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Electric Energy T&D MAGAZINE

JULY-AUGUST 2017 Issue 4 • Volume 21

Ameren's Microgrid: Planning the Grid of the Future

INSIDE 2017 BUYERS GUIDE

Electric Energy T&D MAGAZINE

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Electric Energy Magazine is published 6 times a year by: Jaguar Media Inc.
834 Montée Masson
Terrebonne, QC Canada J6W 2C6
Tel.: 888.332.3749 • Fax: 888.243.4562
E-mail: jaguar@jaguar-media.com
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Post Publication mail agreement #40010982
Account #1899244

POWERPOINTS

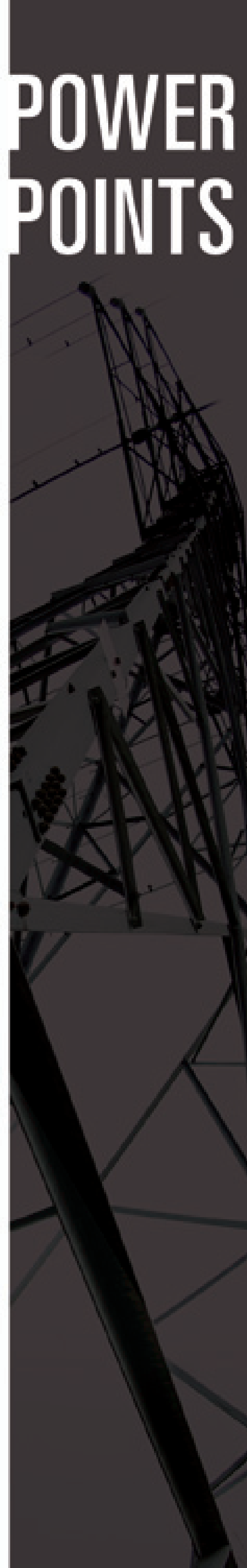
Fuel: The Driving Force Behind Buying a Car

I have been thinking about trading in my 2007 Honda Civic for a newer, more energy-efficient car, but it seems that cars have gotten way smarter than most consumers. I don't know whether to be thrilled with or overwhelmed by all of the options. Today's cars feature in-car internet capability to conduct hands-free searches for music or news; find the nearest coffee shop; discover what traffic jams are ahead, or get directions to that meeting on the other side of town. We also can carry on telephone conversations without taking our eyes of the road. Most recently, we have seen cars that self-park as well as a few that, even more remarkably, self-drive. Flying cars also have hit the scene, but because it will be awhile before they wind their way into the mainstream, I don't expect to be driving one anytime soon.

I ended up with my Honda because the dealer no longer had inventory of the hybrid in which I was interested. Not wanting to wait for the car to come in, I drove off in my new Accord. Ten years later, my Honda is showing wear, and I would like to have a plan in place for a new car before any important parts need replacing.

I would prefer it if my next vehicle were a hybrid or ran on something other than gas. While I have a friend who drives a Prius, and another who drives a Jetta that runs on diesel, I don't have a go-to subject matter expert. I am still in the "discovery" phase of my research, but I have learned a few things that I am passing along in case they come in handy.

According to the **U.S. Department of Energy's Alternative Fuels Data Center (AFDC)**, there only 198 public biodiesel fueling stations in the entire U.S., which means if I were to own such a car I would probably need another that runs on gas or some type of fuel that is readily available. Because the biodegradable fuel used in biodiesel can be made from vegetable oils, animal fats or recycled grease, I envision the people behind me in traffic developing a sudden craving for French fries. It may be a myth that biodiesel fuel smells like fried food, but the thought of smelling grease from my car on the hottest days of summer is enough to steer me away from biodiesel engines for now. Besides, biodiesel fuel may also be problematic for me during the winter, as, there's a chance it could gel on cold days, and I do not relish the idea of being stuck in a blizzard because my car won't start.



Electric vehicles are promising, with their clean fuel and energy efficiency. *Chargepoint.com* claims there are 628,260 EVs on the road in the U.S. and Canada, which is an indication these cars are gaining popularity. The price tag for electric vehicles can be significantly higher than cars that run on regular gas. For example, the MSRP of a 2017 Fiat 500 starts at $14,995, while the MSRP of a 2017 Fiat 500e (electric version) starts at $32,995. A Honda Accord starts at $24,455, while a Honda Accord Hybrid starts at $29,605. There are thousands of charge points available for electric cars but owning one would require better planning habits, as it can take *at least* 30 minutes to charge an EV.

Hydrogen-powered vehicles are an intriguing concept, but according to the AFDC, there are only 36 fueling stations in the United States, 33 of which are in California. Until there is a greater demand for the vehicles and an established delivery system for the hydrogen, the asking prices for these vehicles will remain high (A Honda Clarity, the automaker's new hydrogen cell-fueled car, starts at $60,000. Compare that to the Accord mentioned above that starts at $24,455.) Further, the number of fueling stations will remain few and far between, so a hydrogen fuel cell vehicle is off the table, for now.

Once I am ready to take the leap and purchase a new car, the availability of automobiles and alternative fuel types will be a key factor in my decision, but there are a few more issues I need to think through. Tax credits may currently offset the higher costs of some cars, but as more people begin driving these alternatively-fueled vehicles, the tax credits may either decrease, or go away all together. It's probably a good idea for me to examine if I'm committed enough to a cleaner environment that I'm willing to pay a higher price for an alternatively-fueled car, whether or not I receive a tax credit. Another consideration is if I buy a battery-powered car, what are my plans when the battery no longer works? If I truly want to drive a car that is better for the environment, I had better take the time to find out how to recycle its lithium battery. It would defeat my goal towards a greener lifestyle if I just toss it into my dumpster, without giving a second thought to added waste in landfills and the fact that the battery contains toxic materials.

Based on my preliminary findings, combined with the fact I'm not an early adopter, I am leaning towards the latest model of that hybrid I'd considered a little more than 10 years ago. I'm not ready to rely on a vehicle that runs solely on a charged battery or on fuel that is difficult to come by. With a hybrid, I'd be able to use conventional gas, while also driving a vehicle that is less harmful to the environment. I still have some research to do, but as I continue to educate myself on the topic, I am open to recommendations, if you have them.

If you would like to contribute an article or if you have an idea about interesting technology, solutions, or suggestions, please email me at *Elisabeth@ElectricEnergyOnline.com*.

Elisabeth

AES Announces Winners of Open Innovation Contest at 2017 Innovation Congress

Proposed New Solutions are for Unmanned Inspections in Extreme Heat, a $1 Billion Problem for the Global Power Industry

July, 2017

The AES Corporation (NYSE: AES) announced the winners of its Open Innovation Contest targeted at identifying innovative unmanned inspection solutions for extreme heat environments to help AES avoid hazardous work hours during manual inspections of energy infrastructure while increasing energy availability for customers.

Contest Winners and Proposed Solutios:

- Roland Bruyns (individual, USA): Polymer enshrouded drone
- Sonya Davidson (H2 Energy Now LLC, Israel): Ceramic encased drone
- Alexander de Melo (Lexno Industrias, Brazil): Thermoelectric cooled drone
- David Espinosa Duran (Aronax Technologies Group LLC, Spain): Sound imaging camera

The contest winners were unveiled at AES' 2017 Innovation Congress, a biennial global event where people from across AES convene to showcase ideas and solutions that are shaping the power industry for the future and to celebrate innovation.

"The rapid rate of change and shifting dynamics in the power sector demand new and forward-thinking solutions from inside and outside the industry," said Bernerd Da Santos, AES Senior Vice President and Chief Operating Officer. "AES' Open Innovation Contest is part of our applied innovation approach to adapt proven technologies in other sectors for use in the power industry. The smart application of technologies, such as drones, for existing and emerging power system challenges helps us to rethink our approach and will transform the future of the global electric utility industry."

It is estimated that more than 20 GW of generation capacity is offline globally at all times due in part to outage-related inspections, representing nearly $1 billion in lost power capacity. When system failures that halt electricity generation occur, operators typically need to wait until temperatures reach a sufficiently low level to safely inspect the confined space and repair equipment. This is both hazardous work and increases the time it takes companies to begin generating electricity again.

"Safety is our number one value at AES. We are continually seeking ways to keep our people and communities safer from the inherent hazards of electricity," Da Santos added. "The Open Innovation Contest gives us a new vehicle to source ideas that both increase the safety of our workplaces and improve the services we provide to customers."

AES launched its Open Innovation Contest in 2016, in partnership with NineSigma, a company specializing in connecting organizations with external innovation resources, to help advance a safer, smarter workplace, and identify potential drones and robotics solutions that can resist extreme heat. AES accepted proposals from other companies, consultants, venture capitalists, entrepreneurs and inventors. Submissions came in from nine countries, covering a range of approaches, including drone designs, high temperature resistant materials, acoustic technologies, applied sensor technologies and robotics.

For more information about the contest, please go to www.aes.com.

INDUSTRY NEWS

Nova Scotia Power's annual scholarship program supports inspiring future leaders

July, 2017

Nova Scotia Power is pleased to announce this year's recipients of its annual scholarship program, which will see financial awards provided to 40 outstanding post-secondary students hailing from Ingonish to Yarmouth, and a number of communities in between.

Majd Al Zhouri, set to begin his engineering degree this fall at St. Francis Xavier University, is one of this year's many deserving scholarship recipients.

"Graduating from high school was a very emotional moment for me," said Majd, a 21 year-old Syrian refugee and newcomer to Canada, who has been living with his family in Antigonish since 2016. "I'm so thankful and appreciative of the support I have received from my teachers, the community and everyone else who has helped me and my family since we moved here. I think Canada, and Antigonish in particular, are so welcoming to newcomers and it's a great example of how communities can come together to support each other."

At 21 years of age, Majd could have been graduating university this year, but he was forced to stop his high school education when he was 15 years old because of the Syrian civil war. His family moved around a lot in order to keep each other safe during the war, and they were extremely relieved to be one of a number of refugee families over the past few years to be sponsored and welcomed home by a Nova Scotian family.

Majd worked very hard over the past year to learn English while he was taking extra courses so he could condense three years of high school programs into 18 months. He also found a part-time job to begin saving for his post-secondary education, and to help support his family.

"I can't tell you what it means to me that I was able to return to school and finish my high school education; it was my top priority when we moved here," said Majd. "I feel that students in Nova Scotia don't know how lucky they are to be able to go to school. Honestly, you don't really know how much something like education means to you until it is taken away."

Majd was also recently recognized with a national art activism award for a play he wrote and delivered based on his reflections on life as a teenager in the Syrian civil war. He says it has helped him to cope with the aftermath of those life experiences, and focus on what's important to his future success - education and family. His dream of being an engineer - his father owned a construction company in Syria - will soon be realized due to his perseverance, and we are proud to support him and other future leaders of tomorrow by providing financial assistance through our annual scholarship program.

Scholarships are available each year to qualifying students enrolled in trades and degree programs under specific categories including, Mi'kmaq, Environment, Centennial, Trades, Employment Equity, and awards for Employees' children.

This year, Nova Scotia Power awarded scholarships totaling over $120,000. The program is in place to provide future leaders with opportunities to learn and grow, which is essential to developing an empowered workforce that will help to build the strong, healthy communities where we live and work.

For a complete list of the 2017 scholarship recipients or to learn more about our scholarship program, visit www.nspower.ca/scholarships.

TEP Customers Can Now Review Daily, Hourly Energy Use on Website, Mobile App

July, 2017

Tucson Electric Power (TEP) is now providing customers with monthly, daily and hourly electric usage and energy demand information through the company's website and mobile app.

Customers can see how much energy they used each hour, day or month using My Energy Usage, a new feature on tep.com and the TEP Mobile App. They also can review their usage during on-peak hours and learn about their peak energy demand, which reflects their highest hourly energy use. Detailed data is available back to Jan. 1, 2017. Customers can view their usage and demand data from as recently as the previous day - even before their monthly bill arrives.

"This new service allows customers to learn more about their energy use habits, helping them make small changes that can have a big impact on their monthly energy expenses," said Catherine E. Ries, Vice President of Customer and Human Resources for TEP.

The opportunity to review usage data before bills arrive is particularly helpful during the summer, Ries said. "Many customers don't realize how much harder their air conditioner is working during hot weather until their electric bill arrives," she said. "Now customers can review their daily energy use and decide to make changes that help them avoid higher bills."

Usage and demand data provided through My Energy Usage also will help customers choose an appropriate pricing plan. Earlier this year, TEP began offering four new pricing plans for residential and small commercial customers: Time-of-Use, Peak Demand, Demand Time-of-Use and Basic.

"Customers can review their recent usage during on-peak and off-peak periods to see if one of our time-of-use plans might work well for them," Ries said. "They also can quickly evaluate the impact of any steps they've taken to reduce consumption during on-peak periods."

Customers on time-of-use plans pay less for energy used during off-peak hours, which include most of each weekday, on weekends and on major holidays. Demand plans offer even lower usage rates along with a demand charge based on the customer's highest individual hour of usage during on-peak time periods. More details about TEP's pricing plans are available online at tep.com/rates.

To access the data on tep.com, log in to My Account, scroll over Billing and Payment, and click on "My Energy Usage." On the mobile app, which customers can download for free from Apple's App Store or Google Play, log in and click the "Usage" tile.

TEP provides safe, reliable electric service to nearly 420,000 customers in Southern Arizona. The company, founded in 1892, is commemorating its 125th anniversary this year through various community service initiatives. For more information, visit tep.com.

TEP and its parent company, UNS Energy, are subsidiaries of Fortis Inc., which owns utilities that serve more than 3 million customers across Canada and in the United States and the Caribbean. To learn more, visit fortisinc.com.

THE GRID TRANSFORMATION FORUM

Envisioning the 21st Century Grid

Ameren's Microgrid: Planning the Grid of the Future

For the July/August 2017 issue, we spoke with Warner Baxter and Richard Mark with Ameren about their DER facility in Champaign, Illinois.

EET&D: Tell us about Ameren's distributed energy resource facility. What makes it unique?

Warner: This facility is one of a series of initiatives and partnerships underway at Ameren. We are focused on innovation because we are planning for a future grid that operates much differently—an integrated grid that offers new products and services for our customers. We built our new microgrid in Champaign, Illinois to test how to cost effectively and safely deliver energy from renewable, clean sources to our customers. We have three leased Distributed Energy Resources (DER) on the site: a solar array that can supply up to 125 kilowatts, a 160-foot wind turbine that produces up to 100 kilowatts, and two natural gas units with capacity of 500 kilowatts each. The leased generation assets are supplemented by 250-kilowatt battery storage than can supply about two hours of energy. The industry experts who have visited the facility tell us that it is the most technologically advanced utility scale microgrid in North America because we're able to seamlessly transition the power source for an entire distribution circuit from exclusively distributed renewable generation sources to the traditional grid.

Richard: That seamless transition from "on-grid power" to "off-grid" is what our engineers call islanding. The obvious example where this can come into play is with a major storm. Being able to proactively switch to the distributed energy resources and then back to the traditional grid without customers experiencing an outage is a major breakthrough in technology. In fact, the renewable assets on site can produce up to 1,475 kilowatts and are powering 190 nearby homes and businesses.

EET&D: The battery storage at your microgrid is state of the art. Talk about these features.

Richard: Our engineering and construction partner was S&C Electric Company. We have a long track record of working with S&C, as the company provides the grid protection and switching equipment that we're utilizing in our smart grid build-outs throughout our territory. S&C's battery storage solution is really the backbone of the microgrid. It allows for the full integration of renewable energy sources that can run un-curtailed and even exceed loads. I'm not an engineer, but I understand that having a storage system that can be placed into charging mode while providing reference frequency and voltage is truly state-of-the-art.

EET&D: Warner, while Ameren Missouri is a vertically integrated energy company, Ameren Illinois is delivery only. What are you hoping to learn from your investments in testing distributed generation?

Warner: In 10 years, the electricity generation mix has changed dramatically. An Edison Electric Institute study indicates that one-third of all electricity now comes from zero-emission sources, such as nuclear, hydropower, wind and solar. We see the trend. Larger companies, military installations, and some private citizens are seeking alternative sources of energy and looking to produce it locally. It is incumbent upon even the delivery-only companies such as Ameren Illinois to prepare for the changes that are expected to impact the traditional utility business model. That's what we're doing with our microgrid facility. We're proactively testing and developing the capabilities to manage demand and control and economically dispatch both customer-owned and utility-owned distributed energy resources. We're doing the research and development today to prepare for the future grid. From our perspective, it's about turning a potential disrupter into a business opportunity. The Champaign microgrid is a critical component of this effort, and will also help inform our strategy to transition our Missouri generation fleet to a cleaner, more diverse portfolio in a responsible fashion.

EET&D: Warner, how does this fit into the overall Ameren Corp. business strategy?

