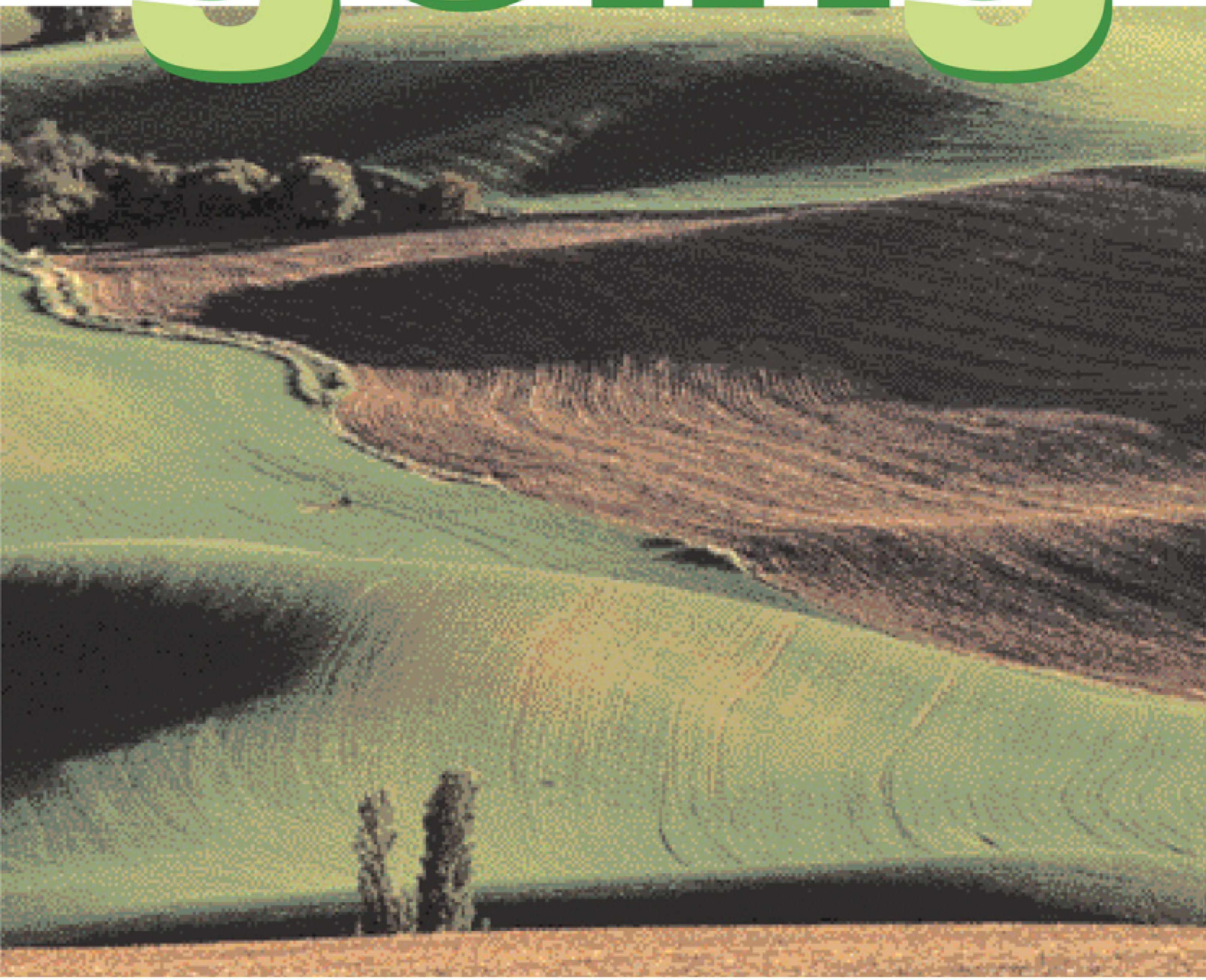
# going



# under ground

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As available space for rights of way becomes scarce, placing high-voltage transmission lines underground is an issue that many utilities are being forced to address. In several states, utilities are required by state law to evaluate underground in addition to overhead alternatives. Utility projects are more and more frequently being routed through densely developed areas, where overhead options may be limited or infeasible.

