An Initial Investigation of Expanding Underground Electric Distribution Facilities in Michigan

Submitted by
Michigan Public Service Commission Staff

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EXECUTIVE SUMMARY

On May 31, 2007, the Commission issued an order in Case No. U-15279 directing the Staff to study the costs and benefits of extending the Commission's underground line policy. The study was to include poorly performing circuits, all secondary line extensions, and road rights-of way undergoing construction. The study would analyze costs and benefits, as well as make recommendations for extending the policy.

The current underground rules (R 460.511 – R 460.519) require underground placement for: (1) new distribution systems in residential subdivisions in the lower peninsula, (2) extensions of commercial and industrial lines in the lower peninsula, or (3) where required by ordinance in heavily congested business districts, or (4) at the utility's convenience. The developer or customer pays the additional cost of undergrounding for items (1), and (2), or if the customer requests that lines be placed underground. There is no initial cost to the specific customer or developer for items (3) or (4).

In Michigan, a decision to place facilities underground involves four considerations: (1) aesthetics, (2) frequency of interruption, (3) duration of interruption, and (4) cost. The first is the most obvious, but also the most difficult to quantify. Obviously, an environment without overhead power lines is more aesthetically pleasing, but the degree of improvement is dependent upon the remaining aspects of the environment, (overhead lines in an industrial area have less impact than in a pristine wilderness), as well as the proverbial "eye of the beholder." In addition, improved aesthetics may also be challenged by potential remaining utility poles with overhead cable, telephone, or other wires.

With respect to frequency of interruption, it is clear that underground lines are less susceptible to interruption because of storm damage, trees falling, ice coating, etc. Conversely, when an interruption does occur, underground lines require more time to repair due to added complexity in locating faults, the need to dig up the facility, more complicated repairs, and the need for specialized training or equipment. The table below provides the relative outage frequency, and duration of outage for underground lines compared to overhead lines.

	Outage Frequency	Outage Duration
Consumers Energy	70 % Less	30 % More
Detroit Edison	83 % Less	70 % More
Other Utilities Studied	50 % to 80 % Less	58 % to 300 % More

With respect to cost, underground lines cost significantly more than overhead lines, but the exact difference depends upon the type of line, location, and specific characteristics of the facilities. Nonetheless, an increased cost for underground of $1 million per mile is a good rule of thumb applicable not only in Michigan but in the rest of the country as well.

From the above, it is clear that the decision to underground involves a tradeoff between the benefits of improved aesthetics and reduced frequency of interruption versus longer outages and increased cost. No one answer is applicable to all situations.

The Commission directed the Staff to analyze three specific situations. First, for poorly performing circuits, the Staff's analysis indicates that there are more options that exist to improve distribution reliability that are less costly than undergrounding those circuits. Undergrounding for the sake of reliability in these cases does not appear to be economically justified, in part because, in many instances, frequent outages on a specific circuit are due to growth on the circuit exceeding (or at least stressing) the capacity of the circuit, rather than any issue relating to undergrounding. The Staff recommends that undergrounding of poorly performing circuits continue to fall under the current policy where the utilities may underground those facilities for their own convenience in those areas where conventional distribution reliability improvements are not enough.

With regard to requiring underground facilities along road rights-of-way undergoing construction, the Staff's analysis indicates that road construction does not normally implicate utility rights-of-way along an entire electric circuit. Undergrounding facilities along such road construction paths would entail repeated transitions between overhead and underground facilities, with a concomitant increase in cost and reduction in reliability. Consequently, the Staff recommends undergrounding along road construction be done only in those situations where it is suitable to do so.

With regard to undergrounding all secondary line extensions that are currently being installed overhead, the Staff analysis indicates that this would require additional expenditures of approximately $100 million per year, which would result in an increase in annual distribution plant costs of approximately 20%. It is debatable whether requiring undergrounding of these lines would be an economic use of resources. In Staff's opinion, a better approach would be to consider a sharing concept similar to what has been discussed by Consumers Energy.

Finally, with respect to changes in the existing underground policy, the Staff suggests that a variation on a proposal put forward by Consumers Energy Company is worth exploring. Consumers recommended that a fund be established to pay for 50% of the additional costs in situations where customers desire to have facilities placed underground.[1] Staff does not support Consumers' proposal because of the complexity of setting up and administering the fund and because it would have the Staff determine who does or does not get to use the fund – a role that we believe is inappropriate for the Staff. Nonetheless, we believe that Consumers raises a legitimate point – undergrounding has benefits not only for the specific customers involved but also for the customer group as a whole and for the State of Michigan. Therefore, we recommend that the Commission explore the option of splitting the costs of optional undergrounding, with 50% being borne by the direct customers involved and 50% as part of general system costs. This allocation would recognize the shared benefits resulting from underground facilities.

BACKGROUND

On May 31, 2007, the Michigan Public Service Commission issued an Order in docket U-15279 directing Commission Staff "to study the costs and benefits of extending the Commission's

[1] Customers currently pay 100% of the additional cost in such situations.

existing underground line policy." Further, the Commission directed that the study shall "include poorly performing circuits, all secondary line extensions including primary lines sharing poles with secondary lines, and primary and secondary lines along road rights-of-way undergoing reconstruction. The Staff shall provide an estimated cost, identify benefits or impediments to the policy extension, and recommend whether the Commission should conduct rulemaking to extend the policy. In addition, the Staff should attempt to quantify the degree to which the security and safety of transmission and distribution systems may be improved by requiring certain overhead circuits to be placed underground. Finally, the Staff shall examine the issue of the difference in service restoration times associated with underground transmission and distribution systems as compared to similar capacity above-ground facilities. The Staff shall file an initial report by November 22, 2007."[2] This document is the initial Staff report responding to the Commission's direction in docket U-15279.

The Michigan Public Service Commission Staff commenced this investigation by gathering input from some of the Commission's jurisdictional utilities. MPSC Staff consulted with the Detroit Edison Company, Consumers Energy Company, and staff from Great Lakes Energy Cooperative. Staff then held a collaborative meeting with all participating utilities and other parties to review and discuss the data and responses supplied by these Michigan utilities. Background material and written responses were received from Detroit Edison and Consumers Energy. In addition, American Transmission Company provided documentation regarding a recent underground transmission line project in their service territory. Staff also reviewed similar studies that have been completed in recent years by Commission Staff from other states, as well as additional studies and background material available from the utility sector.

In order to better understand the responses provided by the parties, and discussions of any potential advantages or disadvantages of underground versus overhead distribution systems, additional background material on electric power delivery systems is provided highlighting some key differences between overhead and underground circuits. Following that, a closer look is taken at the situation in Michigan, and an analysis of potential advantages and potential disadvantages of underground circuits is provided. Cost estimates for the specific underground policy extensions to be investigated are provided, followed by an alternative, and finally conclusions on underground policy extension from the Staff are provided.

BACKGROUND ON ELECTRIC POWER DELIVERY SYSTEMS

Traditional overhead power lines suspended by utility poles can be seen in most areas throughout Michigan. Those utility poles and suspended facilities are susceptible to damage from storms, tree limbs, and automobile accidents. The exposure to the elements provides for multiple opportunities for utility customers to experience outages. Downed power lines are a potential safety hazard to the public when damage occurs during storms. Overhead facilities obstruct the view of the natural environment, and have been characterized as an eyesore. These are a few of the reasons that have sparked the investigation of expanding the use of underground cable in

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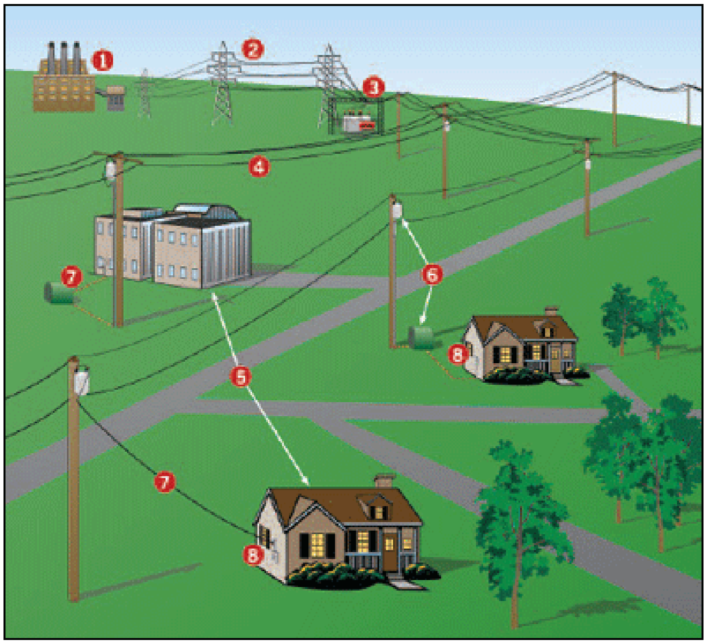
[2] Michigan Public Service Commission Docket U-15279, http://efile.mpsc.cis.state.mi.us/efile/docs/15279/0001.pdf.

place of the traditional overhead power lines. In order to understand the full impact of the advantages and disadvantages of both overhead and underground facilities, a brief description of the electricity delivery system is included. The following figure shows a typical energy delivery system.



