MAY 2016

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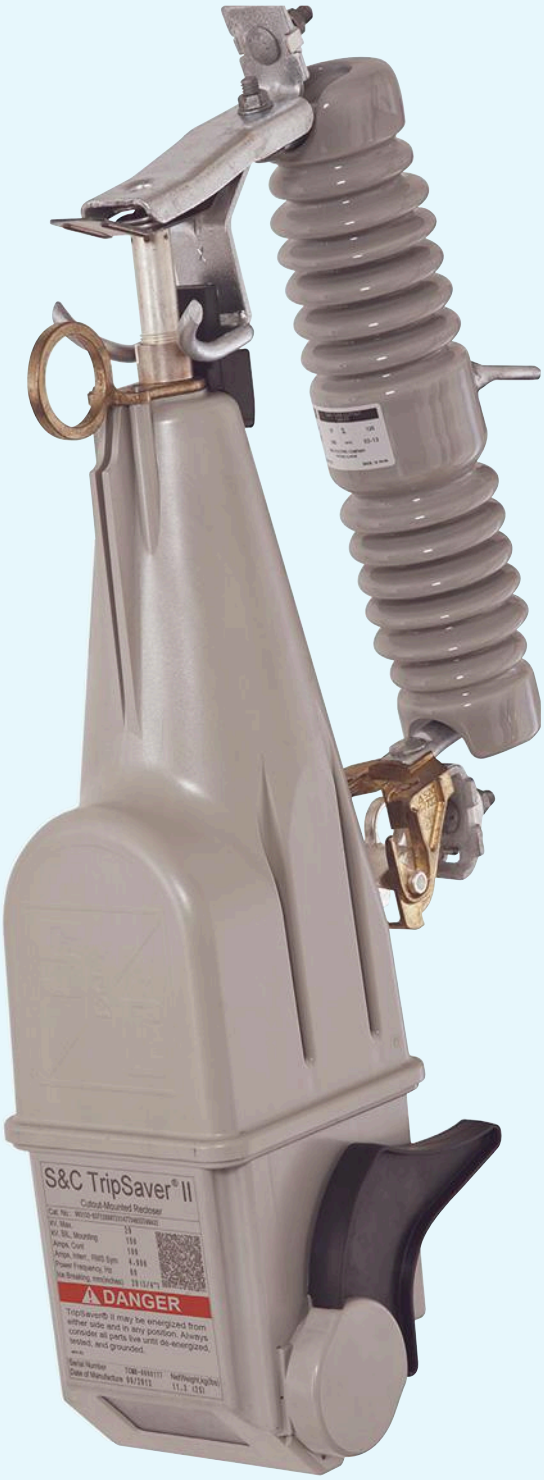

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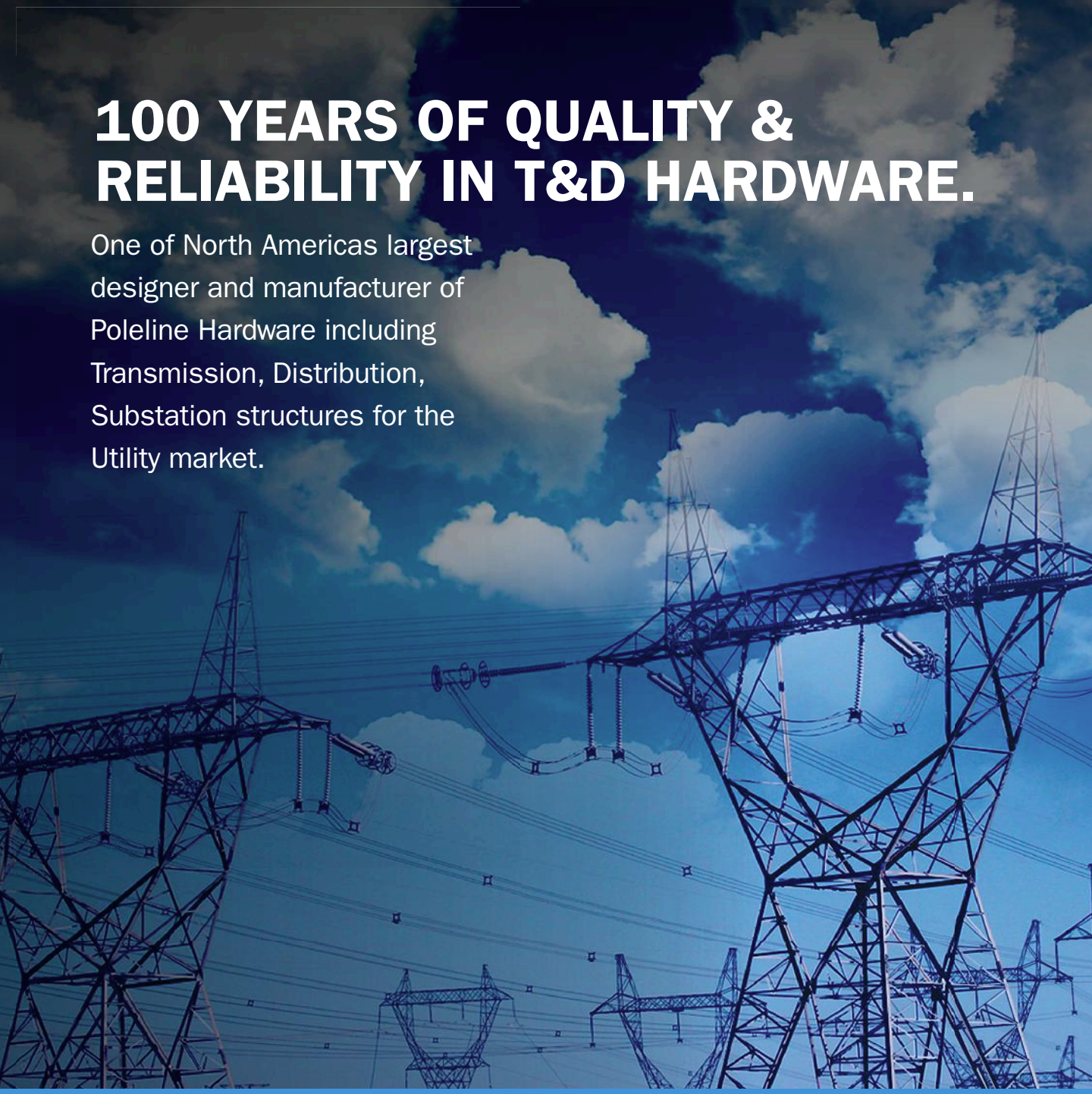

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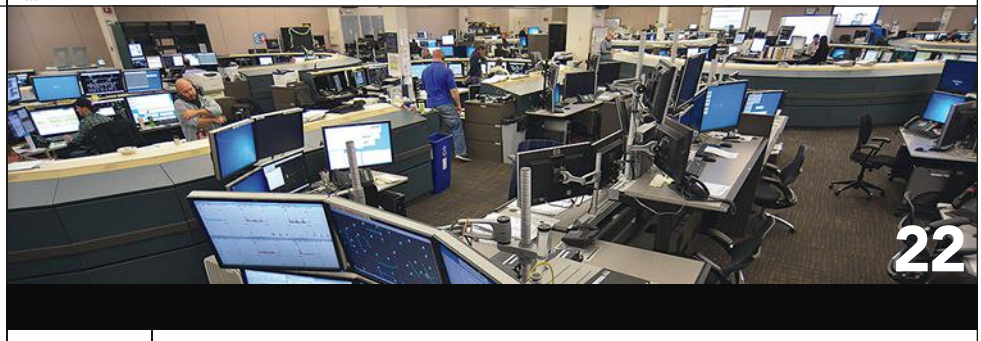

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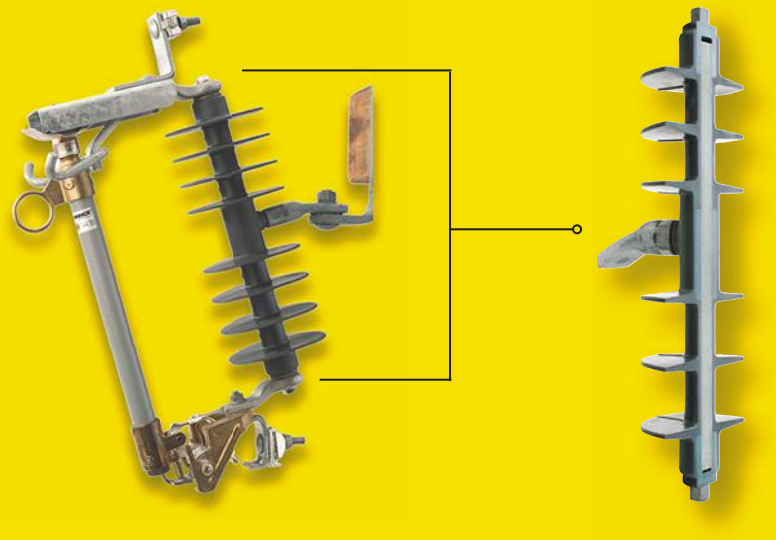

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In Every Issue

ABOUT OUR COVER:

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Gallery:

Storm Soldiers II: No Hero Stands Alone

Hubbell Power Systems Inc. has released Storm Soldiers II: No Hero Stands Alone. HPS partnered with film producer Tytan Pictures on the second installment of the Storm Soldiers project to tell a more personal story of the commitment and sacrifice that comes with being a utility line worker

The gallery features riveting images from the new film, which is a 75-minute documentary that follows six line families from across the United States over the course of 15 months and documents moments of accomplishment, deep reflection and great loss.

Grid Optimization:

Electrical Workers Still on Top 10 Most Dangerous Jobs List

By David Shadle

Electrical workers remain on the top 10 most dangerous jobs list, but utilities are aggressively working to lower the number of accidents.

Vegetation Management Resource Center:

Vegetation Management Support

By Sig Guggenmoos

One of the frustrations vegetation managers face is when someone from the company has given incorrect information to an individual or the public, leaving the vegetation management group to play the bad cop, or to be viewed as a bunch of ill-educated, unreasonable, unyielding bushwhackers.

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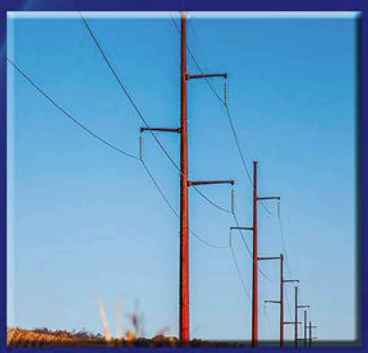

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More Brains, Less Brawn

As I walked into the engineering building at Marquette University in Milwaukee, Wisconsin, U.S., I realized I was walking into a new world.

I was early for my appointment with Dr. Richard Marklin, so I asked the person at the front desk if I could take a wander. The receptionist, an engineering student, pointed me in the direction of several ongoing classes as well as to the mechanical lab.

The building itself is quite impressive. For one thing, there is glass everywhere. Everyone can see out and everyone can see in; the classes are more than open. And this place is clean. There are no cubbyholes available to squirrel away stuff. This is a LEED-certified building, so students don't have to travel far to get educated on high-efficiency building technologies.

I went into this slick machine design lab where undergraduate students were evaluating the various drive chains of high-end bicycles. I found out this lab was the brainchild of Dr. Mark Nagurka and is a renowned world-class lab for teaching undergraduate students the principles and applications of machine design.

I then went into a classroom where students were looking at the design of various gearing mechanisms. Some of the gears had been manufactured from polyethylene on a really big 3-D printer. I could see a kind of crosshatch pattern on the gear surfaces; other gears were laser cut by the students.

At the back of the building, a mechanical bay structure was constructed to allow students to perform tensile, cantilever and torsional tests. This structure could withstand up to a 500,000 lbs of tensile stress and consisted of a two-story column of concrete, maybe 8 ft thick, that went underground for another story. This rebar-filled frame allowed the students to test just about any structure imaginable. Additional structures and frames could be bolted to the reinforced concrete, which had threaded anchors spaced every 4 ft. A student was wrestling with a 20-ft hydraulic cylinder near one wall, and I so much wanted to go into the room and see what he was doing, but it was time to meet Dr. Marklin, so I squelched the urge.

Dr. Richard Marklin was a hero to me, even though we had not met before. We had reported on his ergonomics research sponsored by EPRI's Occupational Health and Safety program. The EPRI ergonomics research started in the late 1990s and continues today. Dr. Lovely Krishen is the current technical director of EPRI Program 62, which has awarded more than US$3 million in ergonomics research to Marquette University since 1999.

Marklin and his team had wired up linemen and measured the forces required for linemen to perform certain repetitive tasks using various mechanical, hydraulic and electric powered tools.

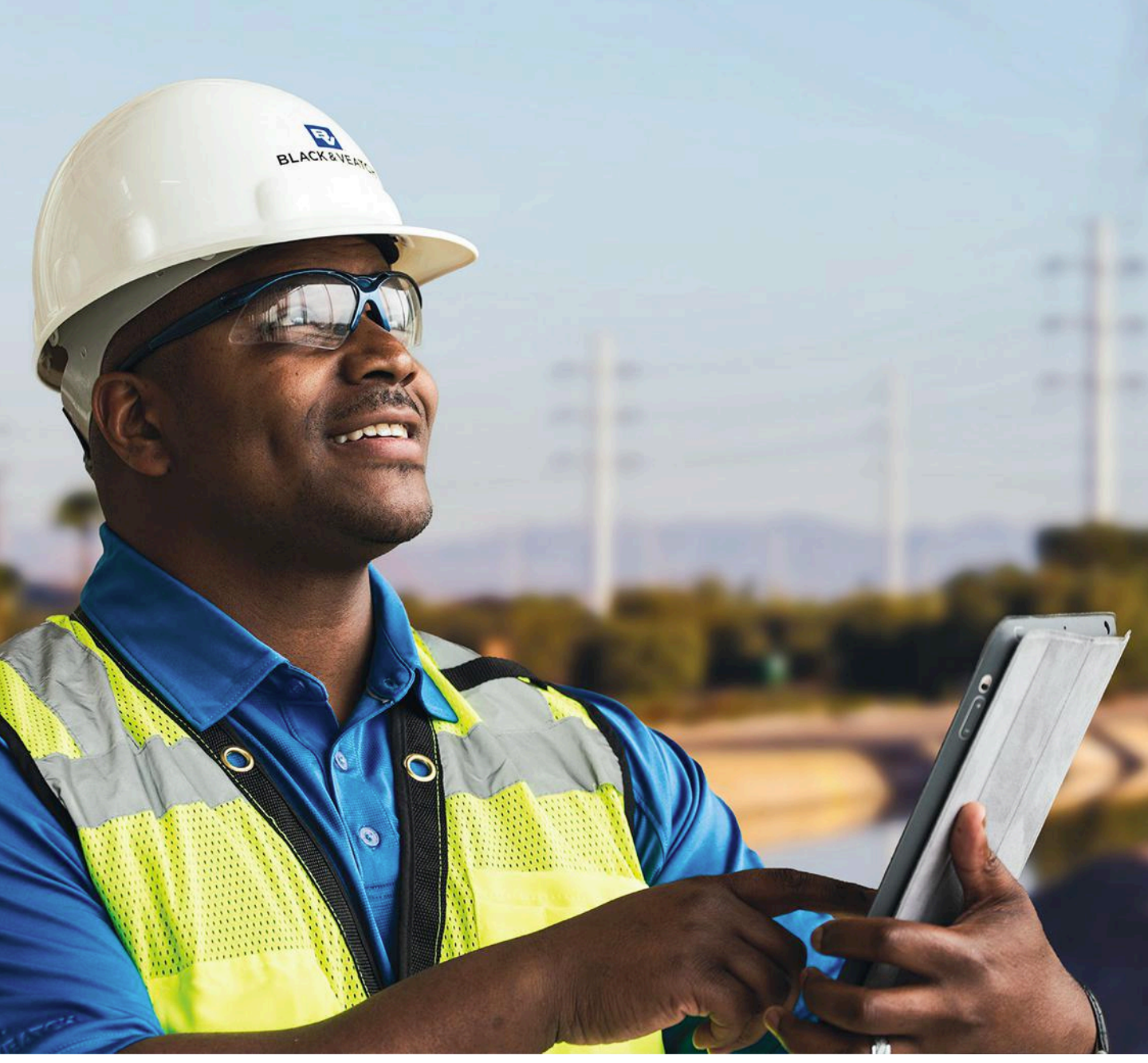
Earlier, I also had met one of the We Energy linemen who had participated in the Marquette University ergonomics studies — a quite opinionated, smart and genuinely nice fellow named Fred Wentzel. He is a lot more than that, being a bear of a lineman. Fred really gets into this stuff.

I also met Pat Seeley, who was an ergonomist with We Energies at the time. I was most impressed that the results of the work being performed by Marklin were being injected directly into the front lines by way of best practices and ergonomic tools. Of course, the results have been shared with EPRI members. Pat and Fred even reported their findings directly to linemen when they presented at the International Lineman's Rodeo in Kansas City.

Dr. Marklin took me up to his ergonomics lab. Two buckets donated by Altec were instrumented to determine the forces impinged on the bucket when linemen climb in and out of the bucket of a bucket truck. The objective was to investigate how different design features of an aerial bucket could reduce linemen's risk of an injury, fall or slip when entering and exiting aerial buckets. Marklin evaluated whether one or two external steps worked the best and also evaluated the value of adding an inside step.

Marklin had cut away the bottom portion of the bucket and then reattached the bucket's lip at the four corners using

In the Marquette ergonomics lab, We Energy's Fred Wentzel demonstrates typical linemen movements and stresses.



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strain gages. Most buckets have steps on the outside of the bucket, so getting up and over when entering a bucket is not too difficult. But because linemen tend to hop down into the bucket, they place most of their body weight on the rim top; and getting out without an inner step is even harder. Marklin has looked at both removable and fixed inside steps that provide an easier transition whether getting into or out of a bucket.

Marklin measured the height of a worker's waist above the bucket's rim, the resultant force on the bucket rim, and the EMG (electromyographic) activity of upper and lower extremity muscles. Sixteen linemen were tested. An inside step lowered the worker's waist above the rim, decreased body weight force on the bucket rim and reduced EMG activity of the triceps.

The most important dependent variable is the percentage of body weight carried on the top of the bucket rim. Without an inside step, a lineman has to exert almost all of his body weight on the top rim. The inside step reduced the force on the rim to one-fourth of the total force.

Marklin works with many line tool manufacturers including Milwaukee Tool in Milwaukee. And working through EPRI Program 62 sponsorship, Marklin and his colleagues, Dr. Mark Nagurka and graduate student Jonathon Slightam, are helping come up with design changes to eliminate many of the nagging irritations of the lineman's job.

When I look at the body of work produced by Marklin and his Marquette University colleagues, past and present, I realize Marquette University research is helping make sure our linemen have the best tools and processes to get the job done while minimizing risk of injuries and saving on the wear and tear of linemen.

Dr. Richard Marklin, with one foot on the inner step, prepares to exit the demonstration bucket.

Rick Bush

Strategic Director

Editor's note: To learn more, contact Dr. Richard Marklin at richard.marklin@marquette.edu or Dr. Lovely Krishen, EPRI technical director, at lkrishen@epri.com.

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(1) Estimate based on Metglas Transformer Optimization Model (2) APPA / NRECA Letter to EPA 27th February 2015 – p. 5 of White Paper in Attachment A

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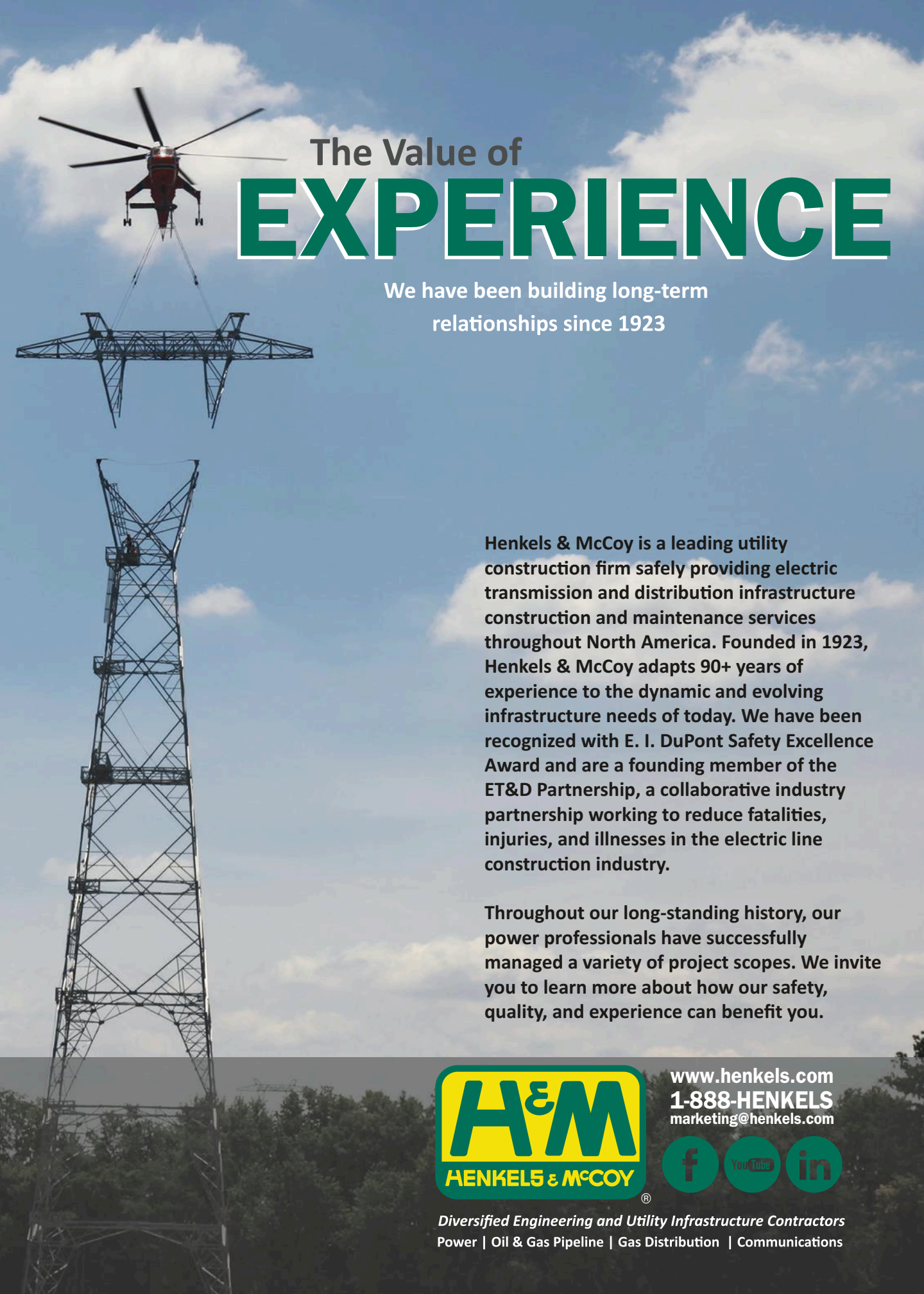

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POWER Engineers Helps National Grid Complete New England East-West Solution

POWER Engineers has helped National Grid overcome a series of complex engineering challenges to complete the last major component of the New England East-West Solution (NEEWS), a suite of electric transmission projects that together comprise the largest improvement to the New England electric grid in many years. The NEEWS projects took a decade to plan, design and construct. National Grid's overall NEEWS investment totaled approximately US$750 million.