Landowners and local governments have intensified pressure on utilities to construct transmission lines underground, partly because they have seen underground distribution lines become commonplace. Many people do not understand the significant difference between distribution (less than 69-kV) and transmission (greater than 69-kV) voltages for underground construction. Distribution lines are cheaper and easier to place underground because they do not generate as much heat as transmission lines, and do not require the technology (such as duct banks and thermal backfill) necessary to dissipate the heat. Because underground electric lines are not visible, landowners typically consider them to be less impacting, which is not necessarily the case. Despite public pressure, utilities often resist building transmission lines underground for several reasons: higher costs, increased maintenance challenges and greater environmental impacts.

## HISTORY

Underground transmission lines were initially installed as far back as in the 1920s.[1] Hundreds of miles of 138-kV and 230-kV transmission lines were installed in the 1960s and 1970s,[2] but individual lengths were generally less than five miles. Most of these lines were installed to avoid populated areas or localized constraints such as airports. In contrast to the approximately 200,000 miles of overhead transmission lines currently operating in the United States,[3] there are only about 5,000 miles of underground transmission cable in service,[4] much of which need upgrades or repairs because of their age.[5]

## UNDERGROUND SYSTEMS

There are four basic types of underground systems:

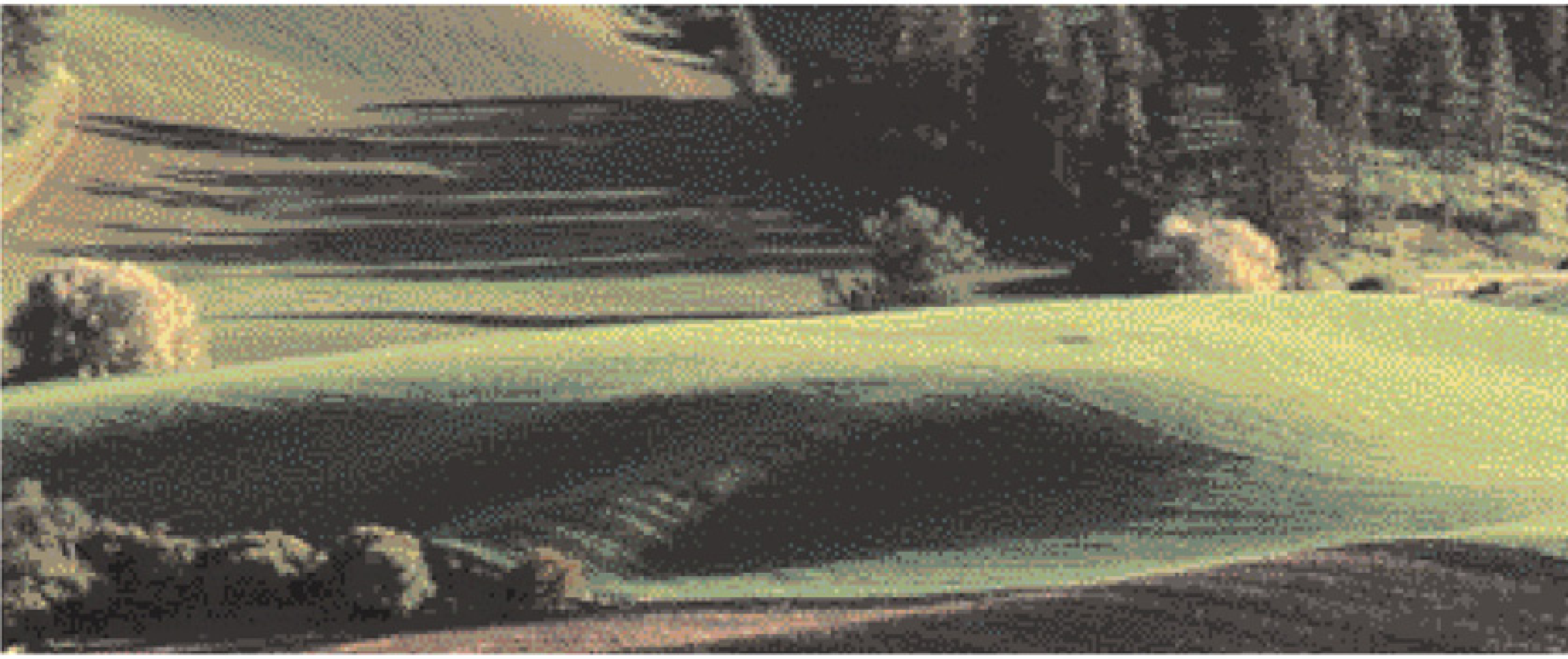
- High-pressure, fluid-filled pipe
- High-pressure, gas-filled pipe
- Self-contained, fluid-filled pipe
- Extruded dielectric