Source: http://www.duke-energy.com/about-energy/delivering_electricity.asp; 10/2007.

The above figure illustrates that (1) Power generating stations produce three phase alternating current (AC) power. The power is stepped up to a transmission level voltage (69,000 kV or greater in Michigan) for transmission on the electric power grid. Transmission lines (2) are utilized to transport electricity to local substations. Next, substations (3)—banks of electrical equipment—convert the transmission line voltage to lower levels that are appropriate for distribution power lines, which are used in local communities. Substations also control the flow of electricity and protect the lines and equipment from damage. Substations may have multiple distribution circuits emanating from them, typically 5,000 to 25,000 volts, and typically include circuit breakers and other devices that allow for separation from the grid. Distribution power lines (4), which can be installed above ground or underground, carry electricity to customers (5). A transformer (6) converts the distribution level voltage to levels that can be used inside your home or business. This voltage is carried from the transformer through an underground or overhead power line — also referred to as a service drop (7) — to individual meters (7). That voltage ranges from 120 to 480 volts.[3]

The focus of this investigation is on distribution circuits, and there are several differences between overhead and underground circuits beyond simply burying the cable underground. The

[3] http://www.duke-energy.com/about-energy/delivering_electricity.asp; 10/2007.

figures below show a typical single phase pole-mounted transformer used in an overhead circuit and a typical single phase pad-mounted transformer used in an underground circuit.

Example of a Pole-mounted Transformer

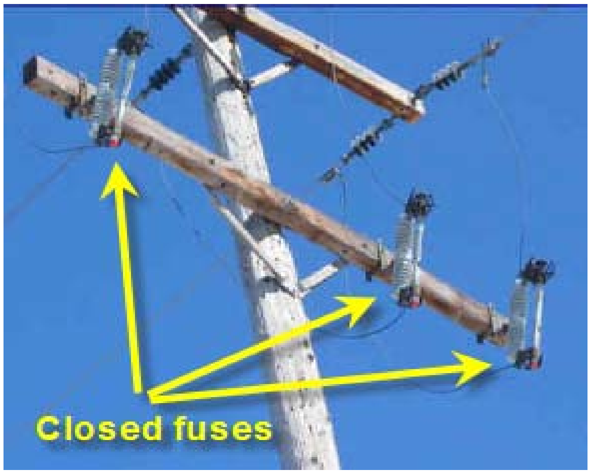
Example of a Pad-mounted Transformer

Note that the photograph of the pad-mounted transformer shows the use of a lock to keep the box closed. The transformer and associated facilities within the box are of similar voltages to the overhead facilities and are locked to protect the public from the safety hazards within.

There are additional differences between the protective devices utilized for overhead and underground distribution circuits. Protection schemes are designed and implemented to prevent permanent damage to the electric facilities that can happen from overload conditions during a fault. The figure below shows three single phase reclosers on an overhead circuit.

When a fault is sensed on the line, the recloser will trip, or automatically open, creating a momentary outage for customers. After a specified amount of time, the recloser will automatically reclose and will restore power to customers in the event that a temporary fault had cleared. Examples of a temporary fault that will resolve itself in a short period of time include conductors which come into contact briefly and a tree branch that temporarily comes into contact with a conductor. If the fault fails to resolve on its own, then when the recloser closes attempting to restore power, the recloser will sense the fault condition and automatically trip open again. This procedure will repeat for a specified number of times, usually three times, before locking out. Once the recloser locks out, as will happen for faults that are not temporary in nature, it takes human intervention to physically come out to the circuit location to clear the fault conditions, and reset the recloser before the circuit resumes normal operation.

One of the most widely used protective devices is the fuse. Shown below are three fuses in the closed position, where the circuit is operating normally, and one fuse that has opened up due to a fault condition.

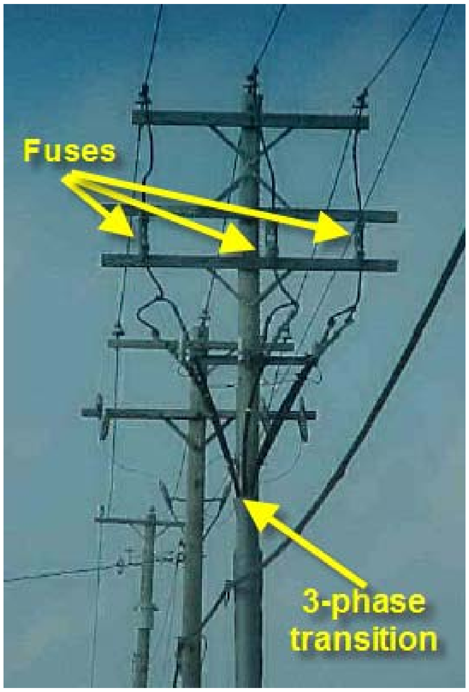


During a fault, the current will heat the fuse beyond a specified threshold, and the heat will cause the fuse to melt and the cutout to drop open, isolating the faulted portion of the circuit. When a fuse cutout drops open from a fault condition, the open cutout serves as a visible cue assisting the repair crew in locating the fault on the circuit. After the fault has cleared, the fuse must be replaced.

Sectionalizers are another type of protective device that may be used. Sectionalizers are used on a distribution circuit to minimize the number of customers affected by the fault conditions, or outage. In a radial distribution circuit, only the customers beyond the point of a tripped sectionalizer will experience the outage conditions.

Reclosers, fuses and sectionalizers within a given circuit must all coordinate with each other, and with switches and circuit breakers at the substation, during fault conditions so that the proper protective devices will function during a fault and isolate the faulted portion of the circuit. Each different type of protective equipment on a circuit will have a unique associated time versus current curve that will show how quickly the device will operate at a given current. The protective scheme for the circuit is designed with selectivity in mind, so that when a fault occurs, the protective devices will operate in a sequence that will effectively isolate only the faulted portion of the circuit. Because of this required coordination, and the varying time versus current capabilities of the protective equipment, there is a finite limit on the number of protective devices that can be installed on any one given circuit.

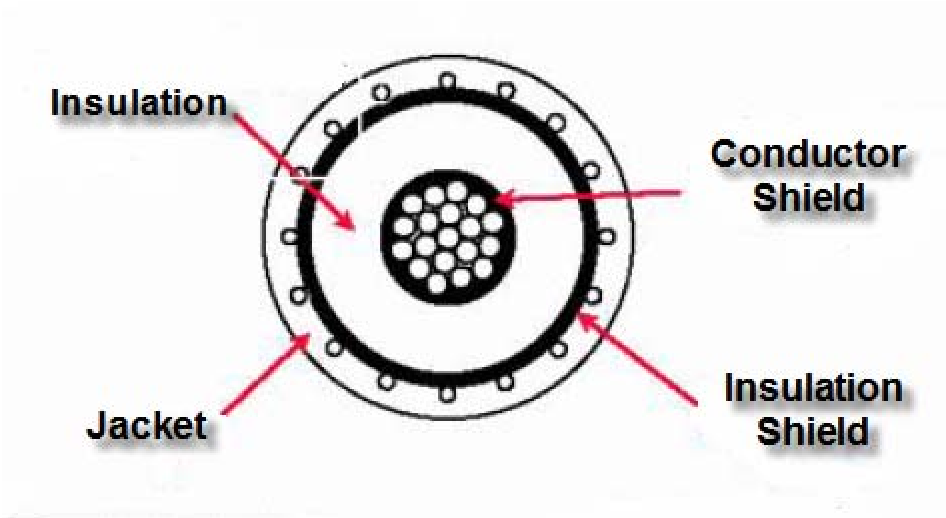
Underground circuits also utilize protective devices to protect the facilities from damage during fault conditions and isolate the faulted portion of the circuit. When an overhead circuit transitions to underground, typically a fuse is installed on each phase prior to the transition down the pole for system protection as shown in the figure below.



The above picture also illustrates that the overhead conductors are typically bare, or only insulated by the air surrounding them. The use of air as the insulating medium causes the need for various clearance requirements for safety, such as the minimum allowable distance between conductors, and the minimum allowable clearance to ground.

As they make the transition down the pole, it should be noted that the conductors are surrounded by an insulator. The insulator provides protection from conductors contacting each other, the pole, human beings, or other facilities.

