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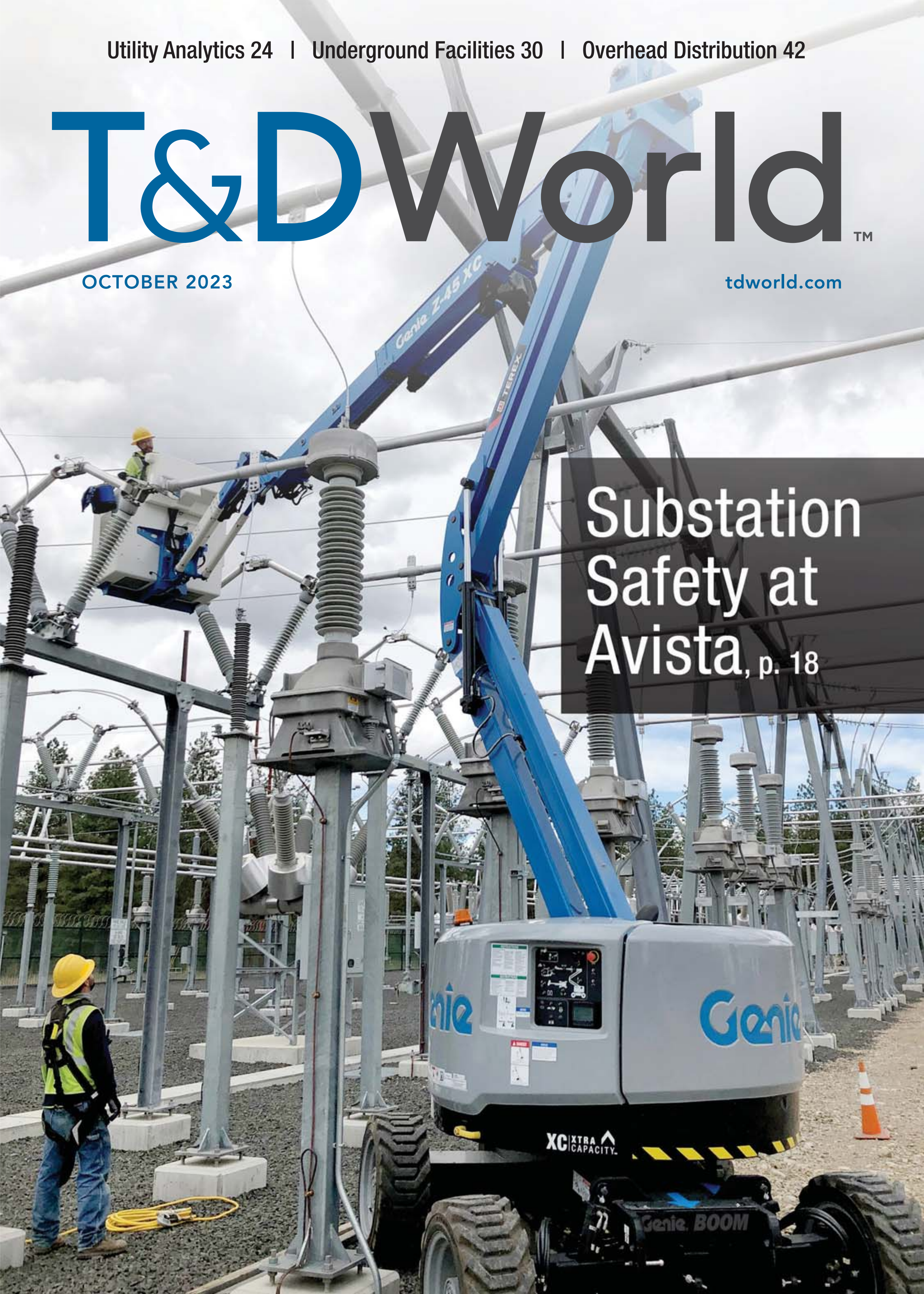

Substation Safety at Avista, p. 18

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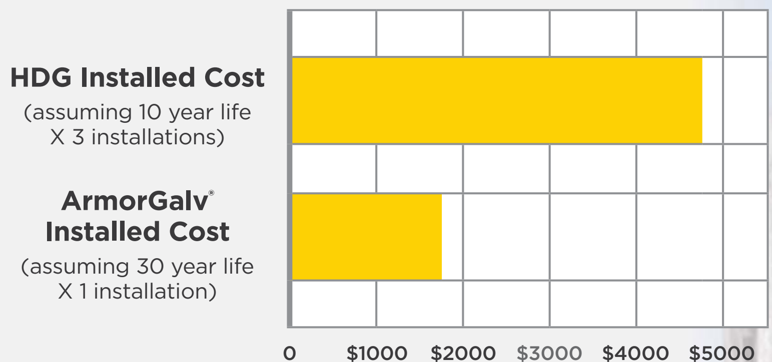

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T&D Trilogy: Climate Change, Carbon Goals and Common Sense

As I'm writing, the UN General Assembly is meeting in New York, where one of the top three topics on the agenda is "climate emergency." The "road to zero" (by 2030) was also a major focus at last month's T&D World Live. I therefore want to talk about climate change. Statistics reveal the electric power industry has successfully reduced carbon emissions over the past two decades. The Edison Electric Institute recently responded to EPA's latest Proposed Rules to Regulate Greenhouse Gas Emissions from Power Plants. In its letter, EEI said carbon emissions from the U.S. electric power sector were 36% below 2005 levels at the end of 2022, resulting in electricity generators' carbon emissions being as low today as they were almost 40 years ago, while electricity use has climbed 73% since then. This is a remarkable achievement but is becoming harder.

I believe climate change is real, but I also believe climate change has been occurring for millions of years. According to the National Oceanic and Atmospheric Administration, the planet has seen two deep freezes: 750 and 600 million years ago. Most scientists say carbon emissions are a major contributor to extreme weather. I'm not a climate scientist, and I'm not going to dispute them. I believe lowering carbon and other emissions is good, but I also know that changes in generation assets can have profound impacts on electricity delivery. Common sense and reasonableness must prevail, and crazy deadlines like zero carbon by 2030 (Yes, I said it.) are neither. In addition, I understand this is a global issue that relies on a global solution and not everyone participates equally. However, like many issues in life, in this case it's important to do your best and, at least to some degree, don't worry about others.

A balance that keeps electricity affordable and reliable while reducing emissions is a must and here's why: This has been a year of record setting heat across the U.S. and the world. The UN's World Meteorological Organization and European climate service Copernicus issued a report in early September saying the 2023 June, July and August period was the hottest such period on record since they began keeping such records in 1940. The organizations also reported that August 2023 was the hottest on record by a large margin and the second hottest only to July of this year.

Grid owners and operators have been impacted by these record-setting temperatures. In late July, PJM, the largest electric grid operator in the U.S., issued a Maximum Generation Emergency/Load Management Alert, which is a notification that emergency procedures might be required. On the same day, PJM also issued an Energy Emergency Alert 1, which signaled that all generating resources were already online or were scheduled to be online.

I wrote about ERCOT's consumption records and conservation alerts in last month's column, but since then it broke another consumption record on Sept. 6, when temperatures are usually getting cooler. On that day, ERCOT issued a Level 2 Emergency Alert, indicating supply was critically low and, in this case, system-wide frequency was below acceptable levels. This was ERCOT's first Level 2 alert since winter storm Uri in February 2021. These are just two of many examples that remind us of extreme heat's impact on grid operations.

Heat isn't the only challenge. According to (NOAA), as of Aug. 8, there had been 15 confirmed weather/climate disaster events in the U.S. with losses exceeding $1 billion each. These events included one flood, 13 severe storms, and one winter storm. Since that report, two more weather disasters occurred in the U.S. On Aug. 8, Hawaii experienced one of the worst fires ever recorded in the U.S. and the deadliest since 1918. For Hawaiian Electric Co., the cost of replacing electricity generation and delivery infrastructure will be large, but that's probably one of the utility's lesser worries. HECO has massive legal issues. Maui County officials filed a lawsuit against HECO saying that the "intentional and malicious" mismanagement of power lines by the utility allowed flames to spark. Law firms have filed numerous additional suits on behalf of victims, claiming the utility was at fault for having power equipment that could not withstand heavy winds, and for keeping power lines electrified during high wind warnings. It will be months before the causes of the fires are determined, and years before the lawsuits are settled, but we've already seen how similar scenarios can impact utilities.

In addition, on Aug. 30 Hurricane Idalia made landfall in Florida, causing billions of dollars in damage, and knocking out power to more than 450,000 customers in Florida and Georgia when it came ashore.

Electric utilities are not strangers to catastrophic weather events, but statistics reveal that their number and severity are increasing. NOAA reports that from 1980 to 2022 the U.S. averaged 8.1 extreme weather events each year resulting in at least $1 billion in losses. The annual average for the most recent five years (2018 to 2022) is 18.0 events. So far, 2023 is shaping up to be average with 17 events, but with three months left in the year, it's unclear if it will remain average.

We've been cautioned about the impacts of climate change and global warming for more than a quarter century. I think we are now learning firsthand, or at least getting a good glimpse of what it's like to live on a warmer planet. The catastrophic events we were warned about have arrived, and climate experts say they will get worse. In addition to working toward net zero carbon goals, we also must prepare ourselves, our structures, and our infrastructures for a harsher, less hospitable world. I don't have to tell you this is a mammoth task for the T&D industry, which is already working on hardening its infrastructure. TDW

International Competitive Bidding
National Electric Transmission System of Chile.

Within the framework of the General Law of Electrical Services of Chile, in accordance with the provisions of Article No. 157 of the Regulation of Transmission Systems and Transmission Planning approved by Supreme Decree No. 37 of 2019 of the Ministry of Energy , the National Electrical Coordinator will carry out the call for International Public Bidding for the Award of Construction and Execution for the following works of the Transmission System:

Project's name	VI USD Referential
Increase in Capacity Line 1x66 kV Monterrico - Cocharcas	892,658
Expansion of Capacity Line 1x66 kV Charrúa - Chillán	6,393,909
New Transformer in S/E La Calera	1,973,981
Laying Second Circuit Line 2x110 kV Agua Santa - Placilla	1,342,647
Line Extension 1x66 kV Las Piñatas – San Jerónimo	399,243

*The final list of works will be confirmed during the bidding process.

To participate in this process, Interested Parties can acquire the Tender Bases corresponding to the Call, which will be available from the second half of October 2023, and request registration in the Registry of Participants,in the manner that will be indicated in the aforementioned Bases, through the website: **https://www.coordinador.cl/desarrollo/documentos/licitaciones/**. These Tender Bases will be available free of charge at the link to the Website

Legal persons, both Chilean and foreign, may acquire the Bases and register in the Registry of Participants, who may participate individually or as part of a consortium or association, complying with the demands and requirements established in the General Law of Electrical Services and in the Bidding Bases.

National Electrical Coordinator

T&D World Live: Raising Questions

Are electric vehicles a coming disruption or a welcome transformation, and how soon is it coming? Are regulators taking the power grid's needs seriously? How can the energy sector decarbonize while also providing cheap, reliable power? How can utilities best prepare for accelerating natural disasters? How much can we rely on technology to solve our problems? I spent a week in Sacramento at T&D World Live, and these are just a few of the questions I heard most prominently from speakers, exhibitors and attendees, as well as from my colleagues.

As one presenter put it, the utility industry is now most preoccupied with the three Ds: digitization, decentralization and decarbonization. The power grid is producing a massive amount of data, more than ever before. Some of our sessions posited that artificial intelligence or machine learning could be a way of squeezing meaning out of that constant stream of information. At the same time, power generation is spreading out across the grid in a way it was not intended to, as customers and utilities too search for ways to make the grid greener.

Members of the *T&D World Live* industry advisory board.

While it's certainly an exciting time to work within this sector, we can admit that the answers to some of the above questions are still open to interpretation and debate, which is one reason why T&D World Live was such a thought-provoking week.

This year's conference and exhibition saw attendees join us from 13 countries, with more than 55 utility companies represented — more utility attendance than our prior year. We also had more than 60 companies joining us on the exhibit hall floor. Our conference had 34 individual conference sessions, not including our keynote and plenary sessions.

All throughout, the unique factor that appealed to me was how easy it was to network and have interesting talks with our delegates and attendees. Both on the floor and off, we got to spend some quality face time with one another (without needing FaceTime). The show encouraged people to get together and allowed us the oxygen to have real conversations. As our vice president of content and conference chair Teresa Hansen put it during her keynote introduction, the utility industry is unique in our competitive business climate in that utilities do not usually see one another as enemies, which leaves us free to collaborate on the problems we share.

For example, another area of concern that frequently cropped up was: In a time when resources are constrained, the supply chain is occasionally unreliable, political support is uncertain and electricity demand is ever-growing, how can grid operators and electric utilities get the most from what they already have? I moderated a panel of technology providers operating in the grid-enhancing technologies (GETs) space and learned that many of them were from outside North America and were seeking to break into the U.S. power grid market. As someone who uses the US power grid and wants it to improve, I was pleased to see so many people willing to tackle the many problems our infrastructure has to face.

I was also gratified to find that the speakers in another session I presented were old colleagues whose working relationships stretched back years, even though one now served in a public utility and another worked for a technology company. Looking out on the convention floor, it was easy to imagine how many similar relationships were continuing — or perhaps being born — right there at the show.

Those speakers were presenting on streamlining power outage responses, and as all three of us have lived and worked in the part of the country called "Tornado Alley," we were all familiar with how treacherous severe weather can be. Intensifying disasters and their impact on utilities was a huge topic this year, with many of our participants coming from California utilities like our host utility Sacramento Municipal Utilities District as well as Pacific Gas & Electric and Southern California Edison — all veterans of battling wildfires. However, we also heard from Mid-Southern and East Coast utilities and their struggles with hurricanes and storm surges, as well as Pacific Northwestern-based professionals who were concerned about the impact of droughts on their resources.

In the coming days and weeks, I plan to keep in good touch with the people I met at the show, not merely to thank them for their support, but in the hopes of starting a good working relationship that I hope will bring our readership more industry insights and a greater understanding of what best practices and technologies can be brought to bear against the problems our power grids face.

Next year, we will be heading into the South, where large investor-owned utilities and huge numbers of cooperatives and municipal utilities work to keep the lights on. So be sure to save the dates, Oct. 1-3 for T&D World Live 2024 at the Hilton Atlanta. I hope you'll join us and bring along your lessons and expertise. TDW

Going With The Flow

Is it me or have you noticed the growing interest in technological applications associated with combating climate change lately? My inbox has been full of announcements, reports, and press releases on a plethora of eye catching subjects like reaching zero-carbon, renewable energy, energy storage systems, etc. One thing all these emails have in common is a focus on making the power grid more resilient throughout extreme weather events fueled by global warming.

On that theme, renewable energy is seen as being a major element of this effort, with energy storage systems making it possible. Several experts went so far as to say energy storage is essential for transitioning the power grid away from fossil-fuel based generation. It's a critical link if you will. At that point, I shifted my reading to the issue of utility-scale energy storage research and development (R&D).

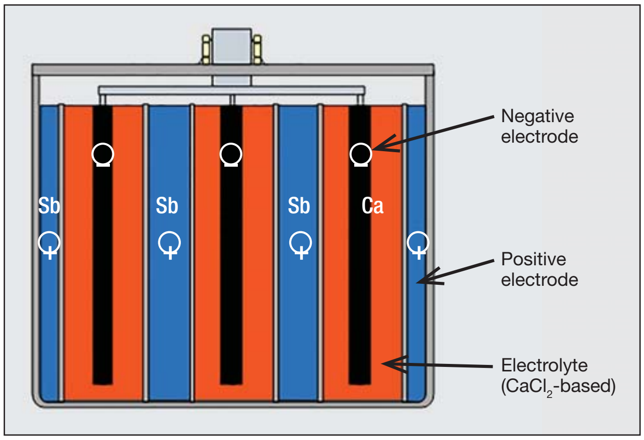
One email getting my attention was focused on the latest R&D in solid-state lithium batteries. They are said to have twice the capacity of today's lithium-ion (Li-ion) batteries. Other emails shifted to alternative technologies designed to replace Li-ion batteries especially for utility-scale battery systems. Let's look at other write-ups.

Maturing Technologies

Another centered on redox flow-battery advancements in the marketplace. They are composed of two liquid electrolytes separated by a membrane. Their capacity is limited only by the size of the electrolyte tanks. Recently, DOE (Department of Energy) announced they were funding R&D along with demonstration projects centered on grid-scale redox-flow batteries. Several marketing research groups are saying the redox-flow battery market is growing. Value-wise their estimates were all over the place, but the figures were impressive. I'll move redox-flow batteries into my trending category and watch it.

Sodium-ion (Na-ion) batteries is one more application drawing interest lately. The reports point out that sodium is much cheaper than lithium. Lithium carbonate cost roughly US$80,000/ton compared to sodium carbonate running about US$300/ton. On the technical side, Na-ion batteries tend to be larger in size than Li-ion batteries, which is an issue for consumer electronics and electric vehicles. It's not a problem for utility-scale storage applications. Globally there are about 20 Na-ion battery factories being planned or under construction. It appears that Na-ion batteries are another technology I'm going to watch.

There's another well-known battery technology that has been advancing; it's the liquid metal battery. Probably the first liquid metal battery technology that comes to mind is the sodium-sulfur battery that was popular many years ago, but there's a new approach that's intriguing. Xcel Energy announced that they were installing a single unit of Ambri's liquid metal battery as part of a demonstration project at the Solar Technology Acceleration Center in Aurora, Colorado. It's expected to be online in early 2024.



Schematic cross-section of Ambri's third generation liquid metal battery cell.
Courtesy of Ambri

Designed for Hard Work

The Xcel Energy project utilizes Ambri's second generation distinctive liquid metal battery system. So, I contacted Adam Briggs, Ambri's Chief Commercial Officer to get a better understanding of the battery's abilities. Adam explained that Ambri's liquid metal battery is designed to be fully charged and discharged twice a day, every day for its 20-year lifetime. It's a hardworking battery that's designed to be worked hard with negligible capacity degradation!

Ambri's cells employ the commonly available electrode materials, antimony and a calcium alloy, which are significantly less costly and more abundant than those used in Li-ion cells. These elements are placed in a sealed insulated container with a salt electrolyte that are heated to 500º Celsius (932º Fahrenheit). Once the system is operating, the charge/discharge cycles generates all the heat that is needed by the system.

The container's insulation keeps that heat inside, which eliminates the need for an external heat source. Also, it doesn't generate gas, which means Ambri's system doesn't need the cooling, fire suppression, or explosion prevention equipment required by Li-ion systems. Ambri is currently working on their third generation battery to increase the capacity of their battery system to the grid-scale megawatt level.

Other emails pushed more breakthrough technologies finding their way to the power grid. These included reports about gravity batteries, oxygen-ion batteries, zinc-air batteries, and iron-air batteries. The R&D is fascinating and challenging to understand, but we have too. Many years ago a friend told me, "storage systems are more relevant to today's utilities than ever before." That's just as true today as it was then. We have to keep up with the developments in technologies if we are going to have any chance combating climate change, but what a rewarding challenge! TDW

Superhighways Are Supercharging The Transmission Grid

Technological advancements can make the electricity supply more resilient.

When the global warming experts gather to discuss the technologies needed to combat the extreme weather events fueled by climate change do they talk about powering those technologies? The short answer is no. It's one of those topics that's usually underrepresented. That's because it's another case of us doing such a great job of supplying electricity no one gives much thought about it. But these technologies require power to do their tasks. If we are going to electrify the transportation system, the electric vehicles doing it require charging, and this is a new load on the grid. Reaching a carbon neutral industrial sector involves cutting sources of greenhouse gas emissions, which increases the industrial sector's demand for more electricity. These are only two examples and there are many more, and they all represent adding more load to the power grid.

Critical to all the additional loads from these technologies is increasing the grid scale wind and solar energy capacities needed to replace the decommissioned fossil-fuel generation. Deploying the technologies and the renewables requires a great deal of support from all the stakeholders including regulators and governments. Luckily this support has been improving.

Much Needed Support

July ended with a bang in the area of regulatory support! FERC (Federal Energy Regulatory Commission) issued its final rule for easing the nationwide backlog of renewable energy projects stuck in interconnection queues. Without going to deeply, it's a major step for streamlining the interconnection process. Foremost, it's implementing a first-ready, first-served cluster study procedure. Next, interconnection studies will be performed collectively, rather than separate studies for each. There are other incentives like deadlines and penalties, but you get the picture.

Technologically, there's a lot to choose from when it comes climate proofing the grid and making it more resilient. "Charging Ahead" has delivered several articles this year about HVDC's (high-voltage direct current) exceptional capabilities in this area. The year started off with the Champlain Hudson Power Express, which addressed the public's resistance to adding overhead transmission circuits. It's a stealth approach moving 1,250 megawatts (MW) via submarine and subterranean cabling from Canada to New York City.

Another article focused on a project developed to address some unique problems that were being encountered as massive offshore windfarms move further from the shoreline. The BalWin1 and BalWin2 offshore grid connections take advantage of voltage source converter (VSC) technology. VSC-HVDC can be operated in bipolar mode giving the BalWin1 and BalWin2 HVDC links the ability to move gigawatts (GW) of power over much further distances. Each of its links move 2,000 MWs from offshore directly to inland load centers located within Germany.

Caithness Moray HVDC link, Blackhillock. Courtesy of Hitachi Energy

The last article looked at the SunZia transmission project, which applies another of VSC-HVDC technology's abilities of combing with power electronic controllers. In SunZia's case, the HVDC transmission line technology was coupled with AC chopper technology. This combination tames any voltage imbalances caused by any line faults that may develop in the course of operation. This results in a robust system that allows the SunZia project to reliably bring 3,000 MW of wind generated power from New Mexico to Arizona for use in southern California.

Supercharging Superhighways

Each of these projects exhibited a steady progression of adapting cutting-edge technology to a changing power grid. It's critical for the power delivery system's ability to supply our customers' growing demands for more clean electricity and VSC-HVDC technology is a powerful tool in that task. The projects mentioned above show how an established technology can be combined with changing realities. This integration gives grid operators an edge when it comes to blending sustainable clean energy into an established power grid with multiple energy sources.

A few months ago, the United Kingdom (UK) gave the world an indication of governmental commitment to clean energy. The UK announced it intends to increase its offshore wind capacity from about 13.7GW to 50 GW by 2030. In order to achieve this goal there will have to be some innovative measures to supercharge the permitting, planning, infrastructure upgrades, etc. processes. One such unique approach is the development of "multiple onshore VSC-HVDC links to accelerate the integration of bulk renewables onto the UK power grid.

As part of this effort, Scottish and Southern Energy Network (SSEN) Transmission announced the selection of Hitachi Energy as their preferred technology provider to supply multiple HVDC converter stations to accelerate the integration of bulk renewables into the UK power grid. SSEN reported that "The parties signed a framework agreement that includes the deployment of up to five HVDC power corridors, or electricity transmission superhighways, to enable large amounts of future renewable power to be transported from northern Scotland to areas of higher consumption in the south."

It's Complicated

Given the complexity of the framework agreement, which is currently being finalized, it seemed like a good subject to discuss with Niklas Persson, Managing Director, Hitachi Energy's Grid Integration business. We started off looking at the physical makeup of the system being developed. The first two projects under the framework agreement are the Arnish-Beautly and Spittal-Peterhead links. Each of these HVDC links will transmit up to 2.0 GWs at ±525 kilovolts (kV). These projects are expected to begin in 2024 and be operational in 2030.

SSEN frame agreement map. Courtesy of Hitachi Energy

The Arnish-Beautly link runs from the Western Isles to Beautly substation on the Scottish mainland with planned upgrades of powerlines from Beauly to Peterhead in Aberdeenshire. The Spittal-Peterhead link consists of a 136.7 mile (220 km) subsea cable route with new HVDC converter stations located close to Spittal substation and Peterhead substation. This is a good point to talk about another aspect of the HVDC power corridors. It's the continuation of moving large blocks of power to the consumer.

The joint venture between SSEN Transmission and National Grid Transmission is set to interconnect the Scottish and English power grids, so let's see how it fits with what is being discussed here. The Eastern Green Link 2 (EGL2) project begins at Peterhead. EGL2 is a 2.0 GW ±525 kV 237.6 mile (440 km) subsea cable and 43.5 mile (70 km) underground cable linking Peterhead in Scotland to Drax, North Yorkshire, England. The project is expected to be operational in 2030.

Persson points out, "This collaborative effort can only be achieved with advanced technologies and new ways of working. By structuring the collaboration as a framework agreement, it enables Hitachi Energy to invest in new production capacity and to undertake large-scale recruitment drives. It also strengthens collaboration, standardization of solutions, and synergies between projects."

Persson continued, "The integration of renewables requires solutions that make the grid resilient, stable, and flexible. Hitachi Energy's innovation and long development of VSC-HVDC technologies, power electronics, and MACH control and protection technologies are designed to meet the requirements alongside many other landmark grid integration projects. This framework agreement reinforces how Hitachi Energy's HVDC technology can be utilized effectively."

Persson explained, "This approach also shows how new business models enable the scale needed to speed up the energy transition. This new methodology allows Hitachi Energy to plan in advance to increase manufacturing capacity, expand and train the workforce, and maximize standardization to increase synergies between successive projects. It also prepares the way for future developments of sharing renewable resources between the UK and European Union (EU)."

VSC-HVDC Backbone

In addition to multiple transmission superhighways, there is a lot of interest in multi-terminal hubs and artificial energy islands forming a VSC-HVDC backbone grid. Such a VSC-HVDC transmission infrastructure would provide backbone flexibility required by tomorrow's load flow patterns. With Europe announcing plans to add about 450 GWs of offshore wind generation by 2050, the push for HVDC interoperability is moving up the scale when it comes to criticality. The challenge of interoperability is getting a system, subsystem, and all of their components to work together.

Along with the technical issues there are many non-technical topics that have to be addressed as the industry moves towards implementing multiple vendor multi-terminal systems. Technically standardization is a massive challenge followed by system modeling and planning. On the non-technical side, contractual issues, warranties, intellectual property rights, a mass of regulatory matters, and a slew of legal uncertainties to name a few have to be addressed.

In the EU, there are HVDC interconnections between countries, between offshore generation and onshore power grids, and between regions within HVDC power corridors. They are looking forward to the time when there will be HVDC mesh-grids comprised of multi-national grid connections, artificial energy islands, and more sophisticated power electronics. Granted it's theory now, but the next-gen VSC-HVDC (i.e., a backbone HVDC grid) is in the foreseeable future.

The EU's InterOPERA project was formed earlier this year with the "goal of enabling interoperability of multi-vendor HVDC grids." They seek to improve grid forming capabilities of both offshore and onshore converters. As gigawatts replace megawatts in the battle against global climate change, this ambitious enterprise is needed. It's an undertaking that must be won! TDW

PATTERN ENERGY GROUP RECEIVES AUTHORIZATION TO CONSTRUCT SUNZIA TRANSMISSION PROJECT

The Bureau of Land Management, U.S. Department of the Interior has issued its Notice to Proceed to begin constructing Pattern Energy Group's SunZia Transmission project at the SunZia East Converter Station in Corona, New Mexico.

"The SunZia Transmission Project will accelerate our nation's transition to a clean energy economy by unlocking renewable resources, creating jobs, lowering costs, and boosting local economies," said Secretary of the Interior Deb Haaland. "Through historic investments from President Biden's Investing in America agenda, the Interior Department is helping build modern, resilient climate infrastructure that protects our communities from the worsening impacts of climate change."

The project is a 550-mile ± 525 kV HVDC transmission line, which can transport 3,000 MW of clean, reliable, and affordable electricity across Western states, between central New Mexico and south-central Arizona.

Pattern Energy's 3,500 MW SunZia Wind project across Torrance, Lincoln, and San Miguel Counties in New Mexico will be constructed together with the transmission project, which will deliver clean power from the wind project.

"More than 2,000 workers will now roll up their sleeves and get to work on America's largest clean energy infrastructure project, harnessing New Mexico's powerful winds to deliver clean power to 3 million Americans," said Hunter Armistead, CEO of Pattern Energy.

Thirty percent of the total project route is made up of federal lands administered by the Bureau of Land Management, Bureau of Reclamation, and U.S. Fish and Wildlife Service. SunZia Transmission has also signed right of way agreements with the New Mexico State Land Office and the Arizona State Land Department to support education and other public institutions.

According to a study conducted by Energy, Economic & Environment Consultants, both the SunZia Transmission and SunZia Wind projects are expected to generate $20.5 billion in total economic benefit, which includes over $8 billion of

Pattern Energy

direct capital investment at no added cost to ratepayers.

The projects are also expected to generate $1.3 billion in fiscal impacts for governments, communities and schools through sales and use taxes, property taxes, community benefit payments and land payments to federal and state agencies.

While SunZia Transmission's environmental mitigation efforts with key stakeholders have restored many acres of wildlife habitat for emerging technology and long-term conservation research investments, SunZia Wind has also set up environmental best practices to reduce project impacts and study effective habitat restoration strategies in partnership with local and state experts.

"Audubon's collaboration with Pattern Energy exemplifies how clean energy developers and conservation organizations can work together to ensure that transmission projects use the latest data and science to minimize impacts on birds and communities," said Jon Hayes, Vice President and Executive Director of Audubon Southwest.

"SunZia is our second project partnership with Pattern Energy, following Western Spirit, and together they will be unlocking vast amounts of renewable wind resources and empowering New Mexico to power the west," said Fernando Martinez, Executive Director of the New Mexico Renewable Energy Transmission Authority. ■

U.S. DOE GRANTS $23.4 MILLION TO MODERNIZE ELECTRIC INFRASTRUCTURE IN WASHINGTON

The U.S. Department of Energy (DOE) has awarded a $23.4 million Grid Resilience State and Tribal Formula Grant to Washington to modernize the electric grid and reduce impacts due to extreme weather and natural disasters.

