

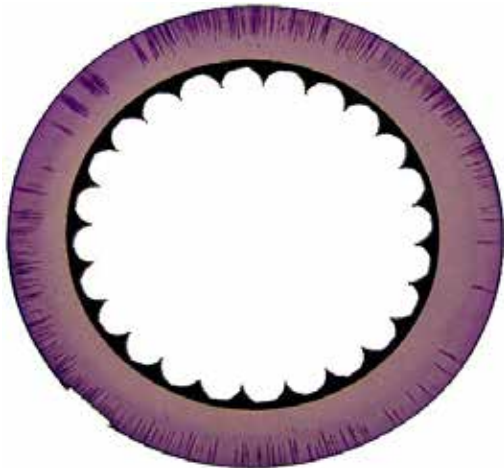
# UNDERGROUND CABLE TECHNOLOGY

Southwire's Novinium Underground services group is the only full-service underground power team partnering with utility companies to keep their networks operating at peak performance, using the most advanced, capital efficient, environmentally friendly methods available.

Southwire's Novinium Underground services continues to advance cable rejuvenation technology, methods, and delivery through its signature CableCure<sup>®</sup> services. In addition to cable rejuvenation, we offer a full range of services including underground cable replacement, fault repair, transformer change-outs, overhead to underground conversion, specialty services, secondary cable life extension, comprehensive data tracking, and end-to-end project management. These programs help utilities of all sizes meet system reliability targets and complex technical challenges efficiently in times of reduced staffing. We offer a unique opportunity for utilities to invest capital in their underground distribution system, reduce their annual O&M expenditures, and increase reliability of their underground grid at a fraction of the cost of replacement programs.

## UNDERGROUND CABLE TECHNOLOGY HISTORY

Starting in the mid-1960s, billions of feet of extruded electrical cables were installed: HMWPE (High molecular weight PE), LDPE (Low Density PE), XLPE (Crossed linked PE), TR-XLPE (tree-retardant XLPE) and EPR (ethylene-propylene rubber). These cables were forecast to last at least 40 years. Instead, many of these cables started to prematurely fail in as little as 8 years, with a large population failing in 20 years. As a result, research was conducted to determine the cause of these failures. Throughout the 1970s, studies and research determined these early failures were the result of underground moisture. Six feet underground the earth is at 54°F and the humidity is 100%. Hence, most of these newly buried cables were placed in a constant temperature “water bath”. This water quickly diffused into the cables. Even jacketed or strand-filled cables were not immune to this problem—it only slowed down the water diffusion. Over time, this causes two major problems:



Cross section of a PE cable with visible water treeing.

### 1. The formation of water trees:

When an AC field is applied to the cable, the water and ions from the ground water creates voids in the insulation, which then fill with water. These water-filled voids looked like trees or bushes when viewed under a microscope.

### 2. The AC breakdown (ACBD) strength of the cable is reduced by the presence of water trees.

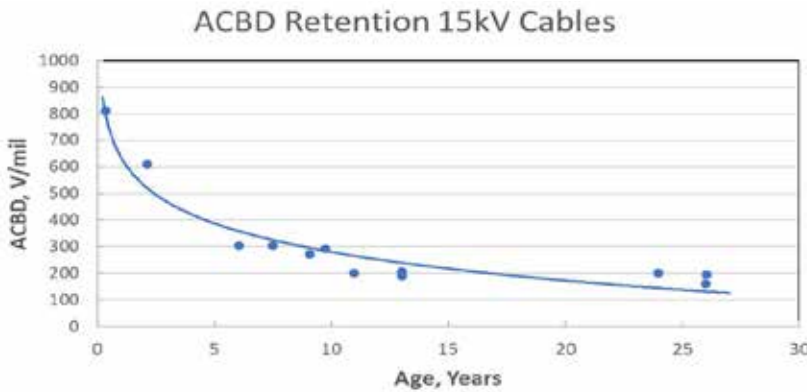
(New PE cables typically have an ACBD of approximately 900 v/mil of insulation thickness.) In water treed cables, the ACBD can be as low as 200v/mil.

