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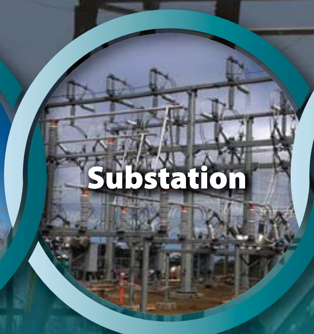

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Russia-Ukraine Conflict Creates Energy Challenges

For the last few weeks, Russia's invasion of Ukraine has dominated the news. The stories and images coming out of Ukraine leave people feeling helpless, which is why most people in the U.S. favor the sanctions levied against Russia. Most are OK with President Biden's executive order that bans the import of Russian oil, liquefied natural gas, and coal to the U.S., even though the move caused a hefty increase in prices at the gas pump. As I'm writing this "Global Viewpoint," NASDAQ reports the price of West Texas Intermediate crude oil is nearly US$110 a barrel, down from its high of nearly $124 a barrel reached on March 8. Natural gas is $4.73 per million BTU, down from nearly $5.02 reached on March 4, and AAA reports the nationwide average cost for a gallon of regular gas is $4.32.

Many experts believe the current gas prices will speed up North America's transition to electric vehicles (EVs). That seems like a safe prediction. I recently read an Associated Press article that described how some people are pushing conspiracy theories on social media, saying that the Biden Administration is intentionally driving up gasoline prices to prod Americans to buy EVs. It would be great for those of us in the U.S. if the President of the United States had the ability set oil and gas prices for the entire world, but it doesn't work that way.

On the flip side, there are experts who disagree with the notion that high gas prices will have a long-term impact on EV adoption, saying swings in oil and gas prices are common in the industry and prices will eventually head back down. They point out the lessons of 2008 when oil reached $147 a barrel and gasoline rose to $4 a gallon but then slid back down quickly. In addition, they point out that it's common for oil and gas prices to spike due to emotional and unwarranted reactions to world events, and not the actual state of energy supply.

It's anybody's guess when (or if) oil prices will decrease substantially, but it is prudent for utilities that will provide the power and infrastructure required to power EVs to consider what might happen if prices remain high. Preparation for EV adoption is more important now than ever.

Another concern stemming from the conflict is Russia's ability and possible desire to attack not only Ukraine's power grid, but other countries' grids. Russia proved twice that it can take down Ukraine's electricity grid. In a 2015 cyberattack, it took down part of Ukraine's grid for six hours, and then in 2016, Russia infiltrated a Ukrainian substation, tripping circuit breakers and disrupting power to a portion of Kyiv for a brief time.

Cybersecurity experts agree that these cyberattacks were meant to demonstrate to other countries, including the U.S. and those in Western Europe, that Russia can disrupt and inflict tremendous hardship on other countries' citizens without stepping foot on foreign soil. Grid owners and operators, along with national laboratories, universities, industry associations, software developers and others have worked for years to put safeguards in place that can prevent a widespread takedown of power generation facilities and transmission infrastructure. Preparation for cyberattacks must be stepped up.

Even though most people agree with the Biden Administration's sanctions and bans on Russian oil and gas, these moves seem to have deepened the divide between proponents of green, low carbon energy and those who promote U.S. energy independence through fossil fuels. The renewable and green energy contingent argues that developing our renewable resources is the best way to gain energy independence from all outside countries. Those who promote traditional energy strategies point out, however, that the U.S. has enough fossil fuel to not only be independent, but also supply our allies with enough fuel to become independent from rogue nations. They suggest that more exploration, drilling, production of oil and gas is the answer. They also call for more pipelines to be built, a move that green energy proponents believe will cause the country to become more entrenched in fossil fuel production well into the future as owners of pipelines try to avoid stranded costs. During a televised interview, West Virginia Senator Joe Manchin said that this potential problem can be solved by converting pipelines into carriers for green hydrogen as that segment of the energy industry develops. Much more must be done to accelerate and advance green hydrogen to a point where it will be plentiful enough to be transported long distances in the country's pipeline system.

You might have noticed that I haven't provided ideas or suggestions on how to address these challenges. I'm not an expert in any of these areas and certainly not in world affairs or geopolitical issues. I do know, however, that the conflict between Russia and Ukraine and the things I've mentioned here have amplified several challenges utilities and energy providers were already addressing. I also know that there are smart people in the world who have ideas and solutions that can help with these and other challenges. I'm happy to tell you that we here at *T&D World* are recruiting many of those people to speak at our upcoming T&D World Conference and Exhibition that will occur Oct. 5-7, 2022, in Charlotte, North Carolina. We've amassed an advisory board of experts, representing utilities, solution providers and associations like EEI, EPRI and Utilities Technology Council. With their help, we are creating technical and panel sessions that are educational and thought provoking, and designed to spur discussions, create new ideas and uncover solutions to today's challenges, as well as those that lie ahead.

We will be announcing session topics and speakers as we confirm them in the coming weeks, so visit *www.events.tdworld.com* often for updates. It will be an intimate event that will allow you to meet and network with peers who face some of the same challenges and opportunities you and your utility face. I hope to see you there. TDW

Advanced Technologies Complement Traditional Methods for Wildfire Mitigation

Weather trends, the presence of fuel and an ignition source are principal factors that contribute to the start of a wildfire. Statistics from the National Interagency Fire Center (NIFC) recorded 58,950 wildfires, which consumed 10.1 million acres in 2020. Electric utilities are keenly aware of wildfire risk, and wisely are pursuing multiple prevention, detection, and mitigation strategies to improve public safety and power reliability. Tried and true "old-tech" as well as new technologies are on the table when crafting the optimal wildfire mitigation plan.

Bad things are more likely to happen to even the best maintained utility infrastructure and, resultingly, electric service during adverse weather conditions. As a result, utilities are increasingly following or engaging in the business of weather forecasting. Case in point, Pacific Gas and Electric Company (PG&E) recently announced it has completed the installation of 1300 weather stations concentrated in high fire risk areas across its territory. Temperature, wind, and humidity data help utility meteorologists evaluate the potential for severe weather conditions and elevated fire risk in real time. PG&E's Wildfire Safety Operations Center uses the information to inform operational decisions, including the need to enact a public safety power shutoff (PSPS) under extreme conditions.

anmbph/Getty Images

While in-house weather forecasting is new for most utilities, the business of weather prediction is not. However, the technologies and modelling capabilities utilized have improved dramatically. For example, the NIFC combines weather, soils, vegetation, and other data to produce a wildlands fire potential outlook that provides a four-month prediction of fire risk potential for every section of the country. This information can augment the intel obtained by utilities that are using vegetation management software that identifies vegetation clearances and risk trees along ROWs based on drone, LIDAR, and satellite imagery. Recently, the firm Terrafuse AI announced that it will be offering a free, publicly available data platform that utilizes daily climate information and machine learning predictive models to assess wildfire risk at a highly localized level.

While old school in some respects, vegetation management (VM) is undoubtedly one of the most important contributors to reliability as well as fire risk mitigation. Vegetation can not only initiate sparks or fire by contacting and damaging electric infrastructure, but it also can provide the fuel needed to propagate and intensify fires. Old school methods of VM include tree trimming and mechanical mowing on a cyclic basis. Updated practices include integrated VM programs customized to achieve specific conditions, including low growth, ROW compatible and pollinator friendly plant species that eliminate the need for mowing and frequent tree trimming. Newer techniques include the use of dormant season herbicides that further reduce habitat impacts and granular herbicides that eliminate vegetation growth in limited zones around power poles. One of the latest technology innovations for VM related fire risk reduction is the utilization of near real-time satellite imagery and AI to determine vegetation clearances and growth rates more accurately along power lines; identify danger tree/hazard tree and high-risk areas; plan cycle trim/line clearance; and schedule the use of herbicides and tree growth regulators.

Always important traditional methods for wildfire prevention include visual inspection of lines and equipment for damage, the use of fire protective coatings for wooden poles and the use of covered conductors. In addition, fire rated equipment protectors such as Reliaguard and Greenjacket protect wildlife and reduce fault and fire potential. Increasingly popular strategies include the use of fire-resistant steel and fiberglass poles and crossarms. Priority Wire & Cable Inc. (PW&C) is promoting a fire resistant-non-propagating (FR-NP) covered wire product that reduces the risk that a line fault will cause a secondary fire.

New fire prevention technologies on the scene help utilities detect impending and invisible risks. One example is the use of intelligent line sensors and analytics that enable utilities to detect real-time anomalies such as transient fault currents. PG&E is deploying distribution fault anticipation (DFA) on multiple circuits to detect incipient failures and other line conditions that high fault current detection methods could miss. Used in conjunction with AMI, line sensors and other surveillance techniques, DFA is proving to help provide a more complete overview of distribution system health. Southern California Edison (SCE) is taking another tack using rapid earth fault current limiters (REFCLs) to reduce the risk of ignition by faults involving a single-phase conductor.

Wildfire mitigation has become a very high priority throughout the U.S. and world. Thankfully, proactive utilities, universities and other organizations are constantly identifying new technologies and improvements to traditional mitigation methods. Check out T&D World's Wildfire Center of Excellence at *https://www.tdworld.com/wildfire* and the company's several E-Books with Wildfire Risk Mitigation titles to get updates on this important topic and to learn more about what the companies mentioned above are doing. TDW

 | BY GENE WOLF, TECHNICAL WRITER

Waterproof, Shockproof & Rugged

I'm sitting in my office writing this month's column, and it's snowing outside. The wind is howling, and the temperature is dropping. Some parts of town are reporting whiteout conditions It's not a good day to be out and about, but it's a great day for being in my home office with a hot cup of coffee.

As the morning progressed, local officials sent out several public service announcements saying the schools had switched to remote learning. They also recommended everybody stay home and work remotely. That got me thinking about how far our digital workplace technology has advanced, and what's next.

When 2020 began, offsite working was uncommon for most of the workforce, but the pandemic shutdown changed that quickly. Suddenly there was a technological stampede to get remote offices set up. The technology was available, but the scale of the situation caused hardware and software shortages. That resulted in shortcuts and temporary solutions.

Mobile Devices

By the start of 2021 the digital office was functioning, but there were problems. The rapid acceleration to setup our digital workplace left rough edges that needed polishing to improve its efficiency. Without realizing it, I got myself caught up with hardware issues like everyone else. I had been adding new devices to my office without considering what it was doing to my network.

It turned out my router was several generations past its prime, and it impacting my internet connectivity. This wasn't uncommon and lot of us had to update our electronics, but there was another issue. Our connectivity relies on fragile mobile devices (i.e., smartphones, tablets, and laptops). According to several surveys the leading causes of damage to these breakable devices is dropping them and/or spilling liquids on them.

Fixing them is almost impossible, so we replace them with similar devices. This has resulted in a growing interest in more sturdy mobile devices that can withstand being hammered or soaked. Today's users can buy a device that meets IEC's IP (Ingress Protection) ratings for better protection. An IP rating of IP00 means there's no protection at all. An IP68 rating can be submerged in a meter of water. Most available devices fit somewhere in between, so be careful.

Toughbook G2 rugged 2-in-1 tablet.
Courtesy of Panasonic.

When it comes to extreme conditions, it gets a whole lot more complicated. The average smartphone, tablet, or laptop is more of a recreational device than being road-warrior worthy and need to be handled carefully. They have a real problem being dropped, pounded, or banged around. For demanding environments, you need rugged equipment and that is why ruggedized mobile devices are attracting attention.

Mil Standards

I talked with Chad Hall, strategic account manager of Utility & Enterprise Mobility Solutions for Panasonic System Solutions Company of North America about this ruggedized technology and received some significant insights. He told me Panasonic celebrated the 25th anniversary of the "TOUGHBOOK" brand last year. These ruggedized laptops and tablets are characterized as being either semi-rugged or fully rugged when it comes to handling extreme conditions.

I found out a fully rugged devices meets all military standards (i.e.,MIL-STD-810) along with the toughest IP and NEMA standards. Fully ruggedized laptops and tablets can likely survive just about any extreme environments that utility personnel encounter in their demanding jobs. When I was building substations I saw a Panasonic "TOUGHBOOK" fall from a bucket truck. It bounced, and was still working when we retrieved it. It wasn't a case of carelessness. It's just that things happen in the field, which is why ruggedized mobile devices are becoming popular on the grid.

Semi-rugged devices like Panasonic's "TOUGHBOOK 55" is a good example. It's a laptop that is able to withstand rough conditions that utility personnel run into more often than extreme environments. Typically semi-rugged devices have spill proof keyboards, magnesium housings and shock mounted hard disks for drop and shock protection. They also can handle a wide range of low and high temperatures, but not the extremes a fully ruggedized device can.

While we're on the subject, there are also a number of smartphones on the market that meet all of the same stringent requirements and fall into the same categories of fully and semi-ruggedized. These sturdy phones are not fashionable, but they are rugged. Whatever your needs are make sure you look into all the device's features and the specifications that make them tough. Ask lots of questions and hopefully the device you pick will last a long time in the field. TDW

Oscilla Power Is Selected By U.S. Department of Energy For Grant To Develop a Utility-Scale Wave Energy System

Marine renewable energy systems are starting to draw awareness from the power world for their ability to produce electricity using hydrokinetic energy power generation systems. Tidal energy technology has been producing renewable energy for many years, and recently it's been receiving some much needed attention in the form of a U.S. Department of Energy (DOE) grant.

Triton.

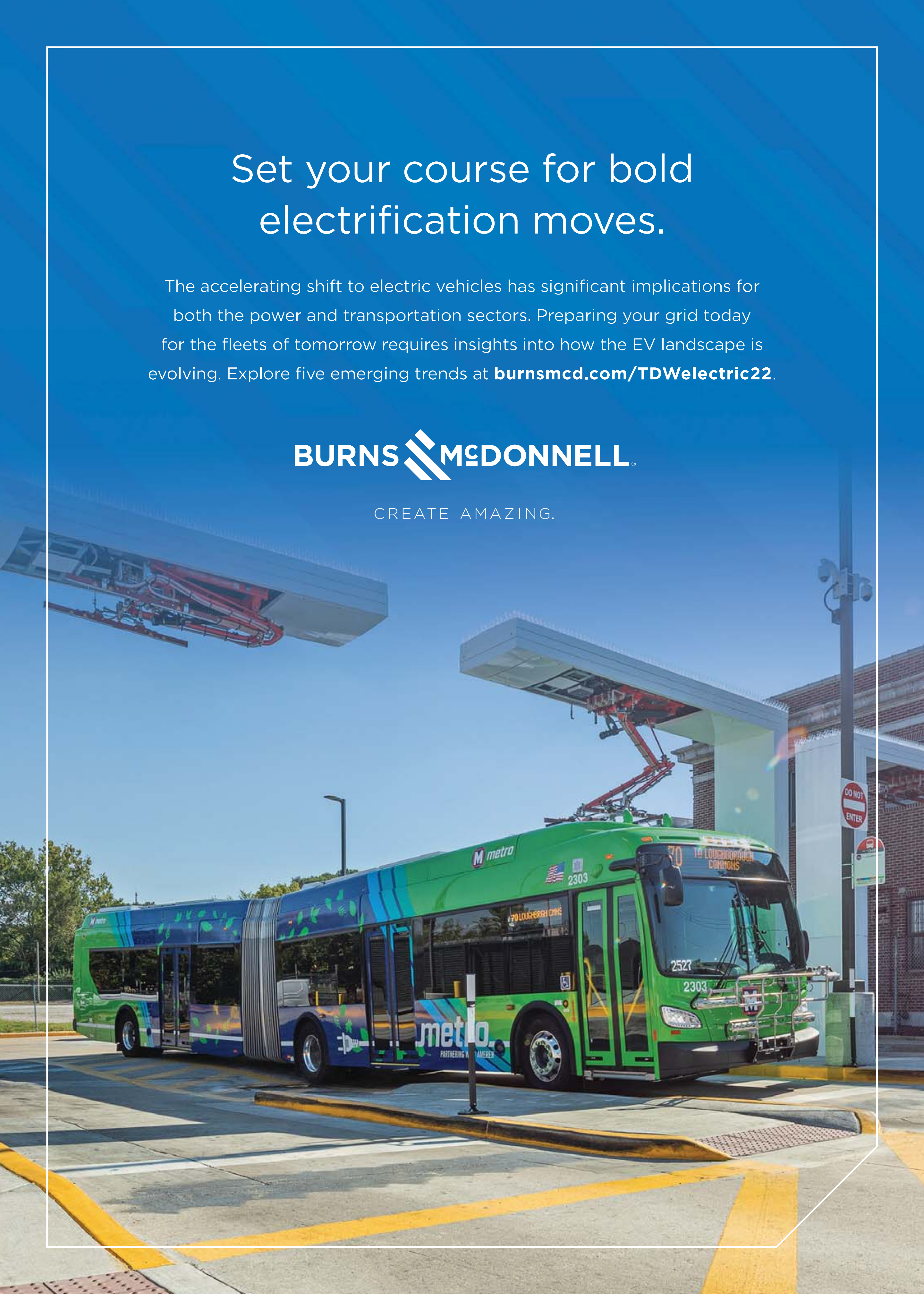
Earlier this year, Oscilla Power was awarded a US$1.8 million grant to accelerate the development of a utility-scale version of the company's core Triton wave energy converter technology. The US$1.8 million will be augmented with an additional US$200,000 in cost-sharing from Oscilla Power and its partners Glosten Associates, Spencer Fluid Power, Applied Motion Systems, Applied Control Engineering, and DNV.