"Electricity is an essential lifeline for communities. Improving our systems by reducing disruptive events is key as we cross the finish line of a 100% clean electricity grid and ensure equitable benefits from the clean energy economy reach every community," said Governor of Washington, Jay Inslee.

The fund will not only help work directly with rural and typical end-of-the-line customers to develop resilience plans but also collaborate with communities and utilities to build a resilient and renewable infrastructure for essential services.

"This is a significant opportunity to supplement our state investments in building a robust, resilient electric grid that supports our long-term vision for clean, affordable and reliable electricity – the foundation for economic growth and job creation that strengthens our communities and keeps Washington globally competitive," said Washington State Department of Commerce Director Mike Fong.

The grant aims to reduce the frequency, duration and impact of outages while enhancing resiliency in historically disadvantaged communities; strengthen prosperity by expanding well-paying, safe clean energy jobs accessible to all workers and ensure investments have a positive effect on quality job creation and equitable economic development and build a community of practice and maximize project scalability by identifying pathways for scaling innovations. ■

ELECTRIC UTILITY CEO: HYPER-LOCALIZED GENERATION WILL BE NORM IN 30 YEARS

In 30 years, the U.S. electric power industry will look different, said Mark Gabriel, president and CEO of Brighton, Colorado-based United Power. The electric cooperative serves nearly 110,000 meters in a 900-mile service territory north and east of Denver. It's also one of the fastest growing utilities in the U.S. with some 11,000 solar rooftops, more than 6,500 electric vehicles and a rapidly growing mix of residential, commercial and industrial members. Gabriel has seen the quickening pace of change, and he said U.S. utility leaders must ready themselves.

"We must be prepared to be comfortable with the uncomfortable," Gabriel said. "Assumptions based on the past will not serve us in the future. We are moving from an industry with investments whose lives were measured in decades to investments measured in years. Technology will change the face of utility operations as we become network providers instead of providers of the only resort."

Gabriel summarized his 30-year U.S. electric power outlook. He said:

- Hyper-localized generation will be the norm.
- Technology will flatten the peaks and valleys as storage and self-generation gain traction over central station.
- Power quality will be more important than power availability.
- Non-traditional players will run the system.
- Markets will split between air traffic control and financial components.
- Energy will be king, and there will be zero value for capacity.

Gabriel's name is known throughout the electric power industry, but his arrival in the industry wasn't part of his plan. "I backed into the industry by accident," he said. "A business friend at the Vermont Marble Power company asked me to help promote a co-generation project being developed to support 800 customers. That evolved into helping with the design of a demand side management program. I was then recruited to join Central Vermont Public Service, and my 30-year adventure in the utility business was off and running."

That career includes working as a utility executive in the 1990s. He also worked as an officer and later acting president of EPRI and served at the Western Area Power Administration. "Now at United Power, we are leading the charge to become hyper-localized, reducing carbon while managing an exciting new future for our members." ■ —*Kristen Wright*

IOWA BOARD APPROVES 525 KV UNDERGROUND HVDC SOO GREEN TRANSMISSION LINE PROJECT

The Iowa Utilities Board (IUB) has issued an order approving a petition for a franchise to construct, maintain, and operate a new electric transmission line in Iowa by SOO Green HVDC Link Project Co, LLC (SOO Green).

The petition referred to as the SOO Green transmission line project in Docket No. E-22436, proposes to build approximately 174 miles of 525 kV underground high voltage direct current (HVDC) electric transmission line in Allamakee, Cerro Gordo, Chickasaw, Clayton, Dubuque, Floyd, Jackson, and Winneshiek counties in Iowa, and continue into Illinois.

All but approximately 18 miles of SOO Green's prposed electric transmission line route will be located on the private rights-of-way (ROW) of the railroad alignment owned in various forms by Canadian Pacific Kansas City Limited (Canadian Pacific Railroad). Canadian Pacific Railroad was formed on April 14, 2023, through the acquisition by Canadian Pacific Railway of the Kansas City Southern Railway Company. The remainder of the transmission line will be located on public road ROW of Iowa Highway 18 in Clayton County.

The order finds that the proposed line is necessary to serve a public use and represents a reasonable relationship to an overall plan of transmitting electricity in the public interest.

The order also found that vesting SOO Green with the right of eminent domain is necessary for public use as discussed in the order. Eminent domain was granted regarding four parcels in Clayton County and two parcels in Dubuque County along the railroad ROW.

The order also states that the franchise granted by the IUB is subject to a condition that the electric transmission line operate as a merchant line under Iowa Code 478.6A, and SOO Green must both provide prior notice and receive IUB approval before changing the business model of operation of the franchise. Failure to comply will result in the automatic termination of the granted franchise.

The IUB retains jurisdiction in this docket under Iowa Code chapter 478 and may at any time during the franchise period make such further orders as necessary, including but not limited to modification of the franchise line to something other than a merchant line or review of requests for additional eminent domain authority.

SOO Green filed its application for its proposed underground electric transmission line on September 24, 2020, in Docket No. E-22436. The franchise petition process was paused at SOO Green's request in February 2021 and resumed in September 2022. ■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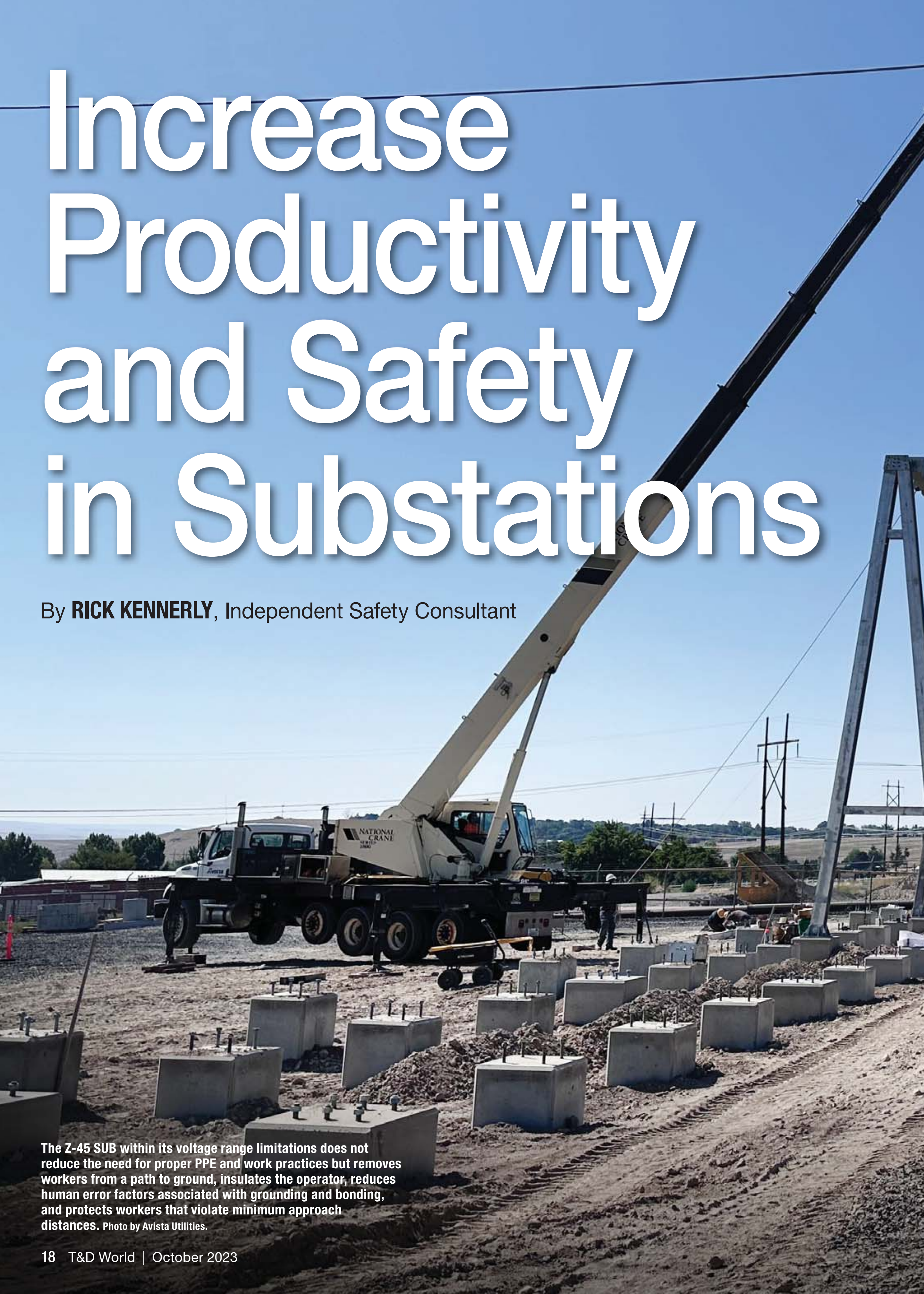
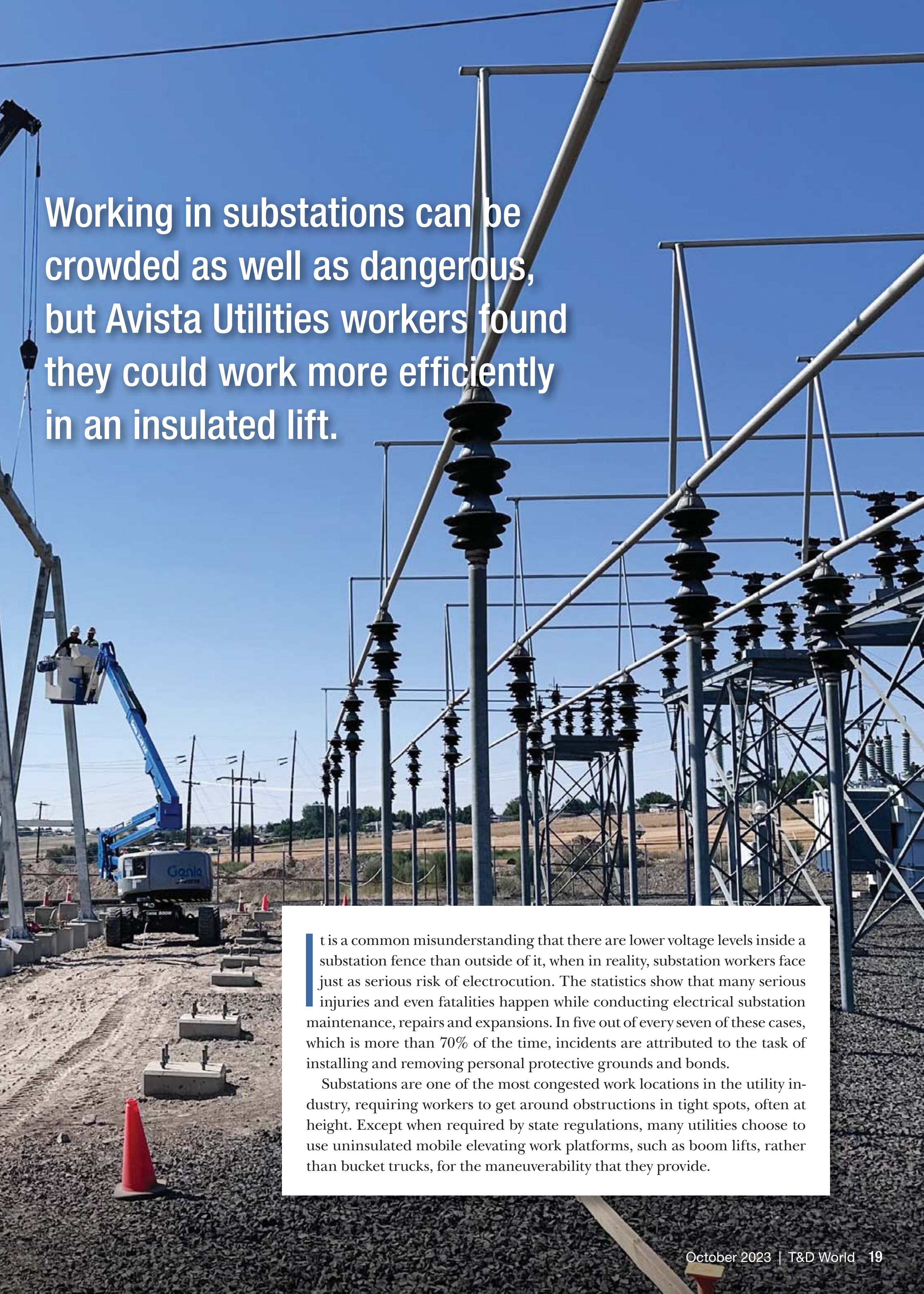
Increase Productivity and Safety in Substations

By **RICK KENNERLY**, Independent Safety Consultant



The Z-45 SUB within its voltage range limitations does not reduce the need for proper PPE and work practices but removes workers from a path to ground, insulates the operator, reduces human error factors associated with grounding and bonding, and protects workers that violate minimum approach distances. Photo by Avista Utilities.



Working in substations can be crowded as well as dangerous, but Avista Utilities workers found they could work more efficiently in an insulated lift.

It is a common misunderstanding that there are lower voltage levels inside a substation fence than outside of it, when in reality, substation workers face just as serious risk of electrocution. The statistics show that many serious injuries and even fatalities happen while conducting electrical substation maintenance, repairs and expansions. In five out of every seven of these cases, which is more than 70% of the time, incidents are attributed to the task of installing and removing personal protective grounds and bonds.

Substations are one of the most congested work locations in the utility industry, requiring workers to get around obstructions in tight spots, often at height. Except when required by state regulations, many utilities choose to use uninsulated mobile elevating work platforms, such as boom lifts, rather than bucket trucks, for the maneuverability that they provide.

Articulated boom lifts, like Genie's Z-45 XC, provide 24 feet of up-and-over capability, a maximum 1,000-lb platform capacity, a 5-foot jib for precise positioning, and zero tail swing. Photo by Avista Utilities.

Articulated boom lifts, like Genie's Z-45 XC, provide 24 feet of up-and-over capability, a maximum 1,000-lb platform capacity, a 5-foot jib for precise positioning, and zero tail swing. Avista substation crews had been using similar articulated boom lifts for typical substation maintenance tasks until Washington State's administrative codes changed, requiring insulated equipment.

Switching back to using an insulated truck-mounted aerial device was problematic because it could not access all areas where the work was located. Even if procedures to protect the worker in an uninsulated boom lift had been permitted, the process is laborious and subject to human error.

For many utilities, however, no such restrictions apply. Best practices for using uninsulated boom lifts in these applications have evolved over many years. The most common solution for protecting workers in an uninsulated boom lift is to bond the basket to the de-energized conductors prior to work being performed so that an equipotential zone (EPZ) is created for the employee.

Risk to Workers

As system fault currents have increased, worker exposure voltage in substations has increased. In the United States, most substation work is performed by de-energizing a circuit, testing for absence of nominal voltage, and applying personal protective grounds (PPGs) and bonds in attempt to establish a safe work zone. Dangerous worker voltage exposure can still occur when one or more existing safe work practices are missed, there are unforeseen equipment failures, or when detrimental environmental factors are present.

One source of worker exposure to voltage is caused by inadvertent energization events. This type of shock hazard occurs when a de-energized piece of equipment becomes energized while a worker is present. There are many ways this can occur, but three examples are energization during switching activities, mechanical failure of vertical switches, and energization by conductor movement.

Another source of worker exposure is induced voltage caused by nearby energized conductors. If a standard steel boom lift is being used on non-energized equipment, there is still a risk of worker exposure voltage caused by capacitive or magnetic coupling and induction. This happens when the boom is being used near energized conductors or equipment such as transmission lines or sections of the substation that are still energized. In these situations, the nearby energized circuits can induce current and voltage to the mobile elevated work platform. Research has shown that low magnitude induced current can still exceed the let-go threshold and cause significant injury.

These risks are sometimes recognized, and a common mitigation method is to ground the lift's drive chassis to the grid. However, because of resistance in the boom from painted surfaces, plated pins, lubricants and wear pads, a difference in potential can still exist between the platform and the structure the worker is in contact with. This may be addressed with breakaway bonding cables attached to the steel platform. This work practice requires knowledge of the risk, proper selection of clamps and cables, and correct installation. Additionally, bonding the bucket can inhibit movement which decreases productivity.

A third potential shock hazard in substations is caused by the improper selection, installation or removal of grounding assemblies.

Selecting the proper clamps and cables is an important but complex part of protecting from maximum available fault current and creating an EPZ. The large number of variables involved in selecting the proper equipment increases the risk that the wrong materials will be selected. In a case where undersized cables or excessive lengths are selected, and the voltage rises, the employee may think they are protected, but they are not.

Even with the proper equipment selected, there is still risk associated with the proper installation and removal of personal protective bonds. Several variables such as contamination, loose hardware, etc., create risk. Clamps commonly loosen due to wind, vibration or simply not being installed correctly.

Certain events such as inadvertent energization, back feed, or induction present shock hazards are very difficult to avoid and are not easily understood by the industry.

Safer Substation Worksites

Transformer maintenance, circuit breaker testing, and inspection of batteries, bus connections, vacuum breakers, and relays are all recommended at monthly intervals. When you consider the frequency with which substation maintenance occurs and how many steps are involved to bond the basket to the de-energized conductors, it is worth exploring alternatives.

Substations are one of the most congested work locations in the utility industry, requiring workers to get around obstructions in tight spots. Photo by Avista Utilities.

Using an insulated substation boom lift manufactured by Genie and upfitted by Terex Utilities helped Avista Utilities protect the operator from shock hazards resulting from accidental energization, induced voltages and current, improperly installed grounds, and violation of minimum approach distance.

Avista has one crew dedicated to substation maintenance of more than 150 substations. They have an additional three crews that are dedicated to substation construction and three crews working in generation facilities. To comply with state regulations, the utility had been using either insulated truck-mounted aerial lifts or customized insulated telescopic booms.

Avista workers found the safety features of this equipment enabled them to work with insulated equipment without sacrificing speed and side cutouts in the insulated bucket provide line of sight visibility to workers on the ground. Photo by Avista Utilities.

While both options protected workers from electric shock, they hindered productivity. The bucket truck required parking, setting outriggers, and then re-setting it if it was not in a position to reach all of the work. The custom insulated telescopic boom was often able to fit in the work zone, but rotation was restricted due to tail swing and longer stowed boom length of telescopic boom lifts.

As the utility already had some experience working with Terex Utilities and the Genie brand, Avista saw a concept for an insulated articulated boom lift from Terex Utilities at a trade show. Launched in 2021, the Z-45 Substation Utility Boom (SUB) is based on the Genie Z-45 XC with the same handling and performance characteristics and features of a fiberglass jib section and fiberglass bucket. The units carry dielectric protection in compliance with ANSI A92.2 standard for Category E insulation rating of 20 kV. In addition, the Z-45 SUB can work in the confined spaces because of its zero-tail swing and dual parallelogram boom structure.

Avista substation maintenance crew members have found installation of bus or air switches to be much easier, faster, and safer with the Terex Z-45 Substation Utility Boom (SUB). Previously a lot of time was spent trying to reach the work with an insulated bucket truck, seeing if it would work, and if not, trying another setup option. Even prior to the WAC regulation change, the Avista crews found it less efficient to use an uninsulated boom lift using the bonding method — which took a couple of minutes each time the machine was moved. In addition, if it was a rental unit, the crew would have to grind, drill, and tap a 1/2-in. hole on the frame to provide a grounding point or have the fleet services department weld a grounding stud.

For repetitive tasks like crimping bus bar pipes, the Z-45 SUB saves a significant amount of time by eliminating repeated equipment setup and bonding procedures. Avista has also maximized its capabilities by using a battery-powered crimper that has the necessary power to get the job done without negating the insulation qualities of the boom lift. Ultimately, Avista crews find that they can do the same work they were used to doing in an uninsulated articulated boom lift but with more protection for the operator.

Side cutouts in the insulated bucket provide line of sight visibility to workers on the ground, and a swing gate makes it easier for workers to get in and out of the bucket.

Avista currently owns two Z-45 SUBs and would likely rent additional units for short-term projects. The Z-45 SUB within its voltage range limitations does not reduce the need for proper PPE and work practices but removes workers from a path to ground, insulates the operator, reduces human error factors associated with grounding and bonding, and protects workers that violate minimum approach distances. TDW

Acknowledgments

Thanks to Matthew Potter, a fleet specialist working in the Fleet Services department for Avista, Spokane, Wash., for contributing to this article. Avista Utilities is involved in the production, transmission, and distribution of energy. Providing energy services and electricity to 411,000 customers in a service territory that covers 30,000 square miles in Washington, Idaho and Oregon.

RICK KENNERLY is a utilities safety expert based in Florida, who has worked with dozens of Investor-Owned Utilities to review equipment, work methods, and in service testing and maintenance procedures for personal protective grounding and permanent structure grounding. He has served on multiple ASTM standards committees, including F855, F2249, F712, F1796, F2939 and an IEEE task group member. He is currently vice chair of IEEE 1048.

Although utilities have digitized their analog records, the legacy grid data is not always consistent and manual processes are still required. Using machine learning to analyze available data can verify its accuracy and simplify the update process. Photo courtesy of Southern California Edison.

Tracking Decades-Old Power Poles with Machine Learning

Utilities must organize and make sense of a tremendous tranche of legacy power grid data, but AI may offer answers.

By **NOE BARGAS, P.E.**, Southern California Edison

Southern California Edison's service area contains over 1.4 million power poles, some of which are decades old. Monitoring these assets and their conditions has been challenging. Although utilities have digitized their analog records, the legacy grid data is not always consistent and manual processes are still required. Using machine learning to analyze available data can verify its accuracy and simplify the update process.

As society transitions to a clean energy future, customers depend on electric utilities to keep the lights on and enable electric transportation, expand electric technologies, integrate energy from rooftop solar and batteries and more. This requires an increasingly digital automated grid. High-quality data is foundational to the digitization of the energy system, which is a crucial step to get to carbon neutrality. Utilities rely on millions of data points, some of which originate from equipment installed decades ago, to make risk-informed asset management decisions.

SCE's electric asset data remediation tool leverages data science and machine learning to improve the accuracy and consistency of asset data for a more dynamic grid — drastically reducing the time it takes to validate data corrections from hours to minutes.

Remediation Tools

For decades, electric utilities kept records in paper-based systems. With the evolution of technology, most records are now digital, including data related to the physical location of poles and transformers. While digital systems often make work easier, converting legacy grid asset data has not always been seamless.

A digital approach is still limited by the dependency on a manual process, such as data entry, which can lead to errors. It also includes other manual processes, like cataloguing unstructured data sets (e.g., photos), confirming location accuracy of known assets, correcting recurring differences between field conditions and inventory records and detecting assets that require maintenance or repair.

Outdated or inaccurate data within the digital systems can lead to inefficiencies in grid planning and operations needed to ensure employee and public safety as well as system reliability. Manually managing digital asset data is also costly. In 2021, SCE performed electrical asset mapping corrections 22,000 times in high fire risk areas using field evidence.

Based on those learnings, SCE estimates that it would cost roughly $16 million and 300,000 worker hours to complete a service area-wide review and update of its more than 1.5 million overhead structures (approximately 300,000 of which require updates at an estimate of one hour of work per structure). A substantial part of the cost is associated with the time it takes to assess the accuracy of the location data found in photo evidence captured over multiple field visits.

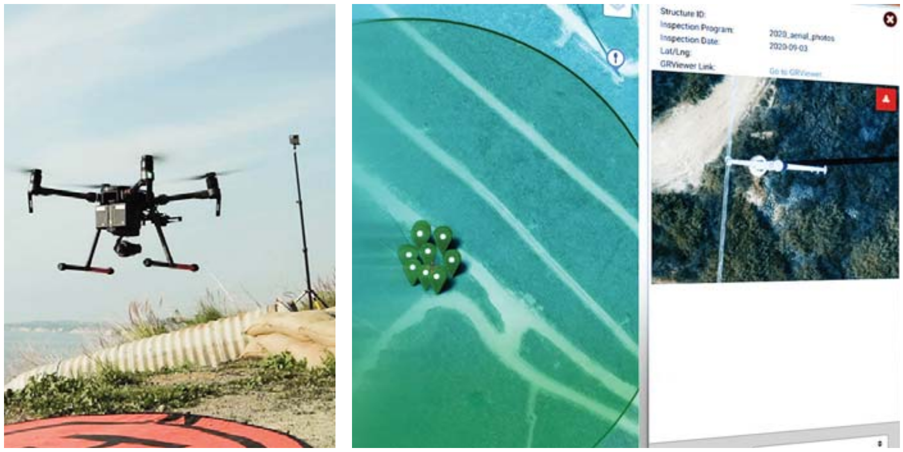
For example, as part of this project, SCE found location accuracy of varying degrees with its overhead structures — while 50% of structures were within 10 meters, 30% were 10-30 meters and 20% were found greater than 30 meters of where legacy information listed the asset location.

Inaccurate asset locations can pose downstream safety risks because of increased time searching for an asset in the field or missing inspection and maintenance activities entirely. It can also lead to significant system challenges when inaccurate location data extends repair outages, including wire down, or increases the possibility of ignition from utility equipment in high-fire weather.

To manage digital asset data more efficiently, SCE looked to integrate high-quality data already being collected through other programs, e.g., high-resolution photos being taken during aerial inspection of assets in high fire risk areas.

In addition to safety benefits, by incorporating the data more efficiently and using an automated process, we estimate the opportunity to result in $8 million in savings, including approximately 170,000 worker hours, if applied to SCE's entire service area.

The broader business challenge of assessing location data accuracy cannot be addressed without solving the technology challenge of automating the extraction of geolocation insights from high-resolution photos to detect mapping inaccuracies.



The cross-functional team successfully developed a user-friendly, innovative in-house application that automates the analysis of millions of high-resolution digital photos to find asset locations with corresponding confidence levels and employ that information to improve accuracy. Photos courtesy of Southern California Edison.

To find a solution, our internal working groups went out to the industry to survey the pervasiveness of the challenge and to see if other utilities had solutions for mapped location accuracy.

Of those that were surveyed, none had developed novel automated solutions. Considering this research, the technical working group partnered with SCE's Information Technology team to devise a solution, bringing together various groups with expertise in artificial intelligence (AI), geospatial analytics, image recognition, machine learning (ML), optical character recognition techniques and statistical methods.

For decades, electric utilities kept records in paper-based systems. With the evolution of technology, most records are now digital, including data related to the physical location of poles and transformers. Photo courtesy of Southern California Edison.

The Solution

The cross-functional team successfully developed a user-friendly, innovative in-house application that automates the analysis of millions of high-resolution digital photos to find asset locations with corresponding confidence levels and employ that information to improve location accuracy. The team began with collecting images for wildfire risk and other field inspection purposes previously stored across separate repositories.

The challenge was not only to organize millions (petabytes) of images for easy access and fast retrieval. But to optimize the analysis of unstructured data using geospatial analytics and AI/ML techniques that take advantage of cloud-based computing power. This included fast search and retrieval of millions of images based on different criteria such as asset identifier, geospatial search and asset condition-based search.

The team developed a Data-as-a-Service (DaaS) visualization tool called the GRViewer to improve how subject matter experts from across the company accessed and evaluated images. With a DaaS approach, the team accessed petabytes of unstructured data on different cloud platforms.

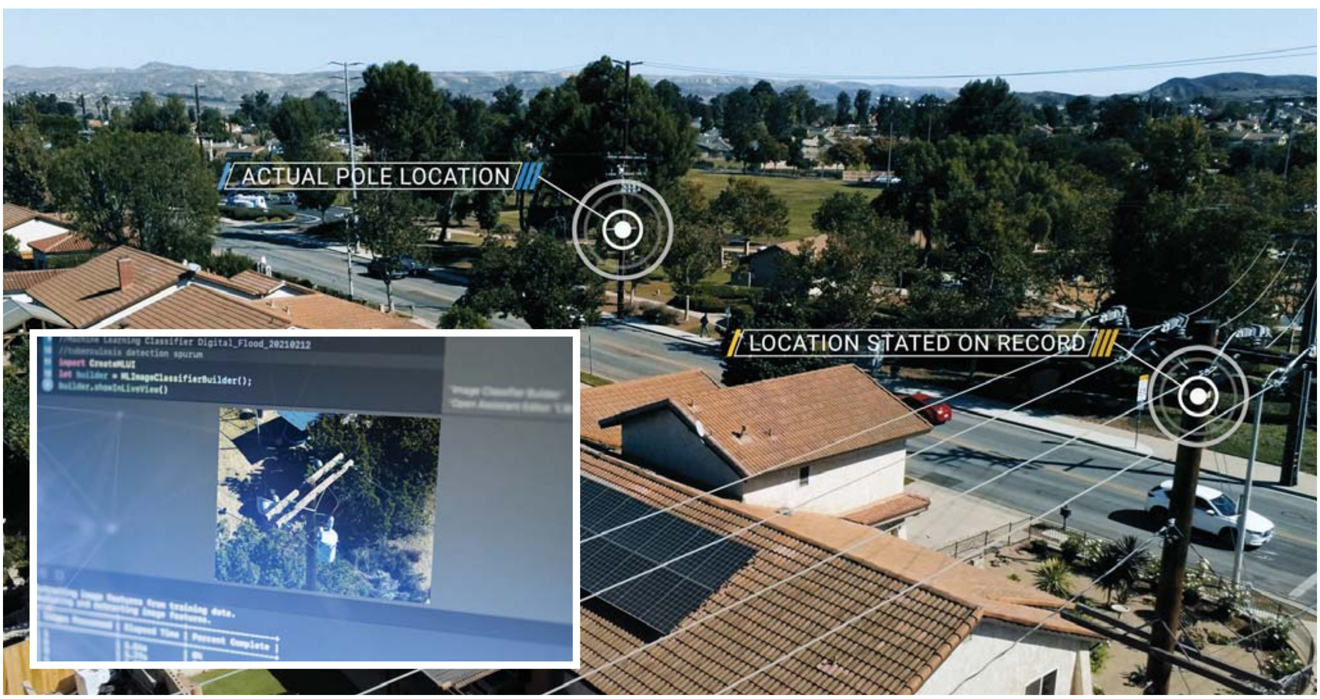
DaaS enables visualization, analytics and AI/ML models execution with easy consumption, fast performance and high reliability. Simply put, DaaS has the same effect on big data that monetary currency had on bartering goods and services — DaaS allows for easy data interoperability across different software applications.