Warner: As the energy needs and expectations of our customers continue to rise, and as exciting, innovative technologies advance, we're not waiting for others to lead. The microgrid facility is one of a series of innovations we are working on. We have devoted significant human and capital resources to our efforts to lead today and transform tomorrow by innovating to ensure we are developing and delivering the innovative products and services of most value to our customers as technologies advance and the energy grid becomes more integrated. We're focusing on the convergence of those technologies that we believe can significantly affect the energy industry, such as battery storage, electric vehicles, utility scale solar and solar partnerships, energy efficiency and digital technologies, as well as analytics. We realize there is no better time than today to focus on innovation and position the company for success as appliances, buildings and cities all become "smarter" in the years ahead. Our microgrid is a primary example of the steps we are taking to lead that transformation.

EET&D: Richard, how does this fit into the Illinois smart grid initiative?

Richard: For the last 150 years, the electric grid has primarily gone unchanged. We're in year six of a massive overhaul of our energy delivery infrastructure. We're investing in installing outage detection technology, storm-hardened poles and wires, and smart meters thanks, in part, to a new state law that allows us to accelerate our investments in building a more advanced energy infrastructure. Since the landmark Energy Infrastructure Modernization Act (EIMA) – or Smart Grid Bill – was passed in Illinois in 2011, Ameren Illinois has met every metric outlined in the performance-based formula ratemaking legislation. These grid modernization initiatives have resulted in an overall 17 percent increase in reliability and saved customers an estimated $45 million each year. The work at the microgrid complements these efforts as we build a smarter grid that is more reliable, more resilient against storms and allows customers to take more control of their energy usage.

EET&D: Illinois is gaining a reputation for its strong energy policy. How is this helping you with projects such as the microgrid?

Richard: Simply put, the ratemaking model in Illinois provides certainty that we can recover investments in our electric and natural gas energy delivery systems more quickly. That's good for our company, our customers, and our investors. For our customers, it means we're modernizing the century-old grid and delivering energy more reliably. A smarter grid means fewer outages and it gives customers the opportunity to save on their bills by participating in pricing and energy usage programs enabled by smart meters. The Illinois state legislature and our public utility commission deserve credit for positioning Illinois as a national leader in the development of a progressive energy policy.

Energy Storage: The Backbone of a Microgrid

By: Chris Evanich

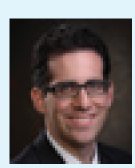
The hype around microgrids is finally starting to make its way onto the electrical grid. While the buzz has always been around increasing grid reliability and the resiliency microgrids offer, there are many reasons they are successful at hardening the grid. However, the most important aspect of the entire microgrid system is the energy storage components involved. Energy storage serves as the backbone of any microgrid deployment – without it, the entire system is limited in what it can accomplish.

As the "Swiss Army Knife of the grid," the fundamental advantage of using energy storage is that these systems can both charge and discharge power – serving as a source or a load, while a traditional rotating machine, or generator, can only discharge power. This means the battery energy storage system can either absorb energy from the renewable generation or push energy out to the grid. The energy storage system can quickly respond to handle the fluctuations in output from renewable energy generation. Energy storage also makes the system more efficient, ensuring that the load can be carried and none of the renewable power generated is lost to curtailment.

At the Ameren microgrid, for example, there are 225 kW of renewable generation on site, comprised of solar and wind. The storage management system can run the microgrid island from the battery and have both renewable sources feeding in. No matter the load—whether minimal or full capacity—nearby end users can be powered exclusively by the renewables and energy storage. If we look at the same approach with generators instead of energy storage, the production of the renewables would have to be curtailed to less than the demand.

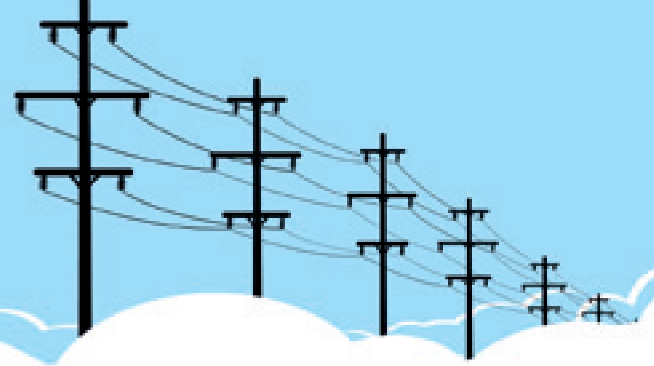
Including energy storage in a microgrid increases the overall reliability of the whole system through fast response. When the battery starts, it's on almost instantaneously after receiving the communication. When using a generator, there is significant lag time as it warms up and prepares to synchronize or accept load. This entire process could take tens of seconds, resulting in a longer duration of loss of power, where energy storage provides faster transitions into and out of islanded operation for end users. Turning off the system has similar challenges when using a traditional generator. Energy storage can be turned off quickly by a simple command to shut down the battery. A generator needs to cool down and lightly unload through a lengthy procedure. Additionally, most generators can only be started and stopped a certain amount of times per day because of the stresses of these activities, while a battery energy storage system is not limited by these constraints.

Implementing energy storage in a microgrid can enable additional renewable generation, and provide improved system performance in a variety of scenarios. Recognizing the significant role that energy storage plays in these systems is key to fulfilling the potential of microgrids around the world, bringing users that much closer to consistently reliable power, regardless of the source.



About the author

Chris Evanich is the manager of microgrids for S&C Electric Company, where he focuses on the global business development of microgrids using S&C's medium voltage switching, protection, energy storage and control product lines. He holds a B.S. in electrical engineering from Cleveland State University and an MBA from Case Western Reserve University. He is an active member of IEEE, including participation in the Standards Association and as an IEEE PES Scholar Mentor.



Warner: In 2016, we invested $2.1 billion dollars in the energy infrastructure serving Illinois and Missouri to make the grid smarter to meet our customers' evolving energy needs. We continue to be strategic and disciplined in our investment approach, with our rate-base growth focused on investment in constructive regulatory jurisdictions, like Illinois. We built this facility in Illinois, in part, because of this regulatory model. Under Richard's leadership, legislation has been passed that has paved the way for Ameren Illinois to implement a world-class energy infrastructure modernization program. It's enabling Ameren Illinois to deploy the latest, cutting edge technology to prevent service disruptions and improve overall reliability. It's enabling us to cultivate the workforce of the future. It's also a major reason why Ameren Corporation continues to invest heavily in our Illinois segment for the benefit of customers, communities and shareholders.

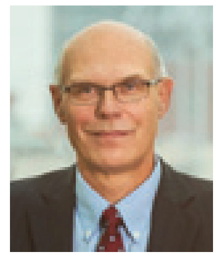
EET&D: What do you want EE T&D Readers to know about your efforts with this microgrid facility and your future plans?

Richard: We're asking our customers to think 10, 15, 20 years ahead. Utility companies such as Ameren will no longer be the only ones pushing power onto the system. Instead, individuals and commercial establishments will also have the capability to generate their own power from a variety of sources. We're positioning ourselves to be partners with our customers to help them safely install and cost-effectively operate these resources, and integrate all of these assets under one control scheme with the distribution monitoring expertise to ensure that it is safely and optimally delivered. We know customers want control of their energy, and we want to give it to them.

Warner: As a company, we have never looked just a few years down the road. The work at the microgrid is occurring today, but it's really about what is going to happen decades ahead. The profile of the energy grid, how it operates, customer expectations, the form of regulation and overall business models will all be different in the future. We believe that the utility industry and Ameren are well positioned to be critical enablers of a transformation that will bring greater value to customers and shareholders. To achieve that "enabling" function, we are leveraging our extensive energy expertise and customer relationships, and pursuing innovative partnerships to integrate smart-grid technologies and deliver more innovative and value-added services to our customers.

We are "leading from the front" on important energy and economic policy matters by advocating for responsible policies that will benefit our customers, shareholders and communities. At the same time, we are relentlessly focused on improving our operational performance. There is no question that we see a future with a stronger, smarter grid capable of delivering the products and services customers value most. We will not waiver in our pursuit of excellence and our focus on delivering superior customer and shareholder value today and in the future.

About the authors



Warner Baxter is chairman, president and chief executive officer of St. Louis-based Ameren Corporation, parent company of rate-regulated energy companies that serve more than 2.4 million electric and 900,000 natural gas customers in Illinois and Missouri. During his more than 20-year tenure at Ameren, Baxter has also served in a variety of leadership roles, including chief financial officer and president of Ameren Missouri.

Baxter earned a Bachelor of Science degree in accounting from the University of Missouri–St. Louis and has made meaningful and long-lasting contributions to higher education through his involvement with the University of Missouri System. He is a member of the University of Missouri–St. Louis Chancellors Council and serves on the University of Missouri 100 Board.

Richard Mark is chairman and president of Ameren Illinois Companies (AIC). He is responsible for energy delivery to more than 1.2 million electric and 816,000 natural gas customers across three-quarters of the state of Illinois. Prior to joining Ameren in 2002, Mark spent six years as president & CEO of St. Mary's Hospital in East St. Louis and five years as COO. Mark served voluntarily for 10 years as chairman of the East St. Louis District 189 State Financial Oversight Panel, an Illinois Governor appointed position. He has received three honorary doctorate degrees for his civic and community work, as well as numerous awards and honors. In 2015, he was named Who's Who in Energy by the *St. Louis Business Journal*. He was also named one of Savoy Magazine's Top 100 Most Influential Blacks in Corporate America for 2016 & 2014.

Keeping the Lights On

By Gil Shavit

Adapting to a Changing Landscape

In the last few months, the world has seen significant changes – new heads of state in several countries; Britain's exit from Europe; shocking terrorist attacks and cybercrime of international proportions. Why do I mention these things? Because they all have an impact on our utilities markets and demonstrate how integral our industry is to the health of our nations.

Due to strict regulation in many countries, utilities have been required to invest heavily in their operations at a time when electricity sales are generally flat or in decline. That's not to suggest that these utilities aren't profitable, but it does add an additional layer of complexity to their businesses.

In North America for instance, Obama's Clean Power Plan saw considerable amounts of money spent on renewable energy sources such as solar and wind. There was also additional pressure placed on utilities to meet a new set of governmental standards, but with President Trump's recent decision to remove the US from the Paris climate agreement, the impact of this decision is not yet clear.

Add these challenges to more fundamental initiatives to upgrade and better balance the grid, utility businesses of 2017 have significant challenges to meet. What's more, the introduction of smart meters and a new consumer awareness to energy consumption has led many leading utility companies to investigate new innovative technologies to support their businesses.

The Cost of Grid Unreliability

One of the most critical challenges is to improve grid reliability. That said, the grid can go down for many reasons and not all of them are avoidable.

In the 2017 Infrastructure Report Card, the American Society of Civil Engineers assigned a "D+" to the US energy infrastructure. It stated that the delivery of electricity in the US relies on an aging and complex patchwork of systems with various ownership and stakeholders. And with the power grid at full capacity, maintenance is paramount.

In 2015, Americans experienced a reported 3,571 total outages, with an average duration of 49 minutes. Momentary blackouts cost the US economy $60 billion, while sustained blackouts cost $50 billion, with some lasting as long as eight hours or more.[1]

Keeping Critical Systems Online for Longer

Whilst electricity blackouts are likely to stay with us for some time yet, many utilities are now turning to alternative technologies, such as fuel cells, to provide immediate, reliable and long-term backup power to mitigate the challenges of power outages. [2]

By installing fuel cell solutions at end-customer sites, utilities can provide clean backup power, with the added ability to push electricity back to the grid enabling improved load balancing and higher quality of service (QoS). Providing important piece of mind and utilizing the technologies immediacy to start in-phase, fuel cells are ideally suited to back-up applications. Supporting the modern 'Energy Cloud', fuel cells are also an important contributor for local peak demand response or 'Peak Shaving'.

Utilities are also installing fuel cells to backup other critical systems such as internal communications, command-and-control rooms and substations. These fuel cells are uniquely designed for installation at utility substations, operating as a direct source of backup power or to recharge back-up battery rooms and keep them at full power. In the case of our own solution, for up to 10 times longer.

Fuel cells achieve this by enabling substations to keep their breakers and controls in an operational mode, so that utilities can quickly restart power and minimize distribution time to end-users once the grid recovers.

But What is a Fuel Cell?

First invented in 1839 by William Grove, a fuel cell is an electrochemical energy conversion device that produces electricity by combining hydrogen and oxygen into water. Like batteries, fuel cells convert potential chemical energy into electrical energy and generate heat as a by-product.

But batteries store chemical energy within them--rather than being self-generated--which means that they can only operate for a limited duration until discarded or recharged. If supplied with an unlimited amount of fuel, fuel cells can continuously generate electricity (hydrogen) and oxygen.

There are five primary types of fuel cells:

- Alkaline Fuel Cells (low temperature)
- Proton Exchange Membrane Fuel Cells (low temperature)
- Phosphoric Acid Fuel Cells (medium temperature)
- Molten Carbonate Fuel Cells (high temperature)
- Solid Oxide Fuel Cells (high temperature)

Each type of fuel cell has its own inherent strengths and weaknesses that make them more suitable for specific markets and applications.

Alkaline fuel cell technology (AFC), which is being adopted by utilities, was originally developed for space applications where reliability and durability are essential requirements. But to achieve those key attributes, space applications featured Platinum and Palladium electrodes and other costly components. As a result, alkaline fuel cells were unaffordable for earth-bound power generation markets.

It is possible to make AFC technology accessible by redesigning many components using less costly materials and being able to eradicate platinum as an electro catalyst. While maintaining the life and efficiency of the AFC, removing the need for platinum removes the cost barrier that has previously prohibited the widespread adoption of this technology.

For utility companies, these innovations provide them with all the sought-after benefits of fuel cells, but at a price point that is competitive with UPS batteries and diesel generators.

Extending Back-up Power, Reducing Costs and Environmental Impact

Why are fuel cells important? Well, as a completely clean power generation process, fuel cells are very attractive to utilities not only from a financial perspective in minimizing downtime, but also in supporting their drive to become more sustainable.

Quite simply, fuel cells produce zero-emissions, are silent and vibration free. They are also suited to both extreme environments and urban settings, so they are highly flexible. What's more, they are extremely reliable, require very low maintenance and can be operated remotely.

Fuel Cell Adopters

So, fuel cells are clearly a very compelling technology for utilities, but who's using them?

Earlier this year, San Diego Gas & Electric (SDG&E), part of Sempra, a leading North American energy company, announced that it had been testing how fuel cells could contribute to their efforts to be the cleanest, safest, most reliable energy company in America.

In addition to SDG&E, another notable and recent adopter of fuel cell technology includes Israel's national utility provider, IEC (Israel Electric Company). IEC provides roughly 85% of Israel's electricity.

With many other utilities around the world adopting or seriously evaluating the use of fuel cells within their operations, it's clear that this technology will be an important solution to one of the industry's key challenges.

Overcoming Barriers to Success

But there are still barriers to wide and rapid fuel cell adoption, and it's mainly an issue of education. When talking to prospects, our first job is often to correct what they think they know by demonstrating that the technology employed today is vastly different to that of the 1970's and 1980's. With previous commercialization issues now resolved, we show them that the modern fuel cell is both robust and affordable.

This type of conversation is no doubt common to all fuel cell manufacturers. But for many utility companies around the world, the fuel cell business case is so compelling that after investing a little time to understand it the cost of a fuel cell to minimize the impact of grid downtime becomes an obvious and sensible decision.

Fuel Cells for the Mainstream

Companies of all types and sizes are already incorporating hydrogen and fuel cells into their businesses. Leading companies such as Apple, Verizon and Coca-Cola are using stationary fuel cells to generate power. Toyota, Honda and Hyundai are coming to market with hydrogen fuel cell powered vehicles for consumers and trucking.

Metropolitan areas and airports are beginning to migrate to emission-free hydrogen fueled buses too. In the USA, the UK and Europe, hydrogen refilling stations are being built, overcoming the challenges of hydrogen distribution for consumers. Indeed, the US Department of Energy notes that hydrogen and fuel cells are on the verge of a "tipping point".[3]

As we transition into a greener economy increasingly fueled by hydrogen, fuel cell solutions for backup and power-on-demand are overcoming the significant weaknesses of other clean technologies such as solar and wind. And thanks to cutting edge introductions that have solved previous fuel cell affordability, this technology is now also complementing or even replacing, legacy backup solutions such as batteries and diesel generators, in use at utilities throughout the world.

About the Author

Since 2011, **Gil Shavit** has served as chairman of the board for GenCell, an Israel-based fuel cell power solution provider and manufacturer. Shavit has more than 25 years of experience in establishing innovative technology companies, including within the utility industry in America. He is a seasoned industry veteran with a proven track record of business success. In addition to serving as the Chairman of GenCell's board of directors, Shavit plays an active role in the ongoing business processes of the company. He received a B.S. in electrical and electronics engineering from Ben-Gurion University of the Negev.

1 ASCE, 2017 Infrastructure Report Card, http://www.infrastructurereportcard.org/.

2 IEEE, The National Cost of Power Interruptions to Electricity Customers. https://goo.gl/TejTrH

3 US Dept. of Energy. "On the Verge of a Hydrogen Tipping Point?" (Oct. 12, 2016) https://goo.gl/6R5HjI

From Research to Action

Who Changed My Connection?