Underground cables have distinct physical differences from overhead conductors. A typical underground residential distribution (URD) cable will have concentric layers surrounding the conductors consisting of a conductor shield, insulation, insulation shield, and an outer sheath or jacket to mechanically protect the cable and ensure electrical integrity. A cross section of a typical URD cable is shown in the figure below for reference:



Source: http://www.olex.com.au/media/docs/Why-Not-Underground-a736de53-d73d-42ac-949b-8bc272893bcb.pdf

The underground cables are laid in trenches that may be in different locations than similar overhead facilities. Many overhead facilities are located along the road rights-of-way, but underground cables should be located some distance away from the road rights-of-way, due to damage that can occur to the cables during road construction projects. Overhead facilities can be located near a tree line such that trimming of tree limbs is maintained, however, placing facilities underground near a tree line may damage the root systems resulting in the necessary removal of such trees.

The underground distribution cables are routed to a pad-mounted transformer to step down the voltage to appropriate levels for customer use. As with an overhead pole-mounted transformer, a single transformer may feed a single customer or multiple customers depending upon the circuit design. The pad mounted transformer typically contains fuses within the cabinet that will isolate a faulted portion of the circuit, similar to the overhead fuse cutouts that were previously discussed. The following figure is a pad-mounted cabinet showing those typical fuses inside.

After the voltage has been stepped down to levels suitable for customer use, it is then routed underground to the customer site and then comes up out of the ground along the side of the building up to the service mast.

While overhead distribution circuits are typically radial in nature, underground distribution circuits are sometimes looped. The main reason for looping the underground circuits is the fact that fuses are used in underground residential distribution (URD) circuits instead of reclosers, because the faults experienced on URD circuits are usually not transient such as the falling tree branch that was mentioned earlier. By looping the URD circuit and utilizing sectionalizers, some customers may be fed by an alternate source until the fault can be corrected, which may help to limit the impact of the sustained outage.

DISTRIBUTION SYSTEMS IN MICHIGAN

Approximately 85% of electricity customers in Michigan are serviced by either Detroit Edison or Consumers Energy. Both of those investor-owned utilities provided significant input into this investigation of undergrounding facilities.

Detroit Edison is located in Southeast Michigan serving over 2.1 million customers spread over 7,600 square miles. Detroit Edison's system has 675 substations that step down to primary voltage levels of 4.8kV and 13.2kV. In 2007, there are 2,654 primary distribution circuits comprised of 10,974 overhead (OH) circuit miles operating at 13.2kV and 17,111 OH circuit miles operating at 4.8kV resulting in 28,085 OH circuit miles in total. Detroit Edison also has 9,032 circuit miles of 13.2kV underground (UG), and 1,873 circuit miles of 4.8kV UG resulting in 10,905 underground circuit miles at primary voltage levels. Detroit Edison reports that 72% of their current circuit miles are overhead and 28% are underground. The newer 13.2kV system is 45% underground due to difficulty obtaining overhead construction rights-of-way in densely populated areas, and reports that aesthetics are also a consideration for new developments in metropolitan areas, shopping malls, and commercial areas.

Consumers Energy's territory covers a large non-contiguous portion of the lower peninsula with many customers spread out further than would be found in Detroit Edison's service territory. Consumers Energy is based in Jackson, Michigan, and reports that it was serving almost 1.8 million customers spread over 21,781 square miles of service territory in 2006. Consumers Energy reports that in 2007, their system consisted of 1,074 distribution substations, 55,525 overhead circuit miles, and 9,586 underground circuit miles. Approximately 85% of Consumers circuit miles are overhead and 15% are underground.

Nature of Customer Requests for Underground Facilities in Michigan

In meeting with Michigan utilities, Staff inquired as to the nature and frequency of requests from utility customers in Michigan to place facilities underground. Although the utilities participating with Staff did not offer any specific data, they did state that the primary reason customers request to have facilities placed underground are for aesthetic reasons. This is consistent with a recent report issued by EEI which states "The aesthetic benefits are virtually impossible to quantify but are, in many instances, the primary justification for projects to place existing power lines underground."[4]

Specific issues related to trees was offered as another reason for customers requesting to have their facilities undergrounded. Such issues include customer unwillingness to allow necessary tree trimming to obtain sufficient clearance from overhead conductors, customer reluctance to pay for excess tree trimming costs (which Consumers Energy stated may be required where applicable) and instances of multiple customer outages related to trees.

Consumers Energy responded that less than half of the customers that request a cost estimate to place their facilities underground actually proceed with construction. Regarding the customers who do proceed with undergrounding, Consumers Energy stated that some customers install their own conduit to reduce their costs. Also, customers building new expensive homes (not in subdivisions) or lake front construction pay for underground facilities more often than modular or mobile homeowners, suggesting that economics plays a factor in the decision.

Another instance of customers considering the option of undergrounding includes local communities interested in undergrounding their existing local overhead facilities. Consumers Energy states that they receive few inquiries from local communities unless there are matching funds provided from state or federal sources. Consumers Energy also states that it has received 10 to 15 such inquiries per year for the last several years, however, several of the recent community projects considered were never finalized or funded. Detroit Edison adds that once customers are aware of the cost of UG compared to OH, they are often unwilling to pay the difference.

[4] Johnson, Bradley W., "Out of Sight, Out of Mind? A Study on the Costs and Benefits of Undergrounding Overhead Power Lines," Edison Electric Institute, July 2006, p. 16.

Representatives from Detroit Edison, Consumers Energy and Great Lakes Energy discussed the impact of the Supreme Court decision in the recent case of the City of Taylor versus Detroit Edison. The City of Taylor passed a local ordinance requiring that certain facilities be placed underground. Detroit Edison agreed to place the facilities underground at the City of Taylor's expense. The City of Taylor insisted that the costs should be borne by Detroit Edison. Lower courts ruled in favor of the City of Taylor. Michigan utilities reported that there was a surge in requests from communities and customers to have facilities undergrounded when it looked like the City of Taylor was going to prevail. Later, the Supreme Court ruled that the City of Taylor should be responsible to bear the extra expenses of placing the facilities underground. Detroit Edison reported that all of the work placing the local facilities underground in the City of Taylor is complete and it is still in the process of negotiating payment terms with the City of Taylor. Both Detroit Edison and Consumers Energy stated that they have received very few inquiries from local communities to place facilities underground since the Supreme Court ruling.

CURRENT RULES ON UNDERGROUND ELECTRIC LINES

The Michigan Public Service Commission administrative rules for underground electric lines; R 460.511 – 460.519[5] are posted on the website and have been in effect since 1971.

The existing MPSC rules state that distribution systems in newly constructed residential subdivisions be placed underground and specifies the method for determining the contributions from the developer for that construction. The contribution from the developer is equivalent to the difference between the costs of placing those facilities overhead and underground. In addition, the rules also specify that new commercial distribution and service lines in the vicinity or on a customer's property and constructed solely to serve a customer or group of adjacent customers be placed underground. The rules specifically mention applicability to apartment complexes and shopping centers, however, commercial distribution is not limited to only those types of customers. Likewise, the contributions from commercial customers will not exceed the difference between the costs of overheard and underground line construction.

The Commission Order in docket U-15279 initiated this study in order to determine whether or not the Commission should undertake a rulemaking to extend the Commission's current policy on underground electric facilities. The following sections explore the potential benefits and the potential disadvantages of underground electric facilities and how those may fit into the Commission's policy on underground electric facilities.

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[5] MPSC administrative rules - Underground Electric Lines R 460.511 - 460.519; http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=46000511&Dpt=CI&RngHigh=.

UNDERGROUND VERSUS OVERHEAD

There are many potential benefits that could result from placing electric facilities underground as opposed to overhead. In a report prepared for Florida electric utilities by InfraSource, some of the most frequently mentioned benefits of underground facilities as opposed to overhead facilities in recent reports and studies are as follows:

Potential Benefits of Underground Electric Facilities[6]

- Improved aesthetics
- Reduced outages and damages from storms
- Lower tree trimming cost & improved utility relations regarding tree trimming
- Fewer motor vehicle / utility pole accidents
- Reduced live-wire contact
- Fewer outages during normal weather
- Far fewer momentary interruptions
- Fewer structures impacting sidewalks

As previously mentioned, improved aesthetics appears to be a main driver for individual customers and local communities in Michigan to investigate undergrounding their electric facilities. It is frequently mentioned that the improved aesthetics from underground facilities will improve surrounding property values. Detroit Edison notes that aesthetic improvements are derived not only through the removal of poles and wires, but also in reduced tree trimming. It should be noted, however, that there are further obstacles to tackle beyond undergrounding the electric facilities in order to remove the utility poles, as there may be several other facilities attached to the utility pole that would need to be relocated underground as well. Consumers Energy provided the following data regarding over one million known attachments by over 360 third party entities on Consumers Energy poles:

Cable TV companies:	623,000 attachments
Large telephone companies:	265,000 attachments
Small telecoms and fiber providers:	74,000 attachments
School districts:	35,000 attachments and growing
Other businesses:	7,000 attachments

Consumers Energy adds that forcing these third party pole attachers to relocate underground could create substantial financial hardships for those existing pole attachers. Also some of the long-standing joint use agreements and pole attachment agreements that Consumers Energy has executed, give attachers the right to purchase any poles that are abandoned by Consumers. In order to achieve the desired aesthetic improvements where there are existing overhead facilities, there must be a coordinated effort to bury all of the facilities that are attached to the utility poles,

[6] Brown, Richard, PhD, PE, "Undergrounding Assessment Phase 1 Final Report: Literature Review and Analysis of Electric Distribution Overhead to Underground Conversion," Infrasource Technology, February 28, 2007, p.3.

and it appears that many entities that are attaching to poles today do not fall under the jurisdiction of the Michigan Public Service Commission.