With this powerful tool, the team built and trained advanced ML models to recognize key objects or features contained in photos, enabling them to perform a range of innovative functions, such as:

- Accurately associating photos with their corresponding real-world coordinates to derive a structure's true GPS location.
- Effectively analyzing many photos captured from different time, devices, programs using geospatial analysis.
- Analyzing multiple factors, including number of photos, capture time of photos, statistical significance of data distribution (mean, standard deviation, outliers), validation among multiple sources, etc.

The data remediation tool substantially reduces the need for manual processes to evaluate millions of photos and supplies reliable data that is as easy for users to curate as any search engine.

Human effort is needed for only a small percentage of assets the tool cannot validate with confidence. Even then, the remediation tool's visualization feature streamlines the effort. As an example,

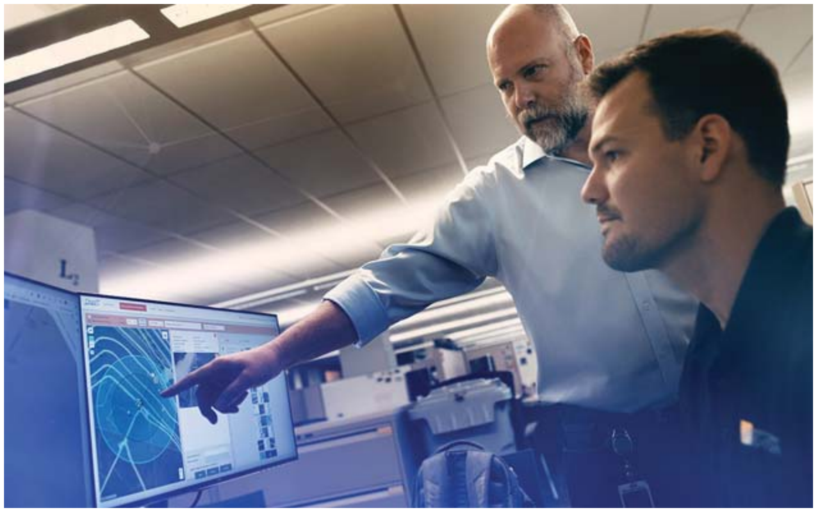


One goal that SCE had was to accurately associate photos with their corresponding real-world coordinates to derive a structure's true GPS location. (Inset) Further development of machine learning on image recognition and LiDAR (point cloud) data will expand SCE's capabilities to inventory assets and detect visual health indicators, such as woodpecker damage to poles and rust on transformers, for a broader set of electrical assets. Photos courtesy of Southern California Edison.

any asset with a nadir image (the vantage point looking directly down on the top of a structural asset) has a high confidence latitude/longitude coordinate value.

For assets without a clear nadir image, the data remediation tool algorithm looks for other clues in collected photos for the next best available location data, such as a picture with a pole tag. The algorithm analyzes multiple images of a specific asset to corroborate the clues and arrive at an associated confidence factor.

A given asset may have hundreds of images collected through various inspections programs over the years. The computer model takes many of these photos and other factors into consideration when generating a projected location with an associated confidence score.



As the team continues to expand and test this approach, it has promising asset data management applications for the entire industry. Photo courtesy of Southern California Edison.

The data remediation tool helps expedite the process and analyzes assets across the entire service area to reconcile inaccuracies. This is a significant breakthrough, where traditional and manual efforts have proven so monumental — taking hundreds of thousands of scarce worker hours over multiple years to canvass the entire service area.

Improved User Experience

The capabilities of the data remediation tool introduce efficiency and improve the human touch points to manage and maintain a modern grid with safety, reliability, resiliency and cost savings in mind. The company's mapping team can have the added confidence of making asset mapping corrections without having to spend research time validating location information across different datasets and systems.

When more research is necessary, the team can efficiently confirm their findings by accessing this central repository of photographic evidence, enabling them to reach a prompt and informed conclusion. On a massive scale, the data remediation tool solves a similar problem that today's television viewers experience navigating video content across dozens of content providers on their Roku or Apple TV. Just as these digital media players' algorithms sift through user data to extrapolate and suggest shows the user might like, the remediation tool similarly sifts through utility photo data to predict equipment location.

Improved location accuracy within 10 meters of the actual structure reduces the treasure hunt inspectors face with "ghost pole" scenarios where they cannot find the equipment due for inspection in the vicinity of the listed coordinates. Utility personnel no longer need to find a needle in a haystack as they hike through varying and potentially unsafe terrain searching for an asset. Missed or delayed inspections will be significantly reduced.

With emerging outages, servicers dispatched to the vicinity of the outage will have increased confidence in knowing they are at the correct point of failed equipment without having to search or trace a pole line. This translates to reduced outage durations for customers. The remediation tool is also very scalable and forward looking because it is built on the DaaS model, which means a retooled and continuously improved data remediation tool can seamlessly access mountains of data (e.g., millions of high-resolution images) that continue to be collected daily. The remediation tool can also be adapted for future-use cases that might find value in this data lake.

Looking Ahead

SCE's data remediation tool allows the company to confirm and correct large volumes of data at a fraction of the time and cost of manual processes. This frees up valuable resources to perform other high-priority work and, most importantly, enables the utility to use accurate data to mitigate safety and reliability risks faster. Further development of machine learning on image recognition and LiDAR (point cloud) data will expand SCE's capabilities to inventory assets and detect visual health indicators, such as woodpecker damage to poles and rust on transformers, for a broader set of electrical assets.

As the team continues to expand and test this approach, it has promising asset data management applications for the entire industry.

Having excellent data quality improves efficacy in grid planning and operations. Whether adapting to climate change and the perils of more extreme weather or creating the pathway to a more electrified economy, complex data analysis requires a solution like the electric asset data remediation tool.

In April, the Edison Electric Institute (EEI) named SCE one of five U.S. and three international electric companies as finalists for the 2023 Edison Award, which is presented annually to electric companies for their distinguished leadership, innovation and contribution to the advancement of the electric power industry. The data remediation tool was submitted as a case study for the 95th annual industry award.

Our team's ability to leverage new technologies like machine learning and AI in new ways is putting us in a better position to ensure that the grid is reliable, resilient and ready for a clean energy future. TDW

NOE BARGAS, P.E., is a Principal Manager of Asset Data & Information Strategy at Southern California Edison. He is in his 17th year at the California utility. Bargas graduated from Cal Poly Pomona with a Bachelor's degree in Civil Engineering.

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Interconnector Brings Flexibility To European Market

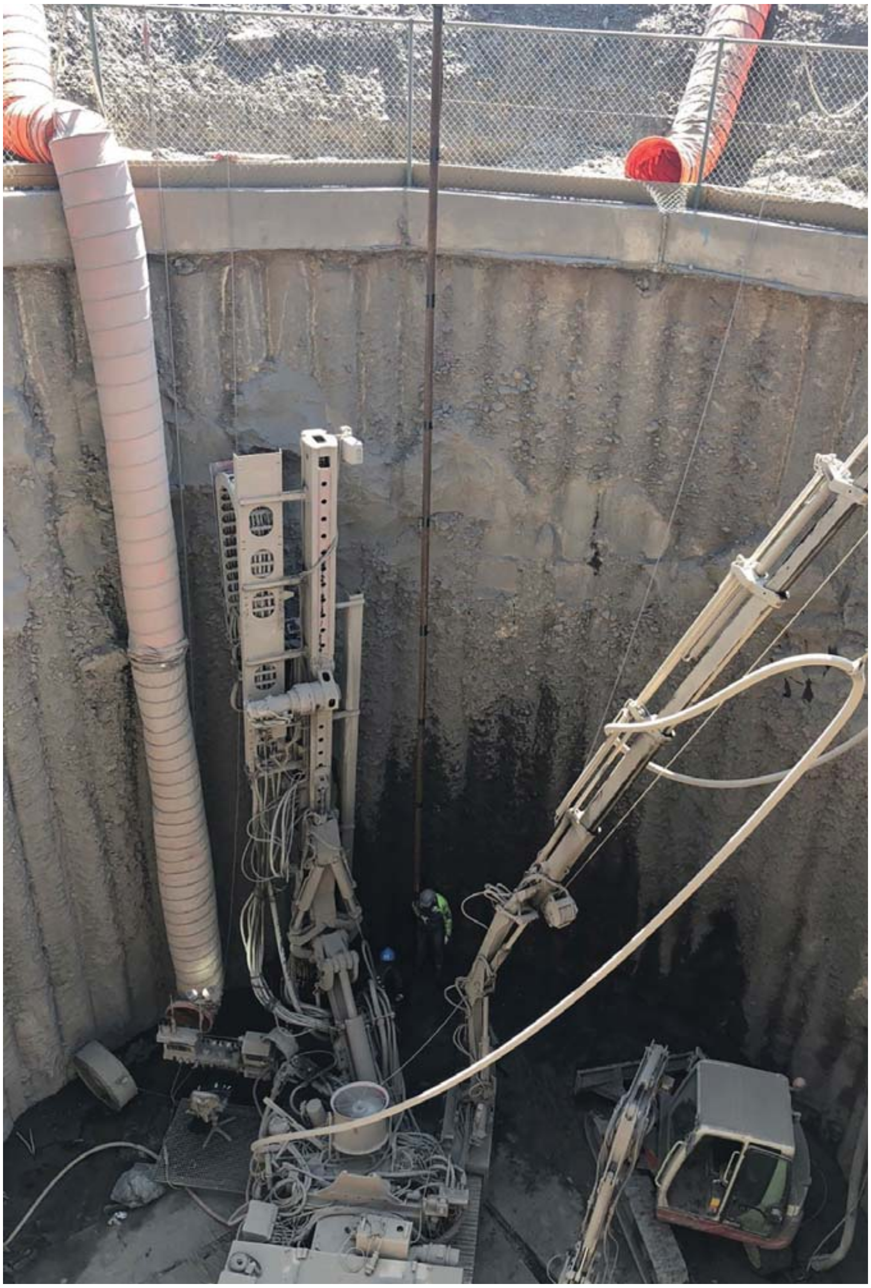
New evolved flow-based approach used for first interconnector between Belgium and Germany.

By **HELEN BURGESS**, Elia Group

Announced at the end of 2019, the European Green Deal aims to ensure Europe becomes the world's first climate-neutral continent by 2050. As part of the deal, the European Commission presented its EU strategy for energy system integration in 2020, outlining its plans to establish an integrated energy system that will support the continent's decarbonization and greenhouse gas (GHG) emission reduction targets. Commissioned in November 2020, the Aachen Liège Electricity Grid Overlay (ALEGrO) interconnector linking Belgium to Germany forms an important part of this future system.

The 1-GW high-voltage direct current (HVDC) interconnector was recognized by the European Commission as a Project of Common Interest in 2017. Research undertaken in preparation for the construction of the interconnector was supported by funding from the European Commission's Trans-European Networks for Energy (TEN-E) program, part of the TEN-E policy, which focuses on linking up the energy infrastructure of EU member states.

ALEGrO was built to address several emerging system needs. Firstly, to help boost the security of supply for both countries by providing access to additional generation capacity they could make use of should they have insufficient generation available to meet their own needs. Secondly, it was built to enable a better and more efficient integration of intermittent renewable energy into the system: The interconnector allows renewable electricity produced in one country to be exported to the other. Thirdly, ALEGrO was built to allow for an increase in price



Construction of one of the access shafts of the tunnel under the Meuse River and Albert canal: installation of concrete pilings to stabilize the surrounding soil and allow digging to occur. Photo courtesy of Elia.

Dry outdoor cooler where the switching losses of the converter are released. Some of the losses are captured and used to heat the building.

convergence — ultimately benefiting consumers through more stable, affordable prices.

Interconnector Route

Based on a feasibility study assessing the different routes the interconnector could follow, Elia Group decided to build the interconnector underground, given it would be crossing highly populated areas on either side of the Belgium-Germany border and could closely follow preexisting railway and motorway routes. Direct current (dc) was chosen over alternating current (ac) because HVDC technology offers a wide range of active power control functionalities and additional ancillary services, and it does not require any reactive power compensation.

The final route was determined following close consultation with a range of stakeholder groups to ensure its impact on the environment (including Natura 2000 zones) and local communities would be minimized. Moreover, once construction work started, progress on each section in Belgium was communicated to members of the public via a dedicated website.

The ALEGrO interconnector is 90 km (59.9 miles) long, 49 km (34.4 miles) of which runs through Belgian soil. It stretches from the Lixhe converter station in Belgium to the Oberzier substation in Germany, mainly by running alongside existing infrastructure such as motorways, high-speed railways and waterways. From Lixhe in Belgium, it runs south along the Albert Canal towpath and then eastward from Herstal, along the E40 motorway followed by a railway, before crossing into Germany. From there, it follows the A44 and 14 motorways for 41 km (25.5 miles), mainly across farming land, to the converter station in Oberzier.

Phased Construction

On the Belgian side, the construction of the interconnector involved three main phases. From 2013 to 2016, Elia worked on proposed revisions to the zoning plan for Wallonia, a regulatory tool for land use and regional planning. The proposed changes, including the converter station in Lixhe and the corridor where the cables would be laid, were sent to the 14 municipal authorities that would be affected by ALEGrO. Having secured approval for these changes in 2016, Elia sought permits for the work to be undertaken, which were granted in late 2017. Finally, construction work began in January 2018 on three parts of the project at once: the converter station; the micro-tunnel, which needed to be built under the Albert Canal and Meuse River; and the laying of the interconnector cables.

On the German side, as part of the permitting procedure for the interconnector, the land along the route had to be checked

Technician inspecting the cooler bank of one of the converter transformers. Photo courtesy of Elia.

Pumps belonging to the water cooling system that release the switching losses of the converter using a combination of demineralised water and glycol water. Photo courtesy of Elia.

for possible unexploded ordnance and archaeological artefacts. The construction work was contracted as different lots for open construction, horizontal directional drilling and micro-tunneling. The process of site clearance proved to be particularly challenging, given most of the German route crosses farmland, which carried restrictions in terms of how the soil must be handled.

Converter Stations

Two converter stations, built by Siemens Energy and located in Lixhe and Oberzier, respectively, convert ac from the Belgian and German grids into dc, so it can be transported across the interconnector. The converter station in Lixhe, Belgium, took two years to build and is 123 m long by 20 m high by 82 m wide (404 ft by 66 ft by 269 ft). It was designed to be optimally integrated into the surrounding environment.

At the Lixhe converter station, ac from the Belgian grid first enters a gas-insulated switchgear room before the electricity is converted into dc. The electrical current then flows through transformers that ensure a constant level of voltage is maintained. Following this, the voltage source converter transforms the ac into dc, which is then transmitted through the interconnector cables. The modular multilevel converter is built in a half-bridge arrangement. This compact piece of converter technology enables grid operators to manually set exactly how much power needs to be transferred in either direction. It has a reactive power of ±300 MVAR maximum when active power transmission is enabled. In static synchronous compensator (STATCOM) operations, up to ±500 MVAR can be provided to the ac connection point. The converter also can react to voltage fluctuations in less than one thousandth of a second, meaning it can be used to help stabilize the electricity network.

Technician checking and locking a switch which forms part of the gas-insulated switchgear to allow safe working. Photo courtesy of Elia.

Cable Systems

The interconnector is a point-to-point symmetrical monopole connection that comprises two 320-kV, 2500-sq mm (3.9-sq inches) HVDC crossed-link polyethylene (XLPE) copper cables with a diameter of 120 mm (4.7 inches) each. Separate engineering, procurement and construction contracts were awarded to General Cable (now part of Prysmian Group) by Elia and Amprion for the work in Belgium and Germany, respectively. General Cable was responsible for the design, engineering, production, installation and commissioning of the complete HVDC cabling system, including civil works and construction of the micro-tunnel in Belgium.

The cabling system was thoroughly tested before use, as experience with 320-kV HVDC XLPE cables was very limited at the time. The system successfully passed an extended testing program, including specific project-based tests that simulated temporary overvoltages that could occur in the system.

Cable sections were laid across the entire route, with a total of 84 cable joints connecting each of these sections together. The cable sections were laid in trenches of 1.8 m deep by 1 m wide (5.9 ft by 3.3 ft), with each section taking approximately six weeks to finish. More than 30 instances of horizontal directional

One phase of the converter transformer, which ensures that the converter gets the required voltage, irrespective of the voltage fluctuations of AC networks. Photo courtesy of Elia.

drilling were carried out along the Belgian section of the route. This was the first time cable installation as part of Elia projects were performed along Belgian motorways, requiring attention to safety.

On the German side, three micro-tunnels — with a combined length of 4.5 km (2.8 miles) — were built so the interconnector could cross residential and commercial areas. Eight sections were built using horizontal directional drilling, so the interconnector could cross existing infrastructure and environmentally sensitive areas. ALEGrO has a rating of 1050 MW, the equivalent of 1/14 of Belgium's average electricity consumption. At nominal power, the interconnector's losses amount to 2%, with 1.6% of this caused by the two converters and 0.4% caused by cable losses.

Micro-Tunnel In Belgium

At the Cheratte viaduct in Herstal, the Elia team had to build a micro-tunnel under the Albert Canal and the Meuse River. The construction of this tunnel — located 30 m (98 ft) underground, a depth required to reach a homogeneous layer for the micro-drilling, and 670 m long by 2 m in diameter (2198 ft by 6.6 ft) — involved state-of-the-art techniques. A drilling machine was used to do the directional drilling for the horizontal part, while micro-piling techniques were used to excavate and construct the two access pits to the tunnel.

Commercial Operation

Capacities for cross-border trading were released in stages: the first capacity was made available to the market via a day-ahead allocation mechanism on Nov. 18, 2020. This was followed by intraday capacity trading in December 2020, and monthly long-term capacity trading in early 2021. Annual long-term capacity trading opened in 2022.

In its first year of operation, from Nov. 18, 2020, to Nov. 18, 2021, ALEGrO proved to be a reliable asset, as it was available for market/trading 93% of the time. A total of 4.3 TWh of electricity was exchanged, with 45% of the day-ahead flows across ALEGrO being directed from Belgium to Germany and 55% of the day-ahead flows being directed from Germany to Belgium. An average of 700 MW was exchanged between both countries when there was a price difference. During its second year of operation, ALEGrO was available for market/trading 98% of the time and 5.07 TWh of electricity was exchanged.

Evolved Flow-Based Approach

The interconnector's location in the center of the meshed ac European grid was challenging, particularly when compared with other interconnectors positioned along the edges of the European continental synchronous ac system, such as Nemo Link. The latter, which links Belgium to Great Britain, has a relatively low impact on the rest of the European grid because of its location. On the other hand, ALEGrO needed to be used in such a way that considered congestion in other parts of the ac grid and would not cause overloads in the grids of connected and neighboring transmission system operators (TSOs). Therefore, ensuring the grid could be securely operated meant the possible tripping of the interconnector (and its redistributive effects on the ac grid) also needed to be considered. Given the day-ahead market is the most significant market time frame in terms of the volume of energy traded, use of the interconnector and its operation in this time frame was the focus of the project.

Adopting a standard approach for ALEGrO, like the net transfer capacity calculation used for Nemo Link and other HVDC interconnectors, was not possible, because the capacity of ALEGrO and optimal flow of energy across it could not be determined in isolation. This led the teams involved to create and adopt a new approach that had never been used before: the evolved flow-based approach (EFB), which is one step further than the flow-based approach implemented in 2015 across the Central Western Europe (CWE) capacity calculation region. (Note that since 2015, the CWE capacity calculation region has been merged with the Central Eastern Europe capacity calculation region, forming a new region called Core. In June 2022, the flow-based market coupling mechanism was extended to cover the day-ahead time frame across all 13 countries of Core.)

As part of the EFB approach, no ex-ante assumptions about the direction or magnitude of the flow of energy across the interconnector are taken. Instead, the set point of ALEGrO

— the optimal flow of energy across the interconnector regarding the distribution of energy flows in the CORE region — is defined as a variable in the market coupling algorithm, thus considering the impact of cross-border exchanges on different critical grid elements. As a fully controllable dc device, ALEGrO is used to steer the flows of energy or distribute them in the most efficient way between itself and the rest of the ac grid, in such a way that congestion is minimized and prices for consumers optimized.

The adoption of the EFB approach means nonintuitive flows may occur; this happens when the market coupling algorithm determines the most optimal flow across the interconnector is from one country experiencing high energy prices to the other country experiencing low prices. Such nonintuitive flows relieve congestion on other critical elements across the ac grid and enable cross-border exchanges to be maximized through other paths of it, with the aim of maximizing the value (or socioeconomic welfare) created by market coupling.

Strong collaboration and regular communication between Elia, Amprion and the neighboring TSOs of TenneT in the Netherlands and RTE in France were essential for the adoption and success of the EFB approach. Additionally, numerous phases of testing and simulations of the EFB approach with ALEGrO were undertaken. Over a six-month period, before the interconnector was commissioned, the results of daily simulations of the grid with the existence of ALEGrO were compared with the actual operation of the grid without it. During this time, Elia and Amprion published the results of capacity calculation and market coupling processes as if ALEGrO were already in operation. These simulations, launched in May 2020, suggested almost €100 million of socioeconomic welfare could be generated for consumers and producers across the CWE region.

The EFB approach was successfully implemented once ALEGrO was commissioned in November 2020, constituting a first step toward including flexibility in the interconnected European market for electricity. The approach has demonstrated controllable devices such as HVDC interconnectors can be optimized.

Maximum Flexibility

The ALEGrO interconnector was built to efficiently enhance Belgium's and Germany's security of supply, facilitate the integration of renewable energy into the electricity grid and contribute to price convergence. From the very beginning, Elia and Amprion — the Belgian and German TSOs, respectively, that built the interconnector — were aiming to ensure ALEGrO could offer maximum flexibility to the market, especially in the day-ahead time frame.

Given its location in the middle of the European meshed ac grid and its use of dc technology, the EFB methodology was adopted for the first time, meaning exchanges between Belgium and Germany and across the entire CWE capacity calculation region could be optimized. TDW

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 BY **ANDRIJA SADIKOVIC** AND **SHANSHAN MA**, QUANTA TECHNOLOGY

Infrastructure damage near San Juan, Puerto Rico, left by Hurricane Maria. 103275668 Cliff Estes, Dreamstime.com.

The Age of Resilience Design Begins Now

The power grid must be designed to withstand and recover from a wide range of extreme weather events — at an affordable cost.

Resilience is finally taking a front stage in the electric power industry. Society recognizes the need to significantly increase investments in resilience as the electric grid ages and faces extreme weather conditions, which impose significant costs on electric utilities and the customers they serve. The U.S.'s Infrastructure Investment and Jobs Act (IIJA) of 2021 confirms the big push to strengthen electric grid resilience, with more than US$47 billion allocated to resilience, including cybersecurity.

Using a nontechnical definition, resilience quantifies and qualifies the electric grid's performance during and after an extreme event. The more customers remain with power during an event and the quicker power gets restored to those who lost it, the better the resilience performance.

Optimal system design delivers the best system performance at minimum cost both during and after a series of extreme events Such design goes far beyond traditional planning practices in utilities and engineering capabilities; it requires a data-driven approach and the use of advanced analytics. This is a major shift in the system design philosophy — simultaneous optimal design across asset management, reliability planning, capacity planning, customer care and system operations functions over a larger geographical area, and in a coordinated fashion between transmission and distribution teams.

Performance Matters

Resilience builds are often costly and necessitate thorough analysis to determine the most cost-effective solutions, ensuring that the system is resilient and performs reliably and predictably. While scoping resilience improvement projects is relatively straightforward, quantifying the return on newly invested capital (RONIC) — especially in terms of system performance during extreme events, a crucial aspect of resilience — can be a complex, data-driven task. Without a clear understanding of resilience RONIC, utilities may inefficiently allocate significant capital, and regulators may face challenges when approving capital expenditure proposals, as they may not fully comprehend the expected performance outcomes at different cost levels.

The process of establishing resilience performance RONIC is fundamentally an information challenge. Resilience planning is significantly more complex than traditional blue/gray sky day planning, which assumes events to have a random occurrence probability and a low coincidence factor. However, this is quite the opposite for extreme weather events. Therefore, resilience planning necessitates simultaneous, coordinated analysis across various organizational functions for multiple anticipated scenarios across vast geographical areas and event durations, a task that surpasses human capabilities.

Pole hardening and line sectionalizing needs for Category 4 hurricane.


Pole and line section geo-positioning before mapping.

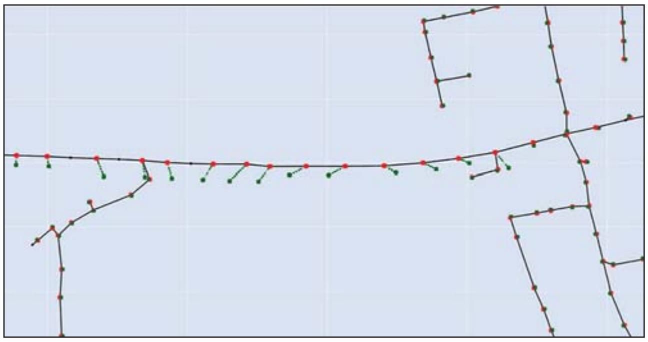
Advanced Analytics

Luckily, today's technological advancements and optimization solvers can find optimal solutions to extremely complex problems faster, cheaper, and without approximation. In the case of resilience, the optimal solution, which balances minimal investment and optimal system performance, can be derived using a mathematical model that represents an entire study area while satisfying all constraints, such as voltage and thermal power flow limits. This applies not only during an event but also during system restoration when numerous system reconfigurations occur. The design decisions result from optimal solutions that take into account system responses, restoration activities, and costs that occur over the entire duration of an event, which can sometimes span multiple days.

The use of unbalanced optimal power flow is necessary to find solutions faster with superb solution accuracy. Searching for an optimal solution can be quite computationally intensive, depending on the number of options to consider. Some resilience strategies may include the use of one or more of the following: hardening, sectionalizing, undergrounding, distributed generation, energy storage placement, or microgrid formation. For example, on a relatively small distribution system with three distribution feeders , there could be more than 8,000 binary decisions with dependencies, creating a vast combination of decision-making options regarding which poles to harden and where to further sectionalize the system. This is a challenging task even without considering power flow constraints, but it becomes far more complex when utility staff wants to ensure that no voltage and thermal issues will occur when the system goes through the reconfiguration process. This is why the most challenging aspect of resilience design is optimizing the solution for system performance during an extreme event and the system restoration process.

Clearly, this is a task where machines outperform humans. With the use of augmented intelligence and advanced analytics, it is possible to find optimal solutions for such complex problems while addressing several event scenarios in a relatively short time, at a lower cost, and with fewer human resources.

In a three-feeder example, it may take only several hours of computing time to find an optimal solution that satisfies power flow



Pole and line section geo-positioning after mapping.

constraints during and after an extreme event using augmented intelligence and advanced analytics. This is in stark contrast to what would otherwise be weeks of delivery time, significant labor costs, and unavoidable process simplifications that could be detrimental. Problem simplifications related to the interplay between investment decisions and restoration/societal costs can have serious consequences.

Optimizing for upfront investment in system upgrades, utility restoration costs, and societal costs due to prolonged power loss can significantly reduce the overall cost in the long run. In some scenarios, optimal upfront investment solutions can result in a two- to three-fold reduction in overall costs for extreme weather events, such as a Category 4 hurricane. However, the main bounding constraint in the optimization process and overall investment decision-making should be societal willingness to pay year over year for such system performance. In business terms, society should only seek new investments in solutions that provide the best resilience performance RONIC while ensuring that long-term rates remain affordable for ratepayers.

The use of augmented intelligence and advanced analytics is inevitable and, alongside change management challenges, is associated with data availability and quality as a key challenge.

Data-Driven Design

Resilience design is also heavily data-driven because the planning process aims to identify idiosyncratic and systematic risks, and define solutions to hedge against those risks. These risks must be quantifiable, which requires a significant amount of quality historical data and reliable forecasts, including but not limited to the following:

- Geographical information system (GIS) data of individual T&D poles (for example, material, class, height and guy-wire attachment) and attached equipment (for example, transformers, capacitors and regulators) on each of the poles.
- Distribution circuit power system topology and characteristics, such as those used in CYME and Synergi Electric models.
- Asset condition and exposure to risk in the field, such as pole leaning angle and vegetation proximity.
- Load growth and mix forecasts, including electrification and corresponding categorization of customer senstivity to power loss.
- Societal and geospatial costs for all customers.
- Geospatial network upgrade costs, such as undergrounding and pole upgrade/replacement costs.
- Restoration times, crew availability for given events and hourly rates.

While utilities continuously collect and store data records, data is often incomplete or inaccurate, posing a major challenge for electric utilities in resilience planning. Often, the process requires data conditioning using advanced analytics. For example, GIS pole geo-locations may not align with distribution model line section geo-positioning, preventing proper pole-to-line section mapping. Using advanced analytics, the pole-to-power flow model mapping process can improve accuracy to over 99% in only one to three seconds per distribution circuit, depending on the distribution circuit's size.

Analytics depends on data. As extreme event simulations unfold, the probability of asset failure is established for each pole and circuit section independently. For instance, each risk model for distribution pole failure accounts for wind and ice loading impacts, including attached equipment like capacitors, regulators, and third-party conductors. Subsequently, numerous time-series events of extreme events are simulated, each posing a time-series problem. Using advanced analytical methods, the most cost-effective system design solution is sought across geographical space and event time.

