Draft Report of Qualitative Advantages and Disadvantages of Converting Overhead Distribution Facilities to Underground Facilities within the Service Territory of the Fort Pierce Utilities Authority

Prepared by:

HiLiNE ENGINEERING, LLC
a GDS Company

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Executive Summary

Through extensive research and the combined years of operational experience of Hi-Line Engineering personnel we are pleased to offer recommendations for the safe, reliable, and economical distribution of electrical energy to the citizens of Fort Pierce and customers in portions of St. Lucie County.

The wholesale conversion of overhead facilities to underground cannot be supported by the research and economic analysis performed in this study. The 2004 Hurricane season saw an abnormally high amount of named storms and two hurricanes category 2 and above on the Saffir-Simpson Hurricane Scale. Fort Pierce was unfortunate to absorb the brunt of two such hurricanes, Frances and Jeanne. Based on historical data for the region, the normal occurrence for a category 2 or above hurricane to have a direct strike is one in every ten years. Although damage was extensive from the dual strikes, the major overhead distribution lines supplying Fort Pierce customers sustained very little major damage. These main lines were restored typically in 72 hours; however, the majority of the extended outage times for customers were due to trees or debris on lateral lines or the overhead service entrance being stripped off the house. The restoration of service for these customers required extensive tree trimming or an electrician to come to the customer, repair and remount the service entrance prior to power being restored by FPUA. Given the large amount of damage to customer equipment, and the small number of available electricians in the Fort Pierce area to handle all the requests, customers endured longer outage times. A positive step FPUA can perform is education of the customer on the benefits of underground service and providing the means to assist the customer in attaining underground service. Currently, the consumer pays the installation cost for the conduit and prepares the meter panel for conversion at their expense. As a primer to entice overhead to underground service conversion, FPUA may consider some type of program which they would financially fund the consumer portion of the conversion, and allow the consumer to payback over time on their utility bill. This may be one of the better programs to help reduce outage times due to severe storms. In addition, a comprehensive, well-funded tree trimming and urban forest management program provides year round reliability, as well as reducing instances of trees damaging lines during a storm.

The strengthening of overhead main feeder lines may be a better alternative to placing facilities underground. Minor changes in current construction practices may increase the ability of the distribution system to withstand extreme winds. The implementation of these practices would require less capital expenditure than an underground project, while at the same time increasing reliability. FPUA is considering a program to harden feeders based upon the same principles. Keeping the main feeder lines above ground and strengthening that system is more economical and prudent. Additionally, gains in reliability of the overhead system can be realized by looping all radial three phase taps. Wholesale looping of radial single-phase taps is not warranted. Instead, this option should be investigated in areas where reliability has been a concern. All main line feeders were looped to allow for ease of system operation in contingency situations and circuit switching.

The current trend with Municipalities is to require all new subdivisions to be served underground and all new houses have underground services. This increases the appeal of the subdivision, reliability, and property values. It is also aesthetically pleasing. This practice is sound and may be considered for implementation if the policy does not currently exist.

The placing of overhead main feeder lines underground does make sense in some areas. These areas are typically near the ocean or scenic vistas. Consideration should be given to these areas, not on a reliability basis, but on an aesthetic basis. This will project a good image of the community for tourists and reinvigorate the current residents. One such project is in the planning stages along Route A1A starting at the intersection of Seaway Drive and proceeding on South Ocean Drive to the end of the service territory. Caution should be exercised when making the decision to place facilities underground near the ocean. Storm surge can create additional problems with underground facilities such as causing an electrical short on the secondary side of a transformer or washing out of conduit or even equipment. The overhead system may fare better in these conditions, but they are also subjected to extreme winds, which is not typical for padmounted equipment.

Based upon extensive economic evaluations by FPUA staff, a case can be made for the placing of single phase taps off the main feeder lines underground. The cost differential is approximately $957 per lot with underground costs of $2,087 and overhead costs of $1,130. The additional cost per lot, for the underground installation, is for running services underground. Even though there is a fair disparity in per lot cost, the reliability gains of having a service underground could out weight the installation cost differential. In addition, a recommendation was made to place overhead services underground for reduction in customer outage time. The placing of single phase radial taps underground, including services, follows the intent of this recommendation. The placing of new single phase taps underground should be considered as a standard practice. As with all installations, some offer more challenges than others. These situations require evaluation on a case by case basis.

Another case where placing overhead facilities may have merit is road relocation or resurfacing. If a road is scheduled for work, a review should be performed to see whether or not the existing overhead facilities would be better placed underground. Factors that may influence this decision include increasing safety within the work area, provide an aesthetically pleasing streetscape, or if it is economically equivalent to the replacement cost new of existing overhead facilities.

Consideration should be given to modification of structures along the Totten to Savannah Road Substations transmission line. Eleven pole structure replacements, eight for Hurricane Jeanne and three for Hurricane Frances, were recorded on the line. No other FPUA transmission line sections experienced structure integrity issues. Placing of these sections underground cannot be cost justified at this time.

