1. ABSTRACT

Large scale changes are happening in the US electrical generation industry. Older energy plants are being closed, newer plants utilizing natural gas are being constructed, and alternative energy from wind, solar, and other sources are being connected to the US electrical grid. On top of all of this, weather patterns, social issues, and security concerns are also being considered when building these new high voltage connectors. All of these factors lead to the use of trenchless techniques for installing critical segments of these transmission lines underground. This paper discusses the use of fused PVC in long lengths installed by HDD and slip lining as a growing method for the trenchless installation of these new grid connections. Conduit properties for both the installation and the end use are presented including cable jacket/conduit friction and thermal resistivity for heat dissipation. Case studies of recent installations will illustrate the applicability of the material and techniques. Bundled conduit installations performed in Colorado, New Jersey, and other locations are discussed to show the unique challenges associated with these trenchless conduit applications.

2. INTRODUCTION

Fused PVC has been utilized as a pressure pipe, gravity sewer, and casing for the last 10+ years in the US for potable water, wastewater, and reclaimed water conveyance. With traditional bell and spigot PVC pipe having about 78% of the water and waste water market, a fused product is an ideal addition to pipe material choices for trenchless such as horizontal directional drilling, pipe bursting, and slip lining. Open cut installations are also a choice when there is limited room in a right-of-way to lay out and installed B&S material.

In addition to these applications, PVC is also the material of choice for underground duct banks for power cables. This is traditional open cut, concrete-encased, solvent welded joint conduit. Typical conduit sizes for high and extra high voltage cables are 6” and 8” nominal diameters.

Having fused PVC to allow long lengths of PVC conduit to be assembled and installed in a single pull-in is a natural fit for underground conduit. Multiple conduits are typically bundled together either loose or with spacers in groups of 4 to 6 conduits for installation. Depending on soil conditions and electrical transmission requirements a casing may be required around the conduits. The casing is installed via traditional HDD methods with the conduit bundle (with spacers) being slip lined into the casing. Two trenchless methods are used.

In both the conduit and casing assembly the PVC fusion process produces an internal and external bead at the fusion joint. Both can be removed as needed for each specific project. Normally for a casing and conduit only the internal bead is removed. This is done by a high speed pneumatic carbide cutter. The results allow the conduit bundle to be
smoothly slip lined into the casing and for the conduit the internal bead removal results in a smooth interior surface allowing cables to be installed with relatively low pull-in forces.

A non-metallic casing is epically important for the ampacity of the cable system. At high voltages, eddy currents and magnetic fields can be generated as electricity passes through cables shrouded in a metallic casing. Ampacity can be reduced by as much as 30% as a result. The use of non-metallic casings reduces this loss by not allowing these interference to form resulting in a greater load being transmitted through the cables.

Aside from the traditional benefits of fused PVC in horizontal directional drilling, fused PVC also has attractive features from an electrical standpoint beyond its non-metallic content. The inner surface of the PVC conduit provides a very low friction surface over which the high voltage/extra high voltage cables are pulled during installation. To confirm this, the conduit ID is tested for a coefficient of friction with the high voltage/extra high voltage cable jacket. Typical jacket materials are LLDPE, HDPE, XLPE, and PVC. Lubricants to reduce the friction between the cable jacket and the inner conduit wall have been developed. Testing is done to determine the coefficient of friction for each jacket material with a variety of possible cable lubricants (2).

Additionally, heat build-up in the cable transferred to the conduit then to the surrounding soil environment is a key consideration. The material property to accommodate this is thermal resistivity. It is measured in testing done to test standard IEEE – 442. This material property times the thickness of the conduit wall is used in the evaluation and analysis of the heat dissipation. For fused PVC, the thermal resistivity is 565 °C-cm/W (3). This is below (better than) the standard value if 600 °C-cm/W typically used for PVC.

Trenchless installation of fused PVC is covered by two primary techniques. These are HDD (horizontal directional drilling) and slip lining. HDD can be used for either a casing or to install a bundle uncased, or in the “slick bore” method. In either approach the HDD installation follows the same methodology as pressure pipe. Bend radius and pull force guidance applies equally to conduit/casing installations.
In addition, ballasting of the casing and conduit is also the same as with pressure pipe. The addition of water to a level below the drill mud elevation reduces buoyancy resulting in reduced friction with the crown of the bore. Lower pull forces are then realized.

From a slip lining standpoint, the pull-in of a bundle conduit relies on the spacer support as the friction interface with the casing. The most common conduit spacers are plastic and have skid pads in contact with the casing or are wheeled. In either case low pull-in frictions are attainable allowing fused PVC conduit to be pulled exceptionally long distances. Care in handling the conduits loose then transitioning to a spaced bundle is the key upfront planning activity.

3. CASE STUDIES

3.1 PSE&G, Hackensack, New Jersey

A bundle of 15 conduits (10 - 6" and 5 - 5") 1500' long was slip lined into a 36" steel casing under the Hackensack River near Carlstadt, NJ. A total of 22,500' of fused conduit was used to assemble the bundle. The 6" conduit are used for 69KV high voltage service with the 5" conduits intended for future service carrying 26/13/4 KV lines.