The water diffuses into the cable. The water carries ions from the ground into these regions as well. Once an AC field was applied, the water, ions and electrical field start to change the amorphous region and leaves voids filled with water that look like trees when viewed under a microscope.



**CUTTING EDGE SCIENCE & TECHNOLOGY: THE SILICONE SOLUTION**

Southwire's rejuvenation fluid is injected into the cable conductor strands. The fluid quickly diffuses into the insulation and reacts with water. This dries the insulation. The silicone fluid then fills the water voids and repairs the damage caused by water trees. This extends the cable life by raising the dielectric strength of even badly aged cables and prevents the cables from failing. Using Southwire's Sustained Pressure Rejuvenation (SPR) process, dielectric strengths increase significantly in as little as 7 days, all without the need for soaking tanks. This is achieved by use of patented Injection Adapters and 3rd Generation fluid technology.



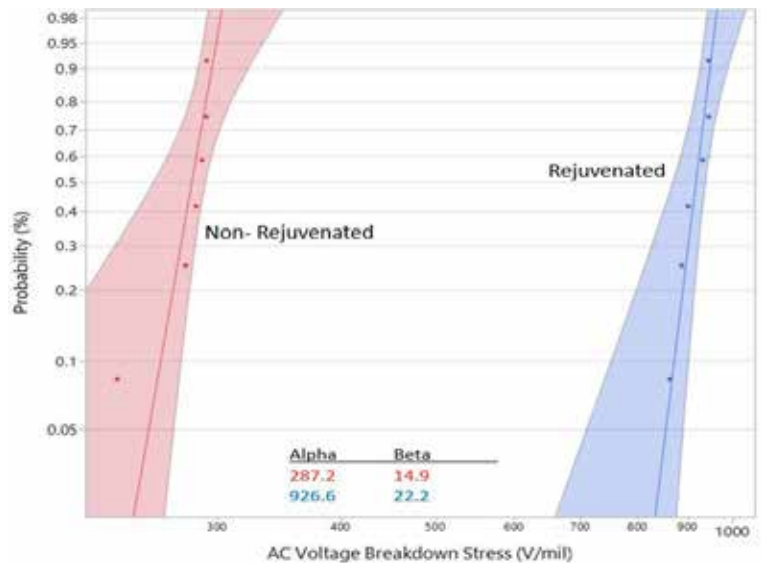
Laurence H. Gross Citrus, UC Berkeley 2008. Gross Failure Diagnosis of Underground Power Cables <http://citris-uc.org/files/>

In a study completed at the University of Connecticut, cables were aged in a high-temperature water bath for 7,000 hours to grow water trees. After rejuvenating the cable and filling the water trees, they continued trying to age for another 7,000 hours. It was discovered that they were no longer able to grow new water trees (Essay Wen Shu, Doctoral Dissertation, University of Connecticut. September 21, 2010). The graph on the left shows what happens if nothing is done.

In a 2009 independent study conducted at Cable Technology Laboratories, an ACBD test was conducted on 25-year-old direct buried cables. Control cables that were subjected to the ACBD test failed at 288 v/mil. Identical sections of this cable were treated with Southwire's rejuvenation fluid and allowed to age for two months. ACBD tests then showed the treated cables ACBD at 933 v/mil, which is better-than-new cable ACBD of—900 v/mil.

Southwire's silicone rejuvenation of underground electrical cables significantly increases the ACBD strength of cables and returns them to better-than-new condition. In addition, the process also prevents future water trees from growing in these treated cables. Southwire's patented cable rejuvenation methods can be used to address all of your technical challenges including URD, feeder, sub-transmission, submarine cable, extreme temperatures, blocked splices, radial segments, and neutral corrosion.

Silicone solutions continue to improve as our cutting-edge research continues. Our technology has proven to be highly reliable and successful. Southwire's patented family of cable rejuvenation fluids are specially formulated to ensure optimal performance in tropical soils, subzero temperatures, and everything in between. Our patented cable injection technologies help improve underground reliability and our utility partners have seen improvements in their SAIDI and SAIFI metrics.



Chatterton et al., A New Generation Cable Restoration Fluid, IEEE-PES ICC, October 2008.



