



Going up or down?

Factors to consider before going overhead or underground

Transmission lines can be constructed one of two ways: overhead or underground. Historically, the biggest, and sometimes the only, consideration for which installation method to use was initial cost. With this being the only criteria, an overhead option has a distinct advantage. Although not every transmission line project is suited for an underground installation, a thorough evaluation should take into account all considerations, not just capital cost. Underground transmission lines are one of many tools in a utility's tool box, and it is important to evaluate and understand in which scenarios underground transmission may be advantageous.

The installation condition and area (regions/states/cities) can dictate the primary evaluation criteria. Environmental considerations can have a larger impact in one region, whereas storm hardening for hurricanes would be more prevalent to other areas such as the Gulf and East coasts. Additionally, different states—and even different cities in the same state—can have varying requirements for a transmission line.

Public consideration can also weigh heavily on installation decisions. Examples may include scenarios such as routing in congested cities where there is no room for overhead poles or when the installation is governed by an entity other than the utility. These scenarios appease the public and/or the DOT when rerouting a roadway. In these instances, going underground makes more sense or emerges as the only option.

Decision considerations

- Installation and geographic conditions
- Land usage
- Environmental impacts
- Weather-prone outage regions
- Public safety
- Public opinion/stakeholder satisfaction
- Capital, life-cycle and operations and maintenance costs
- Project routing/approval



There are also scenarios where capital cost is the driver, but when considering life-cycle cost, going underground may be a better fit. For example, installing an overhead line in a high-wind or heavy-icing area may initially be less expensive, but future repairs and circuit downtime may narrow the cost gap. Analyzing capital cost and life-cycle cost provides a good start to compare overhead installation versus an underground installation; however, there may be additional consideration factors. These factors include environmental impacts, power outages, land usage, public safety, operation and maintenance, stakeholder satisfaction, and project routing and approval. While individual considerations may not be drivers, they should be evaluated.

Note the primary focus of this study is on transmission assets. Distribution installations generally require a different process, which has substantially less regulatory and may have less stakeholder involvement.



Environmental Considerations

Any environmental limitations or restrictions should be considered when deciding on a route for a transmission line. Such limitations could include, but are not limited to, wetlands and water bodies, tree and vegetation clearing, and/or migratory/threatened/endangered species. One example of this would be the scenario where an overhead route needs to cross a river in an urban area. The span across the river is of such length that clearances will not be met for boat traffic without excessively tall towers. Rather than trying to find an alternate location to cross the river, the line could utilize

an underground installation and cross under the river via a horizontal direction drill (HDD). Conversely, there are applications where a wetland or water body is small enough that an overhead line can span the entire area. Poles can be set outside of the wetland with lines spanning across the wetland without the additional cost and complexity of transitioning to an underground installation.

Not only should environmental impacts be evaluated during construction, but also post-construction. One potentially large post-construction environmental impact and/or operational expense could be vegetation management. Tree and vegetation clearing has the potential to be much less impactful along an underground corridor than an overhead corridor. Underground transmission lines will generally require a measurably smaller right-of-way, which reduces overall vegetation impact and management.



In an overhead transmission corridor, tree limbs that grow into the right-of-way need to be routinely cut back so they do not interfere with or pose a risk to the overhead transmission line. Because of this, an overhead right-of-way is typically wider than an underground right-of-way. Again, it is important to understand the project location. If the project is constructing a line across the central United States, or other areas where trees are sparse, tree clearing management is a lesser issue.

In certain regions of the country, migratory birds can present permitting challenges. Adding new overhead obstacles have the potential to affect avian migratory species, posing significant permitting



challenges. Overhead structures, associated clearing, and maintenance may result in issues such as obstruction of flight paths and clearing of nesting and/or breeding areas. These impacts may be mitigated with the use of an underground transmission line in highly sensitive areas, such as designated nesting areas or refuges. If threatened or endangered species are identified near the route, especially if the animal burrows, then an overhead option may be a better choice as there is less ground disturbance compared to an underground installation. Threatened or endangered species along the route can affect routing and dictate which installation method is used.

When faced with an environmentally-sensitive area, a cost and environmental-impact analysis should be performed. This can determine if a shorter underground installation is more cost effective and/or more environmentally friendly than rerouting an overhead circuit.

