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Hendrix Aerial Covered Spacer Cable Systems

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NIKKI CHANDLER, ASSOCIATE CONTENT DIRECTOR, T&D WORLD

Electric utilities must find ways to harden the grid to ensure that lights stay on and critical infrastructure remains operational during times of crisis. One such way to do that is with covered conductor, which is particularly useful in areas prone to hurricanes and tornadoes, where high winds can knock down power lines and cause widespread outages. By using covered conductor, utilities can reduce the frequency and duration of power outage, making the grid more resilient.

One utility found that to be true during the 2005 Atlantic hurricane season. Louisiana's oldest city Natchitoches had recently finished a project to mitigate the increasing load on its grid when Rita roared into the area and caused widespread power outages. In a highly congested, historical area with many trees, the city had chosen to install covered conductor to prevent faults due to phase-to-ground or phase-to-phase contact, tree contact or animal contact. The newly installed aerial cable stood up to Rita. Lines around it came down, huge branches cracked off the old oaks, and the winds whipped the trees for hours during the storm. But there was no damage to the new cable, according to the operations manager for the city's utility services.

National Grid is another utility that grappled with several storms and outages in one year, with 2011 bringing an unprecedented tornado, Hurricane Irene, and then a snowstorm, causing extended outages in Massachusetts. While working on the upgrades and rebuilding, National Grid needed to address lines exposed to potential tree damage and decided to go with 69-kV spacer cable for the rebuild. The conductors were covered, reducing outages from phase-to-phase contact. In this ebook, National Grid tells exactly how the system was designed, constructed and installed.

Another utility with some unique challenges, Fort Loudoun Electric Cooperative in Tennessee, was facing record growth and decided to use a spacer cable system for a substation exit project. The compact configuration and reduced clearance requirement with the spacer cable worked well for the co-op's needs.

Covered conductor systems can help utilities increase reliability and lower costs. Find out what covered conductor consists of and how these systems can be used at distribution and transmission levels. The migration to covered conductor to transmission voltages will continue as reliable power becomes ever more crucial and new transmission construction increases to move renewable power.

TRANSMISSION VOLTAGE COVERED CONDUCTOR SYSTEMS OFFER ADVANTAGES FOR RELIABILITY, ECONOMICS AND ECO-FRIENDLINESS

BY BRIAN J. TRAGER, SENIOR LIFE MEMBER IEEE, DIRECTOR, TECHNOLOGY & INTERNATIONAL - MARMON UTILITY LLC

Aerial-covered conductor systems came about in 1952, starting at 5 kV, and rapidly advanced to 15-, 25-, 35-, and 46-kV systems. Spacer cable for 69kV applications was introduced in the early 1990's at the request of industry leaders. This was followed in 2019 by the 115-kV spacer cable. The trend seems unstoppable, as covered conductor systems provide numerous technical, economic, and ecofriendly advantages.

SYSTEM DESCRIPTION

Covered conductor systems consist of the following:

Three heavily covered, but unshielded, phase conductors. The conductors are usually AAC when in a spacer configuration, since there is no tension on the phase conductors, but can be ACSR or AAAC when installed in a self-supported or "Tree Wire" configuration.

The phase conductors are attached to a high strength messenger by spacers, installed every 30 ft. (10m.) along the messenger. The messenger is a high-strength, alumoweld (AW) or alumoweld-aluminum (AWA) conductor which has several functions. The first is that the messenger is the mechanical strength member, holding the phase conductors up. The messenger can also be used as a system neutral, is a lightning shield, and provides a mechanical protection function by protecting the phase conductors from any items (leaves, branches, trees) that can fall onto the bundle from above.

The spacers are made of high-density polyethylene (HDPE), as are the pin or line post insulators used on the angles, to ensure dielectric compatibility with the phase conductors.

COVERED CONDUCTOR BENEFITS

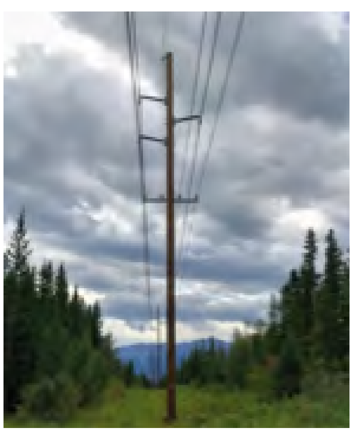
Historically, covered conductor systems were used to overcome reliability issues associated with bare wire systems. Temporary outages from foliage contacting bare wire was eventually deemed unacceptable. Permanent outages from tree falls, animal/bird incidents, lightning, as well as "unknown" and "other" were unacceptable, and a 1990's study by Northeast Utilities showed that these outages could be reduced by as much as 90% by converting to covered wire systems.