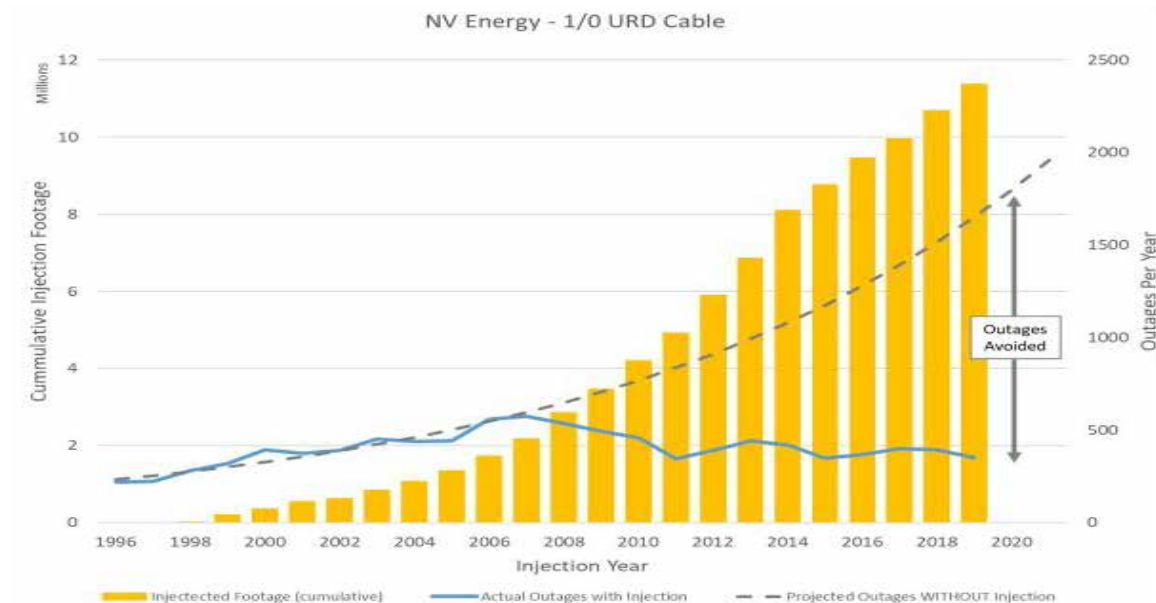
Southwire's underground rehabilitation solutions include cable assessment of neutral corrosion and replacement of splices and terminations. We rejuvenate as much cable as possible, and then can replace any remaining segments to provide complete subdivision rehabilitation. When we are done, your subdivision cable is better-than-new again. Our teams are highly productive, injecting an average of 2-6 segments a day. Our experienced and safe linemen can handle all switching, related groundwork, and reporting. A cable rejuvenation program provides better reliability outcomes than a cable testing program. A rejuvenation program ensures that ALL cables will have an increase in dielectric performance over the next 20 years vs. just evaluating the cables anticipated condition today (with the possibility of needing re-testing every 5 years or less). This increased performance can be achieved at virtually the same cost of initial testing alone. The rejuvenation process is also less intrusive, almost never requiring excavation of yards and is much quicker than traditional cable replacement methods.

## CONCLUSION

In summary, while there are many factors to consider when evaluating a cable maintenance strategy, cable rejuvenation eliminates many of the concerns associated with underground cable systems reliability. Water is the primary enemy of all underground cables (even jacketed and strand-filled cables). Silicone injection of existing assets effectively treats, removes, and prevents water from doing any further damage to your cables. The silicone diffusion also converts the XLPE insulation to an enhanced TR-XLPE cable that prevents future water tree formation for many years to come. Additionally, the silicone significantly increases the insulation's AC Breakdown strength to a better than new condition in a very short period of time. This allows the cables to withstand the various stresses that cause cable failures, thereby improving the utility's outage metrics. Utilizing cable rejuvenation as an integral part of an overall cable reliability strategy ensures that the utility is maintaining the highest level of performance in the most cost-effective manner.

