Location:
UTILITIES - ELECTRIC;
Scope:
Background;

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UNDERGROUNDING ELECTRIC LINES

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You asked for a discussion of the benefits and costs of placing electric distribution lines underground, particularly in urban areas. You also wanted to know whether there are barriers to placing these lines underground. In practice, undergrounding typically involves telecommunications as well as electric lines. This report discusses the cost and benefits of undergrounding both types of lines, but focuses on electric lines. OLR Report 2004-R-0572 discusses issues surrounding the undergrounding of part of the Norwalk-Middletown electric transmission line.

SUMMARY

This report summarizes recent reports on undergrounding electric distribution lines prepared by public utility commissions in Florida, North Carolina, Oklahoma, and Virginia; a legislative task force in Maryland; and a national study prepared by the Edison Electric Institute (EEI), the trade group of investor-owned electric utilities. Several of the commission analyses were conducted in the wake of major outages caused by storms and, in the case of Florida and Virginia, were prepared at the direction of the state legislature.

The primary benefit of placing new or existing distribution lines underground is that it reduces the frequency of outages, particularly those caused by storms. Undergrounding reduces the costs of post-storm restoration of the electric system and reduces revenue losses for electric utilities resulting from these outages. Undergrounding substantially reduces the costs of tree trimming and other vegetation management and damages to electric facilities caused by vehicle crashes. It reduces the risk of the pubic coming in contact with live wires. In addition, undergrounding provides aesthetic benefits by reducing visual clutter. This may increase the value of nearby properties, although this issue is not analyzed in the reports summarized below.

On the other hand, undergrounding is expensive. According to EEI, building a new overhead distribution line costs between $136,000 and $197,000 per mile, depending on several factors including population density of the area served (urban areas being the most expensive). The cost of new underground lines ranges between $409,000 and $559,000 per mile. The Virginia commission estimated the cost of new underground lines to be four to six times more expensive than new overhead lines.

Undergrounding existing overhead facilities is even more expensive. The Virginia commission found that "the relocation of currently existing overhead lines would result in tremendous costs and significant disruptions… [and] could take decades to complete." It estimated that the cost of placing all existing electric distribution lines in the state underground would be about $83 billion or about $3,000 per customer per year. Undergrounding telecommunications lines statewide would cost an additional $11 billion. The Florida, Oklahoma, and North Carolina commissions made similar findings.

We have not been able to find any general cost estimates for undergrounding in Connecticut. However, several years ago Yale University proposed to build a new biology building on Whitney Avenue in New Haven. As part of the project, the university proposed to bury the existing electric and telecommunications lines on both sides of the avenue from Edwards Street to Trumbull Street, a distance of one-half mile. The architect for the project, Pelli Clarke Pelli, estimates that undergrounding the lines in this area, which primarily serves commercial and institutional customers, would cost approximately $2 million ($4 million per mile).

There are several disadvantages to undergrounding besides costs. While underground lines experience fewer outages than overhead lines, it is more difficult to find faults on them than overhead lines and they take longer to repair. Underground lines are less capable of dealing with overloads and are more complicated to upgrade or modify.

Undergrounding in urban areas has several additional barriers. Underground lines need boxes for switches and other equipment. These boxes, which are located above ground, are typically six feet long, eight feet wide, and four feet high. In densely populated urban areas, there may be insufficient room in the existing utility easement for the boxes. In some cases, undergrounding existing lines would require the utility to acquire new easements. New easements may be needed when the utility only has a right to use the space above the surface or when the existing overhead route is inappropriate for an underground line, e.g., when a line goes over a water body. Obtaining new easements may be particularly difficult in urban areas where lots are small. In addition, building underground lines in an urban area may require the use of directional boring rather than trenching, which is less expensive, in order to minimize disruptions to streets and driveways.

Nonetheless, several states and many municipalities require that new distribution systems be undergrounded. The staff of the Florida commission recommended undergrounding of existing systems in several cases, such as when utilities need to relocate their lines in conjunction with road construction.

BACKGROUND

The electric distribution system transports electricity from substations to homes and businesses. Power travels along feeder lines, which usually follow main roads. Tap lines or laterals branch off the feeder lines and run along side streets through neighborhoods to homes and businesses. The system also includes transformers that reduce the voltage to the level generally used in homes or businesses (120 to 480 volts). The transformers are mounted on poles near the premises for overhead service or in boxes at ground level for underground service. From the transformer, the electricity enters the residence or building through a service drop.

