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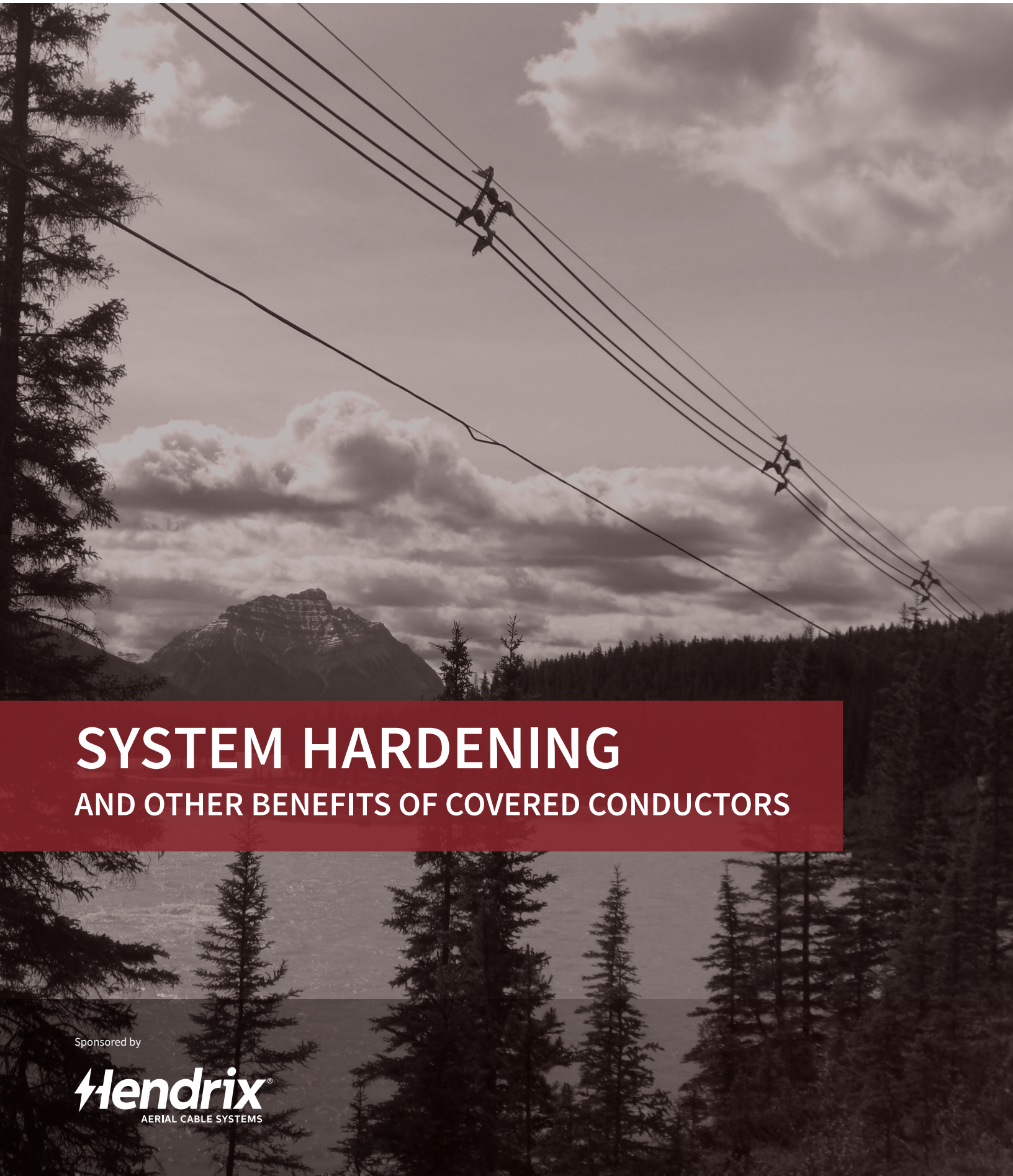

SYSTEM HARDENING

AND OTHER BENEFITS OF COVERED CONDUCTORS

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AERIAL CABLE SYSTEMS

Despite significant capital investment by electric utilities in recent years, energy infrastructure across the U.S. received only a C-minus rating in the latest report card from the American Society of Civil Engineers (ASCE). A major conclusion from the organization's in-depth study is that electric providers need to take further measures to improve distribution reliability and storm hardening.