In general, FPUA's electrical distribution system is sound. The hardening of new and existing main line feeders will provide an economical solution with minimal trade offs. Most reliability gains can be realized from placing overhead services underground and tree trimming. In addition, the Lawnwood substation main line feeder to the hospital, adjoining medical offices, the fire station, the County administrative center, and the adjacent school area should be considered for burial to a central point common to the facilities. This will reduce exposure of these critical facilities allowing for continued operation during extreme weather events. The main line feeder would then return overhead after the central point. Most single phase taps off the main feeder lines should be considered for burial, and in situations were unique challenges exist, solutions developed to minimize economic impact and overhead exposure. The placement of two main feeders under the interstate highway was prudent for safety reasons, and other major thoroughfares and rail lines may also be considered. The placing of overhead facilities underground on South Ocean Drive is also a positive step for tourism. Some consideration should be given to placing overhead facilities from the Coast Guard Station to South Ocean Drive, on Seaway Drive, underground to complete the beach and ocean section for tourism.

Planning and Engineering Design in the Two Types of Construction

Ascertaining Existing Conditions

The system conditions will be determined through the use of maps, existing data, interaction with operating personnel, and a system tour. The key portions of the electric system will be documented through photographs.

Remain Overhead

Pros: Majority of system is overhead, additional training will be minimal, personnel familiar with system and maintenance, backbone system is looped allowing for flexibility in contingent situations

Cons: Additional exposure to extreme storm conditions, overhead congestion produces displeasing aesthetics, system construction varies along with wind withstand capabilities

Convert to underground

Pros: Possible increase in reliability, improvement in aesthetics, new construction can be standardized

Cons: Still susceptible to storm damage through storm surge, more costly to install and maintain, additional training required, manhole system may be required

The transmission system of Fort Pierce Utilities Authority (FPUA) consists of a 69 kV loop throughout the service region except for Causeway Substation which consists of a radial 69 kV line. Additionally, FPUA maintains flexibility within their transmission system with a 138 kV tie line between Vero Beach and FPUA's Garden City #2 Substation. This tie line will allow for the FPUA system to be back fed in case of a 69 kV outage at the H.D. King Generating Plant or the Florida Power and Light transmission feed at Hartman Substation. The line is not capable of carrying the entire system, but can restore a majority of the system quickly. The 138 kV line is a radial feed from Vero Beach to Garden City #2. The transmission system is overhead; however, a section of 69 kV transmission line is scheduled for burial in conjunction with Causeway Substation improvements. The relocation is a short section near Seaway and Indian Drives and E and 2nd Streets.

Assembly at S. Ocean and Gulfstream

The distribution backbone feeders consist mainly of 394.5 AAAC overhead conductors with a summer rating of 306 amperes and a winter rating of 649 amperes. The overhead conductor ampacity derivatives can be found in the Ampacity Rating for OH Conductors table found on page 12. Single and two phase taps off the line were varied; however, most were copper wire #4 or greater. FPUA is no longer using copper for new installations, instead utilizing AAAC. The type overhead construction varies but is typically crossarm and narrow profile construction. The majority of distribution circuits were overhead at a ratio of 90% overhead and 10% underground. It was noted that there are several large subdivisions, apartment complexes, commercial developments, and marinas which were underground loop feed. The underground construction consisted of cable in conduit from a riser pole to a piece of equipment, sometimes a transformer; other times a switching cabinet or switchgear. A manhole system was not evident in our system tour.

The configuration of circuits was similar to that of most utilities. The three phase overhead backbone feeders are loop fed and can be tied to other circuits. Caution needs to be exercised in tying circuits together and placing additional loads on the cables. System loads and emergency capacity for the circuits are critical pieces of information needed to determine whether a circuit will be capable of safely handling the additional load. Single phase and two phase taps off backbone feeders are not looped. This is common in the utility industry; however, looping of these lines can improve reliability. The three phase underground lines were found to be looped for subdivisions, some commercial customers, apartment complexes, and marinas. Some radial feeds do exist; however, the criticality of the load does not indicate the need for a loop feed. The single phase underground lines were also looped for most subdivisions with a few smaller subdivisions having a radial feed. Again, criticality of load and the smaller number of consumers is not indicative for loop feed installation. The transmission system is loop fed as well. It was indicated by FPUA personnel that a customer outage was never caused by a transmission line failure until the 2004 Hurricanes. The tie to Vero Beach is radial and could be susceptible to damage rendering the alternate feed inoperable. This was proven to be true during hurricanes Frances and Jeanne, where the line relayed out and would not reclose. The looping of the 138 kV system may be an item to review in the future.

The FPUA staff indicated the overhead backbone feeders weathered storm conditions with relatively minor damage throughout hurricanes Frances and Jeanne. The backbone system was operational quickly after the hurricane had passed, but the restoration of all customers extended for weeks. This is typical in areas where a majority of services to houses are overhead. The storms resulted in trees uprooting or breaking, damaging service entrances to homes. The customer is then required to have an electrician reattach the electric service to the house prior to power being restored to the location. A case can be made for a systematic program of placing overhead services underground. FPUA staff has such a program in place and have seen a significant number of customers take advantage of the opportunity, approximately 100 per year. The service will no longer be exposed to tree damage or flying debris and will typically have power restored more quickly because no work has to be performed on their service entrance.

After review of the damage caused by Hurricanes France and Jeanne, it was noted an abnormal number of poles broke on the Totten Substation to Savannah Substation transmission line. During Hurricane Jeanne eight poles were replaced on that line and three poles replaced during Hurricane Frances. Consideration may be given to increasing the strength of the overhead transmission structure design on this line or the possibility of placing all or a portion of this transmission line underground. Information provided did not indicate any other FPUA 69 kV transmission structure failures.