Another potential benefit of underground electric facilities that is frequently mentioned is a reduced number of outages and a reduced amount of damage from storms. Overhead facilities do have more exposure to the elements that make them more vulnerable to damage from wind, ice, lightning and severe storms than underground facilities. However, the Edison Electric Institute states "underground power systems are not immune to storm-related outages…. It is unlikely that one hundred percent of the circuit from the substation to the customer can be placed entirely underground. This leaves the circuit vulnerable to the same types of events that affect other overhead lines, e.g., high winds and ice."[7] Upstream portions of underground circuits are usually overhead facilities. Pad-mounted transformers and other associated facilities of underground distribution systems are installed at ground level and are susceptible to damage from severe storms, lightning and public damage.

Although burying electric facilities underground does not alleviate all of the risks of outages due to storms, there are reductions in the number of outages experienced on underground systems as opposed to overhead systems. Not only are there fewer outages due to storms, but there are fewer outages occurring during normal weather conditions, and fewer momentary interruptions as well. Based upon data in a study completed by the Virginia State Corporation Commission, it was reported that underground circuits experienced only 20 to 25 percent of the outages that were experienced by overhead circuits. Another study by the North Carolina Utilities Commission spanning five years reported that underground systems experienced only about half of the outages experienced on overhead systems. Detroit Edison reports that the frequency of outages on their underground system is only 17% of the overhead system outage frequency. Consumers Energy reports that the underground primary interruption rate per mile on their system is over 30% of the overhead outage rate.

Another potential benefit of underground facilities is reduced costs associated with tree trimming. Utilities typically undergo extensive tree trimming programs in order to minimize the number of momentaries and sustained outages associated with tree limb contact with overhead facilities. Reduced amounts of tree trimming may lead to reduced amounts of friction between utility customers and the utility regarding tree-trimming issues such as access, the amount of trimming required, etc. Although the operation and maintenance costs associated with tree trimming would be reduced by expanded utilization of underground facilities, it is not clear that the overall level of operation and maintenance expenditures would be lower for an underground circuit. Some additional operation and maintenance costs for underground circuits may offset the tree trimming costs associated with overhead circuits. These include staking and locating costs associated with the protection of underground facilities and higher replacement costs for damaged or end of life facilities such as transformers and underground cables. A recent report issued by the Virginia Commission Staff concluded that there are likely not to be substantial reductions in overall operation and maintenance costs due to undergrounding.[8]

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[7] Johnson, Op. Cit., p. 5,10.
[8] Commonwealth of Virginia State Corporation Commission, "Placement of Utility Distribution Lines Underground,", Jaunuary, 2005, p. 22.

Improved safety benefits of underground facilities include fewer motor vehicle accidents with utility poles and fewer incidents involving live wire contact. The removal of utility poles would eliminate the occurrence of vehicular pole collisions, however, the utilization of ground level pad-mounted equipment still poses a risk for motor vehicle collisions. The risk is lower for vehicle collisions with pad-mounted equipment because there are far fewer pad-mounted facilities associated with underground circuits than there are utility poles associated with overhead circuits. Another contributing factor to reduced risk is the fact that pad-mounted equipment is typically placed further back from the edge of the road, while utility poles are typically much closer to the edge of the road.

Exposed conductors that are used in overhead circuits provide a higher risk for live wire contact incidents than is found in underground circuits. However, undergrounding does not eliminate the risk of human contact with energized facilities. Consumers Energy reported that although underground circuits may pose little risk to the general public, they can be hazardous for those who may be digging nearby. In fact, Consumers Energy reported that "dig-ins" are the most frequent failure mode that occurs on their underground distribution system. In addition to dig-ins, there is a risk of human contact with energized equipment inside of pad-mounted facilities in the instance of damaged or compromised locks or security on the cabinets, which Michigan utilities reported as something that does happen. In the collaborative meeting with Michigan utilities, it was also mentioned that there have been recent incidents where manhole covers have floated away from flood waters during severe storms, leaving the underground facilities exposed after the storm. Although the risk of third party contacts is reduced, it is not necessarily eliminated in underground circuits because some of the facilities that are suspended on poles in overhead circuits are located at ground level in underground circuits.

Although there are potential benefits associated with undergrounding, there are also potential disadvantages. In a report prepared for Florida electric utilities by InfraSource, some of the most frequently mentioned disadvantages of underground facilities are as follows:

Potential Disadvantages of Underground Electric Systems[9]

Higher construction costs
Stranded asset cost for existing overhead facilities
Environmental damage including erosion, and tree root damage
Utility employee work hazards during vault and manhole inspections
Increased exposure to dig-ins
Longer duration interruptions and more customers impacted per outage
Susceptibility to flooding, storm surges, and damage during post-storm cleanup
Reduced flexibility for both operations and system expansion
Reduced life expectancy
Higher maintenance and operating costs

[9] Brown, Op. Cit., p.4.

According to a report released by EEI, "undergrounding is expensive, costing up to $1 million per mile on average, or almost 10 times the cost of a new overhead power line, and would likely require large rate increases for electric customers."[10] Consumers Energy reported that the full scope of the Commission's request in this docket could cost Consumers Energy nearly $800 million[11] of annual capital expense. The full scope of the Commission's request in this docket could cost Detroit Edison $3.8 billion[12] of annual capital expense. Detroit Edison added that the $1 million per mile for underground distribution lines as reported by EEI is an average estimate, and that some utilities have reported costs of up to $3 million per mile. Detroit Edison reported that the estimated cost to bury the overhead portions of their existing distribution system would cost $56 billion.[13]

There are many cost drivers that lead to these increased cost estimates for underground facilities. The background on electric power delivery systems at the beginning of this report was provided as a first step explaining that there are differences in the equipment required for underground circuits, as well as differences in day-to-day operations. In order to better understand those differences in cost, Consumers Energy provided the following cost estimates for comparison purposes which illustrate some real differences between the capital costs for new overhead and underground construction:

New Installation Capital Cost Estimates[14]

Short Description	Overhead	Underground	Purpose
Small primary conductor (Extend one single phase span)	$2,060	$4,820	Extend one span (Overhead – take off from existing pole and install one new; Underground – Install new cable and terminate on both ends)
Large primary conductor (Extend one three phase span)	$5,080	$20,940	Extend one span (Overhead – take off from existing pole and install one new; Underground – Install new cable and terminate on both ends adding new sw cabinet at one end)
600 Amp Switch	$2,200	$17,980	Overhead – add 3 single phase disconnect switches on exiting pole; Underground – Cut in a new PHM switchgear
Line fuse – 1 phase	$550	$8,900	Overhead – add new cutout on existing structure; Underground – Add new PHM 5 and fuse
Line fuse – 3 phase	$800	$10,500	Construct 3 phase equivalent of the 1 phase line fuse in the previous row
25 kVA single phase transformer	$1,900	$2,940	New assemblies
150 kVA three phase transformer	$7,990	$10,900	New assemblies

[10] Johnson, Op. Cit., p. 4.
[11] Estimate provided by Consumers Energy was not verified.
[12] Estimate provided by Detroit Edison was not verified.
[13] Estimate provided by Detroit Edison was not verified.
[14] Source: Consumers Energy; Installed costs, including all overheads, basic travel times to job sites. Underground reflects trenching and not more costly boring. Reflects relatively simple installations. For comparative purposes only.

The table above highlights the fact that all of the underground components, and not just the underground cables, cost significantly more than their overhead counterparts. Consumers Energy adds that adverse site conditions are a major determinant of increased hours and costs. Overhead costs would be driven by site conditions such as trees. Underground costs would be quickly inflated by obstructions such as roads, driveways, above and below grade obstructions including trees, soil stability and rock content, frozen soil conditions, and the presence of other utilities. Consumers Energy adds that such variables will tend to increase overhead costs and hours required more quickly. Also, difficulty in acquiring easements will drive the costs of all facilities higher. These differences in capital costs need to be taken into consideration not only at the point of new circuit construction, but also when considering replacement costs for failures, maintenance, and system upgrades. The higher capital costs also must be considered when looking at total life cycle costs which include replacement at the end of useful life, as underground facilities have a shorter life span than overhead facilities.