HIGH-VOLTAGE COVERED CONDUCTOR (HVCC) BENEFITS

The impetus for using covered conductor systems at transmission voltages is not unsimilar to the reasons for using it at distribution voltages. The desire to minimize ROW width and clearing, adding circuits in an existing ROW, reactive compensation and improved voltage regulation, improved reliability, protection of flora and fauna, reduced tree trimming, reduced O&M expenditures (saving on tree trimming as well as trouble call reduction) and environmental stewardship (protection of flora and fauna and reduced carbon footprint).

CONFIGURATIONS

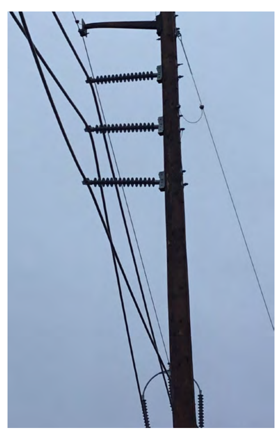
Aerial Covered Conductor Systems can be built in a Spacer Cable configuration (messenger supported) or a Tree Wire configuration (open construction, self-supported). The left photo below shows a 69-kV spacer cable system running through Villarica National Park in Chile, with a 25 kV spacer cable underbuild. The photo on the right shows a 69 kV Tree Wire system in Jasper National Park, Canada. It also has a 25 kV underbuild, but in a tree wire configuration.



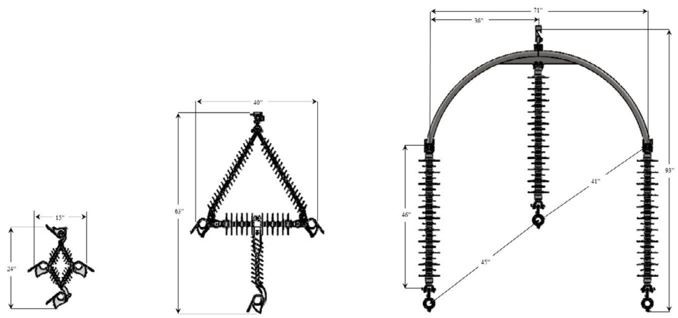
The utilization of covered conductors at transmission voltages also allows the commonplace distribution construction practice of building multiple circuits on a single pole line. The photo below shows a double circuit 69 kV spacer cable in Saint John Energy, New Brunswick.

COVERED CONDUCTOR MIGRATES TO 115 KV VOLTAGE LEVEL

Covered Conductor systems at 115 kV have been constructed to date using the spacer cable configuration. The photo below left shows a tangent pole, while the photo below right shows the general profile, and the larger 115 kV spacer.