Oscilla Power has developed a highly efficient system known as a "multi-mode point absorber." It consists of a geometrically optimized surface float connected to a ring-shaped, vertically asymmetric heave plate by three taut, flexible tendons.

According to the company, that unlike most conventional wave energy devices, Triton's surface float can extract energy from ocean waves in all six degrees of freedom (heave, pitch, surge, sway, roll and yaw). This allows for increased energy capture across a wider range of ocean conditions. It provides a greater average annual energy production and a substantially lower levelized cost of electricity.

The project funding will enable performance improvements and result in a detailed design for a system that is prepermitted for the DOE's PacWave. This is a first-of-its-kind, grid-connected, full-scale test facility for wave energy conversion technologies off the coast of Oregon. The system will be suitable for over two years of continuous operation at the PacWave site and will be designed to ensure a clear pathway to IEC (International Electrotechnical Commission) type certification for the first commercial units.

"The power of this funding is that it not only enables the continued development of our flagship utility-scale Triton system, but it provides a clear pathway and process for commercial testing and deployment at full-scale in a real-world operating environment as the logical next step beyond this program," said Balky Nair, Oscilla Power CEO. "We look forward to working with our partners to complete the Triton design for PacWave through this project and subsequently building and getting our Triton system in the water." TDW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The Connected Grid

Is 5G technology the next digital disrupter or is it an enabler?

Digital electricity. (Shutterstock) Courtesy of Hitachi Energy.

How long has 5G (fifth generation) wireless communications technology been around? It's not a trick question. Smartphone manufacturers have been selling the devices and telcos (telephone companies) have been offering upgrades for years, but what about the infrastructure? A few months ago a story hit the headlines about a conflict between the telcos and the airline industry. The US telcos were increasing their 5G coverage until they hit a snag.

The expansion included new 5G towers around a large number of major US airports, but the airlines claimed these 5G towers would interfere with their aircraft landing systems. The federal government stepped in and delayed the tower energization. After some eleventh hour meetings, the crisis was averted, and the telcos returned to improving their infrastructure. What's that have to do with the power delivery system? Disregarding all the publicity, the bottom line here is it's time to take 5G technology seriously.

5G-powered technology is the next level in wireless communications and 5G infrastructure (i.e., coverage) is being increased around the world for more applications. More importantly, the power delivery industry is part of this growing trend. Utilities understand the advantages offered by the lineup of benefits this next generation of communications technology offers. There has already been a blending of 5G connectivity with smart grid technology for stronger and smarter grid applications.

5G Advantages

Before moving on, it might be beneficial to look at these advantages 5G offers. Since it's such an extensive listing, let's reduce the list down to what really counts. Luckily, several studies had the same idea, and they did the heavy lifting. There are three major characteristics that all 5G scenarios have in common. Leading the lineup is greater speed, and that quality is always followed by the #2 trait called lower latency. The third commonality is the greater number of devices that can be connected to the 5G network.

These faster speeds mean higher transmission rates for big-data. Theoretically the max 5G speed is between 10 and 50 Gbps (giga bites per second), and it's the goal. Latency not a common word for most of us, but it's simply the delay or lag that takes place between the sending and receiving of information. The latency rate most quoted for 5G is about 1 ms.

Higher capacity for devices is pretty straight forward. 5G promises to deliver up to 1,000 times more capacity than 4G. With the growing number of connected devices, this increased bandwidth is extremely valuable. Some authorities have gone so far as to say 5G-powered technologies and its underlining applications "are what it's all about." For the power grid, we need to focus on industrial applications. If you're not familiar with industrial 5G think consumer 5G on steroids.

Industrial 5G

One of the best descriptions of industrial 5G-powered technology comes from Siemens Energy. They said, "Industrial 5G is 5G communication that meets the demands of industrial applications. It is based on Release 16 (or later) of the wireless standard that supports the URLLC (ultra-reliable low-latency communications) scheme. It runs on hardware designed for industrial environments that differ from consumer-based applications. Industrial 5G is run in a local

private network and supports industrial protocols (OPC UA, PROFINET, Safety, etc.)."

The general consensus about industrial 5G is it can be thought of as a catalyst to enabling high-speed and reliable communication for power grids. Deloitte put it in more tangible terms in a report titled "5G Empowers The Future of Electricity." Deloitte estimates "5G-enabled global digitalization revenues for ten major industries will be USD1.3 trillion in 2026, with energy and utilities (water, electricity, gas, etc.) accounting for the highest share of 19%, or about USD250 billion." If this is any indication, then there is going to be a great deal of industrial 5G in the electric utilities' future.

Talking with Michael Dulaney, Hitachi Energy's senior director, Global Operations/GM-Wireless, provided some insights to 5G communications used on the grid. Mr. Dulaney said, "5G is more than just the next evolution of mobile broadband. Wireless communication technologies have long been used to connect power grids, from TETRA to LoRaWAN and Wi-Fi."

Dulaney continued, "However, 5G is poised to create a larger seismic impact than any of its wireless predecessors. To date, 5G as a technology provides some of the most robust cyber security features and architectures for industrial operations, like that required by electric utilities."

Dulaney explained, "5G capability is of increasing importance, significantly improving connectivity for the growing number of mobile, remote, and outdoor applications found on the distribution network. When it comes to mission-critical operations, 5G technology has been integrated into Hitachi Energy TRO600 series routers. They are designed to enable a scalable, flexible and secure, hybrid wireless communication architecture that effectively combines public and private cellular with broadband mesh and fiber, all managed through a single network management system."

5G Projects

Industrial 5G has been referred to as a digital disrupter, but more accurately it's an enabling technology. All things considered, it offers more pros than cons especially when compared to all previous generations of wireless communications. Brazil's second largest power distributor, Enel Distribuição São Paulo announced it was initiating a 5G-powered pilot project in Brazil's capital São Paulo city last year.

The project operates on a 5G mobile network provided by telco TIM utilizing the 3.5 GHz (giga Hertz) band. Qualcomm is supplying chipsets and Fixed Wireless Access customer premises equipment. The outdoor and indoor wireless equipment is coming from Chinese company Fibocom and Taiwanese company CBN. Ericsson is providing antennas and radio equipment. Lenovo's Motorola is supplying mobile edge equipment. The 5G system is being used in a substation serving the Vila Olimpia neighborhood of São Paulo. Enel's goal for the project is to assess the efficiency of 5G for streamline automatic responses in case of power failures. Enel also is evaluating how 5G can enable solutions development, among other applications.

Last year, UK Power Networks (UKPN) announced they were exploring 5G telecommunications technology at substations in Scotland and southeast England. The 5G-powered smart grid pilot project would explore 5G technology as a platform for data collection and flexible arbitrage. Telco Vodafone is supplying a 5G network to connect distributed and intelligent grid devices. The project partners (General Electric, ABB, Siemens, and the University of Strathclyde) are providing high-speed connectivity, software, and sophisticated computers in UKPN substations. UKNP's goal for the project is to enhance the efficiency of its power grid and improve its grid reliability and expanding its renewable energy resources.

Speaking of renewables, there is a lot of expectation when it comes to 5G-powered technology on both sides of the meter. Many see 5G as a way to improve the prosumer's harvesting of electricity, but there is also a lot of research taking place on the utility scale side of the renewable equation. The typical windfarm has hundreds of wind turbines, and the average wind turbine can have more than a thousand sensors, all generating data. The traditional method for data collection is fiber optic networks or 4G wireless.

Recently, GE Renewable Energy published some papers providing insights in how valuable 5G-powered technology will be for wind generation. GE described 5G wireless technology as being a more efficient industrial application than previous generations. Industrial 5G, specifically ultra-wideband 5G, can gather real-time data from thousands of sensors in wind turbines at the same time. This gives a windfarm operator access to data "near-instantaneously" and elevates the windfarm's performance to the next level. With wind turbines, it's all about efficiency. If they are operating efficiently they capture more wind energy and convert it into more electricity.

Not too long ago, EPRI (Electric Power Research Institute) produced a report on the opportunities and challenges that 5G presented to utilities. One of the main business opportunities was the support the digitization of many aspects of utility field work, but it also talked about an aspect missed in many other published studies. EPRI pointed out, " The deployment of the infrastructure to support the 5G network represents an opportunity for partnerships with telecom providers.

EPRI continued, "The low-power "small cells" required to augment cell towers to transmit the high-frequency millimeter wavelengths will require orders of magnitude more locations for mounting, for instance distribution poles and streetlights. Utilities may consider various ownership and leasing models for both the physical 5G infrastructure and services that it enables." Any opportunity that produces a revenue stream for a utility is going to be a huge positive for the power grid.

No matter how we feel about 5G-powered technology, it's here to stay. This article has only covered the tip of the iceberg. There are so many more applications and scenarios to consider with this enabling technology. The power grid is going to hear a lot more in the coming year as the infrastructure expands and more opportunities present themselves. Deloitte report said, "5G empowers electricity." That doesn't sound like a disrupter! TDW

OKONITE

EXPANSIONS CONTINUE TO KEEP UP WITH DEMAND

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Our previous 5 year plan to expand each of our three EPR manufacturing plants was completed last year resulting in over 50% increase in capacity of Okoguard EPR insulated cables. Okonite continues to produce more EPR insulated cable than all of our competitors combined.

Most recently, we just commissioned our new Compound Plant expansion in Orangeburg SC. Okonite produces 100% of our own Okoguard EPR compound at this facility. The expansion involved a brand new and completely redundant compound production line using state of the art equipment along with an addition of 85,000 SF resulting in a 100% increase in Okoguard EPR compound production capacity.

Okonite's continuous expansion and modernization programs are an everyday part of our long term vision. Come see our facilities first hand and share our contagious excitement about the future of Okoguard EPR insulated cable. Okonite has been setting the standard since 1878. We are 100% Made in America and an employee-owned company!

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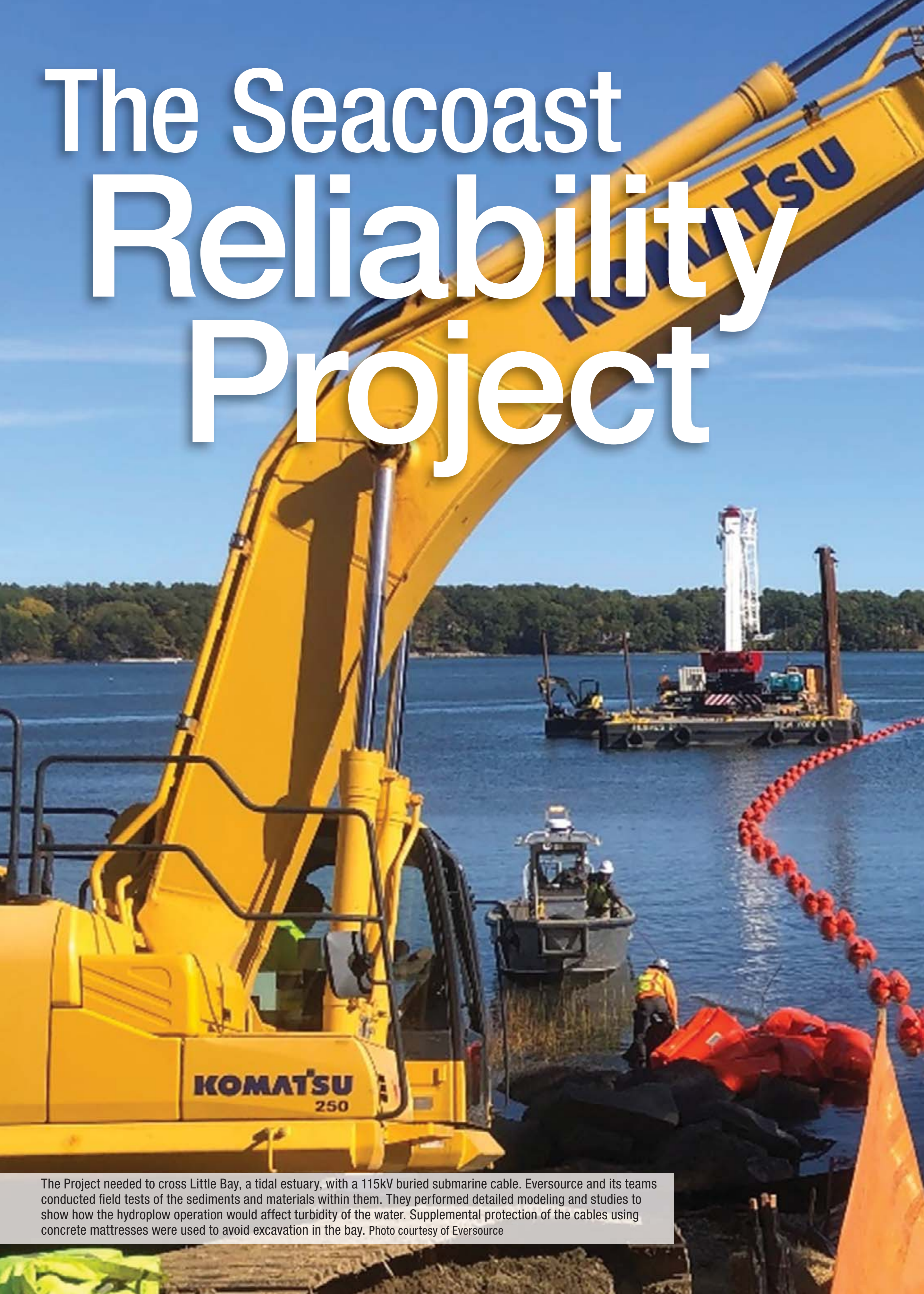
The Seacoast Reliability Project



The Project needed to cross Little Bay, a tidal estuary, with a 115kV buried submarine cable. Eversource and its teams conducted field tests of the sediments and materials within them. They performed detailed modeling and studies to show how the hydroplow operation would affect turbidity of the water. Supplemental protection of the cables using concrete mattresses were used to avoid excavation in the bay. Photo courtesy of Eversource

Eversource balances the need for electricity with the need to protect community priorities, such as historic sites, residential areas and environmental resources.