In addition to new construction costs, there are additional costs to consider when taking existing overhead facilities and converting them to underground. InfraSource describes a potential issue of stranded asset costs that may be associated with undergrounding existing overhead facilities. InfraSource compares this potential situation to "tearing down a house that still has an existing mortgage."[15] InfraSource further asserts "For regulated utilities, FASB (Financial Accounting Standards Board) Statement 71 allows the stranded costs associated with prudent investments to remain capitalized, resulting in the potential for rates to reflect simultaneous cost recovery for both the original overhead system and the new underground system."[16]

The costs of undergrounding are so substantial that the Maryland Public Serve Commission concluded, "If a 10 percent return is imputed to the great amounts of capital freed up by building overhead instead of underground line, the earnings alone will pay for substantial ongoing overhead maintenance."[17] In addition to the costs, there are other factors that need to be taken into consideration when evaluating whether or not to underground facilities.

In order for facilities to be placed underground, open trenching is typically employed during construction. If the location is dense with trees, some trees and stumps may actually need to be removed in order to create a clear path for trenching. If there are trees in the vicinity of the trenching, tree roots may be damaged, which can weaken or even kill trees. In addition to the tree issues, any existing landscaping in the area may be damaged or removed. Open trenching also "destroys surface vegetation and can result in an increased susceptibility to soil erosion."[18]

In addition to the trenching that is required, additional attention to the location and placement of underground facilities is required compared to overhead facilities. For instance, overhead facilities are often times placed in the road rights-of-way, but that is not desirable for underground facilities. Locating underground facilities in the road rights-of-way would leave the utility susceptible to dig-ins, outages, or possibly being forced to relocate facilities due to road,

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[15] Brown, Op. Cit., p. 29.
[16] Ibid., p. 29.
[17] Johnson, Op. Cit., p. 27.
[18] Brown, Op. Cit., p. 30.

sewer, or other types of construction. Just as new construction costs for underground facilities are higher than overhead, costs to relocate underground facilities are also higher than overhead.

As previously mentioned, increased utilization of underground facilities would lead to increased safety incidents relating to dig-ins. Dig-ins are not only potentially hazardous, they also result in a fault on the circuit which, according to Consumers Energy, almost always results in service interruptions to electric customers. Consumers Energy also estimates that there are at least three and one half times more third party damages per mile of installed underground system than third party damage on the overhead system. Infrasource also mentions that there are additional safety risks associated with inspections and routine maintenance for underground facilities as the work must be done in an enclosed spaced instead of out in the open as is the case for overhead facilities. Consumers Energy adds that because all the cable and the equipment in a cabinet is completely out of sight, examining it to determine if it is safe is much more difficult to do and a much more time consuming process. By comparison, the overhead system is very visible from some distance and it is much easier to recognize unsafe conditions that need to be repaired.

One of the potential benefits of underground circuits that was previously mentioned was that there are fewer sustained outages for underground facilities than for overhead facilities. However, for faults that do occur on underground circuits, it takes much longer to locate and repair the problem than it does for overhead facilities which means that the restoration times for underground facilities are longer.

A specialized crew with specialized equipment is required to locate a fault on an underground circuit. Great Lakes Energy reported that sometimes a repair crew with a bucket truck is dispatched to locate and repair a fault, however, it's only upon reaching the destination that the crew realizes that the faulted portion of the circuit is underground. When this happens, another specialized crew trained in the location and repair of faulted underground circuits must be dispatched to the location. Caution must be taken by the crew to ensure that the cable is properly isolated and the testing equipment can safely be connected to detect the location of the fault. In order to detect a fault, the testing equipment sends a signal down the cable, and the signal will change when it detects a fault. That signal may also change as it bounces off splices, even if the splice is in good working condition, and it may be flagged as a fault location, when in fact it is not. Sometimes, a fault will occur in a cable that has developed a small opening in the insulation, and the heat from the fault current will cause the small opening to "heal itself." When that happens, the underground fault finding equipment may never find that particular location that healed itself, and the utility does not make any repairs. All of the utilities that collaborated on this project expressed that specialized crews are required to locate faults on underground circuits and that even with specialized training, it is more difficult and time consuming to locate a fault on an underground circuit than on an overhead circuit.

After the crew identifies the location of the fault, the area must be excavated to completely expose the cable. The following figures are photos of the excavation of a faulted underground circuit near the offices of the Michigan Public Service Commission.

Next the crew must clean and prepare the cable before the repairs or splice can be completed. Consumers Energy added that different voltage and size cable require different splice materials. Great Lakes Energy stated that there are occasions where the crew was dispatched, the fault was located, the area was excavated, and the crew found that the repair would require additional or different materials to make the repair than what the crew had in their possession at the time, causing another trip. Depending on the availability of the equipment and splice materials, the repair itself may require an additional two hours or more.

All of the utilities participating in this study expressed concerns regarding the need for more specialized underground crews to support additional undergrounding activities. InfraSource agrees and says "the availability of utility craft workers with underground cable expertise is limited. These work skills may not be available for large undergrounding initiatives."[19]

EEI quoted a study from the North Carolina Utilities Commission saying that "underground lines require specialized equipment and crews to locate a fault, a separate crew with heavy equipment to dig up a line, and a specialized crew to repair the fault. This greatly increased the cost and the time to repair a fault on an underground system."[20] This means that the outages which do occur on underground circuits leave customers without service for longer periods of time. Consumers Energy reported that according to historical data, on average, underground system outages last at least 30% longer than overhead system outages. Detroit Edison reported that underground circuits on their system experience outages of duration that are 1.7 times the duration of outages experienced on their overhead circuits. EEI reported data from the Virginia State Corporation Commission and said that "underground outages in Virginia take approximately 2.5 times longer to repair than overhead outages."[21]

Another potential disadvantage associated with underground facilities is a probability of more customers impacted per outage. InfraSource reports that "due to the nature of cable and underground equipment, it is much more expensive and difficult to install fuses, circuit interrupters, and sectionalizing switches in underground systems as compared to overhead systems. As a result, underground systems tend to have less protection selectivity, which means that a fault or failure in an underground system will interrupt service to more customers than an

[19] Brown, Op. Cit., p. 32.
[20] Johnson, Op. Cit., p. 10.
[21] Ibid., p.8.

equivalent problem in an overhead system."[22] In addition to the increased cost of protective devices for underground circuits, Consumers Energy added that the transition from an overhead system to an underground system requires specific equipment be installed which includes a fuse for safety and reliability reasons. Due to selectivity, or the need to have each of the protective devices operate in the proper sequence during a fault, there is a limit on the number of fuses that can be installed appropriately from the substation to the end of the circuit. When circuits are designed, reconfigured, or improved, it is important for the engineers to consider the system protection issues for both overhead and underground circuits.

Although one of the potential benefits mentioned was reduced outages and damages from storms, InfraSource reports one of the potential disadvantages of underground electric facilities as "susceptibility to flooding, storm surges, and damage during post storm cleanup."[23] Infrasource reports "underground systems, especially those in manholes and duct banks, are susceptible to flooding. Flooding can cause interruption of, and damage to, non-waterproof equipment, and leave contamination residue on equipment that increases the risk of future failures. Water exposure can also increase the rate of electrochemical treeing (a major failure mode) in underground cable insulation. Flooding can slow restoration activities since flooded manholes and vaults must be pumped out before being entered."[24]

Underground circuits have limited flexibility for modifications or extensions once they are installed and operational. Consumers Energy elaborated on this point saying that if a new customer requires a new transformer on an overhead feeder system, there is minimal impact to other customers, however, that is not the case for underground systems. Most overhead transformers can be installed and energized without having to take an outage to other customers. In an underground system, the cable termination work required to install a new transformer can only be done de-energized and it is highly likely that many other customers would have to see a service interruption in order to install the new transformer on the system.

Underground facilities also have limitations with regard to construction in the winter months. Consumers Energy pointed out that extensive use of underground facilities would mean that there would be a significant portion of the year where utilities will be limited in their ability to improve circuit performance, relocate for road projects, or connect new customers, whereas utilities have the ability to work year round on overhead circuits.

Underground facilities typically have shorter life spans than overhead conductors and equipment. Detroit Edison reported that the maximum life expectancy of underground distribution is thirty five years at which time an entire replacement is required, whereas the typical life span for overhead facilities is fifty years. Underground cables rely on their insulating jackets to mechanically protect the cable and ensure electrical integrity. General aging, moisture ingress, and heating and cooling due to varying power delivered are all causes which eventually lead to cable failures. Detroit Edison adds that cable samples are tested in the laboratory for dielectric strength which is a metric for determining end of life. Consumers Energy uses a standard

[22] Brown, Op. Cit., p. 31.
[23] Ibid., p. 4.
[24] Ibid., p. 31.

industry practice for determining the end of life for a cable segment which is three failures not caused by a specific damage event. That standard has proven to be a valid indicator that a particular cable has deteriorated to the point that failures will continue. "Equipment lifetimes vary for a variety of reasons, but in general industry experience supports this general ratio: overhead facilities tolerate the wear and tear of normal service for roughly 60% longer than their equivalent underground equipment."[25]

All of the utilities participating in this study expressed concerns regarding the availability of components and hardware to implement large undergrounding initiatives. There are very few manufacturers of underground cable, pad-mounted transformers, and associated protective equipment. The utilities expressed that the industry capacity is limited and obtaining cable and underground equipment in quantities could prove to be challenging.

