SRP Enhances Reliability of Underground Distribution Cable

T&D World Magazine
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Sun, 2004-08-01 12:00

Salt River Project (SRP) has been using cable injection technology to treat crosslinked polyethylene (XLPE) cables since 1998, during which time more than 2.5 million ft (762 km) of underground residential distribution (URD) cable has been successfully treated. Nearly 99% of the treated cable has remained in service and failure free.

Ever since the first cables were directly buried more than 30 years ago, SRP (Phoenix, Arizona, U.S.) expected that faults on the system would require some kind of remedial action to ensure continuity of service. As expected, cable faults were a regular occurrence in the early 1990s. By 1996, the total number of 15-kV cable faults had increased to 800 a year. Engineers predicted that the faults on the aging system would continue growing to as many as 1500 a year within the next seven years. At the time, the standard practice was to replace the cable. However, with limited resources and the high cost associated with replacement, an alternative was necessary to keep the problem from turning into a reliability, maintenance and financial nightmare.

One alternative to cable replacement appeared to be the use of cable injection technology. To study this option, maintenance engineers reviewed hundreds of samples of failed cable and found that, although treeing was not a primary cause, they did find numerous voids and contaminants in the insulation and protrusions of the semiconducting strand shield. It appeared that if these imperfections in the insulation could be remedied by the injection technique, replacement could be avoided.

CableCURE Restoration Technology

Invented by Dow Corning in the late 1980s and licensed exclusively by UtilX Corp. (Kent, Washington, U.S.), CableCURE has been used on more than 50 million ft (15,240 km) of cable around the world. The material used, a silicone-based fluid, is injected into the strands of the cable and diffuses into the insulation to fill voids and trees. Tests have shown that cable performance improves at a rate of 0.5% per day after injection and will eventually result in a 250% to 350% improvement in dielectric strength. The fluid slows the growth of trees and can extend the life of even badly aged cable by more than 20 years.*

Pilot Project

In late 1997, SRP organized a pilot project to prove whether the injection technology could repair the cable, be cost effective and be a practical method for use in the field. Of the 31 segments of failure-prone cable selected for test, 70% were successfully injected. While fault history indicated that at least four faults should have occurred on the injected runs, none failed after a summer of service.

The economic benefit was in the range of 5-to-1, with respect to the cost for replacement compared to the cost for injection. SRP began a system-wide program to inject cables with the silicone fluid, based on the results of the pilot project and enhanced by a guarantee from the manufacturer to reimburse SRP the full cost of injection if any treated cable failed within 10 years. Today, UtilX guarantees injected cables for 20 years.

The Process

In selecting cables for the injection process, engineers first consider the age of the cable, its probability of failure and the customers served by the cable circuit. Involved in selecting the candidates for injection are operating groups responsible for fault location, repair, troubleshooting and cable replacement and construction.

The flow chart (Fig. 1) describes the process when a particular run of cable is being considered for injection. After a series of tests has been completed, a decision is made to inject, replace or abandon the segment under consideration. If the tests confirm the cable is suitable for injection, then either a medium- or low-pressure injection method is used, depending on whether splices are detected.

Testing

In the testing phase, the electrical equipment and the cable are visually inspected, and the electrical connections are de-energized and grounded. A Time Domain Reflectometer (TDR) is used to verify cable length and determine neutral condition, and to identify the number and location of splices in the run (Fig. 2). Then, either injection elbows or cable injection adaptors are installed.

Next, technicians perform air flow and pressure tests using nitrogen to determine if splices are blocked and to test for leaks. Injection terminations employing special injection ports are available for both live front and dead front applications. The injection port is used for both the flow test and to introduce the strand desiccant and CableCURE fluids into the cable. All injected cables are tagged for easy identification and recorded in a cable tracking system offered by UtilX (Fig. 3).

Injecting

As previously mentioned, either a low-pressure or medium-pressure method is used, depending on whether there are splices present. In cables with splices, the low-pressure method may be used; in cable without splices, the medium-pressure method is used.

In the low-pressure method, vacuum and feed tank tubes are attached to the injection terminations installed during the test phase, and a vacuum is applied at the far end of the cable, which accelerates the progress of the fluid through the cable and ensures a complete fill. Fluid is injected at 10 to 15 psi and monitored (Fig. 4). Injection time for a typical 400-ft (122-m) run of #2 AWG conductor could take up to a day to complete. However, in this low-pressure method, URD cables may be injected while energized, minimizing outage durations. Once the fluid reaches the other end, the vacuum tank is removed. In this application, multiple cables may be injected from common locations, enhancing productivity (Fig. 5).

In the medium-pressure method, where the cables must remain de-energized, vacuum and feed tanks are installed on temporary cable injection adapters. A pump injects fluid at pressures up to 300 psi. When the fluid reaches the other end, the temporary cable injection adapters are removed and replaced with permanent elbows or live-front adapters. Flow through a 400-ft run of #2 AWG conductor takes about 60 minutes.

The feed tanks remain connected for a 60- to 75-day soak period to allow the fluid to diffuse from the strands into the insulation, where it polymerizes with the water in the micro voids and fills them with dielectric fluid. The soaking process is usually required for cables with conductors smaller than #4/0 AWG to allow enough fluid to be absorbed into the insulation. For larger conductors, no soak period is necessary because there is enough fluid stored in the conductor strands to diffuse into the insulation.

Summary and Conclusion

At SRP, the cable injection program is headed by a project manager with a field support technician. UtilX handles the injection process and subcontracts the electrical work to a local contractor. Most of the cable that SRP has injected has been #2 AWG URD, which to treat, costs about one-fifth of cable replacement costs.

Since the program started, SRP has attempted to inject 3.9 million ft (1189 km) of cable with a success rate of 2.6 million ft (792 km) of cable injected and cured.

Although SRP can't predict the future performance of injected cables, the success of the injection program has exceeded expectations, encouraging continued use of the technology. Treating URD cables has provided an estimated savings of $83 million as compared to replacing the cable. Using the injection process has reduced the failure rate per 100 cable miles from 28 to just over 16 on the 13% of the system currently cured, improving reliability of service for all customers.

*Information provided by UtilX Corp.

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The SRP Distribution System

In 1992, as a result of increasing cable failures, SRP changed its construction practices from direct burial to installation of all new primary and secondary cables in rigid conduit. Today, the primary distribution system consists of almost 26 million cable feet of directly buried #2 AWG all-aluminum URD and another 14 million cable feet of #4/0 AWG and 500 kcmil all-aluminum primary cable. All cables are stranded conductor without strand block and use XLPE as the insulation. Although jacketed URD was introduced in 1985, 75% of direct buried #2 AWG in service is not jacketed.

Handling Splices

SRP has had good experience with fluid flow through the 200-A premolded splices. In some cases splices may need to be dug up and replaced. However, depending on the number and location of the splices, it is sometimes too expensive to make the splice replacements. SRP's current practice is to replace a maximum of three splices in a segment for injection. In the interest of time, segments with numerous splices are usually abandoned rather than injected. In all cases, each situation is evaluated since the number of cables per trench, estimated replacement cost and customer impact must all be considered.