By **JOSEPH SPERRY**, Eversource, and **TODD GOYETTE**, POWER Engineers

The New Hampshire Seacoast region grew substantially over the last decade, straining the existing transmission system and leading to the need for additional transmission capacity. Critical customers in this area include precision manufacturers, pharmaceutical companies, investment firms, universities and a large residential population.

To prevent outages and support the increased demand, the Independent System Operator of New England (ISO-NE) selected a suite of projects, including the complex Seacoast Reliability project, to modernize the system in the region. Overseen by Eversource's engineers and project managers, the Seacoast's 13-mile (21-km) long, 115-kV transmission line was energized on May 29, 2020, after thorough planning and execution. The final route traveled along a rail line, across a college campus, through residential neighborhoods and historic sites, and beneath an environmentally sensitive tidal bay.

The 115-kV design was a hybrid line of overhead and underground construction that included two underground sections and a submarine cable crossing, connected by means of a vault, to a third section of underground. Photo courtesy of Eversource

The transmission line needed to cross Little Bay, a tidal estuary on the state's southern tip. The bay lies between Great Bay and the Piscataqua River, which empties into the Gulf of Maine and is a unique ecosystem and scenic resource to the state. (left). Eversource worked with historic restoration experts to stabilize and relocate the historic building away from the path of the new line. (right). Photos courtesy of Eversource

Workable Solutions

When Eversource energized the Seacoast Reliability project in 2020, it was the culmination of more than seven years of effort. From the beginning, the utility was committed to involving the public, regulators and officials to identify solutions that would work for the community, meet regulatory requirements, and provide safe and reliable energy. The project was subject to review by the New Hampshire Site Evaluation Committee along with other regulators and needed to display clear benefits to the region while mitigating adverse impacts.

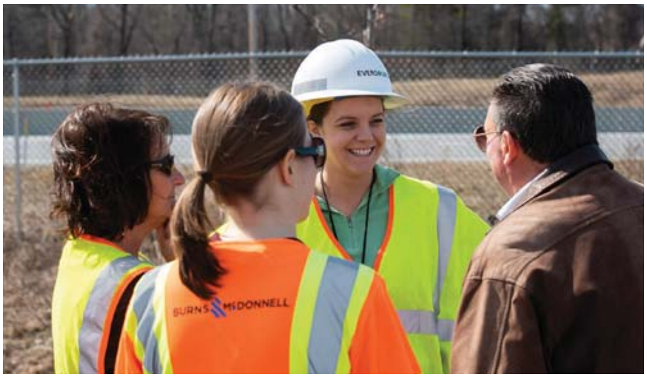
More than 550 meetings were held with external stakeholders where numerous project improvements were identified and incorporated based on their feedback, including more than 20 revisions to engineering design drawings. While the project took longer than originally anticipated, the final designs mitigated impacts to the natural beauty of densely forested areas and seacoast waterways, among other critical natural and cultural resources. They also helped to maintain the historic character of nationally registered historic landmarks and other historic areas.

Eversource assembled a team of industry experts to engineer, site and permit this complicated project. POWER Engineers Inc. was engaged to conduct a routing and siting analysis and perform most of the detailed design work. The routing analysis helped the utility to determine the most appropriate path for the new line. That review identified three potential paths to connect the two required substations, with the primary focus on using existing utility rights-of-way to reduce adverse impacts.

The Best Alignment

The project team evaluated the three potential primary routes as well as multiple sub-routes within those primary paths to identify the best alignment for the region. The criteria under review included how the routes affected abutting properties, the environment and cost, and the electrical and safety requirements of the project. The detailed review confirmed the choice of a preferred route, which enabled the utility to move forward with design, permitting and construction.

Based on this review, the proposed 115-kV design was a hybrid line that included two underground sections and a submarine cable crossing connected, by means of a vault, to a third section of underground. The remainder of the 13 miles was primarily overhead monopole construction with distribution underbuild.



Eversource Energy completed over 550 stakeholder meetings to ensure community engagement in the project.

Eversource and POWER Engineers worked through the detailed design with municipal officials, permitting agencies and abutting property owners to minimize effects on the community. The overhead design reduced the number of structures in parts of the corridor and lowered the structural height by using a horizontal configuration with spacer cable for the underbuilt distribution. This design met the public's desire to reduce visibility of the structures. Where the design itself could not be adjusted, plantings helped to screen the new structures and mitigate impacts.

As a result of these efforts, the New Hampshire Site Evaluation Committee unanimously approved the route in December 2018. The commitment to stakeholder and community outreach and

Crews collected more than 22,000 tons of soil and disposed of contaminated dirt. No contaminated soil was returned to the ground. They also collected and treated around 385,000 gal (1750 cu m) of water. Photo courtesy of Eversource

While hydroplowing is a common technology and industry practice for cable installations in water crossings and estuaries, hydroplow installation had never been used in New Hampshire.

collaboration shown during the design and permitting phases continued through to construction to complete the project successfully.

Going Across Campus

A local university was in the line's path, just south of Eversource's Madbury substation. The proposed route crossed the main access road to the campus, passing by an old train station and a newly constructed football stadium. Eversource agreed to place 2100 ft (640 m) of the line underground to reduce visual impacts and avoid any future design conflicts for the university.

Working on a college campus presented unique challenges. The campus had 150 years of buried and aboveground utilities and facilities. A high-pressure methane gas transmission line for cogeneration, which needed to remain in service, also was located on campus grounds. Furthermore, the university had its own projects and goals. The school only performed major construction when its student population was not on campus, during the eight to 10 summer weeks and four weeks of winter break. The school required Eversource to be held to the same schedule.

The utility worked closely with the university's staff to design a route for the line that would avoid disturbing the campus as much as possible. This included designing around a proposed new athletic field. Led by POWER Engineers, the project's underground team initially planned to build the line before the university finished its new field, giving the crew ample room to install the duct bank and cable. However, because of the time needed for project planning and permitting, the university ended up completing the new athletic field before construction began on the transmission line.

The team adjusted and rerouted the project out of the field and onto the street, including a crossing of the university's most trafficked areas. Working in this very narrow path was like threading a needle at times. Close coordination among the field crews, engineering and university staff was critical to making the project a success.

Under the tight summer timeline, construction began the week following the university's commencement. The project team completed the duct bank, riser poles and foundations, and proof tested the conduit. Despite the team's best efforts, the cable was not fully installed by the end of the summer break.

Therefore, it was decided to complete the cable pulls and terminations during the winter break. To account for cold weather, Eversource's contractor had to take several extra steps. This included heating the cable so it would be soft enough for installation. Under the winter conditions, the project team finished construction just before the school's second semester started in January.

The overhead design and construction used various configurations and installation techniques including spacer cable distribution underbuild and helicopter rope installation to limit visual and construction impacts.

Marine Life Protection

The transmission line also needed to cross Little Bay, a tidal estuary on the state's southern tip. The bay lies between Great Bay and the Piscataqua River, which empties into the Gulf of Maine and is a unique ecosystem and scenic resource to the state. Overhead options were quickly ruled out because of the distance of the crossing, the heights of the structures that would be required and the location of a nearby airport. Directional drilling was evaluated extensively but ultimately eliminated because of the length, location and residential impacts.

A thorough review of design alternatives resulted in burying an armored submarine cable to cross 1.1 mile (1.7 km) using a hydroplow, a machine designed to lay and bury armored cable.

While hydroplowing is a common technology and industry practice for cable installations in water crossings and estuaries, hydroplow installation had never been used in New Hampshire. Regulators and local officials were cautious about signing off on the plan in a sensitive natural resource. Community members were concerned installation of the cable would raise a large plume of silt the current could carry downstream, affecting eel grass beds, wildlife and oyster farms near the project area.

To mitigate these concerns, Eversource and its teams conducted extensive field tests of the sediments and materials within them. They performed detailed modeling and studies to show how the hydroplow operation would affect the turbidity of the water. The teams developed and explained their plan for timing the tide cycle to minimize how the sediments would travel during the operation. Environmental monitoring stations and controls helped to ensure the water quality remained within permitted limits.

The extra modeling and studies paid off. In the end, the actual cable burying operation generally resulted in much lower silt levels than the project team modeled.

Before laying the cable, Eversource needed to clean up work done a century ago. In the early 1900s, utility crews installed a 4-kV cable at the same crossing as part of one of the first long-distance electric lines in the state. Over the decades, the cables were upgraded to 34 kV to meet added demand. These cables had been damaged, repaired and eventually abandoned. This left large cable pieces scattered across the bay floor. Eversource hired the new cable installation contractor to identify the old pieces of cable, cut them up and bring them to the surface for disposal. This eliminated the risk of the old cables affecting the new cable installation.

The National Historic Preservation Act Section 106 consultation process with the New Hampshire Division of Historical Resources revealed the 1900-era cable installation included the original brick cable termination house on the western shore. Constructed in 1902, it was considered a historic building. However, it was in the path of the new construction.

Eversource worked with historic restoration experts to stabilize and relocate the historic building away from the path of the new line. After the new cable was installed, workers moved the house to a new location near the original site and fully restored it for future generations to appreciate.

Historic Farmland

Another community treasure is an old family farm in the Newington Historic District listed on the National Register of Historic Places that has a 1950s-era distribution line and right-of-way crossing the property. To restore the historic character of the farm, Eversource relocated the existing distribution line from the right-of-way in the farm field to the roadside. A half mile (0.8 km) of the new transmission line also was constructed underground within the right-of-way crossing the field.

The new underground transmission line was designed with additional cover to protect it and farm equipment from damage. The civil contractor worked closely with certified soil scientists to segregate each layer of soil before installing the duct bank and then placed the soil back in the same layers, closely monitoring compaction. This enabled the family to continue farming the land over the line without losing soil nutrients.

Eversource accommodated an underground design in several other locations within the town of Newington. The town's Pease Airport became an added challenge to the underground construction, not because of the large cargo planes flying overhead but because of the groundwater. After years of firefighting training at the airport and other activities in the area, the groundwater had become contaminated and flowed into the area of the duct bank. Crews collected more than 22,000 tons of soil and disposed of contaminated dirt. No contaminated soil was returned to the ground. They also collected and treated around 385,000 gal (1750 cu m) of water.

Railway Signals

Three miles (4.8 km) of the 10 miles (16 km) of overhead transmission line run along a Pan Am Railways corridor in the same location as an existing 34.5-kV circuit. Eversource sought to design the new transmission line to avoid any conflicts with railway signals.

The team conducted an alternating-current interference study to analyze ground faults on the existing lines and future 115-kV line and created a virtual world to match the real-world conditions. The study helped to determine a design that would mitigate any potential conflicts with signals on the railroad system and high-touch voltage concerns during faulted scenarios.

Because of the extensive amount of rock in the area, the conductivity of the soil was very poor, reducing the effectiveness of the grounding system. The mitigation design required extensive additional grounding at the transmission structures and counterpoise grounding running between structures in any areas that did not require road crossings or wetland crossings.

The railroad itself also required counterpoise grounding for faulted conditions. However, this grounding could not be connected directly to the railroad tracks during normal conditions because the railroad's signaling circuits include the track itself and would not work properly if grounded. Rail fault protectors were installed between the track and grounding system, which are off under normal operating conditions. Under abnormal conditions, such as a fault or lightning surge, the rail fault protector switch nearly instantaneously turns on and begins conducting, which enables the connection between the track and grounding system.

Key To Success

The Seacoast Reliability project involved all aspects of transmission line design and construction, including underground, overhead, submarine, distribution and substation. With the permitting, public approval process and construction lasting for more than seven years, frequent communication and collaboration among project teams proved essential to keep everyone on track.

The key to project success was communicating both what the plans were and why. Close coordination early on with permitting professionals, design and studies engineers, project managers and construction contractors helped to address challenges quickly and avoided affecting other parts of the project. The project involved numerous stakeholder meetings, briefs and site visits as part of the massive, coordinated effort. As a result, Eversource energized a line that met the needs of the surrounding communities while delivering safe, reliable service to the region's businesses and residents. TDW

JOSEPH SPERRY, P.E., (*joseph.sperry@eversource.com*) is a senior engineer for Eversource. He is an experienced civil and transmission line engineer, including substation, overhead, underground and distribution design. He has a BSCE degree from the University of New Hampshire and a MSCE degree from Norwich University. He has extensive knowledge in the design, permitting, siting and maintenance of overhead and underground transmission lines and distribution facilities from 12 kV through 345 kV. He has been involved in the development of design, construction and structure detail standards for overhead transmission lines and substation structures.

TODD GOYETTE, P.E., (*todd.goyette@powereng.com*) is a senior project engineer with POWER Engineers Inc. He specializes in underground distribution and transmission line engineering. He has extensive experience in the design and operation of high-voltage and extra-high-voltage underground distribution and transmission cables and is knowledgeable in all aspects of design, permitting and licensing, installation, operation and maintenance of underground cable systems. He has experience with self-contained fluid-filled, high-pressure fluid-filled, high-pressure gas-filled and extruded dielectric cable systems. He also is skilled in field construction supervision during emergency events.

Transmission structures for the 230 kV transmission line from Bayou Vista Substation in Bayou Vista, Louisiana, to Segura Substation near New Iberia, Louisiana. Photo by Cleco.

Hurricane Hardening

In three phases, Cleco Power installs US$312 million in equipment that can withstand hurricane-force winds up to 130 mph.

By **FRAN PHOENIX**, Cleco

Since embarking on the largest transmission upgrade project in its 87-year history, Cleco Power has relieved grid congestion by constructing new lines, substations and towers, all of which have strengthened the grid in south Louisiana, a region prone to hurricanes. The region, which was coined the Acadiana Load Pocket (ALP) because of its location and the transmission constraints, is adjacent to the Gulf of Mexico in south central Louisiana. Because customers of all electric utilities in the ALP could be affected by power restrictions, the utilities worked together to improve reliability for the entire region.

"With the completion of this critical transmission upgrade project, Cleco Power's transmission system is now more resilient and reliable because of good transmission planning, well-executed construction and project management, and close coordination with neighboring electric utilities," said Robbie LaBorde, chief operations and sustainability officer of Cleco Corporate Holdings, the parent company for Cleco Power. The ALP upgrades were driven by:

- Growth in the area that led to increased demand.
- Storm hardening to make the transmission infrastructure more resistant to hurricane-force winds.
- New system planning performance requirements.

Cleco Power spent a total of $312 million on upgrades, which included the most modern equipment — higher voltage transmission lines, structures that can withstand hurricane-force winds up to 130 mph, four new substations and other necessary equipment. The upgrades were completed in three phases. The construction work for phase one began in 2010, and the various upgrades continued until the completion of phase three in 2021.

"By completing the upgrades in phases, the company was able to control expenses," said Chris Thibodeaux, manager of transmission strategy for Cleco Power. "Transmission planning is an ongoing process and building new transmission lines, regardless of the size, takes a considerable amount of lead time due to regulatory laws, financing, planning, design, permitting, siting and land acquisition."

Terry Whitmore, vice president of transmission services said that the project supports the growth in south Louisiana, and customers in this region will benefit from the additional capacity and storm hardening for years to come.