By Christine Hertzog and Tim Godfrey

Utilities with demand response and other load management programs face many challenges to effectively manage consumer loads via thermostats, water heaters, charging stations, and other residential and commercial appliances. First, there's a dizzying array of devices, communication standards and protocols to contend with. Then, there are puzzles to solve around building and maintaining customer participation. But there's one issue that doesn't receive as much attention—perhaps because it's been perceived as unsolvable—lack of *secure connection durability* for devices.

The Hidden Problem of Demand Response

Device connectivity can be lost when Wi-Fi™ network parameters like service set identifier (SSID) or security keys are changed by the consumer. The lack of connection durability creates customer support burdens to re-establish connectivity, which can be complicated by technology or lack of customer knowledge about how to reconfigure connected devices. Device security must also be considered.

EPRI and utility members involved in the collaborative R&D associated with our Telecoms Initiative (see the September/October 2016 issues of Electric Energy T&D for more information about the project's scope) realized that rather than create new networks or interfaces for devices, there could be a more cost-effective answer that would be readily deployable.

Leveraging Existing Infrastructure for Multiple Benefits

The approach uses router-based functionality, creating a virtual, Wi-Fi network for connected devices that is independent of the customer Wi-Fi settings. A secure, virtual private network (VPN) tunnel—from the virtual device network to the service provider—isolates the connected devices from the Internet.

There are several benefits to this approach that impact utility top and bottom lines. Using existing networks, such as customer broadband and Wi-Fi, eliminates the capital and operating expenses required by new utility network buildouts. The use of a communications platform that facilitates secure integration of customer systems with grid operations (both distribution and system operator), and third parties like aggregators, can reduce provisioning, enrollment, and support activities.

The value of this technology to utility stakeholders is the ability to securely and durably connect to customer devices using the customer's broadband and Wi-Fi. The ease of provisioning, enrolling, and supporting connectivity to devices, to minimize utility and consumer interventions, also provides value. Secure and durable connectivity to enrolled devices means sustainable and predictable energy efficiency and demand response results; it also enables more effective utility program delivery as well as customer engagement and satisfaction.

The Path Forward

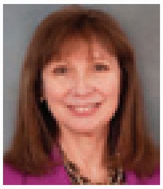
EPRI is extending its Telecoms Initiative research into a field demonstration project that will evaluate this approach to using customer broadband and Wi-Fi for connected devices. The demonstration project builds on the technology platform development being done in the Telecoms Initiative, and supports utility demonstrations of specific use cases requiring durable customer connections. The research will help utilities, service providers, and device manufacturers "kick the tires" on the approach and build understanding of how to apply the findings in their plans.

To support widespread availability and interoperability of this technology, EPRI has joined the Wi-Fi Alliance, and will propose development of a specification. The objective is to make the persistent Wi-Fi capability a standard feature in retail and service provider Wi-Fi routers.

We can eliminate the lack of secure connection durability for devices as one of those challenges of load management programs. That's good news for utilities planning to create more end user load management programs to address increased generation intermittencies in their grids.

About the authors

Tim Godfrey is a technical executive with the Electric Power Research Institute, specializing in telecommunications. He manages the Telecommunications Initiative; a research project addressing the key challenges utilities face related to the telecommunications infrastructure supporting the smart grid. He holds a BSEE from the University of Kansas and has worked in the area of wireless networking and communications for 20 years. He has 23 granted patents. Mr. Godfrey has participated in IEEE standards development since 1994. He is the chair of the IEEE 802.24 Smart Grid Technical Advisory Group, and the IEEE 802.16 GRIDMAN Task Group.



Christine Hertzog is a technical advisor for ICT and Cyber Security at the Electric Power Research Institute. She was previously the founder of a consulting firm focused on smart grid ecosystems and has an extensive telecommunications background. She authored the Smart Grid Dictionary, and co-authored *Data Privacy for the Smart Grid*. She has also served in an advisory capacity to innovators, industry associations, and publications. She has an M.S. in telecommunications from the University of Colorado, Boulder.

Advancing Substation Asset Management at Xcel Energy

By Ming-Wa Hui and Katherine T. Decker

Introduction

On August 21, 2000, Northern States Power Co. (NSP) and New Century Energies (NCE) merged to form Xcel Energy. After the merger was complete, Xcel Energy became the fourth largest combination utility in the country. Due to the increased scale of the company's asset base, new interest arose in formulating a unified methodology for management of the essential substation grid components.

Xcel Energy's comprehensive approach to substation asset management can be thought of in terms of the individual programs that make up the bigger picture. Through the application of targeted plans, the company has been able to mitigate both immediate and long-term risk to the systems, as well as uphold efficient decision-making criteria in the event of a failure.

The newly systematized philosophy allowed all business processes and programs to meet the following criteria: transparency, repeatability, objectivity, and data-centrality. With those factors, the goal was to develop, implement, and execute programs that would focus resources on the right asset at the right time. Unknowingly, this endeavor prompted interconnections among the various programs, which ultimately formed the components to the overall Substation Asset Management system. These components include: Adaptive Reliability Centered Maintenance, Transformer Sparing Strategy, Equipment Failure Tracking, Asset Prioritization, and Repair versus Replace (see Figure 1).

Figure 1: Programs in Xcel Energy's Substation Asset Management Platform

Programs

- **Adaptive Reliability Centered Maintenance (ARCM)**
  The primary mechanism of the ARCM program is the assignment of a Maintenance Number (Mn) to each individual asset of the substation asset base through a complex algorithm. This algorithm accounts for both static and operational data related to an individual asset. Some examples of input data and parameters into the Maintenance Number algorithm include:
  - Equipment type
  - Age
  - Condition
  - Time since last maintenance activity
  - Asset criticality
  - Fault and routine operations

  Once a Mn has been calculated for each of the individual assets, program managers will be able to identify the assets most in need of maintenance, or those with the highest Mn. These identified high-risk assets will be annually assigned to the ARCM work portfolio, which also indicates the type of preventative maintenance work to be performed on the portfolio assets.

- **Transformer Sparing Strategy**
  Due to the heightened criticality and system resiliency associated with power transformers, sparing has been a long-held practice for this equipment type at Xcel Energy. A major component of Xcel Energy's strategy to transformer sparing relies on forecasting failure patterns to effectively minimize risk.

  One way to analyze potential failures in the transformer asset base is by filtering failure rates based on voltage classification. Once a rate has been determined for each voltage class, a spare recommendation can be generated to ensure coverage of one, two, or three standard deviations above the expected failure count. Since any given spare will only apply to certain voltage levels, this method is useful for calculating the actual needs of the system. The selection of the amount of failure coverage depends on the perceived level of acceptable risk.

- **Equipment Failure Tracking (EFT)**
  The Equipment Failure Tracking (EFT) program encompasses the capture and analysis of failure data related to distribution and transmission substation assets, including power transformers and circuit breakers. This process provides a twofold advantage of pinpointing common failure types for deeper analysis and identifying emerging trends in failure rates.

The collected failure data is also used to feed into the Industry-wide Database (IDB), assembled by the Electric Power Research Institute (EPRI). With Xcel Energy's participation, the company will be able to better benchmark performance against other utilities and will also benefit from the failure analytics made possible by the larger pool of data.

- **Asset Prioritization**
  The Asset Prioritization program is a proactive measure for identifying and ranking top equipment replacement candidates. This decision making process feeds directly into the long term capital renewal program, in which the recommendations of the asset prioritization algorithm are actualized into strategic upgrades in the system.

  There are two main inputs to the asset prioritization rank: 1) the criticality of the asset, and 2) the overall health and condition of the asset. Individual asset criticality is determined through existing information on the related system impacts, financial impacts, and black start path reliance. System impacts can be thought of as the implications to system restructuring and restrictions if the evaluated asset were removed, while financial impacts concern the monetary expense associated with asset removal. Black start path reliance simply refers to the importance of the analyzed asset in the event of grid re-energization.

- **Repair versus Replace (R vs. R)**
  The Repair versus Replace (R vs. R) program offers a standardized procedure for the evaluation of options following the signal or occurrence of a failure. As indicated by the program title, the binomial output of the program's algorithm can recommend either a repair or replacement of the failed equipment.

  The R vs. R process is prompted after either a sudden failure has occurred or an alarm has been activated to indicate the suspect equipment must be repaired or replaced to maintain system reliability. If a preliminary determination is made that both the repair and replace options are viable, the algorithm will be run to return a recommended course of action. This mechanism offers a valuable tool when a failure occurs that does not command a clear course of action. The algorithm provides objective, transparent and repeatable results for instances in which human subjectivity or engineering judgment alone is insufficient to make the final decision.

Program Interconnections

- **R vs. R and ARCM**
  For most assets in the annual ARCM portfolios, the preventive maintenance is carried out as expected and no further actions are taken other than potential corrections to the asset database. However, significant operational issues can sometimes be revealed during the standard ARCM procedures. For these cases, there is an option to either perform corrective maintenance on the asset or perform a replacement; thus, the R vs. R program comes into play by quickly suggesting an answer to these ambiguous situations.

  The R vs. R program is an important support to the ARCM program in such instances to ensure final decisions are made true to the consistent, repeatable, and transparent criterions.

- **EFT Validation of ARCM and R vs. R**
  Since both ARCM and R vs. R are relatively new programs, validation of the results and continual refinements have been implemented to provide usefulness and enhance credibility of the programs. To assess their validity, Xcel Energy surveys failure data captured by the EFT program. For example, if the ARCM program indicated maintenance was due for a failed asset, there would be positive confirmation of Maintenance Number algorithm. For the R vs. R program, the EFT program analyzes the validity of the repair decision. If an asset fails shortly after major repairs have been completed, scrutiny would be given to the R vs. R's decision to have had a repair completed. Another aspect of the two programs' interdependency concerns R vs. R's utilization of EFT failure tracking rates, which are used in determining the cost effectiveness of each possible decision. Finally, the information stored within the EFT program informs the asset manager of poor performing assets and helps avoid directing financial resources toward repairing these assets.

- **Transformer Sparing Analysis with EFT and ARCM**
  Informed transformer sparing requires sufficient amounts of reputable data. Two important sources of data stem from the EFT and ARCM programs. The EFT records the age of assets at their time of failure, which is then used to generate age-based failure probabilities. Likewise, the individual Maintenance numbers of the ARCM program can be used to form an overall picture of system risk. In response, sparing can be adjusted accordingly to cover the perceived level of operational risk. The accuracy of the collected failure rates will determine the quality of the transformer sparing analysis results. As such, the data quality improvement of EFT will go hand-in-hand with the analytical results of the transformer sparing studies.

- **ARCM Portfolio and Asset Prioritization**
  The R vs. R program is applied following the discovery of an immediate or impending equipment failure. However, assets do not necessarily require removal or pose any immediate risk to system performance for long-term capital renewal scenarios. In this case, the Asset Prioritization program is used with the ARCM program, which assists in determining the right assets to be included into the long-term capital renewal portfolio. Depending on the capital resources available, the asset manager can select the appropriate number of prioritized assets to be placed in a renewal portfolio for a specific cycle or period. This portfolio is then delivered to the ARCM program managers to prevent use of O&M funds on assets that are already elected for replacement in the upcoming term. The combined information of the Asset Prioritization program and the ARCM program helps the asset manager obtain a clear view of how resources should be dedicated and removes accidental overlap of resource allocations.

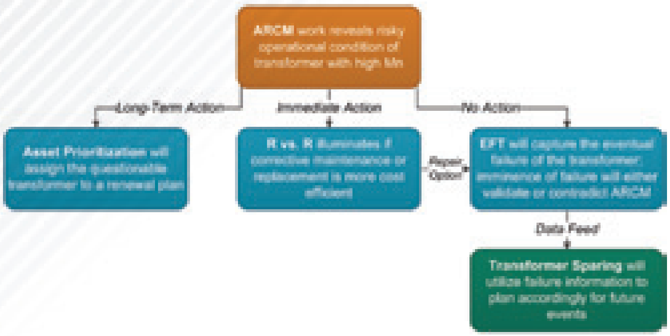


Figure 2: Example of Program Interconnections for Identified High-Risk Transformer

Conclusion

Xcel Energy continues to modernize and improve its internal asset management business processes. Through the development, implementation, and evolution of each program, the organization has benefited from increased knowledge and understanding of effective and efficient substation asset management techniques from both an operational and strategic perspective.

As strengthened visibility of system risk across the substation asset fleet has become available, the organization's ability to make short and long term decisions throughout asset life cycles has improved. Although a greater focus has been given to the uniformity, transparency, and outcome repeatability of business processes and metrics, the fundamentals of equipment operation and maintenance have remained consistent through the years. To account for future changes, Xcel Energy has designed its substation asset management program to accommodate continuous improvement as technical insight and technology progresses.

About the authors

Ming-Wa Hui is a substation system performance manager at Xcel Energy. He has more than 18 years' experience in the Power Engineering field. His focus primarily centers on transmission and distribution substation operations and maintenance. Most recently, his work has been dedicated to the development of substation asset management programs, with emphasis on long term capital finance strategies, asset life cycle decision-making, and asset prioritization analytics. He has a B.S in electrical engineering, Master of Engineering, and Master of Business Administration. Hui is a U.S. Army veteran who served with the 19th SFG(A)

Katherine T Decker works as an engineering intern with the Substation System Performance team at Xcel Energy. She started with the company in May 2015 and has aided in the creation of transparent analytical and communication tools related to Xcel Energy's asset management system. Decker received B.S. degrees in chemical engineering and biochemical engineering from Colorado School of Mines.

The Internet of Things Starts with the Grid of Things

Part 3.5

By Adrian Vallejo

Shortly after the release of "*The Internet of Things Starts with the Grid of Things Part 3*," the team at DataCapable received a few inquiries about our development philosophies, technology recommendations, and future considerations that any software provider in the utility space should be considering as they begin their interoperability journey.

For those of you who missed Part 1, Part 2, and Part 3, The Internet of *Things Starts with the Grid of Things* is a tell-all editorial series that's been documenting the journey of interoperability and the role next generation software plays in the utility industry. Part 1 announced the Grid of Things. It was complemented by Part 2, a step-by-step manual on how to embrace interoperability. Part 3 laid forth the definitions of the individuals responsible; the software developers, product managers, and technical experts.

But as we prepared to dive deep into Part 4 "The Role of Collaboration," Electric Energy T&D's readers reminded us that there was more of a story to tell in Part 3. Enter Part 3.5, a much-needed addition to the *Grid of Things* series.

Image 1 – The Connected Global Grid Vision Is Coming to Life

Part 3.5 – Helping to Build the Connected Global Grid Vision

> *"La visión de la red conectada necesitará colaboración global. Esto requiere armar un equipo que entienda información que se alinee con las necesidades globales de los consumidores de energía. Como mencionamos en la Parte 3, la 'tostadora', en esta serie es intercambiable con cualquier dispositivo en su hogar y es algo que todo el mundo puede relacionar"* – Adrian Vallejo, Analyst at DataCapable

There's a reason why I introduced myself in Spanish. Far too often development teams and business executives forget that the value unlocked from next generation software solutions and associated data has global importance. The entire utility industry is changing fast. Fossil fuels are being replaced with green alternatives. Microgrids, renewables, and batteries are now a common theme at every utility around the world.

The connected global grid vision requires looking far beyond the confines of your office cubicle, a utility service territory, and even the country in which you live. As discussed in Part 3, technology evolution, the power of the cloud and the role of standards are empowering software developers to play an active role in the Grid of Things vision. And while API's and collaboration are enabling software platforms and companies to do things that never were imagined before, the role of data and its global value is just starting to emerge.

Enter the Analyst and its Role in the Connected Grid Vision

The utility industry has figured out how to gather large amounts of data. This is evident with things like smart meter (AMI) data. Most product and service providers have a clear understanding of how to gather and store big data. The next step is translating this data into value. Enter the Analyst.

The job of the data analyst is to:

- Translate the value of data (*more on this later....*)
- Understand the roles of business development, sales strategy, and software engineering have in the execution of a new contract
- Be the liaison between a client's success and their ongoing needs
- Analyze data for new and interesting use cases
- This includes thinking about the global role data has and the value of interoperability
- Understand and create the processes that can be repeated at the next customer with similar use cases
- Update functional and technical findings based on lessons learned
- This includes understanding regional differences in both client management and value translation
- Support the product team on feature requests and general software considerations

The analyst plays a key role in the success at the utility, the software provider, and the unlocking of global value. This requires using the insights gathered from big data and helping the software teams develop functionality that can automate existing inefficient processes at a utility. It also speaks to the value the analyst plays when supporting a variety of markets across the world.

Translating the Value of Data

Recently, I was given the opportunity to support the expansion of software into Latin and South American countries. This global journey is a path many like-minded software providers in the utility industry will embark on in the coming years.

> *"The terms localization or internationalization typically carry engineering and process oriented connotations. A firm is simply checking the box that their software has been translated for convention, dialect, and other locale-specific considerations. It is so much more than this. All of us need to think strategically about our software's global role in energy delivery"* – Zac Canders, CEO and CoFounder at DataCapable.