National Grid recently completed the Interstate Reliability Project (IRP), which will bring more competitively priced electricity to customers in southern New England. Finished on time and under budget at a cost of approximately $265 million, the project included upgrading several substations, installing 40 miles (64 km) of new 345-kV transmission line in Massachusetts and Rhode Island, and replacing structures and conductor along an older 345-kV transmission line.

Crews string 345-kV conductor using swamp mats as work pads along the right-of-way.

On the IRP, POWER's team of qualified field inspectors and field engineers provided inspection oversight for the construction of more than 200 reinforced concrete drilled shafts, 40 miles of 345-kV overhead lines and three substations. As part of the project, POWER provided detailed engineering for three substations and seven transmission lines.

POWER's environmental services team oversaw the placement of approximately 30,000 temporary swamp mats for the project. These mats served as access routes and work pads along the project's right-of-way in Rhode Island and Massachusetts, and minimized the impact on wetlands and watercourses. These services helped the project comply with National Grid's environmental permits and regulatory agency requirements.

The environmental services team also provided environmental licensing, permitting and compliance monitoring for the IRP. The project required environmental permits from Rhode Island, Massachusetts and Connecticut as well as from the U.S. Army Corps of Engineers, and other state and local agencies.

National Grid hired POWER as its owner's engineer in 2007 for the Rhode Island Reliability Project and for the Massachusetts and Rhode Island portions of the Interstate Reliability Project. POWER ended up supporting many parts of National Grid's overall NEEWS effort, including detailed engineering design, procurement support, construction inspection support, environmental permitting and compliance support, commissioning support and scheduling.

POWER worked hand-in-hand with National Grid's project team to overcome several complex engineering constraints related to the NEEWS projects, including challenging terrain, lengthy stretches of narrow right-of-way, limited footprints for substation expansions, a rigorous sequence of outage windows and a general need for fast, safe construction.

For more information, visit www.powereng.com and www.nationalgridus.com.

ABB Survey Shows Most Utilities Value IT-OT Integration for Asset Management

A global survey of more than 200 executives at electricity, gas and water utilities increasingly believe information technology and operational technology (IT-OT) integration is a key component of any effective asset management strategy. Some 80% held IT-OT integration for asset management as valuable; 58% of respondents either have, or are planning to have, a strategy leveraging the Internet of Things (IoT) for asset management; and 55% reported the importance of asset management has increased over the past 12 months.

Interconnecting things, services and people via the Internet improves data analysis, boosts productivity, enhances reliability, saves energy and costs, and generates new revenue opportunities through innovative business models. The industrial Internet and cloud services also offer the benefit of bringing world-class analytics within reach of smaller production facilities.

For more than a decade ABB has been developing and enhancing process control systems, communications solutions, sensors and software that support the concept of the Internet of Things, Services and People.

"Now more than ever, utilities see the need to bring together once disparate technologies and systems to better understand their increasingly complex asset base and share those insights with the people across the organization in order to improve planning, productivity and safety," said Massimo Danieli, managing director of the grid automation business unit within ABB's Power Grids division.

Survey respondents see numerous benefits in this integration. On a scale of 1 to 5, they ranked better long-term planning (4.86) as the highest priority. Increased staff productivity (4.43), improved safety (3.98) and better use of capital (3.68) rounded out the top five.

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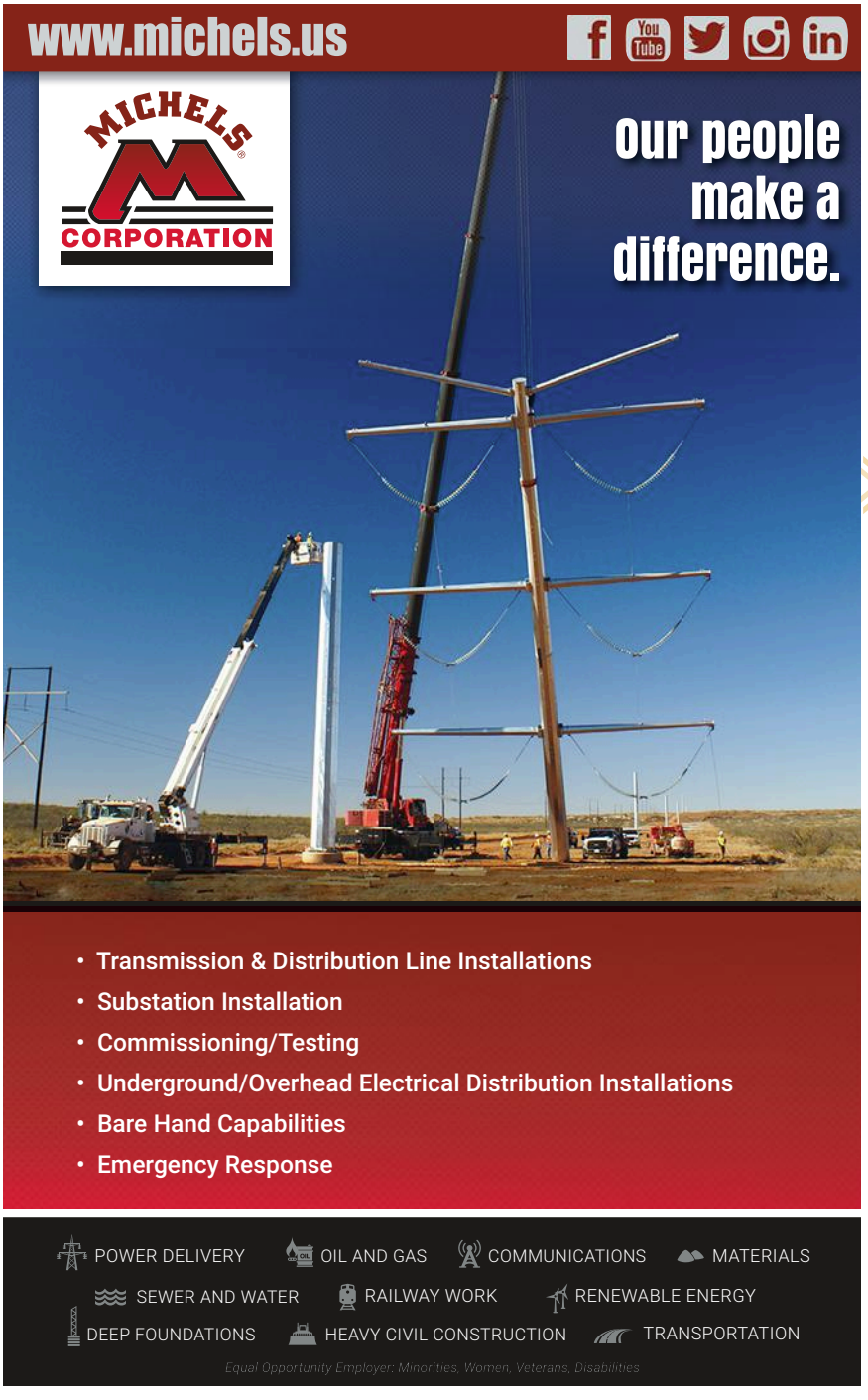
MIT Energy Initiative and AVANGRID Collaborate to Study the Future of the Electricity Industry

Today, the wholesale price of electricity is largely driven by the availability and operating cost of large power plants as well as congestion in the high-voltage transmission system. It does not take into account many of the low-carbon energy technologies that are rapidly being deployed onto the electric grid.

The MIT Energy Initiative (MITEI) — in collaboration with IIT Comillas — is working with AVANGRID, the parent company of New York State Electric & Gas, Rochester Gas and Electric, Central Maine Power and United Illuminating, to create a model that could support New York's Reforming the Energy Vision (REV) plan by simulating how distributed energy resources might impact the power system. This model seeks to identify the scale at which distributed generation becomes beneficial to the grid while taking into account potential impacts on electricity prices, grid reliability and the environment.

MITEI's broader Utility of the Future Study brings together a diverse consortium of leading international companies to address emerging issues in the electric power sector, and uses extensive modeling and analytical tools along with a "first best benchmark" as a means to evaluate and recommend regulatory frameworks and pathways for the ongoing evolution of the power sector worldwide.

Visit mitei.mit.edu.



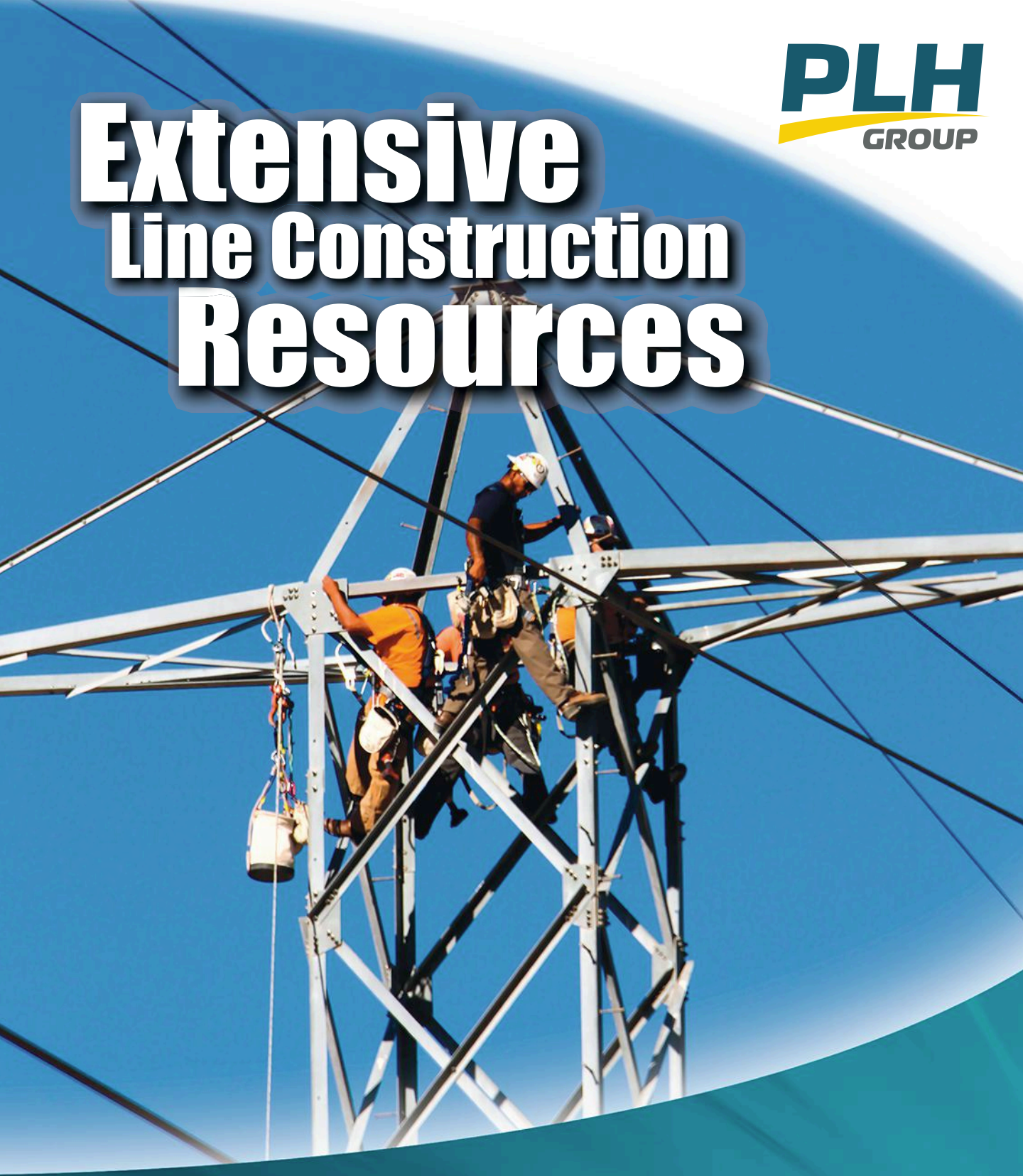
North American Power and Utilities Deal Activity Soars

Merger and acquisition volume and value increased significantly in the first quarter of 2016 both sequentially and year-over-year, according to PwC's quarterly deals snapshot, "North American Power & Utilities Deals: Q1 2016."

The first quarter was the most active for power and utilities deals in recent history, with 22 transactions (with announced deal values greater than $50 million) accounting for $41.4 billion. Comparatively, there were 12 deals totaling $11.5 billion in Q4 2015 and seven deals worth $6.8 billion in Q1 2015.

There was also significant inbound interest from Canada, which is likely to remain as Canadian investors look to the U.S. for growth opportunities. Additionally, as renewable and natural gas generation continues to increase its penetration in the U.S. and as dealmakers look for opportunities to diversify, infrastructure investment is likely to remain a key theme in 2016.

Visit www.pwc.com. TDW



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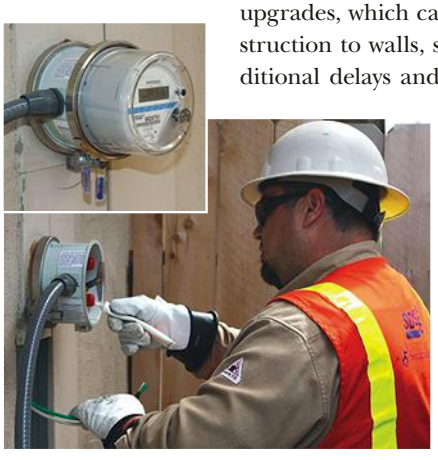
SDG&E Renewable Meter Adapter Saves Time and Money for Solar Customers

Over the last eight months, San Diego Gas & Electric (SDG&E) has helped nearly 3,000 private solar customers collectively save more than US$3 million on the costs to go solar. In August 2015, SDG&E announced its Renewable Meter Adapter (RMA), a technology developed as an alternative for expensive and time-consuming electric panel upgrades that are often required to accommodate solar.

Typically, homes built before 1995 — or nearly three-quarters of San Diego homes — require electric panel upgrades before connecting private solar. These upgrades, which can cost up to $10,000, often include construction to walls, stucco and landscaping, introducing additional delays and permitting requirements. Not only do these upgrades take time, they require intricate electrical work that brings with it safety risks.



The RMA contains a meter collar with a 60-A circuit breaker and a fused disconnect box that can accommodate up to an 11.5-kW system. It also contains the necessary overcurrent protection, which can eliminate the panel upgrade for certain customers.

The RMA can be installed in under an hour, completing work that would have previously taken days and required additional electrical inspections. In addition, SDG&E will operate and maintain the device for the life of the product. Along with the RMA, SDG&E's "fast track" option allows same-day connection of panels, once the panels are deemed safe by the city or county inspector.

For more information, visit sdge.com/rma.

Siemens to Deliver Smart Metering Solution to Austrian Power Suppliers

Siemens is supplying Austrian power utilities Kärnten Netz GmbH and Stadtwerke Kapfenberg in the province of Styria with hardware and software for a smart metering solution for the intelligent recording of electricity consumption data. According to Austria's regulation on the introduction of smart meters, at least 95% of Austrian homes must be equipped with smart meters by the end of 2019. The order comprises a complete system made up of smart meters, secure transmission technology and IT systems for collecting and processing the measured data. It also includes interfaces to the existing infrastructure of Kärnten Netz GmbH, such as the SAP system and the online customer portal.

The data center at Kärnten Netz GmbH in Klagenfurt, Austria, will be equipped with the Siemens smart grid application platform EnergyIP for managing the data by fall of 2016. EnergyIP serves as a data hub that supports the integration of the systems involved — from the smart meter infrastructure to the utility's company-wide ERP system — and transforms the data into relevant information for the business operations of the utility and for its customers. Starting in the fall, the first 10,000 smart meters begin operation as the initial installation of the 95,000 analog electricity meters to be replaced. An option exists for subsequent equipping of the entire network, which will comprise some 345,000 smart meters.

For more information, visit www.siemens.com.

Electric System Upgrades Lead to Shortest Outages in PECO History

As part of PECO's ongoing efforts to provide customers with safe, reliable, affordable and clean energy and energy services, the company invests more than US$500 million to improve its electric system infrastructure through preventive maintenance and equipment upgrades. This work led to customers experiencing the shortest average outage duration and second fewest number of outages in company history last year. Specifically, during the last three months of 2015, PECO completed more than 100 projects to enhance electric reliability for customers. This work is in addition to 580 projects completed during the first three quarters of 2015, totaling nearly 700 projects.

From October through December, 22 corrective and preventive maintenance projects were completed as part of ongoing system monitoring. PECO also continued to upgrade and install reclosers throughout the region. There are nearly 1,700 reclosers on PECO's system, which prevented more than 580,000 sustained power interruptions for PECO customers in 2015.

To help prevent vegetation-caused outages, PECO also installs reinforced tree-resistant aerial electric lines. With nearly 11,000 ft (3,353 m) of this type of wire installed in 2015, PECO now has more than 19 miles (31 km) installed across the service territory.

Rigorous tree trimming also continues to limit the number of power outages caused by trees and other vegetation. In 2015, the company invested around $36 million on tree trimming and other vegetation removal around approximately 2,800 miles (4,506 km) of aerial power lines along the electric transmission and distribution system.

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Tucson Electric Power Reduces Call Handling Time with Oracle Utilities Customer Care and Billing System 2.4

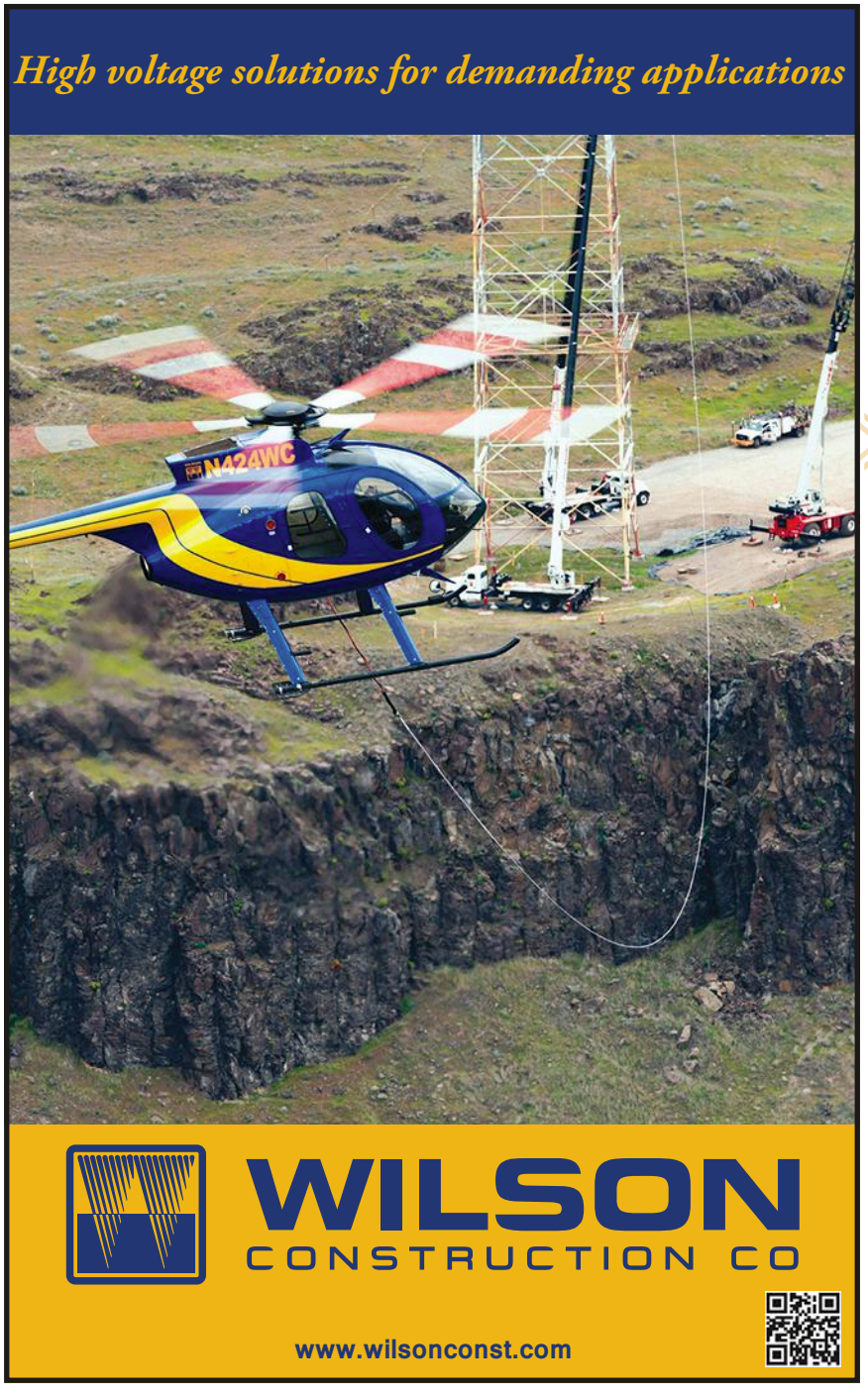
Tucson Electric Power (TEP), which delivers power to more than 414,000 customers in Tucson, Arizona, U.S., has upgraded its customer information system to enhance its customer service. Working with Cognizant and Origin Consulting to upgrade to Oracle Utilities Customer Care and Billing 2.4 Service Pack Two, TEP is able to leverage its existing Oracle investment and ensure compatibility with its enterprise software, including its meter data management system.

With the upgraded Oracle solution, TEP has reduced the average call-handling time by 10 seconds, received new postal discounts by implementing mail stream for customer letters and increased operational efficiency. Oracle Utilities Customer Care and Billing 2.4 also enhanced TEP's visibility of business performance and operations through solution features such as an intuitive user interface, online help, and complete and immediate access to customer account histories.

Oracle Utilities Customer Care and Billing 2.4 enabled more than 50 new features for the utility, including meter-to-cash analytical reporting and report standardization, leveraging integration with Oracle Business Intelligence Enterprise Edition.

The Oracle solution also included encryption features that enabled the utility to reduce risk by allowing it to encrypt sensitive data.

Visit www.oracle.com.



NOJA Power Supplies Integrated SCADA Solution

NOJA Power has successfully provided Ampla (Enel Group) with an integration solution using optical-fiber connections and Wi-Fi. This application provides full remote access via SCADA software as well as local access using the CMS Software and Recloser App through a local network with wireless connection.

Ampla Electricity Utility contacted NOJA Power for an integration solution involving OSM15 automatic circuit reclosers (ACRs) with RC10 controls to address the protection and automation of different feeders. NOJA Power and Ampla already have a long-term partnership for the supply of ACRs. The focus of the project was to determine the correct topology and communications equipment for the SCADA system.

The implementation involved the IEC-60870-5-104 communications protocol, which is not widespread in Brazil, although is fully supported by RC10 and RC15 controllers.

Visit www.nojapower.com. TDW

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21st Century Public Purpose

By **John Baker**, *Energy Editor*

Recently, while going through a box of old files as part of a well-intended-but-little-result "spring cleaning," I came across a note I had written to myself in 2002 as the newly minted chief strategy officer at Austin Energy. At that time, Texas was in the first year of retail competition and the Austin City Council was asking Austin Energy to pursue an aggressive renewable energy agenda while redoubling its energy-efficiency efforts.

As a strategist, I have always felt that one could not come up with the right answers unless one was asking the right questions. My note contained some of the questions that I thought were critical at the time: Do we have a role beyond the construction, operation and maintenance of the electric system? Is our public purpose tied solely to infrastructure?

I wish I could tell you that we definitively answered these questions in ways that addressed all our challenges. I cannot. Although I felt we crafted a solid set of strategies for Austin Energy at that time, we did not fully address these questions.