U-15279 Commission Order

The Commission Order in docket U-15279 acknowledged recent issues surrounding decisions whether to place circuits overhead or underground and directed the Staff to investigate several opportunities for extending the Commission's current underground line policy. The specific investigations requested include extending the underground line policy to include: (1) poorly performing circuits; (2) all secondary line extensions including primary lines sharing poles with secondary lines; and (3) primary and secondary lines along road rights-of-way undergoing reconstruction. The Commission requested an analysis of safety improvements that may be gained from placing facilities underground, as well as an analysis of the differences in service restoration times for overhead and underground facilities.

(1) Poorly Performing Circuits

When discussing opportunities associated with poorly performing circuits, the first task undertaken was to define how the utilities define or determine that a circuit would be considered a poorly performing circuit. It was discovered that each of the Michigan utilities defines and calculates what constitutes a "poorly performing circuit" in a different manner. Second, the utilities were requested to outline actions that they currently typically take to improve those circuits that are deemed to be poorly performing circuits, including undergrounding the facilities. Finally, the utilities were asked to provide an analysis of the impact of increasing the amount of undergrounding to improve poorly performing circuits, including cost estimates, manpower required, feasibility, and potential benefits and disadvantages of taking such actions.

Consumers Energy's Perspective on Poorly Performing Circuits

Consumers Energy defines a poorly performing circuit as being equivalent to "Repetitive Outage Circuits" as defined in case no. U-12270. Reliability standard Rule 32, Part 3, Section J states "The same-circuit repetitive interruption factor. If the same-circuit

[25] Ibid, p. 31.

repetitive interruption factor is more than 5% of circuits experiencing 5 or more same-circuit repetitive interruptions within a 12 month period, then the report shall contain a detailed explanation of the steps that the electric utility is taking to bring its performance to an acceptable level."[26] Any circuit that contributes to not meeting this standard, would be considered to be a poor-performing circuit and Consumers Energy would evaluate the necessity of system investments to enhance the performance of the circuit to acceptable levels.

Consumers Energy reports that their activities are focused on both minimizing the number of customers experiencing outages and reducing the overall number of actual outages. Reductions in the number of customers impacted by an outage can be accomplished by reducing the number of customers exposed to interruptions, by changing the protections schemes of the circuits. An example of changing the protection scheme to reduce the number of customers impacted by an outage would include exchanging a three phase substation oil circuit recloser with three individual single phase reclosers, or by fusing all of the laterals tapped on the main three phase circuit feeder. Either of those options will reduce the number of customers impacted by an outage on that circuit.

Consumers Energy approaches reducing the actual number of outages by investigating ways to reconfigure the system. Examples of system reconfigurations include adding substations, and finding ways to reduce the overall length of the circuit. Consumers Energy reports that they also consider relocating overhead wires from undesirable locations, and the utilization of facilities that are more tolerant of system challenges. An example of such tolerant facilities is spacer cable that reduces outages caused by contact with tree branches, weather extremes such as snow, ice, high winds, and animal or bird contact. A photograph of such spacer cable is shown below for reference:

source: http://www.hendrix-wc.com/hendrix/home.htm

Consumers Energy reported that they implement distribution circuit improvements to 1,200 circuit miles each year, the vast majority of which is overhead based upon their current system configuration. Consumers Energy provided an estimate to place those same 1,200 circuit miles underground at $600,000,000 per year.

Detroit Edison's Perspective on Poorly Performing Circuits

[26] Service Quality and Reliability Standards for Electric Distribution Systems, http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=46000701&Dpt=LG&RngHigh=.

In order to classify poor performing circuits, Detroit Edison uses load based versions the industry standards of SAIFI, (system average interruption frequency index), SAIDI, (system average interruption duration index), and CAIDI, (customer average interruption duration index). SAIFI, SAIDI, and CAIDI are defined in IEEE Standard 1366-2003, and those calculations are based upon the number of customers. SAIFI is an indicator of the frequency of interruptions experienced by the average system customer. It should be noted that SAIFI includes all interruptions that are five minutes or longer in length. Interruptions that are shorter than five minutes are called momentaries, and are not included in the SAIFI calculation. SAIDI is an indicator of the total duration of service interruption for an average customer on the system. CAIDI is an indicator of the average time required to restore service, and is also equal to SAIDI divided by SAIFI.

Detroit Edison uses metrics similar to SAIFI, SAIDI, and CAIDI, however, they use load based versions of those calculations instead of customer based calculations. Detroit Edison deems circuits to be poor performing when the circuit's ASIFI, (average system interruption frequency index), calculated as the connected kVA interrupted divided by the connected kVA served, is greater than 1.5. Similarly, Detroit Edison defines ASIDI, (average system interruption duration index), as the sum of the connected kVA durations interrupted divided by the total connected kVA. For restoration time, Detroit Edison defines an average restoration time greater than 180 minutes for a circuit to be classified as poor performing. On a circuit basis, Detroit Edison defines a poorly performing circuit as one with annual reliability statistics of a frequency greater than 1.5, duration greater than 180 minutes, and the number of sustained interruptions greater than or equal to 4.

Detroit Edison reports that they develop reliability plans to identify and address poor performing circuits and other pockets of poor reliability. Detroit Edison states that they continue to employ proven reliability improvement techniques including supplemental tree trimming, tree resistant conductors and cables, lightning protection, sectionalizing, and automatic throw-over loop schemes.

Detroit Edison's outage frequency (SAIFI) has been consistently in the 1st quartile as benchmarked against the industry by EEI. This past year, Detroit Edison reported that their SAIFI score ranked third out of more than ninety utilities benchmarked by EEI. Detroit Edison reports that their SAIDI results last year were in the 2^{nd} quartile, and their CAIDI results were in the 4^{th} quartile in EEI's benchmarking study. Although Detroit Edison's system has much lower frequency of interruptions for their customers, the average restoration time for outages is much longer than for other utilities in the benchmarking study. Increasing the ratio of underground to overhead circuits on Detroit Edison's system would likely further improve their already top decile performance in SAIFI, and would further challenge their already 4^{th} quartile performance in CAIDI. Detroit Edison also reported that their CAIDI results have steadily and significantly improved since 2002.

In 2005, the Commission opened Case Number U-14603 to investigate distribution reliability problems, for poor performing circuits based upon the number of customer complaints categorized as frequent or repetitive outages received by the MPSC concentrated in certain zip code areas. The majority of those zip codes were in Detroit Edison's service territory. Detroit Edison investigated the causes of the issues on those circuits, and developed improvement plans, and implemented improvements for those circuits by the end of 2006. Staff noted in its report that the majority of distribution reliability issues found by Detroit Edison were overload conditions, tree interference and equipment problems. "In order to address overload conditions, Detroit Edison planned to re-conductor portions of 72 circuits, transfer load on 23 circuits, and perform sub-station upgrades affecting 13 circuits. To improve problems arising from tree interference, Detroit Edison planned to perform tree trimming on 50 circuits with reported problems, and re-conductor portions of 24 circuits with Hendrix cable, which is a design that reduces the impact from tree and animal interference. It should also be noted that Detroit Edison identified 38 circuits where improvements were planned in the area of fusing, sectionalizing, and reclosers which would limit the number of customers impacted by a sustained outage event."[27]

The overwhelming majority of reliability improvements made in this case were improvements made to existing overhead circuits. There were not any instances in this case, where Detroit Edison took any portion of an existing overhead circuit and moved it underground in order to improve the distribution reliability. Instead, there were many overhead improvements made at much lower cost than would have been required to underground those facilities. In this case, Detroit Edison reported that they completed 201 total improvement jobs for a total cost of $27.8 million affecting circuits in more than 19 zip code areas. Comparing this to the $1 million to $2 million per mile estimate to place existing overhead power lines underground as reported by EEI,[28] it should be noted that the 201 reliability improvements made by Detroit Edison for $27.8 million are likely impacting far more end-use customers than would have been the case if they had taken that $27.8 million and used it to place some portions of some of those circuits underground. In fact, Detroit Edison reported that if they were to underground the all of the poorly performing circuits each year, the estimated costs to complete all of that work would be $3.6 billion annually.

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[27] MPSC Staff Report on Distribution Reliability, p. 11. http://efile.mpsc.cis.state.mi.us/efile/docs/14603/0006.pdf
[28] Johnson, Op. Cit., p. 13.