In addition to machine execution, the resilience process heavily relies on an effective and efficient process involving people from different parts of the organization.

Consensus Building

Utility department activities and priorities are highly dynamic. Slow and asynchronous activities across various departments can delay timely consensus building. Resilience design is even more complex and cross-department dependent. Therefore, time is critical, and solutions must involve all departments simultaneously for assessment and refinement. Otherwise, a partial and sequential resilience design will likely result in lower system performance and higher investment and operational costs, not to mention the impact on societal costs.

Work In Practice

LUMA Energy LLC of Puerto Rico piloted a resilience design framework developed by Quanta Technology, a Quanta Services Inc. company. As a tropical island, Puerto Rico is periodically exposed to storms and occasional hurricanes. Following Hurricane Maria in 2017, Puerto Rico's utility at the time worked diligently to restore the electric grid, but it took months to bring some customers back online. The post-Maria system recovery was more of a Band-Aid solution rather than a comprehensive rebuild.

When LUMA, a joint venture between Quanta Services and ATCO Ltd., assumed operations and maintenance of the island's power grid in 2021, it introduced systematic changes to how the system is designed, both for everyday conditions and extreme events. With the assistance of Quanta Technology's integrated resilience planning platform, LUMA can not only enhance resilience activities, encompassing planning, operations, and emergency response, but also use the platform to estimate the proposed reliability and capacity planning network upgrades' contribution to system resilience. These capabilities empower the utility to make informed decisions in the best interest of Puerto Rico's ratepayers.

Continuing Work

For all utilities and regulatory bodies, the standard for decision-making has been elevated when it comes to determining where to invest in resilience efforts and prioritize upgrades to the electric grid. There is no doubt that billions will be spent on resilience over the next several years. Utilities will face capital spending challenges and rising expectations from regulators for superior electric grid resilience performance. While optimal capital spending analysis and justification for appropriate levels of resilience may not be mandatory, they will be unavoidable. Without these efforts, resilience will come at a cost that very few geographic areas can bear.

Quanta Technology will continue to support the industry in implementing customized resilience design frameworks, enabling utilities worldwide to enhance electric grid resilience while maintaining affordable electric rates. TDW

ANDRIJA SADIKOVIC is a director at Quanta Technology. He is a distinguished professional with a track record of innovation and leadership in the field of electrical engineering and grid management. His expertise encompasses transmission and distribution planning, as well as smart grid technologies. Under his leadership, Quanta Technology has achieved milestones, notably the development of an augmented intelligence platform dedicated to system resilience and reliability planning, reducing labor costs and completion time while improving the decision-making process. Sadikovic holds an MBA from The Wharton School, University of Pennsylvania, and an MSEE from Northeastern University.

SHANSHAN MA is a principal engineer at Quanta Technology. She holds a Ph.D. in electrical engineering from Iowa State University, specializing in electric power systems. With extensive research experience, Ma has focused on distribution system planning, resilience, renewable energy integration, and power system optimization, accumulating nearly 1000 citations for her publications to date. She serves as the technical lead for the development of Quanta Technology's reliability and resilience platform.

Lifeline 40B | Parting Shot 40H

ELECTRIC UTILITY OPERATIONS

OCTOBER 2023

tdworld.com/electric-utility-operations

Wildfire Mitigation

OUR OCTOBER FEATURED LINEWORKER

Paul Congleton

E-J Electric

- Born in Ogdensburg, New York.
- Married to his wife, Stacey. They have two daughters: Evie, 7, and Maddie 4.
- Enjoys downhill skiing in the winter and boating and camping in the summer.
- Moved to Yonkers, New York, in 2010 to start his apprenticeship for IBEW Local 1249.
- Currently working on replacing double express aerial cable feeders in Jamaica, Queens.

Early Years

I attended university out of high school, but after a few years, I found I needed to be working with my hands outdoors. I heard of a training school in Georgia, and I attended Southeast Lineman Training Center in the beginning of 2007. I've been in the trade ever since.

Day in the Life

I am currently a working foreman in the field for E-J Electric in Queens, New York. I perform distribution maintenance for Con Edison. It's my job to see the safe, timely and efficient completion of the projects, which are typically reconducts.

Safety Lesson

The birth of my first daughter changed the way I approach the daily tasks and made me more safety conscious. I realized then that I have a duty to return home each day in the safe, healthy way in which I went in.

Paul Congleton says he enjoys working on larger reconductoring projects.

Memorable Storm

My first big storm was Superstorm Sandy in 2012. We ran seven- to 16-hour days for a month, and then did post-restoration for three months.

It was my first really grueling schedule, but I found that, even though it can be tiring, the appreciation from the general public was rewarding.

Tools and Technology

One of the better tools I have purchased recently has been battery-operated cable cutters. Though expensive, they have saved straining my elbows having to use bypass loppers. The battery-operated tooling has made tasks faster, safer and easier on the body.

Future Plans

I have no regrets over my career path I have chosen. I only hope to stay safe and healthy so that I can provide for my family and enjoy a good retirement with my wife. TDW

Editor's Note: If you are interested in being profiled in our monthly Lifeline department or know of a journeyman lineworker who would be a good candidate, email *T&D World* Field Editor Amy Fischbach at *amyfischbach@gmail.com*. To thank lineworkers for their dedication to the line trade, Milwaukee Tool sends each profiled lineworker a tool package.

Colorado Co-op Shares Wildfire Mitigation Strategies

CORE is investing in new technologies and hardening its system.

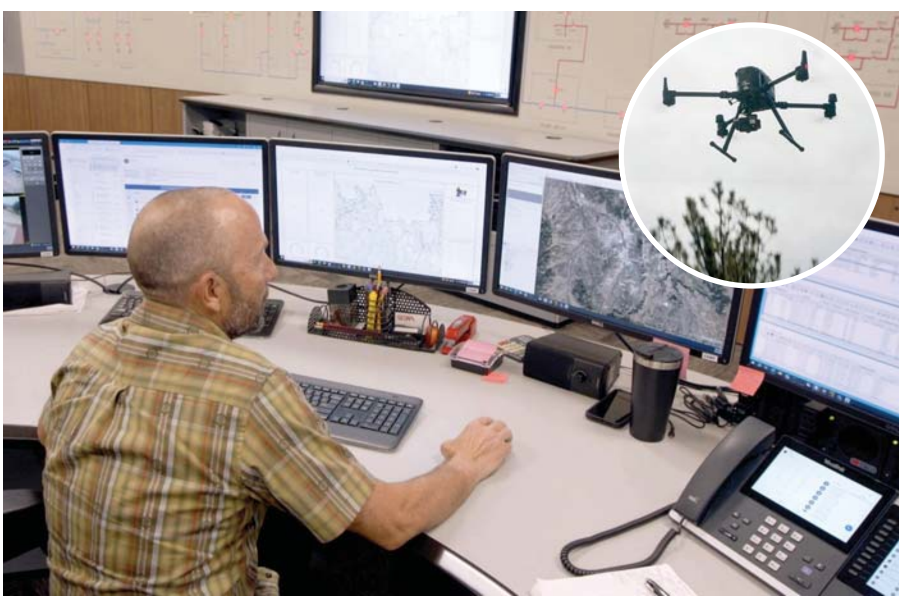
By **AMY FISCHBACH**, Field Editor

CORE Electric Cooperative has always faced an elevated wildfire risk in its 5,000-mile service territory with its mountainous terrain and 157,000 distribution poles. Over the last decade, however, wildfire has inflicted devastating effects to the state's communities and local habitats.

In Colorado, where wildfire season is year-round, CORE's approach to wildfire mitigation and system reliability is centered around proactive approaches.

"We perform daily inspections and repairs of the system as well as implement equipment and components that minimize the risk that our equipment will start a wildfire," says T.J. Havens, Conifer district manager.

Several years ago, the cooperative launched the wildfire mitigation program, and recently it enhanced the program to CORE PROTECT, using a dynamic approach and deploying new technologies. The revised program has four key aspects — risk analysis (understanding the current system); mitigation (addressing potential issues); situational awareness (identifying current and near-future conditions) and wildfire response. Here are six strategies CORE Electric Cooperative and its field workforce use to minimize wildfire risk and protect the community and service territory.



CORE's teams use satellite and AI technologies to examine rights-of-way. (Inset) CORE uses a wide variety of technologies to assess and mitigation risks.

1. Perform Aerial and Ground Patrols.

To take a proactive approach to wildfire mitigation, the cooperative performs both ground and aerial patrols. CORE line crews perform inspections by foot, and contractors specialize in infrastructure inspections using drones. Two contracted FAA-licensed providers capture high-resolution images and use heat-detecting infrared technology to identify wildfire risks.

Case in point: in 2022, more than 15,000 poles were inspected by drone throughout the service territory. The drones capture several images per pole in both high-definition and infrared. They are then analyzed to identify any of the defects from a top-down and side view.

"Thus far, the program has been very successful in identifying defects," Havens says. "They allow lineworkers to focus on repairs."

2. Install Cameras.

To expand its mitigation efforts, CORE employees installed Forest Technology Systems by AEM on radio towers rather than poles to provide the best possible view.

"They have the functionality to point, tilt and zoom to an incredible degree, giving CORE and our emergency management partners the ability to remotely view conditions and nearby active fires in real time," says Jordan Ambrogi, wildfire mitigation program manager for CORE.

The second type of cameras installed on the radio towers are automated fire watch cameras by Pano AI. These camaeras take a new 360-deg panorama every minute. Artificial intelligence (AI) technology monitors the images to detect smoke plumes within minutes of a fire starting. If it detects a smoke plume, it sends an alert to CORE and its partners with a link to the video feed, providing early detection and situational awareness. When two of these cameras can see the same fire, they will triangulate to give emergency responders a precise location of where it is occurring.

Drone inspections are a critical aspect of CORE's wildfire mitigation efforts. (Inset) CORE also performs inspections of the overhead distribution system on a routine basis to identify maintenance issues that pose a risk to fire safety and reliability.

3. Analyze Satellite Imagery to Spot Hazard Trees.

As part of its proactive approach, CORE also is leveraging technology to identify hazard trees in its service territory. The cooperative is engaged in a partnership with Overstory, which uses AI machine learning to analyze satellite imagery and identify dead and encroaching vegetation that poses threats.

"Hazard trees pose one of the greatest external threats to our lines and have been the cause of several catastrophic fires in the West," Ambrogi says. "Overstory can identify areas of widespread decline in tree health, which allows our inspectors to prioritize work in these regions."

4. Install Smart Fault Indicators.

CORE is also piloting smart fault indicators from Sentient. This technology gives the cooperative more precision on the expected location of a fault. In turn, this reduces the patrol time for line crews and allows them to repair and restore power for shorter outages.

In addition, the technology gives the cooperative detailed information on the wave pattern of the fault current that was present. This information can be used to determine the probable cause of the fault.

CORE can also activate more sensitive circuit protection settings during high wind, red flag warnings and other elevated fire risk conditions. If a tree falls into a power line, the settings allow the devices protecting the line to trip instantly.

5. Harden the System and Place Infrastructure Underground.

The cooperative is hardening its system in several ways including building taller, stronger poles that can withstand high winds and snow conditions. Lineworkers are also installing 10 ft fiberglass crossarms designed for improved strength and greater distance between lines. Another top priority is covering up energized parts, which can cause a spark if contacted by wildlife or vegetation.

In addition, the lineworkers are undergrounding lines in high-risk areas.

"Where feasible, all lines scheduled to be rebuilt in high wildfire risk areas as defined by the Colorado State Fire Service are designated to be relocated underground," Havens says.

When considering which lines to bury underground, the biggest consideration is the underlying wildfire risk. The cooperative uses the wildfire risk assessment from CSFS to determine the highest risk lines to be considered for undergrounding. Other factors include the presence of shallow bedrock and sensitive historical and ecological sites that could be disturbed by undergrounding. System design also plays a key role in the decision.

6. Monitor the Weather Conditions.

CORE subscribes to DTN Weather Service to receive daily reports of weather conditions in its service territory including wildfire risk. Additional daily fire risk data is obtained through a combination of map services provided from National Ocean and Atmospheric Association (NOAA)'s Warnings and Watches map service and from the USFS Wildland Fire Assessment System map service.

CORE System Operators log weather conditions and send pertinent information and warnings to all operations personnel and contractors, and GIS republishes these map services to the daily operation map service. "This situational awareness allows CORE to adapt daily operations, emergency preparedness and risk mitigation efforts to changes in fire conditions," Ambrogi says.

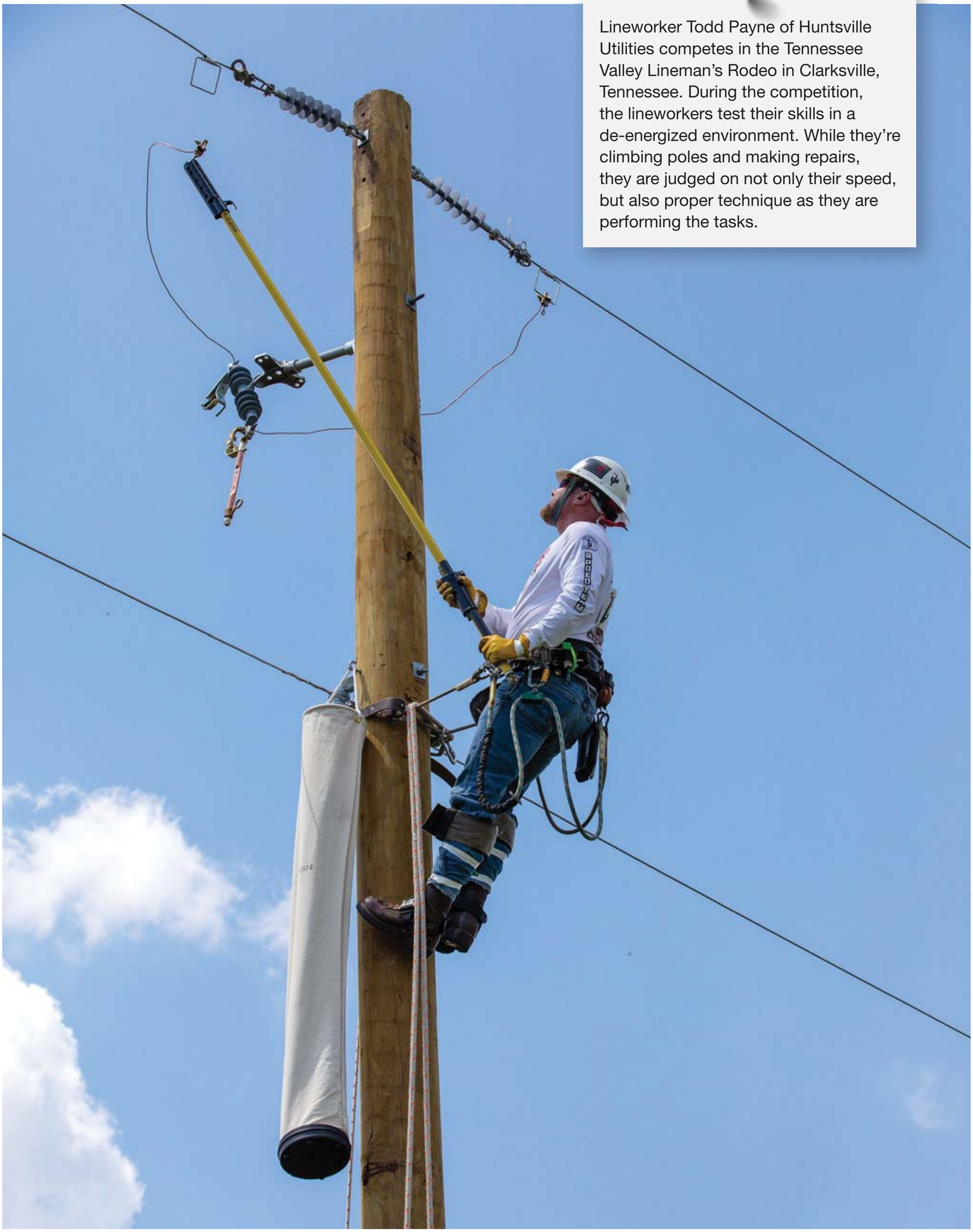
Looking ahead, the cooperative is considering a more advanced risk forecasting tool that will enhance situational awareness. In addition, the cooperative is looking at more sensitive and remotely controllable protection devices.

"We are always evaluating new tools and technologies to stay on the cutting edge of utility-scale wildfire mitigation efforts," Ambrogi says. "We are continually evaluating and optimizing the program and gleaning best practices and learnings from other utilities and partners across Colorado and the United States."

For CORE Electric Cooperative, wildfire mitigation is a top priority. "Many of CORE's own employees live in the high-risk areas of the service territory, so taking action to keep our members, communities and own employees and their families safe is CORE's number one priority," Havens says. TDW

Parting Shot

Photo by **AMANDA TOMCZYK-KEMP**, Huntsville Utilities



Lineworker Todd Payne of Huntsville Utilities competes in the Tennessee Valley Lineman's Rodeo in Clarksville, Tennessee. During the competition, the lineworkers test their skills in a de-energized environment. While they're climbing poles and making repairs, they are judged on not only their speed, but also proper technique as they are performing the tasks.


700 LBS

Alternative Design Measures Limit Pole-Top Fires

Eskom's engineering approach reduces the risk of pole-top fires on its medium-voltage overhead line network.

By **ANDREAS BEUTEL** and **BRUCE MCLAREN**, Eskom Holdings SOC Ltd.

A typical rural overhead distribution line in South Africa. Photo by Eskom.

In common with utilities around the world, parts of Eskom's medium-voltage distribution network in South Africa suffer from pole-top fires, adversely impacting reliability. A.K. Persadh studied this problem in the KwaZulu-Natal, South Africa, province as part of his master's thesis in October 2007. He estimated approximately one fire occurred per 1000 km (622 miles) of 22-kV network annually.

While this might not seem like a large number, every occurrence has the potential for severe consequences that extend far beyond network reliability. Pole-tope fires can result in low-hanging conductors that are energized yet intact and not in contact with any grounded object. This type of situation is not detectable today in a practically viable way, and certainly not on a large, distributed network like Eskom's.

To address this situation, Eskom has designed and implemented measures that do not require further intervention once an existing overhead line network has been reengineered in the affected areas.

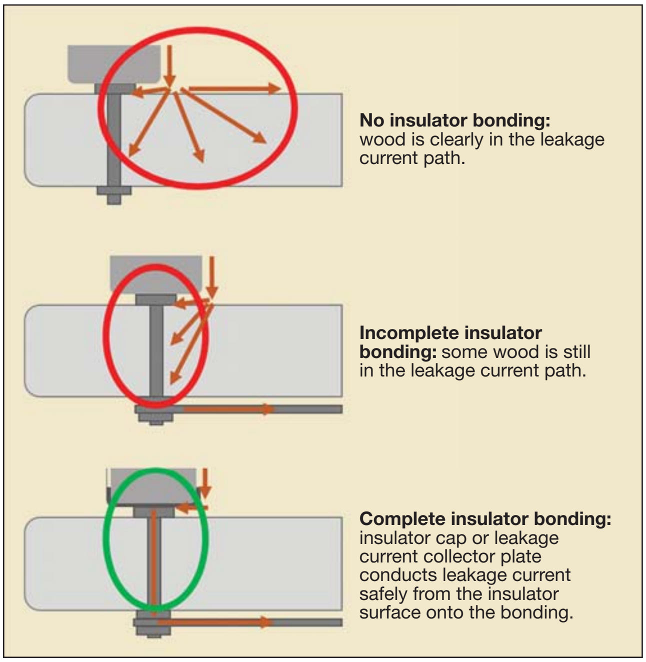
Pole-Top Fires

The reason for pole fires, sometimes referred to as pole-top fires, is leakage current flowing over wet and polluted overhead line insulators, a well-known phenomenon in the electric distribution industry. However, the approach taken to mitigate the problem varies significantly in different regions of the world. Eskom has developed and adopted an approach that has been tested in a natural high-leakage current environment and can be implemented easily in the field. Preliminary studies also took into consideration other causes of wood structure fires and methods to minimize them.

Pole-top fires have been recorded in diverse locations, including the coastal regions of South Africa and Australia, the Middle Eastern desert and the industrial areas of North America. While these areas differ in many ways, they all have certain climatic conditions that encourage insulator pollution and the potential for insulators to get lightly wet at different times of the year.

Prime Conditions

The location of the wood-pole structures, primary atmospheric conditions and surface condition of overhead line insulators in terms of the degree of pollution are all contributing factors



Preventing pole-top fires on phase insulators. Figure by Eskom.

Example of a bonded cross arm. Photo by Eskom.

linked to pole-top fires. Generally, the conditions that can result in leakage current are as follows:

- The surface of one or more of the overhead line phase conductor's insulators has surface pollution.
- The polluted insulator gets lightly wet from mist, fog, drizzle, light rain or condensation. Conversely, heavy rain can help to reduce the risk of pole-top fires because it cleans the insulators, reducing the buildup of surface pollution.
- Wet and polluted insulators offer a conductive surface, resulting in leakage current.
- The leakage current finds its way into the interior and/ or onto the surface of the wood pole or cross arm of the distribution structure.
- Arcing results, leading to tracking on the surface of the wood, which can be ignited.

Mitigation Measures

Electric utilities have numerous mitigation measures at their disposal, including engineering design like electrical bonding

Examples of unbonded cross arms that burned (top). Example of tracking on unbonded cross arm (bottom). Photos by Eskom.

and earthing coupled with or without operational interventions such as insulator washing and leakage current detection.

Bonding unenergized pole-top hardware together diverts leakage current away from the wood sections of the overhead line support. The bonding is earthed by a down-running earth wire. This wire includes an air gap provided by the wood pole in series with phase insulators. The air gap effectively reduces the number of power interruptions from lightning, as induced lightning surges rarely cause the line to flash over at the higher insulation level provided by the air gap.

The increased impedance of the wood-pole path that includes the air gap also improves bird safety, as the risk of birds being electrocuted is reduced. However, there is an increased risk the pole may burn at the air gap because of leakage current flow to earth. Field experience has shown the risk of burning in this position is significantly less than that of a wood cross arm burning.

For new overhead line construction, the use of composite phase insulators with at least a 31-mm/kV (1.22-inch/kV) specific creepage is recommended to limit the magnitude of leakage current. On existing lines, porcelain products with the same specific creepage specification may be acceptable for use as phase insulators.

All phase insulators must have suitable conductive end fittings to ensure leakage current is safely conducted from the surface of the insulators onto the bonding. Post insulators must be capped, and uncapped insulators need a leakage current collector plate to divert the leakage current to the bonding.

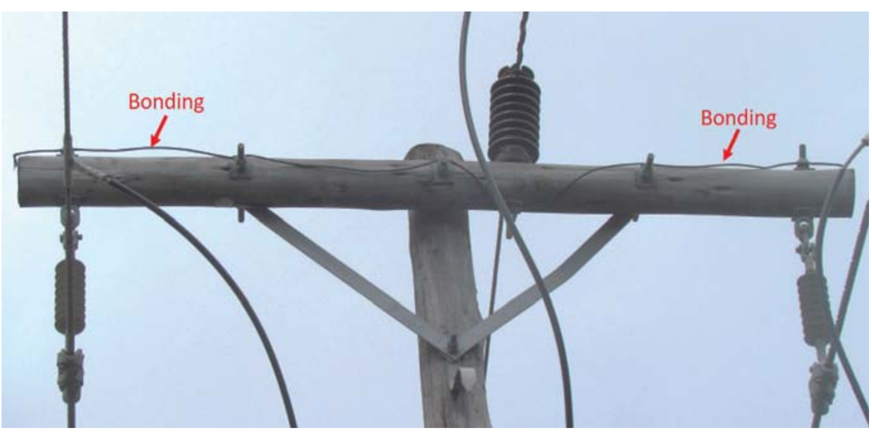
Steel cross arms may be used instead of wood cross arms, eliminating the problem with burning cross arms. Eskom uses steel cross arms extensively, but there are trade-offs with material and labor costs. Steel cross arms cost significantly more than wood cross arms, but they are also relatively simple to install and more robust. Steel cross arms also have issues related to vibration that causes nuts to loosen, steel-weld quality controls and corrosion mitigation. The utility has found steel cross arms achieve the same purpose with respect to pole-top fires as bonded wood cross arms, provided that all mitigation measures are correctly implemented.

Verifying Effectiveness

The effectiveness of these alternative mitigation measures can be verified in two ways: by investigating pole-top fires in the field and testing the measures in a highly polluted environment.

Eskom achieved the former through a targeted field investigation of structure fires. For all structures with pole-top fires in which the cause could be conclusively verified, the utility found those structures did not meet at least one of the mitigation criteria. For example, the overhead lines were constructed before bonding was introduced.

Eskom's Koeberg Insulator Pollution Test Station (KIPTS) served as the high-pollution test environment, as it is located in a natural pollution environment close to the high-water mark of the Atlantic Ocean on South Africa's West Coast, near Cape Town. This site was chosen for testing because of its severe pollution levels and the power and measurement infrastructure were already in place, as the test station was constructed specifically for insulator testing. Six wood-pole test structures were erected and each of the different insulator technologies and bonding arrangements were evaluated. The results of the tests verified the effectiveness of each of the proposed mitigation measures.



Example of a bonded cross arm. Photo by Eskom.

Other Wood-Pole Fires

Pole-top fires are generally restricted to overhead distribution lines and

Design-acceptable insulators for mounting phase conductors: capped porcelain, uncapped porcelain with collector plate and capped composite insulator.
Photos by Eskom.

lower-voltage overhead transmission lines supported by wood poles. At higher voltages, capacitive rather than conductive effects dominate the performance of high-voltage overhead transmission lines.

Wood-pole structures installed to support overhead distribution lines are also subject to burning for reasons other than leakage current flow. For example, a phase conductor or jumper could get disconnected from its insulator and end up lying on the cross arm, a phase conductor or jumper could clash with a pole or stay in high wind, or a failed insulator could conduct excessive leakage current.

Lightning flashover occasionally causes a wood-pole structure to burn. If the structure is bonded and earthed correctly, then the fire would start on the pole at the insulation coordination gap (that is, at the location of flashover across the pole). However, the risk of poles burning in this way is lower than the risks mitigated by inclusion of the gap.

Each of these fires can be mitigated by addressing the cause, such as engineering designs where problems are encountered, ensuring overhead line hardware is adequately specified and scheduling maintenance inspections to detect loose conductor ties and brackets.

Engineering Philosophy

Many of the world's overhead distribution line networks are routed in harsh environments, such as high levels of lightning or pollution. Measures can be introduced at the design stage, prior to construction, or retrospectively to improve the performance and safety of these distribution networks in high-pollution areas, where networks are more prone to pole-top fires. These fires are caused by leakage current flow produced by the light wetting of pollution deposited on phase insulators.

Using Eskom's engineering mitigation measures has the advantages of not requiring frequent labor-intensive and costly interventions — such as insulator washing and leakage current detection — once the measures have been implemented. However, it is not practical or cost-effective to implement these design measures on existing overhead line networks in a short span of time, so long-term programming of these remedial changes is required to eliminate or limit the risk of pole-top fires to an acceptable level.

Example of a typical steel cross-arm. Photo by Eskom.

Eskom has included these principles in its engineering philosophy for a while now on its medium-voltage overhead line network. To date, no unexplained pole-top fires have been reported on structures built following this philosophy. This result is as expected because of the extensive investigation conducted to verify the philosophy's soundness, including controlled testing in a high-pollution environment and determining the circumstances of field failures. This process has proven worthwhile because of the confidence Eskom gained from the recommendations.

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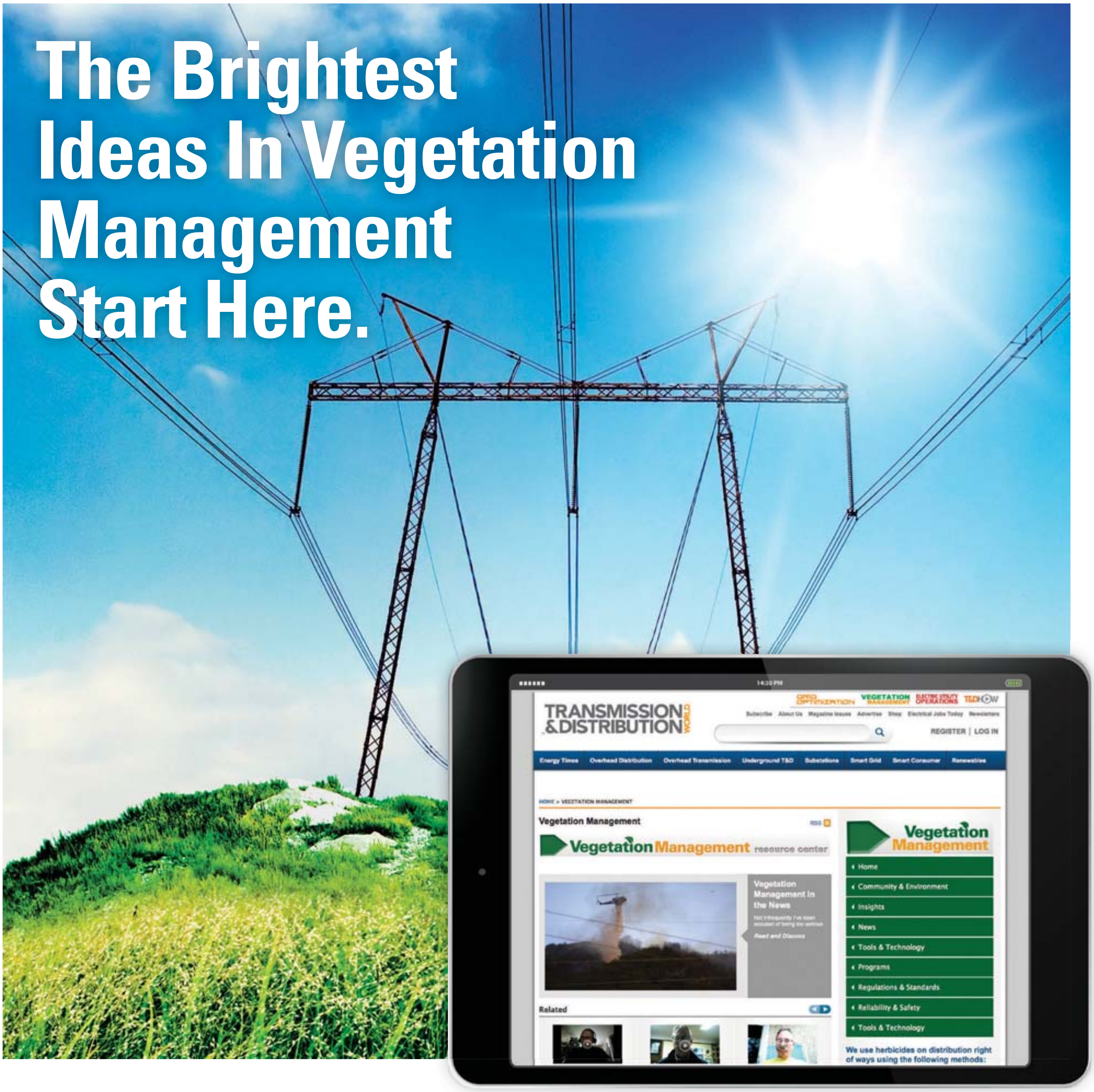

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Rebuilding Lahaina

How can local Hawaiians safely and affordably rebuild their beautiful homes, reclaim their rich history and restore business vitality among the smoldering ruins of Lahaina town?