All of the parts of a distribution circuit can be placed underground, and undergrounding is common in many parts of the country for new subdivisions and other large developments. A number of jurisdictions require undergrounding of new lines. For example, Maryland requires that all distribution lines for new subdivisions be placed underground. Since 1967, the California Public Utilities Commission has required that all new service connections be placed underground. It has also

established a ratepayer-supported fund to help pay for undergrounding existing lines. All investor-owned utilities in Florida are required to have a process where customers can opt to underground existing overhead service by paying the incremental cost.

PUBLIC UTILITY COMMISSION ANALYSES

Florida (2007-2008)

In 2006, the Florida Public Service Commission directed each investor-owned electric utility in the state to investigate the implications of converting their overhead electric distribution systems to underground. The primary focus of the project was the impact of undergrounding on the performance of the electric infrastructure during

hurricanes, i.e., the ability of the electric system to withstand high winds, storm surges, and other damage from hurricanes and to minimize the number and duration of customer interruptions

The project was divided into three phases. Phase 1, published in 2007, reviewed existing research, reports, methodologies, and case studies. The literature review identified a range of benefits and costs of undergrounding. The benefits include increased reliability, improved aesthetics, and decreased costs for vegetation management. On the other hand, the review found an average cost of $1 million per mile, although it noted that actual costs could vary widely depending on customer density, terrain, and other factors. The review found that the costs of undergrounding are "… far in excess of the quantifiable benefits presented in existing studies, except in rare cases where the facilities provide particularly high reliability gains or otherwise have a higher than average impact on community goals." The literature indicated that the wholesale conversion of overhead distribution systems to underground would require electricity rates to approximately double. This phase of the report is available at http://warrington.ufl.edu/purc/docs/initiatives_UndergroundingAssessment.pdf.

Phase 2, also published in 2007, examined four undergrounding projects in Florida, two of which were done in conjunction with road widening. In two, the underground lines were substantially longer than the overhead lines they replaced (by 100% in one case and by 143% in the other). The increased length in these cases was due to an underground loop that was built to provide flexibility in responding to outages. Preliminary data indicated that undergrounding did not significantly affect the reliability of the affected circuit outside of storms. It found that the high initial costs of undergrounding were not fully justified by such things as reduced hurricane damage and reduced operations and management costs. The phase 2 report is available at http://warrington.ufl.edu/purc/docs/initiatives_UndergroundingAssessment2.pdf.

Phase 3 was published in 2008. It developed and tested a methodology for analyzing the costs and benefits of specific undergrounding proposals. The methodology has two components: a normal weather assessment and a hurricane assessment. The model used in the normal weather assessment includes the basic cost of utility capital and operations. It also includes reliability information that allows for the calculation of customer interruption rates and interruption-related costs. The hurricane model determines infrastructure damage and related costs associated with tropical storms of hurricane strength that make landfall in Florida.

The report notes that the methodology is specific to Florida, but the general approach is valid wherever extreme weather events have the potential to wreak havoc on electricity infrastructure. It also states that the model requires specification of many parameters and makes many assumptions. For many of these parameters and assumptions, there is little basis in historical data. The tool should be viewed as a "calculator" and the user must make appropriate decisions about the parameters and assumptions.

The report notes that there are several intangible benefits and costs to undergrounding. These include aesthetic benefits such as elimination of overhead facilities, improved landscaping, and the potential positive impact on property values. The intangible costs include reduced flexibility for both utility operations and system expansion. Undergrounding can have an adverse environmental impact including erosion and disruption of ecologically sensitive habitats.

The report notes that underground equipment is prone to damage by storm surges in hurricanes and by excavations near the lines. The time needed to repair underground lines is often longer than for overhead lines and the specialized crews needed for underground repairs are often scarce during restoration. The report concludes that "it is quite possible that undergrounding an existing overhead system in a coastal area may result in *more* hurricane damage and *longer* restoration times for customers" (emphasis in original). The phase 3 report is available at http://warrington.ufl.edu/purc/docs/initiatives_UndergroundingAssessment3.pdf.