Phase One Transmission Upgrades

In phase one, the project addressed the most immediate need, which was to expand the flow of electricity in south

Louisiana during periods of high demand.

"In this particular area, during the hot summer months when demand for electricity was extremely high, there were constraints on the system," Thibodeaux said. "Cleco Power had adequate generation in the region to serve customers but needed more transmission capacity due to growth in the area."

During phase one, Cleco Power partnered with multiple neighboring electric utilities to construct two, 230-kV lines from its Rork Substation near Eunice, Louisiana, to its Segura Substation near New Iberia, Louisiana. Cleco Power was responsible for 60 of the 90-miles of line. Construction began in 2010 and was completed in 2012.

The new 230-kV lines were placed near an existing 138-kV line to add more transmission capacity to the area, and both lines can withstand wind speeds up to 120 mph.

Steel poles for the 230-kV line from Terrebonne Substation near Houma, Louisiana, to Bayou Vista Substation in Bayou Vista, Louisiana. Photo by Cleco

"A 230-kV line is energized at 230,000 V while a 138 kV line is energized at 138,000 V," said Dennis Westgate, project management engineer. "A line energized at higher voltage can transmit more power than an equivalent line energized at lower voltage. Having multiple lines with a higher rating also provides redundancy, which is one of the most cost-effective ways to increase system reliability."

Redundancy helps prevent disruptions in electric service in the event of a mechanical problem or natural disaster.

"The additional line is like having another highway to travel on when driving. If something happens, and one highway is closed, you can travel on the other highway to get to your destination," added Westgate. "Phase one was a notable example of teamwork," said Walter Halbrook, manager of transmission and distribution engineering and project management. "Phase

Phase 3 include the building of a new 230 kV substation called Caneland in Baldwin, Louisiana. Cleco Power built four new substations as part of the transmission system upgrades. Photo by Cleco

one would not have been possible without cooperation from neighboring electric utilities."

Phase Two Transmission Upgrades

In phase two, Cleco Power partnered with another neighboring electric utility to construct a 36-mile 230 kV line from its Terrebonne Substation near Houma, Louisiana, to its Bayou Vista Substation in Bayou Vista, Louisiana. Cleco Power completed its 12 miles of the line in 2019, connecting its portion from the tie point in Amelia, Louisiana, to Bayou Vista Substation.

The neighboring electric utility completed its 24 miles of the line from Terrebonne Substation to the Amelia tie point in 2018. This line can handle wind speeds up to 130 mph.

"All of the new transmission lines are separate and can function independent of the other, which means if one has to be taken out of service due to maintenance work, for example, Cleco Power can continue to deliver power to its customers," said Westgate. "The goal is to responsibly build redundancy into the system to ensure reliable service."

Cleco Power began routing and designing its portion of the 230-kV line in early 2016 and received the required permits and right-of-way clearing in 2018.

The work in phase two was unique because of the terrain, according to Lance Speer, project construction manager for phase two. "The line constructed in phase two crosses four major waterways, so the contractors relied extensively on helicopters and specialized equipment," said Speer. "Included in that terrain are two islands, Avoca Island and Bateman Island, which have no road access."

To support the line, contractors built 101 new steel transmission structures with many of these structures ranging in height from 80- to 110-feet, which is two-to-three times the size of the average distribution utility pole.

The ALP transmission upgrades were driven by:

- **Growth in the area, which led to increased demand**
  The southern region of Cleco Power's service territory was experiencing transmission constraints due to growth and other changing conditions. Overloads on transmission lines can cause uncontrolled power outages. To prevent uncontrolled power outages and address the changing conditions in the ALP, Cleco Power invested $312 million to upgrade the transmission infrastructure in south Louisiana. The company will continue to systematically monitor its entire transmission system and make upgrades where needed through transmission planning.
- **Storm hardening to make the transmission infrastructure more resistant to hurricane-force winds**
  Some of the most powerful hurricanes to strike the United States have made landfall in south Louisiana which is adjacent to the Gulf of Mexico. The wind speeds and heavy rainfall from these hurricanes can knock down trees and power lines as well as cause personal injuries and even death. During the past two years, Cleco Power and its customers have recovered from four Gulf-Coast hurricanes. Hurricane Laura made landfall in August 2020, followed by Hurricanes Delta and Zeta in October 2020 and Hurricane Ida in August 2021. Cleco Power's new transmission structures can withstand hurricane-force winds up to 130 mph.
- **New transmission system planning performance requirements**
  Transmission planning helps ensure the system operates reliably over a broad spectrum of conditions. For example, a transmission line outage due to maintenance or mechanical problems at one or more generating facilities is a contingency the company must plan for, including any new performance requirements.

A heavy-lift helicopter, the Erickson Air Crane, was used to set the poles for the transmission structures which were built in sections. Photo by Cleco

The largest structures are approximately 239-feet tall, the equivalent of a 22-story building, which was the required height for the line to cross the Atchafalaya River and not disrupt activities on the river like shipping.

The line also crosses three other major waterways: Bayou Shaffer, Bayou Boeuf and the Gulf Intracoastal Waterway. Furthermore, the line is designed to help protect the steel structures should debris fly or blow into the line which significantly lessens the potential for structural damage and speeds up the power restoration process.

Phase Three Transmission Upgrades

In the final phase, Cleco Power constructed a 48-mile 230-kV transmission line that can handle wind speeds up to 130 mph from its Bayou Vista Substation in Bayou Vista to Segura Substation near New Iberia.

Phase three also included the building of a new 230 kV substation called Caneland at Cleco Power's Teche Power Station in Baldwin. The phase three upgrades began in 2019 and were completed in 2021.

"Contractors constructed a 22-mile line from Caneland to Bayou Vista and a 26-mile line from Caneland to Segura Substation," said Doug Gates, project construction manager for phase three. "A short 138-kV transmission line connected Caneland to the existing transmission grid at Teche, providing Cleco Power with an alternate power route to meet the bulk power needs of the local communities."

With all three phases of the project complete, Cleco Power now has multiple interconnected 230-kV transmission lines in the southern portion of its service territory that can withstand hurricane-force winds and meet customers' growing power needs.

"Together, the new and existing capacity make Cleco Power's

One of the new steel transmission structures built during the project. The largest structures are approximately 239-feet tall, the equivalent of a 22-story building. Photo by Cleco.

entire transmission system stronger and more reliable," said Thibodeaux. "The transmission planning group will continue to evaluate grid conditions and produce long-term forecasts of electrical demand to ensure safe delivery of power to customers." TDW

FRAN PHOENIX *(Franchesca.Phoenix@cleco.com)* is a communication strategist III with Cleco Support Group LLC. Fran has more than 20 years of professional experience in communications, public relations, marketing and media relations, including research/writing/editing in two distinct industries – electric utilities/energy and higher education.

A crew cuts trenches running parallel to existing overhead distribution line. PG&E successfully completed undergrounding nearly 4 miles (6.4 km) of overhead power lines in Santa Rosa, California, U.S. Photos courtesy of PG&E.

An Inside Look at a PG&E Undergrounding Project

The utility completes a 4-mile project in the High Fire Threat District of Santa Rosa, improving safety and electric reliability for 11,000 customers.

By **DEANNA CONTRERAS**, Pacific Gas and Electric Co.

During severe weather, Pacific Gas and Electric Co. and other utilities in the West shut off power to prevent vegetation and other debris from encountering energized power lines and starting a wildfire. Pacific Gas and Electric Co. (PG&E) works year-round to harden its system and reduce the number and impact of these public safety power shutoff (PSPS) events. Its system hardening efforts have included installing stronger, more resilient equipment, such as power poles and conductor, as well as removing overhead powerlines and burying them underground.

In September 2021, PG&E successfully completed undergrounding nearly 4 miles (6.4 km) of overhead power lines in Santa Rosa, California, U.S. This project not only did it helped with system hardening and wildfire mitigation, but it also improved reliability for approximately 11,000 customers. Residents and businesses in portions of the Rincon Valley and Oakmont neighborhoods in Santa Rosa had been impacted by several PSPS events over the last couple of years. Now that the lines serving those customers are underground, the risk of a fire from vegetation contact with overhead conductors has been mitigated and the customers have not been impacted recently by PSPS events.

"By placing some of our power lines in the most fire-prone areas underground, we greatly reduce the need to impact our customers and turn off their power for safety during high winds and extremely dry weather events," said Brad Koelling, manager of grid design at PG&E. "Specifically, this project helps eliminate the need for PG&E to turn the power off for thousands of residents in Rincon Valley and the Oakmont community, as well as businesses and schools that are not in a High Fire Threat District."

Reducing Wildfire Risk

Of PG&E's 25,000 miles (40,234 km) of overhead distribution lines, 30% traverse the highest fire-threat areas (Tier 2, Tier 3 and Zone 1) in California. These areas are referred to as High Fire Threat Districts (HFTDs). Since the devastating October

Schedule 40 PVC conduit encased four 12-kV circuits in open trench. Now that the lines serving those customers are underground, the risk of a fire from vegetation contact with overhead conductors has been mitigated and the customers have not been impacted recently by PSPS events.

PG&E contractor runs conduit ranging in diameter from 2 inches to 6 inches, depending on cable. This project helped with system hardening and wildfire mitigation, but also improved reliability for approximately 11,000 customers.

2017 Northern California wildfires and 2018 Camp Fire, undergrounding has become a more viable option as part of the utility's efforts in reducing wildfire risk.

Today, PG&E is in the process of burying overhead electric distribution lines in the town of Paradise and surrounding areas that were destroyed in the 2018 Camp Fire.

The heat from the 2017 Tubbs Fire damaged the utility's underground electrical equipment, such as cables and transformers, in Santa Rosa's Coffey Park neighborhood. While PG&E replaced 22 miles (35 km) of that electric cable, crews

Multiple undergrounding demonstration projects, aimed at converting overhead powerlines to underground, were initiated in PG&E HFTDs, such as in Alameda, Contra Costa, Nevada and Sonoma counties.

built 10 miles (16 km) of a new gas main line in a joint trench that spanned 17 miles (27 km).

Multiple undergrounding demonstration projects, aimed at converting overhead powerlines to underground, were initiated in PG&E HFTDs, such as in Alameda, Contra Costa, Nevada and Sonoma counties. One of the objectives of the plan was to better understand the construction and cost requirements associated with undergrounding.

Overhead To Underground

The Santa Rosa area undergrounding project began in April 2021. With the state's increased wildfire risk and growing need for PG&E to initiate PSPS events in the neighborhoods of Rincon Valley and Oakmont, "time was of the essence," said Josh Eagar, project manager for this undergrounding project.

Veteran Power Infrastructure (VPI), a certified Disabled Veteran Business Enterprise contractor, performed most of the civil work. The state's call-before-digging system was notified and one-call system site locators marked the approximate location of buried utilities with paint and flags along the route of planned excavation.

The route was open-cut along streets and sidewalks, running parallel to the existing overhead power line. Trenches, excavated by PG&E's general construction crews, ranged in depth from 36 inches to 50 inches (914 mm to 1270 mm) and with widths from 18 inches to 24 inches (457 mm to 610 mm).

The overhead distribution facilities were removed and four circuits, 12 kV each, were buried in 2-inch, 4,-inch and 6-inch (51-mm, 102-mm and 152-mm) PVC Schedule 40 conduit. Some of the pole facilities would remain in place to carry telecommunications equipment and service lines that feed power directly to homes and businesses. Summit Construction Solutions Inc. pulled the cable through the conduit.

"Like many construction projects, there were many challenges

PG&E's Commitment to Undergrounding

On July 21, 2021, Pacific Gas and Electric Co. (PG&E) announced a new multiyear infrastructure safety initiative to underground approximately 10,000 miles (16,093 km) of power lines in and near high fire-threat areas. This initiative represents the bold, innovative action needed to meet California's climate challenges and is the largest effort in the U.S. to underground power lines as a wildfire risk reduction measure.

More than one-third of the electric lines that serve PG&E customers are in high wildfire risk areas. California, Oregon and Washington, along with several other western states, continue to experience an increase in wildfire risk and a longer wildfire season. The increased number of dead trees, drought, hotter temperatures and higher winds because of climate challenges have significantly increased the risk of catastrophic wildfires.

How Will It Work?

PG&E is prioritizing undergrounding in areas where it can have the greatest impact on reducing wildfire risk and public safety power shutoff (PSPS) outages. In addition, the utility is focusing on protecting critical facilities, like hospitals, and looking at a variety of factors, including topography terrain (including accessibility for ingress and egress of areas), constructability, vegetation, existing infrastructure (such as the number of services and transformers), reliability, the potential for trees falling into lines and climate change challenges among others.

When possible, PG&E will prioritize its efforts in areas that address multiple needs and deliver the highest level of safety for customers. Prior to its 10,000-mile undergrounding announcement, the utility had multiple undergrounding projects underway, like the Santa Rosa project. It plans to continue those projects under its current criteria.

To meet its 10,000-mile goal, PG&E plans to significantly increase its underground miles annually. The utility has targeted about 3,600 miles from 2022 to 2026, including: 175 miles in 2022; 400 miles in 2023; 800 miles in 2024; 1,000 miles in 2025; and 1,200 miles in 2026. To support the accelerated rate of undergrounding, the utility will use an engineering, procurement and construction strategy to aid in resourcing and work execution. In addition, it will coordinate with the International Brotherhood of Electrical Workers (IBEW) and the Engineers and Scientists of California (ESC) so resources are available to execute the work.

Building and expanding the electric system underground will not only help PG&E to reduce wildfires caused by equipment, but it also will help to protect trees, improve system reliability and, in some cases, beautify hometowns.

By The Numbers

- 10,000 = Miles PG&E plans to underground in and near high wildfire risk areas
- 1/3 = Electric lines that serve PG&E customers in high wildfire risk areas
- 2662 = Total miles of underground distribution lines in high fire-threat areas
- 27,000 = Number of electric line miles PG&E currently has underground
- Over 20% = number of PG&E's distribution lines that are underground
- 1 Million = Trees PG&E prunes or cuts down annually to maintain clearance from power lines
- 100,000 = Approximate miles of overhead power lines PG&E inspects at least once a year

along the way, including a fast-approaching timeline, acquiring new easements, permits and rights-of-way, and construction difficulties brought on by the limited space of the narrow roadway," said Jesse Lorz, an electric distribution engineer with PG&E. "These were compounded by other utilities and substructures within the project boundaries."

"The project also required significant planning and construction coordination with a large volume of stakeholders," noted Project Manager Eager. "Supplementing our internal crews with contractor support was the only way we could complete the work in time before wildfire season."

"Our design engineers responded in a timely manner to questions and concerns identified in the field and helped provide direction to crews all while keeping our timeline. A special thanks goes out to our associated partners in performing the work with a fiduciary mindset on behalf of PG&E and the customers it serves," Eagar added.

Undergrounding also included backfilling and street and sidewalk restoration. Crews were diligent about repairing concrete and asphalt in compliance with city street and sidewalk geometric design standards for pavement cut and repair standards. In a few cases, landscaping was required.

More Undergrounding Ahead

In July 2021, PG&E announced a multiyear commitment to underground 10,000 miles (16,093 km) of distribution lines in or near HFTDs across the utility's more than 70,000 sq mile (181,299 sq km) service area in Northern and Central California. This commitment represents the largest effort in the U.S. to underground power lines as a wildfire risk reduction measure. "Extraordinary times call for extraordinary solutions," said PG&E's CEO Patti Poppe. The unprecedented infrastructure safety initiative will further harden PG&E's system, help to prevent wildfires and lower the need for shutting off power. TDW

Acknowledgment

The author would like to thank these experts at PG&E for contributing to this article: Josh Eagar, a project manager on the T&D project management team; Jesse Lorz, an electric distribution engineer on the grid design team; and Brad Koelling, manager of grid design.