Great Lakes Energy's Perspective on Poorly Performing Circuits

Great Lakes Energy, a cooperative in Lower Michigan, takes a different approach to defining poorly performing circuits as compared to Consumers Energy and Detroit Edison. Great Lakes Energy focuses on reducing the duration of the outages that occur while Detroit Edison and Consumers Energy focus on reducing the frequency of outages. Great Lakes Energy utilizes the industry standard of SAIDI.

Great Lakes Energy defines a poorly performing circuit as one that experiences durations that are two times the average duration experienced on their system. The circumstances surrounding the outages on those particular circuits are then investigated to determine the root cause, such as aging equipment, tree interference or animal interference. Those circuits are then targeted for distribution reliability improvements. Great Lakes Energy pointed out that because they are focusing on duration of outages instead of frequency of outages, many of their poorly performing circuits are underground circuits. Great Lakes Energy added that they are currently in the process of evaluating reconstructing some portions of their underground circuits to traditional overhead construction. Great Lakes Energy is not the only company evaluating replacing underground circuits with overhead due to reliability issues, as EEI reports "two Maryland utilities, Choptank and Conectiv, have replaced underground distribution with overhead systems to improve reliability."[29]

Is Undergrounding Considered an Option for Distribution Reliability?

Utilizing the duration of outages as the basis for classifying poorly performing circuits, Great Lakes Energy would not consider undergrounding a solution to their distribution reliability problems, especially considering the majority of their problem circuits are already underground. Both Consumers Energy and Detroit Edison answered that they do consider undergrounding facilities to improve distribution reliability, however, it is not the first route to take given the large differential in costs between traditional overhead improvements such as re-conductoring, or re-conductoring with spacer cable, compared to placing portions of the circuit underground. Detroit Edison added that there is little reliability benefit to be realized for such a large cost based upon the fact that it has been benchmarked as third compared to utilities across the United States and Canada based upon the frequency of outages. Consumers Energy expressed that they only consider undergrounding as a solution to distribution reliability issues as a last resort. In addition to the higher costs, utilities expressed concern about the ability to easily obtain the necessary private rights-of-way to place existing facilities underground from the multiple property owners that would be affected.

Several studies have been completed over the past several years on undergrounding of distribution circuits, and many studies question the reliability benefits that are touted from placing facilities underground. According to a study completed for Long Island Power Authority, "The primary driver for undergrounding existing overhead power lines

[29] Johnson, Op. Cit., p. 10.

continues to be aesthetic considerations, not reliability or economic benefits."[30] Virginia states "while the frequency of outages may be significantly improved in the short-term, the long-term reliability of undergrounding is more questionable."[31]EEI states "The bottom line – reliability benefits associated with burying existing overhead power lines are uncertain and in most instances do not appear to be sufficient to justify the high price tag that undergrounding carries."[32]

Although there is data available to support the assertion that underground facilities experience lower frequency of outages than overhead, there is also data available that supports the assertion that outages that do occur on underground distribution systems leave customers without service for longer periods of time. The Public Staff of North Carolina states "During severe weather events, customers with underground facilities are less likely to be interrupted but will be among the last to have their power restored when there is an underground fault."[33] Because the typical average outage duration is higher for underground circuits, it's difficult to determine if the undergrounding of distribution circuits provides an overall benefit to reliability. The lack of definitive overall reliability benefits from undergrounding leaves little room for the justification of the higher cost of undergrounding distribution circuits.

Because the cost of undergrounding poorly performing circuits is more costly than some of the traditional reliability improvements for overhead circuits, the utilities would be faced with either limiting the number of poorly performing circuits that could be improved each year due to the lack of funding or spending far more money on distribution reliability improvements each year. Combining the estimates from Consumers Energy and Detroit Edison, more than $4.2 billion would be spent each year in Michigan to underground poorly performing circuits. Extensions to the Commission's underground line policy to include poor performing circuits would likely reduce the frequency of outages on those circuits, however, the duration of outages on those circuits would likely increase. Extending the Commission's underground line extension policy to include poorly performing circuits is not recommended at this time.

(2) Lines Along Road Rights of Way Undergoing Reconstruction

The Commission's order also directed Staff to investigate extending the Commission's underground line extension policy to "primary and secondary lines along road rights-of-way undergoing reconstruction."[34] Consumers Energy pointed out that there are some road reconstruction projects where it would be impractical to involve undergrounding. For instance, some road reconstruction projects are small in scope and may only impact a handful of poles, and converting small sections of overhead circuits to underground

[30] Navigant, Op. Cit., p. ES-3.
[31] Commonwealth of Virginia State Corporation Commission, "Placement of Utility Distribution Lines Underground", January, 2005, p. 47.
[32] Johnson, Op. Cit., p. 1.
[33] Commonwealth of Virginia State Corporation Commission, Op. Cit., p. 46.
[34] Commission Order, Case No. U-15279, p. 1. http://efile.mpsc.cis.state.mi.us/efile/docs/15279/0001.pdf

involves adding necessary down guys and underground riser poles with fuses and lightning arrestors that would add unacceptable congestion without improving aesthetics. For road construction projects involving more poles, Consumers Energy reports that they typically perform 40 different projects each year. Consumers adds that implementing this proposal could take a one mile road reconstruction project and require several miles of undergrounding in order to avoid the situation where one circuit would make multiple transitions between overhead and underground within the same circuit. This practice is not practical, and may not even be feasible due to system protection issues. Detroit Edison adds that rights-of-way and routes for relocations may be dependent upon the specific project or locations.

Consumers Energy reported that they typically relocate overhead poles for 40 road construction projects each year, and that the implementation of this proposal would require approximately 150 miles of undergrounding. The estimated cost to relocate those facilities underground for Consumers Energy would be $150 million per year, and that estimate does not include the relocation of facilities underground in the instances where Consumers reports that underground placement would be impractical. Detroit Edison reported that they typically spend $10 million for overhead relocations due to road reconstruction. The estimate to relocate those facilities underground is $76 million, for an increase of $66 million annually.

Staff recommends that the Commission should not consider extending the Commission's underground line extension policy to include all primary and secondary lines along road rights-of-way undergoing reconstruction without adding some type of qualifier regarding the scope of the road reconstruction project. Due to limitations in system protection schemes that are necessary for safe operation of the system, it would likely not be practical to consider relocating small portions of circuits underground. Staff does not recommend that the Commission extend the underground line policy to include circuits undergoing road reconstruction, however, if the Commission wishes to consider this policy further, the recommendation would need to be qualified to include undergrounding facilities being relocated due to road construction only where it is practical and safe to do so as determined by the utility.

(3) All Secondary Line Extensions

The Commission's order also directed Staff to investigate "all secondary line extensions including primary lines sharing poles with secondary lines."[35] The utilities participating in this study broke that down into several categories, based upon varying costs for different types of installations. Each of those separate categories is listed below and each individual estimate is the incremental cost to complete those installations underground instead of the current practice of installing them overhead. The estimate to extend the

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[35] Ibid., p. 1..

Commission's underground line policy to include all secondary line extensions is the sum total of each of the separated categories, and will be discussed further.

The first category is all secondary residential services which is defined as secondary voltage residential services that are currently installed overhead. Consumers Energy reports that they currently install approximately 4,000 overhead secondary residential services each year, the incremental cost to complete all of those installations as underground would be $1.4 million annually. Detroit Edison reports that they currently install 11,000 overhead secondary residential services each year and that the incremental cost to complete those installations underground would be $1.7 million annually. Extending the Commission underground line policy to include all new secondary voltage residential installations would cost Michigan more than $3.1 million annually.

The second category that was identified by the utilities is all secondary residential laterals. This category includes secondary wires extended off the road to serve a single or a group of residential customers. Consumers Energy reports that they complete approximately 6,000 of these types of overhead installations each year and the incremental cost to complete those installations underground would be $10.8 million. Detroit Edison reports that they install 83 miles of secondary residential laterals each year and the incremental cost to complete those installations underground would be $3.5 million annually. Extending the Commission underground line policy to include all new overhead secondary residential laterals would cost Michigan more than $14.3 million annually.

The third category that was identified by the utilities is lateral primary extensions and associated transformers for residential customers. They are generally installed off the road on private property and serve a limited number of customers. This involves at least one pole and a transformer, fuse, and lightning arrestor that would be put on the ground rather than on a pole. Consumers Energy reported that they complete approximately 2,000 of these types of installations each year, and the estimate to complete these installations underground is an incremental cost of $ 4.4 million annually. Detroit Edison reports that they complete an average of 73 miles of primary residential overhead installations each year and to complete those installations underground would be an incremental $57.5 million annually. Extending the Commission underground line policy to include all new overhead lateral primary extensions and associated transformers for residential customers would cost Michigan more than $61.9 million annually.