The high-pressure, fluid-filled (HPFF)

**THE PRIMARY ISSUE FOR UTILITIES CON**

and high-pressure, gas-filled (HPGF), collectively dubbed "pipe-type," are similar in construction. Both consist of a steel pipe containing three separate conductors (wires that transmit electricity – three separate wires are required for each circuit), which are insulated within the pipe by dielectric oil for HPFF or nitrogen gas for HPGF. HPFF accounts for the highest proportion of cable installed in the United States and has been typically used for higher voltages such as 345-kV.[6] The trend is now shifting to extruded dielectric cables. HPFF requires a high volume of fluid to be pumped throughout the system using fluid pressurizing plants. HPFF also requires high charging currents, has higher maintenance requirements than other cable types, and involves a threat of oil leaks and fire.[8] Self-contained, fluid-filled (SCFF) consists of three independent oil-filled conductors installed in separate pipes. SCFF-type cables have a small amount of oil in the core that is under static pressure. This cable type is used infrequently in the United States, primarily for underwater applications.[9] The relative newcomer is the extruded dielectric cable, which consists of three independent cables installed in a concrete duct banks or buried in separate trenches. Each conductor is insulated with cross-linked polyethylene (XLPE), a thick, plastic-like substance. Regardless of the cable type, underground transmission lines are typically installed 3 feet to 6 feet below ground.

What many people do not realize is that additional facilities, besides the underground



# SIDERING UNDERGROUND CONSTRUCTION IS THE COST.

cable, are required to operate underground transmission lines. These ancillary facilities include manholes (vaults) that contain line splices, transition stations, fluid-pressurizing stations (HPFF only) and access roads along the entire underground route. Splices, transition stations and fluid-pressurizing stations are locations where approximately 90 percent of all underground failures occur.[10] Underground concrete vaults (8'x 8'x 28') are required for access to splices. Splices are required because the amount of cable that can be shipped on a spool and the amount of tension the cable can withstand during pulling are limited. Vaults are required approximately every one-quarter to one-half mile along an underground route. [11] Transition stations, which include terminations, dead-end structures and surge arrestors, are required to convert the transmission line from overhead to underground. In some cases, switches and pumping stations may also be included. Transition stations can be stand-alone facilities – or the necessary equipment, most of which is aboveground, can be placed within a substation (a fenced facility containing banks of electrical equipment that convert high voltages from transmission lines to lower distribution line voltages).

## UNDERGROUND CONSTRUCTION

The typical underground construction process includes digging the trench; laying the welding pipes or pouring concrete duct banks; covering with thermal backfill and replacing the soil; pulling the cable between vaults; splicing cables; and adding oil or gas (pipe-type only). The average progression of construction is about one mile per month.[12] About 20 feet to 50 feet of right of way is required, in contrast to approximately 70 feet to 150 feet for overhead transmission lines. Access for heavy equipment is required along the entire underground route for construction and later maintenance, while only access to pole locations is required for overhead construction. Unlike overhead construction, where some low-growing trees and shrubs may remain in the right of way, all trees and shrubs must be cleared during underground construction to prevent the potential for root disruption to the cables and the loss of soil moisture (needed to cool the conductors) to vegetation. Other underground utilities could also conflict with the placement of the underground transmission cable.