Complexity of Inventory

Many inventory challenges may arise if a decision is made to proceed with placing the electric distribution system underground. An inventory must be maintained to continue running the existing electrical distribution system. Additional inventory, to begin the installation of the underground system, must also be purchased. This may pose warehousing and other issues. Hi-Line will identify common issues found in electric system conversions and utilize the data to assist in the determination of the projects feasibility.

Remain overhead

Pros: No change in stock type or quantities, no additional space requirements

Cons: None

Convert to underground

Pros: Develop vendor relationships to allow for offsite storage until material needed

Cons: Additional space required for equipment, additional cost of equipment, maintain two sets of inventory (overhead and underground) during the conversion process

The decision to place all overhead facilities underground requires the exploration of several key items to determine feasibility. Such key items include: the amount, type, and variety of stock to maintain; the additional warehousing costs to store items during the transition phase; and the increased cost of inventory.

If the decision is made for full placement of overhead lines underground, several issues with inventory are established. Current stock levels for the overhead system must be sustained for maintenance of overhead lines; however, as more overhead is converted, ideally the quantity of overhead stock would decrease. The delicate balance of maintaining sufficient stock for repair of overhead lines without overstocking is an arduous task. Possible solutions to the inventory concern may include working with vendors to stock materials needed by FPUA at the vendor's warehouse, drawing on the stock as needed. This allows FPUA to reduce the stock quantity on hand, freeing up space in FPUA's warehouse to store additional underground material. Also, FPUA would have reduced carrying cost associated with the material, seeing it is only purchased when required and utilized quickly. Problems may arise from this arrangement with vendors; but, they are not insurmountable.

Some issues that may deter this arrangement are: non standard material, vendor stock being depleted, and possible passing of carrying costs to FPUA in the form of higher unit costs. If items used on the FPUA system are different from what is utilized by the vendor's other utility customers, the vendor will be less willing to carry the material. They will not be able to sell the item to another utility in the event it is not utilized by FPUA. In this situation, the most likely outcome is the vendor would stock the item, but, FPUA would pay for it upfront.

Another issue to confront is vendor stock being depleted. In the event of a storm, the vendor may send product to other utilities to aid in their restoration efforts. This could have a detrimental impact on the FPUA system, as a critical item may not be available for their use. In a scenario like this, critical equipment should be maintained at FPUA's warehouse. A review of material to determine what is critical should be performed and those items should be amply stocked at their warehouse. The issue of carrying costs being added to the unit cost should be viewed from a cost standpoint. Is the additional cost added to the material more than the cost of carrying the material in your warehouse? Once this question is answered, one can determine whether to warehouse internally or at the vendors location. Most vendors are willing to warehouse stock for a utility if they know they will continue to receive business, typically at no additional charge.

Moreover, new and varied products will be required which might occupy greater space, increase the cost of inventory, and possibly pose logistical issues. Some larger items required to place facilities underground consist of vaults, manholes, switches, sectionalizing cabinets, switchgear, and padmount transformers. Most of this equipment is bulky and more costly than their overhead equivalent. An example of material required is illustrated with the installation of one mile of 1000 kcmil 133% insulation cable with a maximum pulling distance of 450 feet. A mile of underground cable may require in excess of twelve manholes. The storage area required for the manholes, until installation, would be difficult to find. In addition, there is the space the cable would occupy as well. Additional space would be required for transition boxes and sectionalizing switchgear. All these items may be coordinated so they are not delivered until needed, however, the additional project management required would create a stress on an already over tasked engineering department.

Below is a table of common overhead equipment, its underground equivalent and the cost differential between them. As is evidenced by the table, the cost of underground equipment averages twice that of the overhead equipment.

OH Vs. UG Equipment Costs

Item	OH Cost	UG Cost	% Difference	Cost Difference
10 kV Lightning Arrester	$24.08	$66.85	277.62%	$42.77
15 kV 1/0 URD, 133% Insulation (OH equivalent conductor 155.4 AAAC)	$0.28	$1.24	442.86%	$0.96
15 kV 1000 kcmil, AL, UG, 133% Insulation (OH equivalent conductor 927.2 AAAC)	$2.46	$5.70	231.71%	$3.24
Splice, 1/0 15kV AL (OH equivalent conductor 155.4 AAAC)	$9.34	$18.02	192.93%	$8.68
Splice, 1000 kcmil, AL, UG 15kC (OH equivalent splice 927.2 AAAC)	$40.06	$148.28	370.14%	$108.22
Transformer, 1Ø, 37.5 kVA, 120/240	$1,092.05	$1,489.85	136.43%	$397.80
Transformer, 1Ø, 50 kVA, 120/240	$1,230.94	$1,500.01	121.86%	$269.07
Transformer, 1Ø, 75 kVA, 120/240	$1,236.51	$1,764.53	142.70%	$528.02
Transformer, 1Ø, 100 kVA, 120/240	$1,735.12	$1,843.83	106.27%	$108.71
Transformer, 3Ø, 75 kVA, 120/208 (OH 3-25 kVA Transformer Bank)	$2,655.90	$5,342.83	201.17%	$2,686.93
Transformer, 3Ø, 112.5 kVA, 120/208 (OH 3-37.5 kVA Transformer Bank)	$3,276.15	$5,622.58	171.62%	$2,346.43
Transformer, 3Ø, 150 kVA, 120/208 (OH 3-50 kVA Transformer Bank)	$3,697.82	$6,703.11	181.27%	$3,005.29
Transformer, 3Ø, 225 kVA, 120/208 (OH 3-75 kVA Transformer Bank)	$3,709.53	$6,466.66	174.33%	$2,757.13
Transformer, 3Ø, 300 kVA, 120/208 (OH 3-100 kVA Transformer Bank)	$5,205.36	$7,602.16	146.04%	$2,396.80