Utilities, regulators, and stakeholders use metrics such as the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI) to evaluate utility performance in these areas. Hendrix Aerial Cable Systems, a provider of overhead and underground power distribution products, has worked with clients for decades to demonstrate numerous situations where its spacer cable products and services can improve reliability, help save money and contribute to improved SAIFI and SAIDI on electric distribution systems, the part of the grid that typically causes the greatest number of customer interruptions.

Covered Conductors

Electric utility issues such as the increasing difficulty of obtaining right-of-way (ROW) and tree trimming, maintaining required clearances in congested areas, and periodic concerns over electromagnetic fields have led to expanded interest in using covered conductors in aerial system installations. The term “covered conductor” is used generically to refer to several configurations of heavily covered non-shielded phase conductors. They are distinct from insulated conductor, which mostly refers to underground cable with a neutral shield. Tree wire refers to covered conductor built on crossarms or armless brackets in an open wire configuration. Spacer cable is held together and supported by a high strength messenger cable connected to diamond shaped spacers every 30 feet. The messenger serves as a shield wire against lightning strikes and, on grounded-wye systems, may also serve as the system neutral, especially for express circuits. Our discussion of covered conductors in this white paper will focus primarily on spacer cable.

The current standards for covered conductor require a semicon shield and two layers of insulation, making it capable of withstanding intermittent contact, providing a higher impulse strength (BIL), UV inhibition, abrasion resistance, and track resistance. The inner layer is a semicon conductor shield; the middle layer is natural unfilled polyethylene (HMWPE); and the outer layer is high density polyethylene (HDPE). The expected service life for covered conductors is 45 years, which is equivalent to the service life of bare conductors, although systems have been in place since 1951 and are still operating satisfactorily. Rigorous qualification and production testing are conducted to ensure high quality in covered conductor products so that the design and manufacturing will achieve the expected operating life.

Reliability Metrics

The IEEE Guide for Electric Power Distribution Reliability Indices (Standard 1366) defines the indices used by utilities, regulators, and stakeholders to calculate and consistently report on distribution system reliability. Perhaps the most frequently monitored and reported indices are the System Average Interruption Frequency Index (SAIFI), which is how often the average customer experiences an interruption; and the System Average Interruption Duration Index (SAIDI), defined as the total number of minutes of interruption experienced by the average customer. Interruptions less than 5 minutes in duration and catastrophic events (Major Event Days), which exceed reasonable design or operational limits of an electric power system, may be counted separately from SAIFI and SAIDI occurrences in some jurisdictions.

Outages less than 5 minutes are the most common type on many distribution systems and are commonly referred to as "temporary" faults. Both tree wire and spacer cable provide significant reductions in these types of outages since the heavy covering on the conductors greatly inhibits animals, branches, and other foreign objects from causing electrical faults. In general, SAIFI is heavily influenced by temporary fault occurrences and SAIDI is heavily influenced by faults which result in feeder outages such as those leading to breaker/recloser lockouts. Both SAIDI and SAIFI can be drastically reduced using spacer cable systems, which are effective in eliminating both temporary faults and minimizing permanent faults. Spacer cable systems have the added protection over tree wire due to the use of an adequately grounded, high strength messenger which runs above the phase conductors, protecting it from falling objects such as trees and branches.

Northeast Utilities (now Eversource) found during a two-year mandated study that spacer cable was 75% more reliable when comparing outages per 100 circuit miles/year than bare wire and 42% more reliable than tree wire. The company's three greatest specific outage causes—tree related, animal related and lightning related—were reduced by 90%, 76% and 71% respectively using spacer cable vs. bare wire.