A benefit of the underground cable is that it is less susceptible to damage, primarily because it is not exposed to weather, such as ice, wind and lightning. However, when damage does occur, it is more difficult to locate the fault along an underground system and more difficult and time-consuming to repair. The duration of outages can vary from five days to nine months, depending on the type of cable, the type of failure, the availability of replacement parts (most of which are manufactured overseas in Europe and Japan) and the skill of the repair personnel.[13] In contrast, overhead outages can generally be repaired within a few hours or a couple of days. Cable repairs also result in significant social and environmental disturbance due to the necessary excavation.

## UNDERGROUND COSTS

The primary issue for utilities considering underground construction is the cost. Such costs may vary from between two times to 25 times the cost of comparable overhead transmission. [14, 15]

The actual cost is dependent on factors such as:

- Size of the cable
- Length of the line
- Presence of steep or rocky terrain
- Timing of construction
- Heat transfer characteristics of the soil
- Need for traffic control
- Presence of other underground utilities
- Presence of hazardous waste sites or other constraints
- Number of stream or road crossings and the need for directional drilling
- Right of way costs
- Permitting requirements

Repairs are also more costly for underground cables because faults are more difficult to locate (which usually involves excavation), and because of the high cost of replacement materials. Some factors, however, tend to reduce the difference in costs between overhead and underground construction. For instance, because an underground cable requires a narrower right of way, and often is placed within public streets, right of way costs can be considerably less than that for overhead, especially when locating in areas of high-value real estate. Cost differences may also be reduced when a utility is forced to rebuild existing lines to make room for a new overhead line. Rebuilding includes the cost of constructing multiple overhead lines compared to the cost of installing a single line underground.

A major issue is determining who pays the additional cost for an underground transmission line, especially when feasible overhead options are available. If the utility pays the cost, then that cost is distributed to all its customers throughout its entire service territory. But often the underground option is requested by a special or local interest group, and it only benefits those people. Utilities and public service commissions often take the position that those requesting an underground transmission line will have to pay the additional cost of underground construction.

## IMPACTS TO THE SOCIAL AND NATURAL ENVIRONMENT

A significant advantage to using underground transmission lines is the availability of numerous routing opportunities that are not available for overhead routes. Underground cables can be placed within public streets, through urban and residential areas, near airports and underwater, where overhead lines are either undesirable or infeasible. Because underground transmission lines have fewer surface structures, they are also usually more acceptable to landowners. Underground routes are often shorter (and more direct) than overhead routes because they do not have to detour around physical constraints that would preclude an overhead line. Underground lines, however, have their own set of constraints.

While the impacts to residences and businesses can be substantially less for underground transmission, the environmental impacts can be substantially greater. The primary social impact from underground lines is temporary disturbance during construction or maintenance. Once the line is placed underground, there is little impact to residences and businesses. Overhead lines can span many environmentally-sensitive features, such as streams and rivers, wetlands, archaeological sites, wildlife habitat and cropland, while an underground line requires excavation through these features. The only way to avoid significant impacts to many environmental areas is to route around them. Table 1 is a comparison of the potential impacts of both overhead versus underground lines.

Depending on the type of cable system used and the installation method selected, underground lines may result in lower electric and magnetic fields when compared to overhead lines of similar voltage. Electric fields for an underground cable are negligible; however, magnetic fields are often of primary interest to landowners. When conductors are installed underground within the same pipe or in close proximity, a cancellation effect can reduce the overall magnetic field. HPFF cable types have the lowest magnetic fields because the conductors are installed within the same pipe. When the conductors are installed horizontally or in separate trenches such as for the XLPE type, the magnetic fields may be greater directly over the line than directly below a similar-voltage overhead line. Even with potentially higher fields directly over the line, the magnetic fields for underground cables dissipate more rapidly as one moves away from the line than they do for overhead lines.