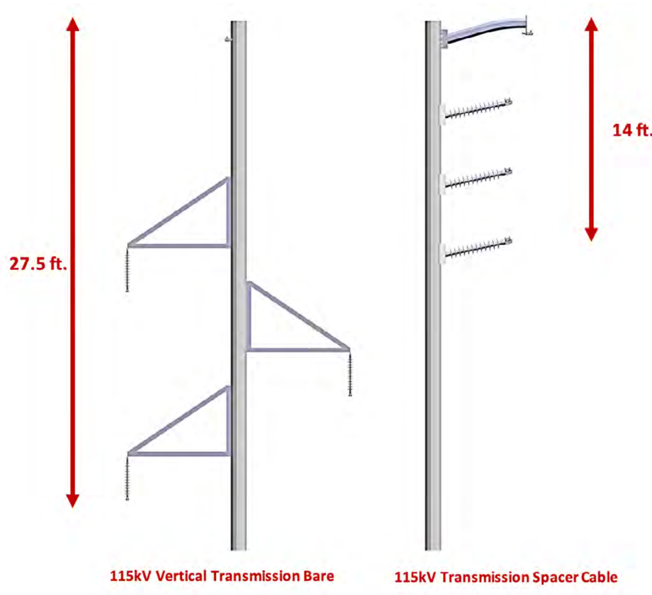


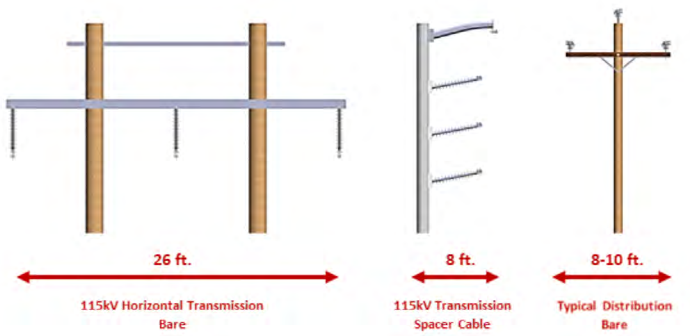
The evolution of covered conductor systems to higher voltages has introduced the need for new spacers, more robust mechanical designs to handle the heavier conductors, and longer longitudinal spacing of spacers. The spacers used for different voltage classes are shown below for comparison.



25-46kV Distribution | 69kV Sub-Transmission | 115kV Transmission

For vertical construction, the diagram below illustrates that spacer cable at 115 kV can reduce pole height by 13.5 ft (4.1 m). This reduction in profile can allow higher voltage lines in areas previously limited to distribution (or sub-transmission) voltages.





If we look at horizontal construction, spacer cable reduces the profile by a full 18 feet, and starts to take on a profile similar in size to distribution class construction. This reduction in height and width has enormous ramifications for tree trimming, danger tree removal, and ensuring that the power line fits harmoniously with the surroundings, while at the same time minimizing disruption to the flora and fauna.

The migration of covered conductor technology to transmission voltages will continue unabated. The need for reliable power, construction of transmission lines in heretofore untrodden locales (getting power back from new wind and solar facilities to population centers), petitioning regulators for new ROWs, negotiating ROW parameters, arriving at consensus regarding how much land/resources are justified for a new line are all challenges which will have the opportunity to be reduced with the consideration of covered conductor construction.

SYSTEM HARDENING WITH 69-KV SPACER CABLE

National Grid upgrades transmission line frequently impacted by storm-related damage.

BY DANIEL WHITE

In 2011, a series of three storms passed through western Massachusetts and resulted in extended outages on a 69-kV transmission line in East Longmeadow, Massachusetts, U.S. In June 2011, an unprecedented tornado caused significant damage to the area. The tornado was classified as an EF3, one of the most powerful to ever come through the region. When crossing the transmission corridor, the tornado shifted course and began traveling alongside the corridor, leaving uprooted trees and broken structures in its wake. In August 2011, Hurricane Irene made landfall in New York and moved north through New England. The strong winds from the storm brought down trees again along the same transmission corridor, tearing down many structures.

Finally, at the end of October 2011, an unusually early snowstorm blanketed New England. The storm hit at a time when most of the leaves were still on the trees, adding an extreme amount of weight to the branches. Many of the branches could not handle the heavy snow loading and came down, including those along the same corridor. Poles broke under the weight of the trees, and the conductor was pulled from the structures, resulting in the third extended outage within five months.

In addition to the major storms, there had been a history of falling tree branches causing momentary outages on the transmission line. National Grid resolved to find a way to storm harden this line.

THE PROBLEM WITH TALL PINE TREES

The 12-mile (19.3-km) transmission line is supported by single wood poles with phases in a triangular configuration. It runs parallel with a second circuit for approximately 4 miles (6.4 km) in a 100-ft (30.5-m)-wide corridor. Further on, it occupies its own corridor for approximately 8 miles (12.9 km) in a much narrower 60-ft (18.3-m)-wide corridor.

The majority of the corridor is lined with tall pine trees, including many that exceed 100 feet in height. All of these taller trees can be easily broken by strong winds and heavy snow. The existing structures on the line were 40 ft to 55 ft (12.2 m to 16.7 m) tall. In the areas where the lines share the right-of-way, a single fallen tree could take out both lines, which would result in the loss of a local substation.

This is typical of the tall trees that are adjacent to the transmission line that experienced all of the outages in 2011.

THE RIGHT SOLUTION COMBINATION

Fortunately, there was already a project in progress to upgrade a portion of the line to 115 kV. The upgrade included taller structures, larger phase spacing and the addition of shield wire for added protection. However, this project was performed to feed a new substation. That meant only 10 miles (16 km) of the 12 miles of the line needed to be upgraded, leaving 2 miles (3.2 km) of the line exposed to potential tree damage — one mile in the solitary right-of-way and a second mile in the shared right-of-way. Several options were considered to address the storm damage concerns:

- **Option 1:** Do nothing. This was not a realistic option. The storms had exposed the weaknesses of the system. Something had to be done to increase the reliability of the lines.
- **Option 2:** Refurbish the line. Replace deteriorated

assets and update the line to meet current standards. However, it was determined that this approach would not address the existing reliability issues.