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For More Information

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The Gull Bay microgrid's use of solar power, battery storage, and grid technology will supply all of the community's energy needs during the day. All photos courtesy of Stantec.

More Energy Independence in Indigenous Canada

Using solar, battery storage and grid technology, a microgrid helps to reduce the use of diesel fuel by 30% in a remote First Nations community.

By **PETER BRIGHT**, Stantec; **SHAWN BREMNER**, Ontario Power Generation; and **KEVIN RITZMANN**, Alltrade Industrial Contractors Inc.

According to its government, Canada has more than 630 Indigenous and nearly 300 remote communities, with many more in the U.S., Australia and other countries around the world. For the Indigenous and remote communities left off the main electrical grids in outlying areas across Canada, finding reliable energy resources — that also are from clean renewable power — has been challenging. Historically, diesel fuel has been one of the only off-the-grid energy sources for these communities, but diesel tends to be expensive because it must be transported by land or sea and has some serious environmental and human health pitfalls, including noise, air pollution, fire risks and spill risks.

Final aerial photo of the Gull Bay Microgrid Project, which allows Indigenous Canadians to use less diesel fuel and be more energy independent.

Luckily, a solution to this challenge exists — one that uses natural weather resources, microgrids and battery storage. In more recent years, utility-scale renewable-energy technology improvements have made renewable energy accessible. Increased production has made wind, solar and energy storage equipment more of a commodity, and large-scale production has paved the way for reducing costs and making projects more viable.

Gull Bay Project

Gull Bay, Ontario, Canada, is home to an Ojibway Nation, Kiashke Zaaging Anishinaabek, where nearly 375 residents live on the reserve and just under 100 homes and 13 community buildings had been using diesel generators since the 1960s.

Ontario Power Generation (OPG) partnered with KZA on Canada's first fully integrated solar energy-storage system based in a remote First Nations community. Recognizing it was not economically feasible to connect the community to the Ontario electrical grid, the Independent Electricity System Operator (IESO) established a fund to support communities and find alternative methods for reducing diesel use. The project received additional funding through the provincial and federal government.

Here is what community's energy plan looks like now: Using solar, battery storage and grid technology, the clean energy microgrid has helped to reduce the use of diesel fuel by 30%, or approximately 130,000 liter (34,000 gal) per year. Around 1000 solar panels, laid out over a 1-ha (2.5-acre) site, supply the northern community's energy needs during the day, while battery storage and diesel power provide energy at night and during the winter months.

Outbuilding housing power equipment. The microgrid uses solar power, battery storage, and grid technology and supplies half of the community's energy needs, replacing the 130,000 liters of diesel fuel per year that the community was dependent on.

The community renewable energy microgrid and diesel generating station are interconnected to maximize the use of renewable energy. Even so, the community continues to use diesel power at night and during days with low irradiance, as some feel hesitant to give up diesel entirely — especially when they have relied on it for generations. Projects such as this prove the technology works in real-world situations. They allow communities to become more comfortable with their new energy system and expand it to full capacity. This process ensures the community's energy requirements are met seamlessly while maximizing the reduction in carbon emissions.

Tents during Kiashke Zaaging Anishinaabek — Gull Bay First Nation meetings. The Kiashke Zaaging Anishinaabek – Gull Bay First Nation is an Ojibway Nation located on the western shores of Lake Nipigon and the surrounding territory. Thunder Bay, Ontario, about 120 miles away, is one of the closest cities to the reserve.

Assembling photovoltaic solar panels.

The remote location in Northern Ontario has limited communications, long distances from major vendors, extreme temperatures down to –45°C (–49°F) and a lack of accommodations for out-of-town workers. Therefore, the Gull Bay project team relied heavily on detailed preplanning to avoid winter work, leveraged off-site prefabrication for the E-House, security camera system, weather station, transformers and string inverters. Alltrade Industrial Contractors Inc. prefabricated photovoltaic wire harnesses and combiners, established seasonal lodgings and set up satellite internet for stable communications to the site.

The location's spring thaw also was identified as a challenge to the overall installation of the microgrid, so sediment and erosion control was crucially important, plus the site sits on a high-water table. After Stantec and Alltrade performed a lot of geotechnical testing and pile pull testing, the project site was shifted some 20 m (66 ft) to the south to take advantage of stronger, more compacted soil.

The existing geotechnical site also presented challenges. By shifting the site back during the design phase, the project team increased the feeder cost to the diesel interconnection and avoided costly foundation refusals. Next, sleeves were added to the

Location Challenges

The approach of installing solar panels in a remote community is not new. However, what is unique is designing a complete microgrid that includes battery storage and doing it in a way that respects traditional values.

On the electrical side of things, grounding was identified almost immediately as a potential issue, as the community's existing electrical system had a floating neutral and the microgrid needed a grounded system. The solution was to keep the microgrid system transformer energized constantly to maintain system grounding.

helical piles prior to pile caps and racking to mitigate frost heaving. Ultimately, this decision eliminated the need for concrete in the overall design — a good call because getting concrete to the remote site would have been a challenge of its own.

The Right Equipment

Selecting the right equipment and integrating all the separate systems was one of the last and biggest challenges of the project. Ensuring the solar inverters and battery energy storage system (BESS) were integrated successfully with the microgrid controller required an enormous amount of open and timely communication with all project stakeholders.

Some of the equipment selected for the project included Polar Racking fixed-tilt solar panels, Fronius Symo string inverters, Canadian Solar 365-W mono-facial modules, and ABB's MGC600 microgrid controller and 300/555-kW/kWh BESS.

Community Partnership

Many benefits came from building a genuine partnership with all project stakeholders, including the local community. A benefit plan based on community expectations included early engagement with the energy liaison, chief and council to aid in site selection, selecting the technology to be used and completing the required environmental screening. As part of the plan, a local job fair was held early on to meet with interested candidates from the community and resulted in quite a few community workers.

Safety requirements and documentation were communicated clearly and shared with new workers and subcontractors. Aggregates for the roads were purchased from local gravel pits. The community was left well versed in the operations and maintenance of the solar system. In fact, Kiashke Zaaging Anishinaabe owns and operates the microgrid and is offering to teach and train other First Nation communities how to operate and maintain the system.

A Repeatable Process

It is possible to bring this microgrid solution to other Indigenous communities, remote towns and work sites. Although each project solution must be based on a location's unique historical weather data and scalable to meet the needs of the community, the process used for this project is repeatable.

Microgrid construction team of local community members and Alltrade team.

Group photo of fire training for the microgrid site.

Lessons learned from the project included conducting front-end site testing to learn about the soil, using off-site prefabrication to help save on cost and labor, eliminating the use of concrete and other scarce materials, using local labor and subcontractors, and close collaboration with all stakeholders.

Not only did this process meet the needs of the community but it also enabled project costs to be established up front, optimized energy production, established the lowest cost of electricity (LCOE) and used one of the best renewable energy combinations available. TDW

Battery energy storage building.

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Manitoba Hydro: Investigating Flashovers on HVDC Transmission Lines

CONGRATULATIONS
TO OUR APRIL FEATURED LINEMAN!
Miguel Angel Carrizales
Evergy

- Born in San Angelo, Texas, and has six brothers and sisters.
- Is first in his family to have graduated college and work in the utility industry. His mother is from Juarez, Chihuahua, Mexico, and his father is from Ciudad Acuña Coahuila, Mexico. They came to the United States as residential workers to pursue a better life for their children.
- Married to Ellizabeth Tellez. They have been together for 11 years and married for more than a year with two beautiful children, Dario, 14 and Mariana, 15.
- Enjoys working on cars and remodeling homes, traveling and devoting time to his family.

Miguel Angel Carrizales says that there is always something new in line work.

Early Years
I came across the utility industry when I decided to return to school to pursue a better life and career for myself and family. My family inspired me to get into the trade. They believed I could do anything as long as I put my mind and heart into it.

Day in the Life
Being a lineman is my first job in the utility industry. As a troubleman for Evergy in Kansas City, Missouri, I am responsible for diagnosing circuits and equipment and handling customer service. Every moment and ticket are different. When I receive power-out calls, I respond to area outages and face immediate dangers and hazards. It is challenging to diagnose problems in the dark. It is rewarding when I can fix a problem to get lights back on, especially in extreme weather conditions where customers have been without power.

Safety Lesson
The first winter storm we had in 2018 was an eye-opening experience. I learned quickly the importance of communication and all the circumstances that come with storms. For example, it's important to have the proper PPE and perform the proper procedures. Voltage checks, isolating the circuits and restoring circuits is crucial to our safety and wellbeing.

Memorable Storm
I have been a part of snowstorms and rainstorms. Getting through the elements when it's snowing and below zero or raining with lightning and thunder is a blessing. High winds can cause old trees to land on the system or homes. Snow makes almost everything impossible to access. But we strap on our boots and find a way to bring power back to the people. Most storm restorations take over a couple of weeks on end and require all hands on deck. It's difficult to work 16 hours on end when we are hungry and have gotten little sleep or home life, but there is no better feeling than the cheers from our customers coming back on with lights.

Labor-Saving Tools
I can't live without any of my tools — from my basic hand tools to electric and pneumatic. They are my prize possessions. The tools are more advanced and are battery-operated now. I respect the past generation of laborers, but I appreciate any tools that can help my body maintain its integrity. My father and I bonded over tools, and I can now show my son my tools and pass them on to him someday.

Life as a Lineman
If I had to do it all over again, I would have done this sooner. It is life changing, challenging and rewarding. When I am asked what my plans for the future are. you are looking right at it. I am 33 years old and found happiness in what I do. I love being a lineman.

Plans for the Future
My plan for the near future is to sharpen my skillset. There are so many options available. Maybe I will lead a crew one day or be senior in my department. TDW

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

An unexplained flashover was captured midspan on a negative pole of Manitoba Hydro HVDC Bipoles on a sunny fair weather day in July of 2021.

Investigating Flashovers on HVDC Transmission Lines

Manitoba Hydro deployed new technology and conducted a research project to measure and mitigate unexplained flashovers.

By **AMY FISCHBACH**, Field Editor

High voltage direct current (HVDC) lines transmit power over long distances in Manitoba, Canada. Back in the 1970s, when Manitoba Hydro first energized the Bipole 1 and II HVDC lines, the utility started noticing unexplained flashovers, which are electrical discharges from energized conductors to ground.

These flashovers occurred mainly in the remote northern portion of its service territory, in the afternoon or early evening, during the summer months, mainly from July to August, and only on the negative poles during steady state conditions with no switching surge.

"We have up to 40 of these events in the summer, and they have occurred since the inception of the lines," said Jeff Laninga, live line and electrical effect section head at Manitoba Hydro. "They were thought to be preceded by precipitation and light winds at the time of the event."

Following a flashover, an HVDC system can recover from the faults in a blink of an eye, Laninga said, but there are consequences. For example, live line work is prohibited between May to October on Manitoba Hydro's on affected HVDC transmission lines. No safety hold-offs are normally given because a fault would result in an outage, and an Emergency Energy Purchase could cost as much as $1 million. Daily outage costs can soar up to $500,000. In addition, the flashovers can delay large, energized maintenance projects, could ignite wildfires or pose risks of arc flash events for workers.

Installing Monitoring Systems

The 1800 MW Bipole I, which has been in service since 1972, spans 895 km, and the 2000 MW Bipole II, installed in 1978, measures 937 km. Four years ago, the utility also constructed the 2000 MW Bipole III, which is 1,400 km long. Large portions of these lines are situated in a remote location with no communications, no AC power and difficult terrain.

Back in 1996, the utility made its first attempt to capture a flashover event using video cameras, VCRs, solar panels and batteries for a total of 12 systems. The video had to be retrieved within 24 hours of an event by helicopter, and only two lightning strikes were captured.

To better understand the problem, Manitoba Hydro worked with Ai4 Technologies and AISPECO to install five camera systems in historically active locations. The team monitored the flashovers through daily LiDAR technology, environmental sensors and 10 hours of video recording at times of interest.

"We put the five systems fairly close together and concentrated in the region," Laninga said. "I chose structure locations with the most active historical events."

On the towers, Manitoba Hydro installed a cabinet, batteries, cameras and a satellite dish for system monitoring and remote data transfer. Environmental sensors measured air pressure, particulate matter, solar radiation, humidity, wind speed and direction and rain. The utility also installed a solar panel that tilted facing south for maximum sun exposure.

"We captured a flashover with the monitoring system on July 20, 2021, and the photo shows an intense arc on the negative pole on the right-hand side," Laninga said. "At the end of the event, you can see the arc dissipating and getting weaker as the system does a fast restart."

To locate the flashover point in LiDAR, the team relied upon spacer dampers, which provided a reference point. "Conductors and rope can only follow a certain curve called a catenary," he said.

At five locations with historically active unexplained flashovers, Manitoba Hydro installed a cabinet with computer hardware and batteries, cameras, lidar, environmental sensors, solar panel and a satellite dish for system monitoring and remote data transfer.

Reflecting on the Data

Using a cloud-based application, Manitoba Hydro and team then analyzed the data. It took many days of analysis to review the images from the LiDAR system, which was part of the fixed tower system, as well as the environmental sensors on the structures.

LiDAR only provided a limited number of reflections from the conductor. Laninga said this is typical because the measurement angle of the LiDAR is not optimal when it is measuring the conductor from the tower.

By measuring the distance to the vegetation from the fitted curve, Manitoba Hydro discovered the closest point between the vegetation and the curve was about 15 ft to 18 ft at the time of the event, which exceeds industry requirements.

"Most of the reflections reflect away from the LiDAR sensors," he said. "The vegetation, however, has more surface to provide greater diffusion."

By measuring the distance to the vegetation from the fitted curve, Manitoba Hydro discovered the closest point between the vegetation and the curve is about 15 ft to 18 ft. At the utility, the Minimum Approach Distance (MAD) for 500 kV HVDC is 10 ft, and the Minimum Air Insulation Distance based on standards with no switching surge is 3.5 ft. Also, the NERC MVCD (minimum vegetation clearance distance) is 8 ft for 500 kV DC.

"It is known that flashovers occur in areas where vegetation has recently been cleared and in areas where there is limited vegetation," Laninga said.

Looking Ahead

Since Bipole III was put into service in 2018, no unexplained flashovers have occurred. The line was designed and constructed with increased insulation length, taller structures for increased clearance and a three-bundle configuration to reduce the voltage gradient stress.

Through further research on the lines, Manitoba Hydro discovered that the flashovers are shown to occur midspan on sunny days in the summer months at the warmest part of the day. They also occur over large clearance distances greater than MAD and MVCD.

"Computer monitoring and vision technology has been shown to be able to continuously monitor the environment and assets in remote locations with no need for helicopter transportation, existing cell phone towers/communications and no power source," Laninga said.

At this point in time, however, further data collection is required. Also, more work is required on standards related to space charge and HVDC for live line work as it is currently mainly based on HVAC testing.

The utility is also examining the impact of smoke on air conductivity and live working and clearance distances through field sensors and high-voltage laboratory tests.

"I want to study the impact of smoke on air conductivity," Laninga said. "Air becomes more conductive with smoke versus no smoke and is another variable that only exists in the warmer in months. There are no tools that exist currently prior to live line work for linemen to assess this risk. It is expected with climate change that wildfires and smoke around transmission lines will increase."