Power Outages

Overhead transmission line power outages can result from a variety of external issues: weather, vehicle striking a utility pole, line strike from construction equipment, etc. There is also the threat of heavy winds, which can cause damage to a variety of structures, and overhead transmission poles are no exception. While strong winds themselves are threatening to structures, there is the added risk of tree limbs and debris striking the lines and knocking out power. Transmission lines generally sustain these storms moderately well. However, after recent major storm events like Super Storm Sandy, Hurricane Harvey, or Hurricane Irma, some utilities started making a push to harden their facilities with key transmission lines relocated underground to prevent future weather-related damages and outages. In this evaluation of storm hardening, utilities are faced with numerous challenges, including line outages due to storm events. Overhead lines can be designed for extreme loadings, but at what cost?



It is important to note that while underground transmission systems are generally less susceptible to storm-related outages, they are not completely immune (a future study will address this subject in greater detail). Because of this reduced influence from storm events and other above-grade risks, underground lines historically have fewer weather-related power outages. However, when an unplanned underground outage does occur, it can be more difficult to locate, and more time consuming to repair compared to overhead lines.

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From a report prepared by the President's Council of Economic Advisers and the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability, between 2003 and 2012, weather-related outages are estimated to have cost the United States economy an inflation-adjusted annual average of \$18 billion to \$33 billion. Annual costs fluctuate but are greatest in the years of a major storm, like Hurricane Ike in 2008. This year, weather-related outages are estimated in the range from \$40 billion to \$75 billion. In 2012, the year of Superstorm Sandy, cost estimates range from \$27 billion to \$52 billion. The costs of outages take various forms including lost output and wages, spoiled inventory, delayed production, inconvenience, and damage to the electric grid. ¹

Again, if the focus is on cost, both capital cost and life-cycle cost need to be evaluated. Fewer power outages mean higher uptime on the network, which leads to more revenue. A higher uptime also tends to lead to happier customers who have constant, reliable power. Prolonged power outages due to major storm events in the United States has the potential to have a significant economic impact on individual businesses, persons, and regions.

¹August 2013. Economic Benefits of Increasing Electric Grid Resiliency to Weather Outages. https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf.



Land Usage

Another consideration when routing a new line is land usage. Transmission line routes can go anywhere from city streets or new developments, to open fields or dense forest. When routing near airports, the Federal Aviation Administration (FAA) has requirements for structure heights and proximity to the airport property. Because of this, various projects around airports may be installed overhead but transition to underground when going through this space. This is a singular example, but when considering new transmission line installations, it is important to consider both current and future land use.



During the routing and planning stages of a new project, it is important to understand the area and potential future land use. Will the right-of-way be developed in the future? An overhead line may go through an open field now, however it may deter future economic development such as a commercial or housing development or roadways. In some instances, an adjacent overhead transmission line right-of-way can reduce property values from an aesthetics perspective, whereas an underground transmission right-of-way can present less of an aesthetic impact. Underground transmission has the potential to become a feature, such as a bike path, walking trail, green space, etc. The challenging aspect of this

approach is forecasting the future land use. At the time of routing, it is critical that utilities and developers work with local stakeholders to determine if there are any plans of development along the proposed route. This approach may mitigate future rework of the transmission line.

One utility learned the importance of working with developers on a transmission project the hard way. Because they did not consider future use, an existing overhead double-circuit transmission line had to be rerouted to accommodate a new highway interchange. Along a portion of the overhead alignment, massive amounts of regrading (adding up to 30 feet of backfill) was planned to account for on/off ramps, bypasses, and highway. The increased grade elevations would not maintain clearances to the overhead circuit, so that portion of the overhead route was rerouted underground. Learning from prior experience, the utility, when routing a new transmission line, located the line underground to prevent any issues if any road expansion were to occur. With any future line relocations, cost sharing opportunities may exist.



Having an overhead line limits the infrastructure that could be built in that same area. With an underground installation, infrastructure, to an extent, can be constructed above it. A new building cannot be constructed over an underground line, but a roadway or parking lot can. Underground duct banks can be designed to meet a wide variety of loadings, up to and including very large traffic, such as heavy-haul roads for mining and other operations. Additionally, duct banks can be designed to handle seismic conditions when needed.



Public Safety

Both overhead and underground transmission lines, under certain, but rare scenarios, have the potential of being safety concerns (downed lines, damaged poles, etc.). One challenge with overhead power lines is that they are directly accessible to the public. While not recommended and designed to prevent access, a person could climb a pole or tower and contact an energized circuit. Additionally, utility poles, especially when paralleling roadways, have the potential to be hazardous to traffic. A vehicle could strike the utility pole, possibly knocking the pole and/or the line down. On the

converse, with an underground installation, there is risk of a splice failure in a splice vault. Although a relatively uncommon event, the industry is continually evaluating and developing manhole explosion mitigation and venting/dissipation methods.