North Carolina (2003)

In December 2002, a major ice storm blanketed much of North Carolina with up to one inch of ice, causing a power outage to approximately two million customers. In the aftermath of the storm, the public expressed considerable interest in burying all overhead power lines in the state. The staff of the Pubic Utility Commission responded by investigating the desirability and feasibility of converting the existing overhead lines of the state's three investor-owned electric utilities to underground.

The investigation

1. compared the operational advantages and disadvantages of overhead and underground power distribution systems;

2. estimated and compared the capital costs of converting overhead lines to underground, along with the differences in operation and maintenance (O&M) costs for the two types of systems;

3. estimated the time and human resources required to bury underground lines;

4. identified potential additional costs to customers, municipalities, and other utilities that may result from conversion; and

5. explored options for financing conversion projects.

The investigation identified the major arguments for undergrounding. These include reduced maintenance, smaller rights of way, less susceptibility to weather damage, fewer traffic accidents involving poles, improved aesthetics, and increased property values. The investigation found that underground systems are more reliable than overhead

systems during normal weather conditions. Based on five years of reliability data, the state's utilities experienced an average annual system rate of 0.57 interruptions per mile of overhead line compared to 0.30 interruptions per mile of underground line.

Like the previous studies, the investigation found that the principal barrier to undergrounding is cost. It determined that undergrounding the existing overhead distribution lines would be "prohibitively expensive." It estimated the cost of undergrounding varied by population density, averaging $218,000 per mile in low density rural areas to more than $2 million per mile in urban areas.

Rates would also be affected by the higher O&M costs associated with underground systems, particularly in urban areas, where underground conductors are four times more costly to maintain than overhead facilities. In addition to the impact on the cost of providing utility service, conversion to underground lines would impose costs on individual customers, municipalities, and other utilities. For example, customers would need to replace their service drops, which would cost an average of $1,481 per customer in suburban areas and $2,346 in rural areas (the cost for urban areas is included in the $2 million per mile estimate).

The investigation found the overall O&M costs for typical underground systems to be nearly identical to overhead systems ($920 per mile per year compared $917 for overhead systems). However, the O&M costs for duct bank systems are nearly four times as high. These systems are used primarily in larger cities to serve commercial loads.

Statewide, the undertaking would cost approximately $41 billion, nearly six times the net book value of the utilities' current distribution assets. Statewide undergrounding would require 237 million man-hours and approximately 25 years to complete. The capital investment would increase an average residential customer's monthly electric bill by more than 125%. According to the investigation, statewide undergrounding would increase commercial rates by 162.6% and industrial rates by 216.0%.

The investigation found other disadvantages to undergrounding. The utility data demonstrated that the typical underground outage takes 145

minutes to repair compared to 92 minutes for an overhead outage. An overhead distribution system is more flexible than an underground system. For example, tapping an overhead line to serve additional load is a relatively easy and low-cost task. Tapping an underground line is much more complicated, time consuming, and costly. If trenching for an underground system takes place near existing trees, there is the possibility that root systems will be damaged and eventually weaken or kill the trees. In addition, a properly maintained underground right-of-way must be kept clear of trees.

In spite of these disadvantages, the commission encouraged each electric utility to:

1. identify the overhead facilities in each region it serves that repeatedly experience reliability problems based on measures such as the number of outages or number of customer-hours out of service;

2. determine whether undergrounding is a cost-effective option for improving the reliability of those facilities; and

3. develop a plan for converting facilities where undergrounding is cost-effective in an orderly and efficient manner, taking into account the outage histories and the impact on service reliability.

The investigation is available at http://www.ncuc.net/reports/undergroundreport.pdf .

Oklahoma (2008)

In 2008, the Oklahoma Corporation Commission issued a staff report on undergrounding electric facilities. The study came in the wake of a major ice storm that resulted in more than 600,000 customers being without power.

The study identified the major benefits of undergrounding as significantly fewer outages, decreased costs for vegetation management, fewer lost electricity sales (both day-to-day and after storms), improved public safety from reduced live wire contact; and improved aesthetics due to less clutter.

On the other hand, the staff found that underground lines are much more expensive to build than overhead lines. It also found that faults on overhead lines can be identified more easily than on underground lines and can be repaired more quickly. As a result, outages that occur on underground lines are longer than those caused by faults on overhead lines. The staff also noted that underground lines are less capable of coping with overloads than overhead lines and present greater risk of utility employee hazards.

