportional to load, so when we control voltage, we control load. VAR is a reactive power, directly proportional to losses.)

Today, with DA, the utility can combine voltage and VAR control with integrated volt/VAR control (IVVC). In fact, a DMS optimizes these applications. But to do so, the DMS requires real-time information, knowledge of what's happening on the distribution system downstream of the substation.

To assess whether an AMI system will support DA functionality, one needs to weigh the response re-quirements of the DA applications. Three metrics must be assessed: speed, bandwidth and latency. For instance, FDIR requires a 2-3 second response for rapid switching. (Those are SCADA-level speeds.) Capacitor controls require about 30-60 seconds. Many AMI systems are designed to support only 15-minute interval reads, yet intelligent electronic devices often need to send megabytes of data upstream at one time, requiring speed, bandwidth and low latency.

Here are some questions to ask yourself: Can your utility countenance delay in operational com-mands being enacted? Are hundreds of milliseconds of latency tolerable? There are other considerations: Cybersecurity practices such as encryption affect the performance of data communications, increasing latency. Seeking the 200 millisecond latency one is accustomed to while adding 'overhead' in the form of security measures may not be realistic.

When the utility adds sensors at both substations and feeders, much more information heads upstream. That has an impact on the system's ability to meet the response requirements of DA applications, in terms of speed, bandwidth and latency.

Avoiding the abyss, and stranded assets

The utility needs to ask hard questions of its vendors to avoid the downside described here - making a short-sighted investment in AMI.

Is there a migration path with your vendor? What's on that path? An easy 'board swap?' A more difficult, more expensive 'box swap?' Maybe there's no swap; maybe it just doesn't exist. If there's no path forward, will that result in a stranded asset? In SCADA procurement, for instance, if a vendor said it would be supported by a top-end X-brand server in the family of servers, then if you need greater computing capacity - and that's a given - the system has no way to grow if it's based on the current top-end equipment.

Thinking through your technology road map with a good understanding of succeeding systems' functional requirements will lead to better results and more cost-effective investments. Hopefully, this exposition of the technology challenge in integrating DA with AMI and the importance of the road map contributes to better choices for stakeholders.

About the author

John D. McDonald is an IEEE Smart Grid technical expert, as well as Smart Grid Business Development Leader – North America, Global Smart Grid Strategy Group, at GE Grid Solutions. He is an IEEE Fellow, past president of the IEEE Power & Energy Society (PES), an IEEE PES distinguished lecturer, board chair of the Smart Grid Consumer Collaborative and CIGRE US National Committee (USNC) VP, Technical Activities, among other affiliations.

Automated Crew Planning Boosts Efficiency at Eversource

By Dennis Desrosiers

Every week, Eversource Energy plans approximately 40,000 hours of work for 410 crews across 40 work centers serving 3.4 million customers in Connecticut, Massachusetts, and New Hampshire. Historically, the vast majority of that work was planned manually – leveraging a combination of work management systems and paper-based job packets. But as new technologies have emerged, the company sought a better way to plan and manage work – a way that would drive efficiency and consistency and ultimately, deliver better service for customers.

"Data drives so much of what we do today, and our employees and our customers have higher expectations for the kind of information we're able to provide," said Steve Gilkey, vice president of Electric Field Operations for Eversource Energy. "That's why we implemented an automated crew management system – creating greater visibility for our leadership into crew operations and eliminating the inefficiencies of a paper-based system that could create delays for customers."

Eversource recently used a program known as Crew Manager to automate the process of planning and managing work for line crews. Now, rather than waiting to be provided with a stack of paper work packets each morning, line crews arrive to work each day and see an 80-inch smartboard displaying which truck they're on, which crew they're part of, and any customer appointments they have scheduled that day.

"Like many utilities, Eversource relied on a combination of work management programs and paper work packets to plan work," said Mike Brubaker, vice president of sales for ARCOS LLC. "Each planning period, the optimized work packets would be released to the area work centers. Unfortunately, the plan sometimes ran into the realities of daily utility work. Crew Manager allows the latest resource management information to be part of the planning process, including who may be gone this morning due to callout last night, re-allocated to different areas, 'crewed up' differently based on need or mobilized for a major storm event."

By using the Crew Manager solution to schedule work and the make-up of crews, Eversource has increased its work schedule maximization rates, and completion rates for planned work have climbed more than 10 percent companywide. The program has also helped supervisors from different states and work locations share best practices, and identify ways to plan and manage work more efficiently.

To boost productivity, Eversource wanted every supervisor to know how his or her peers organized and dispatched crews. In the past, one work center might assign a three-person crew to a particular kind of job that another work center handled with two lineworkers. By displaying this information in Crew Manager for all crews and managers to see, supervisors can now collaborate on how to "right-size" crews for the job.

"I was balancing time between sending out reports and queuing up crews. It could take me one to two hours per day to deal with changes in jobs and the make-up of crews as well as coordinating it with my planner," said Frank White, a supervisor for overhead distribution lines at Eversource. "That extra time has given us a way to do more on-site supervising."

Since all 40 work centers are using the same technology, supervisors also have greater insight into what works best in terms of how to plan and schedule crews and resources. Managers and directors can see which trucks the crews are using on certain jobs, and determine if the crews are accomplishing jobs with, for instance, fewer vehicles. This helps operations management decide if some of the equipment on the property can be better used or redistributed.

That type of resource management is especially useful during major storm restoration. Prior to implementing a single automated system, Eversource relied on resource management software to track crews for major events. As managers moved into storm mode, the utility would have supervisors call and fax dispatchers to obtain storm mode layouts.

"In the past, when a storm was forecast, people would have to pull out an instruction book to refresh their memory about how to use the resource management tool," added White. "What we were looking for – and what we found with Crew Manager – was a system for everyday use, so the transition to storm mode is effortless."

Since implementing the new crew management system for storms, dispatchers and supervisors can see crew data and assignment scenarios as storms approach. And, when faced with a forecasted storm, executives can immediately see if each area has responded properly to resource requests.

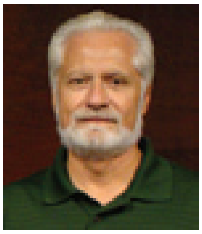
"If we need 25 crews covering the state by 4 p.m., we can see that in Crew Manager," said Gilkey. "The technology helps us avoid making a half-dozen phone calls to verify it's happened."

This same information is readily available to the dispatch center on their display screens. Even after hours, Eversource can see via the new crew management system how much of its workforce is on the property. This approach provides Eversource a data resource beyond just employee scheduling. If there is a need to optimize the fleet, Eversource can drill into how each center is using the fleet as well as their approach to "crewing." This data is used with confidence to standardize the disbursement of various types of vehicles and equipment.

The information helps the company decide if some equipment on the property isn't necessary, which can lead to retiring assets. In the wake of major outages, Crew Manager provides a look back at specific days, hours or minutes to see the location of crews and what they worked on. For any storm, managers can precisely determine how many crews were on the system, which increases confidence when presenting storm cost recovery information. The end result is a more efficient workforce, during normal blue-sky days, and during storm response, when efficiency and productivity is perhaps most critical.

"When we know where a crew is and what they are doing, including the details, we can improve response time and restoration for our customers," said White.

About the author



Dennis Desrosiers is the business integration manager for Eversource Energy. Desrosiers' 25-year career at Eversource includes roles in the Nuclear Generation, Engineering and Transmission & Distribution business units. Currently, he is responsible for the support and training of numerous operations technologies including the callout system and outage management system. Desrosiers received a bachelor's degree in civil engineering from the University of Massachusetts, Dartmouth and a Project Management Certificate from Boston University. Contact him at *dennis.desrosiers@eversource.com*.

Geomagnetic Storms and Geomagnetically Induced Currents

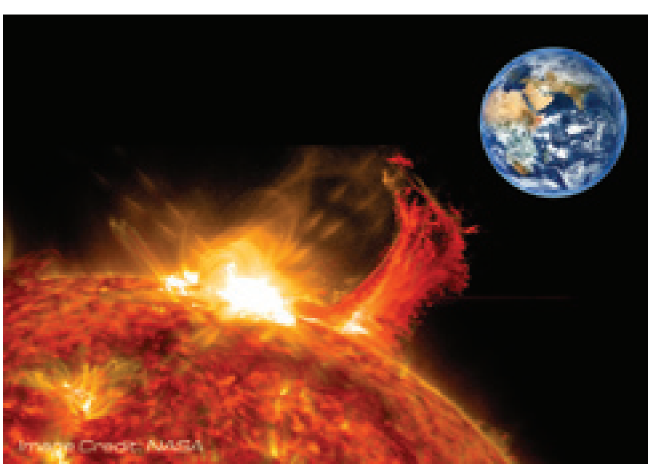
By Jenn Gannon

Geomagnetic disturbances (GMDs), often called geomagnetic storms, and geomagnetically induced currents (GICs), are gaining recognition as a threat to the bulk power system. GICs are the currents that are induced in long conductors during GMD events. This phenomenon occurs with every geomagnetic storm, large and small. GICs can damage system assets in a manner that can be sudden and catastrophic, as in the case the Quebec storm of 1989. The impact of GICs can also be chronic, quietly aging assets during the moderate events that occur on a regular basis. In this article, we will talk about what causes GICs and the science behind the hazard.

Solar impacts on Earth

The 'solar wind' is a continuous stream of particles emanating from the sun. It is a plasma, a gas of charged particles. The solar wind is composed mostly of protons and electrons. Its associated electric and magnetic fields move outward from the Sun along with it. Irregular disturbances on the sun cause bursts of the solar wind that are of higher intensity than normal. A geomagnetic storm occurs on the Earth when a disturbance on the Sun affects the Earth through the solar wind.

The solar disturbances with greatest impact on the earth are masses of ejected particles and electromagnetic fields called Coronal Mass Ejections (CMEs). Large CMEs can travel at speeds close to 2000 km/s and are many times the size of the Earth. Unlike the normal solar wind, CMEs do not emanate more or less uniformly in all directions. Each one is a huge bolus (or blob) thrown out from the sun in a particular direction. Sometimes, a CME strikes the earth.



A coronal mass ejection (CME) from the surface of the Sun.
(NASA artist's composite)

When a CME strikes the Earth, a chain reaction of events occurs. The Earth's magnetic field, which provides a natural shield against the fast-moving plasma, is compressed, sometimes drastically. Electric currents that exist in the ionosphere are enhanced and new ones are formed. Charged particles travel down the magnetic field lines in the Polar Regions, producing the visual manifestation of a geomagnetic storm that we know as the aurora. During very large events, the electric current systems that cause the aurora are pushed very far southward in the Northern Hemisphere and the aurora can be seen unusually far from the north polar regions.

On the ground, the effect of this complicated interaction is a rapidly changing geomagnetic field. Whenever there is a changing magnetic field, an associated electric field is induced. Engineers know this principle as Faraday's Law. It is this geoelectric field, induced by the rapid change in the geomagnetic field near the surface, that causes GICs to arise in long conductors on the surface of the Earth.

The 'climatology' of geomagnetic storms

The Sun goes through a quasi-predictable pattern of activity called the solar cycle, which is typically about 11 years long. A greater number of geomagnetic storms are expected during the maximum of the solar cycle and in its declining phase. However, large storms can happen at any time in the cycle.

To provide a simple index of the strength of geomagnetic storms, the National Oceanic and Atmospheric Administration's Space Weather Prediction Center has defined a geomagnetic storm scale, similar to the manner in which hurricane and other atmospheric storm scales have been devised. (See *http://www.swpc.noaa.gov/noaa-scales-explanation.*)

Moderate storms (G2 on NOAA's Geomagnetic Storm Scale) occur, on average, on about 360 days out of every solar cycle, or about nine percent of the time. Strong (G3) and severe (G4) storms, occur on average about 130 and 60 days per solar cycle, respectively, or about three percent and one percent of the time.

Extreme events (G5 on the NOAA scale) are much less common. On average, there are 4 occurrences of G5 geomagnetic storms per solar cycle, which is about 0.1 percent of the time.

Even among these events, only a few are large enough to be catastrophic in terms of GIC impact. There have been several storms of this magnitude observed in the past 200 years of recorded magnetic history, including the Carrington Event of 1859. The Carrington Event, occurring in the infancy of the electric industrial age, interrupted railroad service in much of the United States for several days, as it made telegraphy between stations, on which train signaling depended, difficult or impossible. Other extreme events include the event of May 1921, during which telegraph equipment and undersea cables were damaged and telegraphy interrupted in some parts of both Europe and North America; the 1989 event that caused the Quebec blackout; and the 2003 'Halloween' event that caused significant and persistent damage in the South African bulk power system.

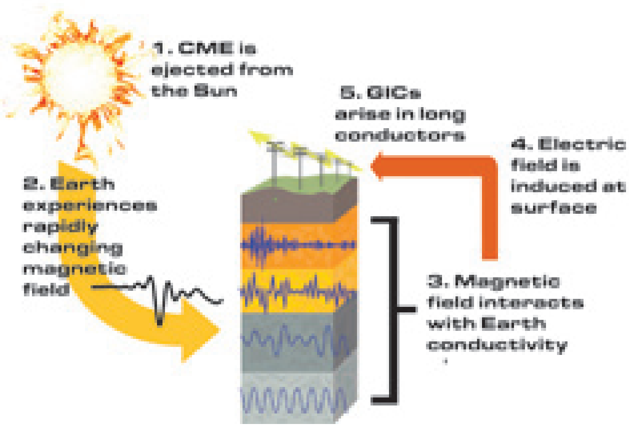
We are fortunate that these events are relatively rare. The past 20 years have been unusually quiet in terms of geomagnetic activity. However, as we become more dependent on an aging and increasingly saturated power system, the potential risk of significant impact continues to increase. The 1921 event, and in particular the 1859 event, would have been very destructive if they had occurred in our present advanced state of infrastructure development and great dependence on electric power and telecommunications equipment.

The role of deep Earth conductivity

As stated above, conditions favorable to GICs are created by a rapidly changing geomagnetic field. GMD events are typically of continental scale, due to the large scale of the upper atmospheric electric current systems that drive them, although there can be 'hotspots' at smaller scales. However, the induced geoelectric field is very dependent on location. The reason for the smaller horizontal scale of variability of the geoelectric field, compared to the GMDs that drive it, is that the geoelectric fields at the surface are due to interaction of the GMDs with the conductivity of deep earth structures. The horizontal scales of variability of these deep earth structures cover the range from sub-continental to local, in contrast to the fully continental scale of the GMDs.

In addition to the effect of location on the Earth's surface, the induced geoelectric field also depends on the frequency content of the geomagnetic disturbance. This is due to an effect known as the 'skin depth' of the conductor, where longer-period fluctuations penetrate more deeply into the Earth. Therefore, different frequency components of the geomagnetic field will interact most strongly with different layers of the Earth. As a result, a single GMD event can induce very different electric fields at two locations due to their having very different conductivity structures beneath them. Conversely, two different storms of similar strength but with different frequency content can induce very different electric fields at the identical location.

