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seek out moisture and polymerize, creating larger particles that fill voids and water trees. The cable insulation is restored to its original dielectric strength and its lifespan is increased by more than 20 years.

Brendan Lemke works for the City of Saskatoon Electric System (CSES) and has overseen its ongoing cable restoration program. He traveled to the US to learn first hand from WireDynamix crews in the field how cable rejuvenation could help the CSES. Most of the entire staff at his utility has since participated in this new endeavor. They have adapted the technology to their needs. The utility linemen perform all craftwork and then Canadian Cable Injection crews are called in to complete the injection work.

BACKGROUND

As with many other electric utilities, CSES has a large portion of its distribution network installed underground. As underground cables reach the end of their life expectancy, the need to deal with cable reliability arises. Until recently, the only option available to the CSES was to repair a failure site or replace the entire cable. The replacement option is generally quite costly and time consuming — particularly where replacement involves extensive landscaping. In the late 1990's cable injection became known to the CSES. The process involves the injection of a silicone-based fluid through the strands of the cable conductor. The fluid migrates into the insulation, restoring its dielectric properties and preventing damage from water ingress, thus extending the life of the cable.

The CSES, as with most utilities, has a power distribution network comprised of a wide variety of cable and conductor types. Approximately 40 per cent of primary conductor in the City's electric system is underground installation. Of this, roughly 70 per cent was installed prior to 1990. The City of Saskatoon began the installation of tree-retardant cable around 1989 or 1990. Since strand-filled conductors are not readily injectable, this leaves approximately 175,000 meters of cable for potential insulation restoration.

Before the cable injection process was introduced to the CSES in 1998, a reactive approach was taken for underground cable maintenance and replacement. Cables were repaired (see Figure

3) when there was a failure, and then, when one segment of cable had three or more failure sites, it was slated for replacement. The cable injection process offered an alternative to replacement and potentially at a substantial reduction in cost. At the time, claims were made that cable injection could be done at half the cost of replacement. The cable injection process also allowed for a proactive approach for dealing with large amounts of cable nearing the end of its expected useful life.

In 1998, CSES began the process of piloting a cable injection project. Complications with labour crews coming from the United States delayed, and ultimately prevented, the achievement of the originally proposed project. In the year 2000, we became aware of a Canadian licensed company (Transec Common, Inc., now Canadian Cable Injection Services Incorporated) that could facilitate the integration of the injection process. The pilot project proposal was revived and the arrangements were made to begin the project in 2001.

COLLEGE PARK SUBDIVISION

The selection of the CSES's College Park subdivision was based on a number of reasons. Known by some as "College Dark" the area was known for frequent outages due to cable failures. The area was developed in the late 1960's to mid 1970's with most of the primary cable installed in the same timeframe. Some cable replacement had been done in the 1980's, but the vast majority of the cable was still in its original state. The College Park residential area is comprised almost entirely of underground distribution cable — largely in unpaved lanes. It was thought that by treating only the primary feeder cable



Figure 4: Cable segments ready for injection

(4.16kV) we would mitigate the outages to the greatest number of customers at the lowest cost. With over 39km of primary cable in 250MCM and 500MCM sizes, it allowed for a significant scope to gauge the effectiveness of the cable injection technology. The aim of the project was to treat as much of the primary feeder cable as possible - regardless of age or apparent condition. The only exception to this rule was cable segments with numerous splices, where excavation and replacement of the splices would not likely result in a cost savings over replacement of the same segment.

The project started in the fall of 2001, work was performed over an eight-week period and concluded with a two-week session in the fall of 2002. CSES's crews completed all the craftwork associated with terminations and splices. Also, the Electric System employees performed the preparatory work involving splice location, airflow and pressure tests. Canadian Cable Injection Services (CCIS) performed all the work related to injection of silicone fluid. Richard Riley of CCIS was called in and provided the required training and was significantly involved on an advisory basis for much of the work. The staff received classroom and job-site training.