Bringing utility software to a new market or region requires looking beyond the physical translation of words. It requires translating the value of data. This speaks directly to the interoperability challenges seen across the planet, and highlighted in Part 2 of the Grid of Things:

- Empower utilities to share their data in real-time with other utilities
- Enable product and service providers to seamlessly access utility data
- Embrace collaboration across the globe

Translating the value of data is one of the key steps in the connected global grid vision. Whether you are a municipality, investor-owned, coop, or government utility, no two are the same. The regulatory landscape, technology adoption challenges, regional differences, language spoken, ownership structure, and even customer expectations create magnitudes of differences. But, across the world, we all share a common element, data.

The Global Outage Tracker is just one example of the value of data:

- A storm in one part of the world can provide a hint of what's to come in another.
- Recognizing a cyber-security incident in one country can help block a future one someplace else.
- Embracing the process by which data was made available on a global scale, can help drive the unlocking of data sets at the local level.

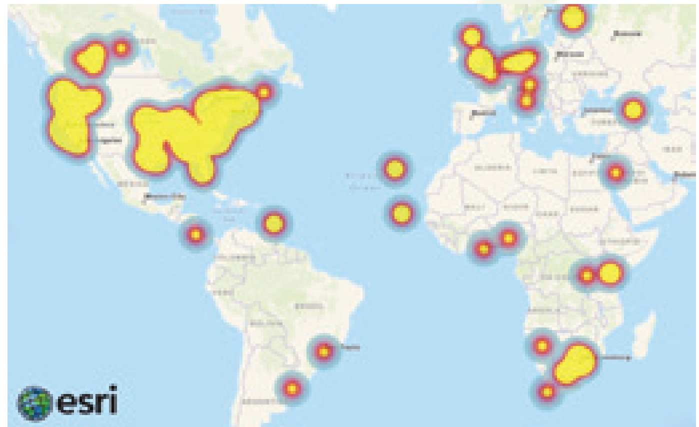
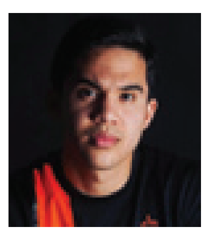


Image 2 – A Global Outage Tracker Hints at the Connected Grid Vision

The Grid of Things Depends on Collaboration

All of us play an active role in the Grid of Things vision. The connected grid vision will require API's, collaboration, and a global view on the value of data. The first step in every interoperability journey is getting support from vendors, utilities, customers, regulators, and associated energy stakeholders. As detailed here, the next step is building the team and technologies to execute on those visions. I'd welcome any feedback on this article and encourage everyone to get involved in the Grid of Things. Send me a note at Adrian@datacapable.com As we look to the next installment of the Grid of Things, Part 4 we will explore "The Role of Collaboration," how we, the industry, are becoming interoperable.

About the author



Adrian Vallejo is an analyst at DataCapable. In this role, he is in charge of supporting sales and product teams with "translating the value of data." Vallejo is a recent graduate of Louisiana State University, where he was actively involved in numerous media analyst activities. He is also supporting DataCapable's expansion into Latin America, South America, and Spain.

The Latest in Circuit Breaker Testing Technologies

By Charles Sweetser

Understanding diagnostic testing of HV Circuit Breakers is essential. When diagnostic tests are performed on HV Circuit Breakers, valuable information can be extracted. From a technical maintenance perspective, these diagnostic tests provide critical information about the condition of the HV Circuit Breakers.

Standard field tests widely applied today in HV Circuit Breaker diagnostics include:

- Timing and Travel
- Contact Resistance (Static and Dynamic)
- Coil and Motor Current Signatures
- Minimum Pick-Up

Circuit breaker technology varies depending on the application. Also, the preferred technology is dependent on the geographical region in which it is applied. Case in point, Dead Tank SF6 Filled Circuit Breakers and Bulk Oil Circuit Breakers are primarily used in North America in HV applications, while the rest of the world prefers Live Tank Circuit Breaker technology.

Overall, circuit breakers, regardless of type and technology, are designed with the following three functions in mind:

1. Direct current flow between desired sections of an electric power system
2. Interrupt current flow under abnormal power system events and conditions, such as faults
3. Carry load current under normal power system conditions with minimal losses

These three functions must be performed under both normal and abnormal (fault) conditions, and must perform under strict performance specifications.

Circuit breakers vary by subsystems:

- Insulation System
- Arc Quenching Method
- Mechanism
- Contact Technology
- Control Circuit Schemes

These subsystems need to be analyzed both separately and as a complete electro-mechanical system.

Timing and Travel

Circuit breaker timing and travel measurements entail three steps:

1. Perform a dynamic timing and travel measurement
2. Calculate performance characteristics
3. Compare results to the manufacturer's recommendations or user-defined limits

Table 4 provides the fundamentals tests and calculations involved in circuit breaker timing measurements and diagnostics.

Table – Circuit Breaker Timing Fundamentals

CONTROL	MEASUREMENT	CALCULATIONS
Trip (O)	Displacement	Main Contact Timing
Close (C)	Contact State (O-R-C)	Resistor Switch Timing
ReClose (O-C)	Command Coil Current	Delta Timing (Pole Spread)
TripFree (C-O)	Auxiliary Contact State (OW-OD-C)	Velocity
(O-CO)	Battery Voltage	Total Travel
(O-CO-CO)	Phase Currents (First Trip)	Over Travel
Slow Close (C)	Dynamic Resistance (DRM)	Rebound
First Trip (O)		Stroke
		Contact Wipe
		Dwell Time (TripFree C-O)
		Dead Time (ReClose O-C)

Contact Resistance (Static and Dynamic)

Contact Resistance can be a complicated subject. Contact assemblies can consist of both main and arcing contact components. To see both main and arcing contact components, the Contact Resistance is analyzed, both statically and dynamically, respectively.

A static contact measurement is to be performed on each phase, using a DC current source. Typical measurements are less than 100 μΩ; however, the manufacturer's literature should be used to determine the actual expected value. Considering all breaker types, experience has shown measurements range from 10 μΩ to 150 μΩ depending on the type, with low voltage vacuum breakers associated with very low measurements, and higher voltage SF6 Dead Tank Breakers producing the higher measurements. It is recommended that at least 100A DC is injected for this test. Also it should be noted that if the breaker is equipped with CTs, it may take several seconds to saturate the opposing effects. Precautions should be taken to ensure that the injected high primary current does not affect protection circuits.

The dynamic resistance measurement is a diagnostic tool to assess the condition of the arcing contacts in SF6 nozzle style interrupters. By measuring the current, voltage, and displacement associated with the contact assembly, it is possible to determine the wear level and integrity of the arcing contact. This measurement, like the static contact resistance measurement, requires high current injection to be successful. Common practice is to use at least 100A DC.

Coil and Motor Current Signatures

Command Coil Signatures – By analyzing the command coil signatures, information regarding lubrication, electrical coil performance and latch operation can be extracted. Lubrication problems are easiest to identify in this scenario. As the armature of the command moves, an expected command coil signature is generated.

Motor Current Signatures – The behavior of motor current shows you the power needed and how it is consumed by the motor. Unusual current levels and motor timing indicate potential electrical fault in the motor.

Minimum Pick-Up

The minimum pick-up measurement is performed to determine the minimum command coil (trip or close) voltage required to operate the circuit breaker. This is the minimum energy needed for the command coil to release the "latch." The latch can either be a mechanical release mechanism or a value used to control a pneumatic or hydraulic system.

This test is done for each control coil of a circuit breaker. Different considerations must be given to "ganged" versus independent pole operation (IPO) circuit breakers. The test needs to be done for all command coils independently. The IPO breaker may require several more tests to include all command coils.

Optimized Toolset

Modern diagnostic test instruments need to be more than just data acquisition systems. The circuit breaker toolset must include not only measurement capabilities, but also an advanced power source. This power source is needed for contact resistance and minimum pick-up. What's more, by having this power source, this will also provide power to control circuits, coils and motors, when substation power is unavailable.

The diagnostic circuit breaker toolset must provide three functions:

- Timing and Travel Analyzer
- μ-Ohm Meter (Contact Resistance)
- Advanced Power Supply

Therefore, the functions will provide the ability for performing the following tests:

- Timing and Travel
- Contact Resistance (Static and Dynamic)
- Coil and Motor Current Signatures
- Minimum Pick-Up

About the author

Charles Sweetser received a B.S. in electrical engineering in 1992 and an M.S. in electrical engineering in 1996 from the University of Maine. He joined OMICRON electronics Corp USA, in 2009, where he presently holds the position of PRIM engineering services manager for North America. Prior to joining OMICRON, he worked 13 years in the electrical apparatus diagnostic and consulting business. He has published several technical papers for IEEE and other industry forums. As a member of IEEE Power & Energy Society (PES) for 15 years, he actively participates in the IEEE Transformers Committee, where he held the position of chair of the FRA Working Group PC57.149 until publication in March 2013. He is also a member of several other working groups and subcommittees. Additional interests include condition assessment of power apparatus and partial discharge.

Performance Analysis of a Power Transmission Tower Using a Boundary Element Method (BEM) Solver

By Dr. K. M. Prasad

Applications in high voltage transmission require the analysis of electric fields that cause corona discharge, dielectric breakdown in insulators, and electromagnetic interference. The insulators that support the power lines are associated with complicated conducting structures. The simulation of a complete transmitting tower along with the power lines is fundamental for the estimation of the electric field levels at an arbitrary point on the insulators, corona rings, and in their surroundings. In this article, we will model a 3-phase, 115 kV transmission tower using a 3D electrostatic field solver.

Geometry

Figure 1a shows the transmission tower. This particular model was imported from a STEP file. The height of the tower is about 30 meters and there are four lines in total, phase a, phase b, phase c, and the ground wire. The power transmission lines are about one inch in diameter. The ground wire is about half an inch in diameter. All the power lines are modeled to a length of about five meters. Figure 1b shows a conductor attached to its corona ring and suspension insulator. The whole model is symmetric about the X = 0 plane. Figure 2a shows the symmetry setup and figure 2b shows the non-symmetric model. For a faster solution, we use the symmetric model.

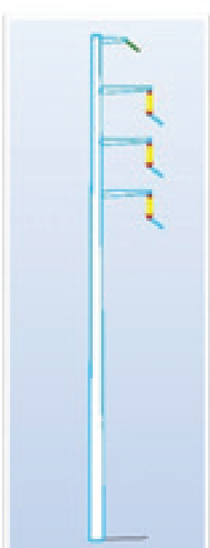


Fig. 1a. The Transmission Tower

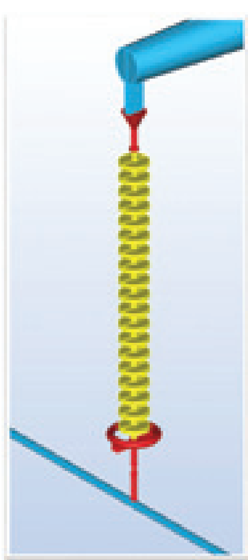


Fig. 1b. A conductor attached to its insulator

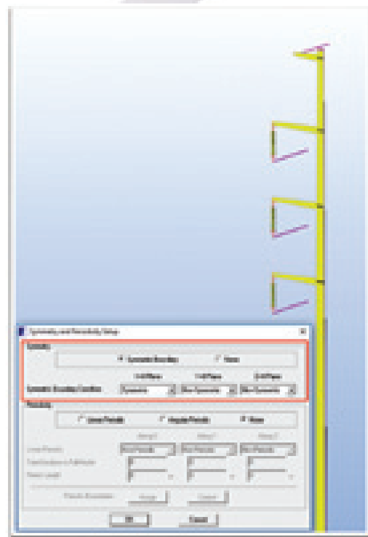


Fig. 2a. Symmetry Setup

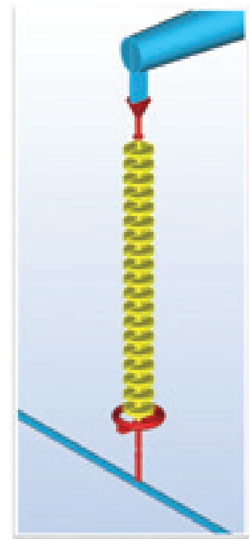


Fig. 2b. Non-Symmetric Model

Materials and Boundary Conditions

The tower and the conductors are made of aluminum. Since the ground wire does not carry any current, it is made of steel (linear).The insulator consists of silicone rubber sheds with a glass fiber filled nylon 6 (40%) rod in the center. The dielectric constant for these materials is calculated at the power frequency (60 Hz). The corona ring and its fixture are made of copper. The ground wire and the tower are at 0 V. The conductors along with their corona ring structures are assigned 115 kV at phase angles 0º, 120º and -120º from the top.

Meshing

This model clearly involves a wide-open space around the device, and problems involving such open regions are best handled by the Boundary Element Method (BEM). Using BEM, only the "active" regions require discretization. Fields can be calculated anywhere in 3D space. It allows for the modeling of the true geometric curvature rather than straight-line approximations. Models with thin layers and extreme aspect ratios are handled more easily. In BEM formulation, the equivalent charges that support the specified boundary conditions are found out.

From these equivalent charges, the electric potential and electric field are calculated by appropriate integration, effectively smoothing out the discretization error. BEM is more accurate and faster than a FEM-based formulation. Figures 3a and 3b show a global and local view of the 2D triangular mesh.

Fig. 3b. Local view of the 2D triangular mesh

Since all the materials are linear, the BEM solver needs to solve for unknowns only at the boundaries. It just requires a 2D triangular mesh on all the surfaces. You can assign the elements automatically throughout the model and refine the local mesh density manually where you need accurate results. This model contains about 101,000 2D triangular elements and requires an optimal RAM of about 14 GB. Without the symmetric conditions, this model would require about 183,000 2D elements and a RAM of about 48 GB. This is a four-fold increase in the memory requirement. It also increases the computational time significantly. Therefore, symmetry about any principal plane should be made use for a faster simulation.

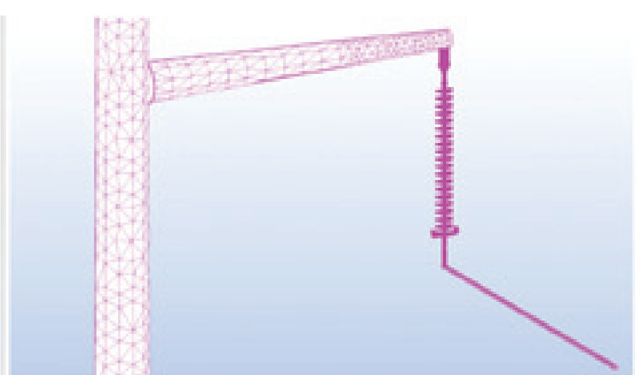


Fig. 3b. Local view of the 2D triangular mesh

Physics and Solver Settings

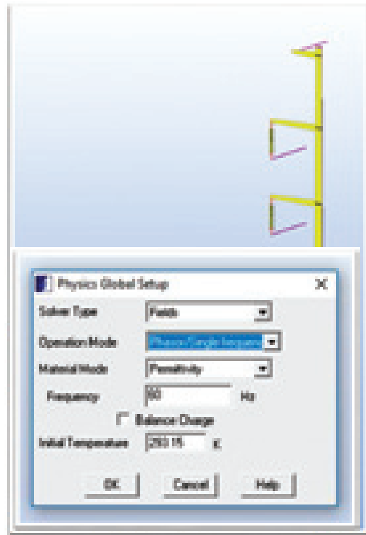


Fig. 4a. Physics Settings

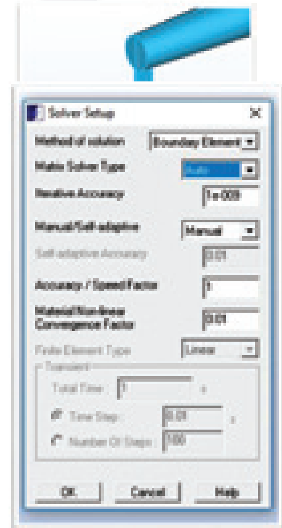


Fig. 4b. Solver Settings

Figure 4a shows the physics settings. The solver type is set to 'Fields'. The operation is at a single frequency of 60 Hz. Charge balance is turned off. In balanced mode, the solver will force the total charge in the model to add up to zero. In this mode, there is need for a reference potential to be set somewhere. In unbalanced mode, the surroundings around the model will hold whatever excess charge is required and the potential at infinity will be zero requiring no potential reference. Only ungrounded sources such as a battery require the charge to be balanced in the model.

Figure 4b gives the solver settings. In the solver setup, BEM is the method of solution. The matrix solver type can be set to 'Direct', 'Iterative' or 'Auto'. In auto mode, a 3D electrostatic field solver will automatically determine the best solver without requiring any user interaction. The direct solver is robust but requires more time than the iterative solver. The meshing can be manual or self-adaptive. However, this model was meshed manually for some good local results.