A one-dimensional (1-D), or layer cake model, is a simple first-order approach to modeling earth conductivity. For the United States, the U.S. Geological Survey has developed a set of 1-D models, based on similar efforts in Canada and the U.K. Nineteen models cover the contiguous United States, with an additional five models covering parts of Alaska. Each model refers to an irregularly shaped region; the boundaries between the model regions are based on geological and geophysical considerations. The models descend to a depth of 1000 km in the Earth. These models can reproduce the observed electric field response in many cases. They successfully capture the 'frequency vs depth' aspect of modeling the geoelectric field. They are often used in broad-scale hazard modeling and 'big picture' analysis of GIC hazards.



The chain of events from a coronal mass ejection (CME) on the Sun to geomagnetically induced currents (GICs) in transmission lines

Unfortunately, real-world conductivity structures are rarely one-dimensional. Abrupt changes in conductivity, for example, at a coastline, or at an interface between two rock structures of different composition, cause the 1-D models to break down. Where a large change in conductivity occurs, large enhancements in the induced electric field may be observed.

Because of the natural complexity of earth conductivity and geomagnetic storms, geoelectric field conditions are highly variable in location and time. Often, geoelectric fields peak during the largest fluctuations, such as at the beginning of a storm, but high frequency components at later times during the storm can also have a large impact.

Major hazard and risk factors for GICs

It is important to understand the difference between hazard and risk. Technical definitions exist for both. However, it is probably easiest to understand the difference by analogy to the more familiar topic of earthquake hazard and risk. The earthquake *hazard* for a particular location is a statistical description of the probabilities of the different kinds and strengths of ground motion. The earthquake *risk*, however, depends on the particular circumstances of the person or infrastructure that is exposed to the hazard. For example, a person in a building is exposed to greater earthquake risk than is the same person in a neighboring open field, although the natural hazard is the same in both cases.

A weak two-story house built of bricks is at greater risk than a neighboring single-story wood frame house, though the natural hazard is the same. The earthquake risk to a person or an asset results from the interaction of the natural hazard with the vulnerabilities of the person or asset.

In a similar manner, the induced geoelectric field is the natural *hazard* for GICs, while the GIC *risk* to a particular utility system is (informally speaking) the danger of loss or damage to that system, based on that system's response to the geoelectric field. Damaging currents are more likely to occur in certain power system configurations than in others.

In assessing the potential for GIC damage to a particular system, the following are some of the hazard and risk factors that must be considered:

Magnetic latitude is a generally well-understood ***h****azard* factor for GIC. The ionospheric electric current systems that are enhanced or created during GMD events are typically fairly far north. For infrastructure that is on or near the ground, the more nearly it is beneath these current systems, the more it will be exposed to the influence of a geomagnetic storm. For the most part then, more northern locations will have greater GIC hazard. However, during a GMD event, the southern boundary of this complex of current systems expands and moves away from the north polar region. Although these effects are reasonably well understood and modeled, it is unknown how far from the pole these ionospheric current systems can move during the most extreme events.

Deep earth conductivity has a large impact on GIC *hazard*, as discussed above. In general, regions with more complicated geological structure have greater hazard because of localized enhancements of the geoelectric field. This includes coastal regions, due to the large difference in conductivity between the water and the land. Also, because the induced geoelectric field depends on the how the solid earth responds to the frequency content of the geomagnetic storm, some regions may be more reactive to GMD events with high frequency (rapid) magnetic field fluctuations, but may not be sensitive to low frequency (slow) variations. In some other regions the response will be the opposite. The vertical and horizontal variation in the earth conductivity thus leads to a geoelectric field hazard that depends both on location and on the frequency spectrum of the particular storm.

System characteristics contribute critically to *risk* factors. The length and orientation of a transmission line with respect to the geoelectric field largely determine the magnitude of the resulting GICs. Longer lines and lines that are parallel to the geoelectric field will have larger GICs. During a large storm, the orientation of the magnetic field fluctuations due to the storm may vary wildly from moment to moment. The fluctuations do not have a directional preference, which means that conducting lines in all orientations are potentially at risk during different time segments of a GMD event. System owners and operators have no control over the GIC hazard, but can reduce GIC risk through appropriate engineering and operations measures.

Resources for GIC hazard and risk analysis

Although GIC hazard and risk analysis can be complex, there are many good tools and new resources to assist in assessing risk. These include:

Extensive sources of geophysical and magnetic field data exist, that can be used for local analyses. Government, academic and commercial data resources are growing rapidly.

Several of the currently available, off-the-shelf software packages that are used to model power systems now include GIC modules. These GIC modules take a user-prescribed geoelectric field as input, so the user can calculate the system's GIC response to a given geoelectric field.

Electric field models, based on geophysical analysis of deep earth conductivity and surface magnetic fields, are available to calculate time-varying geoelectric fields. These calculations may be based either on hypothetical or actual geomagnetic events. The calculated fields may be fed into the GIC modules of the power system software for analysis of a system's GIC response to various electric field scenarios.

Existing geophysical data can be augmented by new low-cost field studies. Using local information can significantly increase the accuracy of local geoelectric modeling.

Real-time geomagnetic fluctuation sensors and near-real time application of electric field models can provide situational awareness for operations. Sensors and models each have their capabilities and limitations, but together they can help inform you of the local conditions during a storm. This knowledge can be important for making informed operational decisions.

Summary

GICs in long power lines occur due to the induced near-surface geoelectric field during a GMD event. This induced near-surface electric field results from the changing geomagnetic field as it interacts with the deep earth. The inductive response of the deep earth varies, due to the spatial variation of deep earth conductivities. The magnitude of the geoelectric field therefore varies greatly with location and also over the evolution of a GMD event. These GMD-induced geoelectric fields constitute the natural hazard that drives GIC risk. The risk to a particular power system depends on how it responds to this natural hazard. Certain system configurations are more susceptible to damage during a GMD event than others. As our understanding of the nature of GMDs and how they drive potential damage from GICs improves, so do the tools and resources that are available. Earth conductivity models, geoelectric models, local magnetic field measurements and power system modeling software are all tools that can be used to analyze and monitor GMDs and GICs, and to assist in protecting power systems from them.

About the author

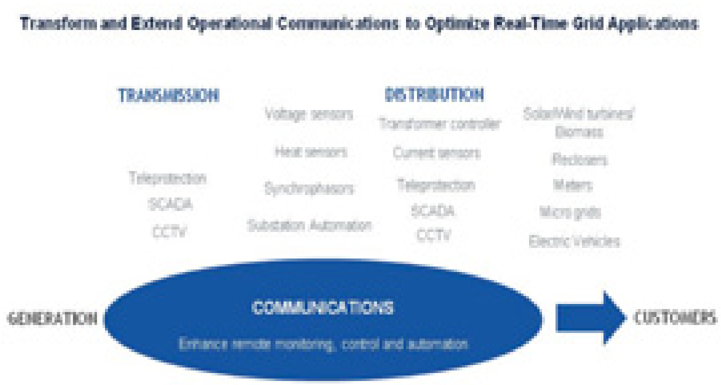
Jennifer L. Gannon has been studying charged particles and electromagnetic phenomena in near-earth space and the solid earth throughout her scientific career. Jenn served as a scientist at the NOAA Space Environment Center and its successor agency, the NOAA Space Weather Prediction Center, and later as a Federal researcher at the U.S. Geological Survey. Moving to the private sector, Jenn co-founded Space Hazards Applications, LLC, of Boulder, Colorado, a consulting firm for space hazards to built infrastructure. Jenn is the author or co-author of many publications in the peer-reviewed literature, as well as several U.S.G.S. Open-file Reports and conference presentations. Jenn received her Ph.D. degree at the University of Colorado Laboratory for Atmospheric and Space Physics in 2006. She currently serves in CPI's Boulder office as Geomagnetic Disturbance Division Lead. You can reach Jenn at gannon@cpi.com or 303-442-3992.

Want a Smarter Grid? You Need a Smarter Network

By David Christophe

Power utilities worldwide are exploring or actively engaged in efforts to make their grids smarter through projects such as substation automation, distribution automation and advanced metering infrastructure. For each power utility, the implementation of a smart grid means something different. Regardless of their overall approach, a smarter communications network needs to be part of their new energy delivery strategy.

Why is this so critical? A key enabler for the transformation of a utilities' transmission and distribution grids is a modern, reliable, and flexible communications infrastructure that can securely route increasing amounts of monitoring, control and status information effectively, efficiently and on time. New smart grid applications provide utilities with better visibility to operate electric systems more efficiently and new options to automate functions. The increased movement of data, coupled with robust analysis capabilities can offer the benefits of enhanced safety, reduced operating costs, increased power quality and improved outage response. The communications network is at the heart of these functions.



It is not just utilities themselves that have an interest in the deployment of smarter grids and the communications networks that make them possible. Governments consider smart grid technologies as a means to improve power quality, reduce need for additional generation capacity and reduce carbon emissions. Business and residential customers can take advantage of new features such as time-of-day charging and the availability of renewable energy from independent power producers. Finally, regulators increasingly view smarter communications networks as a means to more efficient energy markets and continued safe and reliable energy delivery.

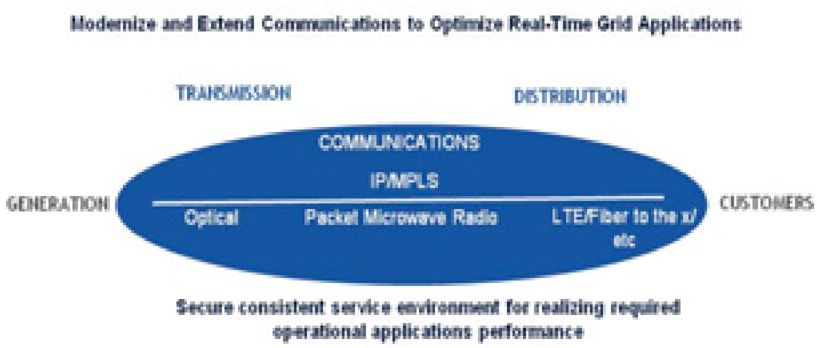
For transmission operators who have been maintaining communications infrastructures, the desire to introduce smart grid applications requires them to consider an evolution of their time division multiplexing (TDM) over Synchronous Digital Hierarchy (SDH) or Synchronous Optical Network (SONET)-centric communications networks. Internet protocol (IP) technology is the communication standard for which new smart gird devices and applications are being developed. It is well recognized that to efficiently support the growing amount of smart grid applications, utilities need to transition to IP-based networks.

Distribution operators, who may have minimal communications coverage in most of their medium voltage grids and often none in their low voltage grid, now face the challenge of extending and deploying new communications infrastructures for distribution automation plus supporting new intermittent micro-generation sources – solar, wind turbines, biomass that could unbalance the grid. A flexible transformation is required to preserve existing investments and to minimize risks. Again, IP-based networks are generally acknowledged to be the path forward.

An approach which has been gaining significant momentum with both transmission and distribution utilities is the implementation of Internet Protocol/Multi-protocol Label Switching (IP/MPLS) technology to support grid operations. IP alone cannot adequately support some mission critical operational communications due to its inability to provide the predictability and reliability required by applications such as teleprotection and synchrophasors.

IP/MPLS takes the non deterministic nature of IP and provides deterministic controls to achieve the required performance for mission critical operations traffic. It supports network resiliency, quality of service, security, and convergence, and provides a management platform to automate and simplify operations management. Reliable communications and end-to-end service consistency throughout the network is essential to meeting key smart grid application requirements, particularly the need to utilize information management technologies and maintain two-way communications.

An IP/ MPLS-based communications network incorporates state-of the-art technologies to enable a power utility to deploy a highly available IP network that can support both current and emerging applications far into the future, while continuing to supporting existing TDM and legacy applications. This new IP/MPLS network will allow the utility to maximize the cost effectiveness and efficiency of its network without jeopardizing reliability. It also enables the deployment of new devices and applications that can improve operational and workflow efficiency. A highly available IP/MPLS network is ideally suited to support mission-critical operations, while providing a platform to address all other business communications requirements – one network can do it all.



One of the key advantages of using IP/MPLS in the core and throughout the network is that it can easily interoperate with other networking infrastructure as needed, such as microwave packet radio or wavelength division multiplexing (WDM) optical transport technologies to effectively reach remote grid substations and devices while providing a consistent service environment. An optical transport backbone can also provide reliable high bandwidth protocol independent layer 1 connectivity to data centers and utility corporate offices. These data transport technologies are designed to address utilities' stringent cyber-security requirements. For example WDM supports capabilities such as intrusion detection and low latency wavelength encryption for operational and business communications traffic on this network. This means that potential physical intrusions on the fiber cable can be detected and located. In case of an intrusion, sensitive data is protected through embedded optical layer encryption, which complements end-to-end encryption that is supported across the entire IP/MPLS network.

In the end, what utilities have is a comprehensive, high-capacity, highly secure and resilient communications network that can address all of their operational and business needs, both today and for the foreseeable future as they deploy their Internet of Things (IoT) strategy.

About the author

David Christophe is Director of Utility Solutions Marketing at Nokia, where he focuses on helping distribution utilities modernize the communications networks that support their grid operations. David has a 20 plus year background in IP/packet networking, and has spent more than a decade working with utilities to enhance their mission-critical communications networks.

Swissgrid Uses IP/MPLS and optical technologies to strengthen grid operations

Swiss electricity transmission system operator Swissgrid has turned to IP/ MPLS and WDM optical technologies for the management of its electrical grid. Swissgrid's new 'Grid Control Network', which became operational early in 2016, provides monitoring and switching for the electricity transmission grid, resulting in better alignment of power supply and demand, enhanced security and an exceptional level of reliability.

For this project, Swissgrid implemented two IP/MPLS -based networks, one an operational network and the other a business communications network. Both IP/ MPLS networks are overlaid on an encrypted Dense Wavelength Division Multiplexing (DWDM) and Coarse Wavelength Division Multiplex (CWDM) network, to support high-speed, high-capacity data transmission.

The solution is supporting mission-critical operational services such as Supervisory Control and Data Acquisition (SCADA) systems, Teleprotection, video surveillance via closed-circuit TV (CCTV), site access control and intrusion detection. With these capabilities in place, Swissgrid expects to maintain the highest level of reliability, safety and security across the entire grid.

The 'Grid Control Network' is being operated by Swissgrid from two mission-critical Grid Control Centers (data centers), which are interconnected through encrypted, redundant DWDM wavelength services. The grid has a length of 6,700 km, and the 'Grid Control Network' links 140 substations as well as a number of power plants, data centers and offices.

In addition to supporting grid operations, the network also enables business communications between electricity substations and Swissgrid locations for tasks such as local area network (LAN) connectivity and voice over IP (VoIP) in a highly secure way.

Integration between Smart Grid DMS and DERMS is key to reliable renewable operation

By Gary L. Ockwell, CTO,
Advanced Control Systems

Renewable Integration

Utility and public interest in renewable integration within distribution networks has rapidly risen in popularity. For the public, general sentiments concerning global warming and the environment have been further stoked by subsidies and economic incentives. Utilities face the technical challenge of anticipating the impact of ever increasing amounts of both utility-owned and private sector-owned renewable generation, while keeping their power grids safe, reliable, and cost effective.

