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Underground vs. Overhead: Power Line Installation-Cost Comparison and Mitigation

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Hurricane Sandy left many electric utility executives, their customers, local and state government leaders and regulators contemplating placing overhead power lines underground. This desire surges into prominence whenever natural disasters cause destruction on the overhead distribution and transmission networks across the country. In the past, the largest obstacle to placing overhead power lines underground has been the higher cost of installation and maintenance for underground lines.

Although overhead power lines are typically more economical, they are susceptible to damage from wind-borne tree branches, debris and high wind and ice-loading conditions from extreme weather. The damages can cause extended power outages that in extreme cases cannot be restored for days or even weeks, as we have seen after Hurricane Sandy.

The cost for repairing the physical damages can be in the billions of dollars. During long outages after a catastrophe, there are also associated intangible impacts to a utility's customers such as despair, discomfort, anxiety and helplessness. In addition to the intangible impacts, there are considerable direct economic impacts to customers resulting from lost economic activity, food spoilage, looting, etc. These tangible and intangible impacts challenge the electric utility industry's attempts to justify the installation of overhead electric distribution and transmission systems.

Cost Differentials

Whenever a major weather-related catastrophe occurs or land is being developed, the question of placing overhead power lines underground surges. The answer to the proverbial question, "Why can't overhead power lines be placed underground?" is, "They can be, but it's expensive."

Higher initial construction costs. According to the May 2011 paper "Underground Electric Transmission Lines" published by the Public Service Commission of Wisconsin, "The estimated cost for constructing underground transmission lines ranges from 4 to 14 times more expensive than overhead lines of the same voltage and same distance. A typical new 69 kV overhead single-circuit transmission line costs approximately $285,000 per mile as opposed to $1.5 million per mile for a new 69 kV underground line (without the terminals). A new 138 kV overhead line costs approximately $390,000 per mile as opposed to $2 million per mile for underground (without the terminals)."

These costs show a potential initial construction cost differential of more than five times for underground lines as opposed to overhead lines for construction in Wisconsin. Costs vary in other regions, but the relative difference between overhead and underground installation costs is similar from state to state.

Technical improvements in cable technology, wire placement, conduit sizing, grounding methods, directional boring techniques and other aspects of undergrounding power lines have advanced the reliability of underground power. They have not lowered their initial construction costs significantly, however, which are mostly associated with trenching through the earth along the entire line route.

Maintenance costs. The present worth of the maintenance costs associated with underground lines is difficult to assess. Many variables are involved, and many assumptions are required to arrive at what would be a guess at best. Predicting the performance of an underground line is difficult, yet the maintenance costs associated with an underground line are significant and one of the major impediments to the more extensive use of underground construction. Major factors that impact the maintenance costs for underground transmission lines include:

Cable repairs. Underground lines are better protected against weather and other conditions that can impact overhead lines, but they are susceptible to insulation deterioration because of the loading cycles the lines undergo during their lifetimes. As time passes, the cables' insulation weakens, which increases the potential for a line fault. If the cables are installed properly, this debilitating process can take years and might be avoided. If and when a fault occurs, however, the cost of finding its location, trenching, cable splicing, and re-embedment is sometimes five to 10 times more expensive than repairing a fault in an overhead line where the conductors are visible, readily accessible and easier to repair.

In addition, easement agreements might require a utility to compensate property owners for disruption in their property use and for property damage caused by the repairs to the underground cables.

Line outage durations. The durations of underground line outages vary widely depending on the operating voltage, site conditions, failure, material availability and experience of repair personnel. The typical repair duration of cross-linked polyethelene (XLPE), a solid dielectric type of underground cable, ranges from five to nine days. Outages are longer for lines that use other nonsolid dielectric underground cables such as high-pressure, gas-filled (HPGF) pipe-type cable, high-pressure, fluid-filled (HPFF) pipe-type cable, and self-contained, fluid-filled (SCFF)-type cable. In comparison, a fault or break in an overhead conductor usually can be located almost immediately and repaired within hours or a day or two at most.

During the extended line outages required for underground line repairs, services to customers are disrupted. The length of customer outages can be mitigated using redundant feeders, but the duration of such outages is still longer than those associated with overhead lines, and they have additional costs associated with them.

Line modifications. Overhead power lines are easily tapped, rerouted or modified to serve customers; underground lines are more difficult to modify after the cables have been installed. Such modifications to underground power lines are more expensive because of the inability to readily access lines or relocate sections of lines.

For example, when a developer or homeowner requests electric service for a new home, if there's an overhead distribution line nearby, the service connection can be designed, constructed and made available for connection to the new home in a relatively short time. Service drops to new residences can be installed within a day or two after the service request is submitted to the utility.

If the utility is requested to provide underground service to the new home, however, the design and construction will take up to a week or two. This time differential increases the cost for underground power.

Who Pays?

As the additional construction time, specialty cable costs and excavation costs continue to increase, the issue of who bears these differential costs remains unsolved. Typically the differential costs for new distribution services are paid by the developer according to a regulated tariff. The developer may then pass those costs to home buyers who purchase property fed by underground power lines. For example, in an Orlando, Fla., neighborhood, each home buyer must pay an additional $15,000 as his or her share of the costs for underground power service.

For transmission lines, it is difficult to determine how to allocate the differential costs associated with placing them underground to a specific developer, customer class or individual customer. These costs typically are absorbed by utilities, and if allowed by the regulatory agencies, the costs are included in the utilities' rate bases. Regulatory agencies usually do not allow utilities to differentiate between underground and overhead services in their rates. Service rates must be the same for each customer classification regardless how the service is provided.