Discussion of Feeder Hardening for Added Wind Load Protections

There are three grades of construction accepted by the National Electrical Safety Code. The relative order of grades for supply conductors and supporting structures is B, C, and N with Grade B being the greatest. Currently, Grade B construction is typically required when crossing railroad tracks or limited access highways in urban areas. Grade B construction utilizes stronger poles, shorter distances, and greater safety factors. These material upgrades come at a greater cost, but afford much greater protections during storm conditions. In addition to the Grade B construction, FPUA may also use extreme wind loading factors to further enhance the resistive affect from storms. The applications of these factors test whether or not a structure and conductors will withstand the forces of wind gusts without yielding. Currently, extreme wind loading is only required if pole height exceeds 60 feet above ground or water. The changes to meet these stiffer requirements come at a steeper material cost; however, if they allow FPUA to recover in less time after a storm, the benefits may outweigh the costs.

Identifying Suitable Locations for Facilities

The most suitable location for underground utilities tends to be the front of houses on the road right of way. Many people will not be accepting of this and request the utilities be buried behind their houses. This raises several issues which Hi-Line will review and recommend solutions.

Remain overhead

Pros: Smaller footprint required for new installations, minimum disruption to area, ease of relocation, most often located within easy reach of an aerial device, easily replaceable for road widening projects

Cons: When installed in backyards access can be difficult and often causes damage to customer property which requires restoration,

<u>Convert to underground</u>

Pros: Aesthetically pleasing to the eye due to reduced congestion, equipment is easily accessible by personnel, reduced expense of tree trimming

Cons: Cannot be relocated easily or quickly, property owners placing bushes around the equipment hindering access, expensive to relocate

The most common location for overhead and underground facilities is within the road right of way. Municipal utilities tend to locate their facilities on the road right of way for several reasons. The municipal utilities tend to have a very good relationship with local and state government. If road widening or relocation occurs, the municipal utility is subject to forced relocation by roadway jurisdictions. Reimbursement for the relocation of their facilities is likely, but not always guaranteed. More success has been realized in the reimbursement of street lighting costs. Investor owned utilities typically purchase easements from homeowners just off the road right of way. Unlike municipal utilities, investor owned utilities do not have the luxury of being reimbursed if their facilities are within road rights of way. However, investor owned utilities see the value of locating facilities on the street front, such as ease of access and repair, and usually less tree trimming in comparison to back yard construction on overhead systems. This is why they are willing to pay to obtain right of way on the front of property. It should be noted, investor owned utilities do not always purchase right of way. They do locate within the city or state road right of way which typically requires the investor owned utility to apply for a permit. The investor owned utility takes a calculated risk to determine if the road will be relocated and the cost of relocation versus the cost of obtaining an easement. The general benefits for location of underground facilities in the road right of way are ease of access, ease of repair, and ease of operation.

The use of road right of way is opposed by some homeowners. The homeowners feel the “box” in their yard is obtrusive and detracts from the value of their property. The placing of overhead facilities underground generally increases property values, but, not always people’s perceptions. Some property owners try to mask the transformer or pedestal by planting trees and shrubs in close proximity. The utility must be vigilant in enforcing offsets for plantings, as they may interfere with operation of the equipment and system.

Locating underground equipment in backyards is not the ideal situation. If backyard construction is unavoidable, it is better to locate the equipment closer toward the home rather than the wood line. This allows for easier access, better grounds maintenance near the installation, and placing equipment near the load it was installed to serve. Also, placing equipment near property lines is beneficial in maximizing direct run services from the transformer to the home and to street lighting on the road in front of the home. Also, access can almost always be obtained through a driveway along a property line. A disadvantage to bringing underground lines closer to homes is homeowners planting trees or gardens in close proximity to lines. This could be avoided by obtaining restrictive easement rights on the occupied strip of property. Another factor in determining the feasibility of placing lines underground behind houses is the amount of obstructions existing. Large number of fences, pools or structures may complicate placing facilities underground. The obstructions can be overcome, but at an even greater price than just the normal underground cost.

Locating overhead equipment in backyards is also not the most desirable situation. The homeowner usually prefers to have the poles and equipment out of their view. This puts the equipment at edge of tree line. This poses problems with tree trimming, access and operations. The ideal situation for locating poles in backyards is to be closer to the homes the line services. This will help reduce tree trimming to some extent, but not eliminate it. Placement of poles typically occurs near property lines to allow for service entrances to homes. Restrictive easements are required here as well to prevent building of structures or planting of trees under the line. This will help to eliminate code clearance problems.

Easement Requirements

People are reluctant to give easements to utilities. The utility would be requesting a restrictive easement on property, not allowing any interference within the area. The easement width will also be a point of contention. Typical utility requirements range from ten to twenty feet, most being twenty feet in width. Hi-Line will recommend easement widths and define the restrictive covenants. Hi-Line will review current easement forms used by FPUA to determine if it is applicable to undergrounding the existing overhead lines. A risk assessment will be performed identifying areas of concern such as non existent or unrecorded easements. These cases represent a risk in undergrounding if the property owners do not respect the quality of the easement rights. Easements forms will also be reviewed for restrictive covenants and recommendations made to improve the rights of FPUA.