With the continuing focus on renewables technology, it seems a safe bet that the trend of increased renewable penetration throughout the power grid landscape will flourish well into the future. Thus, utilities must leverage advanced algorithms and control technology that originated from the Smart Grid era, to effectively manage both the technical and the commercial challenges of a multi-player community of intermittent consumers and producers.

Preceding the interest in renewables, the initial advancement of the smart grid that emerged with the greatest notoriety was automatic switching functionality, or self-healing, which improved network and individual feeder reliability. Self-healing technology, often called FDIR or FLISR, is the idea of providing tools (automation, software, network modelling) which allows the network to figure out what is wrong and to automatically execute a solution which restores power in real-time. Utilities that adopted these early technologies gained the foundational understanding to use these sophisticated applications to augment and support their manned operational control centers. Those utilities will notably benefit by having laid the automation foundation that is critical to successful management of renewable deployment. The technological progression from self-healing to power quality to Distributed Generation (DG) management is a natural evolution of increasing complexity and as the degree of renewable generation deployments increase, the reliance on these advanced tools to support ongoing safe, reliable, cost-effective operations becomes mandatory.

The greatest challenge regarding renewable deployment is that the amount and variability of generation, along with the various points throughout the grid where the generation is operating (injection sites), is always changing. The power grid was not originally designed to operate in this manner, so in almost every instance today, impact of significant renewable injection within a feeder is unknown and unmeasured. The good news is: the original principles behind transforming our old power delivery networks into Smart Grids was based on the idea of using technology to monitor everything happening with the flow of electricity, and using mathematics and physics to make real-time decisions on how the grid should operate. The complexity of developing the network model and load flow solution algorithms is at the heart of the Smart Grid. Those same tools allow utilities to accept and manage the continuously changing flow of diverse renewable generation sites without risking the safety or reliability of the underlying power delivery network.

Changes in Automation

Smart Grids evolved first with the deployment in the field of automated switches and re-closers, the tools that utilities use to re-route power flows. Next, many of those same utilities took the further step of adding software in the form of Distribution Management Systems (DMS) and advanced algorithm-based applications which allow utility grid operators to assess in real-time what is going on in the network and to take action (remotely operate equipment in the field) to maintain the best and most reliable operation. In an area where new renewable generation sites are being added, these smart grid technologies that were installed to enhance reliability and power quality in the feeder's operation will initially operate unimpeded with minimal deployment of distributed generation. At low levels of renewables deployment, the application of distributed generation within the feeder resembles a negative load (because instead of consuming electricity, that site is adding net electricity to the grid). In fact, many DMS solutions simplify the network calculations and modeling of injection points within the feeder in this way.

As more and more renewable generation is brought on-line, the over simplification of treating the distributed generation as a negative load is ineffective. Significant injection will soon threaten the feeder's stability without a feeder load flow analysis that considers the dynamic nature of the injection points. The load flow itself must be capable of handling multiple sources.

To deal with this new challenge, smart grid technologies—specifically Voltage Control (such as Integrated Volt/VAR Control, also known as IVVC)—must be retooled to include control of the inverters at each renewable site with the objective of increasing the coordination of each feeder's maximum injection capability. Switch plan optimization applications must likewise establish an objective function, which maximizes the feeder's ability to accept the maximum injection safely. The solution to successful deployment of significant distributed (renewable) generation injection, builds directly on the classical smart grid automation applications.

Architectural Objectives

The architecture of systems which support distributed generators, distributed energy resources, renewable deployment or energy storage systems must accomplish the following primary objectives:

1. Preserve the viability of the feeder's operation at all times.
2. Maximize the availability of the DGs/renewable generation, meeting a user–selected business case.
3. Maximize the deployment of energy storage assets, meeting a user–selected business case.

A modular renewable management architecture that is well-suited to accomplish these objectives is performed by two main systems: the DMS and Distributed Energy Resource Management System (DERMS). Since the two primary objectives of a renewable network may work in opposition to one another, an architecture that is dedicated to maximizing the two objectives as their primary mission is required.

The operation is best served if the division of responsibilities of the systems ensure the following:

1. The DMS is eminently positioned to perform the secure, reliable and optimum operation at all assets in the feeder under all operational conditions.
2. The DERMS is dedicated to forecast and maximize the output and availability of the DG / DER resources under the objective established by the use case selected by the operator.

Other architectures may apportion the responsibilities differently, for example they bundle IVVC as a DERMS responsibility. More important than the architecture, or the assigned mission parameters of the DMS/DERMS, is that IVVC or IVVC/r must always be run as a mission critical automation application. IVVC, like FDIR/FLISR, must be protected by high availability with real-time performance, especially under severely stressed network conditions.

This goal is a challenge with some ADMS solutions that have functionally evolved from a non-real-time origin. In those cases, a distributed automation architecture such as DERMS is preferred in order to meet the mission critical requirements. Some very large models are equally challenged with respect to maintenance where a smaller distributed model is more easily managed within a distributed network of DERMS processors. In these cases, the DMS is a collector of the distributed automation islands for operator oversight purposes, but it is not placed at risk by a low availability centralized system.

In contrast, if the mission critical requirements can be met along with accurate and timely model maintenance, the DMS centric feeder automation architecture that supports IVVC in the DMS, simplifies the analysis and modeling which is always an important consideration, since the modeling of the distribution network feeder is a continuous and arduous effort. In this architecture, the network model is consumed only in the DMS and it is not necessary to distribute it to the DERMS. In short, the architecture can be a combination of central and distributed intelligence, flexible enough to meet the capabilities and requirements of the mission critical functions.

Modules for Renewables

Not all renewables, or distributed generation, are equal. Therefore, the optimum strategy for their deployment is tailored to the application. The ability for the feeder to be able to safely accept the maximum output capability of renewables such as photovoltaics (PV), without resorting to curtailment, is important. Maximizing the potential can only be accomplished if the forecasted capability of the DG is predicted far enough in advance for the DMS to analyze the hourly impact of the scheduled injection.

If the forecast predicts that the schedule will result in time periods that will exceed the network's stability limits, there are two situations that must be addressed:

1. Can the normal functioning of the Volt/VAR control avoid the violation? If it can, no further action is required. The DMS will handle it.
2. If the DMS cannot compensate for network weakness imposed by the injection a more advanced analysis of the options must be made.

In the latter situation, the DMS has the ability to calculate any network configuration and topology that will support the maximum forecasted schedule or the adjusted forecasted schedule. This may result in switching changes, similar to an enhanced self-healing solution, which will transfer loads and DGs from one feeder to another in order to meet the forecast. An appropriate lead-time to affect change is important since typically few feeder-switching devices are remotely controlled. An optimum integration of sending switch plans from the DMS to crew mobile can improve the efficiency of the switching response.

If the optimized solution cannot accept the forecasted schedule, the last resort option is to surgically curtail the distributed generation at each individual point of injection.

Classical DMS integrated Volt/VAR (IVVC) is an application that flattens and optimizes the feeder voltage at all points in the feeder while improving the power factor. This is accomplished through control of the substation transformer LTC and the down-line feeder capacitors and Voltage regulators.

Enhanced Integrated Volt/VAR with renewable support (IVVC/r) adds the dimension of injecting real and reactive power at the point of injection. This degree of control enhances and compliments the classical IVVC, enhancing the control of the regulators and capacitors. The effect on feeder voltage at the injection points can be closely controlled through leading or lagging reactive power injection as needed. Overall the electrical benefits have demonstrated significant improvement in feeder performance.

Advanced Control Systems™ (ACS™) has led the industry over the past 40 years, and has 15 continuous years of field experience running advanced full automation Smart Grid applications, protecting thousands of feeders worldwide. For more information, visit our website at acspower.com. Or email *info@ACSpower.com*.

About the author

Gary L. Ockwell, P.E., holds a B.S., EE Degree from University of Saskatchewan. From 1973 to 1985, he worked for SaskPower Corporation as a manager of the control department and project manager for the gas and electric system control project. From 1985 to 1995, he worked as a product manager for Harris Controls Division, working with transmission EMS. He joined Advanced Control Systems in 1995, working on both EMS and DMS. From 2007 to the present, he has held the position of Chief Technology Officer. Mr. Ockwell has authored and co-authored two dozen papers and articles for industry conference and publications over the last 10 years. He is an IEEE/PES member.

The Macro View of Microgrids: Addressing Complex Trends and Challenges

By Ron Reed, MBA, PMP

Taking a Macro View of Microgrid Trends

New microgrid installations, along with related growth trends in wind, solar, and energy storage, have been given a great deal of attention recently. The engineering challenges and business issues that need to be addressed to ensure a successful microgrid project include the following five pillars, which we will detail below:

Microgrid Project Success Factors:

1) 'Future-proof' your design
2) Size your facility correctly
3) Maximize potential ROI
4) Ensure project plans meet your overall goals
5) Teamwork, teamwork and more teamwork!

Before detailing these key elements of microgrid projects, we will first describe the overall macrogrid business and engineering context. This will help us to see and prioritize key challenges associated with microgrids, renewable sources of energy, and energy storage, given the actual size of certain smaller portions of the power generation market in relation to larger ones.

Why is it important to take this type of 'macro' view of microgrid trends? Because it seems that a lot of the current discussions about microgrids involve hype, where we can define hype as something that would give a naïve person unrealistic expectations at best, and some seriously incorrect ideas at worst. (Among the latter we can include the mistaken notion that our current grid's centralized generating plants and associated transmission and substation infrastructure were based on some sort of design mistake or outright bias.)

To counter misconceptions and unrealistic expectations about microgrids, we need to remember that the reliable electric service we receive today is the result of benefits accrued over more than 100 years of growth in centralized electric generation and T&D infrastructure. It was 'macrogrid' based infrastructure that created much-needed economies of scale that fueled our industry's growth, by linking diverse customer loads together.

Definitions of Microgrids

What constitutes a microgrid? Some apply a size-based definition, suggesting a microgrid has to be below 50 MW. But a more functional definition that has stood the test of time is the one provided by Steve Bossart, Senior Energy Analyst, at the DOE's National Energy Technology Laboratory:

> *"A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."*[1]

Microgrid ownership categories are described in a recent study which used three groups and-subgroups:

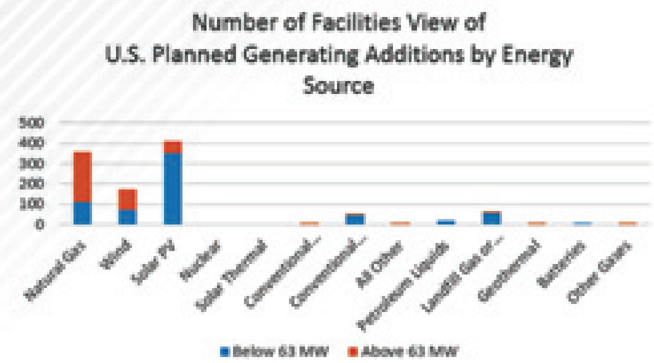
1) Utility microgrids
   a) Full utility microgrid
   b) Hybrid utility microgrid
2) Own-use microgrid
3) Energy service provider microgrids
   a) Landlord/tenant microgrid
   b) Owner/merchant microgrid
   c) Independent provider microgrid[2]

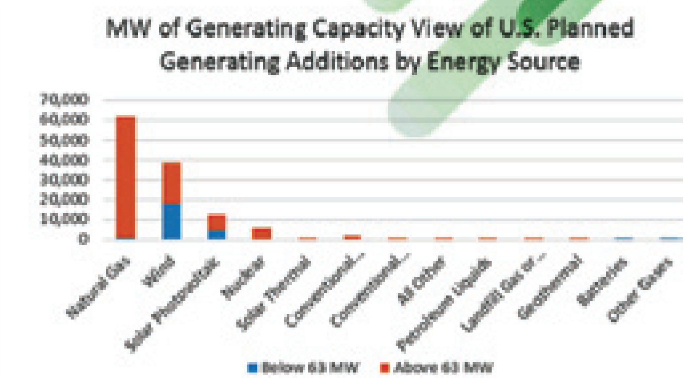
Debunking Key Myths About Microgrids

If microgrid-related challenges are addressed well, the potential long-term benefits are indeed impressive. But first we need to debunk a few myths.

Myth #1--We can all disconnect from the grid and operate as islands with renewable-based microgrids:

It is true that some of the regions with relatively larger portions of their electric service coming from microgrids are either literally islands (such as Hawaii and also Kodiak Island in Alaska), or are islanded electrically for other geographic reasons. Even if we could all switch to microgrids in the near future, we would be dealing with some serious cost issues and other difficulties! In addition, currently two non-renewable energy fuel sources--diesel and natural gas—power most microgrids. While microgrids hold the promise of enabling greater utilization of renewable sources of power, to maintain reliable service in such a world, transmission system interconnections will need to increase, not decrease, so as to deliver renewables-based power where and when it is needed most.





Myth #2—Microgrids may not be mostly renewables-based now, but they are becoming mainly a "renewables" and/or "storage" play: Those who believe this transition is well-underway should answer the following three questions.

Q1: In the U.S., in which year did the total kWhr of electricity generated by wind and solar first exceed the total kWhr generated by hydro?
- a) 2014
- b) 2015
- c) None of the above.

Q2: What portion of the 1,560 energy storage projects in the DOE global energy storage project database have microgrid capabilities?
- a) More than 75%
- b) Between 25% and 75%
- c) Less than 25%

Q3: Which source of renewable energy do you think produced the most electric energy in recent years? Is it Wind, or Solar, or Hydro, or Biomass? [3]

Microgrids and Renewables: Market Drivers and Segment Sizes

Table 1 shows the most recent Energy Information Administration data on relative amounts of electric energy generated from various renewable-based sources in the U.S.

Several things should be noted: First, while growth rates for solar and wind have been impressive, over-emphasizing growth rates without looking at the relative sizes of the segments clouds the fact that more energy was still generated via hydro in 2015, than by wind and solar combined. (In this regard, given the pace of change as shown on the right column in Table 1, 2016 may be the 'cross-over' year for the U.S., where wind and solar combined overtake hydro).

Table 1: Relative sizes of segments of U.S. generation of renewable-based electric energy

Year	Hydroelectric Power Production (Quadrillion Btu)	Solar/PV Energy Production (Quadrillion Btu)	Wind Energy Production (Quadrillion Btu)	Biomass Energy Production (Quadrillion Btu)	Total Renewable Energy Production (Quadrillion Btu)	(Biomass) / (Total Renewables) percent	(Wind + Solar) / Hydro, percent
2015	2.39	0.55	1.82	4.72	9.69	48.6%	99.0%
2014	2.47	0.42	1.73	4.85	9.68	50.1%	87.1%
2013	2.56	0.31	1.60	4.65	9.33	49.8%	74.4%
2012	2.63	0.23	1.34	4.41	8.81	50.0%	59.6%
2011	3.10	0.17	1.17	4.50	9.16	49.2%	43.1%

(Source: U.S. Energy Information Administration 2015 Annual Energy Outlook) [4]

Second, we should not fall into the 'number of projects' versus 'size of projects' trap. This is highlighted by the side-by-side comparison below, where wind and solar projects look big vs. non-renewable sources, when shown based on the relative number of projects, but look small when the same data is displayed based on MW of capacity involved:

Finally, we should not neglect the huge contribution to renewables being made by biomass sources. Local microgrids associated with biomass create significant environmental benefits. Methane leaks from rotting biomass and, as stated in *Scientific American*, methane 'is among the more potent greenhouse gasses.' In addition, the regions where the biomass is generated are often far from populated areas and biofuels are often too bulky to be transported long distances economically.