- **Option 3:** Rebuild the line with taller structures. This alternative would address the concerns related to trees falling on the line. However, the new structures would need to be significantly taller given the height of adjacent trees. If the new structures remained in a triangular configuration, they would lose the lightning protection offered by those adjacent trees, thereby creating the need to use a shield wire. This would require even taller structures and have greater horizontal phase spacing. The footprint needed to accommodate this configuration would not fit on the existing right-of-way.
- **Option 4:** Expand the right-of-way and remove danger trees. The rights for the additional land for this option would be extremely difficult to procure. In addition, the amount of tree clearing required would likely have engendered concern among the abutting property owners and town officials.
- **Option 5:** Do a 69-kV spacer cable rebuild. The 69-kV spacer cable is a fairly new technology and has only been employed in a handful of locations. This installation was the first in the northeast United States. Spacer cable offers a stronger wire system than typical bare conductors. The additional strength of the messenger cable helps to resist damage from larger falling branches and small trees. The conductors also are covered, which reduces outages caused by momentary phase-to-phase contact. The spacer cable configuration has a narrow footprint, enabling more clearance between the conductors and the trees. The challenge with this design is the spacer cable and messenger cable structurally would overload the existing structures.

National Grid decided a combination of the spacer cable option and the refurbishment option offered the greatest opportunity to reduce outages and increase the reliability of the line. Multiple spacer cable solutions were investigated with varying lengths of conductor being installed. In the end, it was determined the most prudent course of action was to install the new spacer cable along a 1.5-mile (2.4-km) portion of the line where tall trees presented a danger. The remaining half-mile portion of the line, which ran through residential areas, would be refurbished using the existing wire.

This typical dead-end structure is leaning and needs maintenance.

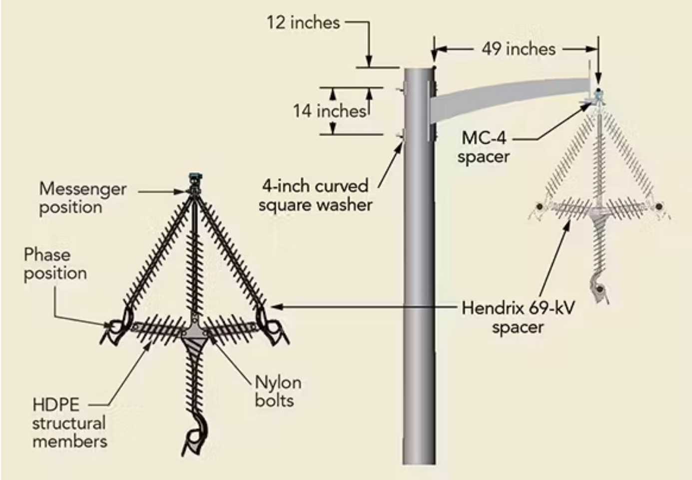
DESIGN CONSIDERATIONS

Spacer cable consists of three covered cables and a single messenger wire. The messenger wire carries all the tension and supports the conductors. This wire also acts as a neutral and shield wire. The full system is strung through spacers at suspension structures, which are 4.7 ft (1.4 m) tall with each cable attached to dead-end structures through horizontal post insulators. Additional spacers are used on either side of the dead-ends to facilitate spreading the cables apart toward the structures. It was recommended double spacers be used, but instead, triple spacers were used for extra reliability.

The manufacturer, Hendrix Wire and Cable, was consulted during every phase of the design and was instrumental in solving many issues that arose during project development. The original concept was to install new wood structures, but it was quickly determined this would not be possible without greatly increasing the number of structures on the line. Typically, 69-kV spacer cable structures consist of a single pole with a single davit arm that supports the messenger and conductors. The cables are covered, so the conductors are heavy. This results in large overturning ground-line moments. To design for these types of loads, small spans on steel structures were used. Dead-end locations required concrete caisson foundations.

Because of the narrow right-of way, the center line of the conductors had to stay in its existing location. The single davit arm design for the spacer cable meant the new structures would have to be offset from the center line of the existing ones. To ease constructability, the new structures were designed to be tall enough to be installed prior to removing the existing ones and to ensure the new conductors would not sag into the existing lines. It also meant designing the new structures to be able to carry the existing conductors if necessary.