In the future, Manitoba Hydro will be studying the flashovers in a high-voltage laboratory through full-scale and small- scale testing to replicate the phenomenon and attempt to mitigate the issue in the most cost-effective way. TDW

Editor's Note: To listen to a Line Life podcast featuring an interview with Jeff Laninga of Manitoba Hydro on Manitoba Hydro's research on flashovers, visit *https://anchor.fm/line-life-podcast.*

AMY FISCHBACH (*amyfischbach@gmail.com*) is the Field Editor for *T&D.*

Parting Shot

Photo by **PAUL SALGADO**, MYR Group

Sturgeon Electric California Crew Foreman Joe Leon and his crew replace a capacitor bank while on the right of way in Wildomar.


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New spools of high voltage cable are deployed for installation in an undergrounding project. The lengths of underground lines are subject to certain physical limitations which, when exceeded, cause untimely wear and tear. Photo by Chris Van Lennep, Dreamstime.

Overhead or Underground Transmission? That is (Still) the Question

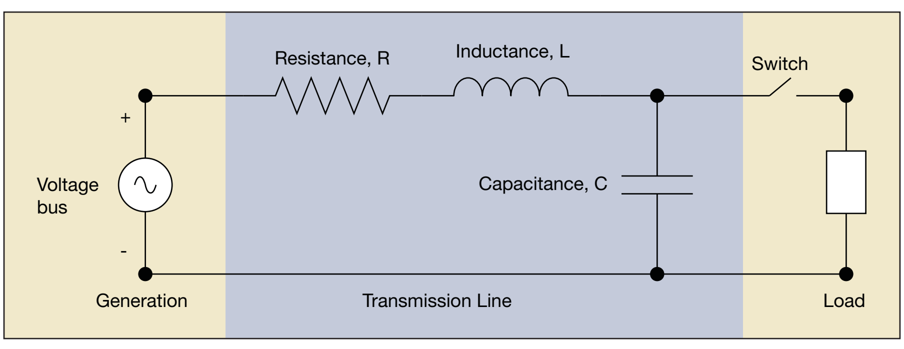
The second part of this two-part series examining underground high-voltage ac lines explores cable length limitations.

By **ROBERT G. OLSEN**, Washington State University, and **JON T. LEMAN**, POWER Engineers

Discussion continues at the national level about power grid upgrades to support increased electrification. In fact, since the first part of this article series ran (*T&D World* March 2022), Pacific Gas & Electric Co. publicized more details on its plans to put 3600 miles (5794 km) of distribution lines in California underground over the next half decade, with the goal of scaling up toward that number and topping 1000 miles (1609 km) annually in both 2025 and 2026. The utility is talking with seven firms about its overall plan to bury 10,000 miles (16,093 km) of distribution lines as part of a plan to help the California power grid operate more safely and resiliently. Plans such as this highlight the importance of careful characterization of underground cable limits.

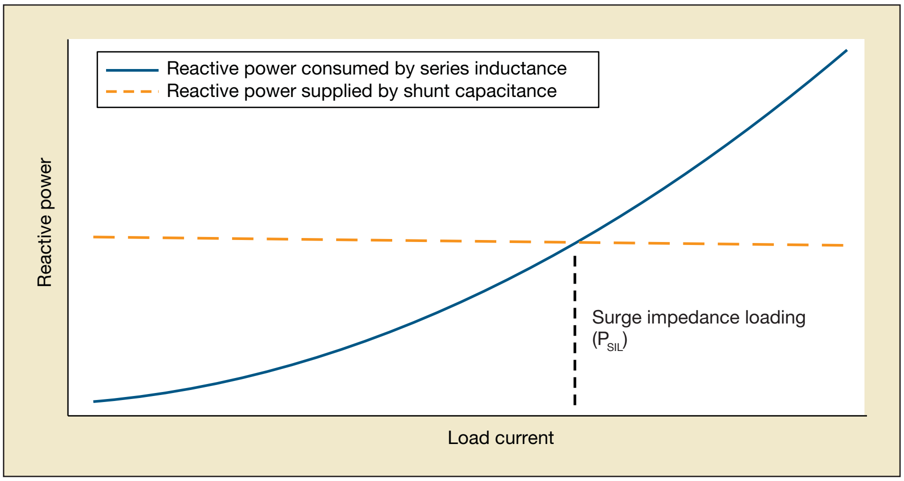
The first part of this article series discussed the specific issues utilities need to consider when evaluating the use of alternating-current (ac) high-voltage cables for long-distance transfer of electrical power. The high costs of design and construction, shorter asset life and maintenance challenges of high-voltage cable systems should be considered by utilities and grid operators when weighing underground vs. overhead options for transmitting bulk electrical power.

In this second part, the focus turns to the ac cable length limitations imposed by electrical impedance characteristics. It is generally understood that ac cable lengths are constrained



Basic transmission line model connection a generator and a load.

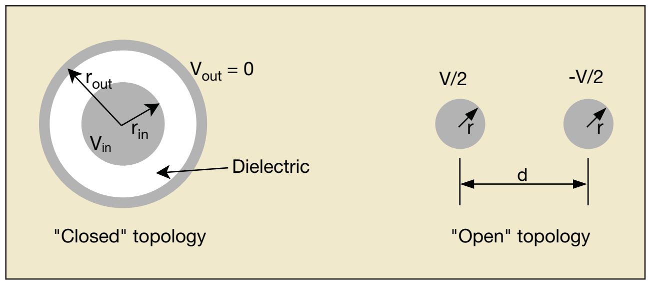
by their capacitive current. A simple calculation of cable current rating divided by charging current per length often is used to estimate maximum allowable cable length. However, further examination of transmission line impedance characteristics leads to a more general approach for estimating maximum cable length. This article discusses these concepts at a high level, and links are provided at the end to an online calculator and more detailed technical information. Application of these concepts can assist utilities in assessing and planning for increased deployment of underground T&D facilities.



Transmission line reactive power balance as a function of load current.

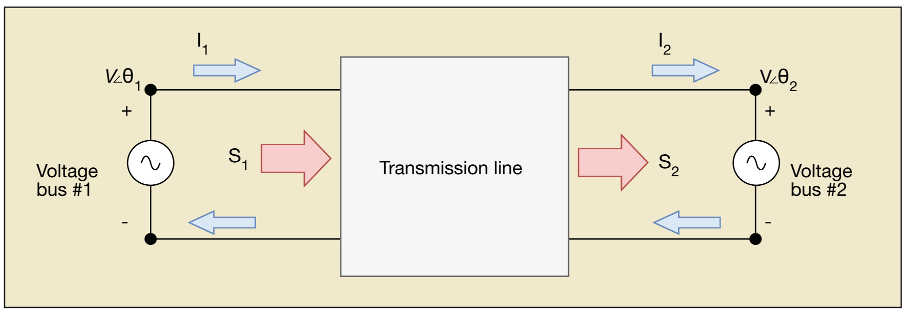
The Optimal State

It is important to review transmission line basics pertinent to this discussion. For simplicity, examples are discussed on a per-phase basis. While helpful for illustrative purposes, actual three-phase equations that include mutual coupling should be used for analysis.



Transmission line reactive power balance as a function of load current.

The figure on the facing page illustrates a simple transmission line connected between a source and a load. The line is modeled with a shunt capacitance and a series resistance and inductance. A variant of this model (not shown) places half the capacitance on either side of the inductance and resistance. This model is valid for lengths less than about 100 km (62 miles). If the load is disconnected from the energized line by opening the switch, current can still flow in the loop that remains through the resistor, inductor and capacitor. The impedance of the capacitor dominates and the current into the line is approximately proportional to the total capacitance, which in turn is proportional to the length of the line. The current in this no-load case is sometimes referred to as a charging current. Because the current is dominated by the capacitance, reactive power is exported by the line and must be absorbed by the source.



Simple power system used to determine length limits for underground cable.

A 345-kV underground cable system (199-kV line to ground) has a charging current on the order of 10 A to 20 A per km. Therefore, an energized open-circuited 10-km (6.2-mile) length of cable may have between 100 A to 200 A of charging current. Beyond some length, the capacitive current alone will exceed the thermal limit, which is on the order 800 A to 1500 A per phase for a typical transmission cable.

This simple method of using charging current to identify maximum length cannot be applied generally to all transmission lines. As an example, consider the case of overhead transmission lines, which have about one-tenth the capacitance of underground lines (that is, one-tenth of the charging current). If no-load charging current limits the length of high-voltage cable to values on the order of tens of km, then universal application of the simplified method would mean high-voltage overhead lines could not exceed lengths on the order of hundreds of km. However, operational experience indicates no such limit applies to overhead line lengths.

In the case of overhead lines, the simplified method fails because it does not account for the inductive properties of the circuit. The reactive power consumed because of current flow in the inductor is subtracted from the overall reactive power supplied by the capacitance. The result is a reduction in the amount of reactive power the generator needs to absorb and a corresponding reduction of the total input current to the line.

To explore this further, assume the switch in the first figure is closed to connect a resistive load to the line. The voltage drop across the relatively small series resistance and inductance is negligible. Therefore, the voltage across the capacitance does not change much and reactive power supplied by the capacitance ($\approx\omega CV^2$) is approximately constant despite changing load. However, as load current increases, the reactive power consumed

Safety signage for buried cables. All high-voltage power lines have thermal limits on how much power they can transfer safely. Photo by Calvin L. Leake, Dreamstime.

by the series inductance increases significantly ($\approx\omega LI^2$, where ω is the frequency in radians per sec.).

The figure at the top of the previous page shows a plot of inductor and capacitor reactive power as functions of load current. At some point the load current is such that reactive power consumed by the inductance is the same as reactive power supplied by the capacitance. No reactive power is supplied to the line or absorbed from the line by external generation. This is called the surge impedance loading (P_{SIL}). The load resistance that gives this load level is called the surge, or characteristic, impedance and is calculated as $Z_S=\sqrt{(L/C)}$. Surge impedance loading can be calculated as $P_{SIL}=V^2/Z_S$.

Topology And SIL Differences

Two different topologies are used for transmission lines in these examples as shown in the middle figure on page 43. The first is a closed topology of two coaxial conductors separated by a dielectric material that fills the space between them. This topology is used for most underground cables. The second is an open topology of two parallel cylindrical conductors separated by some distance in free space. Configurations like this (or with additional wires) historically have been used for overhead transmission lines.

The closed topology of power cables gives characteristic impedances on the order of 20 ohms to 60 ohms (high capacitance and low inductance). The open topology of overhead transmission lines gives characteristic impedances on the order of 200 ohms to 400 ohms (low capacitance and high inductance). Hence, the surge, or characteristic, impedance of an open wire transmission system is on the order of 10 times larger than that of a coaxial cable.

All high-voltage power lines have thermal limits on how much power they can transfer safely. For overhead lines, these limits have their origin in the maximum temperatures of conductors, derived using the type of conductor as well as a balance between ohmic/solar heating and cooling due to convection (wind) and thermal radiation. If thermal limits are violated, excess conductor sagging and loss of conductor strength may occur. For underground lines, heat sources include ohmic losses, dielectric loss and magnetic losses, if enclosed in steel pipe. Heat dissipation is constrained by the thermal conductivity and temperature of the materials in which the line is embedded. If cable thermal limits are violated, more rapid deterioration of insulating material occurs. This shortens the life of the cable. Generally, thermal limits for underground lines are more severe; they must be operated at lower temperatures and, consequently, cannot carry as much current as overhead lines for the same voltage class and conductor diameter.

As an example, the per-phase surge impedance loading for a 345-kV overhead transmission line (199-kV line to ground) with a typical 250-ohm surge impedance is 159 MW (about 800 A per phase). This is reasonable for an overhead line and consistent with many years of experience.

By contrast, an underground transmission line designed for the same voltage will have a much smaller surge impedance, generally around 40 ohms. In this case, the surge impedance loading becomes about 5000 A (about 992 MW). This is much larger than thermal limits typically allow for any single underground cable. Consequently, safe operation of the cable would be well below the surge impedance loading and still results in export of reactive power, even sometimes for relatively short lines.

The bottom line is the reduced surge impedance coupled with reduced thermal limits of underground lines results in an ac length limit that is difficult to overcome.

A utility worker performs work on an overhead line. Fundamental differences exist between underground and high-voltage ac transmission lines because of their topology and heat-transfer characteristics. Photo by Rafael Ben Ari, Dreamstime

Finding Length Limits

The bottom figure on page 43 shows a transmission line connecting two voltage buses with equal voltage amplitudes. Complex power flow (S) can be expressed in terms of transmission line length (l) and voltage phase angle difference ($\Delta\theta = \theta_1 - \theta_2$). It is primarily the difference in voltage angle that drives real power flow from one bus to the other. Further, it is possible to derive an expression in which the magnitude of complex power is shown as some fraction of the surge impedance loading. Equation 1 is conceptual, but shows that the normalized complex power magnitude has real power and reactive power components that are each functions of both line length and voltage phase angle difference. In detailed form, the equation would include parameters associated with wave characteristics and dielectric material properties:

$$\left|\frac{(S_1(\Delta\theta,l)}{P_{SIL}}\right| = |P_1^n(\Delta\theta,l) + jQ_1^n(\Delta\theta,l)| \text{ (Eq. 1)}$$

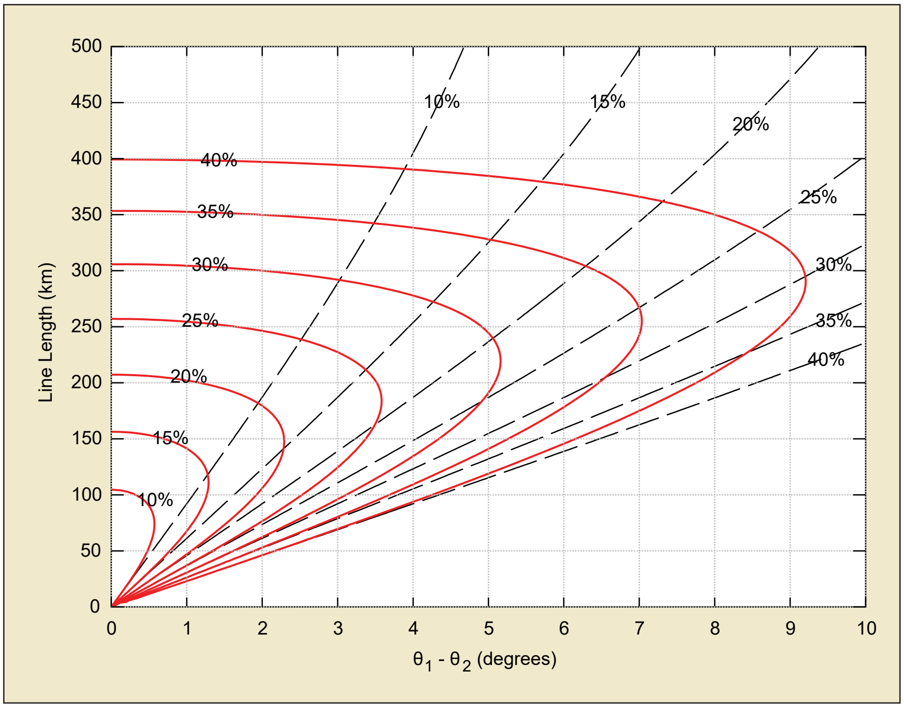
where P_1 and Q_1 are the sending end of real and reactive components of the complex power. At the surge impedance loading, there is no reactive power, and the real power can be written as follows:

$$\frac{(S_1(\Delta\theta,\ell))}{P_{SIL}} = \left|P_\ell^n((\Delta\theta,\ell)\right| \text{ (Eq. 2)}$$

Both real and reactive power contribute to the current at the input to the line. Hence, for conditions in which Eq. 1 is greater than Eq. 2, the real power transmitted will be less because excess reactive power of the cable (which counts against thermal limits) is exported to the rest of the power system.