You may ask why we should consider biomass to be clean or renewable. Some considerations:

- With landfill gas, not capturing and using it leads to leakage into the atmosphere, which is dirtier than burning it.
- In the case of wood-based biomass, it is clean because of the high efficiency levels of the cogenerating plants that use pulpwood materials left over after paper production.
- Biomass sources are renewable not only because the pulpwood trees employed in this process grow to maturity in 10 to 15 years – less than half the lifespan of the generating facilities involved.
- The carbon in the wood derived through photosynthesis, which involved the leaves pulling CO_2 out of the atmosphere, thereby making the burning of that wood a net zero process.
- Ongoing pulpwood reforestation continues pulling additional CO_2 out of the atmosphere.

The biggest per kWhr contributor to the biomass-based portion of renewable electric generation category is from wood energy, which includes electricity generated by pulp and paper mills.

Microgrid cogenerating facilities make efficient use of renewables in other favorable ways. It is even more favorable, not only because trees are being replanted systematically, but also because of CO_2 and waste reductions associated with utilizing recycled materials.

Microgrids and Combined Heat and Power Facilities (CHPs)

A significant portion of the business and operational benefits associated with microgrids have been in play since before the 1970s, and often involved much larger installations: Combined Heat and Power facilities (CHP).

CHP installations generate electricity and recover associated 'waste' heat to a much greater degree than conventional power plants of the past, and put this 'waste' heat to good use. CHPs are also known as cogeneration plants, and they have been achieving impressive efficiency improvements. In contrast to the many older cogenerating facilities in the U.S, these types of facilities below 50 MW in size are in the microgrid category size-wise. As detailed in the U.S. Department of Energy's CHP database, there are currently 4,808 CHP facilities in the U.S.

A trend in CHPs with important beneficial consequences for the microgrid market is the movement toward smaller and smaller CHP facilities. This trend is evident in the following table:[5]

Size and number of Combined Heat & Power (CHP) Facilities in the U.S.

Year CHP System Became Operational	Average capacity, MW	Number of facilities	Total Capacity, MW
Pre-1960	52	152	7,868
1960-1979	49	144	7,079
1980-1999	26	1,759	45,931
2000-present	8	2,665	22,384

In comparison to microgrids, the CHP market is very mature and large, as highlighted in the following comparison of data from the DOE database to a Greentech Media (GTM) microgrid report:[6]

Comparison of U.S. microgrid projects to combined heat and power (CHP) projects

Region	CHP facility current MW of Installed Capacity	Microgrid MW Capacity (Planned plus installed)	MW RATIO of Microgrid to CHP capacity
Alaska	465	70	15%
Hawaii	349	92	26%
Midwest	9542	39	0.4%
Northeast	23552	562	2%
Southeast	18437	274	1%
Southwest	19290	700	4%
West Coast	11769	211	2%

Table created for Electric Energy T&D Magazine by author, from the DOE and GTM data sources listed at the end of the article.

A recent project of ours at ASSET Engineering involved substation upgrades we carried out at a biomass plant, located in Dublin, GA. The plant is 34MW in size.

Green Power Solutions, Dublin, GA Power Plant Generation Interconnection
ASSET Engineering

The Dublin, GA facility operates as a grid-connected CHP microgrid, providing 34MW of base load power to the Georgia Transmission grid while also providing steam for use in the processing of recycled fiber. In order to take advantage of the renewable resource aspect of the steam generation at the SP Fiber Technologies Facility, the generation connected to the SPFT 138kV Bus needed to be reconfigured to connect to the Georgia Transmission 138kV transmission system. The increases in plant efficiency associated with these types of up-to-date cogeneration facilities are impressive. The Green Power Solution plant uses steam cogenerated during electricity production to facilitate treatment of the recycled wood products, thereby putting heat to use which could otherwise have been wasted, and reducing landfill and other waste if the materials hadn't been recycled.

Along with CHPs, other facilities requiring critical power are also good candidates for microgrids.

Business and Engineering Success Drivers for Microgrid Projects

System integration capabilities play a key role in the success of microgrid projects. Since there is a lot of overlap between microgrids and traditional projects across these eight segments, a lot of the specialized engineering and system integration and design expertise required to ensure a successful microgrid project can be found in play in projects done for these areas.

The range of issues involved include addressing voltage stabilization and voltage regulation requirements, optimizing arrangements sale of excess power to support nearby loads, and satisfying all reliability concerns that the customer may have. Voltage regulation presents an opportunity as well as a challenge, given the dynamic changes occurring in regional load profiles and the generating facilities meeting demand.

While microgrids can help stabilize the grid they can also introduce instabilities, especially if their separation and reconnection to the macrogrid is not optimized with respect to grid performance in relation to fault events. In addition, designers are always on the watch for unintended resonance from inverter-based generators and seek optimal ways to avoid it.

While utilities participate directly in serving these needs, as well as their being served by Engineering, Procurement and Construction (EPC) companies who also provide this expertise. The EPC market consists of a wide range of players of diverse sizes, working for and with utilities and utility customers.

Due to the high demand for this type of specialized engineering talent, along with varying workloads, many EPC firms (including the largest ones) subcontract smaller engineering firms for specific engineering design and controls system expertise. The issues involved in substation design for renewables, data centers, and microgrids overlap in numerous ways. As a result, decision-makers need to weigh a wide range of factors in evaluating solution and service providers for microgrid related projects.

Microgrid Project Success Factors:

1. ‘**Future-proof**’ **your design**: Designs need to consider expected growth and future needs for the service area and flexibly address a range of scenarios.

   Microgrid designs vary a great deal as a function of the type of facilities involved. Key categories for microgrids include:
   - Campus / Institutional
   - Commercial / Industrial
   - Community
   - Critical Services / Resilience
   - Datacenter
   - Military
   - Remote
   - Utility distribution

Since designs are not always ‘greenfield’ but also frequently involve upgrading existing infrastructure, cost savings and reliability benefits can be achieved by leveraging the ability of highly experienced engineering design personnel to adapt existing electrical infrastructure, including protection and control systems, while maximizing reliability and updating/adding new equipment optimally.

2. **Size your facility correctly**: It is vital to ensure design decisions regarding a microgrid project take into account good models of load patterns and usage needs for electricity and ancillary energy requirements (steam, hot water, etc.) across all applicable load pattern variables (hourly, daily, monthly, seasonal). All measurements should be triple-checked and no key assumptions should be left unquestioned. It is helpful to dig into data sources deeply (e.g. building management systems and paper as well as electronically-logged data).

3. **Maximize potential ROI**: Ensure all applicable peak reduction Demand Response DR program incentives, and utility and regional rebates and tax credits, are considered in the design decisions. For example, based on specific criteria, Consolidated Edison of NY has provided rebates of up to 50 percent of the capacity costs for installation of microgrids in NYC (to the tune of $1,200 per kW). In addition, forecasting utility rates and modeling operating costs and avoided costs, as part of an overall energy and business model require a great deal of expertise.

4. **Ensure project plans meet your overall goals**: Goals to consider along with construction plans include resiliency, emissions reduction, reliability, dispatchability, etc., and should be included in the processes employed to prioritize design choices regarding generating technology. The cost/benefit outcomes for inclusion of storage with wind or solar, for example, will vary depending on dispatchability goals and options. And in the case of high-efficiency combined heat and power (CHP) facilities detailed below, the choice of prime mover requires significant engineering design analysis to ensure site needs are optimally matched with different output profiles based on choice of generating technology.

5. **Teamwork, teamwork and more teamwork!**: Good teamwork requires building bonds of trust across complex teams and with local utility personnel, as well as numerous stakeholders across the local and regional jurisdictions, local business and community representatives. Keeping in ongoing communication with all key groups is essential. These types of projects can involve a wide range of different contributors from different participants in the project, and being able to collaborate and share data and keep communications open requires creation of a strong culture based on trust. Ensuring successful flexible designs that reliably switch back and forth between island and grid-connected modes requires high levels of cooperation and experience in working with the local utilities and any third-party subcontractors, as well as project management personnel from Engineering, Procurement and Construction (EPC) firms when involved.

APPENDIX

Table 1 – Analysis of Energy Information Administration data regarding U.S. plant additions, 2015, based on Generating Capacity by Energy Source, MW

Energy source	Generating Capacity by Energy Source, MW	
	Below 63 MW	Above 63 MW
Natural Gas	991	61,073
Wind	18,474	20,046
Solar Photovoltaic	4,812	7,811
Nuclear	374	5,670
Solar Thermal	0	200
Conventional Steam Coal	358	1,520
Conventional Hydroelectric	0	488
All Other	21	380
Petroleum Liquids	0	400
Landfill Gas or other Waste Biomass or Wood	263	75
Geothermal	22	210
Batteries	107	0
Other Gases	49	0
Grand Total	25,469	97,874

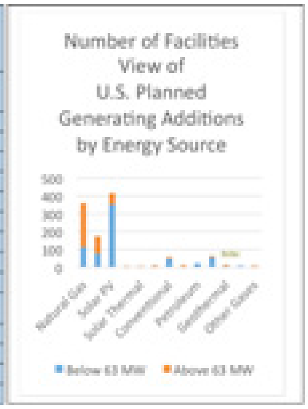
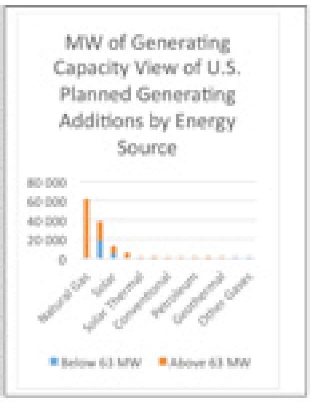


Table 2: Analysis of Energy Information Administration data regarding U.S. plant additions, 2015, based on Number of Facilities

Energy source	Number of Facilities	
	Below 63 MW	Above 63 MW
Natural Gas	112	246
Wind	76	98
Solar PV	353	61
Nuclear	0	5
Solar Thermal	0	1
Conventional Steam Coal	3	3
Conventional Hydroelectric	49	4
All Other	4	2
Petroleum Liquids	21	0
Landfill Gas or other Waste Biomass or Wood	57	1
Geothermal	6	3
Batteries	10	0
Other Gases	1	2
	692	426



About the author

Ron Reed is Vice President of Business Development at ASSET Engineering, in the Jackson, Mississippi area, and has more than 30 years of experience in project management, engineering and business development in energy, chemical, forest products and land development sectors. Ron has been addressing challenging engineering and business requirements while building long-term partnerships, as well as providing innovative solutions for clients, and developing high-performing teams by fostering a results-oriented environment. *ron.reed@assetcompany.com*

References

[1] Source: https://www.netl.doe.gov/File%20Library/Research/Energy%20Efficiency/smart%20grid/presentations/Army-Advanced-Microgrids-060712-short.pptx

[2] (Source: Microgrids-for-Critical-Facility Resiliency in NY State, NYSERDA, Page 109)

[3] **ANSWERS Q1**: It turns out that biomass is by far the largest contributor to renewables-based electric energy being generated in the U.S. For many years, biomass has been providing 50% of all renewable-based electric energy generated in the U.S.

Q2: The answer is (c), since only 160 out of the 1,560 projects include microgrid capabilities. In fact this "below 10% by project" figure is even lower—only one percent—if we rank the 1,560 projects by MW capacity.

Q3: The answer is (c), because Hydro by itself still provides more electric energy than wind and solar combined. Despite the recent growth of wind and solar capacity installations, it turns out that in 2015, more kWhr of electric energy were generated by hydro power in the U.S. than by wind and solar combined.

[4] U.S. Energy Information Administration, May 2016 Monthly Energy Review--Table 1.2: Primary Energy Production by Source

[5] Source: Author's analysis of DOE database: https://doe.icfwebservices.com/chpdb/state/ID

[6] GTM source URL: http://www.ourenergypolicy.org/wp-content/uploads/2015/07/North-American-Microgrids-2015-brochure.pdf
DOE Source URL: https://doe.icfwebservices.com/chpdb/state/ID

Next Generation Dynamic Line Rating Provides Strong Economic Benefits

By Jack McCall

What is Dynamic Line Rating?

Traditional operational limits of a transmission line are established through "static" transmission line rating methodologies. The common practice for transmission line rating is to select very conservative values for the environmental operating conditions of the line. The resulting static line rating is similarly very conservative.

Today, seasonally adjusted ratings (SAR) and ambient adjusted ratings (AAR) push upward a line's traditional static ratings by simply acknowledging that more realistic environmental conditions exist. Dynamic Line Rating, or DLR, is a transmission line's actual real-time or forecast power carrying capacity. It is based on the conductor's operating temperature using real-time line behavior data and weather conditions. Dynamic Line Rating (DLR) is the natural and logical extension of the seasonal and ambient adjusted ratings trend. Why assume a line has only four ratings a year based on seasons when real-time data and line behavior modeling can provide reliable daily or even hourly ratings? This is especially significant as a line's DLR is typically 10 - 25% higher than its static rating.

Numerous studies have shown this additional capacity provides opportunities in economic dispatch, trading, operations, and congestion mitigation. Application of DLR is also a powerful tool for improving contingency planning, cost effectively addressing lines with slow load growth, and deferring or eliminating the need for line upgrades or reconductoring.

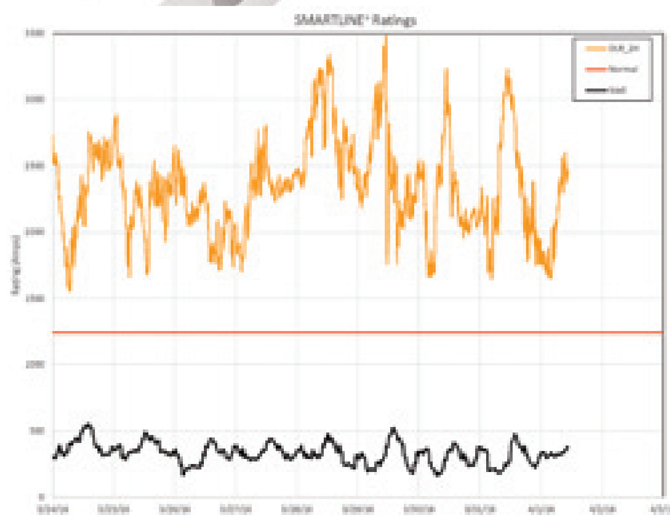
Yet with all these economic advantages, DLR is sparsely deployed. The reasons are two-fold. First generation DLR systems presented numerous issues to early adopters, discouraging wider deployment. Secondly, demand drivers were either weak in the deregulating transmission environment, or were poorly understood.