Remain overhead

Pros: Can install and maintain within 10’ easement if necessary, may be maneuvered away from underground facilities in the area

Cons: Curtailing the use of a person’s real property, unrecorded easement may not be enforceable

Convert to underground

Pros: More likely to obtain an easement for something that cannot be seen especially if no above ground equipment is necessary on the property

Cons: Easement width is crucial especially in backyards, curtailing the use of a person's real property, unrecorded easement may not be enforceable, may have issues arise with other underground facilities

Requesting easements across private property is one of the most arduous tasks for a staking engineer. This charge becomes even more difficult when requesting a restrictive easement. An easement is a grant for limited use of another's real property. A restrictive easement further curtails the use of a person's real property by disallowing any building or structure to be erected on the right of way access strip.

The easement form utilized by Fort Pierce Utilities Authority is a restrictive easement not allowing any building or structures on the right of way. The easement width appears to be a standard ten feet. In review of the easement form, FPUA may consider adding the following items to their easement to further solidify their position and rights on the document. These items are the addition of verbiage to describe the transference of knowledge in a bidirectional manner represented by any form of writing, signs, signals, pictures, sounds, or any other symbols. This will allow FPUA to place communications wires in the right of way for future use, including the possibility of community access television (CATV).

Another item for possible inclusion is an easement forever for the construction, maintenance, and operation of overhead and underground electric utility and communication facilities. This includes wires, poles, guys, cables, conduits, and appurtenant equipment to be installed from time to time. This contract grants the right to; reconstruct, improve, enlarge, change the voltage, as well as alter size of, and remove such facilities or any of them within an easement. This will allow FPUA to upgrade their system to any higher voltage they choose should it become necessary in the future. It will also allow for expansion in case of high growth in the area. FPUA may also want to increase the right of way width to twenty feet if the location of the easement is backyard construction. Vehicle access will be crucial in backyards, especially for underground systems. Equipment such as trenchers and backhoes require working space for installation and repair. On overhead lines, access by digger derrick and lift trucks could also be hampered by the width of the right of way. Most motorized equipment used for the installation and maintenance of overhead lines is eight feet in width, not including outriggers for stabilization.

A situation which may develop and possibly cause issues is existing overhead lines on private property without written easements. This situation occurred frequently in the past with most utilities. The original property owner allowed the utility to come across the land based on a verbal agreement or "handshake". As property owners change, the new owners may question the legality of the property crossing, possibly requiring the utility to relocate. Along the same lines, the utility wishes to bury lines in a property crossing with no easement. The homeowner may or may not allow the utility to bury the lines. Since it is a change of use, even if a right of way was obtained through adverse possession, the utility has no rights to install the line underground. Several remedies can be employed to rectify the situation, all with benefits and disadvantages. The least costly way is to talk to the homeowner and obtain rights to the property. This will allow the utility and the property owner a chance to find a mutually agreeable resolution to obtain property rights. Another method for resolution is property condemnation. The utility gets the access they need; the homeowner obtains fair market value for the detriment to the property. This is not a very good method from a public relations standpoint, typically causing very great disdain by the property owner toward the municipality/ utility. In a political arena, this issue could become volatile. Another method for resolution is line relocation. This can be very costly, depending on the route required to circumvent the problem area. This option will be more expensive monetarily; however, the political aspect will be removed as well as the ill will associated with a property taking.

Obtaining easements is difficult; this is why the integrity of the rights obtained should be inclusive and rock solid. The addition of the above mentioned items to FPUA's easement agreements would secure FPUA's rights to supply customers for now and many years to come.

Flexibility in Unconventional Situations

Overhead lines are considered to be more flexible for changing conditions or unusual situations. Underground facilities can be designed to have some flexibility but are typically considered inflexible. With this in mind, Hi-Line will evaluate the risk of various situations as an evaluative tool for determining the feasibility of undergrounding the system.
Remain overhead

Pros: Adapts well to contingent situations, very flexible in terms of system configurations, sectionalizing may reduce the number of customers experiencing an outage