Post-Processing and Results

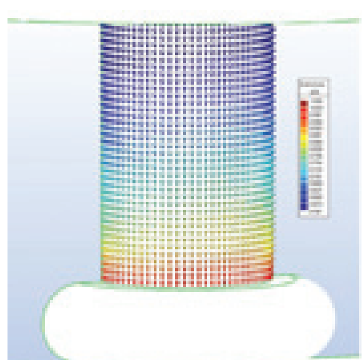


Fig. 5a. E-field without corona ring

The corona ring reduces the electric potential gradient and lowers the maximum electric field value below the corona threshold. Figures 5a and 5b show a comparison of the electric field near the bottom of an insulator with and without the corona ring. This total field at time angle 0º is directed downwards. You can observe that the maximum field reduced from about 1.05 kV/mm to 0.41 kV/mm with the corona ring.

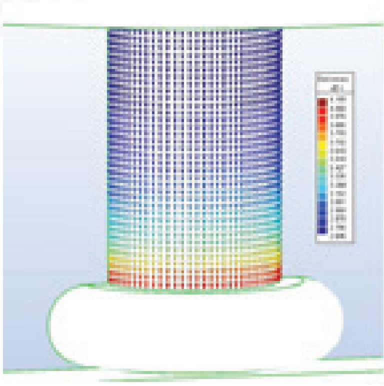


Fig. 5b. E-field with corona ring

Figure 6 shows an arrow plot of the electric field on a corona ring.

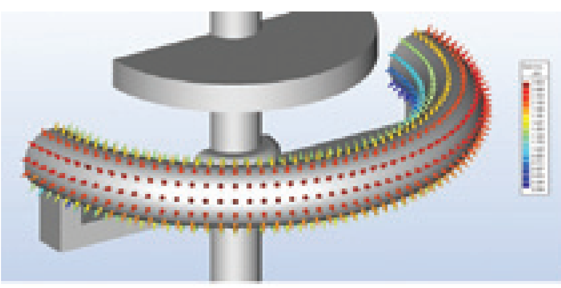


Fig. 6. Electric field on a corona ring

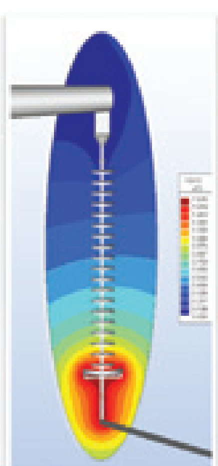


Fig. 7a. Contours at 0º

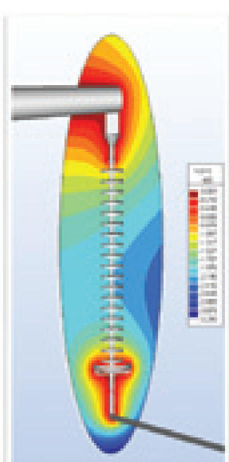


Fig. 7b. Contours at 90 º

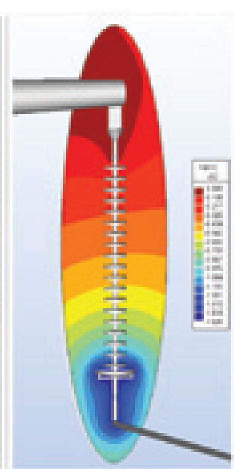


Fig. 7c. Contours at 180º

Figures 7a, 7b, and 7c show a plot of the potential contours on a plane through the mid-section of the top insulator at time angles 0º, 90º and 180º. Initially, the maximum potential near the conductor equals the peak value of line voltage as a cosine function which is square root of 2 times 115 kV i.e. 162.6 kV. At 90º, the maximum potential is 0 kV and at 180º, it is -162.6 kV. Figure 8 shows the potential contours of all three lines on the X = 0 plane.

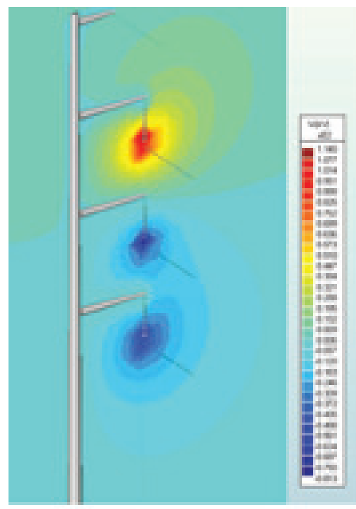


Fig. 8. Potential contours of all three lines on the X = 0 plane

To verify the simulation, we can plot the tangential electric field between two points, a, and b and calculate its line integral, which must be equal to the potential difference between the two points.

$$Va - Vb = \int_a^b E\_tan.\,dl$$

Figure 9a shows an arc is drawn from a point on the top conductor to a point on the tower. In Figure 9b, a graph of the tangential electric field is plotted and integrated along this segment. This integral equals 162 kV, which is the potential difference between the two points at time angle 0º.

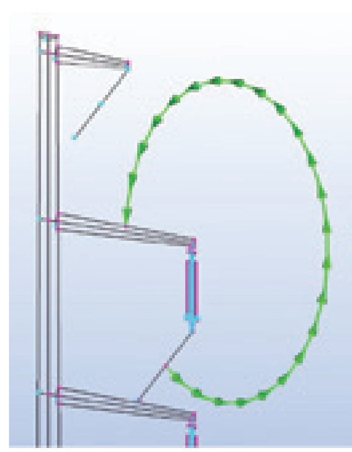


Fig. 9a. Line integral segment

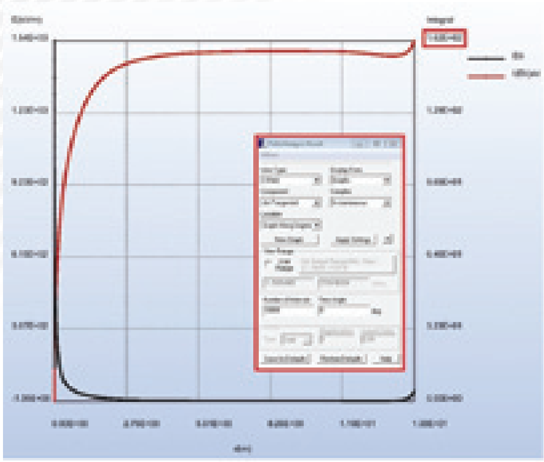


Fig. 9b. Graph of the integral

The value of the electric field surrounding the power line must be lower than a maximum allowable limit for the safety of personnel and people on ground. A 3D electrostatic field solver can efficiently simulate these requirements. For magnetic fields, we can simulate the same model using a 3D magnetostatic field solver. The excitation here has to be the RMS value of the current flowing through these lines.

About the Author

Dr. K.M. Prasad has been involved in developing INTEGRATED engineering software programs for the last 30 years. He obtained his Ph.D. in 1983 and is currently a member of INTEGRATED'S Technical Support Team. The focus of his work has been the simulation of real world electromagnetic field models. Dr. Prasad has considerable expertise in the minimization of the complexity of real world models without losing electromagnetic functionality. With almost three decades of experience in the simulation of electric, magnetic, thermal, and high frequency electromagnetic problems, Dr. Prasad is truly a quick trouble shooter.

Let's Build the Modern Grid

By Chuck Gerry

Connectivity

In nearly every corner of the planet, a network of poles and wires connects power generators to electricity customers. An integrated maze of copper and aluminum cables that move the electrons that power our lives. Regarded as one of the greatest marvels of the 20th century, the electric grid has undoubtedly transformed humanity. As we look into the future, the role of connectivity is rapidly expanding beyond wires and poles. A new grid has emerged. A grid based on the connectivity of people, networks, and sensors. This vision of a multi-layered grid can only be achieved with collaboration. How do we, the electric industry, take that collaborative next step to realize the connected value? Enter the role of the Trusted Advisor.

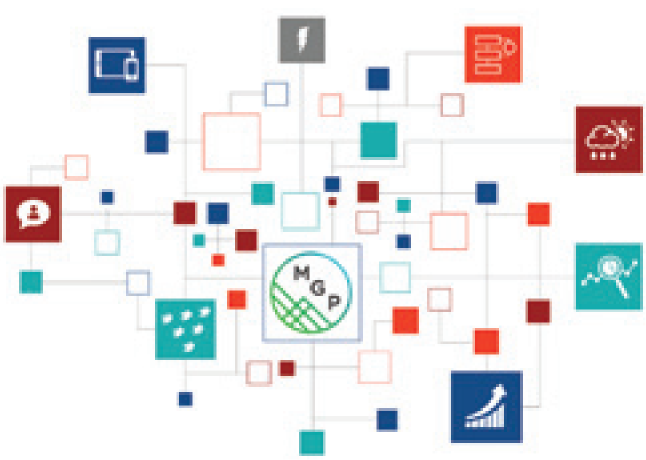


Image 1 – Connectivity is the Key to Collaboration

On October 21, 1879, on a busy street in downtown NYC, Thomas Edison forever changed the face of this planet. With a simple throw of a switch, a new connection was made – the "electric grid." Within a few short years, thousands of power generating units had been installed across the world. The value was real: it was tangible and visible. By connecting homes to generation plans, the electric grid formed the foundation that innovation was built upon.

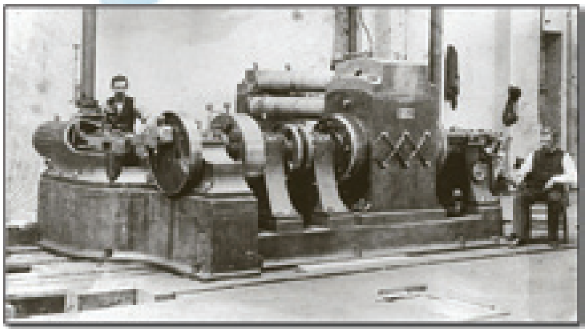


Image 2 – Edison's Pearl Street Station

Happening in parallel, in a small laboratory situated in the heart of Boston, a new network was born – the "telecommunications grid." On March 10, 1876, Alexander Graham Bell and Thomas Watson laid the foundation of communication networks by initiating that historic first phone call.

It's interesting to reflect on how these foundational connections – the electric and telecommunication grids – emerged at nearly the same moment in time. The success of one enabled the success of the other.

- How are telecommunication networks and electrical networks converging?
- What is the role of the Internet of Things (IoT) and the rapid growth in internet connected sensors?
- How can we build a secure grid?
- What is the role of the customer network?
- How can utilities implement innovation first?

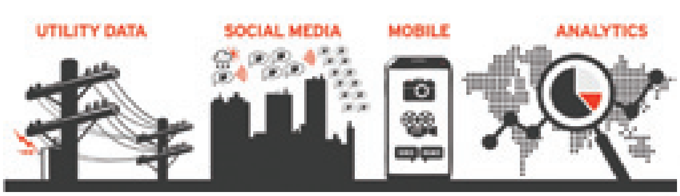


Image 3 - Combining Disparate Data Sets Is Changing the Face of Utilities

A Trusted Advisor

These are tough questions. These are also the questions every utility, vendor, research organization, consulting firm, and customer is asking in 2017. If the connected vision requires the integration of electricity, telecommunication, customer, and sensor networks; then how can we build this interconnected grid? At DistribuTECH 2017, I had the opportunity to have dinner with an executive of a top electric utility. At one point during dinner, the chief technology officer posed a question, "How can I build the future grid?" The answer was simple. **You** can't. To re-align a utility with its strategic goal, optimize communications, enhance project delivery, and build a grid that is interoperable, scalable, and connected; this can only be achieved with **we**.

To achieve the connected grid vision with your trusted advisor you have to "start with the basics." This includes how utilities embrace emerging technologies; drive value in renewables integration; and embrace new value drivers at utilities; depth of talent; deep domain utility knowledge; and breadth of experience to lead and integrate smart grid projects from start to finish.

- A well-planned, step-by-step, technology roadmap.
- Showcase the role collaboration plays with innovation.
- Collaboration is the key to success.
- The moniker of IT/OT convergence may have just emerged, but the industry has long recognized the underlying value. The value of a system, technology, process, etc. grows exponentially as they become interconnected.

These are all key points. The industry must realize that interoperability isn't a requirement; it is the enabler of innovation.

Why a Trusted Advisor is the First Step Toward Collaboration

A major consideration that utilities face is the value and next steps associated with meter data management systems and technologies. These considerations are directly tied to the customer benefit, engineering and operations insight, and forward-looking value of data analytics as tied to many areas of the utility business.

Collaboration also requires having a strong foundation in understanding not only where the grid has been, but also where it is going. The trusted advisor role is to provide decades of experiences from utilities across the world to solve real challenges. For a utility looking for a trusted advisor to support the IT/OT revolution, look for the following characteristics (and embrace a few in your daily processes):

- Require vendors to embrace best practices of interoperability.
- Avoid vendor lock-in by embracing pieces of technology from multiple sources.
- Introduce product and service providers to each other and strengthen their solutions by promoting interoperability.
- Embrace the idea of revisiting the value of a developed solution.
- Develop a long-term vision and design with near-term and long-term requirements in mind.

A Call to Action – Get Involved

Making tough decisions on the future of your utility requires a well thought out plan related to multiple business processes and use cases. The trusted advisor must demonstrate expertise in the following areas:

- Business Case Development
- Customer Experience / Stakeholder Engagement
- Executive Advisory
- Grid Modernization Strategy
- IT/OT Transformation
- Metering and Meter-to-Cash Optimization
- Smart Grid Communications Network Design + Build
- Program / Project Management
- Systems Implementation
- Telecommunications

This includes a deep understanding of the various systems (both current and future) that utility investment must focus on.

How Collaboration Can Drive Change

The alignment of business and technology expertise to support a utilities operation, projects, and future goals is a challenge all electric companies face in 2017. Thankfully, there are multiple organizations across the globe that focus on the mechanisms that help realize the transition to a utility of the future. By bringing together engineers, business consultants, and project managers, all with smart grid expertise, a more reliable grid can be achieved. Choosing the right trusted advisor means identifying the team that has the global expertise, localized knowledge, and a resume full of success with AMI, Telecom, GIS, CIS, OMS, SCADA, and other emerging smart grid solutions. From early stage planning to project closeout, the trusted advisor can help align the strategic vision to drive new levels of connectivity and IT/OT convergence that the future grid will be based upon. I am personally excited to be part of this historic time in the utility industry and invite you to reach out and get involved in building the future connected grid vision.

About the Author

Chuck Gerry is the founder and president of Modern Grid Partners. He is responsible for the firm's business development and delivery of solutions and services across a portfolio of utility customers. Gerry has decades of experience with utility network communications and associated infrastructure build-outs, having overseen the design and deployment of electric and telecommunication systems for several North American utilities. He is a champion of MGP's support for local charities and donates his time and expertise to various nonprofits.

The Role of Cable Rejuvenation in Addressing the Maintenance of Aging Underground Cables

Guest Editorial 1

By Glen J. Bertini

Medium voltage underground cable is designed to be used and not seen. Padmount electrical transformer boxes containing and connected by underground residential distribution (URD) cables are a ubiquitous sight throughout residential neighborhoods, spaced on average 330 feet apart. Consumers who live in the community are generally unaware of the jumble of cables that each box comprises, and they rarely need to consider whether the URD itself is in an adequate state of repair. Most utility providers, on the other hand, are in a constant state of responding to aging cable and the threats it represents.

Over time, utility companies face significant challenges for addressing deteriorating URD conditions. URD cables are most commonly degraded when moisture diffuses into the cable's dielectric layer, gradually diminishing the cable's insulative properties. This condition, called water treeing because of the tree-shaped structure observed when the degraded cable is viewed microscopically, is the most common contributor to URD reliability issues. When the insulation on the cable connecting two transformers degrades to a point of failure, the lights go out in the entire neighborhood.

A portion of the electrical cable insulation is removed to attach an injection adapter in preparation for injection of Cablecure rejuvenation fluid.

Aging URD cables are a growing problem in communities around the world, disrupting customers and causing business challenges for utility providers. But in most cases, the traditional remedy for URD cable failure—taking the impacted cable out of service and putting new cable in its place—has proven to be unfeasible. When cables fail, the resulting outages and the replacement work required to restore power create logistical problems that are usually unpredictable and expensive—costs that must be absorbed by the provider, the customer, or both. Meanwhile, customers often experience multiple outages as the providers install new cable, often disrupting the customers' property and landscaping in the process.

Lineman fans strands of conductor in preparation of electrical cable fluid injection procedure.

Cable Rejuvenation: The Modern Go-to Option for Upgrading URD Cable

When rehabilitating aging URD infrastructure, many utility providers forego cable replacement and opt for rejuvenation as the proven superior method for fixing damaged cable. With cable rejuvenation, the affected cables are left undisturbed and injected with compounds that restore each cable's dielectric strength, effectively adding the same value as a new cable but without the burden of time, cost, environmental disruption, and consumer downtime associated with cable replacement. This method was first developed in 1986 and its use has steadily gained adoption and popularity in the 30 years since.

Preparation of cable for injection by removing sheath and insulation.