Issues with First Generation DLR

First generation DLR systems all shared shortcomings which could be divided into three baskets; unusable data, installation complexity, and dependence on indirect measurements.

Usable Data

- First generation systems provided only instantaneous DLR information in the form of a graph. By nature, DLR changes constantly, appears quite erratic, and is not practical for real-time operation. This is because instantaneous DLR changes based on rapidly varying parameters such as wind speed, precipitation, and cloud cover. As most DLR benefits are actually dependent on knowing the DLR in the future, real-time only DLR was of limited value.



Traditional Dynamic Line Rating (upper line) constantly changes, limiting its usefulness

- Data was often processed by the DLR provider with minimal information being provided to the utility. The lack of underlying data transparency often led to a lack of confidence in the resulting rating.

Complexity Issues

- Complex Installation: Some line sensors used by early DLR systems required the line to be de-energized during installation, and even required tower modifications to properly fit the sensor to the line. This introduces significant costs.
- Solar-charging: DLR sensors often communicated through battery-powered radios recharged via solar panels. A few days of cloudy or stormy weather, snow buildup, or even bird droppings could interfere with proper charging. As DLR requires continuous data feeds, the result was data dropout and compromised DLR system operation.
- Remote Installation: Optimized DLR systems often require monitoring of spans in remote or unpopulated locations, not close to existing communication infrastructure. This limits the practicality of cellular communications.
- Communications: Radio systems require proper antenna positioning and alignment. Connection of line mounted sensors and stand-alone weather stations increasing installation complexity.

Indirect Measurements

Accurate DLR depends on accurate and meaningful real-time data. Physical conductor data (current, temperature), spatial data (conductor clearance-to-ground), and weather are the most important parameters. First generation systems variously fell short in one or more of these areas.

- Physical conductor data was either not monitored on the actual conductor (e.g. current was measured at a remote substation), or was simulated (e.g., using nearby thermal replica devices).
- As conductors heat, they expand and sag, affecting conductor clearance-to-ground. Early systems used quantities such as tension, vibration, or optical sights to estimate sag. This was then used to obtain clearance estimates from look-up tables or standard formulas.
- Local weather stations were often used for accurate real-time weather data, but these stations could not provide forecast weather data.

Next Generation DLR Addresses First Generation Issues

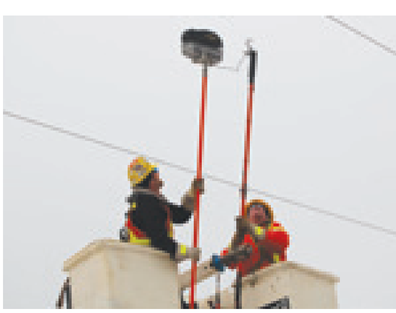
Next Generation DLR, such as Lindsey's SMARTLINE system, have evolved to address all these shortcomings. The result is a system which is simple to install, transparent in its ratings, and most importantly, usable and actionable. Using this system as an example, next generation DLR systems provide:

Meaningful Data: Conductor behavior data is now continuously collected by a self-powered, line mounted monitor. The device measures conductor current, conductor temperature, and the actual conductor-to-ground distance measurement via built-in LiDAR, eliminating the need for sag estimations. The sensor also monitors ground temperature and conductor vibration.

Next generation DLR conductor monitor

Simple Installation and Communications: Simple live-line installation and built-in satellite radio addresses numerous issues. Most importantly:

- Next generation conductor monitors may be installed on energized lines up through 765kV. Power supply and communications are self-contained.



Live line installation of DLR conductor monitor in Cold Lake, Alberta, Canada

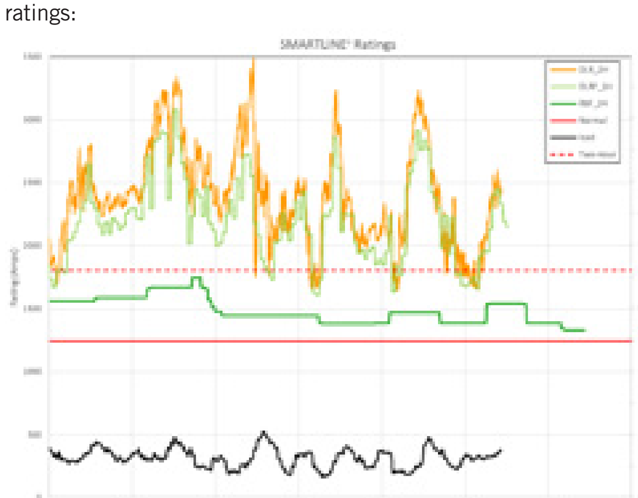
- Built-in satellite radio provides the ability to communicate the monitored data from any transmission span, regardless of location. This eliminates the need for additional or nearby communication infrastructure or equipment.
- High data security. The satellite radio is built-in to the sensor and transmits only non-operational, measured data directly to the DLR software.
- Self-powered devices require no battery or external power source.

Reliable Dynamic Line Rating communications are provided via Iridium satellite network

Actionable Ratings: The system uses the line's instantaneous dynamic line rating as a starting point, not the end result. Next generation DLR eliminates the continuous variability of first generation DLR and provides power line capacity ratings and forecasts that are easy to interpret and act upon in the control room, on the trading floor, or an engineer's desk.

Further, line behavior, as it relates to weather and loading conditions, is learned over time. No one-size-fits-all formulas are used. This is combined with real-time data using reliability-based rating and forecasting techniques to provide ratings with 98 percent or greater equivalent confidence factors.

The SMARTLINE next generation DLR system provides a variety of ratings:



Next Generation DLR provides a full suite of ratings and forecasts. Presented here graphically, the data is supplied as discrete ratings to the EMS system

- SMARTLINE's DLR is more useful than previous DLR ratings thanks to actionable clearance data. Recall the system's line monitors provide built-in, LiDAR-based, clearance-to-ground measurements. This results in DLR ratings which obey clearance compliance limits in addition to traditional thermal limits. The result is the line's maximum instantaneous current carrying capacity which ensures clearance requirements are not violated, while also eliminating the risk of conductor thermal damage.
- The Reliability Based Rating (RBR) is a statistically stabilized DLR rating and acts as a reduced-risk line rating alternative. RBR is designed for operators to ensure the transmission line is operating over time within both clearance and thermal parameters.
- Reliability Based Forecast (RBF) ratings are RBR line capacity ratings adjusted for forecasted future weather conditions. RBF ratings are tailored to address day(s) ahead energy dispatch and trading needs.
- The Block Forecast DLR (DLRF) rating is a forecast DLR value which is good for a fixed period of time (say one or two hours) based on forecasted weather conditions. For example a 2-hour DLRF rating issued at 1pm will provide a fixed line rating capacity that is good until 3pm (a two-hour window). A line could be confidently operated up to that limit during this time without violating its thermal limit or clearance.
- In addition, real-time streaming data views of all measured line parameters are also available.

Demand Drivers on Today's Grid

Pressures on today transmission grid come from many corners, but hot topics such as competitive bidding, renewables, the Clean Power Plan, distributed energy resources (DER), and non-transmission assets (NTAs), underscore new opportunities that next generation DLR may address.

Reduced Budgets and Time Constraints
One of the well documented challenges for the power industry is the need for increased transmission line capacity with either existing or new infrastructure. However new transmission projects are faced with many challenges that often combine to stretch project timelines to ten or more years.

Therefore, upgrading and uprating existing transmission lines is often the preferred approach to increasing power transfer capacity over existing infrastructure. This approach also utilizes existing right of way (ROW) corridors, which are increasingly hard to obtain. Yet traditional reconductoring involves time and considerable investment. Consider In comparison:

- DLR can provide 10 – 25% additional line capacity for a very small fraction of the cost of reconductoring. It can be deployed quickly and become fully operational within days of installation.
- Slow-growth lines encroaching on their static ratings are even more difficult to justify upgrading. DLR is an ideal least-regrets approach to addressing such capacity shortfall.
- Installation of large-scale renewables and distributed energy resources can tax lines that may not have been challenged even a few years ago. DLR can address these issues quickly and inexpensively, even if only as a short-term measure until a larger scale project is engineered and approved.

Energy Trading Opportunities
The ability to accurately forecast higher levels of transmission capacity present many opportunities for energy trading.

- Additional capacity allows for larger trades or higher levels of trading.
- The additional capacity provided by DLR can relieve the congestion that results in congestion charges. If this congestion is regularly and consistently relieved, DLR may also reduce or defer the need for line upgrades or new construction.
- The capacity above static that DLR reveals could be considered a new, virtual parallel transmission path. In this light, DLR can be viewed as a non-transmission asset where any power transmitted down this virtual path could be monetized.

Grid Resilience

Weather or man-made events can stress transmission lines remaining in service

Grid resilience is a key operational topic for utilities today. How can DLR improve grid resilience? Consider a situation where one or more substations or transmission lines is lost to natural or man-made calamities. A resilient grid must be able to provide alternate transmission paths around the damaged portion of the grid. Alternatively, a generating facility forced off-line during peak load periods may require the utility to push additional power across lines that may already be heavily taxed. The ability to deal with either scenario is dependent on the capacity of those transmission lines still in service. In this case next generation DLR with reliable hour(s)-ahead to day(s)-ahead forecasting can provide both short- and medium-term "emergency-equivalent" ratings for all remaining in service lines.

As an additional consideration, uprating lower voltage lines for marginal contingency scenarios is often difficult to justify economically. DLR is a cost effective means to address line capacity upgrades where the economic case for normal contingency scenarios is difficult to make.

Increased Competitiveness for New Line Construction
Competitive bidding on transmission line projects in Canada and the U.S. can also be enhanced by next generation DLR. When DLR is integral to a line's design, this additional capacity may be included. Savings would follow from a variety of sources including the use of a less expensive, smaller conductor. The lighter conductor loads may allow the use of lighter, less expensive line hardware and towers. Lighter towers and conductor loads may extend to less expensive foundations which may reduce construction cost and installation time.

This may provide an additional advantage to incumbent utilities. Installing DLR proactively on existing lines will provide an incumbent utility a history of operational DLR data and the additional capacity identified by the DLR deployment. When included in a competitive proposal this data offers strong rationale supporting the use of the additional DLR capacity as a base of the line design. While this logic could be used for any company submitting a proposal, the incumbent utility operator may have an advantage of validating the additional DLR capacity on their own system under the same climatic conditions which the proposed line may be constructed.

About the author

Jack McCall is Vice President of Sales for Lindsey Manufacturing with global responsibility all sales and business development. Before joining Lindsey, he was with American Superconductor (AMSC) and Cooper Power Systems. Jack has more than 25 year's experience in the utility T&D business holding a variety of business development, strategic planning, product management, product engineering, and system engineering roles. He has published dozens of papers and holds two US patents. He has a Master's degree in Electric Power Engineering from Rensselaer Polytechnic Institute and a BS in Electrical Engineering from Gannon University. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and the International Council on Large Electric Systems (CIGRE).

Summary

Next generation dynamic line rating systems can now provide utilities with meaningful, actionable transmission line capacity forecasts and ratings. Compared to first generation systems, the required monitoring equipment is simple and easy to install, and communications are reliable and maintenance free. The diverse needs of today's transmission operators and dispatch authorities require additional transmission capacity from existing assets, but this capacity must be known in advance, not in real-time. Next generation DLR with its advanced capacity forecasting meets this need.

THE BIGGER PICTURE

BY BRUCE DUFF

Examining Challenges Facing Utility Companies

Executives see the utility industry rapidly changing. Unlike any other time in the industry's history, customers show a strong desire to achieve energy independence. There is a degree of uncertainty among utility professionals as to how to chart a course forward, while maintaining sustainability.

It was within this context that ARCOS hosted a Utility Operations Summit in March 2016 comprised of professionals who have served (or currently work) as presidents, senior vice presidents and vice presidents of electric and gas utilities. The executives' twofold goal was 1) examining challenges facing utility companies, and 2) charting strategies for the future of the industry.

For summit attendees, the industry's most noteworthy trends may also be its challenges. Residential customers have become greater consumers of power due to the proliferation of computers, laptops, mobile devices, large-screen TVs and the electric car. But more efficient appliances and renewable energy have, in some cases, reduced consumption causing utilities to propose rate increases. Many utility executives see putting a proper value on the grid as a pressing challenge for themselves as well as regulators, city councils and co-op members. Utilities provide a service that customers expect to be 'always-on,' and consequently judge a utility by speed of restoration and not day-to-day delivery. Utility executives cited a need to better manage customer expectations and provide real-time updates to customers during service restoration, similar to the way Uber alerts its customers on the location and ETA of drivers. Additionally, integrating critical information with community first-responders, especially during power outages to improve response time, was important.

As for the future of utility operations, managing costs and reducing the price of doing business were chief among these executives' concerns. Among the strategies offered by the attendees for reducing costs was improving 'situational intelligence' – the real-time knowledge of the status of people and resources. This, they say, will align resources with work, expedite restoration and improve customer satisfaction.

Finally, the executives opined that technologies available today, such as drones, GPS and GIS could have an immediate effect on reducing the cost of assessing damage, deploying workers, informing regulators and customers, and restoring service.

What are the Utility Industry's Trends and Challenges?

Summit participants discussed key issues and opportunities facing their organizations, particularly utility operations. Ideas and strategies were discussed for the future of operations as well as the technology needed for success. The major themes offered by attendees were these: the pace of industry change; the need to drive down costs; how best to compete in a strict regulatory environment; creating operational awareness and meeting shifting customer expectations.

Rapidly changing energy industry

According to summit participants, many residential customers have a desire to cut themselves off from the grid. While customers report that restoration and reliability are good, they believe power is too expensive. Educating customers about the way utilities buy power and distribute it could mitigate customer concerns.

Executives see distributed energy generation (DG) playing a larger role sooner versus later. A DG system with 'micro grids' could reduce the impact of storms or brownouts by localizing outages for customers, executives say. DG could also increase efficiency because many smaller power plants decrease the distance electricity travels, thus reducing the amount that is lost.

As residential customers, in particular, look to improve energy efficiency or even reduce energy consumption, they may unwittingly be stressing the grid. According to the U.S. Energy Information Administration, 'the ratio of annual peak-hour electric demand to average hourly demand has risen over the past 20 years.' Summit attendees offered this example: A consumer decides to buy an electric car to reduce his carbon footprint. At his home, he charges his electric car at 240 volts, which could consume more than 6 kWh, and match or exceed the home's peak consumption. This, on a widespread scale, could change the peak profile and strain the grid.

The executives saw energy storage as a sea change for the utility industry. For example, electric car maker Tesla and Solar City have developed home battery systems. However, truly removing oneself from the grid would require a combination of renewable energy sources (e.g., solar panels, wind turbines, etc.) and the use of battery storage. Executives noted that the attractiveness of renewables and viability of storage options has one Southwest U.S. utility predicting that 20 percent of its customers could be off the grid in the next 10 years.