Now 14 years later, in the face of the rapid development and deployment of distributed energy resources, these questions remain at the forefront for the electric utility industry and yet the answers seem just as elusive. This is particularly true about the question of public purpose.

Today, there is much discussion about the need for a new electric utility business model. While the traditional utility business model may be in dire need of change, perhaps we, as a society, should first determine what should be the public purpose for electric utilities in the 21st century. If we were to settle that question, the issue of business model might become more straightforward.

Why is this important? It is important because public purpose was the rationale for granting utilities the right to provide uncontested electric service in the first place. Monopoly status was provided in exchange for regulatory oversight that, in turn, defined much of a utility's business model, including what type of services could be offered, what could be charged for each service and what type of customer could receive each service. It also defined how a utility could bill and collect revenue, and much more. This regulatory compact defines what a utility can do and what it cannot do.

This public purpose has changed over time in keeping with evolving societal perspectives. In the early years of the industry, the public purpose was getting the miracle of electric power to as many people as possible. To that end, some jurisdictions even allowed utilities to sell electric appliances to their customers and the federal government underwrote the electrification of underserved rural areas.

When economies of scale no longer translated into lower customer bills, and a growing awareness of environmental impacts teamed up with energy security concerns to challenge and alter fuel mixes, most utilities were asked to support customer-sided energy-efficiency measures. Investing funds to help one's customers buy less of one's product is not a function that any competitive business would intentionally undertake, but it was pursued under an evolving utility public purpose.

Today, the public purpose has been challenged further with utility customers installing competing (mostly solar) generation. In response, many utilities are considering or pursuing business ventures in rooftop solar, community solar, on-bill photovoltaic financing, microgrids, customer-sited energy storage and more.

With all this activity outside the bounds of the traditional utility public purpose, many utility regulators have been accused of failing to keep up with the rapidly evolving energy technology landscape. In stark contrast, regulators in New York and California are boldly attempting to redefine the public purpose for distribution systems.

In Chicago, Illinois, ComEd is also exploring new frontiers. Similar to New York and California, ComEd is looking at whether its distribution grid can become an energy platform that supports multiple parties offering distributed energy resource options. ComEd is also investigating how it might be involved in microgrids, among other things.

I've been reading about the initiatives taken at ComEd in several dailies and have been impressed with the direction of CEO Anne Praggiamore. In speaking about her company's role in microgrids, she said she doesn't believe it's the utility's job to build a microgrid for a private manufacturing firm. Rather, if there's something that benefits the general public, ComEd is willing and ready to do its part. While Pramaggiore appears to have an understanding of her company's public purpose, there is little consensus nationally.

Ultimately, regulatory and legislative processes will decide the 21st century utility public purpose. Many things may be attributed to these processes, but extraordinary speed is not one. In contrast, the customer and technology revolution is not waiting.

I believe a sense of urgency is needed in defining this new public purpose, for I fear if this question goes unanswered for another 14 years, the resulting electric system, while hosting all manner of new business model, may serve questionable public purpose. TDW

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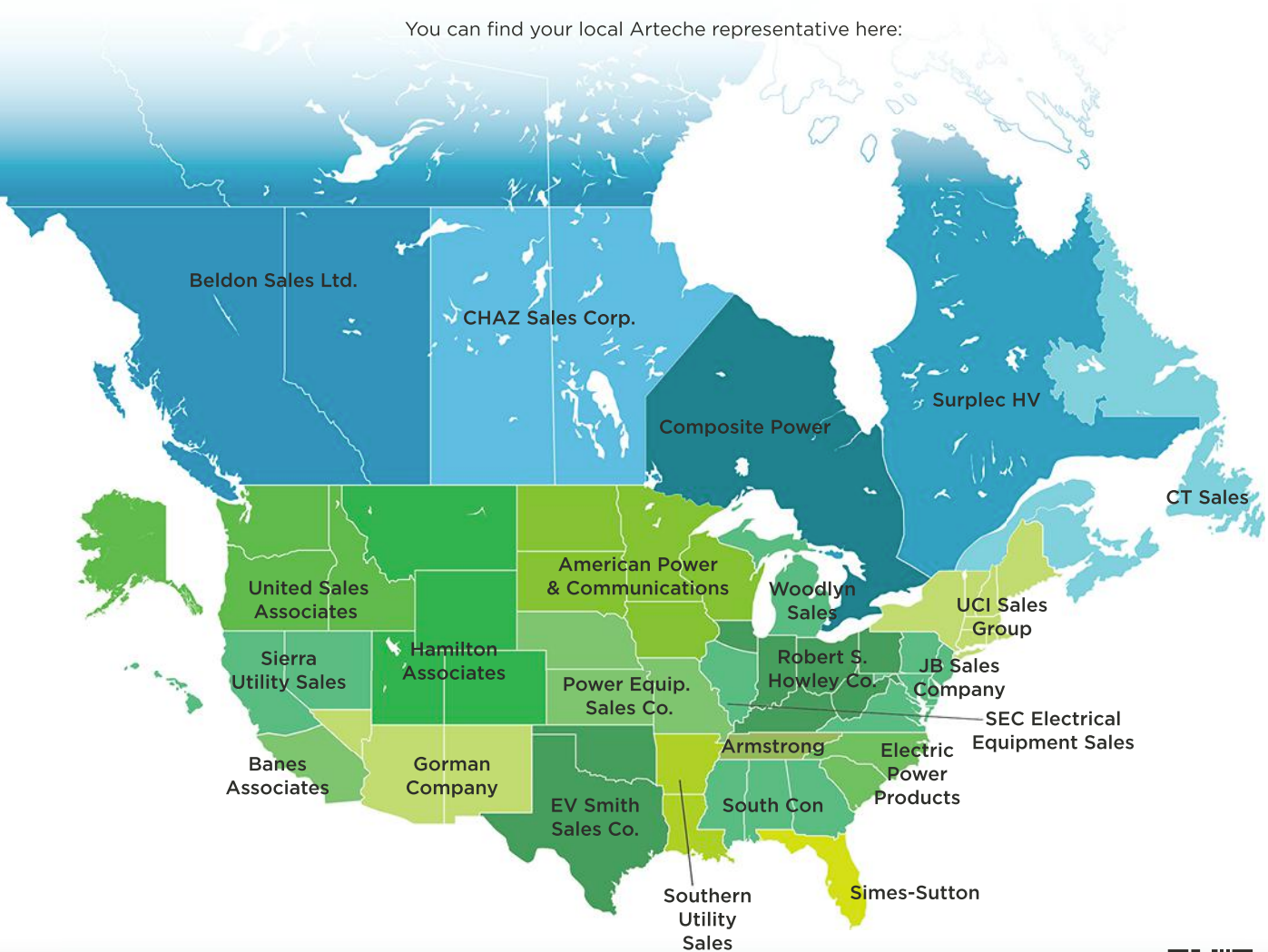

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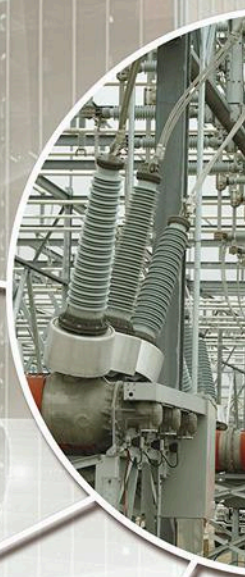

Asset Management

Data is the foundation of a new platform for business intelligence and data analytics.

By **Patrick Graves**, **Shay Bahramirad** *and* **Joseph Svachula**,
Commonwealth Edison

Utilities face a significant challenge in prioritizing investments across a myriad of transmission, substation and distribution equipment to make most effective use of limited capital and operating budgets. Traditionally, Commonwealth Edison (ComEd), a unit of Exelon Corp., has relied on asset health and project risk scoring frameworks to facilitate this prioritization. These are quantitative methods designed to target the worst performing assets and most impactful projects across the system. These methods have produced notable improvements in reliability, environmental and safety performance.

However, ComEd is now benefiting from the growing population of remotely monitored and controlled grid devices, primarily as a result of advanced metering infrastructure and distribution automation installations. To extract the full value from these investments, ComEd is in the process of designing a platform to leverage this growing volume of data. The platform — Business Intelligence and Data Analytics (BIDA) — will be designed in collaboration with Baltimore Gas and Electric Co. and PECO (ComEd's sister utilities) and promises to serve both as the foundation for data storage and access across the enterprise, and to provide the processing tools needed to perform advanced analytics. This will translate to more precise asset health assessments and more targeted asset investment planning.

Asset Management

The rapid U.S. grid expansion in the 1950s and 1960s was followed by a period of decelerated development due to low demand growth. The 1980s and 1990s saw limited investment in system maintenance across the industry, with work being biased toward "extent of condition" type programs (that is, addressing populations of a given asset known to be prone to failure).

These programs took a limited view of asset health and failed to recognize variations among equipment that may have developed over time. While these programs are still appropriate for some assets, reaching to the next layer of asset risks requires a more granular understanding of asset conditions.

In 2007, ComEd began revamping its approach to asset management with the introduction of health indices and risk scores. Health indices assess the condition of individual assets rather than targeting equipment by age or model. Assets with poor health scores are reviewed with the appropriate engineering team and projects are developed to address the identified issues. These projects are then assigned risk scores to provide a measure of criticality that can be used for prioritizing work across the service territory. These asset health and project risk scoring frameworks have continued to evolve as ComEd incorporates its lessons learned over time into these analyses.

Currently, ComEd calculates health indices on a quarterly basis for major transmission and substation equipment. These are based on several equipment-specific factors. For example, the factors for oil circuit breakers include maintenance history, age, power factor test results, oil test results, timing performance, resistance and loading. Each piece of equipment is rated against appropriate factors, followed by weighting and aggregating of the factor ratings, to obtain the final health index, which is fit to a scale from 0 to 100.

For assets with poor or very poor scores (<50), projects are developed to address the condition issues. For transmission and substation equipment, the data needed to perform this analysis is compiled from various systems including supervisory control and data acquisition, PI Historian, Asset Suite, Cascade and additional homegrown databases.

Data collected from sensors in intelligent substations will allow engineers to use predictive algorithms to better direct maintenance activity.

Distribution equipment requires a modified approach to the health index framework. This is because of the significantly larger asset population and lower asset replacement cost for distribution equipment as compared to substation and transmission equipment. For these reasons, the health of these assets is more appropriately assessed using reliability metrics. Metrics such as system average interruption frequency index (SAIFI), customer average interruption duration index (CAIDI), and customers experiencing multiple interruptions (CEMI) are measured at the feeder level to identify worst performing circuits for further engineering analysis and preventive and/or corrective maintenance investment.

For all ComEd electric system investments (distribution, transmission and substation), the annual business planning process creates projects or programs of work to address ComEd's lower-performing asset population as identified through the asset health process. Once projects and programs are developed, they are assigned a single risk score based on probability and consequence of risks mitigated by the investment. This risk score is calculated using ComEd's risk model and ultimately allows work to be compared on a common platform, regardless of work type or voltage class.

Leveraging Data

ComEd's investment in analytics will leverage data from smart meters and distribution automation to identify asset risks more precisely. Several analytics use cases are now being pursued and many more are expected to be identified as analytics develop and additional sensing devices are deployed.

ComEd is designing the platforms and analytical tools needed to integrate real-time data streams into static data sets for transmission and substation equipment to enable a more robust asset health scoring system. This system is expected to provide several advantages over the current, purely static view:

- Equipment health indices will be updated in real time while taking into account system configurations.
- The system will be able to send automated notifications to spur timely preventive or emergency maintenance.
- Engineers and asset managers will be provided with more detailed and timely data to update their asset management strategy.

Data from the installed smart meters and distribution automation devices also will provide unprecedented visibility into distribution system conditions. Initially, this data will be used to develop health indices for entire circuits — similar to the current

Substation equipment is inspected, and the results are used as one of many inputs in the derivation of equipment health indices.

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The Energy Infrastructure Modernization Act

The passage of the Energy Infrastructure Modernization Act (EIMA) by the Illinois General Assembly in 2011 marked a significant advancement in ComEd's asset management programs, especially with respect to the distribution system. EIMA enabled ComEd to launch a systemwide portfolio of investments to replace aging infrastructure and to modernize the grid. The investments significantly accelerated the proactive replacement of distribution assets and further allowed for the deployment of technologies that support better distribution asset condition visibility.

ComEd linemen work to replace underground distribution cable through a program enabled by the Energy Infrastructure Modernization Act.

The five-year EIMA infrastructure programs primarily address replacing and rejuvenating aging distribution assets. The criteria for inclusion of specific projects or equipment in these programs vary from one program to the next, but generally include reliability history or inspection findings. An example of this is the underground rural distribution "Assess, Treat, Replace" program, where fused half-loop circuit candidates are selected based on the number of fuse operations experienced over the past two years as a result of cable faults. For the worst performing circuits, if cable rejuvenation is feasible, cable injection work is performed to fill voids in the cable insulation and to protect against future cable faults. Cables that cannot be injected are replaced.

Another objective of the EIMA programs is deployment of new smart grid technologies. This mainly includes the replacement of all ComEd's retail electric meters with smart meters as well as expansion of distribution automation (DA), among other programs. Through the DA program, S&C Electric and G&W Electric sectionalizing devices with remote communications capabilities are strategically installed on 12-kV and 34-kV distribution feeders to detect issues and automatically reroute power to minimize customer impact. The modernization programs also include the development of 10 intelligent substations over five years through the upgrade of relays and monitoring and control systems.

This accelerated investment portfolio has reduced ComEd's system average interruption frequency index from 1.54 interruptions per year in 2011 to 0.88 interruptions per year in 2015. In fact, 2013, 2014 and 2015 have been the three best years of reliability in ComEd's history. Now a unique opportunity has emerged to improve asset management practices.

practice for transmission system equipment evaluation — by aggregating smart meter data to the distribution transformer level and assessing the loading as well as voltage conditions for each transformer on a circuit. These data points can then serve as one of many factors in the health index calculation for that specific circuit. The circuit ranking tool becomes more robust as additional factors are identified that will further direct engineering analysis to reduce asset risk systematically.

In addition to supporting circuit ranking, this data can be used directly to address abnormal conditions proactively on an individual asset basis. For instance, ensuring equipment is not overloaded can increase life expectancy and enable optimal use of distribution assets. Similarly, overvoltage and undervoltage conditions can be identified and managed to improve the quality of service as well as reduce equipment wear.

Failure Prediction

Analysis is underway to identify patterns and relationships to support predictive capabilities. Preliminary studies have identified a specific voltage profile that may be related to transformer failure. Although too early to declare statistical significance, several cases have been identified where aggregated smart meter data show voltage spikes followed by sustained overvoltage conditions roughly one month to three months before transformer failure.

By studying this relationship, predictive models could soon support proactive replacement of transformers linked to this voltage profile. Similarly, short-duration undervoltage conditions have been found to precede sustained tree-related outages. Detecting this pattern automatically would enable more timely and targeted vegetation management and reduce outage frequency.

As analytics improve, the signatures of specific equipment failure modes could be differentiated. A fast-leaking transformer might be differentiated from that of a slowly deteriorating one, thus allowing crews to be dispatched first to the more critical risk, and accordingly mitigating environmental damage and preventing a future outage. These examples are a few of the many identified use cases being analyzed, with many more still to be conceived.

With several hundred thousand distribution transformers on the ComEd system, condition-based maintenance will allow for targeted use of resources to improve reliability.

Phasor Measurement Units

In line with deploying grid-sensing technologies and data analytics, ComEd is exploring the potential for phasor measurement units (PMUs) to provide visibility down to the alternating-current cycle level. The utility has been involved in the deployment of synchrophasor technology on its transmission system through participation in a PJM Interconnection-led project. Progressing to a more granular application of these devices, PMUs could be deployed on distribution feeders to monitor the operations and condition of nearby devices precisely. It is possible measurements of open and close operation timing for reclosers and automatic switches could trigger alarms when sluggish operations are detected.

PMUs also may detect abnormal operating patterns such as an excessive capacitor switch or recloser operations. This information could point to a feeder problem or control malfunction that could be addressed proactively.

Building the Platform

The development of a robust BIDA platform is being recognized within the Exelon Utilities family as a key strategic initiative that will enable ComEd and its sister utilities to reap further benefits of their smart grid investments. As ComEd progresses toward data-driven asset management, each of the applications being considered clearly depend on the ability to access timely and vast sets of data, and to manipulate them into actionable intelligence using constantly evolving analytical tools.

The BIDA platform is being carefully designed both to serve as the enterprisewide system for universal data storage and access as well as to provide the processing tools needed to support advanced analytics. Flexibility and scalability are core requirements being built into all aspects of this system to accommodate the data streams.

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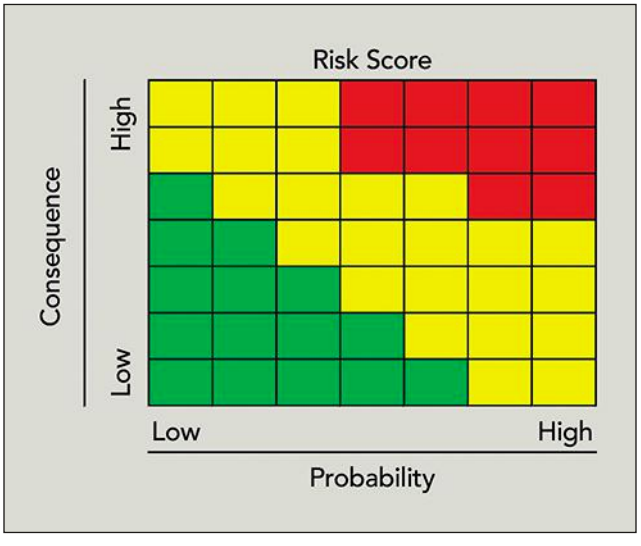
As analytics are developed to extract additional value from the data being collected, equipment alarms could be configured to bring issues to the attention of control center operators in a more timely manner.



The ComEd risk matrix is used to assign risk scores to projects based on the likelihood and impact of the risks they intend to mitigate.

To structure the near-term design, sourcing and deployment of this system, uses cases and system requirements are currently being evaluated and prioritized within five functional domains: advanced metering infrastructure, transmission and distribution grid infrastructure, smart energy services, customer experience and business support.

The transmission and distribution grid infrastructure domain focuses heavily on improving analytics related to asset health and investment planning, which are core components of strategic asset management.

Final Thoughts

With so many aspects of daily life dependent on the presumption of reliable electric service, the critical task of managing the nation's aging transmission and distribution infrastructure must continue to evolve to ensure resources are applied precisely when and where they are needed most. ComEd has come a long way in advancing its asset management strategy over the past decade. The introduction of health indices and risk scores nine years ago delivered a step-change improvement in the utility's ability to direct investments strategically to address asset risks.

With the passage of the Energy Infrastructure Modernization Act in 2011, the system was propelled forward in terms of overall infrastructure condition, and smart grid technologies were deployed broadly across the service territory. Looking forward, ComEd plans to raise the bar for asset management by leveraging the unprecedented level of visibility into system conditions that is afforded by the smart grid. This is an exciting time for innovative and analytical minds to collaborate in driving the next evolution in asset management. TDW

Patrick Graves (pat.graves@exeloncorp.com) is a senior project manager in ComEd's smart grid and technology group. In this role, he focuses on developing service offerings around innovative smart grid technologies and supports Exelon's efforts to strengthen its data analytics capabilities. Graves previously served as a project management office consultant for large-scale infrastructure modernization programs, managed energy-efficiency programs for a leading energy service company, and developed power market forecasts and asset valuation models.

Shay Bahramirad (shay.bahramirad@comed.com) is an IEEE senior member and the director of smart grid and technology at ComEd, where she serves as a strategic business leader supporting the transformation to the 21st century power grid and the new energy economy. She is leading the smart grid organization across ComEd to develop the vision, business models and investment strategy of the grid for future initiatives such as emerging technologies, microgrids and smart cities.

Joe Svachula (joseph.svachula @comed.com) is vice president of engineering and smart grid at ComEd, where he is responsible for the utility's engineering planning and reliability programs as well as developing and implementing operation plans for the installation of ComEd's smart grid projects and other related technologies. He is a senior member of IEEE and former co-chair of the 2014 IEEE Power & Energy Society T&D Exposition.

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Transforming DG

A review and insights of trends in distributed generation integration on the electrical system.

By **Julio Romero Aguero**, *Quanta Technology*

Arguably, the key transformational trend in the power industry over the last decade has been the integration of distributed generation (DG) in transmission and distribution grids. DG proliferation is impacting planning, engineering, operations, business, regulatory and policy aspects of transmission and distribution grids, and is leading to numerous paradigm shifts.

The industry has experienced significant developments in the area of DG over the last 10 years, and several emerging trends are now shaping transmission and distribution grids.

Early Photovoltaic

The proliferation of DG technologies, particularly photovoltaic (PV) systems on distribution grids, was initially approached by electric utilities only from an engineering analysis standpoint, with an emphasis on identifying localized impacts of utility-scale facilities on feeders and substations. In this early stage, the industry focused on the distribution grid because it had not been designed to integrate generation facilities, and in this regard, DG represented a special and challenging case to address.

Transmission grids, on the other hand, had been designed to accommodate large generation units; therefore, DG integration did not represent a challenge, given the relatively small installed capacity of these facilities when compared to traditional centralized generation.

The initial DG integration studies on distribution grids, many of them conducted eight to 10 years ago, helped to identify limitations in modeling and simulation methodologies as well as software tools, and enabled the industry to determine typical solutions that could be included in a portfolio of mitigation measures to facilitate integration of utility-scale facilities (installed capacity on the order of a few megawatts). Some of the needs identified at the time included going beyond performing steady-state snapshot analyses (for a few specific system loading and DG output conditions) and, instead, evaluating a wide variety of operating conditions, which led to the introduction of time-series analyses.

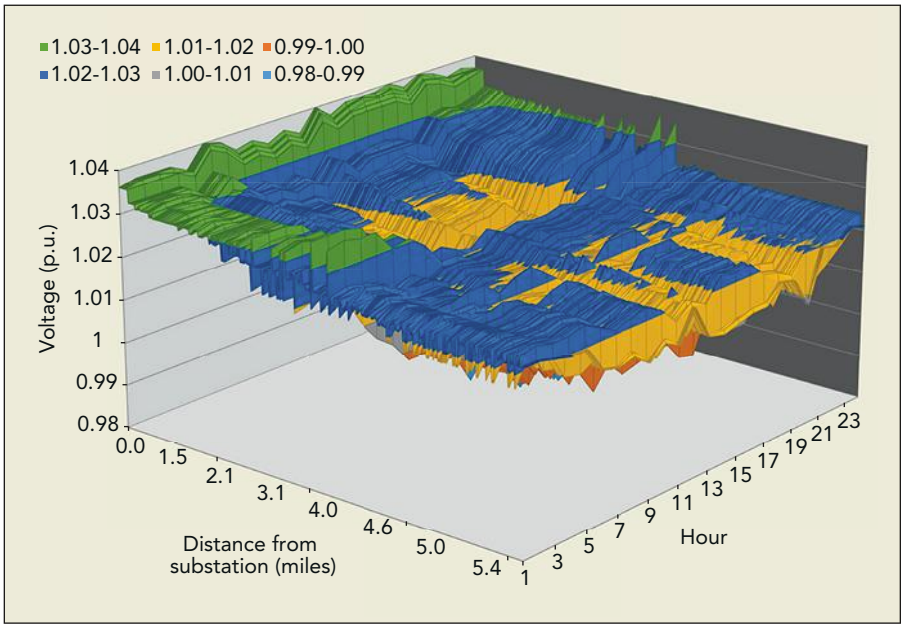
Furthermore, the industry concluded there was a vital need to study the impact of dynamic and transient phenomena to understand how DG output variability and islanding could affect distribution grid planning and operations. This represented an important challenge from two perspectives. First, utilities did not have enough resources with the required training to conduct this type of specialized studies. And second, most commercial modeling and simulation tools typically used in distribution planning and engineering activities did not have the capabilities to perform this type of analyses.