The structures were designed with vangs at the existing conductor elevation so the existing conductors could be attached to the new poles, if needed, and the line could remain in service. This feature was never used because outage constraints were not as restrictive during construction as initially anticipated.



Diagrams show spacer and wire positions (left) and a typical structure with spacer (right).

UNIQUE CHALLENGES

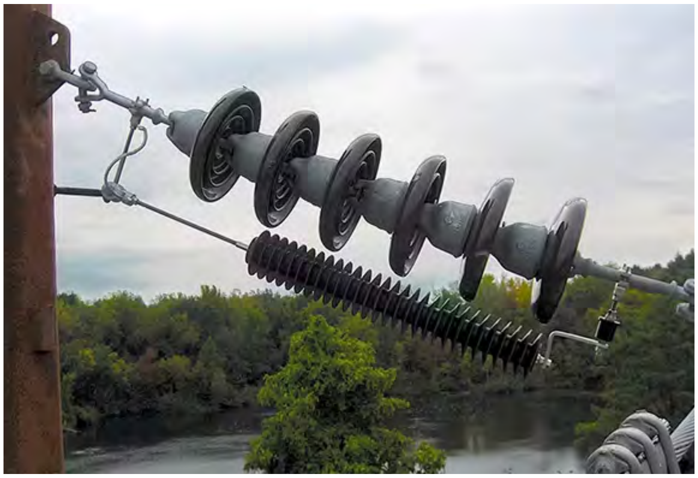
Several challenges arose during the design phase of the project. There is a tap junction on the line where a couple of switches are located and the two existing lines cross each other. Installing spacer cable through this section meant that the switches would have to be replaced and work would be required on the other line to maintain clearances. Therefore, the decision was made to leave the conductor between the switches as standard bare aluminum conductor steel-reinforced (ACSR) and to reuse the switches making construction through this section much easier without impacting reliability.

The area just outside the local substation was also challenging. The substation is located adjacent to a Massachusetts Department of Transportation (DOT) storage area just before the line spans a reservoir. In the storage area, the structure heights needed to be minimized as much as possible. And, the line turned in this area with more than a 90-degree angle. Normally, this would require a structure with a caisson foundation. But, since DOT would not allow installation of this type of foundation on its property, a direct-embedment steel structure was installed. The corrugated metal pipe National Grid installs for all direct-embed structures was backfilled with concrete. The conductor for the last two spans on the DOT property was also left as ACSR to allow for shorter structure heights.

Around the reservoir, the spans were too long for the suspension-structure davit arms. Therefore, it was necessary to design all five structures in this section as dead-end structures.

Lightning arresters were installed at every structure that transitioned from bare conductor to spacer cable to prevent any surges in the bare conductor sections from entering the sections of spacer cable. Without the arresters, issues could develop at the interface between the wire types.

National Grid's standard practice is to install porcelain insulators rather than polymer for transmission lines. However, for spacer cable, polymer insulators are recommended for the horizontal line posts for dielectric compatibility. To follow National Grid practices and avoid dielectric complications, a special trunnion clamp was designed to enable the use of porcelain post insulators. The spacer cable attaches to the insulator through this specially designed clamp.



This is a detail of a lightning arrester installation at a structure with spacer cable on one side and bare conductor on the other.

CONSTRUCTION AND INSTALLATION

With the design complete, construction commenced in September 2015. While drilling the foundations for the dead-end structures, the foundation contractor encountered an abandoned quarry. Rock coring was expected, but large air voids were not. The holes were in danger of collapse as drilling continued. The structures proposed in the abandoned quarry were relocated. Because of abutting property owner requests, several other structures needed to be relocated before stringing could begin.

Hendrix supported the project for the duration of the construction. The company held training for the crews prior to the start of the spacer cable installation and sent representatives to the right-of-way daily while stringing operations were in progress.

There were some small difficulties during the cable installation. The cables are large and stiff, making them difficult to bend. Stringing was a challenge in areas where the cable needed to turn sharply between closely placed structures, and it was a struggle to get all three-phase conductors onto the lead trolley. The three Kellum grips needed to be attached to a single large bolt. It took longer than anticipated to complete this setup, but once it was ready, the stringing went smoothly. Construction was completed in December 2015.

There have been no issues with the conductor since its installation. National Grid is monitoring its performance and, depending on how it performs, will consider using this type of conductor in other locations with similar tree-contact problems.