Increasing focus on driving costs down, finding more efficiency

Participants were careful to point out that a utility cannot cut itself to profitability. And as public utility commissions continue to take away rates of return, utilities must find creative ways to generate revenue, stay relevant and ensure the sustainability of energy delivery in the future.

Summit participants proposed pricing services differently and unbundling the traditional utility service plan. The utility becomes a 'data cloud' for customers. With the birth of the Internet of Things (IoT) and integrated sensors, utilities can (and are) collecting a vast amount of data that they can turn around and sell as information about a consumer's network and consumption trends. The information could help providers of energy-efficiency services and products identify potential customers, which, in turn, may help the utility control demand and save money.

Creating a Level Regulatory Playing Field

Disruptions like net metering present a challenge and an opportunity, say participants of the summit. The challenge is making sure regulatory bodies create rules that equitably and precisely value what energy (and the grid itself) is worth to a customer. One Midwestern executive offers what is being done in New York State as an example of how utilities are sometimes hindered to compete. New York's 'Reforming the Energy Vision' (REV) initiative seeks new ways to regulate, among other things, how utilities and consumers produce, deliver and consume energy. REV aims to look at everything currently a part of producing energy. According to this executive, the current REV construct is to allow utilities to participate in limited situations, mostly where third-party providers do not see a financial payback. There is, says the executive, ongoing discussion with the New York Commission to broaden utility participation, as it has become clear that utilities could offer expertise and understanding that third parties do not understand.

To navigate a path forward amid regulation, some utilities are looking for creative partnerships to squeeze revenue opportunities from an environment that can stifle competition. An example is a partnership in which a utility is exploring a deal with a third party to carry out home appliance repair. The utility essentially has the expertise and tools for this; and it is seen as a way to focus the workforce's acumen on a complementary service for its customers.

Gaining Operational Awareness

As utilities have ramped up the number and type of technologies they use to monitor circuits, outages, work, resources and more, managers are collecting terabytes of data. Ingesting this data requires better means for ferreting out the information that will help operations personnel see what's going on. Top of mind for these executives is access to a single dashboard for multiple systems that utility decision-makers can tap.

Accommodating a Changing Customer Expectation

The ride-booking service Uber was held up by summit executives as an exemplar of what utility customers want from their utilities: Knowledge at their fingertips indicating who's coming to their doorstep and when. Utilities have taken strides to provide outage maps to customers, which have garnered positive reviews. But executives are adamant that the pace of change has to speed up to keep in line with customers' expectations. Technology like Uber already exists, so tailoring alerts about outages and ETRs should follow suit, say executives. If, for example, apps exist to help utility professionals pinpoint damage and prioritize dispatch and repairs, then utilities could provide these same apps to customers to download and identify damage near their home. This kind of access may even reduce utility costs and expedite restoration because cursory damage assessments could funnel in almost immediately after an outage, from thousands of customers who are already on the scene.

Where are the Opportunities for Improvement?

Four areas were noted in which information was seen as either difficult to obtain or there was a lack of real-time information.

1. Preventing Disruptions to the Grid by Weather, Natural Disaster or Cyber Attack

After Superstorm Sandy struck the Northeast U.S., the consensus of summit attendees was that utilities must show that executives can manage the job of responding to and minimizing the impact of disruptions. In the wake of Sandy, they noted their views about resiliency had changed markedly. When the power is interrupted by either weather or an external attack, attendees say a major component to restoration is now about having utility resource management systems and processes in place for evaluating the need for and sharing of resources.

The unprecedented hack of Ukraine's power grid last December made executives keenly aware that their distribution business is now front and center in terms of visibility for this issue. It was suggested that utilities undertake preventative measures including layering their security, ensuring that the biometrics match the employee at the controls as well as the work order.

2. Clear Organizational Communication

Executives say that the typical control center operator might have six screens to monitor – ranging from SCADA to outage management systems. Summit attendees felt the key is integrating this information, so supervisors and executives can reduce the time it takes to make the right decisions. The solution lies in a truly integrated information asset system. A system like this, they say, would help utilities anticipate the resources and costs each day as well as when preparing for major events.

3. Transparency of Operations for Customers

The utilities generally say they do a good job of collecting customer data. But they want to better understand their customer demographics and expectations wherein a millennial may consider information timely if it comes via text to his or her smartphone, but a retiree wants a call that someone is coming to restore service. The solution lies, these executives believe, in giving customers more and varied ways to interact with their respective utilities. Some utilities, such as Duke Energy and San Diego Gas & Electric, have tapped chief customer officers to spearhead the kind of analysis and response that consumers want. However, the executives felt that in many ways the utility industry runs on 'legacy thought patterns.'

4. Reducing the Cost of Doing Business

Some utilities have asked for rate increases, or customer-service charges, that have been as high as 50 percent. Instead of rate increases, summit executives feel they could reduce costs by striking the right balance and mix of work being done by different labor sources (e.g., company versus contractors or other labor sources). Matching the right skill set and size of crew with the job at hand is, in some cases, already leading to cost savings. For example, one West Coast executive explained how technology shows his utility which 'crew sizes' are the most efficient at accomplishing a variety of tasks. Technology like this, he says, can capture data to standardize what it takes to set a pole, change out a transformer or repair a gas line.

How can Utilities Ensure Successful Operations in the Future?

Events like the June 2012 derecho that swept the Midwest, sending more than 3.8 million customers into the dark, have put political pressure on utilities to get all the resources one could possibly imagine on the scene as fast as possible. Managing the expectations of politicians and the public, informing regulators and coordinating restoration with police and firefighters becomes easier when a utility knows with certainty who it has on the job, who is working where and who is on rest time.

Improving situational awareness, baseline information & metrics

Executives believe collecting, centralizing and tapping data in advance of a forecasted event gives them a way to plan what they need and orchestrate a coordinated response that allays the concerns of third parties and establishes realistic restoration times. Executives believe an even deeper layer of awareness can come from combining crew data with GPS devices that can update and draw from a geographic information system (GIS) showing all facilities (e.g., poles, transformers, pad-mount switches, area work centers, substations).

Implementing predictive analysis and automated decision-making – driving down operational costs

Executives at the summit characterize true, predictive analysis as a future state, perhaps as many as 10 years away from implementation. Eventually, say executives, technology will tell customers which technician is headed their way, what piece of equipment he will work on and what the estimated time of restoration will be.

For utilities to remain healthy, they must align the cost of what it takes to do business with what they charge for products and services. Executives say the industry has to be efficient, entrepreneurial and communicative.

The executives pointed to the fact that sizing teams and tracking progress is almost universally a manual process at most utilities. Automating the process helps managers focus on the work at hand instead of spending hours to rebuild crews when 'schedule-busters' occur, and executives have a system-wide plan that they know is carried out. According to the executives, utilities could display this information for all managers to see, so supervisors have the ability to discuss how to 'right-size' for jobs.

Priorities for the Future

Executives say enlisting drones would have an immediate impact on the speed of restoration by accelerating the survey and assessment of damage. The FAA would have to amend flight rules to enable drones to fly over certain areas and beyond the line of sight of pilots. Another immediate impact on speeding up restoration would be encouraging customers and first responders to document post-event damage with photographs from their smartphones.

Summary and Recommendations for Directors and Managers

Approximately half the summit executives saw themselves retiring within 10 years, so they reflected on what to pass along to the directors and managers who will make up the future ranks of the utility industry. First, they challenged directors and managers to look at their processes and think how they might automate each of these – an audacious goal, but necessary to spark innovation. Second, they want their managers to think broadly about what technology can do. For instance, while they may have invested in an outage management system to improve service for customers or reduce operating costs, the executives ask, "What other gaps could these tools fill?"

Conclusion

Executives at the summit also predicted what a utility of the future might look like. They imagine driverless bucket trucks with robotic arms for assisting in blue-sky restoration work with a smaller team, or even one lineman. These self-driving vehicles would eliminate the need for a commercial driver's license for workers. Other executives envision a time when there will be unmanned control stations. Ultimately, each idea offered by the attendees hinged on making utilities competitive, reducing costs, streamlining processes and gaining situational intelligence. By achieving these conditions, the executives feel it will lead to better decision-making and communication, resulting in improved customer service and satisfaction.

ABOUT THE AUTHOR

Bruce Duff is chief executive officer at ARCOS, which is the North American leader in delivering crew callout and crew management SaaS solutions to the utility industry. Duff leads the strategy and execution for the company's operations. He has over 30 years of experience in executive leadership, sales, marketing, operations and strategy development in the enterprise software market in North America and abroad. Contact him at *bduff@arcos-inc.com.*

By Alan Snook

SECURITY SESSIONS

Intra-grid Sensors: The Missing Link to a Comprehensive Smart Grid

A comprehensive smart grid is now available, and the Ontario Ministry of Energy may be leading this important initiative.

In 2014, The Ontario Ministry of Energy continued its leading-edge commitment toward advancing the smart grid. Through its Smart Grid Fund (SGF), the Ministry offered critical funding support to help advance a series of emerging technologies. One of the pioneering solutions supported by the SGF program has given birth to the next meaningful element of an intelligent grid; the intra-grid sensor.

The architecture of a distribution grid is rather simple – substations, endpoint meters, and the vast network of power lines, power poles and transformers that connect them. This network of poles, lines and transformers is the intra-grid, or sometimes referred to as 'the heart of the grid'.

During the last decade, utilities around the world have greatly improved their Substation controls. Similarly, the deployment of Advanced Meter Infrastructure (AMI) has modernized the endpoint segment of many distribution grids. Unfortunately, neither substation controls nor AMI can accurately capture and report the dynamic grid conditions occurring between these opposing spectrums of the grid. And interestingly, the 'intra-grid' itself represents the most dynamic, most vulnerable and most volatile segment of every distribution grid on the planet. The US intra-grid for example, consists of approximately 2.2 million miles of power lines, and 50 million transformers which are virtually unmonitored at this time. Thus, while substation improvements and AMI have helped to create a 'smarter grid' throughout portions of the world, the achievement of a genuine smart grid has remained elusive due to a lack of visibility within the expansive intra-grid space… until now.

Intra-grid sensors, like those which were partially funded by the SGF, now present a cost-effective solution for achieving a comprehensive smart grid. These sensors are typically retrofit onto distribution transformers within only a few minutes. Once the intra-grid sensors are installed, they immediately begin to capture and report vital information from within the heart of the grid. This accurate, timely information is provided to utility personnel via various paths to ensure accessibility and value.

Today, most utilities are suffering from aged transformers, unknown intra-grid conditions, significant power theft, and an increasing occurrence of reverse energy stemming from Distributed Energy Resource advancement (i.e., solar rooftop and wind sources). But this archaic trend can now be stopped. Intra-grid sensors are poised to eliminate these unknown conditions which are plaguing utility operators, unnecessarily driving costs upward for rate payers, and resulting in otherwise avoidable power outages around the world.

The value of intra-grid sensors is akin to the value of 'fitness trackers.' Throughout the last few years, multiple companies have provided consumers with fitness trackers that typically apply to the user's wrist. Once attached, the fitness trackers capture a series of previously unknown, unique data points about one's physical activity, heart rate, calories burned, sleep information, etc. Most fitness trackers are supported by applications which are accessed online via smart phones. In essence, fitness trackers now conveniently and accurately apprise users of their exercise and health information which was previously a mystery. While users may have exercised in the past, they truly had no idea of the factual information regarding their activities, or their bodies. Now they do. In this same manner, without intra-grid sensors, utility operators remain 'blind' to the actual conditions within the heart of the grid. For example, if any utility operator was asked to accurately advise how much power is stolen downstream of any transformer, or how much reverse energy is entering the grid at any transformer, or what the voltages, current spikes or actual loading was on a transformer, the honest answer would be the same for every operator… "I do not know."

That's correct; while the global industry is in pursuit of a smart grid, no one really knows the facts associated with the perpetually changing conditions within the most expansive grid segment… the intra-grid.

While we may have great technology at the substation and endpoint meter segments, presently operators are indeed 'blind' within the heart of the grid. That is, until they apply cost-effective, intra-grid sensors to reveal a myriad of previously unknown information. Now, just like with a fitness tracker attached to one's wrist, an intra-grid sensor attached to a transformer will reveal critical, granular, timely data that was never previously available. Vital information concerning the transformer itself, and the heart of the grid's dynamic conditions no longer need to be a costly mystery for operators or rate payers.

The intra-grid sensor device is typically a lightweight self-contained apparatus that is comprised of sensor technology, metrology, onboard processing, onboard storage, and onboard communications. When deployed upon distribution transformers, actual information such as Energy, Current, Voltage, and transformer Temperature are made available to operators. These accurate data sets can be mathematically extrapolated to further expand the depth of understanding regarding the intra-grid conditions. Commonly supported by a back-end software platform, the timely intra-grid sensor information is received at an approved/secure point(s), then processed and presented to utility operators in a useable format; both historic and real-time information is now made available to operators. In some instances, intra-grid sensors have already evolved to provide automated alert capabilities. These alerting features allow operators to deploy sensors, program desired grid/asset conditions which serve as alarm tolerances, and then enjoy a 'Hands-Free' grid monitoring capability. Accordingly, the intra-grid sensors will provide email, and/or SMS text alerts immediately to operators, notifying them of problematic conditions within the grid. This automated alert feature permits operators to focus on other key areas while the intra-grid sensors function as a cost-effective, stealth watchdog.

The emergence of intra-grid sensors enables operators to receive notifications concerning undesirable grid conditions, and to establish historic intra-grid information for evaluation purposes. Both the real-time and historic data will significantly improve the way operators can understand and manage the distribution grid. Likewise, grid planning efforts can be greatly enhanced by reviewing and interpreting the intra-grid data this is now made available. It is this newest series of pioneering technologies that will complete the quest for a genuine smart grid throughout the globe. And, given the capability to upgrade/re-program these devices remotely via Over The Air capabilities, intra-grid sensors are now future-proof as well.

So, why are intra-grid sensors not being deployed on every transformer in the world? Why is this same technology not being leveraged at the OEM level to evolve smart technology onto new transformer assets? These are great questions which lead to thought-provoking answers.

To date, there has been a series of reasons as to why intra-grid sensors are not proliferating throughout the world's distribution grids. Most obviously, the intra-grid sensor technology is relatively new; although several solution providers have clearly proven through years of deployment efforts that intra-grid sensors are reliable, accurate, durable, valuable, and cost-effective. Less obvious, many utilities have deployed AMI in hopes of gleaning information from within the heart of the grid, only to discover that AMI is unable to accurately capture and timely/reliably report upstream intra-grid information. As an example, the deployment of AMI has apparently fueled an increase in power theft because fewer utility personnel are now visiting customer locations monthly to take meter readings; this lack of utility personnel presence at customer locations has enabled power thieves to gain confidence about stealing power. Power thieves have learned that tapping in front of the AMI meter allows their theft activities to go undetected by a utility, especially when utility personnel almost never step foot on their property following an AMI deployment. To express the seriousness of this impact, the US alone reports approximately $6 billion per year being stolen from its grids. Additionally, as power theft increases, so does the unplanned loading on transformers which leads to accelerated transformer failures. These examples and others support that AMI is truly unable to report with precision the conditions and impacts that are occurring within the heart of the grid since power theft predominantly occurs in front of the endpoint meters thereby being undetected by AMI. To this end, since many utilities have invested millions of dollars in AMI, they must make sure they leverage AMI to its fullest, prior to moving onto the next stage of technology evolution – some utilities are just beginning to accept that AMI is unable to provide a comprehensive smart grid experience. Finally, some utilities are being advised that intra-grid readings can be extrapolated via algorithms, thereby reducing the need for intra-grid sensors. However, the truth is that any algorithm is only as reliable as the foundational data used to achieve the calculation. And, as the aforementioned point supports, so long as power thieves will continue to tap in front of AMI meters, and so long as GIS mapping contains inaccuracies of the transformer to downstream meters association, there is no way that accurate information about transformer loading, intra-grid voltages, reverse energy impacts, and power theft reconciliation can be reported with confidence to operators.