As a result, the first wave of enhancements to methodologies and software tools was focused on facilitating this type of engineering analyses. It is worth noting these studies approached the subject from a deterministic perspective (that is,

DG impact studies at known feeder and substation locations). During this first stage, interest was largely in utility-scale facilities, while small DG, such as residential PV, received little to no attention because its individual relative size (a few kilowatts) did not represent an important problem for distribution grids.

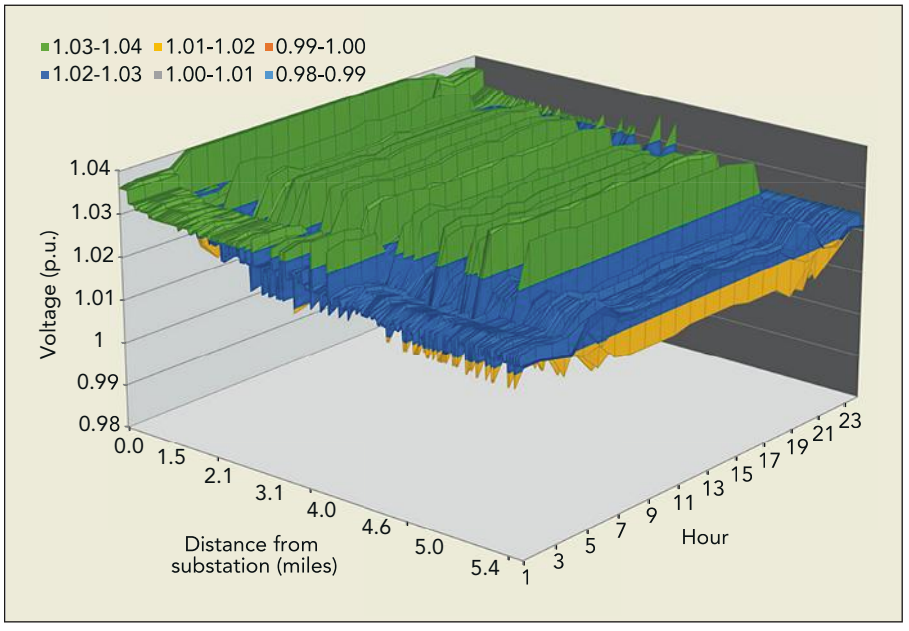
Aggregation Matters

As DG continued proliferating, utilities started paying more attention to the cumulative effect of small-scale DG. While it is true a few residential PV plants do not represent a problem for distribution feeders, the aggregated effect of hundreds or thousands of units could create problems that need to be studied. This need led to the introduction of a second wave of methodological improvements and software tools.

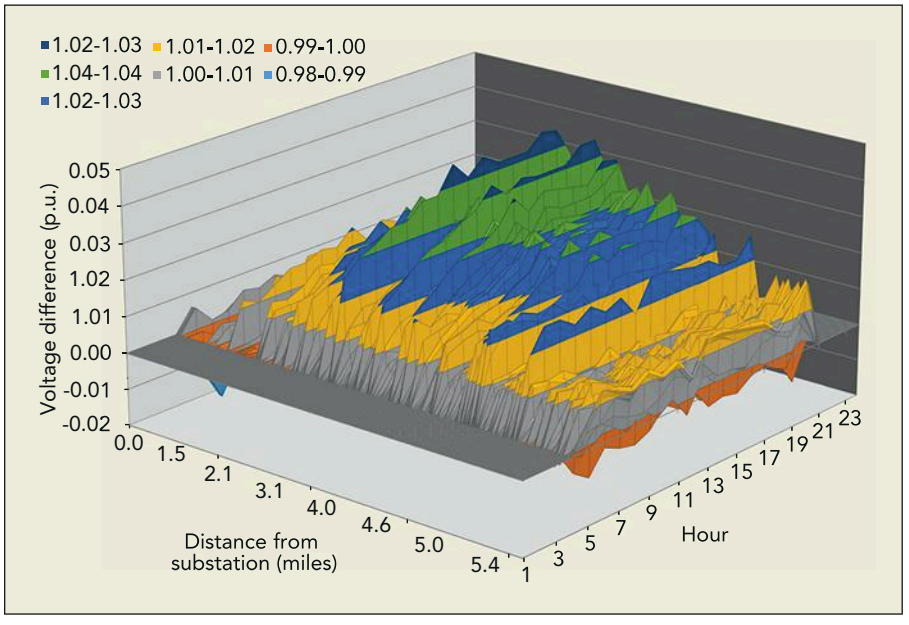


Sample results of PV integration analysis shows the feeder voltage before PV interconnection. Voltages for each feeder node are sorted by their distance from the substation.

The second wave of improvements included the concept of hosting capacity, that is, the maximum DG capacity that can be integrated into a distribution feeder or substation without causing major deterioration of operation conditions and without the need for major infrastructure improvements. This wave also focused on the industry's need to move beyond deterministic studies and conduct probabilistic analyses to



Sample results of PV integration analysis shows the feeder voltage after PV interconnection.



Sample results of PV integration analysis shows the feeder voltage difference due to PV interconnection.

consider the uncertainty about the future location of residential DG units, which is mostly unknown and difficult to predict with accuracy.

Among others, the need for conducting hosting capacity studies and being able to study a variety of locations and penetration levels led to the introduction or enhancement of scripting capabilities in software tools. These scripting capabilities provided the ability to code instructions and routines using a well-known programming language such as Python or Visual Basic, and to perform hundreds or thousands of analyses of interest such as power flow and short-circuit calculations.

This methodology enabled utilities to evaluate the impacts of residential PV proliferation on distribution feeders by simulating a variety of PV penetration scenarios for a group of feeders for each hour of selected days of interest. The spatial distribution of PV plants along the feeder could be evaluated a statistically significant number of times for each penetration level.

Impacts and Benefits

The aforementioned methodology and software tool improvements are notable and significantly facilitated the industry's ability to perform DG integration studies. However, some challenges remain today, such as being able to use the same type of computational models for conducting all studies of interest: steady state, time series, dynamic, transient and protection. Currently, some of these studies require using different software tools and building duplicate models. This is an important limitation most North American distribution software developers still need to focus on, but already has been addressed by some of their European counterparts.

The next stage in the DG evolution is growing interest from utilities, regulators and the industry at large in updating processes, standards and overall distribution practices to consider the impacts and potential benefits derived from DG adoption. Moreover, transmission system operators have started to pay attention to the aggregated effect of DG proliferation in distribution grids, previously mostly negligible from a bulk power system point of view. This has led to growing interest in DG being part of a utility's portfolio of solutions to address transmission and distribution planning needs.

For instance, as requested by state law Assembly Bill 327, the California Public Utilities Commission (CPUC) requested the state's investor-owned utilities to file distribution resource plans by July 1, 2015, that explain how distributed energy resources (DERs), including DG, are proposed to be used in daily operations and long-range distribution grid and investment plans.

AB 327 defines DERs as "distributed renewable generation resources, energy efficiency, energy storage, electric vehicles

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and demand-response technologies." This is leading to the development and introduction of new methodologies and tools to address aspects such as spatial load forecasting and distribution locational marginal pricing.

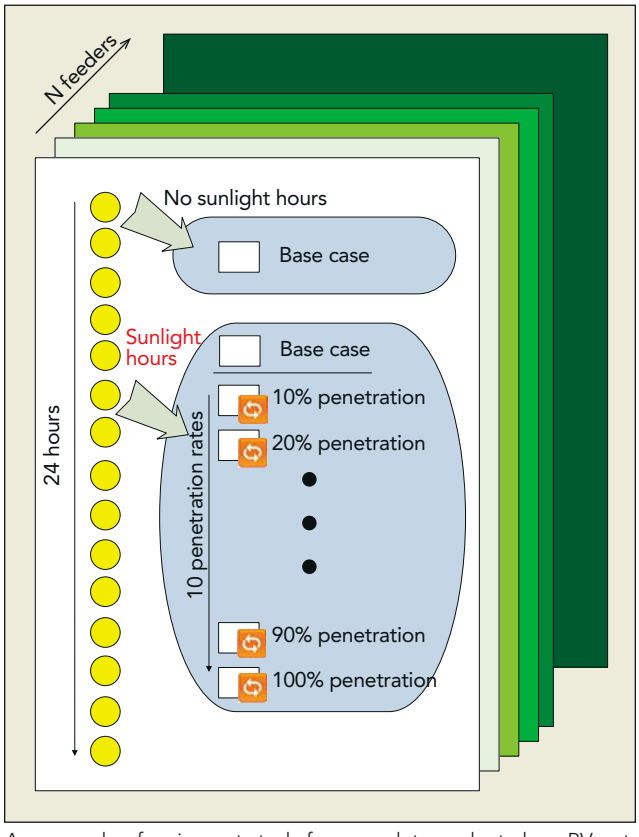
Standards and Policies

On the standards side, IEEE has been leading the review and expansion of the IEEE 1547 Standard for Interconnecting Distributed Resources with Electric Power Systems, which is used as an engineering reference by several U.S. states and countries around the world. The significant changes in technology, DG proliferation and utility practices urged a revision and update of the standard to address aspects such as distribution voltage regulation and control, smart inverter functionalities and provision of ancillary services using DG.

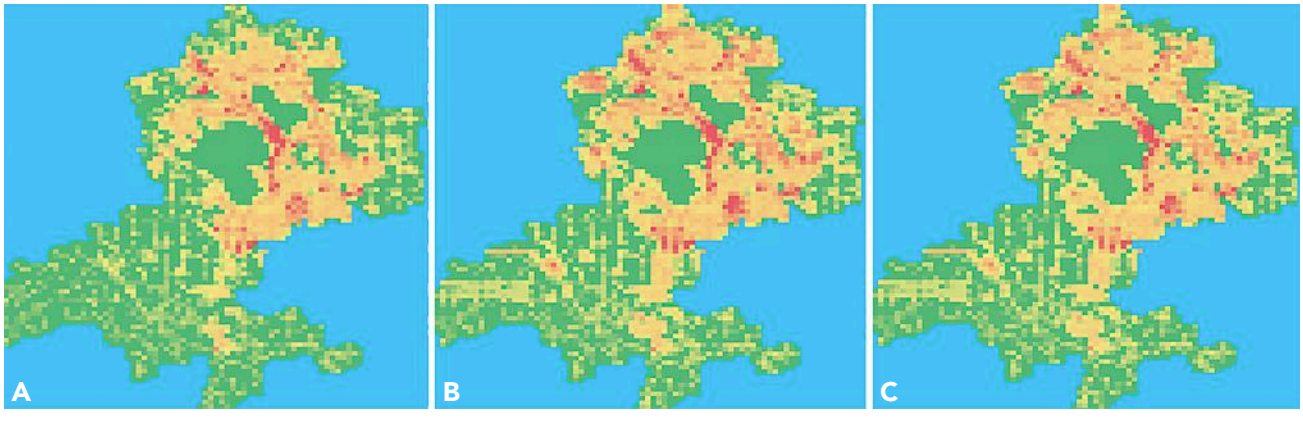
On the transmission side, the aggregated effect from distribution-level DG has started to become more noticeable and to draw attention from system operators. Perhaps the most well-known example is the effect the infamous "duck curve" is forecasted to have on the grid operated by the California Independent System Operator. This has led to growing interest in studies to address how proliferation of renewables in distribution grids could affect transmission system operations and planning, which in turn has prompted the development and introduction of new techniques to aggregate distribution-level DERs and account for the effects of output variability.

One of the most recent and ongoing stages of this evolution is the significant interest in business, regulatory and policy aspects to incorporate DG pricing adequately, particularly PV, into electricity rate design and existing net energy metering (NEM) programs. The proposals in this area are diverse and, at their core, aim to ensure utilities recover investments required to build, maintain and operate the grid while providing fair pricing to customers and distribution-level DERs. This includes several proposals:

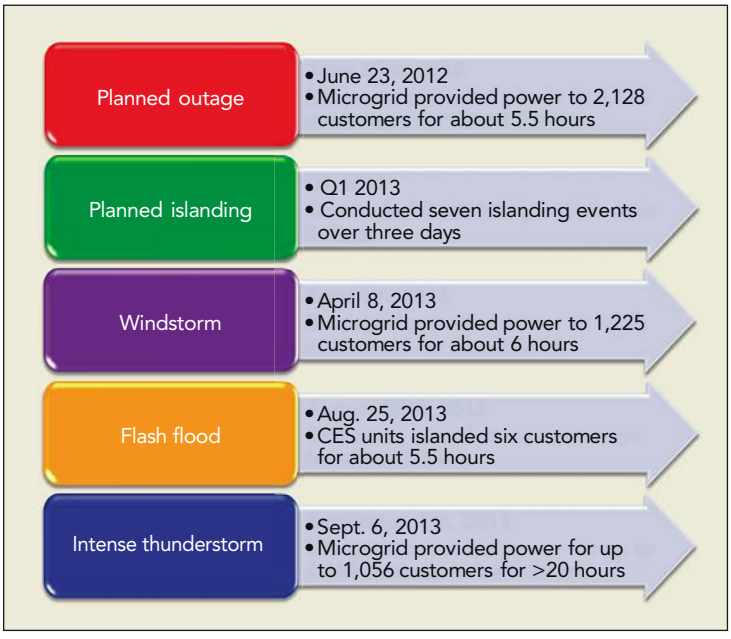
• *Review existing NEM rules.* During Q3 2015, 19 states — including Massachusetts, New Hampshire, New Jersey and New York, among others — were considering changes and clarifications to NEM rules. Some of the most important developments in 2015 occurred in this area, including the Hawaii PUC's decision to close Hawaiian Electric Co.'s NEM program to new participants and the introduction of two new tariffs: a grid-supply option and a self-supply option. Lastly, on Jan. 28, 2016, CPUC voted to adopt the proposed NEM successor tariff, known as NEM 2.0, which includes two substantive changes: defining non-bypassable charges (NBCs) and remov-



An example of an impact study framework to evaluate how PV output affects a selected set of distribution feeders.



An example of the results of potential proliferation of residential PV in a spatial load forecasting study. Plot A shows annual peak loads for a service territory, which has been divided into a grid of small areas; plot B shows projected annual peak loads (20 years into the future) when no PV proliferation is considered; and plot C shows annual peak loads when proliferation of residential is accounted for. The red small areas show greater peak loads than those areas in orange and yellow; green small areas show no loads (greenfield). The red ellipses show examples of small areas where peak demands are expected to decrease because of PV proliferation, for this particular example.



Examples of resiliency improvement experiences derived from implementation of San Diego Gas & Electric's Borrego Springs microgrid. Courtesy of SDG&E.

ing incentives for disadvantaged communities. It is expected the NBC leads to reducing the value of energy exported to the grid by approximately 2 cents/kWh to 3 cents/kWh.

• *Introduce fixed charges and demand chargers.* Fixed charges, in particular, received significant attention in 2015, with 26 open dockets in 18 states — including Missouri, Kansas, Arizona and Wisconsin, among others. States discussing residential demand charges include Arizona, California, Kansas, Oklahoma and Texas. A key development in these last two areas was the Nevada PUC's decision to establish new NEM rules as contemplated by Senate Bill 374. Over five years, the basic service charge will grow in gradual increments; each one will be accompanied by a related decrease in the energy charge. At the same time, the credit for energy delivered by NEM customers will decrease.

• *Determine the "Value of Solar" (VOS).* During Q3 2015, 12 states published, proposed or had ongoing regulatory discussions on the proper value of DG. An example of this initiative is a comprehensive study conducted for the Maine Legislature, which looked at 13 cost-benefit factors in five categories, including avoided market costs (avoided energy cost, avoided generation capacity cost, avoided residential generation capacity cost, avoided natural gas pipeline cost, solar integration cost, avoided transmission capacity cost, avoided distribution capacity cost and voltage regulation). The last five are societal benefits or externalized factors, including net social cost of carbon, net social cost of sulfur dioxide, net social cost of nitrogen oxides, market price response and avoided fuel price uncertainty.

• *Address solar ownership aspects.* Third-party ownership fi-

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nancing of PV was responsible for 72% of all installations in 2014; however, this practice is either not allowed or its legality is unclear in close to 25 states. Delaware, New Hampshire and North Carolina engaged in discussions regarding third-party ownership. An additional trend included efforts from utilities in New York, Georgia, Arizona, Texas and North Carolina to own and operate PV plants. These efforts include operation through unregulated partners and through pilot programs to own solar arrays installed on their customers' roofs.

Proliferation

Finally, on the emerging trends side, much of the attention has been devoted to two areas: the introduction of new concepts and technologies based on the use of DG and DERs in general, such as microgrids, and the development of new business models that enable customers, utilities and the industry to take advantage of the potential benefits of DERs.

For instance, on the microgrids side, San Diego Gas & Electric implemented a pilot in Borrego Springs, California, that was used successfully several times to provide service to customers during a variety of conditions — including planned maintenance and contingencies (windstorm, flash flood and intense thunderstorms) — for more than 20 hours in the latter case.

Commonwealth Edison was awarded two U.S. Department of Energy grants for $1.2 million and $4 million to develop and test a microgrid controller as well as to build a microgrid in the Bronzeville area of its service territory. Moreover, it has requested funding from the Illinois Legislature to deploy six microgrids to enhance resiliency and provide service to critical customers, including the Chicago Rockford International Airport.

PV proliferation is expected to continue, particularly considering the recent extension of the Investment Tax Credit program, and the historical data and forecasts, which indicate technology prices are projected to continue decreasing. Eventually, this will enable PV to achieve grid parity. In this scenario, concerns regarding the potential for customer load and grid defection have prompted growing interest in new business models that enable utilities to diversify and provide additional services beyond kilowatt-hour sales.

This includes discussions regarding the introduction of the distribution system operator concept and the creation of distribution markets, where prosumers and merchant DER can engage in physical and financial transactions. One of the key proposals in this regard is New York's Reforming the Energy Vision initiative. Related proposals to redefine the role of DERs are being discussed in California and Texas.

As distribution systems evolve and DG becomes an intrinsic, if not essential, component of modern transmission and distribution grids, the aforementioned challenges are expected to be addressed gradually, and new and likely more complex issues are expected to emerge.

Ensuring the reliable, secure and economic operation of future dynamic and active transmission and distribution grids will require not only technology and engineering solutions, but most importantly, regulatory, policy and business compromises that recognize the pros and cons of adopting new technologies, while providing customers and utilities with attractive business opportunities. This in itself is arguably one of the most complex and challenging problems the industry has faced in the last decades, making it fertile ground for needed innovative proposals and solutions. TDW

Julio Romero Aguero (julio@quanta-technology.com) is vice president and executive advisor of strategy and business Innovation for Quanta Technology.

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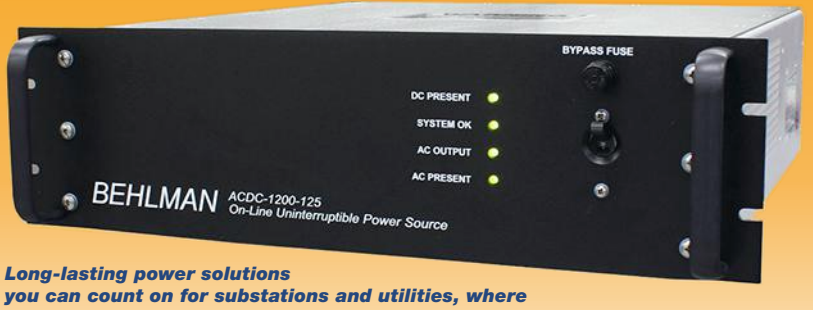

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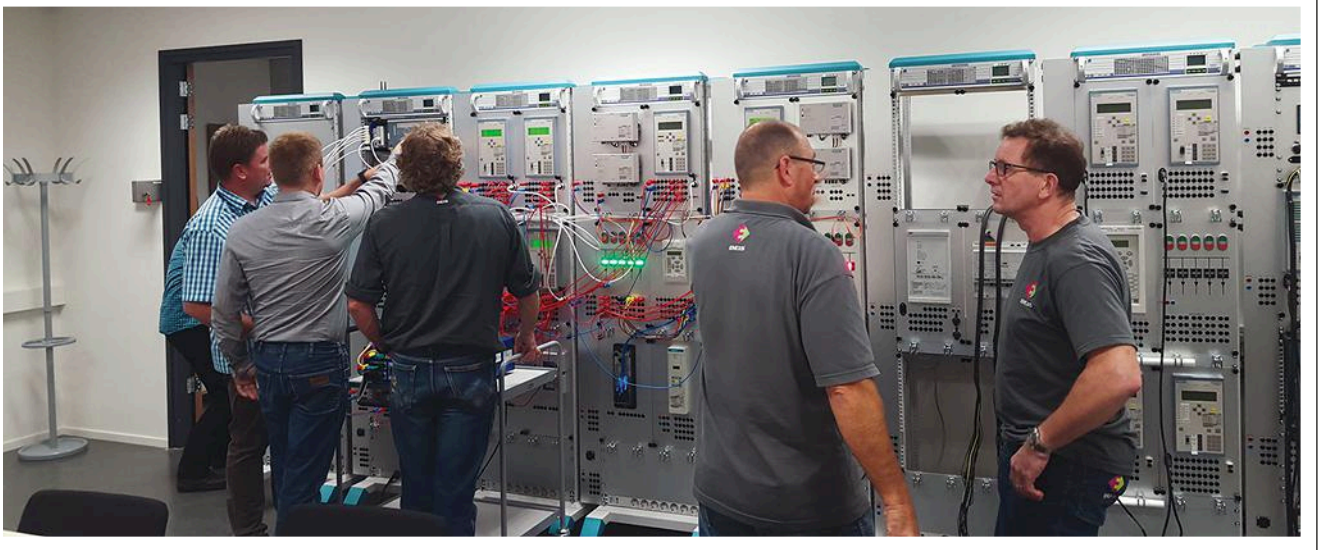


A new hardware training simulator is in use at the new training center for protection, automation and control equipment.

Training Simulator Reduces Outage Times

Enexis employs simulator to train outage crews to improve network reliability and reduce restoration times.

By **Johan Morren**, *Enexis*

As a result of increasing electrification and the vast increase in automation and information technologies, society is demanding a more reliable supply of electrical energy.