Rejuvenation technology focuses on the injection of silane-based fluid into the strands of aging medium-voltage power cables. The fluid is injected by accessing cables through transformers or other cable termination points. Technicians typically open two adjacent transformers and de-energize cables in a way that generally does not impact power to customers. Then, specialty fittings are attached to each end of the cable to allow for fluid injection. As the fluid moves through the cable, it migrates into the conductor shield and insulation. The chemistry and the physics of the insulation are modified and the result is a cable that is returned to full dielectric strength in as little as seven days.

Removing cable sheath and insulation in preparation for injection.

The use of cable injection is approved for capitalization by the Federal Energy Regulatory Commission and hence does not impact tight operation and management budgets.

Sustained vs. Unsustained Pressure

Engineers have developed a variety of injection fluids and techniques over the years, enabling technicians to deploy specific processes depending on a given cable type, circumstance, or environment. The technology is also easily adaptable to different cable configurations, including splices in the cable. In these cases, technicians create splice excavation pits measuring roughly six feet square and four feet deep. These pits have far less impact on landscaping than the trenching or tunneling typically required for cable replacement.

With *sustained pressure rejuvenation* (SPR), cables are restored to full dielectric strength in seven days, and injection can be completed in a single day. The steps are as follows:

1. Isolate, test and ground the damaged cable.
2. Using a time-domain reflectometer (TDR) device, check each segment for splices, neutral corrosion and overall length. If splices are present, technicians pinpoint their locations using a radio frequency locator and measuring wheel. the technicians then dig a pit to expose the splices and replace them with new splice connectors and injection adapters, using templates to insure proper injection adapter placement.
3. Inject each segment at a moderate pressure. A 300-foot segment (100 meters) typically takes 30 minutes or less to inject. Following injection, technicians remove all equipment and install standard elbows at each end of the cable.
4. Re-energize the rejuvenated segment of cable, and then move on to the next segment.

Technicians typically apply the improved *unsustained pressure rejuvenation* (iUPR) process in areas that are difficult to access or cost prohibitive to replace. This process uses a low pressure, so fluid can flow through splices while the circuit is energized. The steps are as follows:

1. Isolate, test and ground the damaged cable.
2. Using a TDR device, check each segment for splices, neutral corrosion and overall length.
3. Perform airflow testing to confirm the rejuvenation fluid will flow properly.
4. Install new connectors and injection elbows.
5. Connect a feed tank to the injection elbow at one end of the cable and a vacuum tank at the other.
6. Re-energize the cable segment, and with the transformer closed, begin the injection process.

With iUPR, injection typically takes 24 hours or less to complete. The following day, technicians remove all equipment. Except for the initial installation of the injection components at the terminations, the cable remains energized throughout the process.

Benefits of Rejuvenation

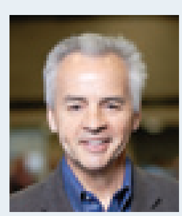
- *Cost savings*. On average, a rejuvenation program yields a 40 percent savings over abandon-and-replace programs. For utilities facing ever-increasing cable maintenance and management demand, rejuvenation helps address and repair more miles of cable for the same budget, compared to replacement.
- *Ecological impact*. Cable rejuvenation reduces new pollution: no resources are consumed to produce new cable; no diesel fuel is spent for installation, and the environment benefits when cables are not abandoned in the ground. For every 10-mile run of cable rejuvenated, cable injection provides at least a 3,000-metric ton reduction in CO^2 equivalent. Each meter of cable that is injected, rather than replaced, saves 195 grams of aluminum, 484 grams of copper, 963 grams of plastic and 1.09 gallons of diesel fuel.

The rejuvenation fluid enters the conductor via an injection pin and injection adapter that is connected to the cable end.

- *Fewer outages*. Because utilities can perform rejuvenation proactively rather than waiting for an emergency, there are fewer occasions when customers will be without power. Even during injection, customers experience a relative continuity of service, as opposed to tolerating planned outages as required for replacement.
- *Low failure rate*. In the past 30 years, more than 116 million feet of cable have been rejuvenated and more than 300 utilities on five continents across the globe have used cable rejuvenation. In that time, the overall post-injection failure rate is less than one percent.

With these benefits all in mind, utilities are best served to consider rejuvenation first when developing reliability programs for the URD cable they manage.

ABOUT THE AUTHOR



Novinium CEO **Glen Bertini** has more than two decades of working with cable-rejuvenation technology, beginning with its development at Dow Corning in 1986. He has published more than 45 articles and 31 patents on cable rejuvenation and related technologies. In 2010, he won the Puget Sound Engineering Council's Industry Engineer of the Year award as well as Seattle Business Magazine's Top Innovators award. Bertini is a senior member of the American Institute of Chemical Engineering (AIChE), an Institute of Electrical and Electronics Engineers (IEEE) fellow, a voting member of the Insulated Conductors Committee (ICC) and a licensed professional engineer. He received a Bachelor of Science in chemical engineering from Michigan Technological University.

Guest Editorial 2

Thermally Managed Outdoor Enclosures Contribute to Stronger, More Reliable Battery Backup Systems

By George Brendahl

Battery backup systems play a critical role in keeping utility substations online in case of outages. Serving as primary or secondary power, battery backup systems enable the station's feeds to trip in the event of a fault, as well as activate the low-voltage main breaker and high-voltage protection of the power transformer. Additionally, the presence of a battery backup system provides reliable power for switchgear and critical standby systems during loss of AC power.

As utilities look to expand the capabilities of their facilities, space becomes a consideration. Having the ability to move battery backup systems outdoors creates space and ultimately minimizes infrastructure costs related to adding brick and mortar to an existing facility. The use of thermally managed outdoor enclosures offers an effective way to ensure that batteries used in backup systems perform at their peak in rugged, outdoor environments.

When considering implementing an outdoor battery backup system, it is recommended to consider a thermally managed enclosure that complies with North American Electric Reliability Corporation (NERC) standards for battery maintenance and monitoring.[1] Additionally, the batteries should be able to recover quickly and survive Partial State of Charge (PSOC) conditions, harsh weather and extreme temperatures. Keeping batteries in their optimal temperature range helps foster high performance and long life of the complete backup power system, with high reliability and low operating expenses.

Enclosures for battery backup systems should be able to:

- Accommodate the full range of applications needed, from initial deployment to large-capacity applications
- Expand with the growth of the application
- Offer a wide range of thermal management technologies to handle seasonal temperatures and humidity, as well as thermal loads produced by internal active equipment
- Prevent moisture ingress
- Consume minimal parasitic power
- Secure the system from unauthorized access

Considerations for Implementing an Outdoor Battery Backup System

There are many factors to consider when implementing an outdoor battery backup system for use in a substation or other utility applications:

Remote Locations

Remote locations can be inaccessible and plagued by unstable grids, frequent outages, and extreme and varied weather conditions. Batteries in an outdoor backup system must be designed to handle these conditions, recover quickly, and survive PSOC and harsh weather. A hybrid approach may incorporate generators, solar power and batteries, for example, which helps prevent interruptions of electrical service.

Battery Selection

A properly sized outdoor battery backup system should be able to support any specified substation load profile. This includes complex load profiles with continuous, non-continuous, momentary and even random loads. A properly sized battery system that is temperature controlled inside an outdoor enclosure ensures maximum site reliability.

Some battery manufacturers are turning to specialized manufacturing processes to develop batteries that reduce ownership costs, while outperforming other batteries. For example, Thin Plate Pure Lead (TPPL) batteries with ultra-thin, corrosion-resistant plates offer more power and energy density, as well as a longer shelf life, than similarly sized batteries. These features along with the thermally managed cabinet add an additional layer of reliability to the battery backup system.

Thermal Management

Many factors affect the thermal performance of an outdoor enclosure, including the thermal load produced by the sun and the equipment inside. While some batteries in outdoor battery backup systems may be more temperature tolerant than others, all batteries in outdoor locations can benefit from the protection of a thermally controlled outdoor enclosure. Thermal management has become increasingly available for outdoor battery enclosures in order to maintain an ideal temperature of 77 degrees Fahrenheit (25 degrees Celsius).

Enclosures with thermal management features can have a large impact on outdoor battery backup systems and can affect operational expenses. If the enclosure does not have thermal management features, it will not have the capability to maintain the proper operating temperature for the batteries. Manufacturers now offer a range of technologies and capacities to match thermal management requirements. Options include Direct Air Cooling (DAC), Thermo-Electric Coolers (TEC), Air Conditioning (A/C) and zone cooling. These technologies help maintain the appropriate thermal environment for equipment, while minimizing ownership cost.

- DAC systems provide excellent above-ambient thermal management performance that is ideal for deployments in locations with moderate annual temperatures. DACs use open-loop systems that bring outdoor ambient air into the enclosure's interior for cooling purposes. The air flows between the batteries as it exchanges heat with the battery walls before being exhausted from the enclosure.

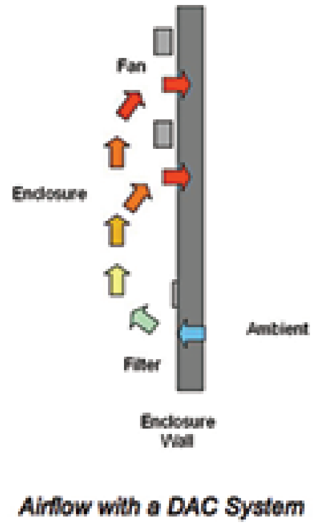
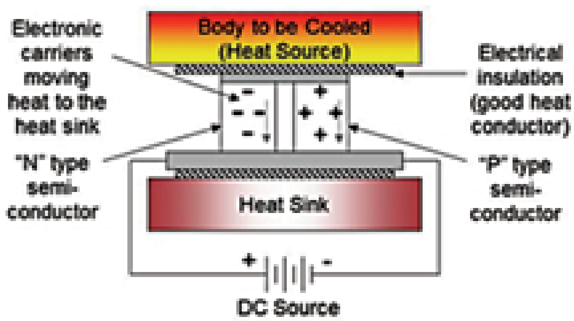


Figure 1: In DAC systems, air flows between batteries as it exchanges heat with the battery walls before being exhausted from the enclosure.

DAC systems normally employ inexpensive mesh filters to prevent particulate contamination from entering the enclosure or, alternatively, can be equipped with high-performance hydrophobic filters that prevent moisture entry. DAC systems are highly reliable and consume little energy, which makes them well suited for operation during commercial power outages due to their low parasitic power consumption from the batteries. They also have long life expectancy; the only moving parts are the fans.

- TECs use the Peltier effect, in which current applied across two dissimilar materials causes a temperature differential. Heat moves from one side to the other, where, typically, a heat sink will absorb it. The cooler side is used to cool the environment inside of the enclosure.

TECs offer variable and scalable incremental cooling and heating in a compact form factor and are ideal for deployment in any temperature climate. TECs also offer high reliability and long life expectancy because, as with DAC systems, the fans that circulate air are the only moving parts. They require minimal maintenance and can operate on battery backup during commercial power outages. In general, a TEC will consume more power than a DAC.

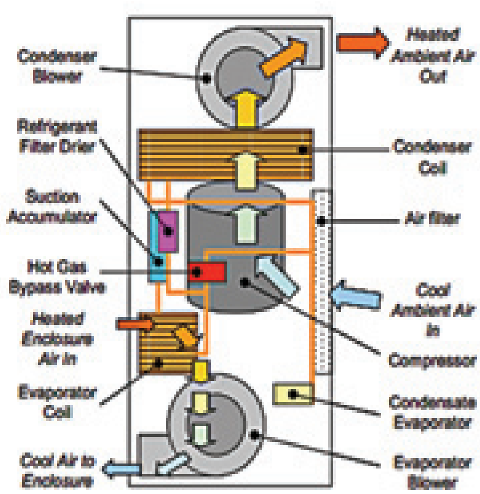


Components and airflow with a TEC System

Figure 2: In TEC systems, heat moves from one side to the other, where, typically, a heat sink will absorb it.

- A/C is based on liquid absorbing heat when it evaporates; this liquid is referred to as the refrigerant. Refrigerants absorb heat by changing from liquid to vapor (evaporation), which cools the enclosure. A/C is energy efficient, as there is a small amount of energy loss during the cycle, and it can manage a large heat load, making it reliable in even very high-temperature climates.

  A/C is among the highest performing thermal-management technologies, as it is able to support high heat loads and cool an enclosure's interior far below ambient air temperatures. Most A/C units deployed in support of outdoor enclosures are closed-loop systems based on a vapor compression cycle. The refrigerant undergoes a change of state (from liquid to gas) that absorbs thermal energy from within the enclosure and transfers it to the outside air. This process also removes humidity from the enclosure.



Components and airflow within an A/C System.

Figure 3: Most A/C units in outdoor enclosures are closed-loop systems based on a vapor compression cycle: The refrigerant changes from liquid to gas, absorbs thermal energy from within the enclosure and transfers it to the outside air.

- Zone cooling separates the enclosure into multiple zones, each using a thermal management technology selected specifically for the equipment or components deployed in each zone. This capability is especially useful for enclosures that house both batteries and electronics.

Enclosures with Expandability

Enclosure systems should be adaptable to changing applications and environments so operators may standardize one enclosure model that accommodates different equipment configurations and deployment challenges.

Conclusion

As utilities expand, so does the demand for space. The use of NERC-compliant, thermally managed outdoor enclosures to house backup battery systems not only provides more space inside facilities for personnel and other equipment, but also ensures that backup batteries are secure and protected from the elements. The availability of a range of thermal management methods enables utilities to select the appropriate backup battery outdoor enclosure to fit their particular needs, even in remote locations. The NERC-compliant, thermally managed outdoor enclosure system chosen should also be expandable to respond effectively to changes in the utility's operations, as well as employ high performance batteries of the appropriate size.

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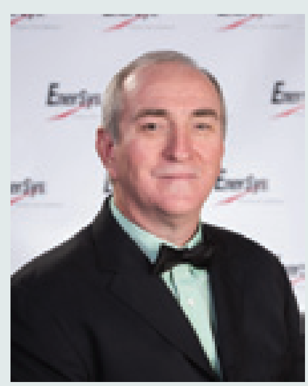

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1. North American Electric Reliability Corporation (NERC), "Protection System Maintenance," Nov. 7, 2012, Standard PRC-005-2, p 1, accessed at http://www.nerc.com/files/PRC-005-2.pdf

SECURITY SESSIONS

By Richard Harada

Designing and Installing a Substation Video Monitoring System

Forward

Video monitoring is a key component of an electric utility's comprehensive physical security plan. For utilities following NERC CIP 014 and the NERC Security Guideline for the Electricity Sector, a video system is required to visually monitor substations and prevent and investigate various types of security threats including theft, unauthorized access, vandalism and sabotage to the critical infrastructure. Unmanned remote sites provide an easy target for intruders, and security threats are constant with the theft of copper and damage to high-value electrical components and material. Theft and vandalism not only cause loss of equipment and revenue but are also a danger to the public, utility personnel, and the intruder, as these actions could affect the performance of the live system.

Installing a video system in a remote substation comes with challenges that are unique to the industry, including, high levels of EMI, voltage surges and interrupts, limited network bandwidth, and extremes in weather conditions. These challenges should be considered if the utility's goal is to have a reliable, low maintenance system that will still provide the necessary features and performance. This article outlines the key requirements including the design, communications architecture and hardware specification that utilities should consider when purchasing and installing a video system.

Introduction

Installing a video monitoring system is one of the first steps that a utility will take when implementing a physical security plan. A comprehensive video system can cover several of the eight concepts in the NERC Security Guideline for the Electricity Sector: Physical Security. While the NERC guideline covers the concepts including suggestions to use a video monitoring system, it does not provide the user with suggestions on how to implement a system that is suitable for a substation environment, the communications network or associated protocols.

Environmental Conditions in a Substation

Electromagnetic Radiation

A high-voltage transmission substation can operate at 500kV or higher. At this voltage level, the electric current flowing through the power lines produces an electromagnetic field that can extend to more than 300 meters. The Electromagnetic Field (EMF) causes interference and misoperation in electronic equipment if the equipment is not designed to mitigate the effects. The disturbances generated by high voltage lines, switchgear, breakers and other apparatus in the substation are known as Electromagnetic Interference (EMI) or Radio Frequency Interference (RFI). Electronic equipment that operates in the vicinity of high voltage apparatus must be designed with immunity to this type of interference to avoid misoperation and loss or corruption of data.

Electrostatic Discharge (ESD)

Because there are large fields of electromagnetic radiation in substations there is a higher probability for electrostatic charges to build up and cause damage. The ESD charges are released when there is contact or near contact with a grounded object at lower voltage potential. The contact can occur from the charged body of a worker or through a tool that is being carried to a grounded object. If the grounded object is a piece of electronic equipment, the high voltage will flow through the circuits and cause damage or destruction to components, if the circuits are not properly protected. To provide proper protection from high levels of ESD the chassis and all network and communication ports on electronic equipment must provide a path to ground that avoids sensitive circuits.

Cameras that operate in close proximity to high voltage lines require immunity to the effects of EMI.

Instability of Power Supply

Substations, where the voltage supply is transformed and switched to and from different voltage levels and circuits, causes voltage ripples, surges and interrupts on the primary power supply that is used for electronic equipment in the substation. Load switching from faults in the electrical system can also cause ground potential rise.