Rather than invest time and energy determining what intra-grid sensors do not address, or how we can find reasons not to deploy them, we must re-direct our industry focus toward how we will leverage this already-present, cost-saving, future proofed, pioneering technology. This global industry paradigm shift is not a luxury, it is a necessity. Now is the time for utilities to embrace this latest version of technology, to thereby reduce unnecessary costs and unnecessary outages for the benefit of their valued customers.

The road that Mabey built: A floating road helped to keep the power reliable for island residents.

When poles and power lines need replacing, engineering and construction departments review the many challenges to access utility sites to safely bring in the necessary crews and heavy equipment for repairs. If the poles are in water, it presents additional access challenges — as was the case for Duke Energy (Progress Energy) in the Apalachicola Bay of Florida.

St. George Island is a thin barrier island in northwest Florida. It is 28 miles long and two miles wide at its widest point and is connected to the mainland by a four-mile long bridge. The power supply reaches the small beach town through power lines that run parallel to the bridge. The lines and poles that support them were aging. New high capacity lines were needed with concrete poles to upgrade the system, especially in storm prone Florida, to keep the electric on.

Frequently utility poles in water are serviced using barges, but three poles, 130 feet tall, were located in water that was just 2-5 feet deep - too shallow for barges to be used. Service Electric Co. (Dillard Smith) was the electrical contractor who previously used Dura-Base® mats and had the confidence these mats could work. After a tough audit by the utility, the Dura-Base® composite matting system was approved to create a 1,800 foot floating roadway plus work pads to provide crews access from the mainland to the poles in the bay. The utility required substantiation that the mats would meet environmental impact standards for the salt grass/marsh conditions and for ground pressure. Mabey's Dura-Base® mats, made with 100% HDPE, prevent cross contamination and the cellular internal construction creates an added element of buoyancy.

The roadway was comprised of interlocking mats that fit together like a puzzle and were secured with locking pins to create a sturdy, continuous road. Mabey's professional installation crew had the expertise and experience to know exactly how to construct the roadway with strategically placed work pads for vehicle turn arounds and to store equipment. The whole project required over 1,800 mats which were installed in 11 days by Mabey's experienced team. With those adjustments in place and Mabey's installation crew paving the way through the bay, the utility crews became confident driving on the mats and accessing the poles.

The tidal changes of the bay required work schedule adjustments to avoid working during high tide and the roadway held securely when a tropical storm with 40 mph winds came through. The mats held the tractor trailers transporting the concrete poles out for each pole and the 250 ton crane stationed for installation.

"When you have tough wetland conditions and time is short but safety is of the utmost importance - that's when the Mabey team and mats perform their best," said Howard Taylor, Vice President National Accounts.

This is only one example of how this composite mat can provide access in challenging conditions. The mats provide temporary roads in muddy, wet, or sensitive areas such as marshland. Site preparation is minimal and these mats keep your crews and equipment safe and operating efficiently. When site conditions require crossing ravines, waterways, canals or gullies, these mats integrate seamlessly with Mabey's QuickBridge® or customized panel bridges to create a continuous roadway. Mabey's engineering team can assess jobs to provide plans to meet all site requirements and challenges.

The fact is that intra-grid sensors are poised to directly benefit rate payers and utility operators through a series of value propositions. Another fact is that global utility operators now have the ability to truly improve the efficiency of their distribution grids – to proactively identify poor grid conditions and weakened assets that will otherwise lead to unnecessary outages; to truly identify and remedy power theft which creates unfair cost burdens on rate payers and introduces unplanned loading on assets; and to enable the embracement of energy conservation practices that will reduce our consumption of natural resources and improve our ability to maximize green energy sources such as wind and solar. In essence, there are many powerful reasons why intra-grid sensors are poised to advance our quest for an intelligent grid. The real fact is, intra-grid sensors are the missing link to achieving a comprehensive smart grid which will ultimately change the way we manage electricity, and will improve man-kinds' sustainability on this amazing planet.

Thankfully, there are utilities in Ontario who have begun to deploy and leverage intra-grid sensors. Likewise, a multitude of utilities in the US, Latin America, the Caribbean, and Asia Pacific are now beginning to lead the way by leveraging intra-grid sensors. The early-adopters are starting to take action; the largest segment of the global utility industry will eventually follow suit as their peers share success stories. Thus far, the early adopter utilities have effectively:

a) Addressed DG/DER impacts including grid instability caused by serious voltage fluctuations, and reverse energy transformer overloading,
b) Identified failing transformer assets in advance of outages (i.e., preventive maintenance),
c) Identified under-sized and over-sized transformer assets (i.e., improved cost management)
d) Identified significant levels of power theft – several utilities have already located power theft levels from $150K to over $400K by just beginning to spot check suspect areas,
e) Monitored loading/overloading impacts associated with Electric Vehicle charging stations,
f) Identified serious imbalances on various legs of poly/three phase transformers,
g) Identified under and over voltages within their grid, (i.e., power quality and cost containment)
h) Identified Current spike levels and frequencies of occurrence,
i) Leveraged intra-grid sensor onboard RF Mesh communications modules serving as range extenders for enhancing hard-to-reach AMI meters not effectively serviced by the AMI infrastructure, and
j) Discovered substantial instances of GIS mapping errors which once corrected then permit accurate loading expectations and improved planning practices

In the near future, comprehensive smart grids will finally be achieved as each participating utility proactively leverages Substation controls, AMI, and the now-available missing link: Intra-grid sensors.

ABOUT THE AUTHOR

Alan Snook is President and a founding member/owner of GRID20/20, Inc. Mr. Snook has led GRID20/20 since inception in 2011. Prior to his current role, Mr. Snook served as an Officer of a privately-held company. He also owns a business consulting firm. Alan is a 1986 graduate of the Pennsylvania State University where he earned a Bachelor of Science degree.

Guest Editorial 1

OpenFMB™ Brings a Standard and a New Tool Set to the Grid's Edge

By Aaron Smallwood

Smart grids are bringing new possibilities to how we manage energy. That's a well-known fact, but what isn't as obvious are the ways that utilities, vendors and other organizations are going to take advantage of the many opportunities that are rising with accelerated grid modernization. Soon, we'll have multi-owner, multi-device grid environments, and we need interoperable breakthroughs to make them work together while providing resiliency, reliability and security. One solution that is impacting the industry is Open Field Message Bus (OpenFMB™) has been ratified as a NAESB standard.

OpenFMB as a NAESB Standard

The North American Energy Standards Board (NAESB) ratified OpenFMB as a standard in March 2016, following a successful demonstration in front more than 1,000 attendees at the DistribuTECH Conference a month earlier. Duke Energy hosted the demonstration with 25 vendor partners to prove that OpenFMB can provide a framework that enables communication between devices in the field and outside of the data center. The live OpenFMB demo in Duke Energy's booth at DistribuTECH 2016, highlighted the collaborative efforts of these 25 vendor partners who built a microgrid that used OpenFMB to demonstrate true interoperability.

At the behest of Duke Energy in December 2014, SGIP (Smart Grid Interoperability Panel) a consortium dedicated to accelerating grid modernization, took on leadership and today facilitates the OpenFMB project and technical working group committee. OpenFMB isn't a product – it's a field message bus – that provides a common data model, command set and messaging infrastructure for field devices in the grid to communicate with each other.

OpenFMB as a Framework

More than sixty organizations including utilities, vendors, consultants and the Department of Energy, have worked together at a rapid pace on the OpenFMB framework. With the OpenFMB framework, intelligent nodes can exchange data at the grid edge, enhancing the abilities of microgrids and other distributed energy sources, such as renewables and storage, to collaborate with the existing distribution systems. It's a catalyst for interoperability, and utilities have already included OpenFMB in their RFPs. The demonstration at DistribuTECH, which used challenging wireless configurations to show the flexibility of the framework, sent a clear message that OpenFMB has emerged beyond concept to reality.

In January 2016, the OpenFMB team kicked off Phase II in the project schedule: SGIP plans to publish OpenFMB code so utilities can start applying OpenFMB functionality to their operations for the first time, and vendors can start developing supporting solutions.

Coming Soon OpenFMB Online Community

SGIP is currently working with members and other technology partners to create an online community where the OpenFMB code will be published. Using an open source model to distribute the code could lead to innovations that don't currently exist, and utilities could develop applications to solve interoperability, legacy systems integration, and other issues. The community site will also include videos, background information, event listings, links, files and uploading options for people who want to get more involved.

Upcoming OpenFMB Demo at 2016 Grid Modernization Summit November 2016

The culmination of these efforts will be demonstrated at SGIP's 2016 Grid Modernization Summit (*http://sgipconference.com*) in Washington, D.C. this November. The OpenFMB committee will conduct another live demonstration at this summit, showcasing new use cases focused on Microgrid Management, Distributed Energy Resources (DER) Management and Management services. The 2016 Grid Modernization Summit will also include a Vendor Expo with 25 participants.

OpenFMB Priorities and DER Use Cases

The OpenFMB committee met in Denver during the last week of June 2016 to define use case requirements for the upcoming demonstrations. The demonstration earlier this year at DistribuTECH was a successful proof of concept upon which the November demonstration will be built.

The functionality in the use cases for the demo at the 2016 Grid Modernization Summit are focused on Distributed Energy Resource (DER) management, including:

DER Circuit Segment Management
- Coordination of Point of Common Coupling (PCC) and Point of Interconnection (POI)
- Voltage, Frequency, and Power Factor support
- Solar smoothing
- Peak power management (e.g. shaving/shifting)
- Volt-Var management

Microgrid Management
- Microgrid optimization
- Unscheduled islanding
- Island reconnection

Management Services
- Cybersecurity
- Provisioning

The OpenFMB committee priority goals for 2016 and 2017 include:
- Define OpenFMB Cybersecurity Roadmap and Use Case Enhancements
- Develop Use Cases for the November Demonstration
- Build and Launch Online Community and Open Source Resources
- NAESB Specification Updates

OpenFMB Addresses Cybersecurity

Cybersecurity is and will remain a chief concern for operations and IT professionals at utilities. OpenFMB has a Cybersecurity Task Force chartered by the SGIP Smart Grid Cybersecurity Committee, and this committee is working with the OpenFMB Priority Action Plan team to create cybersecurity requirements and a roadmap for the framework. The OpenFMB Cybersecurity task force is focused on enhanced cybersecurity functionality emphasizing configuration, communications and provisioning that will be demonstrated at the 2016 Grid Modernization Summit on November 7th through 10th, in Washington, D.C.

In conclusion, with the rising need for interoperability across multi-owner, multi-device grid environments, the OpenFMB framework brings flexibility and a new set of tools to address distributed intelligence and innovation at the grid edge. Join SGIP, the OpenFMB committee and technology partners at the 2016 Grid Modernization Summit to see how. For more information on OpenFMB, *http://www.sgip.org/openfmb/*

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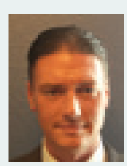


Aaron Smallwood is the Director of Technology Operations at SGIP. He is responsible for leading SGIP's Program Management Office and working with stakeholders in advancing SGIP's technology strategy and agenda.

Aaron has been in Information Technology for 20 years and in the utility industry for the last 15 years. As Director of IT Operations at the Electric Reliability of Council of Texas (ERCOT), Aaron was responsible for the multi-data center IT operations of ERCOT's real-time grid and market systems, deregulated retail market systems, Enterprise Data Warehouse, systems integration, and market settlement systems. In other roles at ERCOT he led business/technology alignment, IT strategy development, program financial management for the Texas Nodal Market Implementation, IT stakeholder relationship management, and the IT divisional project office.

Prior to ERCOT, Aaron was responsible for managing the relationship between IT and utility business units at Aquila, Inc., working with utility and IT leaders to ensure that IT services were aligned with business objectives and that IT was positioned to support their needs.

2017 Revisions and Review Underway to the National Electrical Safety Code (NESC)

Guest Editorial 2

By Nelson Bingel

Over the course of its approximately 100-year history, the effort now known as the National Electrical Safety Code (NESC) has changed its form and procedures to keep up with industry developments. At the beginning in 1915, the NESC was created under the National Bureau of Standards. In 1972 the Institute of Electrical and Electronics Engineers (IEEE) became secretariat of the NESC and still serves that roll today.

The code itself has been written in discreet parts that are presented, as it is today, in a unified document. Its content has always contained some design criteria alongside its focus on safety but is not comprehensive enough to serve as a design guide. The NESC's revision cycle moved to every three years in the late 1970s and, in 1997, it moved to five years. Some of the key changes proposed for the 2017 NESC edition are focused on making the code more readable and intuitive, as well as other additions and amendments that impact particular applications. Here's a look at some of the more significant changes in the 2017 edition.

A good example that underpins efforts to make the code more user friendly is the reformatting of Rule 241C 'At crossings', which has been transformed from a single, long sentence paragraph to a bulleted format that is easier to comprehend. While the requirements are the same, the more readable format demonstrates a general effort to improve the NESC based on users' inputs. Table 242-1 "Grades of Construction…at crossing" was also reformatted for the 2017 edition. The requirements remain the same, but the layout was changed to a more logical sequence of increasing voltages for the columns and rows.

There is one change to note in the content of Table 242-1 that is beyond formatting but still does not change the requirement. The last column in the table is for open supply conductors exceeding 22kV crossing other wires or infrastructure. In the 2012 edition, the grade of construction required in the table was Grade C with a referral to footnote 3. The footnote stated that if the supply circuits will not be promptly de-energized in the event of contact with a lower conductor or cable, then Grade B construction was required. The 2017 edition has Grade B required in the table and the footnote now states that Grade C can be used if the circuits will be promptly de-energized. The requirements are the same but it is better code to show the higher requirement in the table.

Also new in the 2017 edition is a revised Rule 261H1 'Tensions.' This change adds a requirement to address the potential for Aeolian vibration of a conductor and to consider methods of mitigation. Aeolian vibration is low amplitude, high frequency vibration that is most common on transmission lines, and causes damage to conductor strands at suspension clamps and other attachment points. There are multiple ways specified in the rule to mitigate this potential, but if limiting tension is the only option, limits are specified as a percent of ultimate conductor capacities.