The 69-kV spacer cable was installed through dead-end structures with each phased dead-ended with jumpers around the structure.

Reels of 69-kV spacer cable ready to be strung.

ACKNOWLEDGEMENT

The author would like to thank Hendrix for its contribution to this article.

Daniel White joined National Grid in 2009 and is currently a lead engineer in the transmission engineering department. He is a professional engineer in Massachusetts and holds a MS degree in structural engineering. White has performed the engineering on a number of transmission projects throughout New England and New York.

AERIAL CABLE BRINGS RELIABILITY TO LOUISIANA'S OLDEST CITY

Power distribution systems around the world face critical threats to their long-term reliability and performance. In 2010, the U.S. experienced a record number of major transmission outages, often the result of severe storms.

BY BRIAN TRAGER

Power distribution systems around the world face critical threats to their long-term reliability and performance. In 2010, the U.S. experienced a record number of major transmission outages, often the result of severe storms. In fact, 150 of that year's 247 power failures were weather related. In 2013, the U.S. energy infrastructure received a barely passing grade of D+ from the American Society of Civil Engineers. Year after year, aging transmission and distribution equipment in dire need of updating is challenged to withstand intensifying storm activity. Areas of the country close to the ocean are at particular risk.

In the early 2000s, the city of Natchitoches, Louisiana, was experiencing increasing loads on its power grid. To alleviate the strain, the city utility designed a ring bus that would encircle the city and enhance available power to residents. Much of the ring bus was built on new pole installations, but in an area that extended approximately one mile through historic sections of the city that were highly congested and heavily treed, it would have been almost impossible to install new poles to carry the associated three-cable feeder.

The small city of Natchitoches, population 18,000, is the oldest settlement in Louisiana, and is located just 120 miles from the Gulf of Mexico. Historic plantations from the 18th century are located on avenues lined with hundreds of magnificent, stately oaks. These imposing, ancient trees are the pride of the community and are fiercely protected by residents. Trimming or cutting the trees is a very sensitive topic, even if trimming would prevent weather related power outages. Cabling for the new ring bus feeder, therefore, had to run very close to, and even through, the ancient trees, a situation that virtually guaranteed power failures.

During storms, standard cable installed near trees can experience significant damage from falling limbs. When heavy limbs come down, the power is almost always disrupted. In high winds, bare wire cables spark and flash if they touch one another, which can set fire to trees and nearby structures. Coated cable also can flash in storms and experience outages when birds or rodents get caught in it. For all these reasons, the city decided to move away from bare wire and individual coated cables for this one-mile feeder.

They instead looked for an alternative cable that was sturdy, durable and capable of withstanding damage caused by wind, trees and animals.

Because of the congestion in the area of the city where the feeder was being installed, city engineers knew installation of new poles would be cost-prohibitive. The new 69-kV cabling had to be installed on existing poles in the one-mile stretch. Existing poles stand approximately 100 feet tall. The feeder cable could run only where there was sufficient space-under the 138kV transmission line and above the lower voltage distribution lines that were already live and operating on the poles. In addition to placement constraints, the new 69-kV cabling had to extend across 600 to 800 foot expanses between one pole and the next. This was a complicated installation.

After an extensive search, engineers from the city of Natchitoches determined that a newly available 69-kV aerial cable system (ACS) from Hendrix could provide the reliability required for this challenging overhead conductor installation. Designed for strength and stability over long-spans, the ACS features a messenger supported primary distribution system that uses covered conductors in a close triangular configuration. The system has the mechanical strength to prevent faults due to phase-to-ground or phase-to-phase contact, tree contact or animal contact. The messenger cable is made of #8 aluminum, tensioned at 7,500 pounds at 60 F. The system is specifically engineered to withstand high winds, falling trees, damaging storms and long spans.

Hendrix was instrumental in the feeder's design

ACS features four individual cables connected using spacer brackets. A heavy-gauge messenger wire that structurally supports the cable system and withstands environmental damage.

and installation. Company engineers consulted with the city of Natchitoches utility to custom design the feeder installation and provided project management services from start to close of the project. On behalf of the city, the team coordinated installation of the cable onto the existing poles at a height of approximately 70 to 75 feet above ground.

Installation of the feeder cable in the one-mile stretch was completed in about a week. The team accurately mapped the installation and created a customized kit of materials needed to complete the job. Engineers calculated the appropriate sag for the congested installation to ensure cables would not contact vegetation or other cables on or near the existing utility poles while exposed to high winds or under stress, and installed the ACS lines to meet these calculations.