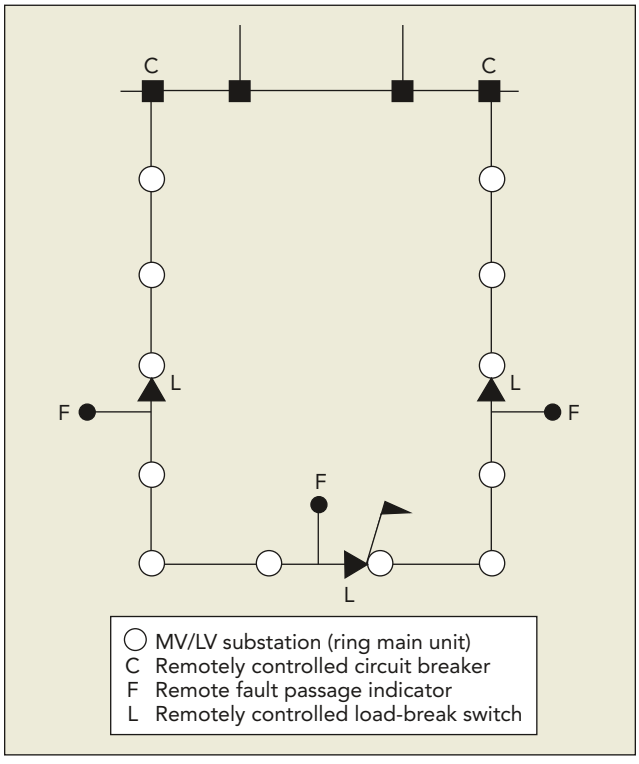
Developed in the 1950s and 1960s, the distribution networks are becoming time-expired, which may result in an increasing number of faults and the need to replace network components. The load on the distribution network is fluctuating more (because of heat pumps and electric vehicles, for example), which may result in higher stress on components. Networks are becoming smarter and, therefore, less predictable, making planning and operation of the network more complex. With the focus on renewable energy sources, an increasing volume of renewables, such as wind turbines and solar panels, are being integrated into distribution networks.

Although the reliability of distribution networks is high, faults can occur, resulting in a section of the network being disconnected. Currently, restoration of supply is often undertaken manually. On receipt of customer messages, outage crews are dispatched to the area where customers are without power. Based on information available from trip indications on protection relays and short-circuit indicators, the outage crews locate the component that failed and restore supplies to the healthy sections of the network. The failed component is repaired or replaced, and normal network configuration is restored.

The reduction of outage time has always been one of the main goals of network operators. Increasing dependency on a stable and secure supply has made this goal even more important; therefore, fast and efficient restoration in the event of a fault is critical. Network operators are applying different technologies to achieve this goal. Enexis, which operates the medium-voltage and low-voltage networks in the north and south of the Netherlands, has invested in several solutions for faster and more efficient fault restoration, such as the application of distribution automation (DA) and the continuous training of its outage crews.

Distribution Automation

DA can reduce the outage time and number of customers



The Enexis distribution automation concept, with its ring-shaped network split into four sections, is remotely controlled with circuit breakers and load-break switches. The load-break switch with the flag is open under normal operating conditions.

Enexis Distribution Network Statistics	
Length of the low-voltage network (400 V)	90,800 km (56,421 miles)
Length of the medium-voltage network (10 kV and 20 kV)	44,300 km (27,527 miles)
Number of customers	2,667,000
Energy consumption	17,470 GWh
Geographical area	About 40% of the Netherlands (in the north and south)

affected by a fault outage. Therefore, in 2011, Enexis started a large-scale rollout of DA in its medium-voltage networks, which include only underground cables. With DA, sections of the network can be restored remotely within a few minutes, instead of more than an hour, as is the case with manual restoration.

As soon as a fault occurs, the circuit breaker will disconnect the feeder. In a conventional situation, the fault first had to be located and isolated manually. When this was done, power supply to the feeder could be restored. With DA, the load-break switches (ring main units) and circuit breakers can be controlled remotely. Depending on whether the fault is in the first or the second part of the feeder, at least one-half of the feeder can be reconnected remotely within a few minutes, resulting in a significant reduction of customer minutes lost.

Since the rollout of DA in 2011, some 1,000 distribution substations have been automated. Initial results show the ef-

The original hardware simulator used for training outage crews was a 110-VAC network that included the most common protection relays used by Enexis so that single-, two- or three-phase faults could be simulated.

fectiveness of this strategy is even better than the utility expected. In the coming years, Enexis will continue its rollout of DA. It is expected more than 50% of the utility's distribution network will be controlled with the DA concept by 2020.

Outage Crew Training Program

While the rollout has started, DA is not yet available for the largest section of Enexis' distribution network. Although DA enables remote switching, the restoration process still requires some manual input. Therefore, to improve the efficiency of manual operations required in the restoration process, Enexis started a large-scale training program in 2011 to enable outage crews to restore outages faster and more efficiently. Currently, the scope of the training is limited to the medium-voltage network, as most of the customer minutes lost are caused by outages on this section of the network.

The outage crews received specified training goals:

- During the restoration of a fault, close cooperation between the outage crews and the network operators in the control room is required.
- Network operators all have their own procedures for outage restoration, and it is important outages crews know these procedures in detail and apply them.
- In the process of finding the location of a fault, interpretation of the indications on protection relays and fault indicators is important.
- Distributed generation has an impact on the flow of fault currents in the network and, therefore, also has influence on the indications given by protection relays and fault indicators.
- The number of substations with DA is steadily increasing, and outage crews have to understand the principles of DA and how it interacts with the manual fault restoration.

To meet the training goals, the two-day training program consists of five courses:

1. *Characteristics of distribution networks.* The outage crews must be familiar with the medium-voltage distribution network and, in particular, the earthing principles of the network. This helps the crews to determine the magnitude of single-phase earth-fault currents. Equally important is the impact of distributed generation on the network, as this might result in incorrect operation of fault indicators.
2. *Distribution network protection.* Faults in the distribution network will be isolated by protection relays. Therefore, it is important for outage crews to know the basic principles of protection relays, the protection philosophy and the combination of protection relays that provide the protection of the complete distribution network.
3. *Training with hardware simulator.* Following the first two courses, participants receive practical exercises to apply the knowledge gained.
4. *Outage restoration.* Network operators always have certain agreements and procedures for the process of outage restoration. For example, important issues are the responsibilities of the operators in the control center and the outage crews outside, the information exchange between them and the order in which the substations are visited, respectively.
5. *Training.* The final step is training with the software simulator.

Outage restoration is one of the key activities of network operators. Therefore, it is important to train outage crews continuously. Enexis has decided its outage crews must repeat the training program every four years, and courses are continually updated and adapted to include the changing important issues.

The training program started in 2011 with a basic training period of two days and was given to some 250 staff members of the outage crews. Now, every year, 60 to 80 staff members of the outage crews receive a two-day repetition course in groups

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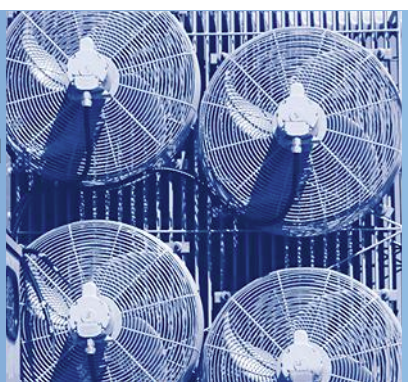

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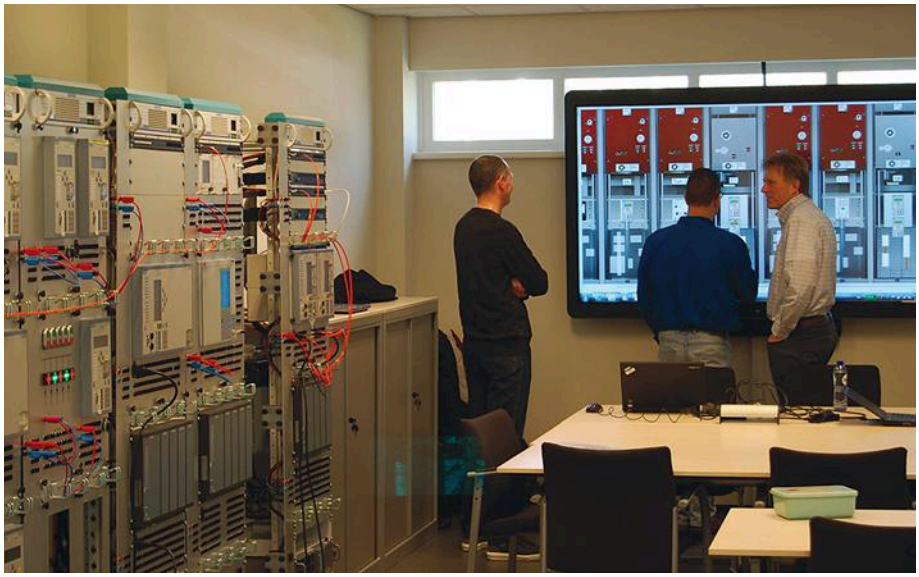
of eight to 12. The training is delivered by a team of two to three trainers. All new outage crew staff members must take the basic course first, followed by repetition training courses every four years afterward.



The most recent crew training session is discussed among the operators who conducted the training. The software simulator, which is key to the fifth step of the crew training, is located on the back wall and the hardware simulator is on the left wall.

Hardware Simulator

The hardware simulator is designed to include several of the most common protection relays used by Enexis and a network model of a medium-voltage network. The 110-VAC network comprises several discrete components that make it possible to simulate single-, two- or three-phase faults on several locations in the network. Protection relays connected directly to this network (without current and voltage transformers) will respond to the fault current and operate accordingly. Based on the indications given by the protection relays, the participants have to identify the component (either a cable or a substation) that contains the fault.

The simulator is built in such a way participants are only able to visit one substation at a time, just as in reality. This trains them to register what they have seen in a substation before they go to another one. The usage of the hardware simulator has proven to be quite effective, as even the well-trained outage crew members report this form of training with the simulator is both useful and instructive. In the spring of 2015, two new training centers for so-called protection, automation and control equipment were put in operation at Enexis. These new centers have a new version of the hardware simulator installed that offers greater flexibility. Faults are no longer simulated in a 110-V network with discrete components but rather with test equipment from OMICRON or similar devices.

Software Simulator

The software simulator is based on the Vision Network Analysis program developed by Phase to Phase, which is widely used in the Netherlands. The advantage of basing the simulator on Vision is all Enexis' MV network models are available already in Vision. The program has a special training environment in which a fault can be introduced in the network model, resulting in a fault for which the protection relays and fault indicators show the same indications as they do in reality.

Based on the messages received in the control room, outage crews have to start the restoration of the fault by visiting substations, interpreting the indications on the protection relays and taking all actions needed to restore power. During the simulation, a clock is recording the time the outage crew takes to restore power.

As a starting point, an overview of the network is given that has no information on the position of the fault. Following the training, participants receive messages related to the fault from protection relays that have tripped or from customers who are without power. Using this information, they have to decide how they will start restoration of the network in a section where the substations can be controlled remotely. This is common for most high-voltage/medium-voltage substations and also for substations equipped with DA. The simulator offers the possibility to switch them remotely, just as it is done in reality from the control center.

However, the majority of substations are not subject to remote control and, therefore, require a substation visit. During the simulation, all time taken to visit subsequent substations is recorded, so it is important participants select the correct sequence to reduce their time and, depending on the infor-

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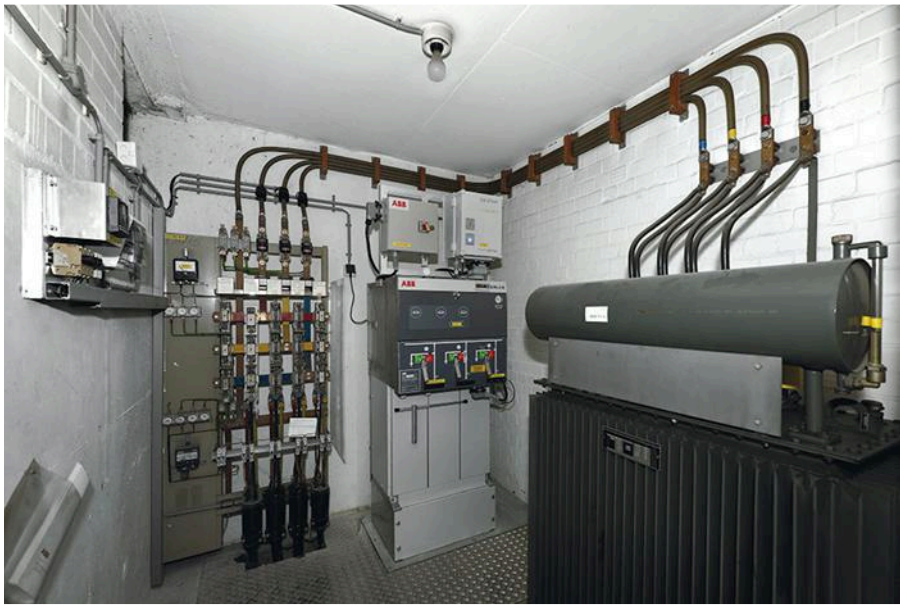

This is a typical Enexis medium-voltage/low-voltage indoor substation that includes a MV/LV distribution transformer, MV switchgear and a LV distribution board that has been upgraded to include distribution automation.

mation received, visit some substations equipped without DA. Normally, the information from the substations with remote control is analyzed before a decision is made on which substation to visit. In most cases, this will be a substation with protection relays, as they often provide useful information on the type and location of the fault.

A medium-voltage switchgear installation equipped with distribution automation and protection relays, showing different relay and switchgear indications.

The simulator provides the outage crew with a photograph of the substation they visit and, on entering, an overview of the switchgear installation, with all position indications and also the indications on the protection relays. By touching a protection relay, it is possible to receive more information.

In the substation, several actions can be performed, such as operating circuit breakers, voltage detection and integrity testing of cables. In this way, outage crews demonstrate they understand how the different types of switchgear have to be operated. As safety is always of utmost importance, crews also can show they understand the safety procedures and act accordingly.

When participants indicate they have performed all the necessary actions and all customers have been reconnected, the simulation is complete. Participants then receive an overview of all the actions executed, mistakes that were made, the time required to complete the simulation and whether all customers were re-energized. This report is then discussed with the instructor to highlight where improvements could have been possible in the restoration procedures.

Enexis has developed this outage restoration training program to enable its crews to restore fault outages in the fastest, most efficient and cost-effective manner. The key and most important element of the training program is the software outage simulator, which can continuously replicate all types of fault outages and record all steps taken and the time to complete the process of outage restoration. TDW

Acknowledgement

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Improving Distribution System Performance

Westar Energy added fault location, isolation and service restoration as well as volt/VAR control to enhance reliability and reduce system losses.

By **Mike Watson**, **Jeff Hauber** *and* **Clayton Stubbs**, *Westar Energy*

Westar Energy was awarded a U.S. Department of Energy cofunded Smart Grid Investment Grant for its SmartStar Lawrence project. The three-year project consisted of installing advanced metering infrastructure, a meter data management system and distribution automation (DA).

The utility chose the city of Lawrence, Kansas, U.S., as the initial location for implementing this technology because of its size and customer base, which includes many higher-education student residents, commercial and industrial customers, and educational institutions. While Lawrence customers will be the first to benefit from these new capabilities, the utility plans to continue installing similar equipment throughout its service territory.

By implementing a pilot DA system, Westar Energy sought to achieve several important objectives:

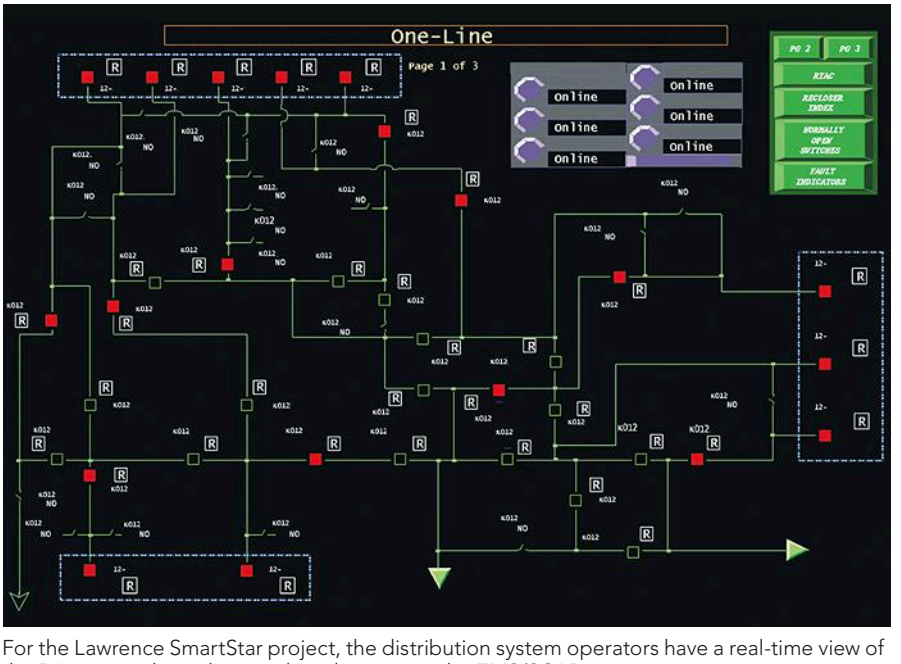
- Increase system reliability
- Reduce outage restoration times
- Minimize distribution system losses
- Reduce system loadings during peak conditions
- Improve system operation and understanding
- Improve service to customers.

To minimize the impact on distribution system operators, Westar Energy also wanted to pass information from the DA system to the existing energy management system/supervisory control and data acquisition system (EMS/SCADA) so a separate interface would not be needed. This would enable operators to use the same system they were already intimately familiar with operating.

DA System Implementation

The DA system was implemented on 24 out of 1,338 circuits across the Westar Energy distribution network. The feeder circuits used reclosers at normally open tie points to interconnect two or more power sources. Additional reclosers were installed throughout the feeder circuits to enable sectionalizing capabilities in the event of permanent faults occurring on a line section. The system used the following equipment:

- 33 new SEL-651R advanced recloser controls and SEL-2401 satellite-synchronized clocks paired with G&W Electric reclosers
- One legacy Cooper recloser with Form 6 controls
- 53 S&C Electric capacitor bank controls retrofitted for existing capacitor banks
- 10 substation transformer load-tap changer (LTC) controls, six of which needed to be upgraded



For the Lawrence SmartStar project, the distribution system operators have a real-time view of the DA system through a one-line diagram on the EMS/SCADA system.

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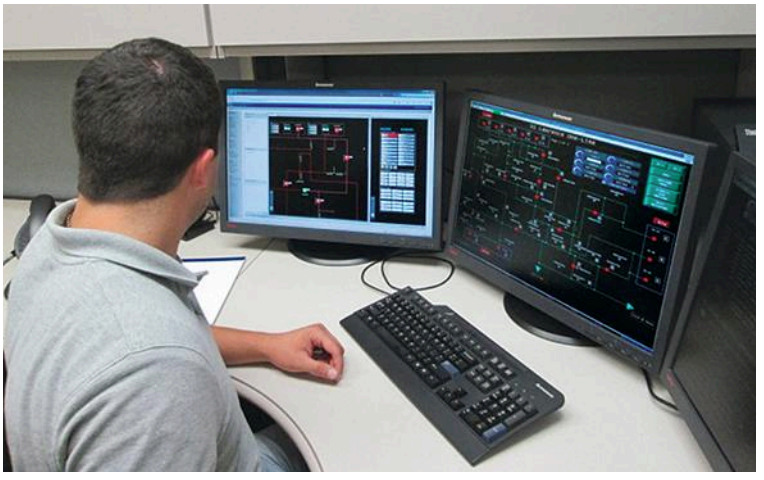

Westar Energy distribution automation engineers use HMI and SCADA screens to maintain the DA system as well as interfacing and commissioning new equipment being deployed to the field.

• 39 existing non-telemetered switches

• 87 Sierra Wireless 3G and 4G cellular modems for feeder intelligent electronic device (IED) communications and control

• One SEL-3530 real-time automation controller as a distribution automation controller (DAC), providing centralized system intelligence

• One SEL-3620 Ethernet security gateway that provides comprehensive security measures, including IED password management.

The SEL DAC communicates with the substation transformer LTCs and protective relays by messages relayed through the EMS/SCADA system to the substation remote terminal units. To maintain awareness of the system configuration, a server-based software solution monitors the utility's outage management system and provides the status of the non-telemetered switches in the system back to the DAC, thus maintaining awareness of abnormal operating system conditions.

Several communications protocols were implemented across the system, including DNP3, SEL and Modbus. The protocols were selected either because of legacy equipment limitations or because they provide desired IED functionality. The DAC also acts as a protocol converter, enabling the various IEDs in the DA scheme to communicate and operate together as a holistic system. Additionally, the DAC provides port-routing functionality for remote-access capabilities using various proprietary vendor software interfaces. This enables a mix of new and legacy IEDs as well as controllers from different equipment manufacturers to be used, thus minimizing the installation time and the cost of implementing the system.

Because the automation system was being deployed primarily for system restoration and voltage control, high-speed communications were not required. All protective functions are performed locally within the IEDs, so the loss of communications would be acceptable, although not desirable.

Cellular communications enabled Westar Energy to minimize deployment times because there was no back-end infrastructure to build and maintain. Although there were ongoing data charges, data rate plans were negotiated with the cellular providers that offset the costs that would have been associated with a utility-owned system. Additionally, the cellular network is being built continually to incorporate new technologies with increasing data throughput rates and decreasing data plan costs.

Westar Energy implemented the SEL distribution network automation (DNA) system in two phases, starting with the fault location, isolation and service restoration (FLISR) capability (phase one) and then adding volt/VAR control capability (phase two). This enabled the reclosers to be installed initially, followed by the replacement of capacitor bank controls and LTC integration at a later time. SEL provided the initial FLISR and volt/VAR programming by creating a system model and configuring standard DNA libraries for the Westar Energy distribution system.

Human-machine interface (HMI) displays were developed for use during commissioning and testing. SEL also provided remote interactive training so engineers at Westar Energy would be proficient at maintaining and implementing changes to the system to accommodate additional IEDs or feeder circuits in the future. Westar engineers further developed and implemented features in the system, including the deployment of automated password management, remote IED

To accommodate automated switching in the field, the SmartStar distribution automation system uses the SEL-651R advanced recloser control, the SEL-2401 satellite-synchronized clock and Sierra Wireless 3G cellular modems.

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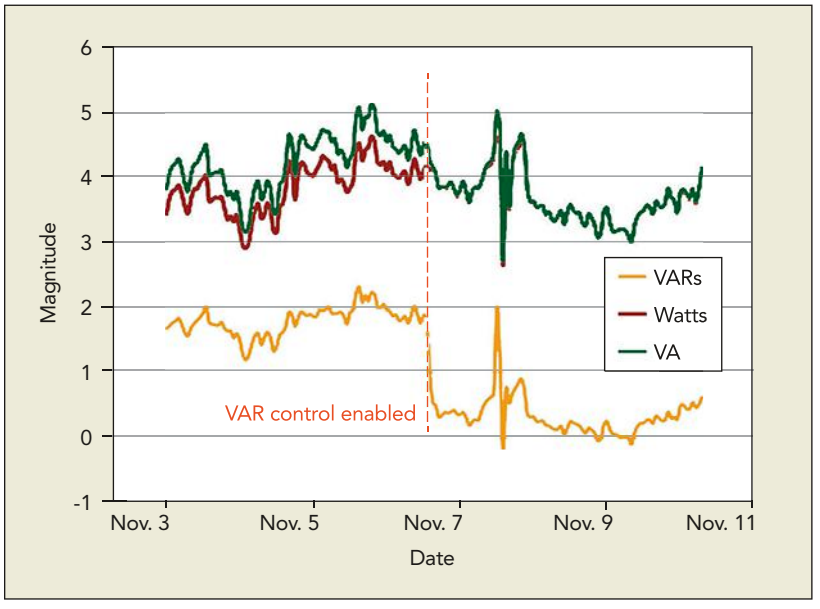

Enabling the volt/VAR capabilities resulted in a notable reduction in VARs, correcting to near-unity power factor immediately when applied.

management capabilities, automated SMS/e-mail routines and additional HMIs to aid with routine system monitoring and operations.