Because the visibility of an underground line is negligible and electric and magnetic fields (EMFs) may be reduced, landowners are often more receptive to underground transmission lines, thus reducing public opposition. The benefits from reduced public opposition, however, may be offset later by increased environmental permitting efforts and costs.

In summary, the choice to build a transmission line overhead or underground depends on many factors, including the construction and right of way cost and social and environmental impacts. Though an underground transmission line will be less visible, may have lower EMFs and may be more acceptable to landowners, it is more likely to result in significant environmental impacts. As a result, underground cables are more feasible in developed areas where viable overhead options are not available, where property values are much higher and where environmental impacts of underground construction would not be prohibitive. While underground technology continues to improve, offering utilities less expensive and more reliable underground options, it is currently used only as a last resort when no other alternatives are available. In most cases, the cost and operational challenges are still prohibitive. ❖

[1] Orton, H.E. and R. Samm. 1998. "Underground Transmission Cables are a Vital Part of any Power Transmission System: The Electricity Forum." www.electricityforum.com/et/Aug98/cable.htm.

[2] Williams, J.A. 2002. "Pumping Power Underground: Transmission and Distribution World." http://tdworld.com/ar/power_pumping_power_underground/

[3] U.S. Department of Energy. 2001. "Superpowering the Electric Grid." www.eren.doe.gov/superconductivity.

[4] Williams, 2002.

[5] U.S. Dept. Energy, 2001.

[6] Williams, 2002.

[7] Connecticut Light and Power Company. 2001. Application to the Connecticut Siting Council for a Certificate of Environmental Compatibility and Public Need for an Electric Transmission Line Facility between Plumtree Substation in Bethel and Norwalk Substation in Norwalk, Appendix 2.

[8] Ibid.

[9] Public Service Commission of Wisconsin. 1999. PSC Overview Series…Underground Electric Transmission Lines. http://psc.wi.gov/consumer/brochure/document/6011b.pdf

[10] Ibid.

[11] Connecticut Light and Power, 2001.

[12] Power Delivery Consultants, 2001.

[13] Public Service Commission of Wisconsin. 1999.

[14] Ibid.

[15] National Grid Group. 2000. "Overhead or Underground?" http://www.nationalgrid.com/uk/library/brochures/overhead_underground/mn_background.html

TABLE 1. POTENTIAL IMPACTS OF OVERHEAD VS. UNDERGROUND LINES

| ISSUE | OVERHEAD | UNDERGROUND |
|---|---|---|
| Visibility | Poles, Cleared areas, Substations | Cleared areas, transition stations |
| Water Crossings | None due to spanning | Disturbance during trenching or boring, potential oil leaks |
| Wildlife Habitat | Tree removal/fragmentation, collisions, electrocution | Tree removal/fragmentation |
| Wetlands | Loss only at pole footings | Disturbance during trenching<br>Potential oil leaks |
| Archaeological Sites | Disturbance only at pole footings | Disturbance during trenching<br>More difficult to avoid |
| Historic Sites | Visual intrusion | No impact, except transition stations |
| Land Use | Some height and use restrictions in right of way | More restrictive, no structures and limited use,<br>Land out of use longer, but narrower right of way required |
| Agricultural Lands | Poles and guy wires may cause obstructions | Plowing depth restricted, soil compaction and erosion premature seed germination, land take for vaults |
| Forestland | Loss of tall trees<br>Wider cleared right of way | Loss of trees and shrubs, narrower cleared right of way |
| Road Crossings | Span | Trench or bore |
| Along Roads | Outside right of way, some traffic control requirements, some construction limitations | Within right of way, significant traffic control requirements, significant construction limitations |
| Airports | Obstruction | Non-obstruction |
| Noise | From conductors and substations | From transition stations and substations |
| Access | Required only to poles | Required along entire route |