The study estimated the cost of undergrounding existing distribution lines at between $435,000 and $2.5 million per mile, depending on certain conditions, resulting in an estimated statewide cost of $30.5 billion. Part of the cost is for materials. The commission estimated that underground lines cost 10 to 14 times as much as overhead wires carrying the same voltage. In addition, to minimize damage from water and to meet insulation and heat dissipation requirements, underground lines are much thicker and heavier than overhead lines designed to carry the same amount of power. As a result, only short segments of underground lines can be pulled through conduit, requiring splices and underground access vaults every few thousand feet, depending on the line's voltage. The study also noted that if overhead lines are abandoned before they are fully paid for, customers are liable for the resulting stranded costs.

The staff concluded that requiring electric utilities to underground all of their facilities is generally not a feasible solution. However, they recommended:

1. burying all new lateral distribution lines (those that serve neighborhoods) except where low population density makes it impractical,

2. burying existing lateral distribution lines when requested by a majority of customers in a neighborhood,

3. burying fully urbanized main distribution lines when wires are replaced, and

4. requiring utilities to underground distribution lines when relocating for major road and highway projects.

The report is available at http://www.occeweb.com/pu/PUD%20Reports%20Page/Underground%20Report.pdf

Virginia (2005)

In 2004, the state legislature requested the Virginia Corporations Commission to study the feasibility, costs, and funding options regarding placing existing and future utility distribution lines underground. Part of the motivation for the study was Hurricane Isabel. The study looked at an unusually wide range of variables. In addition to looking at construction and operation costs, it considered the cost of rebuilding a system after a 100-year storm, the loss of electric utility revenues from outages, and various costs associated with vehicle crashes with utility poles. Commission staff also prepared a case study of undergrounding an existing line in the city of Norfolk.

The study found that the primary advantages of undergrounding were improved aesthetics and overall improved reliability. Underground systems fail less often and the average customer outage time (averaged over all customers) is generally less than for overhead systems. Undergrounding nearly eliminates the need for extensive restoration efforts after catastrophic storms. It also eliminates most momentary outages (e.g., those that occur when a tree brushes against an overhead line). Underground lines require little tree trimming and are much less susceptible to vehicle accidents.

But the study also found that:

the relocation of currently existing overhead lines would result in tremendous costs and significant disruptions. In addition, a major relocation initiative could take decades to complete and encounter complications regarding underground damage prevention and attainment of new easements.

In Virginia at the time of the study, the cost of building new overhead lines ranged from $10,000 to $250,000 per mile, depending on terrain, voltage, and labor costs. The cost of new underground lines was $40,000 to $1.5 million per mile.

According to the study, the cost of placing existing distribution lines underground would be much higher than the cost of new construction. It estimates that undergrounding existing facilities would cost $150,000 to $3 million per mile, with costs higher in urban than rural areas. The major costs were:

1. materials associated with new underground facilities (net of the salvage value of the old facilities),

2. labor for removing the old facilities and installing the new facilities (mostly trenching or boring),

3. administration and other overhead,

4. contingencies, and

5. acquisition of new easements.

The study estimated that the cost of placing all existing electric distribution lines in the state underground would be about $83 billion. This would be approximately $3,000 per customer per year. Customers would also face a one-time cost of $1,000 to $7,000 to replace their service drops. In addition, the cost of burying existing telecommunications lines would be about $11 billion. According to the study, electric and telecommunications facilities are typically placed in separate trenches with separate construction schedules.

The study estimated that undergrounding would produce annual savings and avoid costs for the economy and the electric utilities of at most about $3.9 billion, or about 5% of the cost of placing the electric lines underground. The study concluded that the potential benefits, both to the economy and the utilities, of undergrounding do not appear to offset the initial construction costs. It found that placing all new distribution lines underground, while less costly, is probably not cost-effective. However, the study noted that its estimates of benefits and costs (1) were not based on detailed engineering studies and (2) contain a significant amount of uncertainty. In particular, actual costs are highly case specific and may vary substantially from the study's estimates.

One potential barrier to undergrounding, particularly in urban areas, is the amount of space needed for switches, transformers, and other equipment associated with underground utilities. This equipment is placed in a box that is typically six feet long, eight feet wide, and four feet high. The box needs a large open space around it to open its access doors.