Electronic equipment in the substation must be designed to withstand interruptions and operate seamlessly under many variations of power sources, including switching from primary AC power to backup AC or DC power, when the primary power source fails.

Lightning

Due to the nature of substations being built with tall metal structures in remote areas, they are naturally more exposed to lightning strikes. Even though many substations are designed with sophisticated lightning protection and grounding systems, there are many substations with no lightning protection. When lightning protection is employed, it generally covers a 30º arc under the lightning protection cable and often does not protect the fence line where the camera poles can be located. Even with proper lightning protection in the substation, problems can still arise from voltage surges and ground potential rises for electronic equipment that is not designed to withstand it. Electronic equipment must not only be designed to withstand voltage surges but must also be installed correctly with particular attention to proper grounding.

Extremes in Weather and Climate

While some modern substations have control rooms that are climate controlled, the vast majority of remote substations are unmanned and without climate control. Even if the control room is climate controlled the electronic equipment is expected to operate reliably in outdoor environments with or without equipment cabinets. The equipment must be able to withstand extremes in high and low temperature and humidity. Equipment that operates outdoors must have the correct ratings to be protected from sun, dust, dirt, wind, rain, snow and ice. The operating temperature ratings must not rely on the use of fans as moving parts are usually the first point of failure.

Designing for the Effects of the Substation Environment

Eliminating the Most Common Failures

The components in electronic devices that are most likely to fail are 1) power supplies and 2) motors. High-reliability equipment designed for substation use should be designed with redundant power supplies that can be powered from independent sources. This provides redundancy on the unit's own power supply as well as from the power source. If the primary AC source goes down the unit can draw DC power from the substation battery to keep running. Secondly, the electronic equipment should be designed without moving parts such as spinning drives and cooling fans/filters. Substations in remote locations are difficult to access and perform maintenance on and the mechanical components are among the first things to fail. The substation standard specifies equipment must operate at full specified temperature ratings without cooling fans so they are virtually maintenance free.

Fiber Optic Cables

If the communication links inside the substation are copper based they are potential paths for voltage surges as well as being excellent receptors for EMI. Using fiber optic cables for communications in the substation is a common practice to both eliminate these potential sources for interference and failure and also to provide a longer communication path between devices. Copper Ethernet cable standards limit the distance to 100 meters between devices, whereas fiber optic cable can communicate over several kilometers.

A junction box provides fiber optic communications and power for the cameras

Substation Standards

Substation Engineers recognized the fact that intelligent electronics devices (IEDs) would be increasingly used in substations. They also knew that they had to be designed differently to work reliably in the challenging environmental conditions. The IEEE created a standard known as "IEEE 1613 Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations." Along the same lines the International Electrotechnical Commission, (IEC), created a standard known as IEC 61850-3. This standard, "defines the general requirements, mainly regarding construction, design and environmental conditions for utility communication and automation IEDs and systems in power plant and substation environments." The IEEE standards are more recognized in the U.S. while the IEC standards are more recognized globally but both provide a minimum level of requirements for substation electronic devices. It is generally a requirement for IEDs being used in a substation to meet the requirements of either one or both of these standards. For a manufacturer that markets products globally, it is common for them to ensure their products meet both standards.

Video Monitoring Design for Low Bandwidth Communications

Many substations have minimal communications to remote substations. These networks were originally designed to provide SCADA communications between the substation and the control center to provide remote monitoring of the power system. SCADA systems generally require small amounts of bandwidth and a utility will often require the video system to use the same low bandwidth communication path. Streaming video can take up large amounts of bandwidth and overwhelm existing connections, therefore, it is preferable to process the video at the remote substation and only stream video when an event is detected. The video analytics such as motion detection, boundary crossing, tampering, loitering etc. should be done at the substation, and if an event is detected, an alarm can be generated and sent to an operator. The operator can then open a video stream to investigate further. This design conserves network bandwidth and prevents the operator from having to manually monitor the video feeds.

Network Design

Modern Industrial Video Monitoring Systems use digital technology to send images over an Internet Protocol (IP) network. An IP network is commonly used for Internet connections and corporate LANs making it a very common and easy to use and deploy technology. Use of IP technology allows video systems to be connected to existing corporate networks and to be managed by existing personnel and policies minimizing installation costs and training. IP networking techniques allow the video system to be secured and segregated from the Internet and from the corporate LAN but remain connected to the control center and the SCADA network. As an example, video systems from several substations can be accessed for viewing from the control center, connected to the energy SCADA system and connected to a remote archive server, all over an IP network.

Design for Security

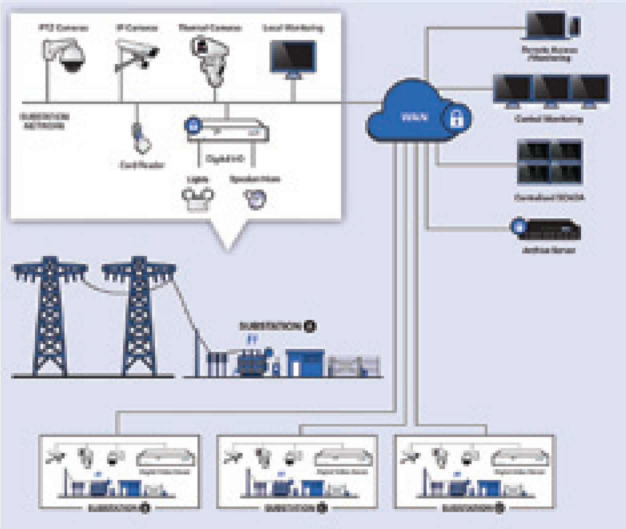
Substation automation networks are industrial, process-based networks that run critical applications to keep substation equipment and the power system protected and running safely. Process-based communications are machine-to-machine, so uninterrupted and timely delivery of data is critical to keep processes running correctly. Process-based networks must, therefore, be kept isolated from the Internet and other corporate traffic to ensure that the data flow is secure and free of losses. In an IP network, technologies such as Virtual Private Networks, (VPNs), subnets and firewalls are used to keep the substation network isolated from the rest of the corporate LAN. The video monitoring system is connected to the substation network so it can communicate with the SCADA system at the control center with alarms, messages, visual, and thermal information of the operating conditions at the substation. The information can be fed into the control system for automated responses or for operators to make decisions and take actions. Since the substation network requires access privileges, the video and SCADA systems are not accessible to personnel without proper authorization and authentication.

Design for Resilience

During the April 2013 attack on the Metcalf substation in California, the first thing the attackers did was cut the communications lines that served the substation. Attackers with a high level of knowledge will know how to disable primary communication networks that link the substation to the control center. The primary link between a substation and the control center is typically a physical cable, either utility owned or leased from a network provider. The video monitoring system network can be designed to mitigate the risk of this cable being disabled by:

Local or network edge processing of video – if the processing capability of the video system is inside the substation – can continue to analyze and record video, even if the connection to the control center goes down. The system analytics will detect events at the substation and generate alarm messages. The video recordings done locally can be recovered for post-event analysis.

Providing a secondary backup link can provide communications if the primary link becomes disabled. This can be a private wireless network or a carrier-based cellular network that will re-route the signals when the primary network fails. The system generated alarms and video can continue to be viewed over the wireless network.



Distributed architecture processes and stores the video at the substation to improve reliability.

Integration With Other Systems

The video system can be integrated with other physical security systems such as access control, lights, sirens etc. The motion detection of the cameras can be linked with lights and sirens to let intruders know that their presence has been detected. This may be enough of a warning to deter the intruders from causing damage or theft at the substation. The notification of the alarm should also be sent to the control center security and operations either into the email system or directly into SCADA.

Utilities may require personnel to notify the control center when they are on site or they will have a credentials-based access control system at the remote site. A video system will provide visual confirmation and identification of personnel on site. The video system can be linked to an access control system to automatically record personnel entering and exiting the site and ensure that proper security and safety procedures are being followed. If the notification to enter the site is done by radio or phone the control center can visually confirm and record the personnel entering the site.

The video system may also be linked to other monitoring systems such as visual or thermal asset monitoring. This can allow the utility to leverage some of the installed infrastructure to run other monitoring systems.

Conclusion

A video system is a key component of an overall physical security plan; however, there are many things to consider when purchasing and installing the system in a substation. The main goal should be to install a system that is reliable, while providing the monitoring features that are required by the utility and the regulating authorities. Equipment with certifications from recognized industry bodies will provide utilities with assurance that the system will operate reliably in a substation environment. Ensuring that the system is secured inside the utility network firewall will prevent tampering and cyber attacks on the system.

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Richard Harada heads the product management team at Systems With Intelligence and has more than 20 years of experience in industrial networking communications and applications. Harada has previous work experience at RuggedCom and Siemens Canada, where he was focused on product management for communications in the electric power market. Harada is an electronic engineering technologist and has a Bachelor of Science in computer science from York University in Toronto.

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Tel: 819-821-3636 • 1-877-996-3636
Fax: 819-563-7517
Web: www.surplechv.com

Surveying And Mapping, LLC (SAM)
4801 Southwest Parkway, Building Two, Suite 100
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Tel: 512-447-0575
Web: www.sam.biz

SAM is one of the largest geospatial companies in North America. We utilize the latest technology to deliver precision surveying and mapping services for electric energy, oil and gas, transportation, railway, telecommunications, and public sector clients. We routinely integrate data across service disciplines to provide innovative and cost-effective solutions.

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Web: www.systemswithintelligence.com
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SWI supplies intelligent video and asset monitoring solutions designed specifically for electric utilities. SWI's "substation hardened" digital video recorders and cameras, with video management software incorporating advanced video analytics technology, insures the electric utility's critical infrastructure is operating at peak efficiency and is protected against outside intrusion and disruption.

T

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See ad page 9

For nearly 60 years, Tallman Equipment has served those who build and maintain the electrical transmission and distribution systems that power North America. From conductor stringing & sagging to cutting & crimping and everything in between, Tallman has what you need to get the job done. For Sales, Repair and Rentals, Tallman has you covered.

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See ad page 6

Tech Products, Inc. is your local source for identification tags including, Everlast Distribution pole tags, phase marking, transformer labels, Tech-3D substation signs, Fasttag cable markers and Transmission tower aerial observation tags. Since 1948, Tech Products, has been innovating great new products to mark everything from URD Distribution cable to O/H Phasing.

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Tel: 888-280-1349
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Terra Spectrum Technologies is an e-planning and productivity solutions company committed to developing and supporting vegetation management software applications for the utility industry.

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Fax: 905-632-8116
Web: www.stresscretegroup.com

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Thomas & Betts - Utility Group
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Web: www.tnb.com
See ad page 15

Thomas & Betts serves the electric utility industry with a wide variety of products for overhead and underground transmission, substation and distribution applications. With market-leading products and brands like Elastimold®, Hi-Tech®, Homac®, Blackburn®, Joslyn Hi-Voltage™ and Fisher Pierce®, you can count on Thomas & Betts to provide quality, reliability and performance.

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Tel: 1-800-466-1102 X 234
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See ad page 15

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Tel: 717-227-2600
Fax: 717-227-2603
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Fax: 901-566-6650
Web: www.trinitymeyer.com

U

Underground Devices Inc.
420 Acadamy Drive
Northbrook, IL, U.S.A 60062
Tel: 847-205-9000
Fax: 847-205-9004
Web: www.udevices.com

Uticom Systems, Inc.
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Fax: 610-857-2986
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Fax: 205-968-7201
Web: www.valmontutility.com
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Winola Industrial Inc. is the manufacturer of the original McGregor Ladders. We also fabricate a wide variety of application-specific climbing devices and related accessories for transmission, distribution and communication structures. Standard designs are frequently in stock. We also provide arrange of field services to our manufacturing, utility, mining and cellular customers.

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Hastings Fiberglass Products Inc.
Tel: 269-945-9541
www.hfgp.com

Tallman Equipment Co.
Tel: 630-860-5666
www.tallmanequipment.com

COMMUNICATION SYSTEMS

Arcadian Networks
Tel: 914-579-6380
www.arcadiannetworks.com

Milsoft Utility Solutions
Tel: 325-695-1642 • 1-800-344-5647
www.milsoft.com

S&C Electric Company
Tel: 773-338-1000
www.sandc.com

SISCO, Inc.
Tel: 586-254-0020
www.sisconet.com

COMMUNICATION SYSTEMS - PROTECTIVE RELAYS

ComNet Communication Networks
Tel: 203-796-5300
www.comnet.net

COMPOUNDS - SEALING

American Polywater Corporation
Tel: 651-430-2270
www.polywater.com

COMPRESSION DIES

Condux Tesmec, Inc.
Tel: 507-387-8069 • 1-888-980-1209
www.conduxtesmec.com

Tallman Equipment Co.
Tel: 630-860-5666
www.tallmanequipment.com

COMPUTER CONTROLS AND AUTOMATION

Mitsubishi Electric Visual Imaging Systems (MEVIS)
Tel: 714-252-7826
www.me-vis.com

Open Systems International, Inc.
Tel: 763-551-0559
www.osii.com

COMPUTERS - SOFTWARE

Copperleaf
Tel: 604-639-9700
www.copperleaf.com

EDX Wireless, Inc.
Tel: 541-345-0019
www.edx.com

INTEGRATED Engineering Software
Tel: 204-632-5636
www.integratedsoft.com

CONCRETE - POLES

Accord Industries, Prestressed Pole Div.
Tel: 407-671-7676 • 800-477-7675
www.accordindustries.com

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www.stresscretegroup.com

CONDITION ASSESSMENT SYSTEMS

Doble Engineering Co.
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OMICRON electronics
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www.omicronenergy.com

CONDITION MONITORING

CPI Geomagnetic Disturbance Division
Tel: 303-442-3992
gmd.cpi.com

Kinectrics Inc.
Tel: 416-207-6000
www.kinectrics.com

CONDITION MONITORING EQUIPMENT

Academy of Infrared Training
Tel: 604-516-6646
www.infraredtraining.net

Doble Engineering Co.
Tel: 617-926-4900
www.doble.com

FLIR Systems
Tel: 503-498-3394 • 800-464-6372
www.flir.com

Morgan Schaffer Inc.
Tel: 514-739-1967
www.morganschaffer.com

OMICRON electronics
Tel: 1-800-664-3766
www.omicronenergy.com

CONDUCTOR - ALUMINUM - ACSR

APAR Industries Ltd.
www.apar.com

CONDUCTOR - HIGH CAPACITY, LOW SAG - ACCC

CTC Global Corporation
Tel: 949-428-8500
www.ctcglobal.com

CONDUIT - ACCESSORIES

Thomas & Betts - Utility Group
Tel: 1-800-326-5282
www.tnb.com

Thomas & Betts Canada Utility Division
Tel: 1-800-466-1102 X 234
www.tnb.ca

PRODUCTS AND SERVICES

CONDUIT - PLASTIC

American Pipe & Plastics, Inc.
Tel: 607-775-4340
www.ampipe.com

Thomas & Betts - Utility Group
Tel: 1-800-326-5282
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CONDUIT - POLYETHYLENE, CONTINUOUS

Arnco Corporation
Tel: 800-321-7914
www.arncocorp.com

CONNECTORS - BOLTED - DISTRIBUTION

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Tel: 1-800-326-5282
www.tnb.com

CONNECTORS - COMPRESSION, DISTRIBUTION

ASK Products Inc.
Tel: 630-896-4056
www.asklug.com

CTC Global Corporation
Tel: 949-428-8500
www.ctcglobal.com

Thomas & Betts - Utility Group
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www.tnb.com

CONNECTORS - COMPRESSION, TRANSMISSION

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CONNECTORS - TECK CABLE

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CONNECTORS, UNDERGROUND - TERMINATING

Thomas & Betts - Utility Group
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Thomas & Betts Canada Utility Division
Tel: 1-800-466-1102 X 234
www.tnb.ca

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Tel: 714-252-7826
www.me-vis.com

CONSOLES - T&D CONTROL CENTERS

Mitsubishi Electric Visual Imaging Systems (MEVIS)
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www.me-vis.com

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www.asplundhconstruction.com

Pike Electric, Inc
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www.rokstadpower.com

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www.sandc.com

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www.alliedindustrialmarketing.com

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www.sargentlundy.com

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www.snclavalin.com/en/power

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CN Utility Consulting
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www.sandc.com

Wright Tree Service
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PLH Group, Inc.
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www.me-vis.com

VuWall Technology Europe GmbH
Tel: +4970715499206
www.vuwall.com

CONTROL - SUPERVISORY

S&C Electric Company
Tel: 773-338-1000
www.sandc.com

CONTROL CENTER DESIGN

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www.me-vis.com

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www.advpowertech.com

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www.elliottequip.com

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Amistad Fiberglasse Co., Inc.
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www.amistadfiberglass.com

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Hughes Brothers, Inc.
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www.sandc.com

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www.getcurricula.com

Open Systems International, Inc.
Tel: 763-551-0559
www.osii.com

D

DAMPERS - VIBRATION

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www.arproducts.org

DATA ACQUISITION SYSTEMS

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www.livedata.com

DETECTORS - PARTIAL DISCHARGE

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OMICRON electronics
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www.omicronenergy.com