While the injection of the silicone fluid can generally be performed with the cable energized, the City of Saskatoon Electric System was not able to take full advantage of this opportunity. The distribution system in College Park is primarily composed of live-front transformers and switching cubicles (express feeder system). Many of these devices are now operating outside of their originally designed intent (see Figure 4).



Figure 5: Mobile generator provides temporary power, as cable segment is de-energized



Figure 6: Saskatoon Linemen replacing splices.

A significant portion of the work was done with the equipment de-energized. In spite of this, the power outages were kept to a minimum and short in duration. The crews made frequent use of a trailer-mounted generator unit to supply individual transformers (see Figure 5). Switching procedures became a significant factor in the injection project and required extensive planning and increased costs.

Existing splices in the College Park area were typically either a hand-taped splice or two-piece compression typesplice. The two-piece splices was unable to hold the pressure required for injection of the fluid and so all splices of this type needed to be replaced.

Debate arose over the effectiveness of hand-taped splices, and whether they could withstand the pressure from the fluid injection. It was decided to try injecting in a singular instance and see how the splice performed. The splice was able to withstand the pressure, so it was concluded that hand-taped splices didn't need to be replaced. It has since been discovered that this is not always the case. Since then, the use of reinforced hand-taped splices is limited to special situations. In general, a cold shrink body that is installed over special sealing tubes must replace feeder splices. On cables smaller than 3/0AWG, pre-molded one-piece EPDM reinforced splices are used.

Of the 188 cable segments in the College Park area, 145 segments were injected for a total of 31,400 meters of

injected cable. It took 10 weeks to complete the work, including training of more than 30 employees. In total, our crews retrofitted 290 terminations (57-600 Amp elbows and 233 live-front terminations). As well, nearly 100 splices (see Figure 6) were located and replaced. The longest cable segment injected was 790 meters long and took almost 75 hours to inject the fluid. It was also interesting to note that in one segment of 266 meters long 500MCM cable, eight litres of water were flushed from inside the cable (see Figure 7).

The cost of cable injection for the College Park project including all associated costs (supervision, switching, overhead) was approximately \$33.00 per meter. The contract for training, labour, and material from CCIS accounts for about 70 per cent of the total cost. The remaining 30 per cent was the City's portion of the materials and labour, including excavation work and engineering and other overhead costs.

WESTVIEW HEIGHTS SUBDIVISION

In 2002, the City of Saskatoon Electric System started a subsequent

injection project in a second area: Westview Heights. This area was very similar in nature to College Park and of similar vintage. However, a substantial amount of cable had already been replaced with tree-retardant cable. There were also a few segments of cable with many splices that did prove to be cost effective for injection. In a two-weeks period about 6,500 meters of cable was injected, at a final cost of approximately \$32.50 per meter.

A more significant reduction in the overall cost per meter was expected since many of the difficulties would have been dealt with in the pilot project. Since cable segments were typically of shorter length in the Westview area, the cost of the terminations on a per meter basis was higher. Also, more time was spent terminating and testing cable that ended up unsuitable for injection of fluid.

RESULTS

Since the conclusion of the two projects there have been three cable failures on the injected primary feeders in the College Park area. In two cases it was

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determined that the failures were the result of existing “water tree and electric tree damage”. Restoration fluids cannot restore electric trees. The third failure occurred at a section where only two of three phases were treated. Both the untreated phase and one of the injected phases failed. It was impossible to identify the source of the initial failure. Since injected cable is covered by warranty, CSES had the option of a cash refund or credit toward future work.

There was also one failure that occurred on an injected feeder cable in the Westview Heights area. The investigation revealed that the failed portion of the cable was subjected to excessive stress caused by exceeding the bend radius limits.

The fluid injection phase is a quick process and a great deal of fluid cable can be injected in a short period of time. Time was lost when the fluid injection work done by CCIS occurred simultaneously with the preparatory termination and splice work performed by CSES crews. There was an enormous time pressure placed on the crews to stay ahead. A lead-time of two to three weeks is advisable and proved to be a good buffer against unforeseen circumstances.

A significant side benefit to the Cable Injection projects has been the opportunity to closely inspect the system infrastructure. Maintenance and improvements were performed conjunctively, further reducing the potential for future outages. As well, the system component database was updated and reviewed.