To determine line length limits, the constant contour values of Eq. 1 and Eq. 2 can be plotted as functions of both $\Delta\theta$ and line length. More specifically, the constant values represent specific rated power flow as a fraction of the surge impedance loading. Different underground transmission lines will have thermal limits that are different percentages of their respective surge impedance loading.

Contour plots of the total complex power magnitude (that is, Eq. 1) in red and real power (that is, Eq. 2) in dashed black are plotted in the graph on the next page. One well-known characteristic of cables easily can be discerned from this graph. For zero real power transferred (that is, phase angle difference equal to zero), the maximum allowed complex power magnitude at the line input (in this case, all reactive power) increases linearly as the line length increases. This is consistent with the idea that



Contour plots of (1) and (2) superimposed for the underground transmission line of the power system shown in the bottom figure on page 43 as a function of both line length and voltage phase difference. The numbers on the graph represent the total apparent power (solid red lines that curve back on themselves) and real power (dashed black lines which extend upward) expressed as percentages of the surge impedance limit.

Table I. Hard and Practical Line Length Limits for Commercially Available 1500 -kcmil XLPE Underground Cables Designed for Different Voltage Classes.

Voltage, kV (Line-to-Line)	Thermal Rating, (MVA)	Surge Impedance, (ohms)	Surge Impedance Load, (MW)	Thermal Rating, as a Percent% of P_{SIL} (%)	Hard length limit, (km)*	Practical length limit, (km)**
115	70	24.6	177	40	400	160
230	145	35.8	487	30	300	100
345	197	42.5	932	20	200	80

*Location on above graph where $\Delta\theta = 0$ given the solid red contour corresponding to thermal rating as a % of P_{SIL}.
**Approximately where the respective dashed line in the graph departs from the corresponding solid red contour (that is, the length at which reactive power begins to have a significant impact on the total apparent power).

capacitive current is larger for longer line lengths when there is no real power transfer (for example, no load and no voltage difference between the generators).

Once the fraction of rated cable current to surge impedance loading is determined, the thermally safe operating conditions for the cable are enclosed by the region to the left of the corresponding contour. For example, if the cable thermal rating is 20% of the surge impedance limit, the only portion of the plot that corresponds to allowable operation is to the left of the 20% contour in the graph (solid red contour lines).

It is important to note that even the no-load case (that is, $\Delta\theta = 0$) assumes sources are connected to both ends of the cable and each absorbs the same amount of reactive power. If a cable is unloaded but energized from only one end, the theoretical maximum line length would be about half that indicated in the figure. In such a situation, it also is important to consider the steady-state voltage at the open end of the cable.

Some Examples

In this section, maximum line lengths are determined using a single-phase representation of commercially available 1500-kcmil cross-linked polyethylene (XLPE) cable designed for several different voltages. The hard length limit is determined by finding the maximum length for the no-load case (that is, $\Delta\theta = 0$). The practical length limit is the longest length for which the total power and real power are approximately equal. Lengths longer than the stated practical length limit could be used but would have to be derated for real power transfer. Again, it should be emphasized the limits derived here are for lines between voltage buses with equal voltage amplitude (that is, the same reactive power is exported at each end of the cable). Limits for other situations may be smaller. (See Table 1)

It is clear from the table the practical use of underground cable is limited to lengths less than the theoretical hard limit. Further, the higher the voltage, the shorter the practical length limit.

Maximizing Length

Options for mitigating line length constraints are few. A cooling system could be used to raise the thermal limits of underground lines. However, this would require additional infrastructure and add substantially to the cost of underground transmission lines. Reactive compensation distributed at intermediate points along the line could be used to reduce that portion of the cable ampacity used up by reactive power flow. This could be done using shunt reactors, although the amount of compensation needed would depend on the load required. Furthermore, using shunt reactors could cause other operational issues, such as unintended resonances. High-voltage shunt reactors are costly, often require a small substation and present switching challenges that require special-purpose circuit breakers designed to interrupt inductive currents.

High-voltage direct-current (HVDC) could be used since there is no reactive power at dc. Note also the length of any transmission line as a fraction of wavelength becomes zero in this case. In fact, HVDC transmission lines are used exclusively for long undersea connections for which no ac system would be possible. However, dc transmission lines require both special cable and costly ac-dc converter terminals at each end.

Fundamental Differences

Fundamental differences exist between underground and high-voltage ac transmission lines because of their topology and heat-transfer characteristics. For underground lines, these differences result in length limits that are more restrictive for higher voltages. The same limits do not apply to overhead lines because they can be operated at or near surge impedance loading. As a result, replacing long ac overhead with long ac underground high-voltage transmission lines presents major challenges derivable from fundamental physics.

The approach discussed in this article for determining maximum ac cable length is general and can provide insight into hard and practical length limits. The analysis suggests that, from a physics perspective, maximizing power flow for a given underground cable length is not necessarily achieved with the maximum voltage, as is often the case with overhead lines. TDW

For More Information

Those who want to learn more about the theory behind this article can consult a background paper at *www.electricutilitytools.com/education/ugtransmission*. A free calculator also is available at *www.electricutilitytools.com/calculators*. This calculator allows estimation of maximum theoretical and practical ac cable lengths using detailed three-phase-based computation.

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A worker repairs a cable sheath on a power cable installed in the 1970s. As discussed in the first part of this series, repairs on average underground cables can be more time consuming and expensive than those on average overhead lines. Photo by Spettacolare, Dreamstime

Destination New Orleans

The 2022 IEEE PES T&D Conference and Expo will be held April 25-28 in New Orleans, Louisiana.

By **NIKKI CHANDLER**, Associat Content director

The 2022 IEEE PES Transmission and Distribution Conference and Expo is just around the corner. The March issue of *T&D World* included extensive coverage of what visitors can expect to see and learn during their week in New Orleans, Louisiana, U.S. This issue offers additional details on the super sessions and information on other features, as well as more products and services that will be on display on the show floor.

Super Sessions

The IEEE PES T&D conference is once again featuring super sessions with presentations that cover past and present, data analytics, resilience and decarbonization.

Opening Session: How the Past is Powering the Future — The session title is a hint of what the hour will hold. This group of power and energy industry leaders will be moderated by IEEE PES Governing Board President Jessica Bian. The panel includes Ed Schweitzer III, owner and founder of Schweitzer Engineering Laboratories; Paul Hinnenkamp, COO of Entergy; Allison Silverstein, independent consultant and industry strategist with key contributions including work at FERC and DOE; and Damir Novosel, president of Quanta Technology and previous president of IEEE PES.

Exploring the Roadmap of Data Analytics and Artificial Intelligence for the Future Grid: The first super session of 2022 will focus on the implementation, application, and challenges for big data and AI within the energy grid. This includes discussion on the integration and operation of renewables, electrification, and the potential uncertainties of the energy business and operation model. The conversation will feature representatives from leading research and development companies that are driving our industry to the future through science and data analytics.

Preparing for Anything: Resilient System Design — Climate and other disruptions continue to present enormous challenges for the fundamental role of utilities and the communities they serve. This session will explore lessons learned from recent extreme events, and also share current efforts on improving the resiliency and reliability of the grid to prepare for uncertainties in the future.

Decarbonization and Grid Modernization: Organizations from across the energy ecosystem are exploring ways to optimize energy generation and usage to improve customer experience, while also developing a more efficient system to meet eco-friendly regulatory goals. This session includes multiple utilities in conversation around ideas and initiatives driving decarbonization and grid modernization.

More Educational Opportunities

Conversation with FERC Commissioner Allison Clements: On Wednesday, April 27, there will be a special session with FERC Commissioner Clements, in conversation with Peter Wells, CEO of Smart Wires.

Professional Development Hours (PDH) and Continuing Education Units (CEU): Opportunities are available for attendees needing to meet ongoing certification requirements, as well as individuals wanting to utilize these sessions to attain and meet their own personal and company developmental objectives.

- PDH certificates can be earned by attending Panel Sessions.
- CEU certificates can be earned by attending Tutorials, IEEE Plain Talk, and the IEEE Building Business Relationships Workshop.

Panel Sessions: Featuring some of the industry's best minds, Panel Sessions provide comprehensive discussions on a diverse range of important trends, issues, and real-world applications and solutions. Key trends explored include grid resiliency, energy storage, renewable energy, big data, smart grids and more. Start building out your onsite agenda at *https://ieeet-d.org/* by favoriting the sessions you'd like to attend.

Technical Tours: A diverse and exciting lineup of offsite Technical Tours gives participants the opportunity to tour and learn more about industry-related sites and products. Separate registration and additional fees are required and will be available when conference registration opens. Spots are limited so we encourage you to sign up early!

- **TT-01:** Laser Interferometer Gravitational Wave Observatory (LIGO)
- **TT-02:** Entergy Grid Storm Hardening
- **TT-03:** Naval Air Station Joint Reserve Base New Orleans
- **TT-04:** Entergy Grid Modernization Labs

IEEE PES Plain Talk: The Plain Talk courses for power industry professionals will provide a greater understanding of the technical aspects of the electric power industry, even if you do not have an engineering background.

Separate registration and additional fees are required and will be available when conference registration opens.

Tutorials: Tutorials feature in-depth examinations and presentations covering topics important to power and energy professionals and will take place on Monday, April 25, only.

Separate registration and additional fees are required and will be available when conference registration opens.

Building Business Relationships Workshop: Building Business Relationships guides participants to gain valuable insights about themselves and others by discovering actionable ways to build more effective relationships with others. Through the use of a self-assessment, participants receive detailed information regarding their style and how best to work with other styles to create more effective and productive relationships. The intended result is improved communication, reduced conflict, increased engagement, improved organization effectiveness, team collaboration, and enhanced leadership capability.Separate registration and an additional fee are required and will be available when conference registration opens. Registration closes March 25.

Collegiate Program, Poster Session and Student Poster Contest: Offering an exciting and comprehensive schedule of student and young professional sessions and activities, the Collegiate Program is designed to help new talent launch successful careers in the power and energy industry. The Poster Session and Reception provides a relaxed environment for registered conference attendees to enjoy hors d'oeuvres and beverages while viewing hundreds of accepted papers in poster format.

For more updates and information on the technical program and IEEE PES Expo exhibitor list, visit *https://ieeet-d.org*. *T&D World* editors will also attend this year and will provide previews and updates at *www.tdworld.com/ieee-pes-show-update*. TDW

EVENT SCHEDULE 2022

Sunday, April 24	
12:00 p.m. – 5:00 p.m.	Registration Open
Monday, April 25	
7:00 a.m. – 5:00 p.m.	Registration Open
7:30 a.m. – 5:00 p.m.	Tutorials, Plain Talk, Building Business Relationships Workshop
9:00 a.m. – 2:30 p.m.	Technical Tours
1:00 p.m. – 3:00 p.m.	Ethics Session
6:00 p.m. – 9:00 p.m.	Conference Opening Reception at Mardi Gras World
Tuesday, April 26	
7:00 a.m. – 5:00 p.m.	Registration Open
7:30 a.m. – 5:00 p.m.	Plain Talk
8:30 a.m. – 9:30 a.m.	Opening Session
10:00 a.m. – 3:00 p.m.	Technical Panels Sessions
10:00 a.m. – 5:00 p.m.	Exhibits Open / Innovation Stages and Smart Cities Pavilion
11:30 a.m. – 1:00 p.m.	Conference Luncheon in the exhibit hall
3:00 p.m. – 5:00 p.m.	Super Session 1
5:30 p.m. - 7:30 p.m.	Women in Power and Young Professionals Reception
Wednesday, April 27	
7:00 a.m. – 5:00 p.m.	Registration Open
7:30 a.m. – 5 p.m.	Plain Talk
9:00 a.m. – 4:00 p.m.	Tecnical Tours
10:00 a.m. – 6:00 p.m.	Exhibit Open / Innovation Stages and Smart Cities Pavilion
10:30 a.m. – 11:30 a.m.	Super Session 2
1:00 p.m. – 5:00 p.m.	Technical Panel Sessions
4:30 p.m. – 6:00 p.m.	Networking Reception in the exhibit hall
5:00 p.m. – 7:00 p.m.	Poster Session and Reception / Student Poster Contest
Thursday, April 28	
7:00 a.m. – 2:00 p.m.	Registration Open
8:00 a.m. – 10:00 a.m.	Super Session 3
8:30 a.m. – 10:30 a.m.	Technical Tour
10:00 a.m. – 3:00 p.m.	Exhibits Open / Innovation Stages and Smart Cities Pavilion
10:00 a.m. – 12:00 p.m.	Technical Panel Sessions
3:00 p.m. – 4:00 p.m.	Closing Reception and Raffle: Welcome to Anaheim in 2024

To see the latest exhibitor list and floor map, as well as the full schedule for the show, visit *https://www.ieeet-d.org.*

Transformer Fluid

FR3 fluid by Cargill is the leading natural ester, used in more than 3 million transformers throughout the world. With a 25+ year history, FR3 fluid provides higher levels of fire safety, reliability, loading capacity, and environmental benefits compared to mineral oil. Cargill's 155,000 employees across 70 countries work to achieve the company's purpose of nourishing the world in a safe, responsible and sustainable way. It combines 156 years of experience with new technologies and insights to serve as a trusted partner for food, agriculture, financial and industrial customers in more than 125 countries. Cargill is working to build a stronger, sustainable future. For more information, visit Cargill.com and FR3fluid.com.

Cargill | Cargill.com
Booth #3755

Capacitor Switch

Eaton's Cooper Power series three-phase TriSync capacitor switch provides customers with an efficient and reliable capacitor switching solution for power generation, transmission and distribution electrical systems. The TriSync switch is designed and manufactured in accordance with IEEE Std C37.66 and IEEE Std. C37.100.2 standards, and is available in 15 kV, 25 kV and 38 kV class ratings for system applications up to 66 kV. Each phase of the TriSync switch includes a single vacuum bottle with permanent magnet solenoid mechanism. The single vacuum bottle design eliminates the need for complicated calibration processes and tedious maintenance requirements. The TriSync switch delivers an environmentally friendly solution in a compact installation footprint while providing repeatable, reliable performance. Each voltage class is available in Zero Voltage Closing (ZVC) compatible designs. The switch can be used with any industry capacitor control, including Eaton's Cooper Power series CBC-8000 capacitor control, to provide Integrated Volt/VARControl (IVVC), leading to overall cost savings for utilities.

Eaton | www.eaton.com
Booth #6813

Corona Camera

DayCor micROM is a compact HD corona camera designed for use on UAVs or inside small gimbals. It is light in weight, has low power consumption, supports most commonly used communication protocols, and is electromagnetically shielded. micROM is a dual sensors camera composed of a highly sensitive Solar Blind UV and a visible light sensor. As a result, micROM can detect, pinpoint, and image corona in daylight. The camera offers on-board recording in real time of corona partial discharge as it is emitted. The camera output is used as a means to investigate electrical and mechanical infrastructure faults that are related to corona partial discharge. micROM camera for drones incorporates the DayCor technology. Its patented UV filter ensures encompassing every corona signal in the inspected arena, leaving out sporadic distracting noise. HD footage is transmitted live to a remote monitor leading inspectors to faulty locations that call for closer investigation. Interfaces to GPS links the corona imaging with findings' locations. A full integration Plug-N-Play solution package is ready to be used and offered to DJI m300 drone operators as an accessory. micROM is easy to integrate through a set of commands that are supplied with the camera.