Cons: None

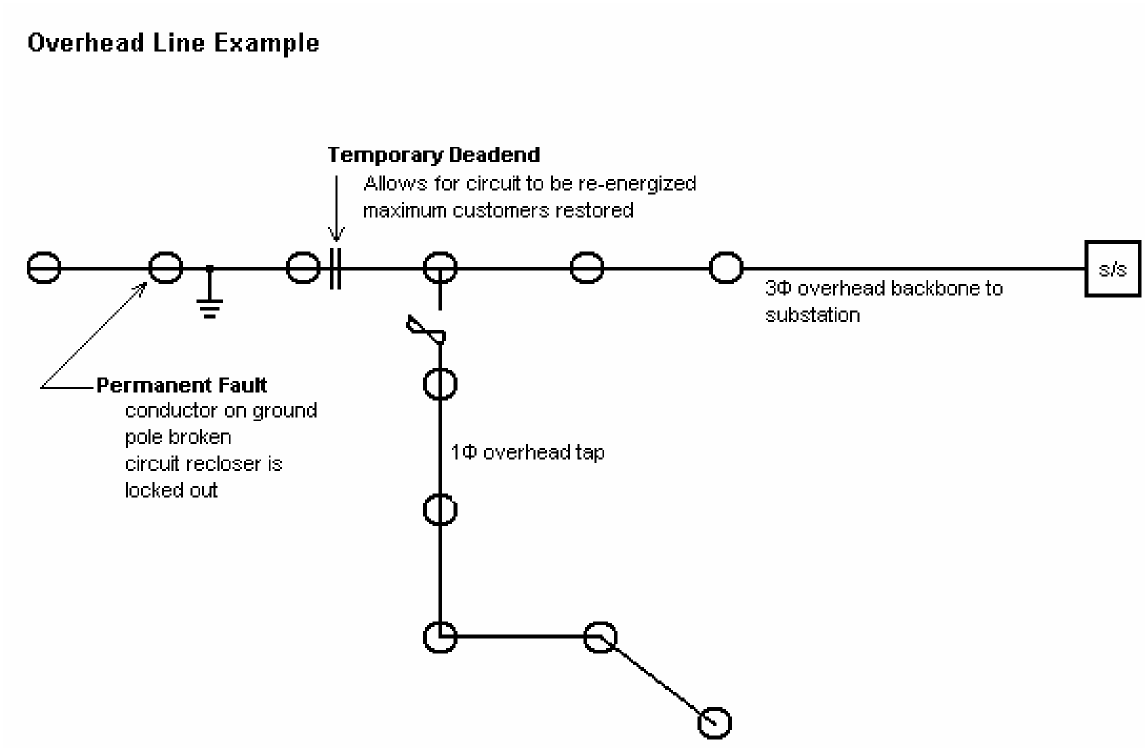
Convert to underground

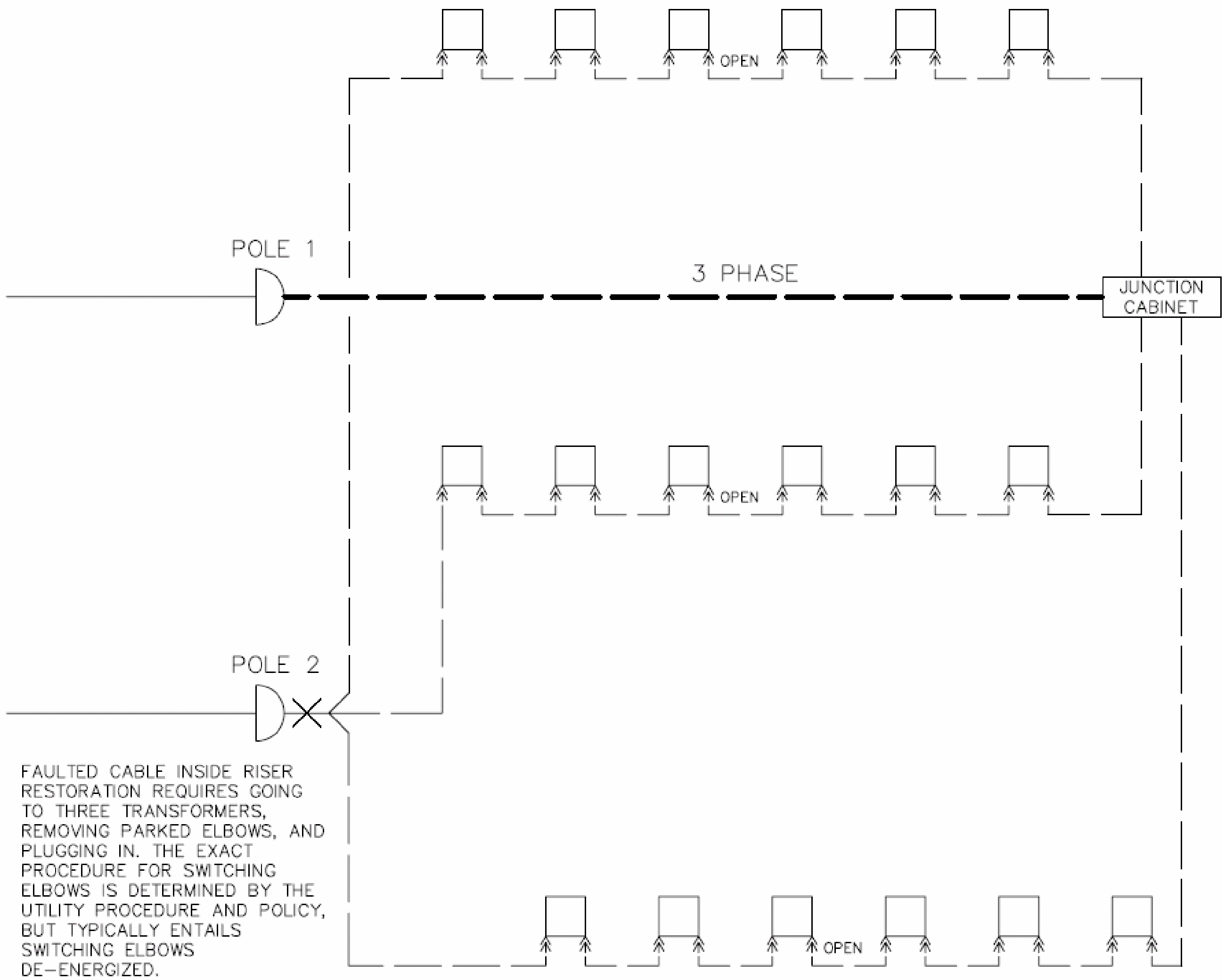
Pros: Fort Pierce Utilities Authority sized existing underground conductor amply