Phenix Technologies Inc.
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www.phenixtech.com

DIAGNOSTIC EQUIPMENT

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www.sandc.com

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www.abb.com

Advanced Control Systems, Inc
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www.acspower.com

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www.sandc.com

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Tel: 1-800-326-5282
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www.tnb.ca

VIZIMAX Inc.
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www.vizimax.com

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Asplundh Tree Expert Co.
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www.asplundh.com

PLH Group, Inc.
Tel: 214-272-0500
www.plhgroupinc.com

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Tel: 1-847-806-6300
www.charlesindustries.com

ENCLOSURES - FIBERGLASS-REINFORCED

Concast, Inc.
Tel: 507-732-4095
www.concastinc.com

Mersen Canada
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ep-ca.mersen.com

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www.charlesindustries.com

ENCLOSURES - METERING EQUIPMENT

AE Products, Inc.
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www.aeproducts.net

Easi-Set Worldwide
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www.easiset.com

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www.adalet.com

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www.charlesindustries.com

HindlePower
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www.hindlepowerinc.com

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energywatch-inc.com

Lindsey Manufacturing Co.
Tel: 626-969-3471
www.lindsey-usa.com

Open Systems International, Inc.
Tel: 763-551-0559
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ENERGY SAVINGS PRODUCTS

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Tel: 818-597-9494
www.adgecolp.com

Aztech Associates Inc.
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www.myaztech.ca

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JRG Mechanical Inc – HVAC Services GTA
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jrgmechanical.ca/

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www.lewistree.com

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Sargent & Lundy LLC
Tel: 312-269-2000
www.sargentlundy.com

Surveying And Mapping, LLC (SAM)
Tel: 512-447-0575
www.sam.biz

GIS - SOFTWARE

Bentley Systems, Inc.
Tel: 610-458-5000 • 800-236-8539
www.bentley.com

EDX Wireless, Inc.
Tel: 541-345-0019
www.edx.com

PRODUCTS AND SERVICES

Milsoft Utility Solutions
Tel: 325-695-1642 • 1-800-344-5647
www.milsoft.com

Track Your Truck
Tel: 815-717-8482
www.trackyourtruck.com/systems

GLOBAL POSITIONING SYSTEMS (GPS)

Autovision Wireless Inc.
Tel: 416-700-2673
autovisionwireless.com

GLOBAL POSITIONING SYSTEMS - MAPPING SYSTEMS

Milsoft Utility Solutions
Tel: 325-695-1642 • 1-800-344-5647
www.milsoft.com

GLOVES - TESTING

Phenix Technologies Inc.
Tel: 301-746-8118
www.phenixtech.com

GRIPS - CABLE-PULLING

Hastings Fiberglass Products Inc.
Tel: 269-945-9541
www.hfgp.com

GROUND RODS - COPPERWELD

Thomas & Betts - Utility Group
Tel: 1-800-326-5282
www.tnb.com

GROUNDING - EQUIPMENT

Hastings Fiberglass Products Inc.
Tel: 269-945-9541
www.hfgp.com

GROUNDS - TRAVELING

Tallman Equipment Co.
Tel: 630-860-5666
www.tallmanequipment.com

GUARDS - ANIMAL AND BIRDS

TransGard
Tel: 717-227-2600
www.transgardfence.com

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HANDHOLES AND MANHOLES

Charles Industries
Tel: 1-847-806-6300
www.charlesindustries.com

HARDWARE - POLELINE

Hughes Brothers, Inc.
Tel: 402-643-2991
www.hughesbros.com

HARDWARE - TRANSMISSION LINE

Anti-Galloping Solutions
Tel: 587-984-5106
www.anti-galloping.com

Hughes Brothers, Inc.
Tel: 402-643-2991
www.hughesbros.com

Lindsey Manufacturing Co.
Tel: 626-969-3471
www.lindsey-usa.com

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Asplundh Tree Expert Co.
Tel: 1-800-248-8733
www.asplundh.com

Lewis Tree Service, Inc.
Tel: 585-436-3208
www.lewistree.com

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Tel: 630-860-5666
www.tallmanequipment.com

HUB SWITCHES

American Moistening Co.
Tel: 704-889-7281 • 1-800-948-5540
www.amco.com

ComNet Communication Networks
Tel: 203-796-5300
www.comnet.net

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IMAGING

Surveying And Mapping, LLC (SAM)
Tel: 512-447-0575
www.sam.biz

INDICATORS - FAULT

Thomas & Betts - Utility Group
Tel: 1-800-326-5282
www.tnb.com

Thomas & Betts Canada Utility Division
Tel: 1-800-466-1102 X 234
www.tnb.ca

INFORMATION TECHNOLOGY AND MANAGEMENT CONSULTING

Copperleaf
Tel: 604-639-9700
www.copperleaf.com

INFRARED CONSULTING

Alain Tremblay, Inc.
Tel: 418-543-6358
none

INSPECTION - FIELD SERVICES

Kinectrics Inc.
Tel: 416-207-6000
www.kinectrics.com

MinMax Technologies
Tel: 972-980-0000
minmaxtech.com

S&C Electric Company
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www.sandc.com

INSTRUMENTATION POWER QUALITY

ACR Systems Inc.
Tel: 604-591-1128
www.acrsystems.com

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Doble Engineering Co.
Tel: 617-926-4900
www.doble.com

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www.polycast.ca

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Tel: 630-860-5666
www.tallmanequipment.com

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Petro-Canada Lubricants Inc.
Tel: 1-866-335-3369
lubricants.petro-canada.ca

INSULATION TAPES - ELECTRICAL - CABLE REPAIR

Arlon Inc., Silicone Technologies Division
Tel: 302-834-2100
www.arlon-std.com

INSULATORS - COMPOSITE

Meister International LLC
Tel: 513-923-2712
www.meisterintl.com

INSULATORS - GUY STRAIN - FIBERGLASS - REINFORCED

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Tel: 416-292-2008
www.k-line.net

INSULATORS - POLYMER

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Tel: 416-292-2008
www.k-line.net

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www.polycast.ca

S&C Electric Company
Tel: 773-338-1000
www.sandc.com

INSULATORS - PORCELAIN

America Asia Group Co.
Tel: 626-309-0198
www.aagcusa.com

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INSULATORS - POST-HORIZONTAL

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www.k-line.net

INSULATORS - SUSPENSION

K-Line Insulators Limited
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www.k-line.net

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K-Line Insulators Limited
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www.winola-industrial.com

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Tel: 269-945-9541
www.hfgp.com

LED PRODUCTS

Arani Systems Corp.
Tel: 1-888-992-7264
www.arani.ca

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CN Utility Consulting
Tel: 844-764-2682
www.cnutility.com

Pickett
Tel: 813-304-2898
www.pickettusa.com

Surveying And Mapping, LLC (SAM)
Tel: 512-447-0575
www.sam.biz

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www.hlinstruments.com

S&C Electric Company
Tel: 773-338-1000
www.sandc.com

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www.aquatronics.com

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www.inner-tite.com

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www.techproducts.com

Uticom Systems, Inc.
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www.uticom.net

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Canada Metal North America
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www.canadametal.com/

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minmaxtech.com

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www.albarrie.com

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www.novinium.com

Solidification Products International, Inc.
Tel: 203-484-9494 • 800-758-3634
www.oilbarriers.com

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www.asplundhconstruction.com

Rokstad Power
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www.rokstadpower.com

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www.edx.com

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www.techproducts.com

Uticom Systems, Inc.
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www.uticom.net

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MARKERS - POLES

Tech Products, Inc.
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www.techproducts.com

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www.techproducts.com

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northernmat.ca

MATS - GROUND PROTECTION

Northern Mat & Bridge
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northernmat.ca

MATS - ROADS

Northern Mat & Bridge
Tel: 780-538-4135 • 800-354-4144
northernmat.ca

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www.comnet.net

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www.valmontutility.com

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www.inner-tite.com

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sterlingpadlocks.com

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Engineering Unlimited, Inc.
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sterlingpadlocks.com

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Accuenergy
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https://accuenergy.com/

METERS - MAGNETIC FIELD

Computational Physics, Inc
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www.cpi.com

METERS - MICRO-OHMMETER

Phenix Technologies Inc.
Tel: 301-746-8118
www.phenixtech.com

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Avistar
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www.avistarinc.com

Hastings Fiberglass Products Inc.
Tel: 269-945-9541
www.hfgp.com

PRODUCTS AND SERVICES

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Manta Test Systems Inc.
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www.mantatest.com

Phenix Technologies Inc.
Tel: 301-746-8118
www.phenixtech.com

METERS - VOLT

Hastings Fiberglass Products Inc.
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www.hfgp.com

MOBILE WORKFORCE MANAGEMENT

Lewis Tree Service, Inc.
Tel: 585-436-3208
www.lewistree.com

MODEMS - DATA COMMUNICATION

ComNet Communication Networks
Tel: 203-796-5300
www.comnet.net

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S&C Electric Company
Tel: 773-338-1000
www.sandc.com

MONITORING - EQUIPMENT

API-Camille Bauer Div. of Absolute Process Instruments
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www.apicb.com

MONITORING - TRANSFORMERS

Dynamic Ratings, Inc.
Tel: 262-746-1230
www.dynamicratings.com

LumaSense Technologies
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www.lumasenseinc.com

Morgan Schaffer Inc.
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www.morganschaffer.com

MONITORING SECURITY SYSTEMS

Systems With Intelligence Inc.
Tel: 289-562-0126
www.systemswithintelligence.com

MONITORS - TEMPERATURE

Dynamic Ratings, Inc.
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www.dynamicratings.com

MOTION SENSORS

Lindsey Manufacturing Co.
Tel: 626-969-3471
www.lindsey-usa.com

MULTIPLEXERS - DATA COMMUNICATIONS

ComNet Communication Networks
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www.comnet.net

MULTIPLEXERS - FIBER OPTICS

ComNet Communication Networks
Tel: 203-796-5300
www.comnet.net

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OIL - CONTAINMENT EQUIPMENT

Albarrie GeoComposites Limited
Tel: 705-737-0551 • 866-269-8275
www.albarrie.com

Solidification Products International, Inc.
Tel: 203-484-9494 • 800-758-3634
www.oilbarriers.com

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Tel: 705-737-0551 • 866-269-8275
www.albarrie.com

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www.oilbarriers.com

OIL ABSORBANTS - PADS, ROLLS, BOOMS, SOCKS

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www.albarrie.com

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www.oilbarriers.com

OIL PURIFYING - RECLAIMING SYSTEMS

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Tel: 417-865-2844
www.allenfiltersinc.com

OIL SPILL EQUIPMENT

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www.albarrie.com

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www.oilbarriers.com

OIL TESTING - DISSOLVED GAS ANALYSIS

Doble Engineering Co.
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www.doble.com

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www.morganschaffer.com

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www.lindsey-usa.com

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Tel: 514-739-1967
www.morganschaffer.com

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S&C Electric Company
Tel: 773-338-1000
www.sandc.com

Southern States, LLC
Tel: 770-946-4562
www.southernstatesllc.com

OPERATION SUPPORT SYSTEMS

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www.datavoiceint.com

Milsoft Utility Solutions
Tel: 325-695-1642 • 1-800-344-5647
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Open Systems International, Inc.
Tel: 763-551-0559
www.osii.com

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PADLOCKS

Engineering Unlimited, Inc.
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sterlingpadlocks.com

Inner-Tite Corp.
Tel: 508-829-6361
www.inner-tite.com

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HindlePower
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www.omicronenergy.com

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www.conduxtesmec.com

Hastings Fiberglass Products Inc.
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www.hfgp.com

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www.tallmanequipment.com

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Arch Wood Protection, Inc.
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www.wolmanizedwood.com

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POLE LINE HARDWARE

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www.accordindustries.com

The StressCrete Group
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Valmont Utility
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POLES - DISTRIBUTION - STEEL

Valmont Utility
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www.valmontutility.com

Winola Industrial Inc.
Tel: 570-378-3808
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POLES - DISTRIBUTION - WOOD, LAMINATED

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www.alusmartbobo.com

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www.stresscretegroup.com

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www.valmontutility.com

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LOCWELD Inc.
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www.locweld.com

Trinity Meyer Utility Structures
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www.trinitymeyer.com

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www.astro-med.com/tmindex.html

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www.alber.com

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www.amsc.com

S&C Electric Company
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Commonwealth Associates, Inc.
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www.cai-engr.com

RFI - Rutkoski Fencing, Inc.
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www.rutkoskifencing.com

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www.conduxtesmec.com

PULLERS - CABLE, AERIAL

Condux Tesmec, Inc.
Tel: 507-387-8069 • 1-888-980-1209
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PULLERS - CABLE, UNDERGROUND

Condux Tesmec, Inc.
Tel: 507-387-8069 • 1-888-980-1209
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PULLERS - CONDUCTOR

Condux Tesmec, Inc.
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PULLERS - ROPE

Condux Tesmec, Inc.
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www.tallmanequipment.com

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RADIO TWO-WAY - FIXED

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RECLOSERS - SINGLE-PHASE

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RECORDERS - EVENT

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REMOTE INFORMATION SYSTEMS - AUTOMATIC

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www.osii.com

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S&C Electric Company
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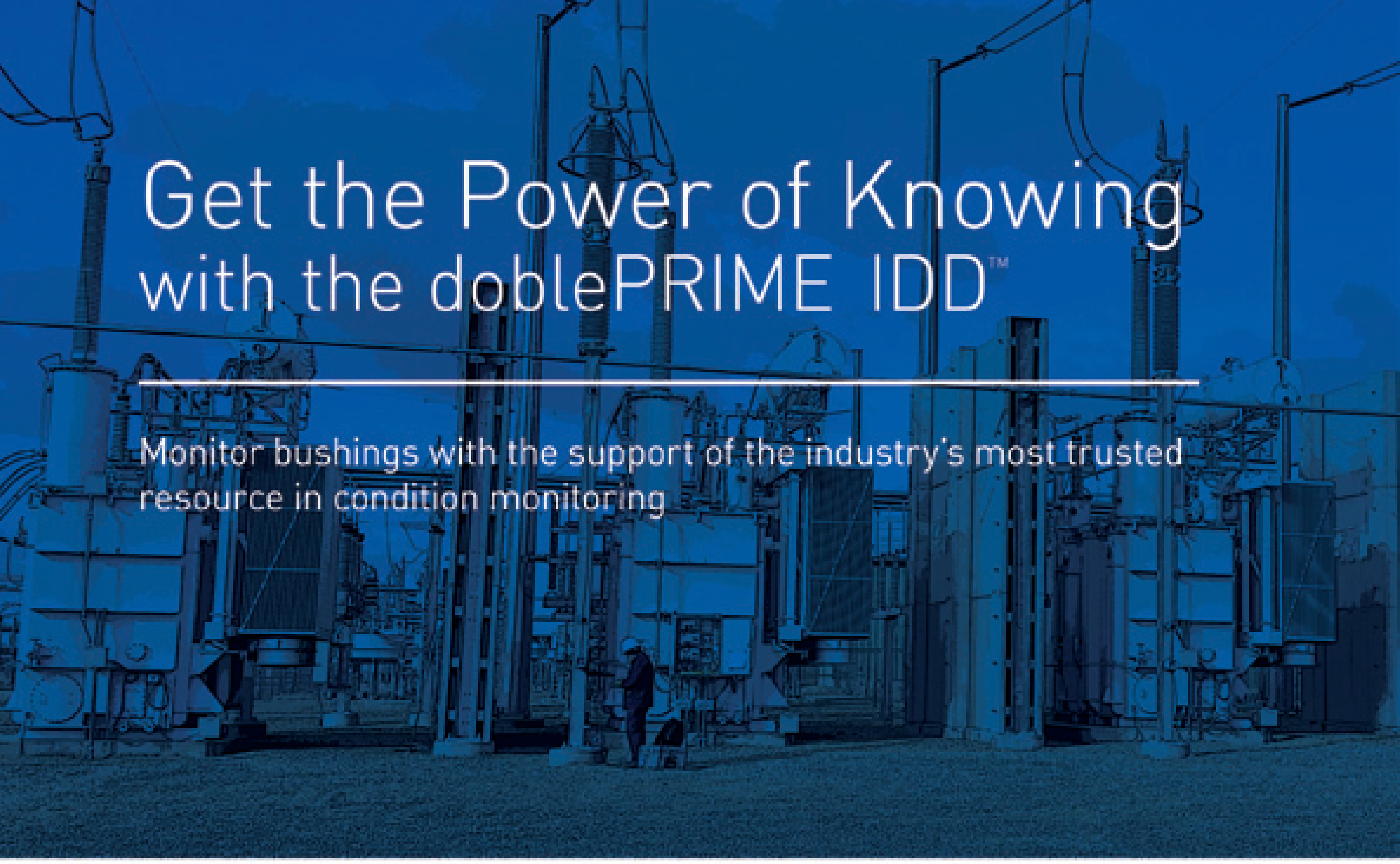

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