Cable injection has been shown to be a viable and cost effective alternative in most situations. While costs for cable replacement can vary widely depending on the circumstances encountered, the cost of cable injection is stable and additional expenses for unforeseen circum-

stances are virtually eliminated. To date, our total cost including all associated tasks to inject and restore cable segments is approximately \$33.00 per meter. To compare with a replacement scenario, the material cost alone for our 500MCM cable is \$22.00 per meter. To this must be added the labor and equipment costs for drilling/trenching, restoration, switching and termination work.

The cable injection process is particularly beneficial in instances where significant landscape restoration is involved.

CSES has also concluded that cost savings associated with cable injection increased significantly when the number of splice replacements per segment decreased. Also, all preparatory work should be completed before the arrival of the injection crew thereby significantly reducing work overlap and bottleneck situations.

EXPECTATIONS

Today, the CSES has restored over 35,000 meters of existing cable using cable rejuvenation technology. We are now at the start of our third year of restoration work using the cable rejuvenation technology and have acquired extensive hands-on experience. Our plan for 2003 involves two underground distribution areas. One area is a lane-less subdivision with backyard installation of primary cables. The other is undergoing an extensive reconfiguration.

Restoration will be coordinated with the other upgrades. In both cases, the cable is nearing the end of its expected life. Fortunately, these areas have not yet experienced a high failure rate. This means the presence of fewer splices, which translates into fewer splice replacements and increased profitability. Overall restoration costs should vary favorably as the number of splice replacements will be low. The plan is to perform all the preparatory work in 2003 so that in 2004 the fluid can then be injected without the time pressure.

The cable restoration selection of

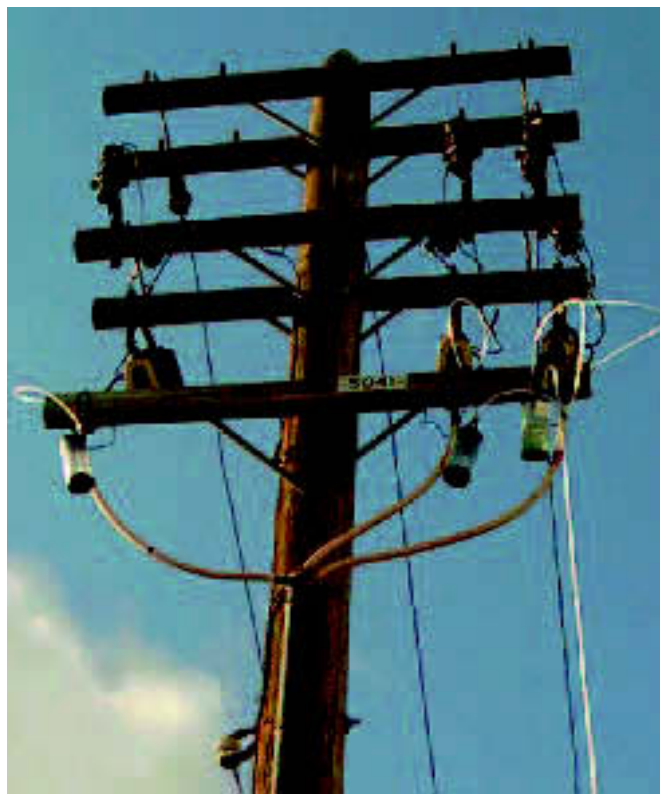


Figure 7: Water flushed from cable at riser.

which individual segments of cable to inject will also be a more selective process. Criteria such as the number of splices per segment have a direct impact on injection costs and will carry more weight in our decision-making. The ‘blanket’ approach used in the previous projects allowed for a greater amount of work to be done but at a higher cost. More effort will be placed in determining the condition of the cable and whether it is worth restoring the dielectric properties of the insulation or replacing it outright.

In particular, a more rigorous test of the condition of the neutral or of the shield will be done. In the end, it is expected that we can further reduce our cost to inject and restore cable insulation and continue to extend the life of our system, minimizing the frequency and duration of outages to our customers.

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