By **MIKE BEEHLER**, Mike Beehler and Associates LLC, and **RICHARD GASAWAY**, Green Stewardship, LLC

The devastating Aug. 8 fires in Lahaina, Hawaii changed lives forever.

It was a tragedy that deeply saddened the watching world — the loss of lives, and loss of a way of life unique to the beautiful setting that Lahaina and the Island of Maui provided.

Although Lahaina and the people lost can never be replaced, the grieving community already is showing its resolve to build back. How can local Hawaiians safely and affordably rebuild their beautiful homes, reclaim their rich history and restore business vitality among the smoldering ruins of Lahaina town?

Wildfires like this one in southern California raged out of control in beautiful Lahaina and west Maui killing over a hundred people with hundreds more missing. GomezDavid / iStock / Getty Images Plus.

Rebuilding starts with a plan. A plan made by and for the local people of Lahaina, Maui and greater Hawaii, not some federal government agency or multi-billion-dollar conglomerate. A resilient and sustainable building plan starts with critical infrastructure like power, water and sewers, sanitation, transportation and communications. These things may not provide the character of a community but are essential for providing the firm foundation of a sustainable and resilient community.

Infrastructure starts with energy. Energy lights and conditions homes, schools and commercial buildings, it pumps and purifies water, it provides certain types of transportation and mobility, and is critical to communications and broadband technologies.

Hawaii has ambitious goals for the use of energy that impacts each aspect of rebuilt infrastructure. Hawaii hopes to achieve the use of 100% renewable energy by 2045. Could rebuilding Lahaina help to meet that goal? The answer is yes!

So how can local Hawaiians in Lahaina rebuild a safe, reliable,

Aerial of Lahaina Harbor on the island of Maui before the fire. 23736125 © Makahiki87 | Dreamstime.com.

Rebuilding the critical infrastructure of first responders will be an important part of Lahaina's short-term plan for recovery. 5949075 © Monkey Business Images | Dreamstime.com.

resilient and affordable net-zero energy electric power generation and delivery system in Lahaina in the short run while planning on 100% renewable in the long run? Rebuilding Lahaina must employ proven approaches to master-planned infrastructure that include strong community input to the use of emerging technologies, zoning and densities; green infrastructure for storm water control, retention and detention; parks and recreation facilities with more native plants and xeriscapes; underground utilities that add system resiliency and beautify the streetscape; and human mobility and transportation features such as pedestrian and bicycling zones and the possible use of electric vehicle charging/hydrogen fueling capabilities.

This Lahaina-town master plan will include the interconnection of new, highly energy and water efficient residential, commercial and government buildings that use transactive energy to share distributed resources across the grid and "net zero" buildings that over the year, use the energy and water that they produce and potentially store on site.

These features of a rebuilt Lahaina will help to reflect, enhance and promote the history, character, sustainability and vision of the people of Lahaina, imbed a robust community infrastructure for Maui, and integrate with some of the already current long(er) range plans for the State of Hawaii all in a manner that will honor the people it is meant to serve.

Net Zero Designs

Hawaii hopes to achieve the use of 100% renewable energy by 2045. This is a hugely ambitious goal that impacts each aspect of the master planned, rebuilt infrastructure. In the short run of the next few years, reaching this goal will start with designing, constructing, operating and maintaining net

Benjamas Deekam / iStock / Getty Images Plus

The aesthetic value of underground cannot be measured in beautiful Lahaina.

zero energy buildings. *https://www.energy.gov/eere/buildings/zero-energy-buildings-resource-hub*

Net zero can be defined several ways. The best definition for early applications is "the net energy or water used for an asset over the course of a one-year period is produced on site." Buildings, facilities and plants experience peak periods of energy and water use as temperature, humidity, consumer use and production levels vary. During these peak periods, the facility will need to be connected to the electric, gas or water distribution systems (the grid) of the utilities like Maui Electric Company or the Maui County Department of Water Supply. And, current fossil plants connected by 69kV transmission will be needed until reliable energy storage and alternative, clean and dispatchable electric repowering is available. These transmission lines and their substations provide valuable electric infrastructure that will be needed for every other type of infrastructure that Lahaina will rebuild. The transmission lines must be rebuilt quickly and on strong, resilient and fireproof steel poles. The substations must be rebuilt with resiliency in mind.

Underground Utilities

A net zero Lahaina will require a highly reliable and resilient transmission and distribution (T&D) system best delivered by undergrounding the electric distribution system.

Undergrounding offers several advantages compared to overhead lines to include significantly reduced vulnerability to extreme weather events like tsunamis and floods, lightning, hurricanes, and wildfires. By reducing the impact of future fires, severe weather conditions and reducing other potential outages caused by falling tree limbs or vegetation contact, car hit poles, birds and rodents, mylar balloon impacts, ground line wood rot and more, undergrounding contributes to a much more reliable and resilient electric distribution system.

The industry defines reliability with outage duration and frequency while resilience is defined as the ability to withstand a high impact, low probability (HILP) event with little or no customer outage. Reliability is measured in outage minutes and resilience is typically measured in days. Underground provides a much more resilient system and is the proven level of performance that a rebuilt Lahaina will require.

Today, the electric distribution system in America is approximately 20% underground, and Hawaii in general is pretty close to that. Yet, some public power utilities like Ft. Collins, Colorado Springs, and Anaheim have had underground ordinances for years. They have beautified their cities and improved the performance of their systems. Fort Collins is 99% underground and is 99.9% reliable. Colorado Springs started in the 1970's and today is 77% underground with 99.9% reliability. Anaheim has been engaged in its Home Underground Program (HUG) since 1990 and its 12kV system is currently 60% underground. And, the phone and cable TV utilities in Anaheim paid to go underground as well. In addition, Dominion, WE Energy, PHI, Georgia Power, Florida Power & Light, PG&E and many more public and private utilities are building new 21st-century underground systems to replace antiquated overhead systems and improve system performance and resiliency.

Moreover, the fiber, telecommunications and cable TV will all share same underground trench. High-capacity broadband will enable local community leaders and local entrepreneurs to employ selected new and emerging technologies that bring value to end user customers. Broadband connects people. It harnesses the power of data, turning data into information, and ultimately, action. Theoretically, this connectivity and the resulting data is used to create something new and desirable in our resilient communities including safety and warning features for the citizens of Lahaina.

Once a safe, reliable and resilient T&D system is designed, other utilities can be considered on joint use poles or joint use trenches. Poles may accommodate telecommunications cables or antennas and underground trenches may be uniquely modified to accommodate electric, water, wastewater and the aforementioned telecommunications infrastructure. This is not a common practice, but innovation, new local building codes and special allowances by the Hawaii Public Utilities Commission and state legislature should be allowed for this emergency rebuild of critical infrastructure.

Homes, School and Businesses

After basic short term utility infrastructure is in place, construction of homes, schools and commercial businesses can start. Designs for this new construction should include:

- Customer Solar- Integrating rooftop and canopy PV solar to provide power and/or hot water without increasing valuable land usage.
- Customer Storage- Capturing renewable on-site power generation in battery storage systems or even small-scale hydrogen storage in safe, containerized metal-hydride systems.
- Distribution scale battery energy storage (short duration four hours or less) – Possibly located at existing power plants, substations or distribution network points and provides a community energy storage aggregation point.
- Strong emphasis on energy efficient designs with heavy insulation in walls and roofs, dual pane or glazed glass,

high efficiency heat pumps, and chillers, etc following the principles of LEED (Leadership in Energy and Environmental Design) by the US Green Building Council.

- Native Hawaiian plants and xeriscape provide beautiful, drought tolerant species of colorful ground covers, hardy shrubs and shade giving trees for a rebuilt Lahaina. The University of Hawaii at Manoa has a Cooperative Extension Service that is an excellent resource for owners, planners, landscape architects and contractors.
- Demand Side Management (DSM) is a series of rate structures or incentives that provide energy and water customers with financial incentives to change their resource use patterns to the benefit of the local utility. Demand Response (DR) is the ability of a utility like Maui Electric to incent aggregated customers (under FERC 2222) or commercial customers to shed load as system needs require load reduction.

100% Renewable by 2045

Once a safe, reliable and resilient T&D system is rebuilt and the community starts to rebuild homes, schools and businesses with state-of-the-art net zero energy and water practices, local leaders in Lahaina, Maui County and the state can start to evaluate other, long-term methods of achieving their final goal of 100% renewable by 2045.

Waste to Energy

Maui's main landfill handles approximately 450 tons of waste per day for the 100,000 residents plus visitors that inhabit the island. Even with recycling 30% of the refuse, the landfill options are filling. Maui can collect and burn some methane gas from existing landfilled areas, but should consider a small 10-15 mW waste to energy plant. It is a huge challenge to accept the combustion of waste or continue to use valuable land and potentially impact groundwater quality.

Water and Wastewater Treatment

Water and wastewater transportation and treatment is a very energy-intensive process. Lahaina has the potential opportunity to co-locate water and wastewater systems with other utilities using state of the art distribution piping systems that 1) have few if any leaks and 2) detect the size and location of leaks. Non-potable water delivered to homes, schools and businesses can be used for irrigation or sanitation and treated on site with reverse osmosis systems for drinking, washing, cooking and any other human contact. Reducing the energy used in water and wastewater treatment and transportation will reduce community peak loads and help achieve net zero energy use.

Geothermal

Conventional geothermal resources on Maui could be developed or developers or Maui Electric could use closed loop geothermal technology. Closed loop geothermal provides continuous renewable power production and on a small surface footprint. The difference with closed loop technology is not needing sub-surface water and hot rock at the perfect temperatures and depth, since the fluid cycles in tubes, acting as a heat exchanger to drive the electric generation.

Bio-fuels

Bio-energy and bio-fuels production can be another possible low carbon replacement for fossil fuels in Hawaii's 2045 plan. Bio fuels can provide sustainable and reliable power for stationery and mobility applications on demand. There are many vacant agricultural fields from old sugar and pineapple production that are overgrown with non-native grasses. These grasses could be harvested to produce biofuels and at the same time cut down on the risk of wildfires.

Hydrogen

In striving for net zero resilient communities, it is hard to "electrify everything" and rely completely on the electron to do the job. That is why more and more communities are looking to clean hydrogen. A low carbon intensity produced molecule, such as green hydrogen can complete the circle, providing sustainable and resilient community infrastructure needs in power, transportation and industry.

Large underground and undersea HV and EHV cable projects like this project at SCE are becoming more common in the T&D industry.

Traditionally, hydrogen is produced from methane or water using energy intensive processes to separate the molecular elements. These processes are improving and new and exciting developments for hydrogen are in the "clean" hydrogen space. It can support electric system operations and microgrids in several ways:

Hydrogen can be used as a form of energy storage for electric systems. Excess renewable energy, such as from geothermal, wind or solar, can be used to produce hydrogen through electrolysis. The hydrogen can then be stored and used to generate electricity during times when renewable energy production is low.

Fuel Cells

Bio-fueled fuel cells or hydrogen fuel cells can be used to generate electricity, providing a clean and efficient alternative to traditional combustion-based power generation. In addition, fuel cells can be used to power electric vehicles, homes, schools and businesses. Bio-fueled fuel cells or hydrogen fuel cells can be used to balance the electric grid by providing a flexible source of power that can respond quickly to changes in demand or supply. Hydrogen fuel cells can be used to provide backup power during times of peak demand, reducing the need for fossil fuel-based peaker plants. And, hydrogen fuel cells can be used in addition to batteries to power remote sensors and monitoring equipment on the T&D system. Finally, hydrogen fuel cells can be part of a portfolio of generation, storage and demand side management tools used to successfully operate and maintain net zero energy buildings.

Another opportunity for the greater good could be to tie into the State of Hawaii's plan to participate in a U.S. Department of Energy (DOE) hydrogen hub. This of course would require a higher level of coordination at the State level but could positively impact the timeline and scale of greater hydrogen availability.

Undersea Cable

An undersea electrical power cable to the geothermal resources of the Big Island of Hawaii was studied by Hawaiian Electric Company in 1990 and found to be technically feasible.

Notwithstanding any cultural issues, perhaps now is the time to implement an undersea cable to Maui and, if that works well, complete it to Oahu. Many long submarine power cables around the world already exist or are currently under construction including:

- The 53-mile Trans Bay cable from Pittsburg, California, to San Francisco.
- The Champlain-Hudson Power Express line will be 339 miles long and carry 1.2 gigawatts, from a Hydro-Quebec substation near the New York State line to Astoria, Queens by 2026.
- The 447-mile North Sea Link, a 1.4-gigawatt cable, transmitting electricity between the north of England and southern Norway,

Pumped Storage Hydro

If the geography characteristics are favorable, and siting agreeable to the Lahaina community and Maui in general, pumped water energy storage is still one of the most reliable sources of energy storage.

Small Modular Reactor

Although not in the present Hawaii plan, consider Small Modular Reactor (SMR) nuclear technology to provide carbon-free base-load electrical power and off-peak power to water desalination and electrolysis plants for hydrogen generation.

Local Hawaiians must rebuild their beloved Lahaina town. Rebuilding starts with a good short term and an ambitious long run infrastructure plan. We have explored critical energy infrastructure and demonstrated how innovative energy solutions can impact other critical infrastructure like water, transportation and communications which would be critical to the rebuilding Lahaina-town in the vision of the local people.

Conclusion

While the lives and property lost in the horrible fires can never be replaced, the people of Lahaina can rebuild, reclaim and restore their beloved Lahaina. Together, they can restore charm and character of their homes and make Lahaina a cleaner, safer and more affordable community in the challenging years ahead and then, for decades to come. TDW

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SMUD
During the final day of the 2023 T&D World Live conference, SMUD's Chief Zero Carbon Officer Lora Anguay took the stage along with SMUD's former general manager and current President of the Large Public Power Council John Di Stasio to discuss the opportunities and challenges utilities are faced with on the road to zero for a more sustainable future.

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(1) Outside-county paid/requested mail subscriptions stated on PS Form 3541	18,748	18,177
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c. Total requested copy distribution (Line 15f) + requested/paid electronic copies (Line 16a)	25,221	25,387
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17. Publication of Statement of Ownership is required and will be printed in the October 2023 issue of this publication.
18. James Marinaccio, Audience Development Manager, 09/14/2023
    I certify that all information on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).
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We Need a Wartime Effort for Transmission

Any lingering doubts about the need for increased transmission development across the North American grid have largely faded. Studies indicate that the grid must expand by up to 60% by 2030 and potentially triple by 2050, necessitating a significant boost in transmission investment.

In a report prepared for WIRES (*https://wiresgroup.com/the-coming-electrification-of-the-north-american-economy/*), the trade association that promotes investment in transmission, The Brattle Group estimated that between $30 billion to $90 billion of incremental transmission investments will be necessary in the United States by 2030 to meet the changing needs of the system due to increasing electrification alone, with an additional substantial investment needed from 2030 to 2050. These investments are in addition to the investments needed to maintain the existing transmission system, replace aging assets, and integrate renewable generation built to meet existing load. This level of new investment is equivalent to $3 billion to $7 billion per year on average through 2030, and $7 billion to $25 billion per year on average between 2030 and 2050.

A subsequent report released by ScottMadden, Inc. (*wiresgroup.com/informing-the-transmission-discussion*) found the pressing need for more transmission investment in all regions of the country, to meet the challenges posed by changing energy resources, increasing electrification, a greater need and preference for location-constrained renewable generation, and ever-growing concerns about the risks to the resilience of the North American electric power system. Despite the evidence that more transmission is needed, ScottMadden found that regulatory policy has failed to support this growing need and that the financial incentives to developers of transmission which successfully drove signi-ficant transmission investments through the early 2000s are being reduced.

Against the backdrop of the need for an unprecedented increase in transmission, the fact of the matter is that builders of transmission today face significant uncertainty in the current regulatory and economic climate. Investment in transmission is a long-term proposition, and investors require certainty that they will recover their investment and earn a reasonable return. The current unstable economic climate, with above-average inflation, uncertain regulatory environment, lengthy and ever-growing lead times for construction of transmission, and long depreciable life of transmission assets necessitate regulatory policies that reflect stable ratemaking processes and clearly and unambiguously incentivize investment in transmission.

For these reasons, it is critical for regulators like the Federal Energy Regulatory Commission, or FERC, to adopt and implement policies designed to promote and facilitate investment that must be made to meet the future energy needs of customers, and of the nation. For years, FERC successfully encouraged transmission investment through robust rates of return on equity (ROE) sometimes enhanced by targeted incentive adders. In addition, in the past FERC creatively developed and effectively employed non-ROE ratemaking tools, including the Abandoned Plant incentive, the construction work in progress (CWIP) incentive, and transmission formula rates (TFRs) in a manner that has proven effective in supporting the development of needed transmission infrastructure. History has shown that the deployment of all of these tools support transmission development by improving cash flows, reducing risks, enhancing regulatory certainty, and helping to ensure cost recovery.

Regrettably, today's regulatory policies are not in alignment with that historical approach. Instead of incentivizing transmission investment, recent actions and those under consideration by FERC have made building new transmission infrastructure riskier and financially less attractive. As the ScottMadden report observed, the evolution of FERC policy has not supported the basic understanding that transmission is needed across the country to support reliability and the integration of renewables, as "incentives policy, which drove significant investments through the 2000s is changing, and returns on equity and adders are being reduced." FERC policies have resulted in the gradual erosion of ROEs notwithstanding the greater economic uncertainty and higher inflation of recent years. Worse, FERC has exacerbated the uncertainty around transmission investment in some regions for years by failing to resolve administrative proceedings to establish ROEs. Recent proceedings by FERC to consider reducing, restricting, or eliminating longstanding policies on ROE incentive adders and other non-ROE incentives create even more regulatory uncertainty and, if implemented, would discourage, rather than promote and incentivize, transmission investment that is necessary to meet the nation's future energy needs.

As former FERC Chairman Joseph Kelliher recently stated while reflecting on how to make the grid more reliable during a WIRES-sponsored webinar on the 20th anniversary of the 2003 blackout, "I also think FERC policy should encourage transmission investment… it is illogical to make an investment riskier and less profitable and expect more of it will result." I have often said that we will need the equivalent of a wartime effort if we are to build out the grid on the aggressive timetable needed to meet ambitious clean energy mandates and goals. During World War II as Britain stood alone against German forces, British Prime Minister Winston Churchill pleaded with the American government, "Give us the tools, and we will finish the job." FERC has the tools today in its regulatory toolchest to incentivize the large-scale investment in transmission that is critically necessary in the decades ahead. FERC needs to use those tools, and help finish the job. TDW

LARRY GASTEIGER is executive director of WIRES.

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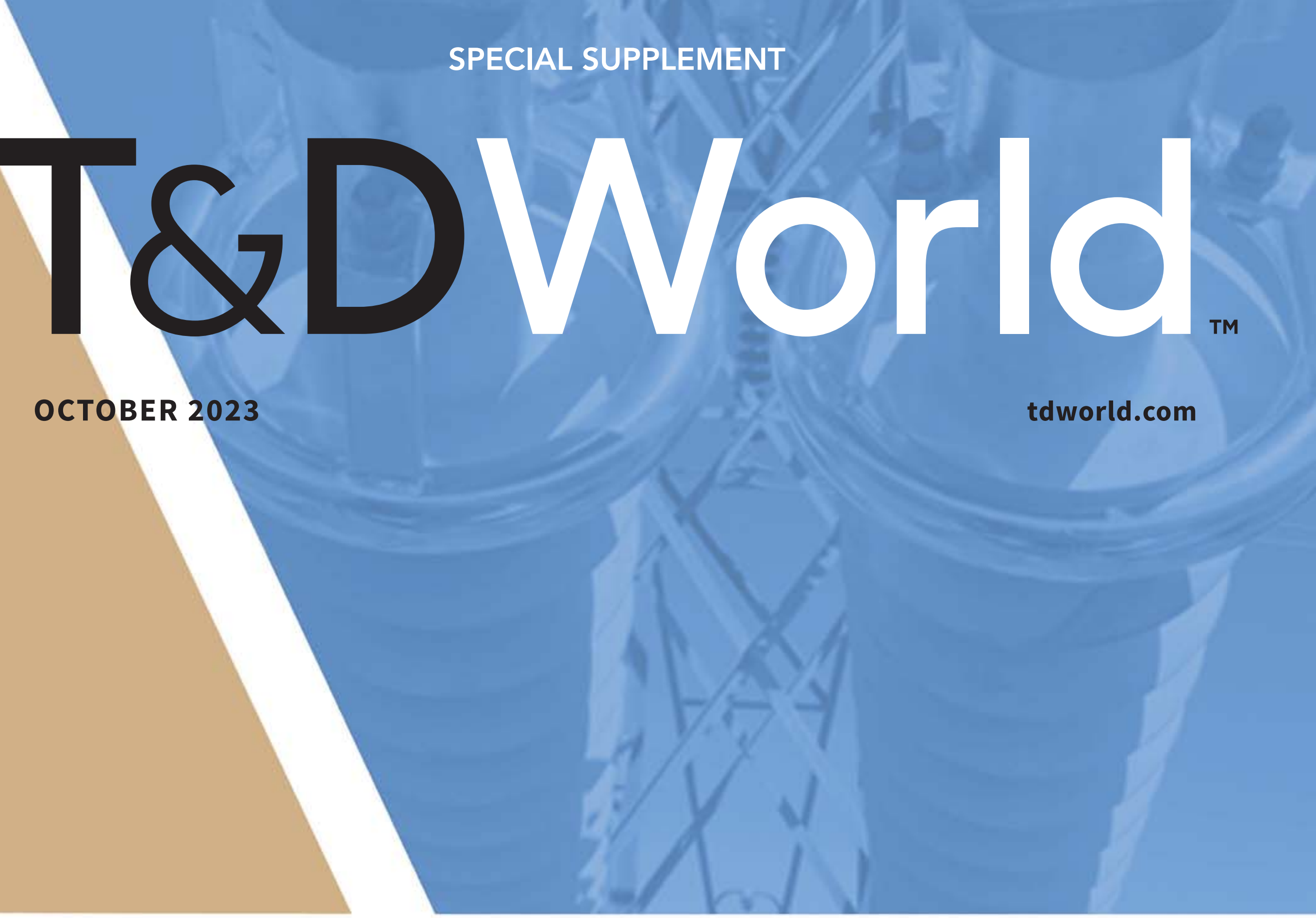

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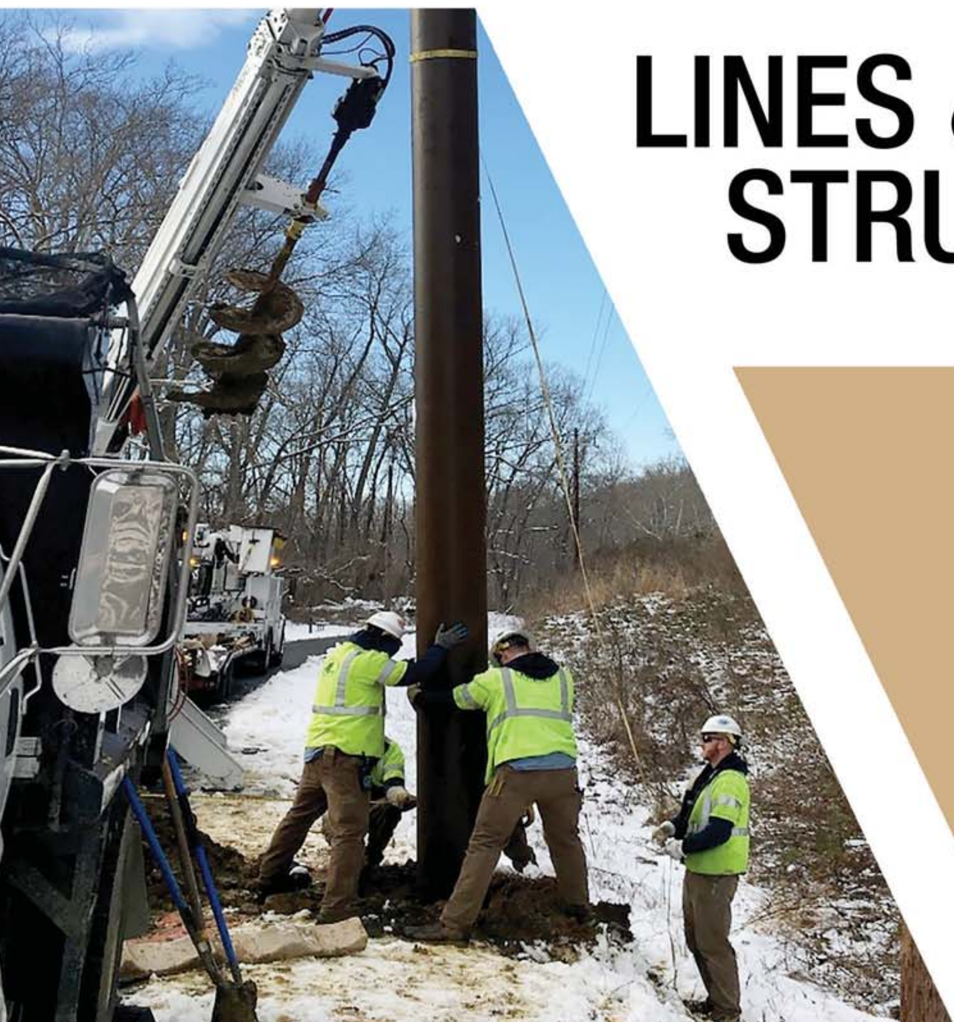

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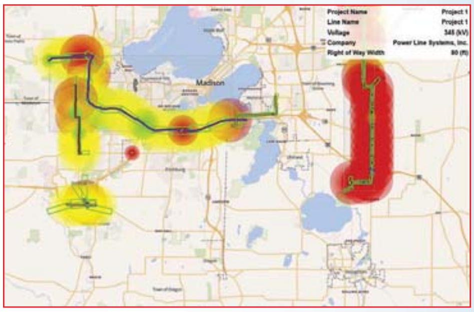
An Engineering-based Digital Twin



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Do the Right Thing

By **OTTO J. LYNCH**, Power Line Systems

Do the right thing. My entire life I have tried to follow this proverb. My father ingrained this into me early in life, and it was further reinforced throughout Boy Scouts. Whether the right thing is trustworthiness, loyalty, bravery, ethics, or many other adjectives, we all know what the "right thing" means individually; however, it does not mean that there is only one "right thing." I have had many disagreements with people that I greatly respect because we both think we are doing the right thing, but it may not necessarily be the same thing.

My wife and I went to see *Oppenheimer* recently. Not a movie spoiler, but when nuclear physicist David L. Hill (played by Rami Malek) testified to Congress regarding the nomination of Lewis Strauss as United States Secretary of Commerce, he was asked why he was testifying at the risk of his reputation in the scientific community. His answer was, "It is the right thing to do." My wife poked me in the ribs as she knows I strive to live similarly.

It is no secret that we have some problems with our electric grid. With sensitivity to many in our industry that have faced and are currently facing issues that I will not delve into here, the structural integrity of our grid has known weaknesses. Just last month, our home was without electricity for more than 24 hours after a reportedly 60-mph straight line wind storm front. Of the meters served by my co-op, 54% were out of service for one to four days. As an engineer who always plans for contingencies, I have a generator. I greatly applaud the linemen who were able to restore such a major outage in my region within a relatively short time. But what about those without generators who must go for days without electricity? Customers ask why it takes days to get their electricity back on and why it went out in the first place as there was no single catastrophic weather event such as a tornado or ice storm.

So why do we continue to have so many outages? Many will argue that all outages are due to vegetation. I have seen millions even billions of dollars spent on vegetation management effort, which I agree is a very good investment. Many are doing what I call "scorched earth" clearing, which basically clears everything to the ground for the full right of way width. So why do we continue to see poles and other structures that fail when no tree is in sight? **Should we not make the same investment in the structural strengthening of our physical grid infrastructure?**

The American Society of Civil Engineers (ASCE) has an overall standard (ASCE 7-22) that develops wind, ice, and other meteorological loadings for buildings and other structures. These loadings are primarily intended for structures that people live in, work at, or commute on. Some have suggested that our overhead electric infrastructure should meet these same loadings. However, to design our electric grid so that there are hardly ever any failures would be excessively expensive. Our industry focuses on resiliency which is the ability to 'bounce back' quickly as this is more cost effective.