The fourth category that was identified is the installation of electric service and secondary for commercial and small industrial customers. Consumers Energy reported that they complete approximately 1,000 of these installations overhead each year and the incremental cost to install them underground would be $1.15 million annually. Detroit Edison reported that they complete an average of 1,800 commercial overhead service installations and 8 miles of secondary commercial overhead laterals each year. The incremental cost to complete those installations underground is estimated to be $0.6 million annually. Extending the Commission underground line policy to include all new overhead installations of electric service and secondary extensions for commercial and small industrial customers would cost Michigan at least $1.75 million annually.

The fifth category that was identified is lateral primary extensions and associated transformers for commercial and small industrial customers. They are generally installed off the road on private property and serve a limited number of customers. This involves at least one pole and a transformer, fuse, and lightning arrestor that would be put on the ground rather than on a pole. Consumers Energy reports that they complete approximately 500 of these installations overhead each year, and the incremental cost to complete those installations underground would be $5 million annually. Detroit Edison reports that they complete an average of 7 miles of primary commercial overhead extensions each year and the incremental cost to complete those installations underground is estimated to be $5.1 million annually.

The last category identified is large industrial customers. Most large industrial customers are fed at higher voltages, and many large industrial customers have unique electrical needs. Many times the electrical facilities serving them are on the customer's property and out of sight of the public. For those reasons, Consumers Energy recommended that no new requirements be placed on those customers. Detroit Edison reported that they install on average on 1 mile per year of primary overhead extensions for large industrial customers and that the incremental cost to complete those installations underground would be $0.7 million.

The estimated incremental cost to complete all current overhead installations of all new secondary line extensions and underground installations, including primary lines sharing poles with secondary lines for Detroit Edison and Consumers Energy is the sum of all of the incremental costs of the separate categories listed above and totals $69.1 million annually for Detroit Edison, and $22.75 million annually for Consumers Energy. Extending the Commission's underground line extension policy to include all new secondary line extensions including primary lines sharing poles with secondary lines would cost Michigan more than $91 million each year.

Funding for Underground Initiatives

As previously discussed, the primary justification for placing distribution lines underground has been for aesthetic reasons. The primary beneficiaries of the improved aesthetics and any adjustments in reliability are the local customers. Due to the impact that the underground versus overhead decision has on local customers, the Commission's current underground line extension policy states "In the case of all underground extensions of electric distribution facilities as covered by these rules, the real estate developer or customer shall make a contribution in aid of construction to the utility in an amount equal to the estimated difference in cost between overhead and underground facilities."[36] Although, some believe that additional undergrounding may provide benefits to the entire customer class and the State of Michigan as a whole.

At the collaborative meeting, the consensus was that because the benefits are realized primarily by local customers, the local customers should continue to be responsible for the additional associated costs for undergrounding. Detroit Edison argued that the present underground policy should not be extended and any programs to convert to underground in specific areas must include a substantial cost sharing on the part of the municipality or customer requesting the direct benefit.

Consumers Energy offered an alternative concept that would provide for additional undergrounding in a more orderly fashion than piecemeal impact that could result from underground conversion for poorly performing circuits or for road construction relocations. It also would not go so far as to mandate undergrounding for all secondary line extensions. Consumers Energy proposed that to promote the use of underground circuits in local communities of the State of Michigan in the specific areas that the communities themselves find desirable, the Commission would establish an account funded through customers' rates that would be available, along with matching funds from the requesting communities, to finance specific projects that the communities recommend. Consumers Energy proposes that the MPSC Staff would select the projects to be funded. This would provide local communities a significant voice in where funds are allocated towards undergrounding existing electric systems. This will also ensure, through the local community funding and the Staff's input, that the most advantageous projects are completed first. Because of workload issues, and overall rate issues, Consumers Energy proposed that a maximum annual investment amount should be specified in order to limit the impact on retail customer rates. If the process proves to be successful, Consumers Energy proposed that the maximum annual investment amount could be adjusted in the future.

Because it's been shown that the initial costs of undergrounding are more than typical customers are willing to bear, it has been suggested in various forums that additional funding for undergrounding should come via increased customer rates. Following are estimated rate impacts from various studies if all undergrounding costs that they studied were to be funded through rate increases:

Long Island:	154%	increase in rates[37]
Florida:	81%	increase in rates[38]
North Carolina:	125%	increase in rates[39]
Virginia:	$3,577	per customer annually[40]
Tahoe-Donner:	$1,924	per customer annually[41]

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[36] Administrative rules - Underground Electric Lines R 460.511 - 460.519; http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=46000511&Dpt=CI&RngHigh=
[37] Navigant, Op. Cit., p. ES-3.
[38] Johnson, Op. Cit., p. 15.
[39] Ibid, p. 15.
[40] Ibid, p. 15.

Funding through rates would allow for more undergrounding to be constructed, however, expanding the Commission's underground line policy in a manner that placed a percentage of the burden on ratepayers could have a substantial impact on customer rates. According to a recent study prepared for Florida utilities, "No state is requiring extensive undergrounding of existing distribution facilities."[42]

The Staff recognizes that the proposal outlined above offered by Consumers Energy would be more technically feasible due to the concentrated areas where the undergrounding would be focused, and also would be less expensive for all customers than any wholesale extension of the Commission's undergrounding policy. Underground initiatives could be implemented in areas where the customers were requesting the conversion, and those customers would still pay for a portion of the undergrounding costs but would receive matching funds. The matching funds would be those collected from all of the customers' rates. Staff agrees that a cap on the amount of matching funds to be made available through at large ratepayer funding should be kept to a reasonable level. As Detroit Edison points out, the Michigan Economy is suffering, and investments also need to be made in generation, renewables, and environmental controls.

Considering that electric rates should remain reasonable and affordable for the citizens of Michigan, Staff recommends that any underground line extension policy contemplated by the Commission should contain provisions for a maximum annual investment amount to be set by the Commission instead of any wholesale expansion of the Commission's underground policy. Also, Staff recommends that any underground line extension policy should contain provisions allocating a significant portion of the increased costs to those customers receiving the local benefits, so that all of the costs are not transferred to the entire system's rate payers.

Before any policy changes should be made, there are several questions that are yet to be answered. One question is the extent to which customers would be willing to accept a surcharge on their bill in order to fund optional undergrounding initiatives in specific local communities that may be far away from where they live. Also, to what extent are customers willing to bear higher rates that may be associated with the higher life cycle costs (due to decreased life expectancy) of underground utilities. Would customers who already have paid to have their facilities placed underground when they moved into their new subdivision, be willing to accept a surcharge on their bill in order to fund undergrounding for others?

CONCLUSIONS

Any policy decision made to expand the amount of undergrounding in the State of Michigan must take into consideration both the anticipated costs for consumers as well as the expected benefits. EEI's report states "The report finds that burying overhead power lines has a huge price tag, costing about $1 million a mile on average, or about ten times what it costs to install overhead power lines. Studies of statewide undergrounding initiatives in Florida and North

[41] Ibid, p. 15.
[42] Brown, Op. Cit., p. 5.

Carolina suggest undergrounding would require rate increases ranging from 80 percent to 125 percent. A Virginia study calculates the annual cost of a statewide undergrounding initiative would be approximately $3,500 per customer."[43]

Undergrounding has a huge price tag, but are the expected benefits worth the price? Michigan utilities implement distribution reliability improvements to their poorly performing overhead circuits each year that improve the frequency of outages, without increasing the duration of outages, and at significantly less cost than converting those circuits to underground. Undergrounding for the sake of reliability does not appear to be economically justified. "The bottom line – reliability benefits associated with burying existing overhead power lines are uncertain and in most instances do not appear to be sufficient to justify the high price tag that undergrounding carries."[44]

Since reliability improvements do not appear to justify the cost of undergrounding, are customers willing to pay for the aesthetic benefits? "Most consumers do not fully appreciate how much undergrounding costs, and, when faced with the real costs of undergrounding, most individuals are not willing to pay the substantially higher electric bills or monthly payments that are required."[45] As the majority of consumers appear to be unwilling to pay the cost differential to have their electric distribution buried, Staff does not recommend extending the Commission's current underground line extension policy to include poorly performing circuits, or circuits along road rights-of-way undergoing construction, or for secondary line extensions at this time.

An alternative concept was recommended by Consumers Energy that may be worthy of further consideration with some modifications. The concept would allow for funding of locally targeted optional undergrounding projects with 50% of the funding being provided from the local customers and 50% of the funding being provided through all of their customers' rates. Such a concept would enable specific local customers to underground their facilities at a lower initial cost by sharing those costs with all of the rate payers.

Considering that electric rates should remain reasonable and affordable for the citizens of Michigan, Staff recommends that any underground line extension policy contemplated by the Commission should contain provisions for a maximum annual investment and should contain provisions allocating a significant portion of the increased costs to those customers receiving the local benefits, so that all of the costs are not transferred to the entire system's rate payers.

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[43] Johnson, Op. Cit., p. 1.
[44] Ibid., p. 2.
[45] Ibid., p. 1.

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