TRANSMISSION & DISTRIBUTION WORLD

HV Transmission Goes Underground

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by Vito Longo, Technology Editor

IT IS EITHER AGE OR SOME INTRACTABLE FEATURE OF MODERNITY: Things that used to be crystal clear are now more than just a bit murky. The old overhead versus underground transmission line comparison used to be a no-brainer. Two decades ago, underground lines cost 20 times or more than overhead lines. Unless you were in a large metropolitan area with no other realistic option, promoting underground transmission was not a career-enhancing decision. It also could lead to protracted bouts of loneliness; no one would talk to you. A decade ago, the price multiplier had dropped to 10 times, and it was pretty much the same story.

Today, there are significant lengths of 230-kV underground transmission operating in the United States, and the number of 345-kV underground transmission projects is exploding. What brought about this change?

UNDERGROUND: PIPES TO PLASTIC

Paper is a pretty fundamental insulator. It is an even better insulator when impregnated with oil. For a long time, this was the foundation of underground cables at all voltages. Since the 1920s, pipe-type fluid-filled cables were the option of choice if one had to use underground cables. As voltages increased, the size of the cables and pipes increased, too. Eventually, the oil in the pipe was circulated to improve the heat transfer and capacity ratings of systems. But, in the second half of the 1900s, the industry discovered that the insulating oil had environmental and health impacts. For this reason, new projects migrated away from using this type of underground cable.

Meanwhile, the plastics industry was coming of age. High-molecular-weight polyethylene was first used for cable insulation in the 1960s. Then cross-linked polyethylene (XLPE), with its higher thermal tolerance, came into use. There were plenty of bumps in the road along the way. Early cables based on polyethylene insulation had failures as manufacturing processes evolved, quality-control procedures improved and installation practices matured. This stifled product acceptance for a time.

The U.S. industry has been cautious in adopting this and other new technologies. The progression for XLPE cables has been to install shorter unspliced lengths and progress to longer installations. Today, the solid dielectric cable industry provides a mature product that has seen installations up to 500 kV in China and Japan.

OVERHEAD TRANSMISSION TRENDS

Overhead line design and construction has seen steady refinement in the last 30 to 40 years without yielding any significant breakthroughs. Likewise, the materials used in overhead line construction, with the exception of line insulation, have seen incremental, as opposed to fundamental, change. The most substantial change in the environment surrounding overhead transmission lines is the permitting process.

In the distant past, the need for a line was established within the planning offices of a utility. Proposed routing usually consisted of drawing a fairly straight line from Point A to Point B. Regulatory commissions, which were also interested in maintaining low costs, generally went along with the proposed need and routing unless there were considerations not met by the utility.

Today, there are long, involved public hearings where thousands of stakeholders are put on notice about the need for the proposed line and routing. It is not uncommon to have many institutional and private interveners in this process. Their motives cover the entire spectrum of possibilities, from thoughtful and critical with the objective of improving the entire process, to what has been reduced to the acronym NIMBY (not in my backyard). The seemingly unending nature of this licensing and/or permitting process has introduced an enormous uncertainty into the overhead line design-to-construction process.

This uncertainty of getting an overhead line approved is the major modern trend. The cost differential between overhead and underground has also lessened. This is made more complex by congestion charges for network bottlenecks caused by line permitting delays. All this uncertainty and the change in economic environment gives the underground option an appeal that was previously absent.

“This is an extremely exciting time for all of us in the underground transmission cable business. Many factors are increasing the domestic use of underground transmission cables, and we are prepared to meet the wide variety of utility needs,” said Axel Schlumberger, general manager with Southwire HV Solutions (Carrollton, Georgia, U.S.), the only North American manufacturer of transmission voltage cable.

RELIABILITY CONSIDERATIONS

On one hand, overhead lines are exposed to more things that cause them to fail, turn off or need to be periodically maintained: wind, ice, lightning, contamination, trees and so forth. Underground lines simply miss out on all the excitement to which overhead lines are exposed. On the other hand, when overhead lines need to be worked on, the process is usually straightforward. When underground transmission fails, the repair process usually takes longer and costs more. However, because of the lack of required routine maintenance, some evaluations present a case for underground transmission having a lower lifetime cost than the lower first-cost overhead option.

At the end of the day though, when utilities examine and rank the root causes of distribution system reliability indices (SAIDI, CAIFI and the like), transmission system outages are nowhere near the top 10 causes. This is true for utilities with robust bulk power-delivery networks. So, unless transmission-caused outages are a significant component of customer distribution reliability indices figures, the relevant impacts of the possible unreliability of elements in the transmission system is not a long discussion.