Cons: Inflexible in terms of system configurations (typically less points to tie systems together), may place more customers out of service longer especially if system is not looped or sectionalized

The backbone overhead electric system is considered to be the better type of construction to adapt to changing system conditions. The ability to quickly change how an overhead circuit is fed or to temporarily cut in a dead end structure to isolate a problem and keep power on to as many customers as possible, are just two of several benefits realized in unconventional situations. The underground backbone system typically does not have the flexibility to isolate sections as easily as the overhead system. When you can isolate on a backbone underground system, more customers are typically left without power than is necessary. This is caused by the location of a sectionalizing device, which may or may not be close to the actual location of the problem. Switching on the backbone overhead and underground system is about the same, provided the systems are looped. When switching for normal operations, it is easier to overload an underground circuit than an overhead circuit. Underground cable ampacities typically do not mimic their overhead counterparts; however, FPUA has taken this factor into account and sized underground cables to match or exceed the ratings of their overhead conductor. On single phase or two phase tap lines, overhead and underground systems operate about the same, and underground systems are more likely to be looped than overhead in the single and two phase configuration.

Below are a few examples of how unconventional events affect the backbone overhead and underground systems and which systems perform better for the given contingent situation.





These two practical examples show how a fault on the system can affect the operation of the system. The overhead scenario will typically be quicker to temporarily restore most of the affected customers, while it will take longer to restore the underground customers. However, all underground customers will be able to be restored, provided the cable was sized properly, more quickly than in the overhead case by closing the three open points. The repair on the underground system will typically take longer, especially if the fault in the riser caused a welding affect to the conduit. The customer will not see the long outage time in this case. The situation would be much different if the underground system was not looped. The overhead example could also isolate the fault better if it is looped and the loop can be closed. This would entail adding a second temporary dead end to the affected area prior to energizing from the other source.

Ease of Relocation

Cities are constantly growing causing strain on existing infrastructure. This growth causes infrastructure upgrade, such as water and wastewater line replacements and road widening. The impact can be great on overhead and underground facilities. Hi-Line will assess the relocation impact on both types of facilities and utilize the information in determining the feasibility of placing lines underground.

Remain overhead

Pros: Easily and readily relocated, least cost system to relocate

Cons: May have problems with locations of poles

Convert to underground

Pros: Access is conducive to underground implementation especially on roadway widening

Cons: Very difficult to relocate typically requiring parallel facilities to be built, very costly to relocate

As infrastructure ages, replacement becomes inevitable. The replacement process can be difficult when underground electric utilities are involved. The relocation of underground electric facilities is more involved than relocation of overhead facilities. Factors such as time, cost, and ease all favor relocation of overhead facilities. The process of setting a pole, framing, and stringing conductor is completed in a fraction of the time required to trench, pull conductor, and set padmount equipment for the same section. The cost to relocate underground three phase is four times greater than overhead; based upon information furnished by FPUA for one mile of 600 ampere three phase underground construction ($446,022) and one mile of 600 ampere three phase overhead construction ($114,058). This is important on jobs which do not involve Federal money and is not reimbursable to the utility.

In areas with favorable growth rates, typically near the water, there is a greater chance of some type of infrastructure change. These areas are typically where electric systems are placed underground for aesthetic and property value reasons. A well planned underground system, possibly outside the road right of way, may be the best defense against the high costs of relocation.

Alternatively, infrastructure repair or replacement may be a good tool for placing overhead facilities underground. As infrastructure is replaced, the access to underground facilities is opened. If an area is exposed to large growth possibilities, consideration can and should be given to placing facilities below ground. A good example is Hutchinson Island near the Harbour Isle townhouses. Here, overhead facilities were converted to underground in front of the development and remain underground throughout the development. This renovation provided an aesthetically pleasing view, which increases property values and sells homes more quickly. This would also hold true for areas which have high tourist traffic, providing clear scenic vistas for tourists and residents alike. A second example, which illustrates the point on tourism, is the plans to underground a three mile section of Highway A1A on Hutchinson Island. This will provide a positive experience for travelers coming through Fort Pierce.

Typically, areas that have existing overhead 600 ampere backbone circuits should remain overhead during an infrastructure upgrade, unless it meets the criteria above. Upon relocation of the overhead, the circuit should be re-designed to make it more resistant to storm damage and hurricanes. Care should be taken to make the installation as aesthetically appealing as possible, while obtaining the high reliability goals. In addition, pole locations should be chosen so not to interfere with vehicles.

Insulation Requirements

The insulation requirement for overhead systems in coastal areas is much greater to reduce the risk of flashovers. Similarly, underground systems need to be over insulated in high lightning density areas to aid in preventing failures from surges. The cost differential will be assessed and insulation levels recommended.