Ofil Ltd. | https://ofilsystems.com
Booth #7832

Dead-Tank Circuit Breakers

Meiden America Switchgear (MAS) is a leader in manufacturing eco-friendly high-voltage, dead-tank circuit breakers using vacuum interrupter technology and dry air insulation. The highly engineered products range from 38 kV to 145 kV with higher voltages in development and on the horizon. Recently the company delivered the "world's first" Dead Tank Dry Air Insulated Vacuum Interrupted 145 kV Circuit Breaker in the industry. Meiden said it is proud of this engineering accomplishment and looks forward to working with customers who want to standardize on its operational capability, and provide an environmentally friendly alternative to their SF_6 gas circuit breakers. "Say no to SF_6!"

Meiden American Switchgear, Inc. | /www.meidensha.com/mas/
Booth #3437

Impulse Test Equipment

HV Technologies, Inc. provides impulse test equipment from HAEFELY. Impulse voltage test systems are designed to generate impulse voltages that simulate lightning strikes and switching surges on a variety of HV apparatus, such as transformers, cables, switchgear, and much more. Complete test systems are provided with the HVC 300 Impulse Control with modern and intuitive software and the HiAS 744 Highest Resolution Impulse Analyzer. Rugged fiberoptic cables ensure complete galvanic isolation between hardware in the test field and equipment in the control room providing excellent interference immunity and the highest safety standard for operators.

HV Technologies, Inc. | www.hvtechnologies.com
Booth #7138

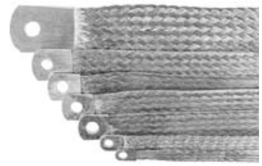
Rescue Body Hooks

Designed to comply with OSHA 1910.269(j) for the construction of live line tools and OSHA 1926.957 for the use of live line tools, the Saf-T-Gard Voltgard Telescopic Insulated Rescue Body Hooks are coated and heat treated with an 18" hook opening and mounted on a 6' or 8' telescopic fiberglass handle to safely withdraw injured personnel from confined spaces, in vaults, near electrical cabinets or switch gear. The unique retractable design potentially saves hundreds in shipping costs due to the "over-length" fees charged by common carriers when shipping fixed-length hooks. The retractable design also is much easier to store, either in the shop or on the truck. Additional features and benefits that set the Saf-T-Gard® Voltgard Telescopic Insulated Rescue Body Hooks apart include a thicker, sturdier hook than most competitive models (which is less likely to break), a Hi-Viz yellow color at the top of the telescopic handle that provides added visibility and a "No-Twist" triangular design that allows the telescopic handle to remain in a locked position when fully retracted.

Voltgard, a Division of Saf-T-Gard International, Inc. | www.saftgard.com
Booth #4511

Grounding Jumpers

Installers get extra flexibility for mechanical grounding with the flexible-braid one-hole copper grounding jumpers introduced by Hubbell Burndy. The BB-ML-TN ferrule ends provide superior connection points in applications where movement or vibration can occur. Flexible braided jumpers are designed to take up linear expansion and contraction. This compensates for any misalignment and absorbs vibration from electrical equipment and devices. The connectors are made with extra flex tinned copper stranding to provide maxi longevity in the harsh and corrosive environments. The tinned copper ferrule ends prevent fraying and deliver extra strength at the bonding point.

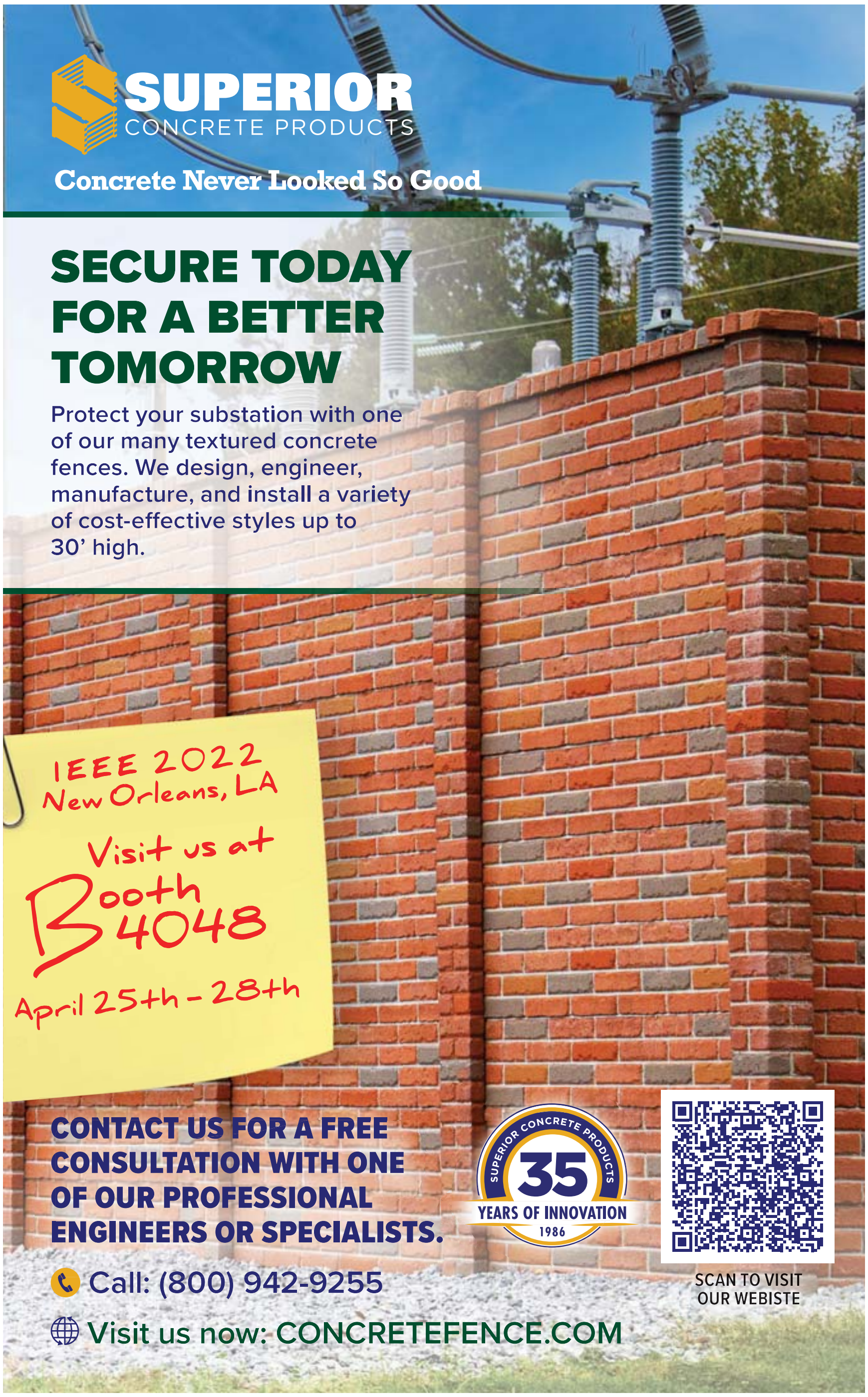


Hubbell Burndy | www.hubbell.com/burndy
Booth #5913

Self-Resetting Interrupter

S&C Electric Company has released the VacuFuse II Self-Resetting Interrupter, the latest lateral solution for grid-edge protection. The VacuFuse II interrupter brings fault-testing to the edge of the grid and mitigates nuisance outages, ensuring greater reliability for customers and fewer truck rolls for utilities. As severe storms become more frequent and as more people work from home, outages at the edge of the grid are having a greater impact than ever before. These areas are typically protected by overhead distribution transformer fuses, which operate whether a fault is temporary or permanent. When up to 70% of these faults are caused by nuisance issues, such as wildlife or foliage, overhead distribution transformer fuses are causing lengthy power outages that can be avoided. S&C's new VacuFuse II interrupter tests whether faults are temporary and automatically restores power when they are. Because issues at the edge of the grid tend to cluster into pockets, this advanced protection device can target troublesome spots on the grid. The VacuFuse II Self-Resetting Interrupter works with overhead distribution transformers from 7.2 kV through 12.5 kV and is available in sizes compatible with 15-kV and 25-kV cutouts to accommodate most lateral systems. At only 12 pounds, the VacuFuse II interrupter is easy to install and is factory-configured prior to shipping with standard curves (i.e., K, KS, T), customizable curves, or S&C's new transformer-specific curves.

S&C Electric Company I www.sandc.com/
Booth #8229



Insulated Cable

Okonite is headquartered in Ramsey New Jersey, approximately 30 miles northwest of New York City. At its six manufacturing facilities, the company make cables that range from 300 V to 345 kV insulated products that include Instrumentation, power and control, medium voltage, and high voltage cables. These cables are manufactured with a variety of insulating and jacketing materials including Okoguard EPR, laminated polypropylene paper (LPP), and other thermosetting and thermoplastic compounds.(which is less likely to break), a Hi-Viz yellow color at the top of the telescopic handle that provides added visibility and a "No-Twist" triangular design that allows the telescopic handle to remain in a locked position when fully retracted.

The Okonite Company I www.okonite.com
Booth #7446

5G Wireless Routers

Hitachi Energy has launched its new TRO600 series wireless routers with 5G capability, which are purpose-built to help industrial and utility customers achieve high reliability and resiliency in mission-critical operations. With the integration of 5G technology, Hitachi Energy's routers enable a scalable, flexible and secure, hybrid wireless communication architecture. A hybrid network seamlessly combines the best of public and private cellular with broadband mesh, all managed through a single network management system. This approach unifies communications to all devices, ensuring fast, secure, and reliable connectivity for each operational need. Integrating 5G connectivity in the TRO600 series ensures efficiency for multiple customer use cases across smart cities and utility applications. The high throughput supported is expected to drive greater adoption of virtual and augmented reality and video applications to aid operational efficiency and optimize processes. The reliable low latency communications allow for digitalization of operational infrastructure.

Hitachi Energy I www.hitachienergy.com
Booth #7135

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SMUD
Here's a recent photo of the solar canopy under construction at the River City Food Bank! This project is part of our Community Solar program, where the support of generous SMUD customers helps us partner with nonprofit and low-income housing organizations to power our community with renewable energy.

Amy Marston Director Of Community Relations at Central Maine Power Company
When one of your employees shows up out of the blue with a gift and says "when I saw it, I knew you had to have it"

Oncor @oncor
Thanks to the long legacy of hard work and service, our lineworks are essential to powering customers across 400 communities and 100 counties. They work around the clock to provide power to our customers & educate students on the importance of electrical safety. #ThankALineman

Tennessee Valley Authority 94,459 followers
Almost a million pounds of debris have been removed from Kentucky Lake from the storms that moved through the area in December! Our partner Living Lands & Water have been hard at work for months pulling close to 18,000 pounds of debris daily from the lake. 👏 #KYStrong

Consumers Energy
This year, we partnered with the Detroit Pistons to empower women with care packages and inspire young women as they begin thinking about what life looks like for them after high school.

Midwest Electric @ MidwestREC
This broken pole was reported by Noble Township Trustees while plowing snow. Our crews are working to repair it to avoid an outage. Thanks to the trustees for being diligent and quick to report safety issues they see!

Sally Thelen @DE_SallyT
This pic is a prime example of how hard it can be to get to our poles in hard to access areas. This @ DukeEnergy lineman climbed the pole to do his job in Harrison, OH today.

AD INDEX

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BY GARY VIVINUS AND JIM McMAHON, CHARLES RIVER ASSOCIATES

Utility Planning Solutions for a Decentralized Grid

Gary Vivinus

Jim McMahon

Over the next decade, we will likely witness a redefinition of the role of the electric utility in many parts of our country. New and improved energy technologies, progressive policies, changing consumer sentiment, and the growth of competition will combine to disrupt the tried-and-true business model. We are already seeing evidence of change. In some parts of the country, third-party energy service providers have had meaningful success connecting with utility residential and business customers and offering distributed energy resources, demand response, energy efficiency, microgrids, and a range of related services. These advances threaten utility growth and profitability and raise serious strategic and tactical issues regarding the utility's relationship with its customers.

Despite growing competition, utilities are well positioned to lead the transformation of the energy sector and redefine their role with customers. Utilities own most of the transmission and distribution infrastructure in the U.S. (and in some places, the generation infrastructure), offer services to their customers that are at least partly insulated from competition, and are generally experienced or most knowledgeable about their customers, the emerging technologies and the regulatory environment that are driving change. With the right strategies, utilities should be able to enhance and expand their customer offerings, tap new revenue sources, and deliver strong overall performance over the long term.

One challenge utilities face in developing a transformational strategy is adapting the planning function to address today's unique challenges. In traditional utility planning, generation and transmission was planned relatively independent of distribution. Generation and transmission planning considered the best set of transmission connected resources to meet customer demand while distribution planning focused primarily on deliverability. Today, the penetration and decreasing cost of distributed energy resources has forced utilities to plan more holistically. Many utilities have identified "integrated planning" as an important area of development for their organizations.

Here are three main obstacles to implementing an integrated planning function, and how utilities can move forward.

Obstacle 1: The Value Proposition: Utilities need a vision for the future of the industry, which will create a strong value proposition for an integrated (generation, transmission and distribution) planning effort. Utilities have the burden of not only developing new strategies, but also the weight of justifying the resulting investments to regulators. Many intervenors and regulators are pushing hard for rapid deployment of DERs and low or net-zero carbon futures. Planners need to understand the implication of rapid distributed and utility scale renewable energy resource growth and how this is driving concerns about the reliability and resilience of the grid.

Obstacle 2: Roadmap Development: The path to integrating the utility planning functions can take months or even years depending on the starting point and the desired end state. Utilities without a clear roadmap can struggle to make meaningful progress as other demands intercede and momentum is lost. A well-constructed planning roadmap will use a maturity model that can identify gaps in current planning practices to address key issues today, in the near- to mid-term, and in the longer term. Deficiencies that might need to be addressed include misalignment of planning horizons or assumptions, model limitations, inaccurate data, and cultural differences among planning departments. Near-, mid-, and long-term requirements can be driven by regulatory requirement, stakeholders or managements who want to get ahead of the regulators and drive planning before it is dictated to them by external forces. The roadmap will provide for a clear, well defined program that will achieve near, mid- and long-term objectives in a cost-effective manner.

Obstacle 3: No Silver Bullet: Utilities may be attracted by the idea that a single model or tool exists for integrating planning efforts. In our experience, this is fallacy. While the utility and the industry might one day evolve to a point where a single model can handle the task of planning the entire generation, transmission, and distribution system, this does not exist today. Utilities can spend unnecessary time and money in pursuing these solutions.

Integrated planning can be conducted in a relatively short period of time with existing models and databases if a well-structured planning process is put in place. Initially this may involve a manual process of iterating between existing generation, transmission and distribution models. But this approach will yield effective results quickly and more cost effectively than more technology-based solutions. Over time, automation and effective database management can be added to improve efficiency. But incremental steps using existing resources will allow utilities to stay ahead of the regulatory pressures and provide needed insights into a wide range of solutions.

Despite the industry-wide acknowledgement that integrated utility planning is becoming increasingly important to addressing decentralization of the grid, utilities face significant roadblocks to change. Building an integrated planning function takes time, investment, and serious commitment by many employees in the organization. Utilities should spend the time to clearly articulate the value proposition to gain support from employees, develop a roadmap that sets expectations and milestones, and acknowledge that the solution is not instant, or purely model based. Utilities that take these steps will be much more strategically positioned to address the industry's transition. TDW

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