Crews prepare to install spacers at 20 foot intervals by using string to measure the distance between each spacer, an easy and accurate method of installation.

"Once it was up and running, the Hendrix system worked flawlessly," said Charles Brossette, operations manager for the city's utility services. "Hendrix personnel were very helpful and extremely accurate during the installation phase of the project."

The Atlantic hurricane season of 2005 started shortly after the installation was completed. This was the season that rewrote the record books. Three of the most intense Atlantic hurricanes ever recorded, all category 5 storms, developed in the Gulf of Mexico, and two of these storms made landfall in Louisiana. This record-breaking year of devastation included Katrina, the storm that gained notoriety for its powerful demolition of New Orleans and its threat to human life. Katrina is ranked among the five deadliest hurricanes on record.

While it devastated New Orleans, Katrina did not have any major impact on Natchitoches. But within a month of Katrina, Hurricane Rita, the fourth-most intense Atlantic hurricane ever recorded-stronger and potentially deadlier than Katrina-and the fifth major hurricane of the 2005 season, stormed into Louisiana. The storm surge devastated coastal communities and winds, rain and tornadoes caused fatalities and a wide swath of damage from eastern Texas to Alabama.

With sustained winds of 120 miles per hour (195 kilometers per hour), Rita knocked out hundreds of electrical lines, disrupting service in many areas of Texas and Louisiana for weeks. People living in parts of the country hardest hit by Hurricane Rita consider it "The Forgotten Storm," because the devastation it caused got far less attention than Katrina, mostly because it struck less populated areas and was less of a threat to human life.

Many areas in the city of Natchitoches lost power during Rita, keeping the utility division busy for weeks. But according to Brossette, "The newly installed aerial cable stood up to Rita. We had no outages in that one mile of 69-kV feeder. Lines around it came down, huge branches cracked off the old oaks and the winds whipped the trees for hours during the storm. But there was no damage to the new cable. It proved its strength during that massive storm and many smaller ones that have come in the 10 years since."

ACS runs very close to, and even through, the city's ancient trees, and is installed under the 138kV transmission line and above the lower voltage distribution lines.

The ACS cable was the only possible solution for an installation with limited space, where the only place for the new feeder was under the existing 138-kV line. The feeder has reliably operated over the last 10 years without an outage or any damage despite multiple storms and long-term exposure to high temperatures and humidity. This specialty cable minimized both the potential for downed conductors and the need for expensive ongoing preventive maintenance activities.

"The cable is holding up great," explained Brossette. "It's like we just put it up. I am pretty sure from what I see of the ACS cable's performance, we will not have to do any maintenance on it for the next 10 to 15 years."

Brian Trager *is director of technology for Hendrix Wire and Cable. He has held various positions in engineering, consulting and management at American Electric Power Co., Cooper Power Systems and Fisher-Pierce, as well as at Hendrix Wire and Cable He is a member of the IEEE and received his bachelor of science and master's degrees in electric power engineering from Rensselaer Polytechnic Institute in New York. He also holds a master's degree in business administration from the University of Pittsburgh. Mr. Trager has authored over 50 technical papers and articles for the IEEE and other national and international organizations.*

SPACER CABLE HELPS TENNESSEE COOP HANDLE RECORD GROWTH IN REGION

Fort Loudoun Electric Cooperative (FLEC) faced serious challenges keeping up with the area's growth. While the recent economic downtown has slowed development.

BY CHAD KIRKPATRICK

Fort Loudoun Electric Cooperative (FLEC) faced serious challenges keeping up with the area's growth. While the recent economic downturn has slowed development somewhat, the area has grown at a record pace for the past 20 years. This primarily was due to the explosive expansion of residential, commercial and educational facilities in Blount County, the second-fastest growing area in Tennessee.

The challenging mountainous geography and limited rights-of-way drove FLEC to look for alternatives to traditional open-wire structures, especially at substation exits. One possible solution was the use of a spacer cable system, which features a compact configuration as well as reduced clearance requirements.

INCREASING FLEXIBILITY

FLEC had used spacer cable in the 1970s to under-build a congested area of the small town of Friendsville, Tennessee. This allowed engineers to add a new line by weaving through the area without having to reconstruct the existing open wire structure. The spacer cable system was supplied by Hendrix, a New Hampshire-based Marmon Berkshire Hathaway firm that provides underground cable, spacer cable, tree wire, insulators and other overhead accessory products worldwide.