The 2017 NESC edition now reflects the work that insulator manufacturers have pursued for changing insulator ratings. The effort was a combined effort within ANSI C29 and IEEE along with members of NESC Subcommittee 5 over the last ten years to change the rating method for Line Post and Transmission Suspension insulators. The former and new ratings are:

Line Post Insulators

- Former rating: an average value with no single insulator less than 85% of the average
- New rating: a minimum value for all insulators

Transmission Suspension Insulators

- Former rating: 1.2 Standard deviations (approx. 80% of insulators exceed the rated value)
- New rating: 3 Standard deviations (99.7% of insulators exceed the rating)

The 2017 NESC adopted a comprehensive change proposal for section 27 that adopted these and other changes related to insulators. First to note is a new exception added to Rule 274. "Factory tests" which reads:

2017 Revisions and Review Underway to the National Electrical Safety Code (NESC)

"*EXCEPTION*: Where guy insulators are manufactured per designs for which validation tests have been performed as specified in Rule 279A1b "Guy span and insulators-Electrical strength" and a valid quality assurance program is followed, this rule does not require that dry and wet flashover tests be performed on each guy insulator unit."

Most of the other 2017 significant changes appear in Table 277-1 'Allowed percentages of strength ratings.' First to note is there are now separate allowable percentages of strength for Rule 250B versus Rule 250C and D. Previously, only Rule 250B was addressed by this table, with the inclusion of a statement that proper allowance needed to be made for Rules 250C and D.

Other industry changes adopted into the table include adjusting the allowable percentages of strength values where changes in the ratings have taken affect and creating Distribution and Transmission classes for suspension insulators.

Additionally, an Exception was added to Rule 277 allowing the use of strength rating percentages different from the values in Table 277-1 if they can be supported by a qualified engineering study, operating experience or manufacturer's recommendations.

These are just a few highlights of the proposed changes to the 2017 NESC edition. An NESC Workshop is scheduled for October 18-19, 2016 in San Antonio, TX. A review of the changes in all sections of the code will be presented on the first morning. Additional segments will discuss the adoption of solar and wind power into the NESC along with new technologies and a vision for the code of the future The new code itself was published on August 1st, 2016, along with training and learning tools, including a new handbook and a MOOC scheduled for August 2016.

Learn more about the NESC and related products at *standards.ieee.org/nesc/*.

ABOUT THE AUTHOR

Nelson Bingel, Osmose Utilities Services, is a member of the NESC Main and Executive Subcommittees and chair of NESC Subcommittee 5.

Guest Editorial 3

Quality LED Neighborhood Lighting Improvements offer Reduced Maintenance and Efficiency Incentives for Co-op

By Cathleen Shattuck

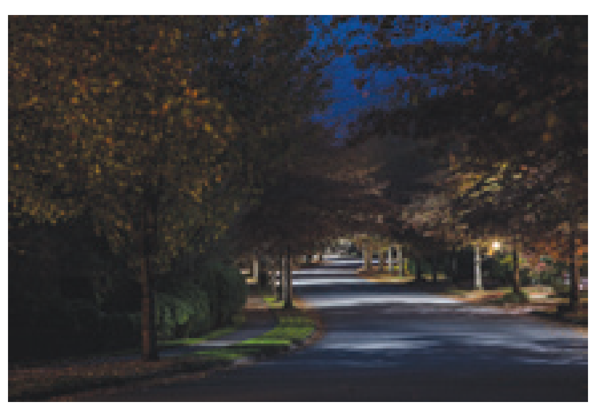
The need for an economical, low-maintenance, dark-sky friendly neighborhood lighting solution was apparent to Jim Anderson, Tanner Electric's Manager of Operations and Engineering. When Jim joined the team at Tanner in 2013, "We were probably rolling a truck at least once a week to go out and change out a photocell or investigate why a light wasn't working. Maintenance was an issue." Complicating serviceability was the wide variety of lights on the system at the time. "We had a mixture of different wattages, different bulbs, different ballasts, and different lenses, three or four different manufactures as well."

Working Locally

While researching solutions, Jim talked with another Washington utility, Okanagan County Electric Co-op, "They told us they had done a case study for their Board of Directors. The payback was enough that they could support installing new streetlights throughout their system." David Gottula, Okanagan's General Manager, had told them about the LED AreaMax manufactured by Evluma, a local company based in the Seattle area. Working locally was important to Jim and LED would offer efficiency gains and reduced maintenance. Plus the AreaMax offered Photocontrol Failsafe™ putting an end to time-consuming and costly photocell change outs, a big concern for Jim and his crews.

Light Quality

After seeing the AreaMax at a tradeshow, Jim took advantage of a promotional offer to buy 8 AreaMax for the price of 4, the Evluma 4x4. Ordering a mix of 40W and 70W units Tanner Electric was able to perform a small study on their own. "I was very strategic in where I placed these units," said Jim. One member wanted to light up an intersection close to his home, so Jim's team opted to place a 70W at that location- "a rural country road - and the feedback from him? He just couldn't believe how bright and white it was. The Dark Sky initiative is very important to [Tanner] because of where we are located. A light that put out the amount of light that the AreaMax put out brightened up the intersection and made all the residents feel safer, even those that didn't support the light originally." When a board member reported favorably to the Board of Directors on the quality of the light from the AreaMax Jim had placed at his house, Tanner knew they had a good project.



Energy Efficiency Rebate

An incentive from BPA (Bonneville Power Authority) was available to Tanner Electric. “The dollar amount that we had for conservation was large. Not huge – it wouldn’t pay for the project, but it was enough for us to approach our board and General Manager for the approval to proceed.” In 2015, Tanner Electric replaced over 400 fixtures varying from 100-400W with 40W AreaMax in residential areas and used 70W at intersections, “anywhere where there was a large volume of traffic.” BPA rebated $30,000.00 to Tanner Electric once the project was complete.

Member Approval

North Bend is an upper bedroom community of Seattle. As Tanner Electric rolled out the conversion, residents would leave for work in the dark, with the old lights on. Later that day, commuters coming home in the dark immediately noticed the new AreaMax lights. Members promptly commented on the evenness of the light and that they could see the entire sidewalk. “They could see into the dark spots that they were missing before. This area has a lot of kids. So safety is important. The quality of the lighting changed the appearance of the neighborhood, made it friendlier, safer. It is what members expressed they had wanted in the first place,” said Jim.

“We rolled this project out 100 percent. We dedicated 2 crews for the majority of the summer. They were out there about 1 month changing out every light they could find. At the end of the project our final number was closer to 480.” Once the system has paid for itself Tanner is hoping to re-evaluate their rates and pass savings back to the members.

ABOUT THE AUTHOR

Cathleen Shattuck is the Creative Director at Evluma and has been working in the LED and photographic equipment industry for over fourteen years. Her photographs have appeared in Seattle Magazine, Seattle Business Magazine, Business Energy, The Seattle Daily Journal of Commerce and more.

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www.minmaxtech.com

VIZIMAX INC.
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www.edx.com

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ROCKWELL AUTOMATION, INC.
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www.rockwellautomation.com

S&C ELECTRIC COMPANY
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THOMAS & BETTS - UTILITY GROUP
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THOMAS & BETTS CANADA UTILITY DIVISION
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ESKER
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www.esker.com/order-processing-automation-software/

OPEN SYSTEMS INTERNATIONAL, INC.
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www.osii.com

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B

BATTERIES & ACCESSORIES - DC BATTERY CHARGERS

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www.hindlepowerinc.com

BATTERY CAPACITY AND MONITORING EQUIPMENT

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PRODUCTS AND SERVICES

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www.pupicrossarms.com

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UNDERGROUND DEVICES INC.
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AMERICAN WIRE GROUP, INC.
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www.morganschaffer.com

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UNDERGROUND DEVICES INC.
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CONTACTORS

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Tel: 514-935-2323
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www.sandc.com

CONTROL TRANSFORMERS

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www.prolecge.com

CONTROLLERS/CONTROLS - PROGRAMMABLE

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Tel: 773-338-1000
www.sandc.com

CONTROLS

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Tel: 773-338-1000
www.sandc.com

CONTROLS - CONTROL BOXES FOR TRANSFORMER COOLING FANS - SINGLE OR MULTI STAGES / EXPLOSION PROOF

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www.californiaturbo.com

PRODUCTS AND SERVICES

CONTROLS - LTC TRANSFORMER

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Tel: +52 818 030 2000
www.prolecge.com

CONTROLS - TAP CHANGER

ADVANCED POWER TECHNOLOGIES, LLC
Tel: 973-328-3300
www.advpowertech.com

CONTROLS - TEMPERATURE

CALIFORNIA TURBO, INC.
Tel: 909-854-2800 • 800-448-1446
www.californiaturbo.com

KRENZ & COMPANY INCORPORATED
Tel: 262-255-2310
www.krenzvent.com

CONTROLS - VAR

S&C ELECTRIC COMPANY
Tel: 773-338-1000
www.sandc.com

THOMAS & BETTS - UTILITY GROUP
Tel: 1-800-326-5282
www.tnb.com

THOMAS & BETTS CANADA UTILITY DIVISION
Tel: 1-800-466-1102 X 234
www.tnb.ca

COOLERS - TRANSFORMER OIL

PROLEC GE INTERNACIONAL, S. DE R.L. DE C.V.
Tel: +52 818 030 2000
www.prolecge.com

CRANES - MANUFACTURERS/DISTRIBUTORS

ELLIOTT EQUIPMENT COMPANY
Tel: 402-592-4500
www.elliottequip.com

CRIMPING TOOLS - ELECTRICAL

TALLMAN EQUIPMENT CO
Tel: 630-860-5666
www.tallmanequipment.com

CROSSARMS, WOOD - LAMINATED

LAMINATED WOOD SYSTEMS, INC.
Tel: 402-643-4708 • 1-800-949-3526
www.lwsinc.com

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HUGHES BROTHERS INC.
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www.hughesbros.com

CURRENT SENSORS

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www.awesense.com

LINDSEY MANUFACTURING CO.
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www.lindsey-usa.com

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Tel: 773-338-1000
www.sandc.com

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www.sandc.com

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PRODUCTS AND SERVICES

OPEN SYSTEMS INTERNATIONAL, INC.
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www.osii.com

D

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www.datacapable.com

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DETECTORS - PARTIAL DISCHARGE

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www.comnet.net

EDX WIRELESS, LLC
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Tel: 773-338-1000
www.sandc.com

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ADVANCED CONTROL SYSTEMS, INC
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www.acspower.com

GE DIGITAL ENERGY - MULTILIN
Tel: 1-800-547-8629
www.gemultilin.com

OPEN SYSTEMS INTERNATIONAL, INC.
Tel: 763-551-0559
www.osii.com

S&C ELECTRIC COMPANY
Tel: 773-338-1000
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SIEMENS ENERGY INC.
Tel: 919-365-2200
www.usa.siemens.com/energy

THOMAS & BETTS - UTILITY GROUP
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www.tnb.com

THOMAS & BETTS CANADA UTILITY DIVISION
Tel: 1-800-466-1102 X 234
www.tnb.ca

VIZIMAX INC.
Tel: 1-450-679-0003
www.vizimax.com

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www.udevices.com

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www.charlesindustries.com

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www.concastinc.com

MERSEN CANADA
Tel: 416-252-9371
ep-ca.mersen.com

ENCLOSURES - METAL

CHARLES INDUSTRIES
Tel: 1-847-806-6231
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ENCLOSURES - METERING EQUIPMENT

EASI-SET WORLDWIDE
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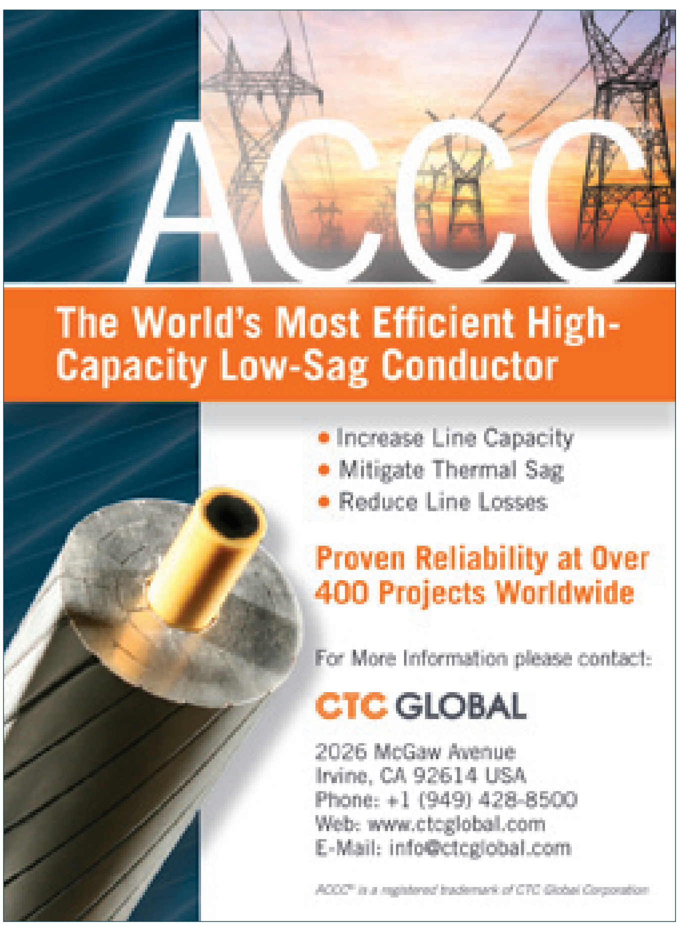

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www.snclavalin.com/en/power

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www.rokstadpower.com

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CPI GEOMAGNETIC DISTURBANCE DIVISION
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gmd.cpi.com

JRG MECHANICAL INC – HVAC SERVICES GTA
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jrgmechanical.ca/

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SNC LAVALIN
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UTILITY LINE CONSTRUCTION SERVICES
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www.utiliconltd.com/acc.htm

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CTC GLOBAL CORPORATION
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www.comnet.net

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www.hlinstruments.com

FIBERGLASS - PIPE, TANK

HASTINGS FIBERGLASS PRODUCTS INC.
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www.hfgp.com

FIELD AUTOMATION

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www.lewistree.com

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Tel: 773-338-1000
www.sandc.com

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GRID ONE SOLUTIONS, INC.
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www.gridonesolutions.com

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www.southernstatesllc.com

FILTRATION SYSTEMS - OIL

BARON USA, LLC
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www.baronusa.com

C. I. AGENT SOLUTIONS
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www.ciagent.com

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Tel: +52 818 030 2000
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FLOODLIGHTS

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FUSES

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ep-ca.mersen.com

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GENERAL CONTRACTORS - CONSTRUCTION

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HARDWARE - TRANSMISSION LINE

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Tel: 617-926-4900
www.doble.com

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www.baronusa.com

PETRO-CANADA LUBRICANTS INC.
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lubricants.petro-canada.ca

PROLEC GE INTERNACIONAL, S. DE R.L. DE C.V.
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SEVES - SEDIVER
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www.k-line.net

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www.movitherm.com

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