One issue addressed by the study, although not quantified, was the easements needed to underground facilities. It notes that some, but not all, overhead utility easements, have provisions for the installation of underground facilities. This could require the acquisition of new easements from numerous property owners. In some areas where existing overhead lines cross wetlands, bodies of water, or rough terrain, relocation of the line over the existing route may not be appropriate. In some cases, longer routes would be needed, which could increase construction costs.

The case study analyzed the cost of undergrounding electric and telecommunications lines in a seven-mile section of Route 60 in Norfolk. The utilities serving the area estimated the cost of undergrounding at $54 million, the vast majority of which was for the power lines. They estimated that the project would take two to five years to complete. According to the local electric utility, the high cost of the project ($7.7 million per mile) was due to the limited space available to install facilities and the need to bury the line more than four feet deep to avoid conflicts with existing infrastructure. The deeper trenches add costs for excavation, shoring, and water removal.

The overall study concluded that a comprehensive statewide initiative to underground all existing overhead lines does not appear to be reasonable, although it noted some targeted local initiatives. These local initiatives have implementation schedules that can be as long as 50 years. The study is available at http://www.scc.virginia.gov/comm/reports/report_hjr153.pdf.

MARYLAND LEGISLATIVE TASK FORCE (2003)

Legislation adopted in 2002 established a task force to prepare recommendations on how to facilitate and reduce the cost of undergrounding utility lines. It submitted its report in 2003.

The task force made a number of findings that were similar to those made by the public utility commissions described above. These include that:

1. in many cases, improved aesthetics is the primary reason to underground facilities;

2. undergrounding can enhance public safety;

3. these reasons are sufficient to support undergrounding in some cases;

4. undergrounding is very expensive (the utility members of the task force estimated an average cost of undergrounding electric lines at $900,000 per mile, with an additional $100,000 for telecommunications lines);

5. economies can be achieved by undergrounding electric and telecommunications lines simultaneously or integrating undergrounding with other infrastructure work such as highway reconstruction; and

6. while undergrounding reduces the frequency of outages, the outages that do occur take longer to repair and thus the overall effect of undergrounding on reliability is questionable.

The task force made several recommendations, including that:

1. the state department of planning (somewhat equivalent to the Office of Policy and Management in Connecticut) should serve as a clearinghouse for municipalities and groups interested in undergrounding and

2. the department, state and local highway authorities, and municipalities should identify opportunities for undergrounding in construction and repair work and work closely together.

The task force report is available at http://www.msa.md.gov/megafile/msa/speccol/sc5300/sc5339/000113/003000/003915/unrestricted/20070734e.pdf

EDISON ELECTRIC INSTITUTE (2009)

EEI reviewed the studies discussed above, as well as several earlier studies. It identified a very wide range of potential benefits and costs of undergrounding. In addition to the benefits described above, it notes that undergrounding eliminates outages caused by animals (e.g., squirrels), provides greater reliability and lower route congestion near urban substations, and allows maintenance to occur at ground level rather than requiring the use of bucket trucks. It also noted that one of the major benefits of undergrounding, from the utility's perspective, is that it creates positive community relations by reducing the visual impact of the distribution system. The study reviewed available reliability data for investor-owned utilities and found that underground systems have slightly better overall reliability than overhead systems, with the decreased frequency of outages being largely offset by the increased time needed to restore power.

On the other hand, underground lines have more complex operational needs than overhead lines. For example, installation of underground lines requires much more coordination between the utility and the customer. It is not possible to inspect underground lines from the ground, which makes them more costly to maintain. Underground equipment typically has a shorter lifespan than overhead equipment (on average 30 years versus 50 years), increasing the long-term costs of underground systems.

According to EEI, building a new overhead distribution line costs between $136,000 and $197,000 per mile, depending on several factors including population density (urban areas being the most expensive). The cost of new underground lines ranges between $409,000 and $559,000 per mile. It found an average cost of underground lines to be $724,000 per mile in suburban areas and $823,000 per mile in urban areas.

The report also has an extended discussion of state policies and utility approaches to undergrounding. The report is available at http://www.eei.org/ourissues/electricitydistribution/Documents/UndergroundReport.pdf

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