In the early 1990s, FLEC used the spacer cable system to solve tight space constraints and recently began to consider other uses for spacer cable that would add more capacity. Spacer cable is the best solution for FLEC for three main reasons:

- Limited right-of-way is the driving factor; there is simply no way to obtain the additional right-of-way needed for open wire circuits.
- Spacer cable gives FLEC the ability to be flexible with the number of circuits in the right-of-way corridor and the configuration and clearance requirements
- The spacer cable solution allows the use of the existing pole line.

The coop does not want to have to change poles, and the spacer cable makes it relatively easy for linemen to add an additional circuit on an existing line using spacer cable. Under-building using the same poles results in significant savings.

FLEC offers its customers the option of spacer cable whenever feasible, in a rocky area, for a tap line or when there is a lot of vegetation. Many customers have chosen single-phase spacer cable when there is just enough right-of-way to get the line through. Also, since much of the service area is located in the foothills of the Smoky Mountains, FLEC tends to leave hardwood trees close to the circuit, so any softwood trees that fall tend to be caught by the hardwood instead of falling on the line. FLEC still maintains clearances but not as much as are needed with open wire structures.

ALLOWING MULTIPLE CIRCUITS ON A SINGLE POLE

Spacer cable systems feature a compact configuration and reduced clearance requirements, which means multiple circuits can be installed on a single pole. Over- or under-building spacer cable systems in substation exits can reduce the cost of adding capacity.

A spacer cable system consists of a messenger cable that supports the structure, polyethylene spacers to hold the cable across spans and covered conductor cable. The messenger cable is the support member for the structure and serves as both system neutral and lightning shield. Their mechanical strength makes them suitable for long spans.

Clipped to the top of the messenger wire is a series of spacers, molded using a proprietary, gray, track-resistant, high- density polyethylene. The spacers support, separate and clamp the phase conductors in a triangular, diamond-like configuration.

Spacers are placed between spans of about 30 ft to 40 ft. They feature quick, easy installation and removal. No ring ties are required; patented integral clamps are used for conductors and messenger. The clamp design accommodates a full range of conductor and messenger sizes. The wedge-shaped messenger hook provides maximum grip.

The spacers have weather-washing characteristics, and their design provides high short-circuit strength. They are highly resistant to shock, impact or rifle fire, and can be installed with hot line tools.

Covered conductors consist of stranded hard drawn aluminum conductors with three extruded layers, the thickness of which depends on the voltage rating. Hendrix's proprietary, high-density outer layer resists abrasion, electrical tracking and UV degradation. Also, reduced NESC phase spacing is possible because of the high impulse strength covering. The three-layer covering withstands temporary contact with tree branches and other vegetation, thus reducing outages and improving power quality. This, along with the compact configuration of the system, greatly reduces the need for vegetation removal during circuit installation, cutting tree trimming costs significantly. The covering also protects wildlife from exposure to lethal currents.

APPLYING SPACER CABLE TO SUBSTATIONS

FLEC faced with a design challenge when it came to the problematic underground exits. Also, the coop faced serious right-of- way issues associated with taking five circuits for eight spans away from the Madisonville substation to the north and three circuits to the south, before splitting up and going in separate directions.

The coop began looking seriously at spacer cable circuits as an option, based on previous positive experience with spacer cable lines in tight areas and along roads with limited right-of-way. After preparing profile drawings of spacer cable circuits, the coop discovered that the system could accommodate the required number of circuits exiting the station in both directions.

Each of the substation exits uses a "vertical fence" feeder exit strategy, with four conductors

Over- and under-building on poles can increase capacity.

per circuit. With the vertical fence configuration, "E-type" brackets can be used to support each circuit, and it is simple to configure phase orientation. Three positions are available and phases are stacked vertically, which can be tapped off the bracket and dropped into the substation.

This could not have been done with open wire, and spacer cable made the project much less complex. The other alternatives would have required at least three pole lines, crossing under a transmission line, and over a railroad track and a four-lane highway, which would have been difficult with open wire. FLEC would have had to use a more costly underground wire option if it didn't have Hendrix spacer cable.

Following the success of the Madisonville substation exit project, FLEC has since used the same design at the Jena and Niles Ferry substations. While the use of spacer cable systems at substation exits was not standard practice for FLEC, it was relatively easy for the company to get approval from the Rural Utilities Service.

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