As such, ASCE has another Manual of Practice (ASCE 74-19) that is specifically tailored for overhead line loadings. This manual takes the significant meteorological research and data in ASCE 7 and adopts it specifically for use on overhead lines. Rather than a 3000-year MRI that ASCE 7 says to use on "power facilities," ASCE 74 uses a more realistic 100-year MRI for the overhead lines.

At the request of many inside and outside of our industry, the effort is well underway to bring Manual of Practice 74 into the present as a new ASCE Standard. It is too premature to divulge the details of its development in the committee at this time, but it is safe to say that there are obviously respectful differences of opinions on where it should land. Do we make no changes? Do we continue to design our distribution grid using loadings that have not changed in 82 years? Do we go to the other extreme and gold-plate all of our overhead line grid? The answer is obviously somewhere in the middle.

When this Standard is published, we will not be rebuilding our entire grid; instead, any new or replacement construction should follow these higher standards, as well as when additional infrastructure is added to existing structures. It will take a generation before we see the benefits of such a change.

As this standard is developed, I simply ask that everyone "Do the Right Thing." First, recognize that vegetation does not cause all outages. Also, recognize as we design our grid to loadings that are expected to happen like wind and ice, the grid will be much stronger even with vegetation events.

Let's all be like nuclear physicist David L Hill, and at the risk of potential scorn of our employers, clients and some others in our industry who do not want change, let's please Do the Right Thing for the integrity of our grid moving forward. TDW

OTTO J. LYNCH is VP of Bentley and head of Power Line Systems. He is a member of American Society of Civil Engineers, IEEE, and National Electrical Safety Code. He is a registered professional engineer.

Pole base setting with line energized. Courtesy of SMECO.

Keeping It Close:

A Composite Solution Redefines Compact Design and Construction

CREATING NEW STANDARD CONSTRUCTION PRACTICES TO MEET CRITICAL CUSTOMER NEEDS

By **HUGH VOEHL III,** Southern Maryland Electric Cooperative and
JOHN WILLIAMS, Booth & Associates, LLC

There are several critical customers located in Southern Maryland Electric Cooperative's (SMECO) territory that depend on an uninterrupted power supply due to the nature of their industry. In 2012 SMECO purchased an approximately four-mile (6.44 km) long radial 69-kilovolt (kV) transmission line that feeds a critical facility owned by an important SMECO customer. The line was originally built in the 1940s and is the primary source of power outside of the facility's generator system. When the line was purchased by SMECO, it was understood that previous maintenance had been minimal and eventually a significant portion of the line would need to be replaced.

In 2018, after performing routine maintenance and pole replacements as needed, a route study was performed by SMECO identifying that the first 2.5 miles (4.02 km) of line needed to be rebuilt. There were numerous challenges that had to be addressed, including:

- The line would have to be rebuilt while the existing line was energized due to the radial configuration.
- an abandoned railroad parallel to the line, which had been converted to a hiker/biker trail with significant pedestrian traffic.
- that the line traverses part of the Mattawoman Creek watershed, which is recognized to be a critical area by the Environmental Protection Agency (EPA).

SMECO realized that standard construction practices would not be practical within the project's parameters. In conjunction with the project engineer, Booth & Associates, SMECO evaluated several options for rebuilding the line. It was determined that the most practical option was to rebuild the line using composite poles on an offset centerline 10 feet (3.05 m) from the existing centerline.

Existing wood pole line condition. Courtesy of SMECO.

ADDRESSING ENVIRONMENTALLY SENSITIVE AREAS

The railroad track that was converted into a hiker/biker trail runs through the Mattawoman Creek Watershed, designated by the EPA as a critical area and recognized as a Tier II watershed by the Maryland Department of Natural Resources. Any new development and construction in this area is severely restricted, and construction projects have been denied in the past to protect this area. Acquisition of new right of way for a new line was deemed not feasible for the project and the exiting right of way was to be followed.

CONSTRUCTION EVALUATIONS

The 69kV line is situated along the Northern side of the hiker/biker trail in existing right of way that is shared with the trail. To minimize outages, new tree clearing and environmental impacts, the option chosen was to rebuild the line parallel to the existing line and edge of the pavement. The existing centerline was approximately 15 ft. from the edge of pavement with the conductors attached to cross arms five feet on either side of the pole. The new structures were located an average of 10 ft. (3.05 m) away from the existing structures with approximately 5 ft. (1.52 m) between the new structure and the existing nearest 69kV conductor. This five-foot separation exceeded the OSHA minimum approach distance of 3 ft. 40 in. (.01 m) for 69kV, but by less than 2 ft. (.61 m).

A vertical phase configuration was used with the insulators positioned away from the existing line to provide maximum clearances for conductor stringing operations. This allowed work to be completed between the first structure outside the substation and the next to last structure on the line without an outage. Outages would only be required for installing the new conductor between the substation and the first structure and between the last structure and the next to last structure to tie into the existing line. Once the new conductors were installed, the existing pole line and conductors would be removed while the new line was in service. Three pole materials were evaluated for use on this project: wood, steel, and composite. Constructability and maneuverability were determining factors during the evaluation. There were pros and cons for each of the pole types considered.

- Wood poles are much heavier and would require larger equipment for installation and transportation during construction, increasing the risk of damage to the hiker/biker trail. In addition to being the heaviest of the material options, the wood poles are also the most cumbersome to maneuver. Wood poles must be set as one piece, and there were concerns that minimum clearances could not be maintained from the energized line during the pole setting process.
- Steel poles are typically manufactured in two-piece sections that can be delivered separately, and the smaller sections would be easier to maneuver along the trail. The sections are heavier than composite sections, and fewer steel pole sections can be hauled at once using lightweight equipment. This required more travel along the trail, increasing the risk of damage.

Existing hiker-biker trail. Courtesy of Booth & Associates.

Southern Maryland Electric Cooperative Pole Analysis			
Option	A	B	C
Material	Wood	Steel	Composite
Life Expectancy (years)	50	80	80
Maintenance	Required treatment every 3 years; insects, fungus, woodpeckers	None	None
Set Case without Outage	No	Yes	Yes
Stock Item	Yes	Yes	No
Portability	Heaviest and longest; 1 piece	Mid-weight; 2 piece	Lightest; multipiece
Pole Drilling	Drill holes	Predrilled	Predrilled

Since the steel poles are two sections, all the pole bases could be set without an outage on the existing transmission line.

- Composite poles can be manufactured in multiple sections that are shorter than steel pole sections. They are light enough for pickup trucks to be used to transport each pole section to site. The ability to use lighter equipment helps reduce the risk of damage to the trail and additional costs to the project. Just like steel poles, composite poles are fabricated in sections, and all the pole bases could be set without an outage along the existing route. Steel and composite poles were both higher in cost than comparable wood poles, but they both lowered installation costs by reducing outage requirements.

Composite poles were chosen over wood and steel for their lightweight construction, long life expectancy and overall project cost compared to wood and steel.

The composite poles selected utilized straight round sections spliced together with a coupling that slides over the outside of the two sections, secured in place using acrylic adhesive and set screws. Construction could require a pole top to be set and put under conductor load during a single two-day outage. It was critical that an acrylic adhesive be selected that had a quick set time even during the cold winter months when the work was planned. The composite pole manufacturer worked with SMECO to select an alternate adhesive with a set time of 30 minutes at 14°F (–10°C), which was deemed acceptable. There were also locations on the line where the contractor wanted to use pole foam to backfill the pole base annulus to eliminate the risk of unsuitable soils for backfilling. The composite pole manufacturer confirmed that neither the naphtha in the pole foam nor any of the other components would have any adverse effects on the pole integrity. Although the chemicals could affect the paint applied to the pole at the factory, it would be out of sight below grade.

MINIMIZING CUSTOMER OUTAGES

Several options were considered to minimize the outages required during construction. The option chosen was to install all the bottom sections of the poles first and then set the top halves in two separate segments between dead-ends. Installing all of the lower pole sections at once eliminated the need for any temporary reconfiguration of the existing deteriorated poles. By avoiding temporary hot line transfer of the existing conductors to the new poles, the possibility of existing hardware failure causing an outage during construction was avoided. This strategy of setting all of the pole bases before the pole tops, which shortened the outage requirements for pole setting, only works for multi-section pole designs such as steel and composite poles.

It was determined that two outages were still needed before the circuit could

Lifting the pole top into place with line energized. Courtesy of SMECO.

Backfilling of poles with foam. Courtesy of SMECO be energized. However, the separation between the new line and the existing line was great enough that the majority of the conductor could be strung without an outage. This would be done by using dead-end strain structures for the first pole outside the substation and the last pole prior to tying into the existing line and stringing conductor between the two floating dead-end sets.Temporary guys and anchors would be utilized for the conductor pulls. An outage would only be needed to string conductor from the source substation to the first pole outside of the substation and install jumpers to the existing line. This would require much less outage time than would be needed to string the entire line at once.

CONSTRUCTION PLANNING

After finalizing dates with the facility, construction was scheduled to begin in the winter of 2019 to support March outages. Prior to starting, a thorough on-site review of the existing transmission line and overall project was conducted with SMECO, its contractor and county staff to coordinate the closure of the trail. Extensive safety protocols were put into place for pedestrian traffic including portable barriers, signage, personnel dedicated to controlling construction traffic, and continuous trail monitoring.

Because all the poles were guyed, direct buried and backfilled with pole foam, the project avoided concrete trucks on the path. County staff was highly impressed with the safety and construction plan and agreed to the closure of an entire trail section and allowing weekend work as needed, further accelerating construction.

Outages were scheduled for Thursday through Sunday when the facility was operating with less staff for conductor cutovers. During the first outage, an issue occurred, and facility asked for the line to be quickly returned to service after only one day. Crews were in the middle of pulling wire into the substation, but in less than four hours after SMECO received the call, the line was restored.

With the first section of the line complete, focus turned to the last segment of construction and the facility's resistance to allow a second extended outage. In order to minimize the second outage to complete the line, a plan was created to have all the conductor installed without requiring an outage.

Construction complete. Courtesy of SMECO.

To ensure there was adequate clearances to set the pole tops safely. SMECO's contractor surveyed the line on their own to confirm the OSHA minimum approach distances were being met. Once the top pole sections were set, the second outage was only needed to install jumpers and remove poles. This turned out to be prudent, as shortly after the second outage began, one of the facility generators failed. Work was completed and the line returned to service the same day. Construction was completed without the use of heavy equipment and restoration was completed in less than a week.

CONSTRUCTION COMPLETE

Though it was only 2.5 miles (4.02 km) consisting of 55 poles, the rebuild of an existing, radial 69kV line presented numerous challenges to overcome. In today's world, acquiring new right of way can be detrimental to a project and using existing routes is typically the most prudent option. Because of this, SMECO chose to rebuild a section of line through environmentally sensitive areas in existing right of way to eliminate risk since the rights were already there. Careful coordination between the local government and the facility owner had to be managed to ensure success.

The project team also managed concern through extensive outreach to all affected parties and starting planning early in the process. Communication is always key, and everyone was candid and upfront with affected parties about the construction process and timing. This, in turn, earned their trust that SMECO and the contractor would do what is right. The relationship with the trail staff to this day is paying dividends as they have taken it upon themselves to monitor the line and inform SMECO of line issues before they become significant. Trail staff even does touch-up paint on the base of the poles as a courtesy to SMECO.

From the outset of the project, SMECO realized that their standard construction practices of heavy wire and steel poles would not be ideal. A new type of construction would have to be implemented to reduce construction time and costs while still maintaining safety and reliability. Lightweight composite poles helped SMECO achieve that goal.

The construction team performed admirably throughout by accelerating construction and identifying risks ahead of time. Because of this, the project was completed with only two outages lasting a total of two days when the original plan called for 8 days of outages. It is often thought that the larger the project, the more difficult and challenging it will be. While that is generally the consensus, significant challenges can come with any type of project large or small. TDW

HUGH VOEHL III is the Transmission Engineering & Construction director with Southern Maryland Electric Cooperative in Hughesville, MD. Voehl received a B.S. in Mechanical Engineering from the Johns Hopkins University and has over 20+ years of experience in the utility industry.

JOHN WILLIAMS, PE is the vice president of the Baltimore office for Booth & Associates. He graduated from North Carolina State University with a BSEE. He is a registered professional engineer and has 22 years of experience designing transmission and distribution projects.

Optimization of Transmission Line Structures

BRACED POST INSULATORS HAVE REPLACED SUSPENSION INSULATORS FOR THE COMPACT DESIGN OF POWER LINES

By **DIMITRI GEORGOPOULOS**, REVMA Powerline Consulting; **KUMAR KISHOR**, AltaLink L.P.; **JEFF FRASER**, West Power Energy

Modern transmission line projects face several challenges with different priorities than projects in the past. There is now more emphasis on reducing environmental impacts, producing aesthetically pleasing designs, public acceptance, lowering life cycle costs and minimizing right-of-way widths due to ever rising land prices. All this needs to be considered while maintaining a safe, robust, and reliable design.

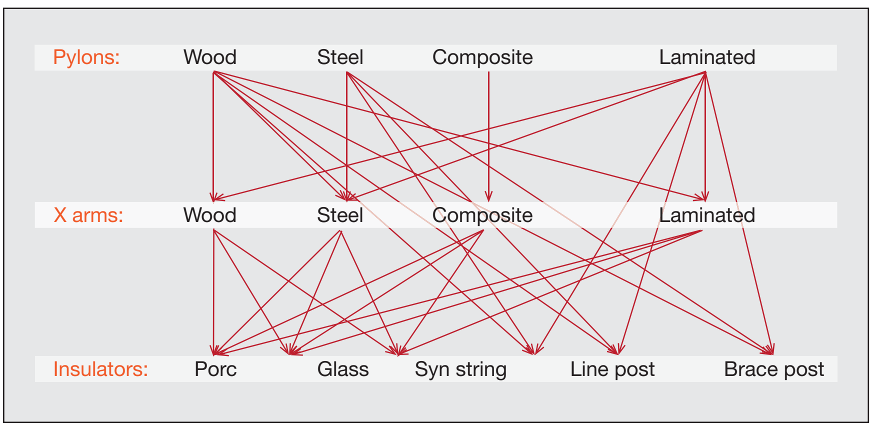
One option that has gained popularity over the past few decades is the use of post and braced post insulators instead of traditional suspension strings for 69kV to 240 kV applications. Depending on the location and voltage class of a project, braced post insulator designs might prove to be the optimal design option for designers. There are now several manufacturers that can provide custom post insulators tailored to the specific needs for any structure design.

OPTIMAL HEAD (PHASE CONFIGURATION) DESIGN

In our present state, simplicity is difficult to obtain only because over the years we have created a complex web of choices or what one can refer to as the 'MENU' in the graphic. The secret to simplicity is to 'regularly' review new and legacy material and designs with a 'holistic analysis' approach and remove what is no longer appropriate. This will ensure a lean and effective menu.

Labor costs are the highest component of project costs, therefore promoting designs that decrease labor is key. By reducing the 'menu' it also provides a tremendous opportunity to reduce the appropriately corresponding materials kept in stock to a minimal requirement.

There are six single pole 138kV tangent structures in AltaLink's current 'menu' that functionally serve the same purpose. Two are holistically more efficient and cost effective than the other four, so why stock material for all six when two will suffice for greenfield, brownfield and operational maintenance remediation including urgent and emergency repair?



The 'Menu' confusion: focusing on optimal means reducing the items on the menu. Courtesy of AltaLink

The improved post designs are "simple." Unlike legacy designs, they basically require six bolts with nuts and washers. Simplicity in design not only reduces the amount of material per structure it also reduces the 'variability of material'. This means there are not only fewer pieces to install but less variability of pieces which has the advantage of reducing labor cost due to quicker installation.

Not only are post designs simple, but they are also very versatile. Designing with posts allows greater head design flexibility to manage many environmental, manmade and design adversities with the same material and multiple configurations (Modular Design).

Post and braced post designs manage height and right-of-way restrictions by eliminating the need for traditional I-string insulators. Vertical phase and circuit spacing can be easily reduced or increased as required with little effort (shorter spans can use less vertical spacing which will then require shorter poles). Post insulators have the versatility of being used on wood, steel or composite structures. They can be used for 138kV single circuit or double circuit framing and can also be used on monopole or H-frame structures without any additional requirements. Post insulation can be used to limit conductor swing out, which may avoid the need to widen an existing right-of-way or cut additional trees.

LINE OPTIMIZATION STUDY RESULTS

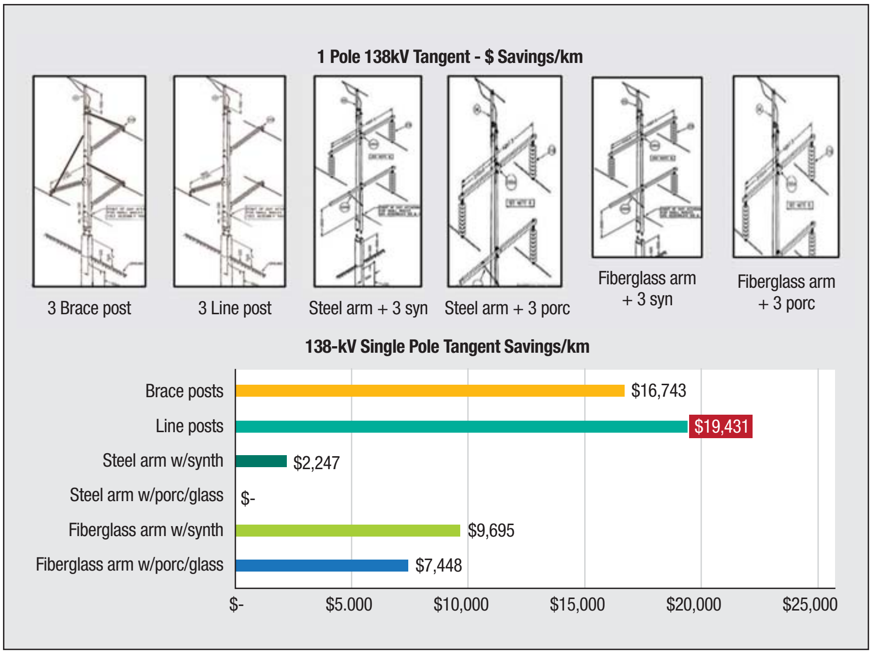
The line optimization studies (LOS) conducted over the past five years have been undertaken with the most robust analysis methodology in AltaLink's history. The projects that have been analyzed to date are 138 kV and 240 kV, single and double circuit lines.

The mandate of the LOS was to be able to cost analyze multiple line design options simultaneously, which included multiple foundation types (direct embed, pipe piles, screw pile clusters, grillage, caisson), multiple pylon materials (wood, steel, composite, FRP, lattice), multiple conductor types (266ACSR to 1927ACSS), multiple ruling spans (150 m to 350 m) and with multiple line lengths (3 km to 58 km).

With this capability we analyzed 17 projects over various geographic locations, structure loading zones (wind and ice), soil conditions and alignments (on road allowance and right-of-way) to ensure a robust and diverse sampling.

In all case studies, the results indicate post design (line-post or brace-post) on steel monopole for single circuit and double circuit 138 kV and 24 0kV was ranked the optimal design with 'the same or better functionality' and 'with the same or better reliability at less cost'.

Also, of the 17 projects, 16 concluded a direct embed or screw pile foundation contributed to the lowest cost option. This may indicate large foundations and their large costs may not be the most cost effective strategy. **DF (douglas fir) was later updated to steel due to increase in DF cost.*



138-kV tangent design and cost comparison. Courtesy of AltaLink.

CUSTOMIZED APPLICATIONS: INSULATED ARMS

Composite Insulated Cross Arms (CICAs) are not a new phenomenon. They have been on the periphery for quite some time, but have only matured to a viable solution over the past 10 years.

Insulated arms have been used in many different applications internationally and are considered viable options to AltaLink in multiple scenarios:

1. Replace lower arms on lattice towers to mitigate clearance issues.

2. Replace all arms on a lattice tower to mitigate Self Damping Conductor (SDC) corrosion issues and clearance correction.

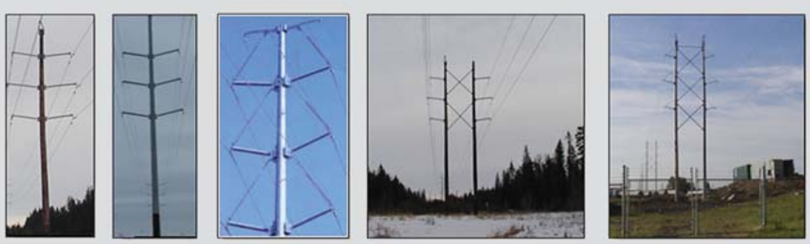
3. Thermal uprating projects.

The CICA arm replaces the entire existing lattice arm/insulator assembly with an insulated synthetic arm assembly. The benefits of this include:

- Increase clearance by 2.2m (240kV application)
- Improves maintainability
  - Can be worked on while energized
  - Can be maintained from the tower
- Customizable so it can be used for multiple voltage levels and design applications.
- Improves insulation, better contamination management capability due to improved leakage distances, hydrophobic material and self- encapsulating properties.
- Alleviates right-of-way constrictions (i.e. vintage half span line design methodology)

The analysis only included the CICA arms to replace the bottom phases of a double circuit 240kV lattice tower.

138-kV single-circuit (monopole). Courtesy of AltaLink.



138-kV double circuit. Courtesy of AltaLink.

Optimal Designs of 17 Projects.

Project	Voltage	Head Design	Pole Material	Conductor (MCM)	Foundation	Ruling Span	Length (KM)
'A'	240kV	D/C Monopole brace post	Steel	1590	Direct Embed	202M	6
'B Opt1'	240kV	S/C Monopole brace post	Steel	2X795	Screw piles	170M	58
'B Opt2'	240kV	D/C Monopole brace post	Steel	2X477	Grillage	200M	58
'C SegA'	240kV	D/C Monopole brace post	Steel	1927 ACSS TW	Screw Pile	250M	13
'C SegB'	240kV	D/C Monopole brace post	Steel	1927 ACSS TW	Screw pile	150M	23
'C SegC'	240kV	S/C Monopole brace post	Steel	1927 ACSS TW	Screw pile	200M	12
'C SegD'	138kV	S/C Monopole brace post	Steel	266	Direct embed	175M	6
'D'	240kV	S/C Monopole brace post	Steel	1590	Screw pile	240M	60
'E'	240kV	S/C Monopole brace post	Steel	1590	Screw pile	240M	50
'F'	240kV	S/C Monopole brace post	Steel	1033	Screw pile	210M	n/a
'G'	138	S/C Monopole line post	Steel	397	Direct embed	170M	n/a
'H'	138kV	S/C Monopole line post	Steel	397	Direct embed	175M	n/a
'I'	138kV	S/C Monopole line post	Steel	397	Direct embed	150M	28
'J'	138kV	S/C Monopole line post	Steel	397	Direct embed	150M	54
'K'	138kV	D/C Monopole line post	Steel	477	Direct embed	175M	3
'L'	138kV	S/C Monopole line post	*DF	477	Direct embed	175M	12.6
'M'	138kV	S/C Monopole brace post	Steel	397	Direct embed	200M	n/a

Courtesy of AltaLink.

A comparison between the original tower and the CICA modification is shown below.

The original tower and the CICA modification tower design calculations were both carried out according to ASCE 10. PLS-TOWER (version 15.5) was used to complete the structural analysis for the towers. Nonlinear analysis was selected to analyze and compare the structural strength of tower variations. The CICA modification tower has the same loading tree as the original tower ("L"). The analyzed internal force of the original tower and the CICA modification tower were similar. The structural analysis indicates there are overloaded members in both the original tower and the CICA modified tower for the load cases that were run. The stress level in the tower legs and the cross braces slightly increased in the insulated arm structure model. The leg stress levels increased by 1%, and the brace stress levels increased by 2%. These increases are deemed acceptable. It is important to note that when we reduce the length of the suspension string, the residual longitudinal tension load will be increased. This is something that must be considered when analyzing the use of a CICA arm.

Additionally, the phase separation from middle to bottom phase also needs to be evaluated. For this specific case AltaLink found the "L" tower to meet the Canadian Standards Association (CSA) phase spacing requirements.

- CICA is a new product to AltaLink, therefore it will be closely

Composite insulated cross arm (CICA) field installation. Courtesy of AltaLink.

monitored, especially the 'triple point' nose area for: Signs of erosion or arc burn on the surface of the composite insulator

- Signs of premature aging such as brittle fracture and cracking
- Signs of degumming, sealing failure, obvious slippage, etc. in the contact zone between the insulated core rod and the insulated casing
- Signs of damage on the grading ring, such as rust, arc burning, deformation and so on
- Signs of avian damage (i.e. pecking, streamers)

CUSTOMIZED APPLICATIONS: TOTALLY INSULATED FRAMING SYSTEM

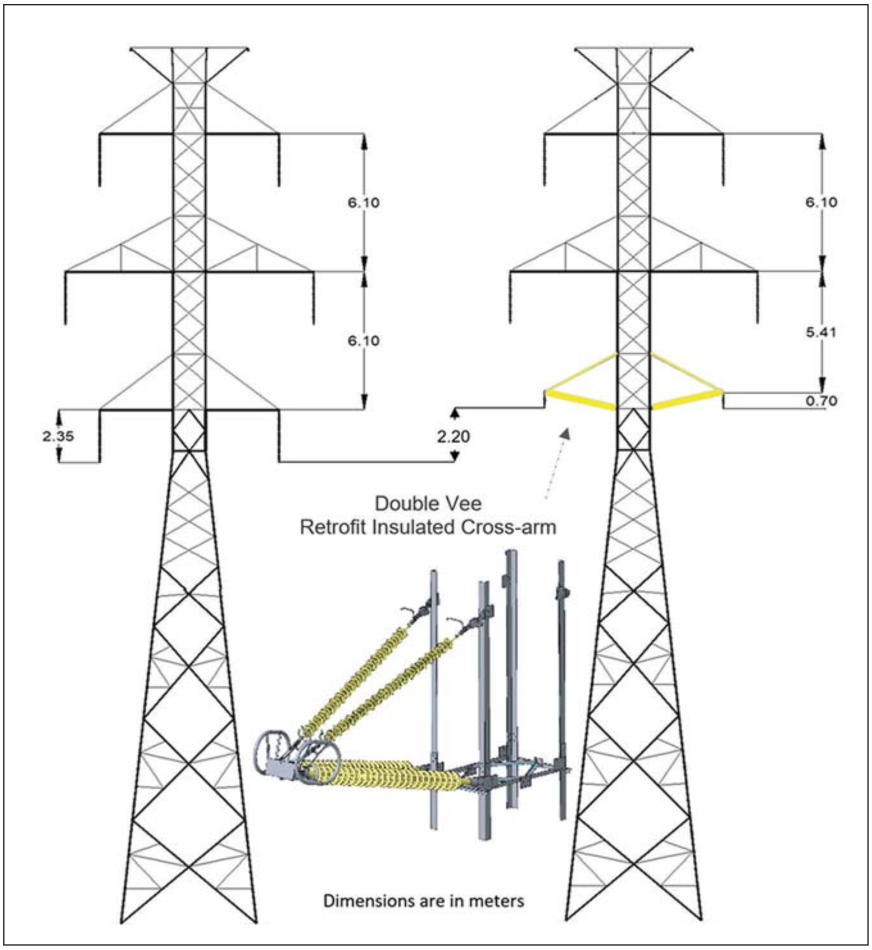
A new concept being implemented at AltaLink is something called a 'Totally Insulated Framing' (TIF) system. This is a retrofit assembly designed to completely replace the crossarm and suspension insulators for H-Frame structures. This reframing solution is specifically aimed at addressing clearance violations without having to replace the existing structure.

The TIF assembly is essentially four brace post assemblies mounted on two poles, with the middle two being joined at center phase. This design was initiated and supplied by K-Line Insulators. K-Line provided the strength parameters and the TIF was modelled in PLS-POLE to verify the strength for the site-specific loading of this structure.

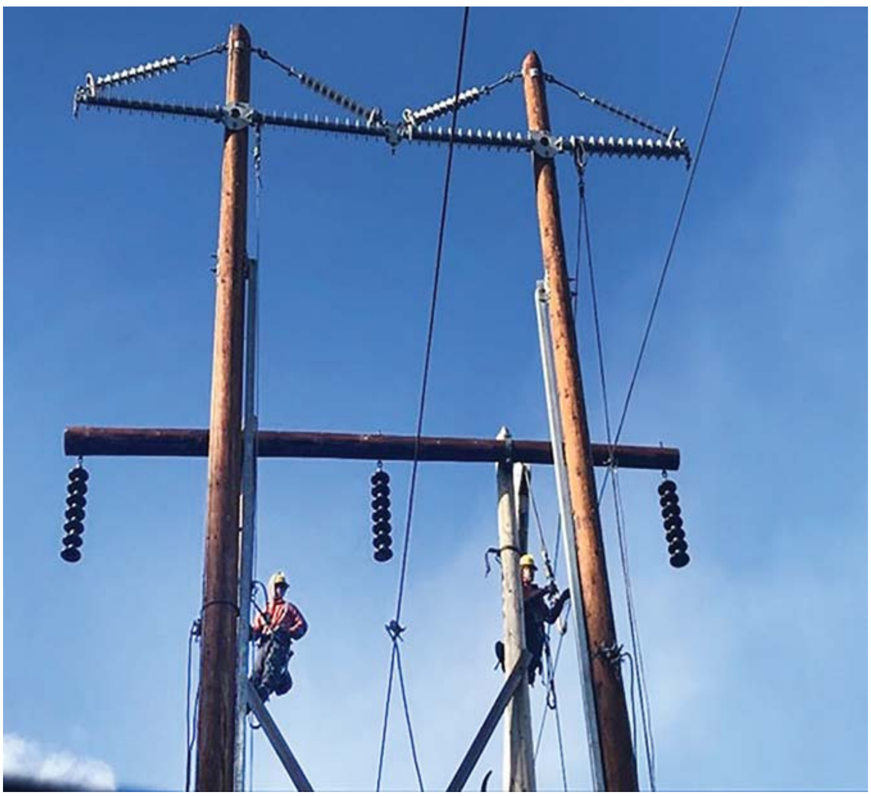
The TIF assembly was first used on the AltaLink system for a clearance mitigation project on a 138kV line. For this project, the conductor needed to be raised by one meter to address a midspan violation. The project team decided that this would be a great pilot candidate for the new TIF assembly and installed on new poles.