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Spacer Cable Applications for Continuing Reliability Priorities

Storm Hardening

Storm hardening has become a critical objective for utilities in the face of more frequent high impact storm events. Strategies for improving the reliability of distribution networks include more frequent pole inspections, pole upgrades, selective undergrounding, the installation of spacer cable, and even smart grid innovations. While some measures improve recovery—which is good—actions such as storm hardening using spacer cable designed specifically to prevent storm related outages make it less likely for one's system to suffer an outage in the first place.

One New England utility found that storm related outages accounted for nearly 42% of its distribution system customer interruptions (SAIFI) and 77% of the outage minutes (SAIDI) during a three-year study period. Storm hardening with spacer cable can help address such vulnerabilities. It is designed with the mechanical strength to endure severe wind/ice/snow events and the electrical strength to prevent faults due to phase to phase or phase to ground contact, tree contact and animal contact. The cable configuration and spacers, along with the messenger, improve resistance to tree damage and ice/wind induced galloping. The messenger cable and proper use of insulators and hardware also increase resistance to lightning related weather damage.

Wildfire Hardening

Wildfire mitigation has become as significant an issue as storm hardening for electric utility infrastructure. According to research by the Scripps Institution of Oceanography, inflation adjusted damage caused by wildfires cost the economy $10 billion per year from 2017 to 2020. Power lines contribute to wildfires in several ways, including lines blowing into trees during high wind events; high impedance faults causing fires when conductors hit the ground without blowing a fuse or tripping a circuit breaker; branches spanning two phase conductors causing a fire; conductor clashing; and repetitive faults. In addition, mylar balloons touching a power line or other distribution equipment can cause short circuits, power outages, and fires.

Utilities are using a range of measures to reduce the incidence of fires caused by distribution power lines. Obviously, increased inspection and repair of damaged lines, insulators and fixtures should be part of every program. Thereafter, system improvements may involve the strategic replacement of bare wire

lines with covered conductor such as spacer cable and tree wire, or by undergrounding. In a 2015-2017 study of distribution infrastructure in fire prone areas, Southern California Edison found that the use of covered conductors would have prevented approximately 60% of the drivers causing historical ignitions. The leading drivers were contact from objects, equipment/facility failure, and wire-to-wire contact.

Spacer cable improves upon the benefits of covered cable by providing a cradle system and messenger cable to further reduce the risk of abrasion and object damage as well as to provide lightning protection, which may still be an issue with tree wire. Undergrounding is a third option for extreme situations. However, the cost of materials is generally three to four times that of covered cable; some areas are not conducive to undergrounding; and UG systems make it more difficult to find faults and to expand.

Addressing Unique Field Challenges

Spacer cable has proven to be highly effective when utilities must work within environmental constraints. A common challenge is heavily treed ROWs. Power lines in areas with a dense tree canopy are far more susceptible to damage from abrasion and falling limbs and they require more frequent foliage removal and tree trimming, which angers customers. The use of spacer cable in heavily treed areas requires much less ROW than tree or bare wire, resulting in a reduction in tree trimming by up to 80%, both in terms of lengthening the trim cycle and the amount of foliage which must be removed. This has ramifications for maintenance cost reduction and reliability, as well as aesthetics, environmental stewardship, and reduction of our carbon footprint, as trees are consumers of greenhouse gases. It also serves to protect sensitive wildlife and migratory bird species in preservation areas.

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Maintaining and replacing existing distribution infrastructure frequently involves its own set of challenges such as physical ROW limitations. The use of spacer cable can yield lower project and operations costs, a shortened timeline, and improved reliability in many situations. The National Electric Safety Code (NESC) Rule 234-1 allows 2 feet less clearance when using covered conductor, helping to address building and other restrictions in tight alleyways and other urban settings. This is particularly valuable where trenching or a directional boring for underground circuits may be cost-prohibitive and required clearances for conventional open wire systems pose significant insurmountable challenges.