With such a high number of conduits carrying power cables, heat could be an issue affecting cable performance and longevity. As a result the annular space between the conduits inside the casing was filled with a thermal grout engineered to conduct heat away from the conduits. The grout mix for this application is highly flowable, low in air content, and low in any retained water. Both air and water are insulators so minimizing these is an important part of the grout make-up. The thin wall of the PVC coupled with the high resistance to external pressure that may develop during grout placement made PVC the preferred choice for the conduit.

As with most work area in the New York City metropolis, space was limited. Fusion and assembly of the conduit bundle was done on a 2 shift basis. This took advantage of the limited area by allowing assembly of the casing spacers and pull-in during daylight hours, then adding to each of the 15 conduits on the second shift. This expedited installation in a very efficient manner.

![Figure 2. Photos of the Assembled 15 Conduit Bundle](image)

3.2 Cherokee Substation, Denver, CO

Xcel Energy needed to connect the proposed Generator # 7 to the Cherokee Substation Bay # 13 in Denver, Colorado. The power cable system will operate at nominal 115,000 volts. Overhead power lines were considered, but logistics rendered the option impractical. Instead, Xcel decided that underground power lines would be the better solution.

The proximity of the substation to the adjacent power plant was the largest hurdle to overcome for successful installation of the six 115 kV lines. The substation sits relatively close to the power plant, but is elevated roughly 100 feet above the ground floor of the power plant, with an extremely steep side slope (more than 60% grade) between the...
two locations. Operating heavy equipment on the slope would have been almost impossible and even a trenchless underground installation would prove challenging.

Xcel turned to horizontal directional drilling (HDD) as the trenchless solution for the conduit alignment between the substation and the power plant. Conduit pipe failing to meet the post-installation mandrel test would be rejected. Pulling an HDD bundle of eight 6-inch conduits (six lines, plus two spares) and five 2-inch conduits (for grounding cables and communication lines) would require a very large borehole with high hydraulic forces downhole during pull-back. The contractor recommended that Fusible PVC® pipe for the conduits, made for a routine passing of the mandrel test was well as sufficient external load resistance due to the aggressive elevation change.

![Figure 3. Photos of substation bundle lay out and insertion](image)

3.3 PV Woodbridge Energy Center, Woodbridge, NJ

Six fused PVC casings 30” in diameter with a total length of 11,000’ were installed by Carson Corporation by horizontal directional drilling for CPV (Competitive Power Ventures) to transmit 230 KV power from the CPV 700 MW Energy Center. The tie-in substation was 3 miles away with wetlands and a river crossing that could not accommodate a traditional above ground installation. Each of the six casings (the longest being 2600’) held 4—8” conduits (3 for the cables with a spare totaling 44,000’, 2—2” conduits (for grounding and fiber optic), and a 3” sacrificial thermal grout placement tube. A spacer system held the conduit and tubes in the required spacing for each crossing.
3.4 SMECO, Solomons, MD

Over the last 20 years, Southern Maryland Electric Cooperative (SMECO)’s number of customers has more than doubled and energy demand has tripled creating the need for more capacity and to ensure reliability and minimization of power outages.

This project was developed to meet these demands and consisted of the installation of two parallel bundles of five 8-inch Fusible PVC™ pipes, at 4,522-feet each, underneath the Patuxent River to run a new 230 kV underground transmission line between St. Mary’s and Calvert counties in Solomons, Maryland. The Southern Maryland Reliability Project (SMRP) includes a segment of underground transmission line crossing the Patuxent River using 230 kV high voltage solid dielectric (XLPE) cables.

The land based underground portion of the route was installed conventionally in concrete encased duct bank with conduit provisions for a future circuit. The Patuxent River crossing portion of the route was installed in a Horizontal Directional Drill (HDD) with a separate parallel HDD with conduit installed for a future second circuit.

3.5 Pantego Creek, Pantego, NC

The Tideland EMC (an Electric Membership Corporation) serves over 22,000 customers in northeastern North Carolina. Tideland’s recent system improvement initiative included replacement of power transmission cable across Pantego Creek. This crossing would upgrade the existing cable configuration that had been damaged by a lightning strike some years ago.

A variety of installation options were considered including casings of plastic a metal construction span Pantego Creek with 4 – 4” conduits covering a distance of 3800’. An additional 500’ of conduit was fused to the crossing distance to be installed via open cut allowing for a single installation pull of 4300’ for the 4” bundle. The most efficient installation was the elimination of the casing and installing a “slick bore” uncased bundle of fused PVC conduits.

Cable rated at 25KV was then installed to complete the crossing installation.
4. **CONCLUSIONS**

The trenchless methods of horizontal directional drilling and slip lining work well with underground high voltage power cable installations. With the introduction of fused PVC, a plastic material already used for open cut duct banks can now be assembled in pulls measuring thousands of feet spanning river crossings, wetlands, and other installation barriers.

Fused PVC conduit provides excellent heat resistivity and low friction for high voltage cable installation.

5. **REFERENCES**

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