DNA System Capabilities

The phase one portion of the Westar Energy system provided centralized automated controls that perform autonomous FLISR activities. As part of the FLISR functionality, the SEL solution included the following features:

- Loss-of-source detection
- Open-phase detection
- Miscoordination detection and mitigation (provides operator notification and sectionalizes the correct portion of the system with the fault)
- Overload mitigation and load shedding (smartly selects an alternate source with available capacity, shifts sources if loading increases beyond the limits or sheds load if no alternate sources with capacity are available).

In phase two, automation and control for voltage and reactive power flow were implemented. The implementation used the same centralized system DAC and feeder information but added control of voltage regulators, capacitor banks and substation transformer LTCs to the system model. This simplified the effort to add volt/VAR control while enabling both systems to operate as an integrated system. A benefit of implementing the system in this manner was that even after system reconfiguration, volt/VAR capabilities could still be performed on the reconfigured system.

The SEL volt/VAR capabilities also included several additional features:

- Minimized VAR flow (system losses)
- Voltage operating limits flattened across feeders, resulting in feeder voltage reductions while not exceeding the minimum voltage limits to end-use customers
- Feeder voltage reductions that resulted in reduced energy consumption during peak demand (dependent on load characteristics), also known as conservation voltage reduction
- Flexible operator control modes to do the following:
  - Optimize voltage on the feeder
  - Optimize power factor on the feeder and on the station bus
  - Provide demand response for peak load reduction
  - Optimize VAR set point on the primary side of the transformer for transmission VAR support.

System Features in Action

A benefit of having secure communications to substation and feeder devices is it enables remote engineering access. Now engineers are able to retrieve and change IED settings as well as pull event data (sequential event records and oscillography) from all devices on a feeder circuit, facilitating faster event analysis as well as helping to refine settings for improved system operation and protection.

Westar Energy also has implemented automated password management and automated SMS text and e-mail messaging routines for configured alarms and events.

Since the system was placed into service, multiple isolation and restoration incidents have occurred, resulting in reduced outages to customers. In one instance, a ground wire located on the primary line between the substation breaker and the first downstream recloser failed and caused the circuit to lock out. The DAC initiated isolation of the faulted section and closed a normally open recloser to restore power to 894 customers fed from an alternate feeder source in less than two minutes. In another instance, a fault resulting from a failed insulator was also successfully isolated and customers restored.

In addition, Westar used the DA system to identify a sympathetic fault on a feeder in the automation scheme. As a result of the remote data collection capabilities provided by the system, Westar engineers were able to identify a location upstream of a faulted line section where conductors were slapping together as a result of the magnetic fields associated with high fault current levels. The engineers believe similar intelligence can be designed into the system so this process of fault identification can be automated in the coming years.

Another benefit realized as a result of the addition of reclosers and recloser controls to the DA system is the reduction in customer interruptions, even without FLISR system interaction. To date, the reclosers and automation system have eliminated more than 333,000 customer minutes interrupted.

Lessons for the Future

Westar Energy learned some valuable lessons from this

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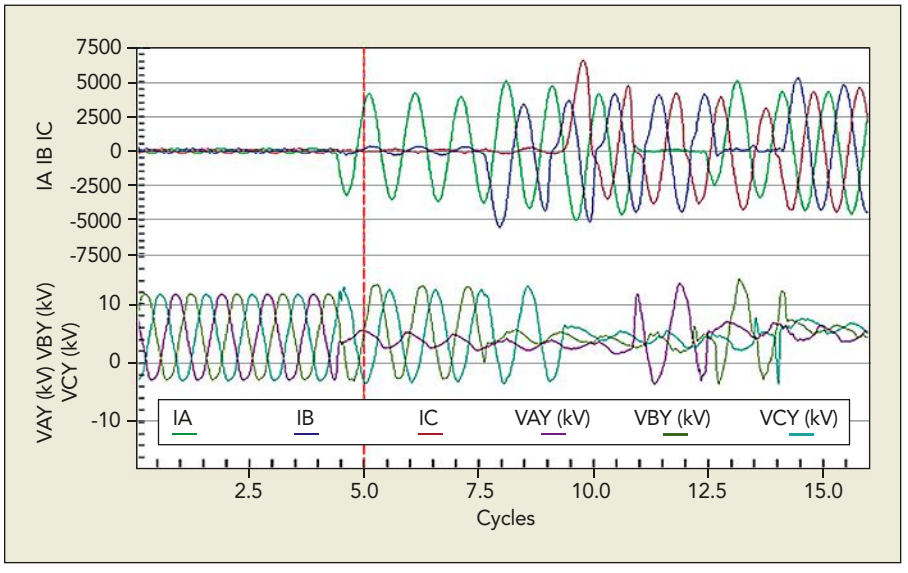

Example oscillography centrally retrieved from remote IED speeds event analysis provides visibility into system conditions, which otherwise may have been undetected.

project that will be incorporated in future projects:

- Building relationships with information technology groups and personnel involvement — including information technology security — was instrumental in successfully designing and securing the system.
- Cross-functional communication between the various interacting groups was key, beginning in the early stages of the project.
- New devices deployed en masse, in contrast to a small trial installation, resulted in some challenges with wildlife protection (faults experienced that required rework).
- The use of cellular modems required some communications handshaking and latency issues to be overcome, some of which required vendor firmware modifications.
- Autonomous (closed-loop) system acceptance by operating groups was aided by education and training, and was a key part of the implementation.
- Fault-bit logic in SEL recloser controls and protective relays is useful for identifying fault locations and miscoordination events. This technology could be used as an early warning system for problem areas.

A Successful Start

The Lawrence area is realizing the benefit of improved system reliability, which includes fewer outages and a reduction in outage durations as a result of faster restoration to unfaulted line sections. This benefits both the customers and Westar Energy, thus creating a win-win project.

Westar Energy implemented the DNA system, which is providing a capable and fully automated FLISR and volt/VAR distribution solution. The system has the ability to translate between various communications protocols and seamlessly interface with Westar's existing EMS system. The DNA system leverages some of Westar's existing legacy equipment as well as positions the utility for future deployments.

Using the DAC and security gateway hardware at Westar Energy has opened the door to a systemwide deployment of communications devices across the utility's entire territory. The DNA system was designed to maximize system effectiveness, enable improved system awareness and increase work efficiencies across the utility, primarily as a result of the new remote access capabilities.

Through collaboration between SEL and Westar Energy, the Lawrence SmartStar DA project was a key success and has provided valuable experience that will be leveraged as Westar continues to expand DA to other parts of its system. TDW

Mike Watson (mike.watson@westarenergy.com) is the director of distribution operational technologies at Westar Energy. He has more than 26 years of utility industry experience. He received his BSEET degree from Oklahoma State University and spent the first 10 years of his career in power system design and systems engineering in the nuclear environment. The following 16 years of his career have been focused on various aspects of the electric distribution field, including power system design and planning, operations, power-quality impacts and system automation. He is a professional engineer in Oklahoma.

Jeff Hauber (jeffrey.hauber@westarenergy.com) is a senior engineer in the distribution automation/technologies group at Westar Energy. He received a BSEE degree from the University of Kansas in 2005. He started at Westar Energy as a distribution engineer with responsibilities including planning, coordination, design, power quality and reliability. He began working in the distribution automation group in 2013. He is a professional engineer in Kansas and a member of IEEE.

Clayton Stubbs (clayton.stubbs@westarenergy.com) is a distribution automation engineer at Westar Energy. He received a BSEE degree from Kansas State University in 2012. Stubbs began working for Westar Energy in 2011 as an intern and became a full-time employee upon graduation. He is a member of IEEE and received an Intern Engineer certificate in the state of Kansas.

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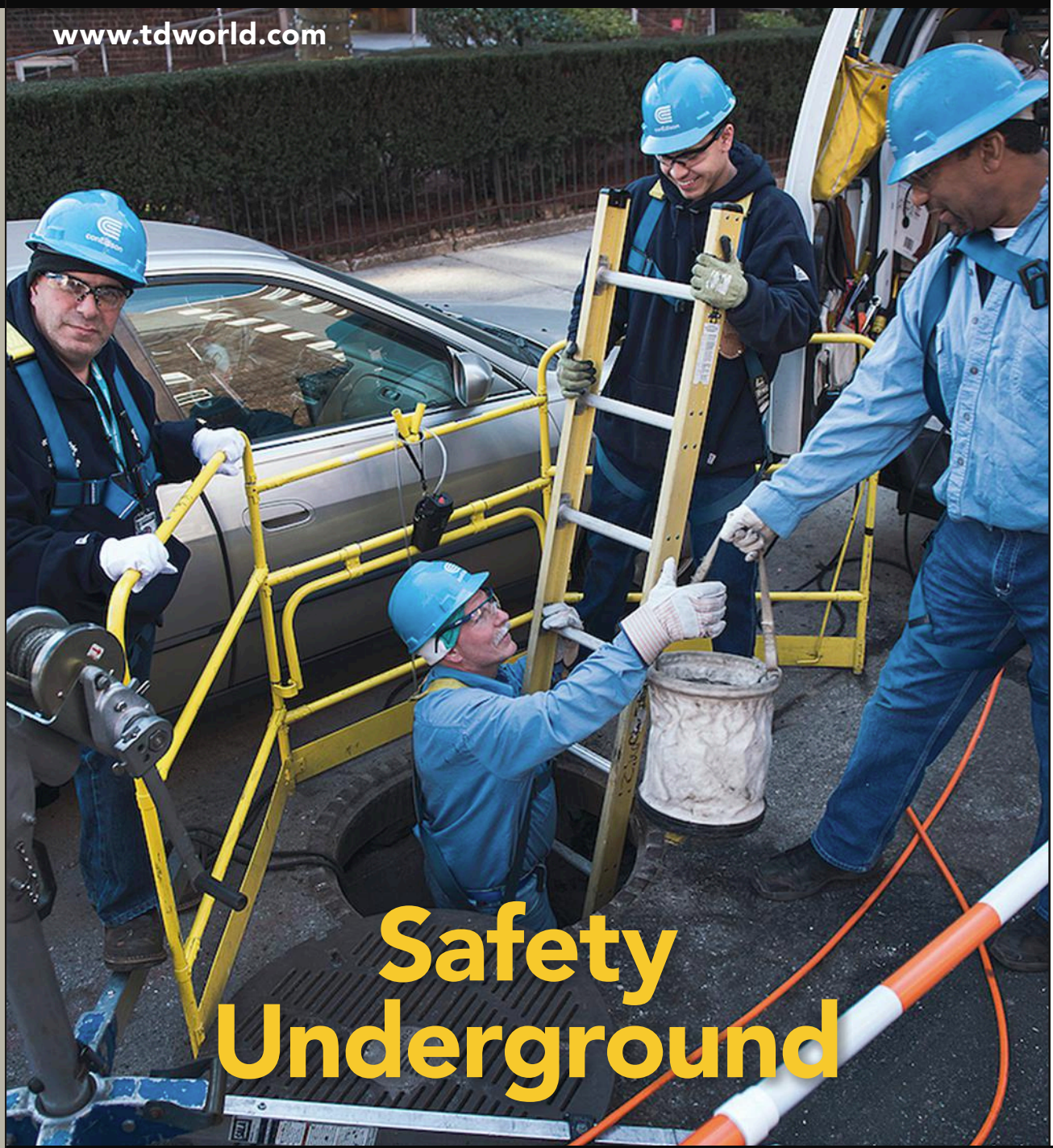

Safety Underground

LifeLine

Shannon Fitch

Seattle City Light

- Born in Tillamook County, Oregon.
- Enjoys camping, fishing, being outside and attending social gatherings.
- Played 15 years of World Cup-level rugby and 10 years of women's professional football.
- Her dad was a career logger and timber faller, and her cousin Simon has followed in her footsteps in the line trade.
- Can't live without her climbing gear.

Shannon Fitch, a journeyman lineman for Seattle City Light, serves as a relief crew chief for her utility.

Early Years

While I am the first journeyman lineman in my family, I was inspired to pursue a career in the line trade by a friend's father, who is a lineman for Seattle City Light. One night, my friend and I were cutting wood for a bonfire, and he noticed how comfortable I was with a chainsaw. He asked me if I ever thought about being a lineman. I thought he meant an offensive lineman in tackle football, which I was playing at the time. I said I didn't want to play in the front row because the girls were much bigger. He told me he meant a power lineman and asked me if I was afraid of electricity or of heights. He said Seattle City Light had a diverse field crew, and I should consider applying for the apprenticeship program. After doing some research, I realized it was something I could do as a career.

About a year later, Seattle City Light invited me to attend one of two sessions at the University of Washington. About 1,200 people had applied for the program and only 12 of us were accepted. We had to jump through lots of hoops and pass written, physical and skills tests before getting hired on in 2004. Only six of us finished the four-year apprenticeship program, and I was the only woman left standing. During my apprenticeship, we did it all — we rotated to the underground, network, pole crews and high line.

Day in the Life

Every morning, I go into work for our safety meeting. Our supervisor then gives us instructions on our scheduled jobs, and we gather our materials for the day. On my crew, I work with two other journeymen, a crew chief and an apprentice on transmission, distribution, residential and tower work.

Safety Lesson

A year after I topped out as a journeyman, I was involved in an accident when part of a tree flew up and hit one of my fellow crew members in the face. While he was fine and not injured, it showed me the importance of everyone staying on the same page.

Memorable Storm

I'll never forget when I worked for eight days straight to restore power following a 2008 storm in Seattle. There was a lot of ice and it was brutally cold. Poles were down everywhere, and we quickly ran out of inventory. To get the power back on, we had to pull poles that were already set. Everything was iced over, and the limbs busted off and fell across the phases, knocking out power for much of Seattle.

Traveling Line Work

After topping out as a journeyman lineman, I left Seattle City Light and tramped around the country for five years before coming back to the utility. During that time, I worked in Denver; Pasadena, Calif.; Calgary and Alberta, Canada; and Oregon. Anywhere I went, the trucks, voltages and equipment on the poles were different. I learned a lot by working across North America. If you have a family and want to go home to your own bed every night, working for a utility is amazing. If you have no family or kids and are not in a relationship, then outside construction is the way to go.

Getting Support

During my career in the line trade, my male coworkers tested me. Once they knew I was not going to give up and I had some knowledge, they taught me how to make my job easier by working smarter, not harder. I will be forever appreciative of my previous supervisors and other linemen who have taught me the skills I need to do my work.

Future Plans

At this time, I want to continue working as a journeyman lineman on the dock at Seattle City Light until, physically, I am unable to do the job anymore. I enjoy working out in the field. I can't imagine myself not being a lineman. It is the best thing that ever happened to me. All my other jobs were boring and I lost interest. In this job, I enjoy waking up and going to work every day. TDW

FieldApplications

Advanced Technology Replaces Traditional Conductor Sagging Method

By **Lee Pope**, *Contributing Writer*

When installing and maintaining overhead transmission lines, linemen must allow for the proper tension. If the tension is too high, it can lead to conductor breakage and failure. At the same time, low tension can cause the conductor to dip down to an unsafe clearance from the ground.

When initially installing power lines, linemen allow for a certain amount of elongation and stretching as a result of ice, temperature variations and high winds. On many projects, however, linemen install power lines with sags that are too low to begin with, causing problems in the future. As a result, utilities may face fines. For example, leaving conductor low in mountainous areas can be a NERC infraction with possible fire issues.

Using Traditional Methods

In the past, electric utilities have calculated sagging in a variety of different ways. For example, the dynamometer, also called the dyno, is one device to measure the tension of the conductor. While it is suitable for single spans, it can leave the conductor low in the longer sag sections if not used properly.

Another tool often used in the field is the rifle scope, which is mounted down on the sag span. It measures the down provided feet in sag per temperature on both the target structure and transit structure. If the conductor is horizontal, it levels across, and if it is vertical, it moves the transit each time. This process requires linemen to work on the structure and at very high tensions, which is always risky. Also, this method is often not accurate because most of the time, the temperature changes in the duration of sagging, and linemen may be reluctant to move the transit.

The third approach is called jerk sagging or the stopwatch method. Once the linemen know how much sag they need, in accordance with the manufacturer's recommendations, they string up their cable or conductor with roughly that much sag. Then they jerk the conductor or cable at one end with a rope to measure the actual amount of sag. Next, the linemen will feel the rope to look for each return wave of the conductor.

The line crew believed that this conductor was at engineer design sag, but an inspection found that it was not sagged properly.

After the inspection, linemen were able to correct the sag. HiLine has discovered problems with transmission line sag nationwide.

After timing the return of three waves, they checked on a sagging chart for the Return Wave Method. The amount of time measured should correspond exactly with the actual amount of sag, in inches, from the sagging chart.

In addition, linemen can rely on a special stopwatch, called a Sagwatch, which has the face recalibrated to measure the actual sag without a stopwatch. When a crew jerks the wire and measures the return waves, the stopwatch will show the exact amount of sag in inches. This approach saves the time required to look up a regular stopwatch reading on a chart.

The drawback is that linemen must mount ropes on conductor in sag spans, which is time-consuming. On higher voltages, they must also set up a crane or hang ladders to access the conductor while installing equal potential grounding. This method also requires linemen to hit the stopwatch at the exact time the wave return hits, which can involve some level of human error.

Finally, the Bonneville Power Administration quick-sag/overhead-cable-sag calculators all require proper measurements of conductor to transit. Many variables can lead to mistakes with these programs such as different travelers in sag span and shackle hanger attachment. In addition, the panel measurements on the lattice tower and elevation differences can change the angle to shoot dramatically.

Uncovering Sag Issues

When utilities hire inspectors to verify conductor sags, these inspectors often ask the field crews two questions: At what temperature is the conductor sagged and what did the dynanometers read for tension? They then write this information in their book without any further verification.

If the inspectors are more knowledgeable or experienced, they may consider the angle that is being shot with the Bonneville Power Administration sagging tool. In many cases, they will still not verify that the pin hanger to transit measurements has been checked. As a result, span lengths and elevation differences as-built in the field are never verified, and sag is only configured from the plan and profile.

Because the field crews and inspectors may overlook certain issues, the conductor may experience a variety of problems when it comes to sag. For example, HiLine Nation, a transmission inspection business, has found the conductor is left an average of 2 ft to 3 ft low or even more. On one project, for example, a crew sagging 2,700 ft of span thought they were at sag, but the true measurement showed the conductor was 80 ft low. While the construction crew knew there was an issue, they thought it was due to an engineer specification problem.

At another company, a crew working in a substation on an A-frame to A-frame span thought they had the conductor at sag. A problem was evident because the underneath switchgear could not open without clearance issues. The HiLine inspector verified sag to be 7 ft lower than design specifications.

In addition, one crew missed a hole panel measurement, leaving conductor 19 ft low, while on another job, an engineer over-designed the tension and deflected the tubular steel pole. Fortunately, this issue was immediately brought to the attention of the utility and re-engineered.

Often, contractors will give utilities excuses for the issues with sagging such as blaming it on the spacer installation,

Common Installation Mistakes

When conducting inspections and verifying sags, HiLine Nation has discovered several errors made by contractors:

- Using incorrect methods based on past theories on elongation
- Not considering traveler drop measurements
- Just using plan/profile drawing of structure without accurate measurements
- Not documenting temperature verification
- Not calculating correct dead-end "growth" from dead-end installation
- Not understanding which span should be used to verify sag
- Not documenting pin hanger to transit measurement
- Using a dynamometer
- Not rechecking sag after dead-end completion

which does not change the conductor sag at all. Others may claim the polymer dead-end insulator has grown, a sleeve is weighing it down or the conductor immediately elongated.

Trying a New Approach

In the past, several electric utilities faced both NERC and FERC violations because of low conductor sags resulting from field errors. Using the traditional sag methods, linemen may not have been able to verify the true and accurate span lengths and elevation differences in the as-built, real-world condition. With the Total Station sag method, along with Topcon's laser, field crews can verify sagging and dead-ending, complete the process in one set up and minimize the possibility of anything falling from the structure since it uses the side-shot method.

Unlike other approaches, this method can verify span lengths and elevation differences in seconds, and it allows linemen to compute sags quickly with engineer sag data. On reconductor projects, linemen can quickly verify the tension of the existing conductor in the air for correct hoist, choker and shackle size. In addition, they can use laser-precision technology for as-built field measurements and swiftly conduct a sag verification with temperature per degree rather than in five-degree increments.

Currently, HiLine Nation is working on training apprentices and journeymen linemen nationwide how to use this tool and methodology, therefore, minimizing the problem of conductor sagging and improving reliability. TDW

Lee Pope (lpope@hilinenation.net) is a journeyman lineman in Phoenix, Arizona. He started a minority-owned transmission line inspection business called HiLine Nation, which focuses on conductor sags and quality control and assurance.

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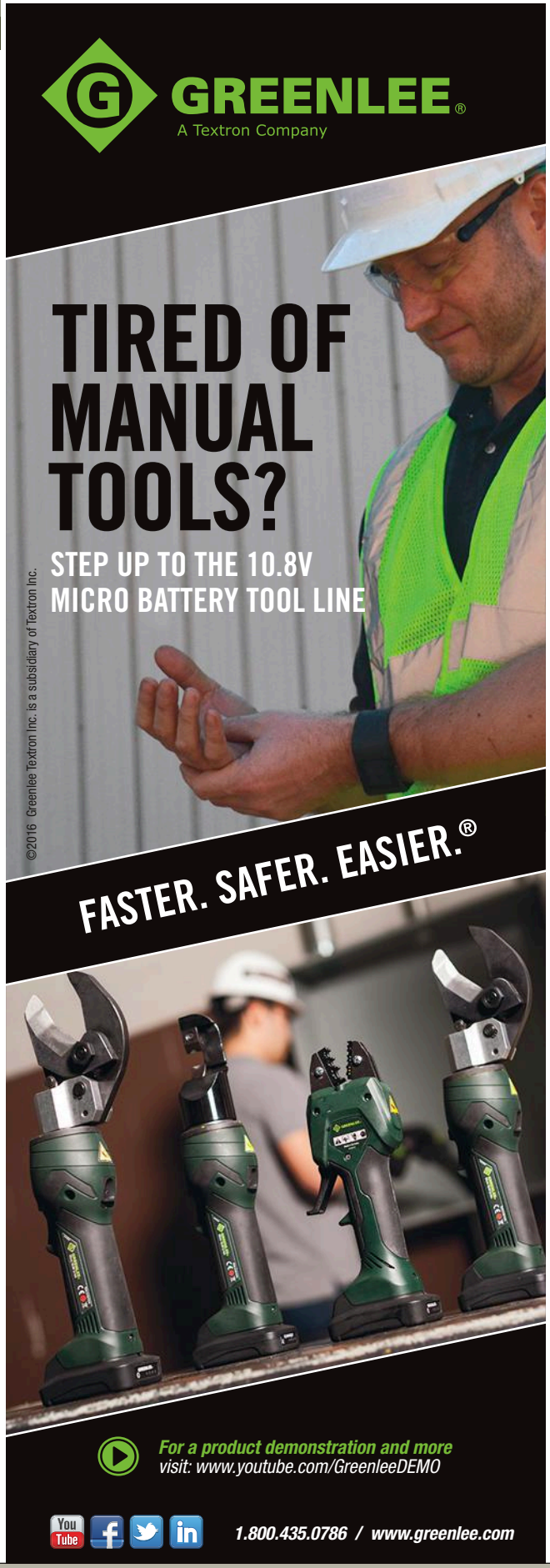

Con Edison Secures Safety of Underground System

New York utility installs vented manhole covers and new underground cabling to protect the public and prevent outages.

By **Adrianne Ortizo**, *Con Edison*

When snow or sleet hit New York, hundreds of trucks roll to drop salt on the slickened streets. The salt helps drivers avoid fender benders; however, it also damages components of the underground electrical system when it washes into manholes and service boxes. The salt-water mixture coats the underground wiring and equipment, leading to customer outages, smoke and — on rare occasions — fires and explosions.