There are signs that regulatory agencies are modifying their approach, however. For example, southeastern Connecticut, a generation resource-limited area, is also one of the wealthiest areas of Connecticut. A new 345-kV line was required to connect new generation facilities to the New England power grid. Because of large opposition from southeastern Connecticut citizens, portions of the line had to be built underground using HPFF and XLPE cables. Because the bulk power generated would benefit consumers throughout the region, the costs of those new generation facilities and associated overhead transmission tie line were shared by all New England ratepayers. The differential costs for undergrounding portions of the 345-kV tie line, however, were borne only by the southeastern Connecticut ratepayers. This rate differentiation must be the norm and not the exception.

Restrictions enforced by regulatory agencies try to ensure utility customers are not unduly burdened with system improvements that benefit a limited number of customers. In addition, nearly all regulatory agencies base their standard power delivery models using overhead line construction. Any proposed underground line installations that exceed the specified voltage, dollar or line length limit must be justified and approved by the regulatory agency prior to design and construction.

Investor-owned utilities (IOUs) face additional cost challenges. Unless special exceptions are obtained ahead of time, IOUs are not allowed to include their expenses for works-in-progress into their rate bases. A new power line-whether overhead or underground-cannot be included in the rate base until it is energized and serving customers. Therefore, lengthy and costly underground projects result in higher financing costs the utility must absorb without being able to recover them until the project is completed and permitted by regulators.

In addition, most regulatory agencies require utilities to justify the need and costs of new facilities. The need for a new power line typically is supported by load growth. The cost of new facilities is justified by who benefits and by performing a typical industry cost comparison.

If a new facility cannot be justified to the regulatory agency, the utility must bear the costs or at least the differential costs of designing, constructing and operating the facility.

In the U.S., more than 97 percent of the transmission line miles are installed overhead, so it is difficult to justify installing underground power. Established standard design and construction practices are to place such lines overhead. Unless undergrounding is justified by physical constraints, the utility would be responsible for the differential cost between the overhead and underground installation of the line. That differential cost must be financed and will impact the utility's return on investments to their stockholders.

Changes Required

Regulatory reform. The first required change is a redefinition of who is responsible for the differential costs associated with building and maintaining power lines underground and converting overhead lines to underground. Currently for distribution lines, those costs are passed on to the land developers who request underground services who, in turn, pass the costs on to home buyers. This seems an equitable way to handle the initial construction costs. Under these arrangements, however, utilities remain responsible for the higher maintenance costs over the life of the lines. In addition, for those utilities without underground facilities on their systems, the initial costs for converting overhead lines to underground lines would require additional startup costs associated with staff training, stocking their warehouses with underground materials and equipment, developing new standards, and purchasing new equipment for underground installation and maintenance.

A more equitable approach might be to develop separate rates for customers served underground and overhead. Maintenance costs would be tracked and allocated according to the type of service provided to each customer. This would increase the utility's commitment to place distribution lines underground. Under the current system, the utilities have the means to recover initial construction costs. Their reluctance to undergrounding distribution lines stems from the higher maintenance costs they have to absorb when underground lines fail.

Independent assessment of differential costs. Another change needed is the development of an independent assessment of the differential costs associated with installing power lines underground. Utilities cannot take this on, first, because constructing overhead structures-let's say a few structures within a mile-is less expensive than trenching a mile's worth of land to 8 feet or more in depth, and second, because customers generally do not accept a utility's estimates or explanations as credible.

In addition, preparing the independent cost comparisons is fraught with challenges. For example, when trying to average the costs of excavating a 10-foot deep trench to a width of 5 feet and include the necessary 2:1 sloping or appropriate shoring required to prevent cave-ins, it is difficult to provide a realistic average cost that considers the types of soils or rock encountered. This is because the cost of excavating is determined by the amount to be excavated and what is to be excavated. There is no average subsurface or soil type in the U.S. that would support such a calculation. The unknowns lead to variable excavating costs that are unrealistic to a U.S. utility and hard to justify to regulatory agencies and customers. This calls for local costs to be developed and examined.

Other changes already are taking place to consider underground power delivery more seriously. Engineers and planners are developing lists of costly obstacles to overcome while customers continue to demand underground power delivery. As storms leave behind damages that cost billions of dollars, everyone will focus more intently on the justification for undergrounding. This change is not revolutionary but reality.

The placement of power lines underground typically is driven by the lack of available right of way or aesthetics. Placing lines underground in heavily populated, urban areas is a decision readily justified to regulatory agencies. Typically, construction costs for those lines are approved by regulatory agencies to be added to the utilities' rate bases; however, for lines that are requested to be installed underground by a community concerned about the aesthetic, it is only just to have the community absorb a portion if not the full amount of the differential costs. This concept has been employed by several Florida utilities that needed to construct transmission lines through established, residential communities. In at least two cases, reasonable agreements were reached by the utility and government agency for sharing the differential costs of placing the transmission lines underground.

The Answer

"They can be, but it's expensive," is the proverbial answer concerning underground power delivery, but the time is quickly approaching when utility customers and government officials will demand an answer that provides a more in-depth, independent look at how much more expensive underground power delivery is compared with overhead power delivery. Changes will be precipitated by power outages associated with natural disasters, citizens who don't want their homes devalued by nearby overhead lines, and competitive economic forces that drive utilities to consider placing power lines underground.

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