## UTILITY PARTNERS

NV Energy began its initial pilot of Southwire's Novinium injection technology in 1998. Over the last 20 years, NV Energy has injected over 11.6 million feet of 1/0 and #2 15 kV URD cable. As one of NV Energy's longest running maintenance programs, they have invested over \$100 million into improving reliability. This strategic investment has saved over \$800 million of cable replacement costs and significantly reduced the number of yearly URD faults. This chart depicts the NV Energy's annual underground outages over time in relation with the amount of cable rejuvenated by Southwire Novinium Underground Services. Note the number of actual outages versus the projected outages (on an annual basis) without cable injection.





**Oncor** is one of the earliest adopters of Southwire's Novinium Underground injection technology, first injecting cable in the mid-1990's. Since then, we have injected almost 9 million feet of #2 and 1/0 URD cable, plus 1.4 million feet of feeder cable (500 kcmil and 1000 kcmil). We provide Oncor a full turnkey approach that includes URD injection, fault repair, secondary service cable injection, feeder injection, cable replacement and specialty services.

**Florida Power and Light** has trusted Southwire's Novinium cable rejuvenation technology for over 30 years. The multi-method approach adopted by FPL includes URD cable injection, feeder injection, fault repair and cable replacement. To date, we have injected almost 11 million feet of cable at Florida Power and Light.

**Duke Energy** initially partnered with Southwire Novinium Underground Services in 1995 for a multi-state total turnkey project to address their aging underground grid, which included both cable injection and fault repair. Since the beginning of the program, we have rejuvenated 7.5 million feet of cable for Duke Energy.

**AEP's** partnership with Southwire's Novinium Underground Services began 20 years ago in 2000. Initially, the utility only focused on cable injection, but starting in 2018, AEP adopted a full turnkey program: a test, treat & replace strategy in Columbus, Ohio, which addressed 1.2 million feet of cable. To date, we have rejuvenated over 5 million feet of cable for AEP.

**Salt River Project (SRP)** partnered with Southwire's Novinium Underground Services in 1989, we have rejuvenated over 8.5 million feet of SRP's underground cable. The utility is confident that by including rejuvenation in their asset management plan, they have achieved the highest reliability at the lowest cost for their customers.

## A FEW WORDS FROM OUR PARTNERS

*"We are seeing cable failure rates of less than 1 percent. Through cable rejuvenation, we are significantly improving SRP's bottom line."* – Richard Hudson, Engineering Supervisor, Salt River Project

*"Replacement costs would have been astronomical. By injecting cable, we save the company and customers tens of millions of dollars."* – Michael Surran, Director of Underground Operations, Intermountain REA

*"Our holistic approach to improving the reliability of our aging URD infrastructure has been extremely successful. We've restored the addressed population of cable to new, or like-new condition, while essentially eliminating cable failures—at 34 percent of the cost of replacing all of the cable."* – Stephen Shroba, Senior Distribution Engineer, St. Charles Municipal Electric Utility

*"I was very pleased with Southwire's dedication to the project. They were able to mobilize several crews out here to make sure it got done. They had good people with good experience both on the 1000 MCM cable that we have and the 500 MCM cable that was involved in the project."* - Jeff Dahlinghaus, Operations Manager, Dayton Power and Light

*"Southwire is a very good partner and the project came in under budget. We haven't experienced any more faults in the treated subdivisions, and we are hoping to have them back next year to rejuvenate cables in two apartment complexes where we have had a lot of problems."* – Mike Nix, VP of Electrical Distribution, Greenwood Utilities

*"The reliability of rejuvenated cable is the same as replaced cable. Cable rejuvenation is a major part of our URD asset management plan."* – David Waldner, Manager of Engineering, Mountain View Electric Association

*"The cost to replace these aging cables would have been astronomical and our capital budget would have had to double if we had to dig them up and replace them. And since we have not had to raise rates to cover the cable replacement cost, our paying customers are happy as well."* – Ed Jambor, Director of Operations, London Hydro

*"The thing that impressed us the most was the speed with which Southwire's Novinium Service team got the injection project done. The team was highly professional. We plan to continue to perform more cable injection work in the years to come."* – Rick Campos, Superintendent, Inland Power and Light



## TECHNICAL RESOURCES APPENDIX

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