To keep New York City safe for the millions of pedestrians and drivers who traverse the busy streets every day, Con Edison is installing vented manhole and service box covers and investing in an aggressive program to replace underground cable.

Preventing Manhole Events

Now in the 11th year of its replacement program, Con Edison is swapping out traditional solid covers with vented covers. That way, if the underground wiring begins to smoke or catch fire, the vented cover design allows gases to escape, reducing the risk of explosions. The smoke billowing through a vented cover also can serve as an early warning system to the utility that underground wiring has been compromised.

The program has replaced more than 120,000 covers and plans to make another 55,000 replacements over the next four years. Overall, Con Edison maintains 246,000 manholes and service boxes in an expansive and complex underground electrical delivery system serving 2.5 million customers in New York City and Westchester County, New York.

Con Edison originally considered replacing all of its old manhole covers with vented covers. Instead, the utility worked with Columbia University researchers who developed an algorithm to target certain structures in Con Edison's service territory. For example, under its former strategy, Con Edison might have replaced or vented three covers in the same intersection. The research with Columbia, however, showed it was only necessary to vent the middle structure because interconnected ducts vent the other two structures. By using the algorithm, the utility optimized its replacement program by targeting certain manholes, thus helping to control the costs and still reducing the risk of a manhole event.

A Con Edison crew replaces underground secondary-cable in Lower Manhattan.

Swapping Covers

Con Edison has collected and analyzed endless data on the performance of its electrical distribution system. To protect public safety, the utility began working on the development of new vented cover designs in the late 1990s. Over the years, the vented cover designs have evolved, and the company has worked with two different suppliers — East Jordan and Ross Tech-

nology. These manufacturers have produced the manhole covers in different shapes and sizes for Con Edison. While designing the covers, the vendors follow certain specifications. To ensure that the manufacturers are meeting the specifications, Con Edison provides them with standard drawings that they use during the production process.

For example, the covers must be within a certain weight range so they will not rattle when cars run over them. In addition, they must be vented at 22% for the optimal release of the combustible gases.

Currently, Con Edison is exploring modern designs for its covers. The utility is working with three manufacturers and testing new kinds of vented covers that it may start installing this year. The company is considering different venting designs or a cover with channels that reduce water runoff into the structures.

The utility also has an R&D initiative to test a cover that will be restrained or attached to the underlying structure. While it may open up at an angle or lift up vertically, it won't soar into the air and possibly cause damage to nearby property or bystanders. Con Edison is waiting for test results from EPRI before installing these types of covers on the underground system.

More than 833 miles of new cable was installed in the Con Edison service territory in 2015.

Replacing Underground Cabling

In addition to replacing solid covers with vented covers, Con Edison has an aggressive program underway to replace underground cable. In 2015, workers added 833 miles of new wiring alone. Unlike traditional underground cable, the replacement cable is dual-layered and insulated with a low-smoke, fire-retardant jacket. If this cable does catch on fire, it won't release any poisonous gases into the atmosphere.

Rather than replacing all of its underground cable, Con Edison is first targeting the sections with a history of failure due to years of exposure to salt, vibrations from traffic, biting by rats and other wear and tear. Through its proactive cable replacement program, the company uses the new cable during an emergency or a burnout. When considering whether or not to replace the cabling, the crews consider the age of the cabling as well as other factors.

By replacing solid manhole covers with vented covers, Con Edison has been able to protect its field workforce when working underground.

Optimizing Replacement

In Manhattan, New York, the entire power infrastructure is underground, while the outer boroughs — the Bronx, Staten Island, Brooklyn and Queens — have a mix of underground and overhead cable.

To minimize inconvenience to residents, businesses and drivers, Con Edison coordinates its work with the city. For example, if the city is in a neighborhood digging in a street, the utility may replace cable in the area, possibly avoiding opening up the street again.

By replacing vault covers and aging underground cable, Con Edison maintains its reliability and protects the millions of people who are in the city every day. TDW

Adrianne Ortizo (ortizoa@coned.com) is a manager in the distribution engineering department for Con Edison in New York, New York. She has been with the company for 14 years and is responsible for helping to manage the company's public safety mitigation program, which includes vented manhole covers, contact voltage testing and capital projects to rebuild secondary systems.

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Photograph by **Art Mochizuki**, *Los Angeles Department of Water and Power*

Following a rainstorm in February, LADWP linemen repair a downed line that spanned across the Los Angeles River. High winds and branches and debris falling on tree lines caused the outages. By working around the clock, crews restored power to 100,600 customers, and the linemen remained in the field to restore power as quickly as safely as possible to the remaining 1,600 customers.

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28 Markets Combine

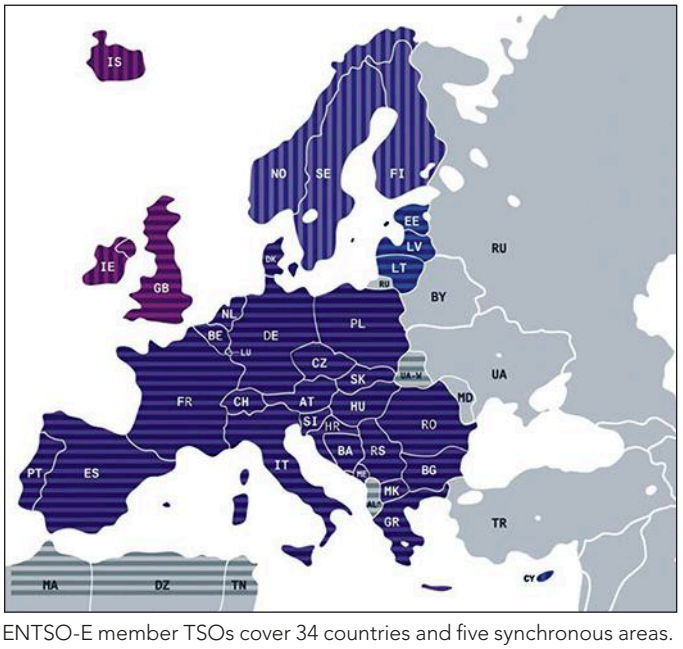
ENTSO-E lays out plans to integrate the world's largest and most competitive electricity market.

By **Konstantin Staschus**, *European Network of Transmission System Operators for Electricity*

Integrating and liberalizing 28 electricity markets is a task the European Union (EU) has been making progress on since the mid-1990s. In parallel, it has committed itself to the near-complete decarbonization of its power system by 2050. As Europe's electricity backbone, the transmission system operators (TSOs) represented by the European Network of Transmission System Operators for Electricity (ENTSO-E) are at the center of this evolution.

In the countries served by the ENTSO-E members, there are five different synchronous areas that differentiate technical operations but not the integrated market. The challenge is getting greater as increased penetration of intermittent generation from renewable energy sources requires adjustments to system operations, system development and connection conditions, as well as wholesale and retail market rules. These issues are becoming particularly important as Europe's security of energy supply is becoming the focus of attention.

Europe's energy policy rests on three pillars: affordability, security of supply and sustainability. These pillars are interlinked. Integration of a high share of renewables affects electricity prices and the security of system operations.



ENTSO-E member TSOs cover 34 countries and five synchronous areas.

Liberalized and Integrated

In principle, all consumers in the EU — household, commercial and industrial customers — can choose their electricity supplier freely and are able to switch suppliers within three weeks or less. The market is accessible to all suppliers, especially small and renewable energy producers. To achieve this, the transmission system and distribution networks provide open access to all consumers and producers. They are regulated, non-discriminatory natural monopolies; therefore, they are unbundled from suppliers and generators. Three successive EU Internal Energy Market legislative packages defined these principles in European binding laws.

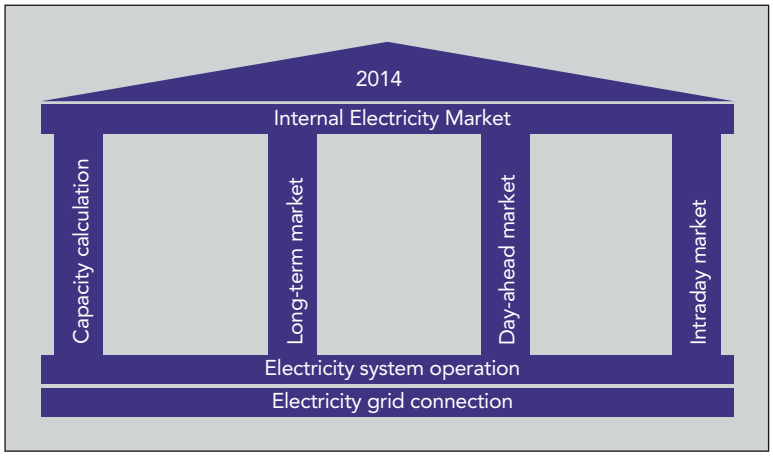
To make this liberalized market work across all of Europe so customers in one country can choose to be supplied from generation in another country requires many detailed rules valid across Europe. At the heart of this market structure is the concept of a balance responsible party (BRP), which is a company that balances on an hourly or quarter-hourly basis the generation and the customer load it contractually includes, using electricity trading to cover any gaps.

The BRP may own generation and have direct customer contracts, may provide the balancing for several companies or may engage primarily in trading. At any time, it must be clear for all loads and generators to which BRP they belong. In addition, the TSOs and distribution system operators (DSOs) contract generation and demand response for system services (for example, frequency and voltage control to balance the overall system).

Because generation costs differ strongly across Europe — being very cheap in hydro-dominated areas when there is abundant rain, or in areas with much wind or solar power when there is wind or sunshine — customers and suppliers have strong incentives to trade electricity Europe-wide so they can meet the demand at the lowest cost.

The demand for traded electricity can exceed the capacity of the grid. This is why TSOs declare congested interfaces in their network and allocate the limited transmission capacity to those trades that create the highest economic value. This is handled with nondiscriminatory approaches for the different market times, forwards, day-ahead and intraday. For each market time, a consistent

method for capacity allocation and congestion management is applied Europe-wide.



The European market integration target model.

Pan-European Rules

The EU's third Internal Energy Market Package of 2009 established ENTSO-E and created a new way to legislate energy market details in Europe. ENTSO-E covers 34 countries — going beyond EU borders — representing 41 TSOs that serve 532 million people in Europe and operate 307,503 km (191,074 miles) of transmission lines. The net generation capacity on the grids account for 1,004 GW, comparable to the U.S. or Chinese grids. It represents one-fifth of the world's total installed capacity.

The European network codes are sets of rules that become binding at the end of a process in which ENTSO-E drafts the law and consults with its stakeholders. The European Commission prioritizes the areas in which network codes need to be developed. European regulators, through the Agency for the Cooperation of Energy Regulators (ACER), define the policy framework guidelines the network codes must respect. The ENTSO-E draft is reviewed by ACER and the European Commission, and is submitted to a committee of EU member state representatives for adoption.

The eight codes are grouped into connection, operational and market codes. In December 2014, the first code was adopted when the 28 EU member states agreed on the regulation on capacity allocation and congestion management (CACM). The adoption should speed up that of the seven other codes ENTSO-E has delivered or is finalizing, all of which have already received an ACER recommendation for adoption.

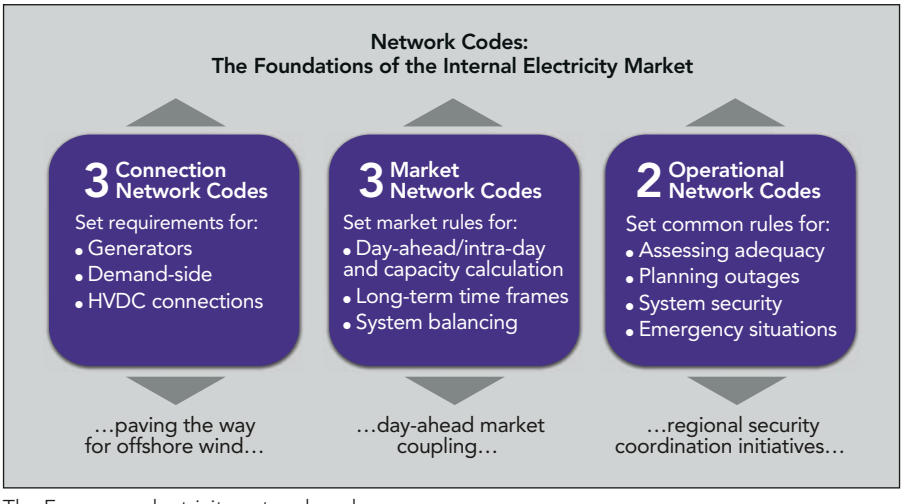
In parallel, TSOs, regulators and power exchanges are working on early implementation projects of CACM to complete the integration of the European electricity market as fast as possible. A particularly relevant example is the markets of 17 European countries, representing 75% of the electricity demand, were coupled by mid-2014 in the day-ahead time frame, leading to a substantial savings for customers.

Integration of Renewable Energy

The other fundamental axis for EU energy policy is decarbonization. The EU Energy Roadmap 2050 aims to reduce greenhouse-gas emissions by 80% to 95% below 1990 levels, implying 96% to 99% reduction within the power system. This requires massive increases in renewable energy. The European political momentum, national support schemes and significant decreases in generation costs have led to rapid increases in wind and solar generation. Non-hydro renewable energy sources (RES) account for 435 TWh, or 13%, of the total generation mix of ENTSO-E member TSOs; including hydro, RES accounts for 31%. To meet the EU targets, this should increase to 45% over the next 15 years and to 60% by 2050.

Secure integration of RES is the key determinant for European TSOs. Fluctuating RES is challenging for the operation of systems where generation needs to meet demand every second. Generation is becoming more stochastic, weather-dependent and widely dispersed. More continental-scale power trading is needed to transport temporary regional surplus wind or solar generation to other parts of Europe with less wind or sunshine at that time, or to hydro storage reservoirs in the Alps or Scandinavia.

Partly because many of the solar and wind installations are owned by customers, European customers become more active electricity market participants. The need and the opportunities for flexible demand grow as Europe's energy-efficiency and carbon-dioxide reduction policies support the electrification of transport with electric vehicles and heating with heat pumps. As distributed generation and demand response



The European electricity network codes.

become larger parts of the resource mix, the cooperation between TSOs and DSOs intensifies.

Planning the Future Grid

The uncertainties for Europe's electricity system and market make long-term system planning particularly difficult:

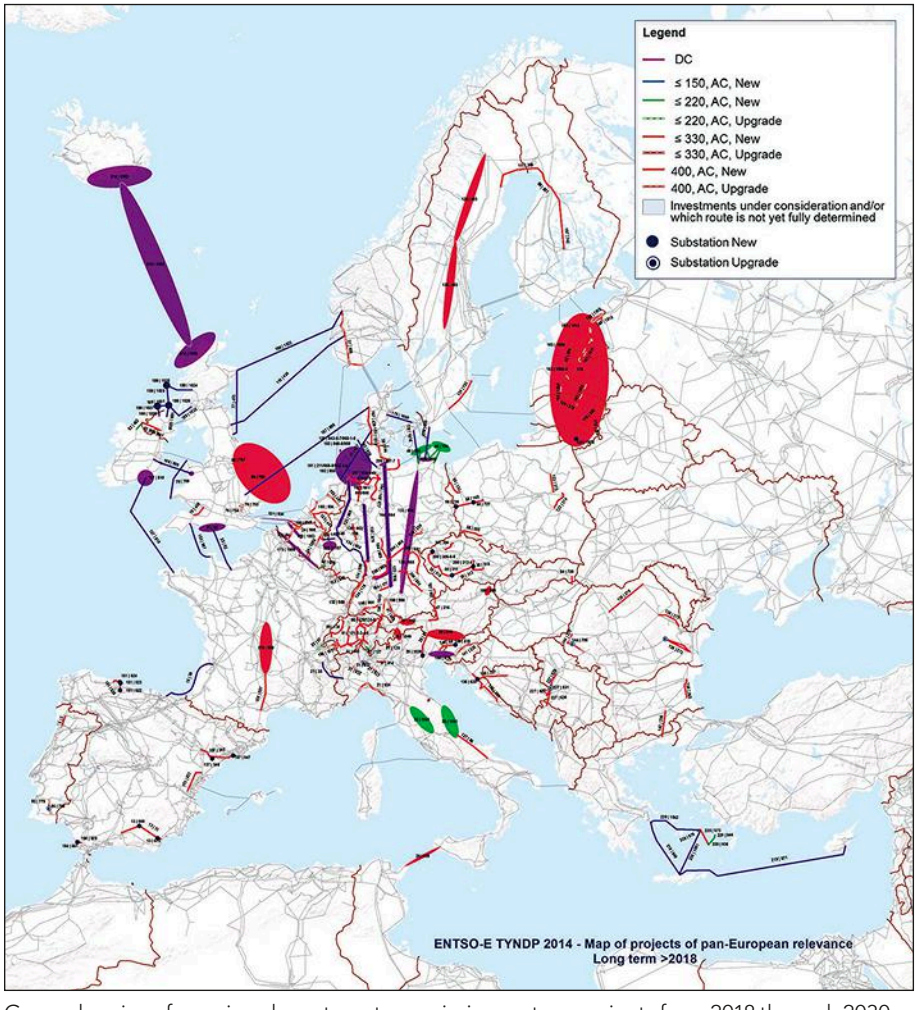
- Will photovoltaic and wind energy become cost competitive?
- Will there be a global agreement on climate protection, and with what implied price for carbon dioxide?
- How big a difference will smart metering, dynamic pricing and demand response make for household customers?
- Will markets be allowed to allocate electricity supply to the highest value continent-wide, even when — for hours, days or weeks — there is a widespread shortage as a result of gas import problems, insufficient power plant investment or prolonged lack of sunshine and wind?

European Union Power System

	2012	2030	2050
Carbon-dioxide price range, euros/ton (US$/ton)	5.8 (6.8)	31 to 91 (36.5 to 107)	42 to 310 (49.4 to 365)
European annual electricity demand, TWh	3336	3610 to 4327	3161 to 5364
European annual peak load, GW	350-520	444 to 653	231 to 926
Renewable energy installed capacity, GW	355	635 to 1138	356 to 1548
Centralized renewable energy capacity, GW	–	239 to 276	254 to 929
Non-centralized (distributed) renewable capacity, GW	–	40 to 88	51 to 929
Fossil fuel-fired capacity, GW	463	357 to 413	0 to 258
With carbon capacity storage	463	0.3 to 13.36	0 to 258
Without carbon capacity storage	0	360 to 402	0 to 79
Nuclear capacity, GW	125	107 to 112	0 to 205

Note: Ranges of key forecasts are taken from different scenarios of recent ENTSO-E publications.

Along with the network codes, ENTSO-E's main legal mandate from 2009's third Internal Energy Market package are the biennial Ten-Year Network Development Plans (TYNDP). These involve hundreds of TSO and stakeholder experts as well as formalized multi-criteria cost-benefit analyses, as the 2013 EU infrastructure regulation makes ENTSO-E's TYNDP the sole basis for selection of the projects of common interest, which can leverage EU grants and benefit from swifter permitting procedures.



General regions for various long-term transmission system projects from 2018 through 2030.

The TYNDP 2014 defines system development to 2030 and uses four distinct, fully quantified visions of Europe's electricity system and energy mix as the basis for analyzing 120 projects, requiring an investment of 150 billion euros and 50,000 km (31,069 miles) of new high-voltage infrastructure. This only represents a 1.5 euro (US$1.76) increase on the end-user's bill, compared to a reduction of electricity bulk prices by 2 euros/MWh to 5 euros/MWh ($2.35/MWh to $5.88/MWh) because of the new lines (saving roughly twice as much as they cost).

The driver for 80% of TYNDP projects is RES integration. Most policy makers agree growing RES penetration will lead to frequent needs to transmit power from regions of temporary surpluses to other regions of temporary deficits. A strong grid is a prerequisite for growing amounts of renewable energy.

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ENTSO-E Research and Development Program Clusters

Cluster	Name	Outcomes
1	Grid architecture	This cluster provides a set of scenarios and methods for developing network infrastructure that hosts massive amounts of renewable energy sources and growth in demand with acceptable network investments and operating costs beyond 2020. It is of utmost importance to develop coordinated pan-European planning to cope with the multiple dimensions of these tasks. Furthermore, technology and construction criteria much be defined for new grid selections while risks of making wrong decisions and investments must be reduced.
2	Power technologies	This cluster addresses the affordability and technical performance of emerging technology components that can significantly improve the operations of the interconnected transmission systems. This reduces the extra costs that arise from the management of variable power generation and volatility of demand inherent in renewable sources and demand management.
3	Network operation	This cluster studies ways of operating transmission systems that maintain high security of supply at reasonable costs. All TSOs have embraced and implemented a risk-based approach for making real-time and short-term decisions that affect both the security of supply and the functioning of the market.
4	Market designs	This cluster studies the ways and means to facilitate interactions between the European electricity markets and the pan-European grid. The aim is to achieve a more efficient and integrated market by optimizing the energy mix at the pan-European level while ensuring sectary of supply. Possible review of market designs must be analyzed in order to ensure that they facilitate the integration of the increasing share of variable renewable energy generation with demand-side management and storage.
5	Asset management	This cluster determines the most beneficial asset management strategy on a cost-effectiveness basis (value for the money). New methods of performing cost/benefit analysis at the power system level must be developed that utilize advanced measurements of power system health. With ICT, better knowledge of the constraints faced by network components help optimize maintenance and replacement strategies in a grid where new and old assets exist.
6	Joint TSO/DSO R&D activities	This cluster evaluates the smart grid initiatives by DSOs and their possible utilization for supporting the transmission grid with regulation and ancillary services provided at the interface with the distribution system.

Technological Challenges

Fundamental changes in generation and demand will require new technologies. Heat pumps, water heaters, air conditioners and electric car chargers need to be smart grid-ready to avoid an inefficient, expensive duplication of distribution capacities so they contribute to system balancing. Storage will be essential in the European electricity system to maintain security of supply.

The TYNDP already includes large-scale storage facilities connected at the transmission level. However, there will be a need for fast small-scale storage. To meet these technological challenges, ENTSO-E issues European research and development roadmaps. These include six clusters ranging from grid architecture, integration of power technologies, new tools for network operation, market designs, asset management and collaboration between TSOs and DSOs.

Cooperation Is Key

ENTSO-E's products are designed to be complementary to the research and development roadmap, the TYNDP and the network codes. All of them will play a role in achieving the EU energy policy targets. Their respective time periods and technical details interlink to develop infrastructure measures to respond to the challenges identified, first researching, then specifying and constructing the infrastructure or users' capabilities, and then operating the system and integrated European market. The result of these deliverables will be a smarter infrastructure and smarter investments — along with continuous evolution and adaptation of the technical and regulatory framework as well as evolution of the market design — leading to a reliable, competitive and sustainable energy system.

Uncertainties and Potential

All ENTSO-E work products are subject to extensive stakeholder consultation, which takes into account their views on the challenges and solutions. The challenges and uncertainties for Europe's electricity system are enormous, but the potential for a secure and affordable electricity supply that contributes to energy efficiency and climate protection are equally enormous. This is what European lawmakers and TSOs are convinced of and what they are committed to delivering to European consumers.