While neither system is always 100% safe, with overhead lines, all the electrified components are exposed and have a greater potential for human interaction.

Operation and Maintenance

After a transmission line is constructed, either overhead or underground, some form of maintenance should be routinely performed to ensure the longevity and safety of the line. General maintenance for an overhead line would include wire and insulator inspection, painting of structures, right-of-way clearing, vegetation management, and access road clearing and maintenance. General maintenance for a cross-linked-polyethylene (XLPE) underground line would include items such as splice, cable, and manhole inspections. A high-pressure-fluid-filled (HPFF) underground line would require additional maintenance associated with the pumping plant and cathodic protection, but is still relatively minor. In general, overhead lines require more maintenance than an underground line, especially if the overhead line is in a vegetation-dense location.



Repairs are necessary when there is damage to an asset. Damage on an overhead transmission line could result from equipment failure, weather-related damage, or human interaction. Damage on an underground line could result from cable, splice, or termination failure, or excavation into the cable. While an underground repair may take longer to complete than an overhead repair, these typically occur less frequently than overhead lines. Performing repairs costs money for material and labor, and, if major damage is incurred, loss of operational flexibility while the circuit is out of service. Because cost is an important factor, it is critical to incorporate the estimated operation and maintenance costs when evaluating life-cycle costs for each installation type.



Stakeholder Satisfaction

While everyone wants to have dependable and reliable power, typically no one wants to have it by their residence. The “not in my backyard” mentality is a continual issue, even if a project is for the greater good. After construction has taken place on an underground line, what remains are a few splice-vault covers and a fresh patch of asphalt or restored green space. The only potential visual impact would be at the terminations, located at either a substation (which most likely has other equipment) or at a transition pole. (A transition pole is the location where a line transitions from underground to

overhead. At a transition pole, the underground route continues downline as an overhead route.) Post construction, the route is less visually impacting. During construction, however, because underground routes are typically within roadways, there is disruption to traffic, usually a lane closure or two depending on the construction activity. Some of this disturbance can be mitigated with night work.

An overhead route, which has visible poles, towers, and wires, can be seen post-construction; however, there is typically less disturbance to the public during construction.

Keeping the stakeholder happy was demonstrated by a utility when a new golf course was planned for construction under an existing overhead line. The utility and the golf course worked closely together to relocate a portion of the existing overhead line underground. Additionally, the developer requested that a line of trees on the edge of the greens be avoided, so a trenchless technology was utilized in this area. When routing a new transmission line, it is important to consider areas with high “aesthetic value” where stakeholders have strong opposition to visual impact, like historical areas, parks, or areas with a scenic view. Pushback from stakeholders can cause schedule delays both in the routing and permitting phase of projects, as well as during construction.



Project Routing and Approval

Both overhead and underground transmission lines face their own unique routing and permitting issues: dense vegetation, congested downtown areas, water crossings, etc. Different installation environments can necessitate a specific installation type. During the routing and siting process, it is important to consider both overhead and underground options, or a hybrid of these installation types. Consideration should also be made when routing through a historical area. This is a common challenge with projects in the northeastern United States. It is important to understand if there are limits to the height of new structures for a project. The limited height for an overhead pole can reduce span lengths and/or clearances. Reduced span lengths mean more poles, which equates to higher cost. Underground lines may allow a transmission line to take a route previously not considered due to constraints that would prevent an overhead installation.

Here's an example of how one utility addressed developing through a historical area. There was a need to connect two substations with a new transmission line. The straight line between the two substations went directly through a historical town in the northeastern United States. Due to space and structure height constraints through the town, there was no room to install overhead transmission poles. If an overhead option was selected, the route would have to go around the town, adding substantial length to the line. Ultimately, despite congested buried utilities and an aging utility infrastructure, an underground solution was chosen for the most direct path.

Final Thoughts

There are many factors, other than capital cost, that should be analyzed prior to the selection of an overhead or underground route. An underground route is not the perfect solution, but can offer many advantages, when applicable, compared to an overhead installation. While capital cost is an important factor, life-cycle cost and other components should be considered to make the best and most informed decision for the utility, the stakeholders, and the public. Don't forget to look down, before going up.

This white paper was researched and written by Burns & McDonnell as a commissioned project by Power Delivery Intelligence Initiative (PDi2).