FUTURE ATTRACTIONS

I called John Rector, a project manager at Black & Veatch (Overland Park, Kansas, U.S.), to find out how busy the underground divisions of engineering firms are these days. His comment, “We are managing to keep up with our customer requests, but just barely.” The answer is the same from just about any consulting engineering firm. Why the increase in underground transmission?

Utilities and transcos are investing in their transmission systems on a scale that has not been seen in years. Much of this investment is upgrading existing lines or installing new lines near the urban and suburban areas that have seen marked load growth. These areas that require the transmission system reinforcement are the very locations where new rights of way and permitting is the most sensitive to procure. Thus, the overall need to reinforce transmission soon becomes concerned with underground transmission.

In this issue of *T&D World* is a description of the campaign by Connecticut Light & Power (CL&P; Hartford, Connecticut, U.S.) and The United Illuminating Co. (New Haven, Connecticut) to communicate the need and routing for a much-needed expansion of the transmission system in southwest Connecticut. As a result of their campaign, the first of several 345-kV transmission projects with significant underground components is taking place. The growing list of projects includes:

- CL&P's Bethel — Norwalk project. This project will have 2.1 miles (3.4 km) of 345-kV XLPE cable, from Plumtree Substation to Hoyt's Hill Road in Connecticut. Completion is expected by November 2006.
- CL&P and United Illuminating's Middletown — Norwalk project. This project will have 24 miles (39 km) of 345-kV XLPE cable from East Devon to Singer and Singer to Norwalk in Connecticut. Completion is expected by summer 2008.
- ComEd's Transmission Reliability Reinforcement project. This project will be 10 miles (16 km) of 345-kV XLPE cable connecting the Crawford, Taylor and West Loop substations in Chicago, Illinois, U.S., with completion targeted for 2008.
- ITCTransmission's Bismarck — Troy project. This project will be 10 miles of 345 kV in Detroit, Michigan, U.S., scheduled for completion by June 2008.
- Neptune Regional Transmission System (RTS) and Long Island Power Authority's (LIPA's) Duffy Avenue Converter Substation to Newbridge Road Substation project. There will be about 2.5 miles (4 km) of 345-kV XLPE cable, expected for completion by summer 2007. (This is just a small part of the overall Neptune RTS project, which consists of 67 miles (108 km) of a 500-kV high-voltage dc submarine cable system.)
- LIPA and New York State Department of Transportation's Newbridge Road connector project. A total of 13 miles (20 km) — 4 miles (6.4 km) of the Western Connector and 9 miles (14.5 km) of the Eastern Connector — of 345-kV XLPE cable is proposed. A completion date has not been set.

These are truly exciting times in the underground transmission part of our industry.

CABLE INVENTORY

Worldwide, the use of underground transmission is considerable. There are more than 500 miles (800 km) of 230-kV solid dielectric cables in operation, with the earliest installations, by the French, in the 1980s. Less than one-third of this inventory is in the United States, all of which was installed in the last five years. The following table summarizes the 230-kV projects in the United States that are more than 3.1 miles (5 km) in length.

Recent 230-kV Projects in United States

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Location	Length (km)	Year
Pittsburg, California	40.9	2001
Arvada Service Center	10.9	2001
Fredrickson IPP	5.3	2001
Xcel Energy	7.7	2002
Arizona Power Systems	7	2002
Nevada Power	5.4	2002
Nevada Power	8.8	2002
San Jose, California	56.9	2002
Nevada Power	8.8	2003
PG&E Tri Valley	67.4	2003
BG&E	25	2003
Xcel Energy	5.1	2004
Santa Clara, California	25.6	2004

Source: Excerpts from a forthcoming handbook on *Long Life XLPE Insulated Power Cables*, edited by Rick Hartlein and Harry Orton.

Internationally, there are also more than 1000 miles (1600 km) of solid dielectric cables in operation at voltages in excess of 230 kV. As shown in the following table, roughly one-third are at voltages greater than 345 kV. None of the over 230-kV cable is in the United States.

Total Worldwide Cable Circuit Lengths by Voltage

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>	220 kV to 230 kV	Between 230 kV and 400 kV	400 kV and Higher
Kilometers	875.4	1104.3	566.8
Miles	543.7	685.9	352.0

Source: Excerpts from a forthcoming handbook on *Long Life XLPE Insulated Power Cables*, edited by Rick Hartlein and Harry Orton.

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