This project demonstrated the ease of installation and effectiveness of the TIF system. AltaLink has since added the TIF system to its 'toolbox' as a viable solution to address clearance violations on H-frame structure types.

The traditional ways of designing transmission structures with arms and suspended insulators are being challenged. These designs are proven and have been used for more than a century, but is there a better way?



Comparison between the original lattice tower and the new CICA design. Courtesy of Shemar.



Totally insulated framing (TIF). Courtesy of AltaLink.

AltaLink has initiated a Line Optimization Study process to assess the available design options and compare the old way with newer alternatives for new 138kV and 240 kV projects. This process has been fine-tuned over the last five years and has consistently shown that monopoles with post or braced post insulator assemblies are the optimal structure design. In general, AltaLink has found that braced post insulator designs reduce overall transmission project (lifecycle) cost by 10% to 15% over traditional suspension structure designs. Right-of-way width savings are harder to quantify as land prices vary by region, but it can be assumed that the land savings are proportional to the right-of-way width reduction.

Over the past 50 years, composite line post and braced post insulators have come a long way. They are now much stronger, more resilient, and versatile than ever before. The design of the braced post insulator has the flexibility to be customized for almost any application and provides a compact phase configuration; neither of these attributes can be matched by competing insulator products.

By simply using braced post insulator assemblies, an equivalent H-frame structure can be reduced to single monopole with the added benefit of lower lifecycle and right-of-way maintenance costs. There is also evidence that the fire risk will be reduced due to contamination resistance (hydrophobic) of a composite braced post insulator.

Every utility should consider the use of braced post insulator assemblies and the benefits they can provide for new transmission line projects. Braced post insulators may not be the preferred solution for every project, as they do have their limitations, but they provide flexibility to meet the needs of external stakeholders that older designs of the past could not. Transmission utilities worldwide have been increasing the use of line post and braced post insulator assemblies over the past few decades because of the benefits they provide. Based off the line optimization results from AltaLink there seems to be good reason for this. TDW

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JEFF FRASER is a senior civil engineer and a Transmission Lines team lead with West Power Energy, an engineering consulting firm specializing in transmission line design. He is a registered professional engineer in provinces of British Columbia and Alberta. Jeff has over 11 years of experience in the industry in all areas of Transmission line design with familiarity in the use and construction of steel, FRP & wood pole structures.

DIMITRI GEORGOPOULOS is a registered Professional Licensed Engineer in the Province of Alberta. He is a Consultant (REVMA Powerline Consulting) specializing in Transmission Line Optimization and Innovation. Dimitri has over 42 years of powerline experience with a core focus on insulation and its effect on optimizing structures and lines based on the principles of using a holistic value engineering analysis strategy.


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New Neo-Panamax cranes passing under the transmission line crossing. Image courtesy of Duke Energy Progress

A Tall Order: Duke Energy's North Carolina State Ports Authority Project

THE EXPANSION OF THE PANAMA CANAL REQUIRED UPGRADING CRITICAL TRANSMISSION INFRASTRUCTURE.

By **JOHN TAYLOR**, Duke Energy, **GANGA PONTULA**, formerly of Duke Energy; **E.J. BENTON** and **BEN WADSWORTH**, Pickett and Associates

Cargo ship sizes are literally reaching new heights. The expansion of the Panama Canal in 2016 allowed for larger vessels to call ports in the United States. These larger vessels, classified as Neo-Panamax, stimulated a flurry of upgrades to ports in the Americas to accommodate the Neo-Panamax vessels. This included the North Carolina State Ports Authority's (NCSPA) $200 million capital investment plan for the Port of Wilmington.

The NCSPA also requested Duke Energy to increase the air draft at a double-circuit 230kV transmission line crossing that was downstream from the Port. Increased air-draft would first be required for the delivery of new larger cranes to be installed at the Port and ultimately allow for the safe passage of the New-Panamax vessels themselves.

Duke Energy's 230kV double circuit transmission crossing was constructed in 1972 and consists of three spans totaling 6,080 ft .(1,853.18 m) in length. There are two 335-ft. (102.1 m) tall steel lattice structures located in the river on each side of the shipping channel. The channel crossing span is approximately 2,000 ft. (609.6 m). The three spans are anchored on each bank of the river by 115-ft. (35.05 m) tall, guyed, lattice structures. The 1972 installation provided for 165 ft. (50.29 m) of air draft above mean high water (MHW).

NOT WITHOUT CHALLENGES

The Port's request to raise the line crossing for the crane delivery and the Neo-Panamax vessels was not without challenges. The cranes were to be delivered the following year, providing little time. The channel was also on a busy waterway that commerce depended upon. Therefore, the channel needed to remain open as much as possible. Additionally, both crossing circuits connect to the nearby Brunswick Nuclear Plant. Thus, at least one of the two circuits had to remain energized. Last, but not least, the crossing is situated in the environmentally sensitive Cape Fear estuary. Taking all this into account, the project team set out to devise a plan that accommodated the Port's clearance needs while also considering the associated cost.

ONE THING AT A TIME

The cranes were to be delivered the following year. Raising the double circuit lines by this time seemed like an impossible task. Undaunted, the team decided to focus on the issue at hand. The team set forth to determine exactly how much additional clearance was needed for the rapidly approaching crane delivery. A scaled drawing was developed that integrated the position of the cranes on the transport vessel relative to the transmission line conductors. Then, an as-built PLS-CADD model was developed based on a LiDAR (Light Detection and Ranging) survey, finite-element wire model, and data from various sources, including the Army Corps of Engineers.

Using the model, the project team determined that 12 ft. (3.66 m) of additional clearance was required. Conventional ground surveys were used to validate the determination. Additionally, the team went as far as to survey the actual height of the cranes before they left their port of origin in China.

The team now had a clearly defined target and they moved forward to achieve the 12 ft. (3.66 m) goal. Ultimately, the team hatched a plan to temporarily raise the bottom conductors. The double circuit configuration consisted of two circuits with three vertically aligned phase wires on each side of the crossing towers, six phase wires in total. Given the outage constraints, one circuit, or three phase wires, had to remain energized.

The team devised a plan to reconfigure the circuits so that the top phase wire on each side along with one of the middle phase wires would comprise one circuit rather than having a circuit on each side of crossings towers. This would allow for the bottom conductors to be deenergized. Once deenergized, the bottom conductors could be detached from their insulators, hoisted up and attached directly to the tower arm. The hoists would be attached to the middle arms above.

However, many other events had to take place before the plan to temporarily raise the conductor could be implemented. First, the condition of the existing structures was evaluated. This included developing a tower climbing plan and then physically climbing the towers for visual inspection. A dive team was also deployed to inspect the foundations in the river.

Fortunately, the towers and foundations were found to be in good condition. Then, the loading conditions for each step of the construction sequence were evaluated. The construction team devised plans for how the rigging and hoists would be attached and how tools and equipment would be transported up hundreds of feet above the river. Additionally, the team coordinated with several stakeholders, including the Port and the Cape Fear River Harbor Safety Committee, regarding the need to close the channel at times. Switches and jumpers were also installed on the two circuits to allow for the power to be shifted between phase wires and the bottom phase wires to be deenergized.

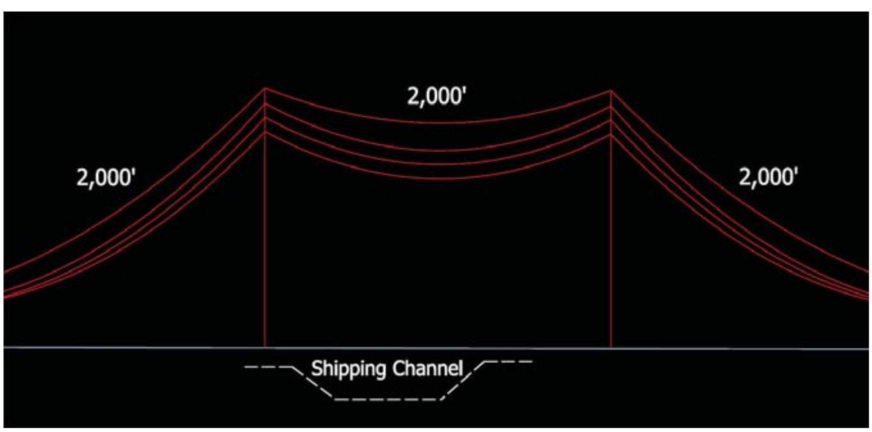
Map showing the shipping channel to the Port of Wilmington. Image courtesy of Pickett and Associates.

With all the pre-work done, the temporary phase raise was completed, and the green light was given for the new crane delivery. It was a typical spring morning on the North Carolina coast, with clear skies, light winds, and mild temperatures, when the transport vessel entered the meandering shipping channel and progressed towards the tower crossing. Tide charts were checked once again, and the survey equipment was readied to check the cranes' travelling height one last time. The Cape Fear River Harbor Safety Committee stopped all other marine traffic in the channel. The surveyors confirmed the height was as expected and the cranes passed safely underneath the line crossing. The first part of the request had been achieved.

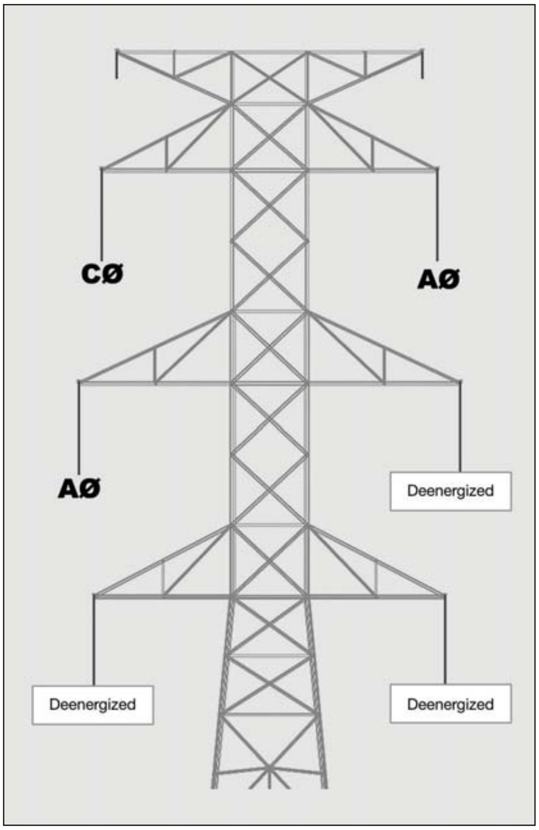
ON TO THE PERMANENT SOLUTION

After the cranes were delivered, the wires were returned to their typical configuration. Now, the team turned their focus on finding a long-lasting solution that increased the air draft at the line crossing enough to allow for Neo-Panamax vessels to begin calling the Port. The team evaluated numerous options, including various modifications to the existing line, building a totally new overhead line, and even putting it underground. Each potential solution was scored based on environmental impact, time, schedule, and the long-term reliability and resiliency.

Ultimately, the team decided to reconfigure the double-circuited, vertically configured towers to a double-circuit, delta-type configuration. This would increase the air draft by 28 ft. (8.53 m). The middle arms would have to be replaced with longer arms that could accommodate two phase wires on each side rather than one. The



Elevation view depicting the line crossing geometry. Image courtesy Pickett and Associates.



Temporary phasing configuration to allow for crane delivery. Image courtesy of Pickett and Associates.

bottom arm was to be removed and its phase wire would be relocated to the new arm above it.

Additionally, the team decided to replace the 2500 AACSR conductor that was installed at the time of the original construction in 1972. The conductor would be replaced with new low sag high temperature ACCR conductor. A new ACCR conductor type was designed for the crossing that met the ampacity needs while also reducing the diameter and maximum sag when compared to the original AACSR conductor. The conductor replacement allowed for an additional air draft increase of 13 ft. (3.96 m). Thus, the permanent solution would allow for a 41 ft. (12.50 m) air draft increase so that the new clearance above MHW was 206 ft. (62.79 m).

Even more so than the temporary solution, much pre-work had to be completed prior to the beginning of construction. First, new loading requirements were determined based on upgrading the towers to today's loading standards, the new delta configuration, and the new conductor. Then, the structures were evaluated for the new loading requirements. The team determined that some members must be replaced and sized those in addition to designing the new longer tower arms. A sequence was then defined on what order the individual tower members must be replaced. The loading evaluation also considered specific construction loads. For instance, the original bottom arms must be removed and hoisted down to the river using the original middle arms. Thus, the team checked to make sure the original middle arms could handle this loading condition.

Once the tower members and arms had been evaluated and designed, they were fabricated in Texas. One of the arms was assembled at the steel manufacturer's facility and the team traveled to the facility to evaluate the fit-up. A replica of the middle portion of the crossing towers where the new arms would attach was also assembled so the fit-up between the new arms and existing tower body could be checked. Minor adjustments were noted that included adjusting some of the connections to ensure working room for tightening bolts.

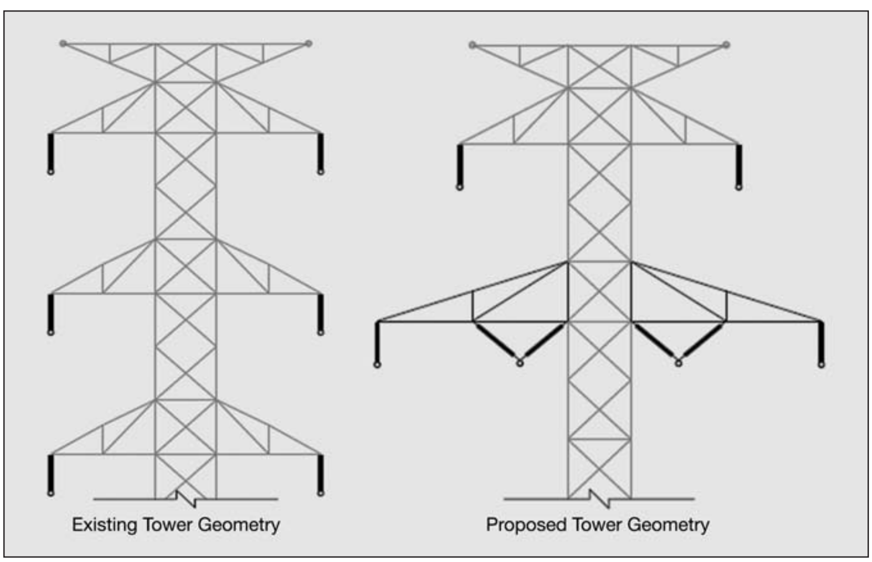
As with the temporary solution, much coordination took place with the many stakeholders regarding the construction schedule. The channel would have to be shut down several times over the course of the construction period.

Construction began in August 2019. Through the course of construction, twelve channel closures were required, each closure consisting of three days. The construction team faced many challenges including Hurricane Dorian passing through the area in September 2019, as well as record temperatures. A record-high temperature was experienced (or endured) in October 2019 as well as record low temperatures in November 2019. The team took it all in stride and construction was completed in January 2020.

HISTORIC ACHIEVEMENT

History was made on May 20, 2020, when the MV Hyundai Hope with an air draft of 204 feet crossed below the newly raised Cape Fear River transmission crossing; the ship is one of the largest container ships calling on the United States East Coast and was the largest to ever dock in North Carolina, according to a 2020 article of Wilmington Business Development. The Port's ability to service the Neo-Panamax vessels like the MV Hyundai Hope will provide lasting economic benefits to the state of North Carolina.

In summary, the project team added a total of approximately 41 ft. (12.50 m) of additional clearance. The reframing provided 28 ft. (8.53 m) of extra clearance and the new low sag conductor provided over 13 ft. (3.96 m) of additional clearance. The line switches and jumpers that were installed on each side of the crossing during the temporary solution will continue



Comparison of original and new permanent tower configuration. Image courtesy of Pickett and Associates.

New ACCR conductor compared to original AACSR conductor. Courtesy of 3M.

to remain in place to provide flexibility to adjust which phases are energized for future maintenance.

The final solution had three main benefits: 1) it was preferred from a cost and environmental impacts perspective, 2) it met the port authority's timeline and clearance needs, and 3) improved future reliability for customers in the area. TDW

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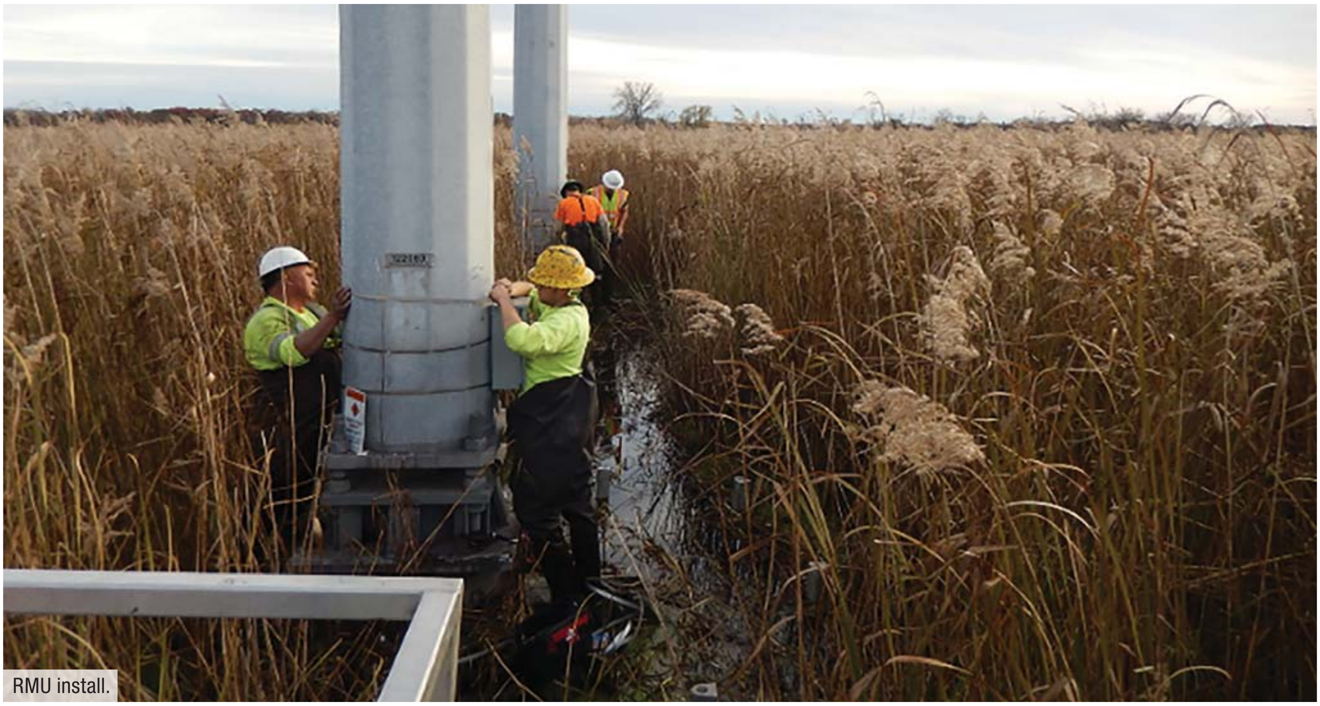
GANGA PONTULA, PE, (*gpontula@gfnet.com*) is a senior consultant and supervisor at Gannett Fleming with over 20 years of experience in the power industry and is a licensed engineer of North Carolina. Specializing in the design of electrical transmission lines and its components in various challenging conditions, his experience includes generation planning and corporate strategic analysis. He received his master's degrees in mechanical engineering from Purdue University and in transmission and distribution engineering from Gonzaga University.


RMU install.

What You Can't See Can Hurt You

CATHODIC PROTECTION TECHNOLOGY PROVIDES SOLUTIONS TO PROTECT ELECTRIC UTILITY STRUCTURES.

By **KEVIN NILES**, Osmose Utilities Services Inc.

Corrosion of steel structures in electric transmission, distribution, and substation applications has been around for many years, but it's getting more attention as electric utilities become more aware of the problem. While corrosion can affect any portion of the structure, it is particularly aggressive below grade where it is the most difficult to access. Because of this and other factors, electric utilities are beginning to initiate programs to assess structures for corrosion damage. They are evaluating restoration options and implementing corrosion mitigation to extend the useful service life of these important assets.

STRUCTURAL ASSESSMENT

The structural condition of steel structures is typically determined by measuring structural components and calculating the loss of strength. As structures are evaluated, they can be grouped into specific condition categories for more effective management. Structures in good condition with little or no corrosion can be scheduled for reassessment during subsequent assessment cycles. There are, however, structures needing more immediate attention, which can be focused on for immediate follow-up. Corrective actions can include restoration and application of coatings and cathodic protection.

This system allows for better management and helps estimate budget dollars more accurately for follow up action. By utilizing a recurrent cycle of assessment, mitigation and restoration the reliability of older structures can be greatly improved.

ENVIRONMENTAL ASSESSMENT

The rate at which steel corrodes belowgrade varies significantly based on site conditions, especially soil. Environmental factors at any given site can be evaluated through the collection of soil conditions and characteristics to determine potential corrosion activity.

Primary risk factors in the local soil environment include, but are not limited to, soil resistivity, structure to soil potential, soil pH and REDOX or the oxygen reduction reaction. Other contributing factors can include time of wetness, temperature, land use and soil contaminants (i.e., chlorides)

The evaluation of this data is used to categorize structures into manageable groups for follow up mitigation. The categories can be defined as follows:

- **Mild** – Slightly elevated environmental factors that indicate potential for corrosion. Structures are at the threshold where they may require some type of mitigation to prevent the start of corrosion activity.
- **Moderate** – More serious potential for corrosion activity. Structures should have some type of mitigation applied to offset corrosion deterioration.
- **Severe** – Factors indicate a severe corrosion risk. Structures should have mitigation applied in the form of coatings at a minimum and be evaluated for cathodic protection.

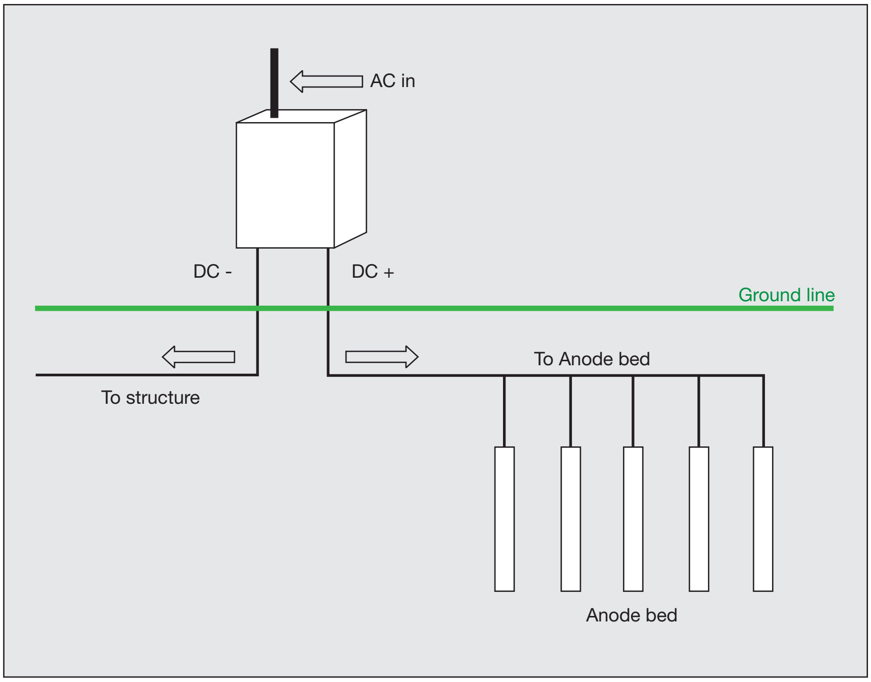
As environmental site conditions are not static, structures should be reinspected at regular intervals or anytime site conditions change due to nearby construction, agricultural activity, or other contributing factors.

MITIGATION

The most practical and effective mitigation efforts include the application of protective coatings. Coatings are the primary means of corrosion protection in most corrosion control systems because they create a barrier on the steel surface to protect against corrosive elements.

Coatings are available in several different types to suit a wide variety of applications in almost any environment. It is very important that the correct coating is selected and properly applied to achieve the desired level of protection.

However, in many instances when coatings alone are not sufficient to protect structures from the effects of corrosion, an additional level of protection can be applied in the form of cathodic protection.



Rectifier general overview. Courtesy of the author

CATHODIC PROTECTION

Cathodic Protection (CP) is an advanced secondary method of corrosion mitigation often used in conjunction with coatings, but also used separately when conditions dictate.

Through the installation of CP, corrosion activity can be effectively transferred to sacrificial anodes. Through this application, the anodes now corrode in place of the structure. Installation is typically achieved by placing the anode in soil near the structure and bonding it to the structure by a conductive lead wire.

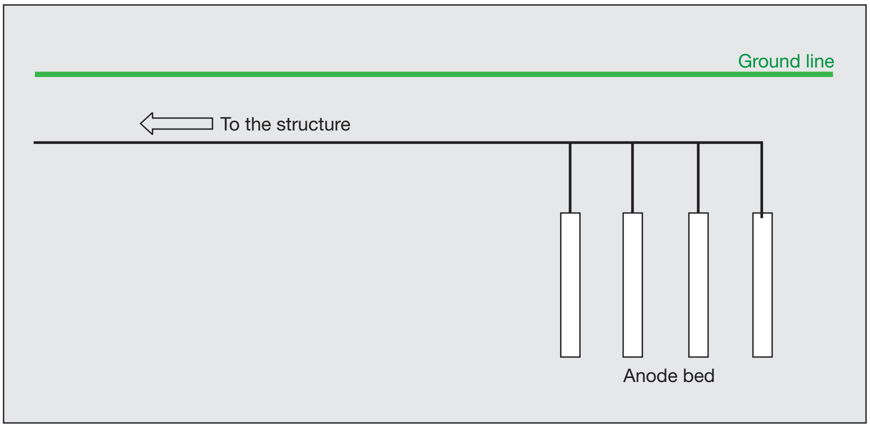
TYPES OF CATHODIC PROTECTION

Impressed Current Cathodic Protection (IC-CP) systems are considered an active protection system typically used on large structures, like oil and gas pipelines and other applications where there is need for more protection.

IC-CP uses anodes of various specialized materials connected to a rectifier. These systems are commonly used when the surface area of the structure being protected is large (pipeline, tank farms, ships, and offshore platforms) and the CP requirement needs are constant.

Even though IC-CP is more active and can protect large constructs it does have limitations:

- **Cost** – on average rectified systems are more costly to purchase, install, and maintain.
- **Power** – they require a consistent source of power which can be a challenge in remote areas.



Galvanic anode overview.

Bare anodes.

- **Maintenance** – IC-CP systems require frequent periodic inspection and maintenance at regular intervals.
- **Age** – depending on the manufacturer as rectifier models age their components may no longer be readily available requiring replacement.

Galvanic Cathodic Protection systems protect the structures they are bonded to by means of simple galvanic reaction. Because the anode is higher in electrochemical potential than the steel it therefore has a more "active" potential. The corrosion process is transferred from the steel to the anode. These are considered passive systems because they rely on surrounding site conditions to drive the anode reaction.

The majority of cathodic protection installed for electric utilities is galvanic due to its ease of installation, limited maintenance requirements, and lower costs.

Some of limitations of Galvanic CP systems include:

- **Size** – typically used on smaller structures where the CP needs are less.
- **Adjustment** – performance cannot be adjusted without the addition or removal of anodes.
- **Limited protection** – greater protection cannot be achieved by simply adding more anodes. At some point, the balance of performance vs. cost limits the number of anodes applied.
- **Seasonal performance** – dependent on-site conditions and may become dysfunctional, if they dry out, especially if they are set shallow.

SIZING AND SELECTION

The type and number of anodes installed at each structure vary based on the exposed surface area of the structure and surrounding soil conditions. The size and length of the anodes also vary and are selected depending on several factors including expected performance, site conditions, and design criteria.

Galvanic anodes come in two different forms; either unpackaged (bare –) or packaged with an engineered backfill (bagged). Each has its benefits and specific uses and can be selected based on application requirements.

The backfill contained in the bagged anodes is most often composed of gypsum, bentonite, and sodium sulfate. This material absorbs water and helps to provide a uniform saturation of the anode so it can achieve its full protection potential more quickly after installation. Backfill is also available packaged separately for application with bare anodes.

Bagged anodes.

CRITERIA AND MONITORING

Regardless of the type of cathodic protection, there are three primary CP industry standards used by the Association for Materials Protection and Performance (AMPP) previously the National Association of Corrosion Engineers (NACE) to ensure protection and performance on buried steel (NACE SP0169). It is not necessary to meet more than one of the following:

- Considering all current and resistance drops and with CP applied, achievement of structure to soil electrochemical potential measurement of equal to or more negative than *-.850 mV_{cse}.
- Assuming no current or resistance drop and with CP applied, achievement of structure to soil electrochemical potential measurement of equal to or more negative than *-.850 mV_{cse}.
- Considering the existing structure potential and with CP applied, achievement of a polarization change or "shift" equal to or more negative than *100 mV_{cse}.