Climate protection and the transition to renewable energy drive much of this agenda, but affordability, efficiency and security of supply must not suffer. The market, customer choice, European integration and smart grid innovation can provide the solution for this apparent contradiction, and ENTSO-E's work products aim to turn these solutions into reality. TDW

Konstantin Staschus (konstantin.staschus@entsoe.eu) holds a Ph.D. in operations research from Virginia Tech. After nine years at Pacific Gas & Electric, Staschus held management positions in German utility associations, including six years as managing director of VDN, the association for over more than 400 German electricity T&D system operators. In 2009, he was appointed secretary-general of the European Network of Transmission System Operators for Electricity in Brussels.

Editor's note: This article was adapted from a paper drafted in 2015 and represents data from 2015.

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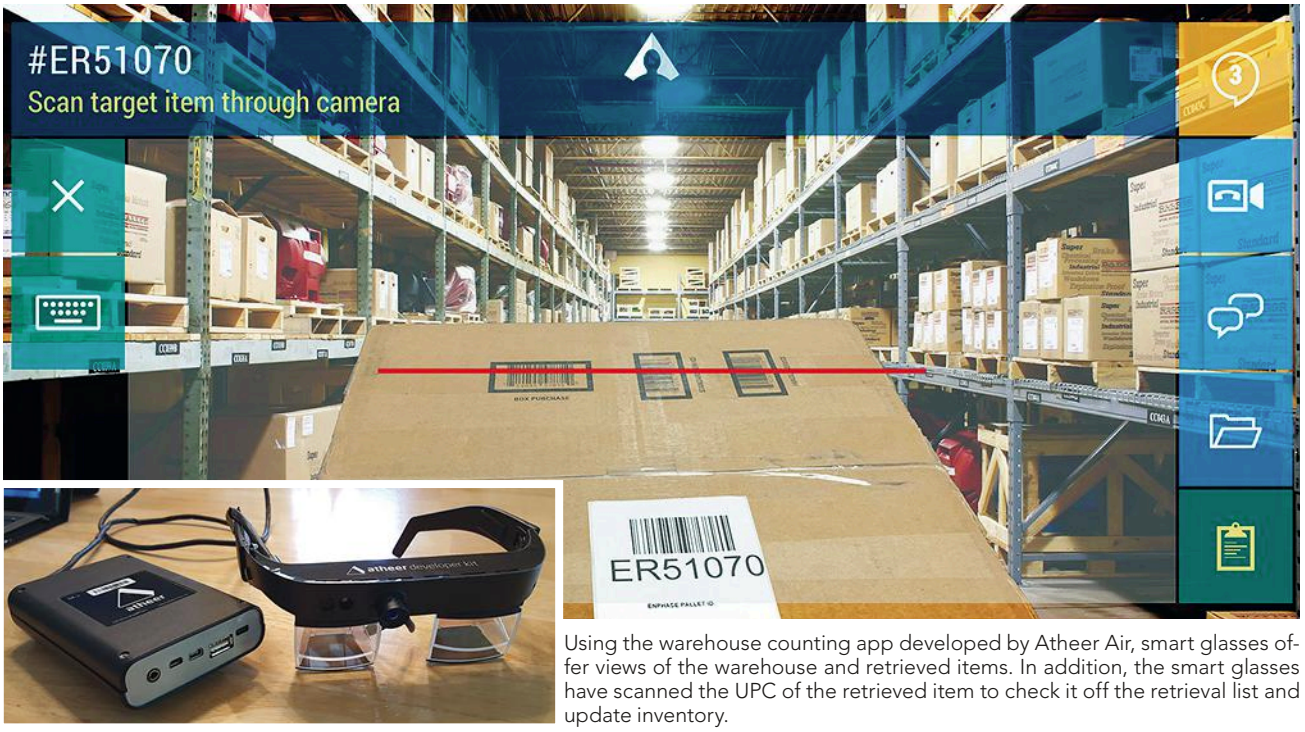


Using the warehouse counting app developed by Atheer Air, smart glasses offer views of the warehouse and retrieved items. In addition, the smart glasses have scanned the UPC of the retrieved item to check it off the retrieval list and update inventory.

Duke Augments Reality

Duke Energy works with EPRI to investigate and pilot the use of smart glasses in electric utility operations.

By **Aleksandar Vukojević** *and* **Chet Johnson**, *Duke Energy, and* **John J. Simmins**, *Electric Power Research Institute*

Paper-based work management worked well for the utility industry for more than half a century. But with the increased productivity gains from digitization of the office environment, pressure gradually built to extend those efficiencies to the field. The limitations have always been the size and weight of the computer platform as well as the connectivity back to the central office.

Revolutions in physical layer technologies — cellular, WiMAX, WiFi and Bluetooth — along with the rate at which computer platforms have been miniaturized, have outpaced the rate of utility implementation. The ruggedized laptop that seemed so leading-edge 10 years ago now seems quaint in retrospect. Today, it is possible to carry in hand what would have been considered a supercomputer 10 years ago.

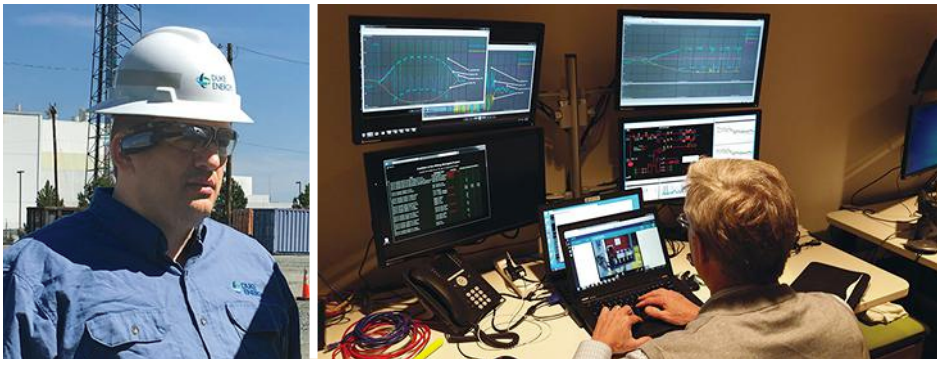
These advances in technology and communications have provided electric utility operations and maintenance personnel with new devices for running day-to-day operations and potentially reducing costs. However, quite a few emerging technologies are still in their infancy, and full-scale implementation is probably three to five years away. While many technologies are too immature to deploy, they are at a perfect level to investigate.

Enter Smart Glasses

Two technologies to investigate are smart glasses and virtual and augmented reality. Augmented reality technology overlays information in real time onto a view of the world through the use of mobile computing devices and graphics. Augmented reality goes beyond the mobile computing and geospatial information system (GIS) technologies utilities are using today. Augmented reality could be an effective way to aid the worker in performing activities such as inspecting assets, performing inventory transactions, maintaining substations, obtaining remote expert help, repairing equipment, retrieving documents, switching, tracking radiation exposure, and taking or reporting routine measurements.

Numerous companies have emerged to develop and use augmented reality in many different industries. These com-

panies have expertise in augmented reality and wearable computing technologies as well as creative ways of displaying information that enhance productivity, but they have little to no understanding of electric utilities and their working environments. Several questions still need to be answered around the use of augmented reality for electric utility activities: Are there crew activities that would benefit from augmented reality and wearable technologies? Would augmented reality be more of a distraction than a help? Can the technology operate in an electric utility environment? What is the business case to justify a utility's investment in augmented reality?



Aleksandar Vukojević uses Vuzix MX100 glasses in the field, while David Lawrence is in the operations room using the live video and audio communications app to enhance operational efficiency.

Pilot Projects

To address these questions, Duke Energy and the Electric Power Research Institute (EPRI) have launched a series of projects that place wearable technology and augmented reality in the middle of several common utility work flows. The Duke Energy projects are internal but also overlap with EPRI as part of its collaborative research model.

Duke Energy's emerging technologies team started its first augmented reality project in the fall of 2014 to understand the current capabilities of the hardware and software offerings at the time and to investigate the possible range of use cases. At that time, a handful of vendors on the market were offering smart glasses. The team tested three use cases using four different technologies: Google Glass, Golden-I by Kopin, Vuzix MX100 platform by XOEye Technologies and Atheer Air.

The first pilot project tested the use of a live video and audio feed between field personnel and the operations office. The team learned three major lessons during this part of the pilot project. First, the IT security firewall blocked all audio and video content, so a separate network needed to be used. Second, given the glasses do not have a cell modem installed, the solution required use of either a hot spot through the phone or a Jetpack. The download and upload speeds were in the 0.2-second to 0.4-second range, and depending on the strength of the network, the speeds were faster from the location that was 300 miles (483 km) farther from the operations office, compared to the location that was 20 miles (32 km) away. Finally, the team found having live video and audio was more helpful than a phone call for field personnel who needed assistance.

Training App

The second pilot project was initiated with Atheer Air to develop an app for training. The use case for this project was a 10-step procedure from a generation plant. The use case is common for substation personnel who regularly change the settings on a SEL-351A relay to put it into maintenance mode and, upon completion, return it back to the normal operating mode.

The Atheer Air hardware provides an option for the user to pick the preferred app, outline the procedure step by step and mark each of the steps that have been completed, or view a picture or video to get specific directions to perform the task. At the end, the app enables the user to store the data and text, send an e-mail or make a phone call to notify a person of the completion time and any other information that needs to be relayed.

Overall Activities

The third pilot project was completed as part of EPRI's augmented reality supplemental project. The objective of the Assessing Augmented Reality project was to identify utility activities that might benefit from augmented reality and then develop use cases collaboratively around priority activities. EPRI worked with member utilities, like Duke Energy, to measure performance characteristics of select activities prior to augmented reality application to establish benchmarks, and then measured performance characteristics of the same activities after augmented reality application to compare them to the established benchmarks.

The Atheer Air O&M app consists of instructions, pictures and videos associated with settings change on an SEL 351A substation relay to put it into maintenance mode and then return it back to normal mode.

Next, EPRI developed an augmented reality solution assessment framework and an approach to assess the ef-

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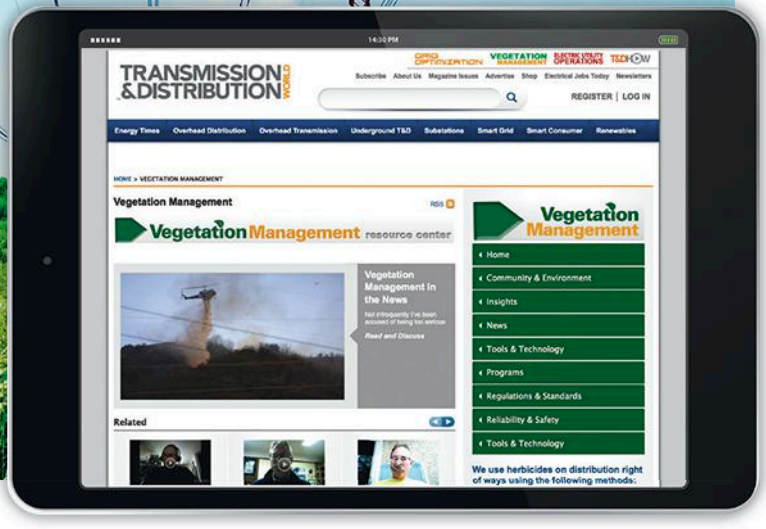

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fectiveness of different augmented reality solutions for various use cases. Finally, EPRI performed cost-benefit analysis on the identified activities to measure the value of adopting augmented reality. The EPRI project also measured the impact on the worker from an ergonomic perspective, analyzing the impact on muscles, bones, eye strain and situational awareness when augmented reality and wearables were introduced.

Vision through the glasses of the app to help warehouse employees by assisting in picking and warehouse navigation.

This use case was focused on creating an application that would aid a warehouse employee in performing inventory counting, one of the most commonly executed procedures in warehousing. The procedure includes obtaining and reviewing a list of bins and items that need to be counted, verifying the desired item has been located through barcode scanning (bin and item), and performing the count through verbal commands. The application automatically compares the counted value to the Maximo database value and, if it does not match, provides the user the option either to recount or to save and move to the next bin or item on the list.

More Work

The next iteration of the warehouse counting application is to develop internal navigation from bin to bin. Beacon technology is being considered for this application. WiFi devices also were considered, but from the standpoint of accuracy, beacons may provide the best solution.

Duke Energy is currently initiating a warehouse picking application pilot project. Currently, warehouse personnel use different ways of picking items from the shelves for different orders. The objective of the warehouse picking application is for the user to review the list of all orders, and for the user to be guided through the warehouse in the shortest and most efficient route to fulfil the order. When locating the item, confirmation would occur through barcode scanning and a notification would be sent to Maximo indicating the item has been picked.

In addition, Duke Energy will be working with one of the universities to build a complete suite of apps on the Atheer Air platform that will cover substation inspections of transformers, breakers, batteries and other assets. Based on feedback from the end users, this might be expanded to cover not only the asset inspection but also asset repair application.

Future Efforts

Duke Energy's plans include the development of a storm restoration application. The objective of this application is to provide the field user with images and data about the assets that were previously in operation before being taken down during a storm. This would be especially useful to non-native repair crews being deployed for restoration work. Taking a picture of the affected area, tying it to a GPS coordinate and having a connection to the GIS should enable the glasses to display the original asset location and make it easier for field personnel to visualize the work that needs to be performed.

An additional benefit would be the automatic generation of a bill-of-materials the supply chain business unit could use to aggregate purchasing needs for the warehouse replenishment of storm restoration needs.

Moving forward, Duke Energy and EPRI will collaborate with other utilities to investigate the capabilities of virtual and augmented reality further. Several use cases are being developed currently, such as warehouse picking, substation equipment maintenance protocol and, ultimately, smart glasses being able to see the area affected by a storm, having a connection to the GIS

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and overlaying images of assets taken down by the storm, like wires, poles, transformers and insulators. Finally, the glasses and augmented reality app would be capable of issuing a request to the warehouse for the material that needs to be used to bring the system back up.

The preferred option for moving forward will be a function of the cost of ownership, change management support, the ability to incorporate multiple integrated data streams, and most importantly, the ability of personnel to do their job without the equipment being a hindrance or having a negative effect on implementation. TDW

Aleksandar Vukojević (aleksandar.vukojevic@duke-energy.com) is the manager of emerging technologies office at Duke Energy. His duties involve developing, installing, testing and evaluating new technologies. Vukojević holds a bachelor's degree in applied mathematics from Kennesaw State University, a BSEE and MSEE degree from the Georgia Institute of Technology, and a MBA degree in corporate finance from Georgia State University. Currently, Vukojević is pursuing a Ph.D. degree in electrical engineering at the University of North Carolina at Charlotte.

Chet Johnson (chet.johnson@duke-energy.com) is the lead enterprise asset management strategic business consultant for finance, fleet and supply chain business units across Duke Energy. His duties involve consulting with internal business units, worldwide peer users and IBM to advance the use of the IBM EAM Maximo product suite and associated products and technologies.

John J. Simmins (jsimmins@epri.com) is a technical executive at the Electric Power Research institute, where he manages the information and communications technology for distribution project set. His current research focuses on integrating back-office applications with devices and personnel in the field. Simmins also leads EPRI efforts in the use of augmented reality, social media, data analytics and visualization to improve grid resilience. Prior to joining EPRI, Simmins was with Southern Maryland Electric Cooperative, where he managed the engineering and operations applications. He holds a bachelor's degree and a Ph.D. degree in ceramic science from Alfred University.

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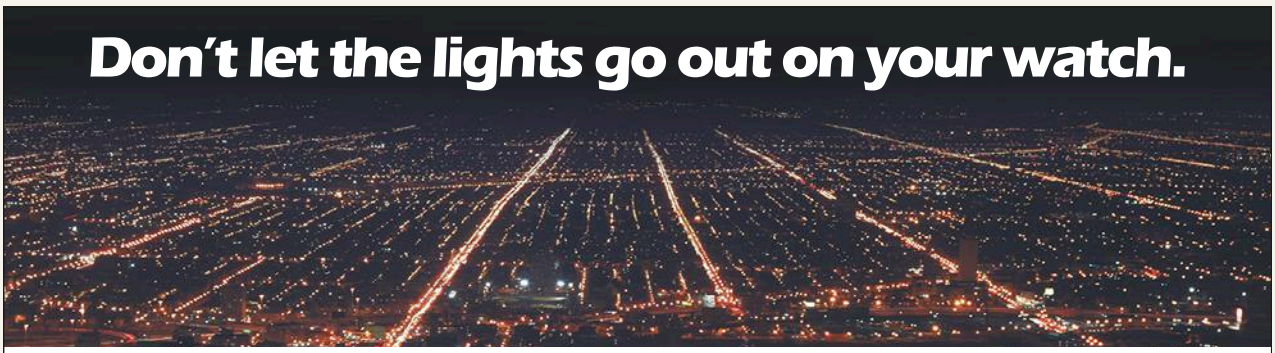

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JOB SPECIFICATIONS

Education:

- Bachelor's Degree in Electrical Engineering or equivalent
- Ability to obtain P.E. license is desirable

Experience:

- Five years' of progressively more technical responsibility in the design and application of relay and metering facilities and equipment
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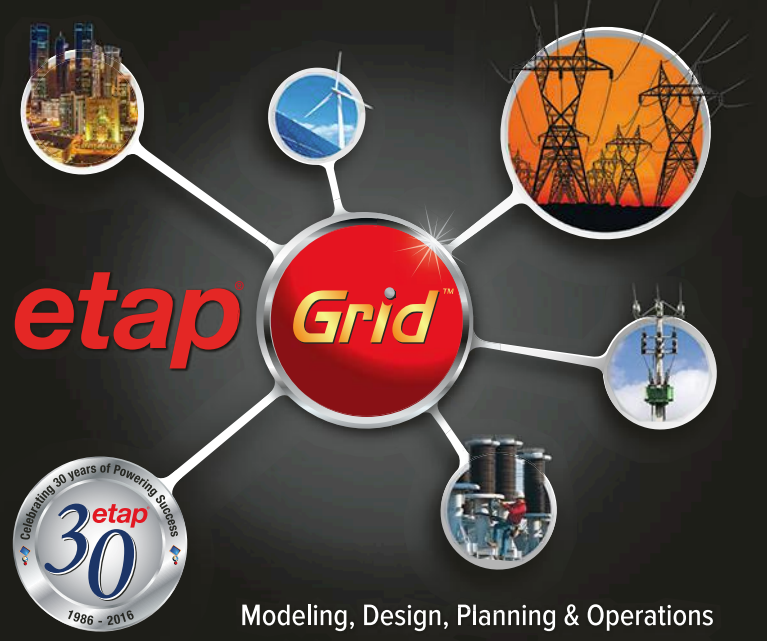

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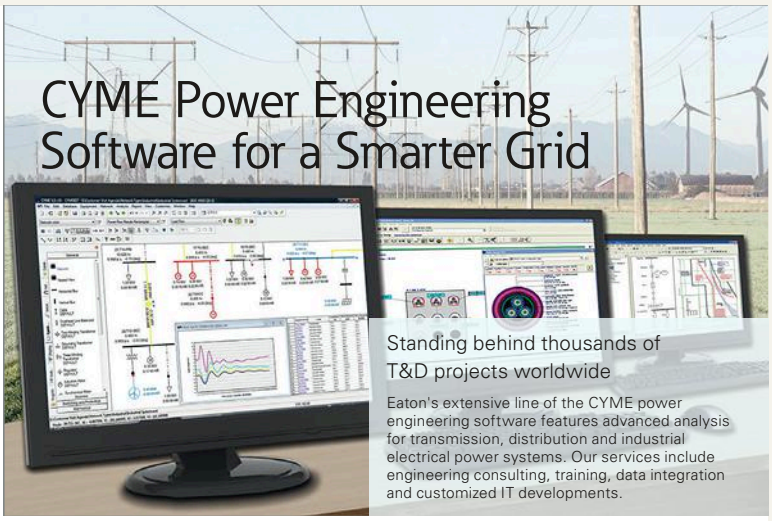

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Our Energy Future

By **Doug Houseman**, *EnerNex*

Time is not our friend. Coal generation will go away, with much of it gone by 2020 and little surviving beyond 2030. Once most of the coal is gone, we will see natural gas generation come under pressure to close down. Nuclear generation is not economically feasible today, and regulatory changes would be needed to make it viable. Expect to see wild rivers organizations push to remove hydroelectric facilities.

Expect wildlife groups to try to limit or ban wind turbines from areas that have higher levels of bird and bat strikes. Local communities are enacting zoning ordinances that limit placement of both wind and solar installations that are visible outside the owner's property. Society is fragmenting on what it wants in the way of generation: BANANA (Build Absolutely Nothing Anywhere Near Anyone). In short, generating any power at all in the emerging regulatory environment may be difficult. It will not get as bad as I opined, but some days it will feel that way.

FERC 1000 already influences how transmission is planned and funded. New FERC regulations will impact our transmission planning and capitalization; ultimately, it will determine how the industry sites and uses transmission to connect to new renewable generation. These rules impact who pays, which will result in pushback from state commissions. Expect FERC rulings to be challenged so the courts may have final say.

Distribution is heavily in flux as Solar City, the Rocky Mountain Institute and others propose to take distribution grid operations away from the utilities and put it into the hands of independent distribution system operators.

What about solar? Solar leasing companies want to put solar roofs onto the homes of all homeowners who meet minimum credit standards to qualify for a second mortgage, without regard for technical issues. They are also pushing to install the largest, economically feasible generation capacity a site will support, even beyond net zero.

Distributed generation (DG), including solar, will have a heavy impact on planning, engineering and operations in the distribution organization; in many cases, we will reverse the trend to smaller planning and engineering staffs as planning and operations become much more complex and critical to the future of our distribution utilities.

Given the radical changes coming, regulators will "encourage" customers and distribution utilities to work together to solve issues, with a wide array of third parties, aggregators and additional support groups involved in the process.

Getting this new ecosystem to work will be a major hurdle going forward. There will be divergent goals in the ecosystem with no single entity in charge. Some will look only at how much money they can make; others want to protect economically disadvantaged groups. And others may set regulatory limits on who can do what.

If every state required 1 kW of photovoltaic (PV) generation on the roof of every one of the 130 million residential units, a lot of PV would be installed and the impact on the grid would be minimal (in comparison to other options). This would provide effectively a "negative load" impact on the grid. It would have a massive revenue impact on the utility industry and would change the daily load curve, changing the generation mix for the rest of the needed power.

Most states have adopted a "first come, first served" method of allowing DG. If the distribution grid can support it, then permission is given to install the DG. If an early mover consumes all of the available capacity on a transformer, then their neighbor can be denied permission because of a lack of capacity. If the neighbor is willing to pay the cost to change the transformer or make other needed changes to allow the grid to host their DG, then they can have permission. But the first mover does not have to pay any of the costs, even though they used all of the hosting capacity. This may end up in lawsuits and changing regulations in the near future.

To balance the system, markets will evolve. At the lowest level, homeowners may trade lighting for A/C to stay within their budget. The markets will probably become a hierarchy that starts within a home or business, then to the transformer, and then to the segment and phase of the distribution circuit, on to the whole distribution circuit, then to the substation and finally up to the typical wholesale markets. Expect that implicitly there will be ancillary services, capacity and energy markets at each level. Expect most of these markets will cost more to run than they offer in savings.

Regulatory changes are now pushing utilities and customers to take a fresh look at how electricity is generated, distributed and consumed. In some states, the changes are coming fast and furiously. In other states, the process will be years or decades in the making. Be assured that tomorrow's utility industry will look quite different than the one we work in today.

Do you want a say in the shape our industry will take? Then get involved! We will never see a more seemingly chaotic yet challenging and exciting period in our lifetimes. TDW

Doug Housemen (doug@enernex.com) is vice president of technical innovation at EnerNex. He is a senior member of IEEE and an active member of the Power & Energy Society.

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