For road widening projects, spacer cable's compact configuration and the ability to build the circuit on either side of the pole can eliminate ROW challenges when relocating distribution circuits. When addressing backlot bare wire service in older neighborhoods, spacer cable resolves potential power quality deterioration due to landscape planting interference with distribution lines, restriction of trimming for aesthetic reasons, and access concerns. Further, when reconductoring distribution lines, new spacer cable circuits often can be installed under existing energized circuits. The original circuit can be left in service, or a double spacer cable circuit installed, saving time and money while providing continual service. Finally, the superior mechanical and electrical properties of covered cable make it a more cost-effective solution for long spans, river crossings, and multiple circuit applications.

Spacer Cable Safety

Covered conductors must comply with the standards and specifications defined in Insulated Cable Engineers Association (ICEA) Standard 121-733-2016, the Standard for Tree Wire and Messenger Supported Spacer Cable. Further, the conductors need to be installed on insulators and/or spacers adequate for the service voltage with consideration regarding the dielectric compatibility of the covering, insulator, spacer, and tie wire.

Hendrix uses a surface leakage design goal of 1/3rd milliamp (mA) at the 15kV voltage class for a downed conductor in contact with a solid ground. Higher kV ratings may have a higher design goal, with up to 1 mA at 69 kV. While it must be emphasized that any downed line is a safety hazard, if a solidly grounded human came into contact with the 15 kV conductor by touching it with a shoe, for example, they probably would not feel it. If a person were to contact the cable with their bare hand,

they would receive a capacitive shock that feels equivalent to a pin prick. The IEEE 80 standard states that the "let go" current is above 1-6 mA, and the NIOSH standard says the maximum "let go" current is as high as 16mA. Other work indicates current between 7 and 10ma will fibrillate the heart, which is the point where the hand cannot be retracted from contact (except by gravity). Across the board, professional electrical safety references indicate the current required for serious consequences such as heart fibrillation is anywhere from 7 to 30 times the amount of current which is available from a downed spacer cable conductor in a fully grounded short circuit condition.

The extremely low surface leakage levels exhibited by downed covered cable provide insufficient current to operate protective devices such as breakers, reclosers and fuses. Obviously, this is one of the reasons spacer cable is used to prevent nuisance trips and improve reliability. If spacer cable is used in remote areas, Hendrix recommends line patrols after major storms and periodically during the year. In addition, there are methods for detecting downed conductors, including the sensitive earth fault (SEF) system and a growing number of newer protocols, such as REFCL (rapid earth fault current limiting).

Cost Considerations

Financial analysis is used to evaluate capital improvements such as the installation of new or replacement distribution cable. Such studies demonstrate that spacer cable normally pays for itself in under two years. The initial cable investment cost is offset by reduced maintenance costs, lower supply quality and outage costs, fewer callouts, and reduced ROW requirements. In addition, while not necessarily quantified in dollar terms, spacer cable contributes significantly to lowering the incidence of fatalities or injuries to the public and to wildlife as well as better pole-top working conditions due to shorter cross-arms.

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Hendrix offers a new "Value Calculator Tool" that helps customers develop return on investment (ROI) comparative business case scenarios customized to their specific project scope and application. In addition, all spacer cable projects are supported by Hendrix's complete engineering services, which provide technical assistance from design through inspection and preventative maintenance.

Conclusion

Hendrix spacer cable is designed to minimize the impact of the root causes of outages on overhead distribution systems, including storm related interruptions and wildfire risks, while improving important reliability metrics such as SAIFI and SAIDI. Spacer cable provides cost and time saving options for areas difficult to engineer with standard wire systems, and financial analysis consistently shows spacer cable investments provide an attractive return. Hendrix spacer cable systems deliver all these advantages while providing significant safety benefits compared to bare wire installations. It is easy to take distribution system storm and wildfire hardening, as well as overall reliability, to the next level with the complete project planning to system operation support services available from Hendrix.