**With reference to a $CUSO_4$; (Copper/Copper Sulfate) reference cell.*

PLUG AND PLAY: REMOTE MONITORING SYSTEMS

Regular assessment of CP systems is necessary to ensure performance but can be costly and represent challenges when

RMU install.

installed in remote, restricted, or difficult access areas.

Because of this, modern Remote Monitoring Units (RMU) can be used to monitor performance from a distance. Designed to regularly transmit information through cellular networks or via satellite, RMUs have been developed to periodically access cathodic protection performance without the need to visit the site.

After installation, the RMUs can be configured and programmed via Bluetooth using a downloadable cell phone or tablet app connection. When active, the RMUs "wake up" on a regular schedule and collect measurements of the CP system's performance, communicate that information to the electric utility customer, and then goes back into hibernation.

Once the RMUs are installed, setup can be verified by means of contact with the monitoring service provider so their operations can be verified before leaving the field.

The user account is set up through the monitoring service provider similar to the setup of a new cell phone service. The electric utility customer retrieves their information by logging in to their personalized account and viewing the data via webpage. This information can be downloaded in the form of a Microsoft Excel spreadsheet for viewing and record retention.

The typical download information can be customized to include:

- Site name (structure number)
- Battery status
- Performance (amp output, structure potential, individual anode performance, etc.)
- Security (open door)
- Temperature

Units come in various sizes, capabilities, and program options so it's important to determine the correct model well in advance of any installation project.

ECONOMICS

Electric utilities across the U.S. are struggling to assess their risk on thousands of assets and pressures on operations and maintenance (O&M) budgets seem to grow daily.

While scraping together enough spare O&M budget for a small project may work occasionally, it likely won't address the long-term financial support of an effective asset management program.

Because steel structures are defined as "long-lived (fixed) assets" which incur "post-acquisition expenditures" during their service life, costs associated with measures are expected to provide a more permanent benefit in longevity, utility, or worth (betterments) that can be capitalized.

To meet the betterment definition under Generally Accepted Accounting Principles (GAAP), the measure must improve the asset in at least one of four ways:

- Increase the asset's useful life over that which was originally estimated.
- Improve the quality of the asset's output.
- Increase the quantity of the asset's output.
- Reduce the costs associated with operating the asset.

The use of capitalized budget dollars on the installation of cathodic protection systems meets the unit of property threshold under the Federal Energy Regulatory Commission (FERC) criteria and resets the appreciation/accounting time cycle on the asset.

Though corrosion deterioration is still a large problem for electric infrastructure, there are many options to address the growing concern.

Galvanic cathodic protection is simple, relatively inexpensive to install, and usually requires low maintenance, while providing reliable corrosion protection for the structures. When integrated into an effective assessment management program, valuable time and resources can be saved for utilities.

With the utilization of these combined technologies, the idea of "plug and play" cathodic protection systems are at hand and may now be more attractive to utilities who have avoided their use in the past.

It is hoped that this information generates further interest and investigation into practical economic corrosion control solutions to help maintain the national power grid through the responsible use of practical economic solutions that improve system reliability and resiliency. TDW

KEVIN NILES is a product manager and Corrosion Engineer employed by Osmose Utilities Services, Inc. with over 30 years of experience in the Electric Utility Industry assessing, maintaining, and restoring steel and wood utility structures throughout the US, Canada and Australia. He also has significant experience assessing, restoring and maintaining underground distribution and grounding systems. Kevin is an AMPP (Formerly NACE) Senior Corrosion Technologist and an active committee member with AMPP, IEEE, ASTM, ASCE and ASNT. He is also a current committee officer on the AMPP SC 11 Electric Power standards development committee and IEEE WG 12 Joint Corrosion Committee.

Structures elevated above the design flood elevation can provide additional resilience during extreme events.

Is My Substation Ready for the Next Extreme Event?

ALTERNATIVE DESIGN STANDARDS AND GUIDELINES CAN GIVE UTILITIES THE GUIDANCE THEY NEED TO IMPROVE SUBSTATION RESILIENCE.

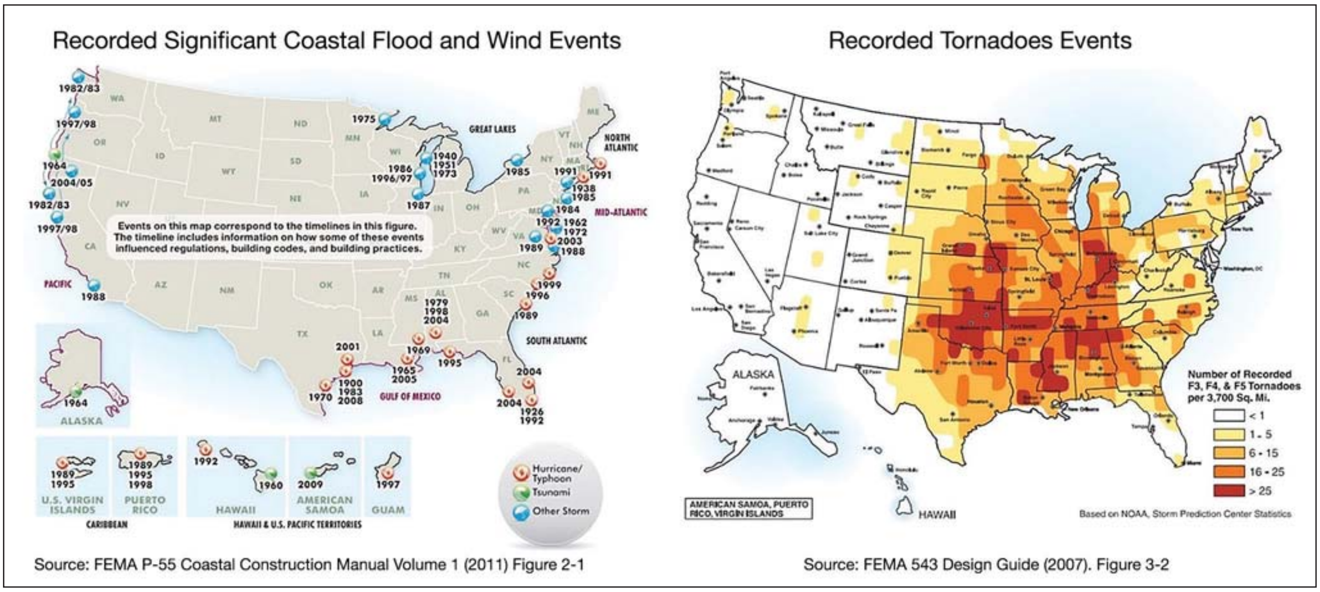
By **CALEB JERGENSEN** and **CONNOR BOWEN**, Burns & McDonnell, and **PRAPON SOMBOONYANON**, AEC Lionstech

The reliability and resiliency of the electric grid is one of the primary concerns of an electric utility. While there are many challenges in maintaining a robust infrastructure, severe weather-related events and other extraordinary events pose a threat to the electrical grid that may catch utilities unprepared. Not only have these extreme events occurred with greater frequency recently, but many substation infrastructures may have not been designed to withstand these extreme events.

From 1900 to 2010, severe weather events — primarily hurricanes, typhoons, and other intense storms — have steadily grown in frequency along coastal regions of the U.S. and its territories. As the data clearly shows, these events have grown even more frequent in a relatively short period. Tornados also pose a significant threat to most regions of the midwestern United States.

RESOURCES ARE EVOLVING IN RESPONSE

Utilities have traditionally referred to ASCE 113 for substation structural designs. This publication, titled Substation Structure Design Guide, is generally based



Recent historical extreme events in the United States.

on ASCE 7-05 with modifications to better suit substation structural designs. This guide covers extreme wind and seismic loadings but does not provide any provisions related to extraordinary events such as floods, hurricanes, tornadoes, and tsunamis.

However, there are several other resources that can provide utilities with guidance to include loadings from these extraordinary events in their designs, where applicable. For example, ASCE 7, Minimum Design Loads for Buildings and Other Structures — provides the design criteria utilities need to counter forces caused by floods and hurricanes. A more recent version of ASCE 7 — ASCE 7-16 — added design criteria for tsunami loadings, and a chapter for tornado loadings was added in ASCE 7-22. Additionally, there are several FEMA documents outlining design information and other considerations that can assist engineers in designing substation structures to withstand these extreme events.

Hurricane (Saffir-Simpson Hurricane Wind Scale)			Tornado (Enhanced Fujita Scale)		
Hurrican category	Wind speed 3-s gust (mph) over land	Type of damage	EF scale rating	Wind speed 3-s gust (mph) over land	Type of damage
1	81-105	Minimal	EF0	65-85	Light
2	106-121	Moderate	EF1	86-110	Moderate
3	122-142	Extensive	EF2	111-135	Considerable
4	143-172	Extreme	EF3	136-165	Severe
5	>173	Catastrophic	EF4	166-200	Devastating
			EF5	>200	Incredible

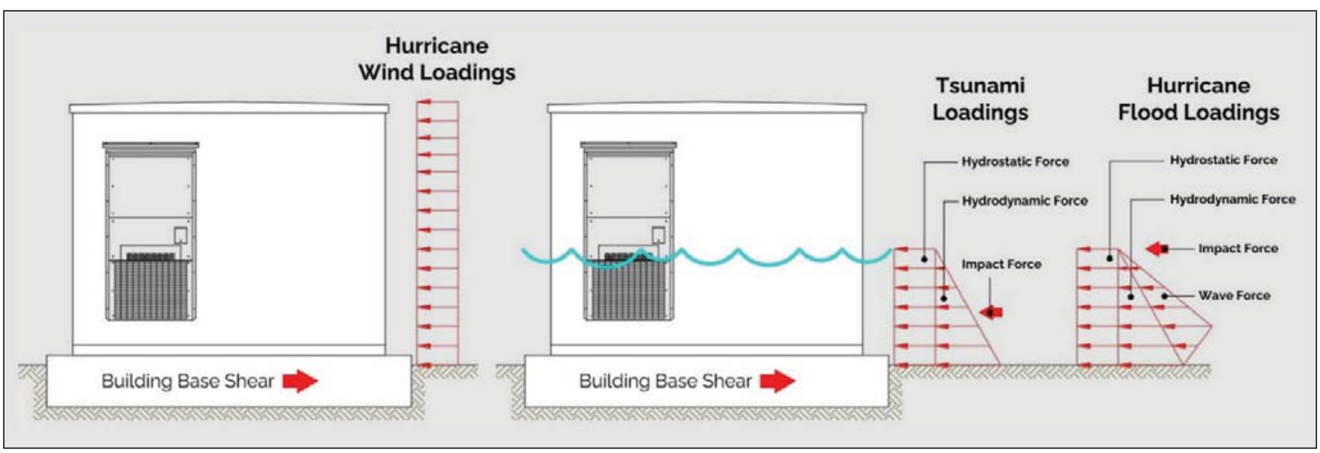
Source: ASCE 7-16 Table C26 5-2

Source: ASCE 7-16, Table C26 14-1

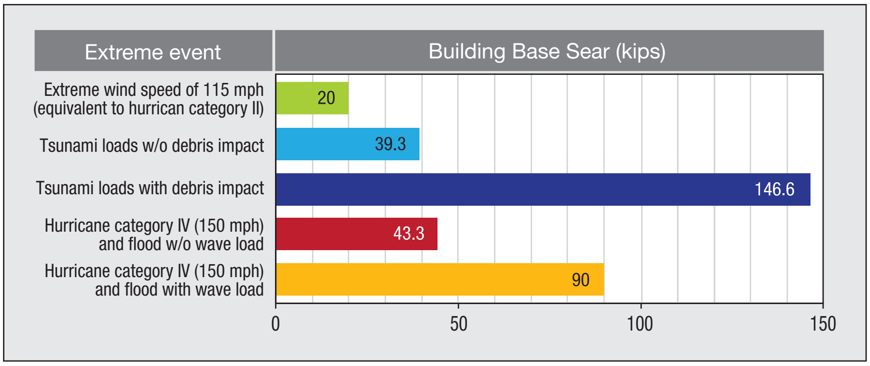
EXTRAORDINARY EVENT LOAD CHARACTERISTICS

Although each extreme event is triggered by a different source and its load characteristics are addressed in separate sections of codes and standards, there are some similarities among these events related to how the loads cause damage to structures. Hurricane and tornado events produce high winds. In addition to wind loads, hurricanes can also cause a storm surge resulting in area floods.

While hurricane classifications are



Case study for load comparison.



Building base shear case study.

established by the Saffir-Simpson Hurricane Wind Scale, the Enhanced Fujita Scale is utilized for tornado events with both sharing the same key design parameter for computing wind loadings – 3-second gust wind speed. Wind speed is an important metric that is often directly attributable to the amount of damage that can be expected at substations.

ASCE 7 does not contain a specific chapter addressing hurricane loads. Instead, the effects of hurricane events are addressed separately within different chapters depending on load type, either extreme wind or flood loadings. The associated chapters for both wind and flood loads – Chapter 26 and Chapter 5, respectively – must be referenced to determine hurricane design loads as these loads can occur simultaneously in coastal regions. In addition to ASCE 7, ASCE 24, Flood Resistant Design and Construction — is an excellent resource for designs and considerations for structures resisting flood loads. Flood depth and flood velocity are key design parameters used for computing wave runup and crest heights and thus are key metrics to determine criteria for flood loadings.

Although tornadoes produce strong winds like hurricanes, their load patterns are different. Wind pressures induced by windstorms and hurricanes are based on straight line wind while tornadoes produce greater updrafts. Tornado wind pressure calculations are similar to those outlined in ASCE 7 with modifications as suggested in Section B3.2.4 of FEMA P-361. These modification factors are combined into a single factor, Tornado Factor (TF), to adjust wind pressures computed from ASCE 7-16.

Triggered by underwater earthquakes or other seismic or volcanic activities, tsunamis produce flood-like events with high flow velocities that can cause damage to substations. These events can result in devastating loads which are much higher than hurricane storm surge events with equivalent flow depths.

Due to the models utilized in the development of ASCE 7-16 Chapter 6, Tsunami loads provided are only applicable to Alaska, Washington, Oregon, California, and Hawaii. For other regions where a tsunami is determined to be a threat, ASCE 7-16 suggests that the site-specific procedure, outlined in Chapter 6, could be developed and used in conjunction with other recommendations provided. Like coastal flooding, the two key parameters used for computing loadings caused by tsunamis are inundation depth, effectively "water depth", and flow velocity.

CASE STUDY FOR LOAD COMPARISON

A case study was performed to quantify the magnitude of the various loads of extreme events in comparison to each other with the intent of providing clarity on how these loads can affect substation structural designs. The case study compared the base shear results from different extreme events acting on a substation control building. The extreme events considered in the case study include a 115 mile per hour gust wind speed (Category II hurricane), tsunami loads with and without debris impact, and a 150 mile per hour gust wind speed (Category IV hurricane) including flood loads with and without wave load.

When subject to tsunami loadings, the total base shear is nearly two times higher than the baseline event when excluding the debris impact load and can be more than seven times higher when including the debris impact load. When subject to a hurricane Category IV, the total base shear contributing from wind and flood loads is approximately double and more than four times higher than the baseline event, when excluding and including flood wave load, respectively.

Distribution was no match for extreme high winds. Photo by Gene Wolf

Since there is no standard providing guidelines for designing substation infrastructures under these extreme events, the comparison from this case study could provide guidance as to how utilities choose to include or exclude each load component that best suits their acceptable risk. Also, it should be noted that results from the case study are based on certain variables and design assumptions. Different site locations and design assumptions may yield different outcomes.


Egress is a critical consideration in the design of elevated structures.

CONSIDERATIONS FOR EXTREME EVENTS

Most extreme event load effects considered in ASCE standards and various FEMA guidelines are generally geared toward building designs. However, there are several load aspects described in these standards and guidelines that could still be applied to substations, e.g., a control enclosure that is similar to an enclosed building and contains many electrical components critical to substation operations. Here are a few additional suggestions and considerations:

1. Water infiltration can cause severe damage to electrical equipment, particularly in a control enclosure. It is recommended that building envelopes, such as doors, windows, and skylights, be tested in accordance to ASTM E1886 and ASTM E1996.

2. Erosion and scour during flood events are concerns addressed by ASCE 24, Section 2.5. Slab-on-grade foundations are not recommended in coastal high hazard areas due to their susceptibility to larger scour depths. Additionally, when using deep foundations, increased foundation loads must be considered due to higher foundation reveals and reduced embedment depths from the effects of erosion and scour.

3. Consider performance-based design when designing substations, as withstanding the entirety of prescribed loads may not be economical or practical. Section 1.3 of FEMA 543 describes how performance-based design could be leveraged as an alternative approach to design. This could allow utilities to establish acceptable risk and performance levels for their assets and allow tailored design requirements to better align operational goals during and after extreme events.

4. Alternatives to withstand tsunami loads are addressed in Section 6.15 of ASCE 7-16 with providing three options 1) to protect against tsunami inundation, 2) to elevate structures 1.3 times above inundation elevation, and 3) to design to withstand effects of tsunami loads.

5. Protective coatings addressed in section 3.3.1.2 of FEMA 543 suggests that greater-than-normal thickness should be specified when a substation is within 3,000 feet of the ocean.

6. Helpful design checklists and best practices are available from a number of resources that are relevant to substation applications, including:

- FEMA P-424 for a checklist for buildings exposed to high winds.
- FEMA 543 for best practices in hurricane-prone regions and a checklist for critical facilities exposed to high winds.

CONSULT APPROPRIATE RESOURCES

There is a growing concern over the risks to power grids posed by more frequent occurrences of extreme events. Still, despite these growing risks, the effort and costs of hardening the entire network should be carefully evaluated for practicality.

Adding complexity to these decisions is the reality that these extreme event loadings are excluded from the current version of ASCE 113 widely used for substation structural designs. There are several other resources that can better provide guidance for extreme event loadings. These include ASCE 7, ASCE 24, and a number of FEMA documents. Through a better understanding of the design requirements and associated loads, utilities can design substations to be more resilient and better prepared for the next extreme event. TDW

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The 'Golden Age' of the Electric Grid Buildout

By **RONALD CARRINGTON**, POWER Engineers, Inc.

"Toto, I've got a feeling we're not in Kansas anymore." Dorothy's sudden realization that her world had changed is how many of us feel as we look at the unprecedented transformation of the electric grid currently underway. And this transformation shows no sign of slowing down.

The successful transformation of the electric utility industry requires the best efforts of all involved. So, friends and colleagues please STOP for a moment, look up from your computer, pause that email you're composing and put down your mouse. I'm asking you to take a deep breath, look around and appreciate that you are a key player in what has become a most dynamic industry. Planning, designing, building, operating, and maintaining the electrical grid has never been more exciting or challenging than it is right now!

Awareness of the electrical grid, recognized as the greatest machine on earth, is no longer relegated to industry trade magazines and obscure conferences. Conversations about our industry, the electrical grid, are now often found on the front page of newspapers, on the nightly national news and in presidential and congressional agendas. And yes, these conversations are even occurring across the backyard fence with your neighbor. There has never been a better time than now to share our passion and knowledge with those around us.

Many of you have committed a large portion of your career advancing the art and science of transmission, substation, and distribution engineering and construction. And as you look around, I think you'll have to agree that you are living in the 'golden age of engineering' of the electrical grid. Today is a perfect day to "stop and smell the roses", appreciate how far we've come and energize yourself for the exciting challenges of tomorrow.

Winds of Change

The tailwinds of decarbonization, electrification, and climate change are creating projects of every type imaginable. Projects for EHV bulk transmission, HVDC, wind and solar interconnections, microgrids, battery storage, system hardening, wildfire mitigation, electrical lifeline and more, on a daily basis, are presenting an abundance of opportunity. Thankfully we have a large cadre of dedicated professionals turning these opportunities into reality for the benefit of us all.

A prime example of the energy, enthusiasm and deep technical knowledge of our industry was on full display last October at the Electrical Transmission & Substation Structures (ETS) Conference. This 'must-attend' event had over 1500 professionals in attendance and showcased our talent and expertise thru a pre-conference workshop, 35 presentations and a dozen posters.

Those attending were able to reconnect in-person with industry experts and colleagues while taking advantage of the educational opportunities in the technical sessions and exhibit hall. In addition, this conference gave more than one hundred authors the opportunity to share their most exciting and relevant efforts that they have been working on since the 2018 conference. If you missed it, here is your chance to catch up on some of the exciting projects shared by your colleagues. This supplement has five articles written from some of the best papers presented at the 2022 ETS Conference.

Share Your Experience

In September 2025 the Electrical Transmission & Substation Structures Conference returns and will provide another opportunity for our most talented to share their experiences with some of the coolest and most important projects on the planet.

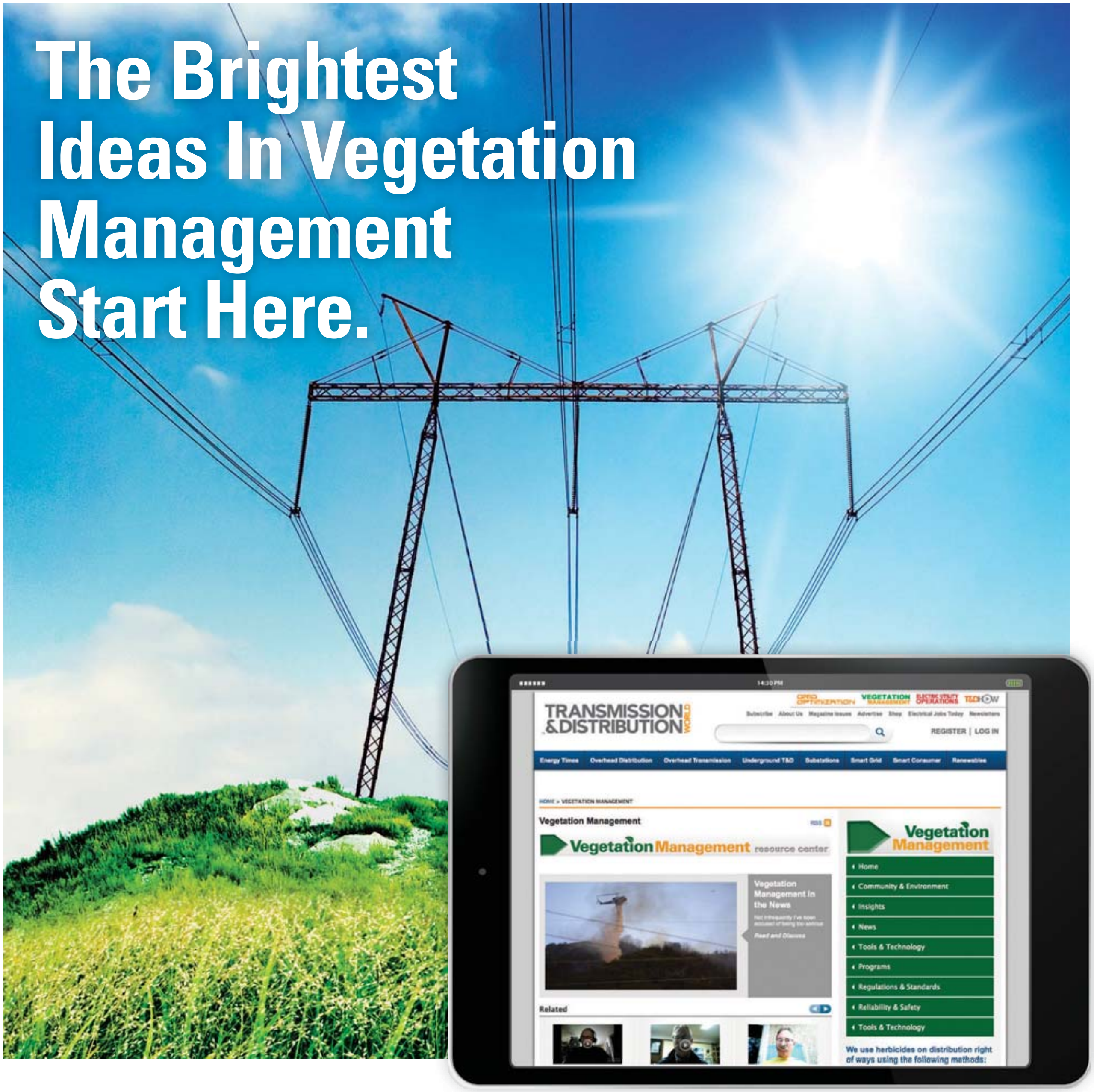
Although two years away, the ETS steering committee, supported by ASCE is already hard at work. So please mark your calendars for September 14-18, 2025. It is not too early to start thinking about how you might be able to share projects that highlight collaboration, innovation, or overcoming challenges. Over the next six months be on the lookout for the call for abstracts/papers. We look forward to everyone's contribution.

If you need additional evidence that we are in a 'golden age', there is groundbreaking work underway to develop a loading standard for overhead power lines (Minimum Design Loads for Structures Supporting Overhead Power Lines & Wired Telecommunications Infrastructure). This much needed standard, years in the making, is being built on the foundation of 4 editions of Manual of Practice 74: *Guidelines for Electrical Transmission Line Structural Loading*.

When completed, this standard will reduce or eliminate our reliance on the NESC for determining structural loading and incorporate a datacentric approach, bringing consistency to all areas of the country. Approximately 35 of your colleagues and industry experts are meeting on a nearly continuous basis to complete this standard. They are deserving of your support, appreciation, and thanks.

Now as I circle back to the beginning, do yourself a favor, "stop and smell the roses!" In doing so, reflect on your strengths and experiences and look for opportunities to apply those to some of the biggest challenges our industry has ever faced. You are living in a 'golden age,' and we need your talents to address the challenges of our ever more complex and essential electric grid. Good Luck to us all! TDW

RONALD CARRINGTON is an executive vice president and executive board chair at POWER Engineers, Inc.



1. Transmission & Distribution World's Vegetation Management Resource Center

It's your resource for management from programs and safety, to tools and technology. Regulatory compliance, public health standards and environmental topics are also covered.

tdworld.com/vegetationmanagement

2. Vegetation Management Insights Arrives Monthly In Your Inbox

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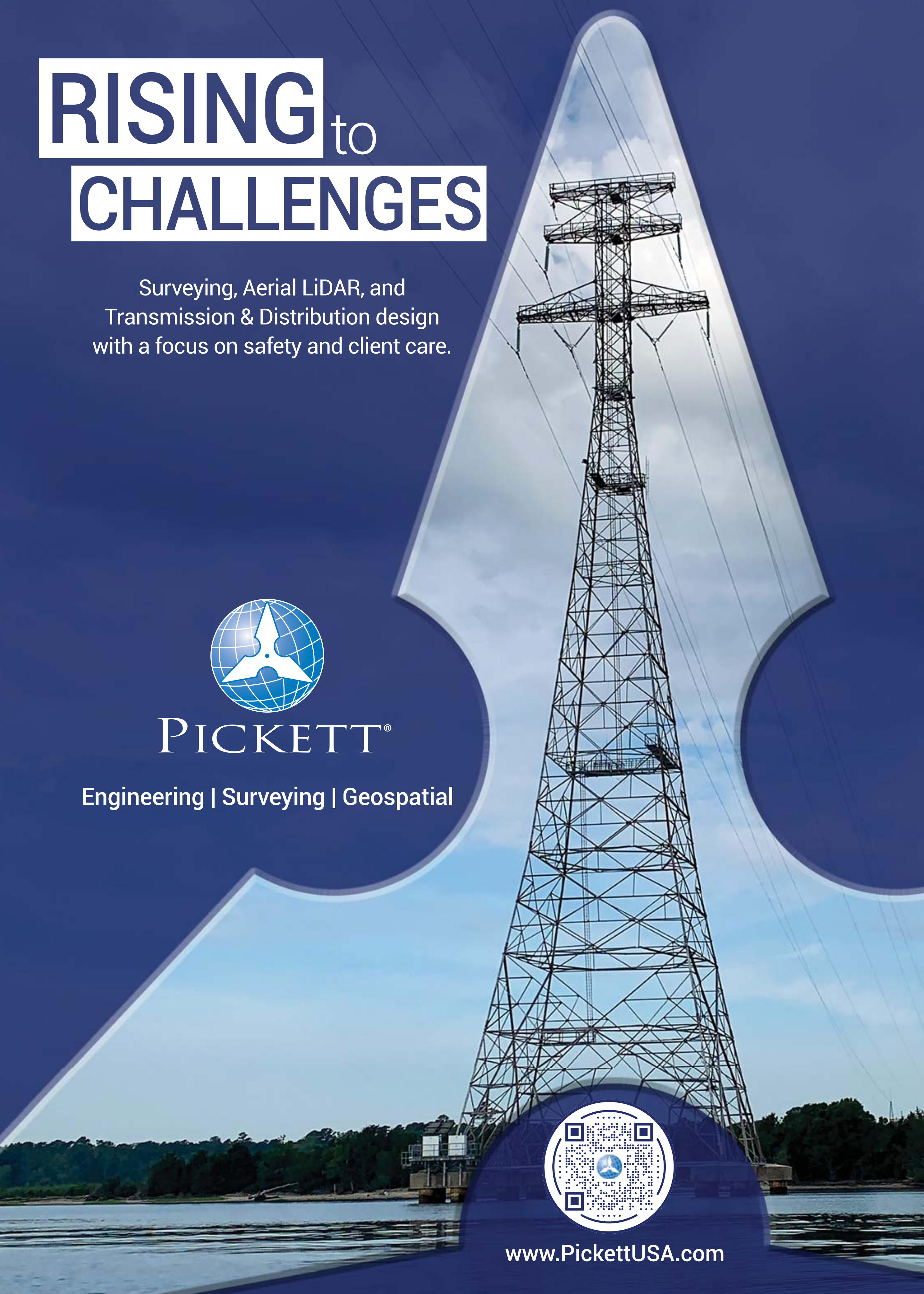
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