Remain Overhead

Pros: Easy to change, cheaper lightning protection, long life

Cons: Increased expense for larger class insulator, subject to vandalism, flashovers/tracking

Convert to Underground

Pros: Safer with dead front, easily accessible

Cons: More expensive, lightning protection is more expensive, subject to treeing

Overhead insulators along Blue Heron Blvd

The City of Ft. Pierce, FL is located just minutes from the Atlantic Ocean. Due to the close proximity of the Fort Pierce Utilities Authority's (FPUA) electric distribution system to the coastal areas, there is a definite need for increased insulation on the overhead and underground electric distribution system. Increased insulation is necessary on the overhead system to increase basic impulse level (BIL) and to mitigate against salt water spray contamination, which causes tracking and flashovers on the insulators. The underground system can benefit from increased insulation levels by making cables less susceptible to lightning damage. FPUA has taken proactive steps to insure that insulation levels are adequate on the overhead electric distribution system. Presently, FPUA utilizes 35 kV class insulators and metallic components are bonded to ground on poles located within close proximity of the coast. Lightning protection is provided via lightning arresters on the overhead system at each polemounted transformer, riser pole, and most deadends and open points. On the underground system, elbow mounted MOV's are used inside end of the line padmounted transformers and some specialty transformers contain oil immersed lightning arresters. The cost component of the various types and classes of insulation for overhead and underground components can vary greatly. FPUA uses 35 kV insulators on the overhead system and uses 15 kV class underground cable with 133% insulation on the underground system. The chart on the following page details the different insulation types and classes along with their individual pricing and source of pricing.

Comparison of Different Insulation Types and Pricing

Item	Insulation Class	Price	Unit	Source
Polymer Suspension Insulator	15 kV	$ 10.25	Each	TVESCO Reliable DS15G
Tie-Top Post	15 kV	$ 13.50	Each	TVESCO Domestic Insulator
Polymer Suspension Insulator	25 kV	$ 13.75	Each	TVESCO Reliable DS25G
Tie-Top Post	25 kV	$ 17.00	Each	TVESCO Domestic Insulator
Polymer Suspension Insulator	35 kV	$ 16.55	Each	FPUA
Tie-Top Post	35 kV	$ 17.96	Each	FPUA
Load Break Elbow, 1/0, 200 A, 100%	15 kV	$ 23.16	Each	Same price elbow is available that will do both 100% and 133%.
Load Break Elbow, 1/0, 200 A, 133%	15 kV	$ 23.16	Each	Same price elbow is available that will do both 100% and 133%.
Load Break Elbow, 1/0, 200 A, 100%	25 kV	$ 45.00	Each	TVESCO with jacket seal
Load Break Elbow, 1/0, 200 A, 133%	25 kV	$ 45.00	Each	TVESCO with jacket seal
1/0 URD , 133%	15 kV	$ 1.24	Foot	FPUA
1000 MCM AL UG, 133%	15 kV	$ 5.70	Foot	FPUA
1/0 URD , 100%	15 kV	$ 0.95	Foot	Coop Estimate
1000 MCM AL UG, 100%	15 kV	$ 8.01	Foot	Southwire Estimate
1/0 URD , 133%	25 kV	$ 2.35	Foot	Southwire Estimate
1000 MCM AL UG, 133%	25 kV	$ 5.10	Foot	Coop Estimate

From the price comparisons above, it is easy to see the trend of rising cost for insulators as you progress from 15 kV through 35 kV. On the underground system, there is a significant increase between 15 kV and 25 kV insulated cable. Since elbows are now available that can handle both 100% and 133% level of insulation, this variable is not a real factor. This comparison shows that the insulation levels required preventing flashovers and lightning damage is more expensive on underground equipment.

Conductor Ampacity

The conductor types of both overhead and underground systems will be evaluated. Recommendations will be made to determine proper sizing of conductors for given loads and future growth. The ability to switch circuits, especially with underground cable, will be given special attention. Focus will be on reliability and flexibility with the system.

Remain Overhead

Pros: Higher ampacity, easy to change out, easier to backfeed/switch, sectionalizing

Cons: Susceptible to storm damage, contact faults, splices weaken conductors

Convert to Underground

Pros: Protection from contact faults, aesthetics

Cons: Reduced ampacity due to conductor heating, specialized skills/equipment required for installation, problems with cable pulling limitations, tougher switching/backfeeding, cable/equipment cost more

FPUA utilized 5 main sizes of overhead conductors that are of All Aluminum Alloy Conductor (AAAC) construction. The sizes utilized include 77.47, 155.4, 394.5, 559.5, and 927.2 AAAC. FPUA utilizes AAAC conductor to minimize corrosion and the breakdown of the steel core used in Aluminum Clad Steel Reinforced (ACSR) type conductors. The Southwire Thermal Ampacity Rating Program was used to derive the ampacity rating of each of these conductors for summer, winter, and Emergency operation based on IEEE Standard 738. It was assumed that a 4 ft/s wind would be typical due to FPUA's close proximity to the ocean. Emergency operation is to be used for single contingency outage only. The program results are listed below:

Ampacity Rating for OH Conductors				
	Normal		Emergency	
	Summer	Winter	Summer	Winter
Ambient Temp.	95 F (35 C)	32 F (0 C)	95 F (35 C)	32 F (0 C)
Conductor Temp.	120 F (50 C)	120 F (50 C)	167 F (75 C)	167 F (75 C)
77.47 AAAC	116	234	N/A	N/A
155.4 AAAC	176	361	311	435
394.5 AAAC	306	649	560	785
559.5 AAAC	374	806	696	978
927.2 AAAC	501	1111	953	1349

FPUA utilizes 3 types of primary underground cable consisting of both aluminum and copper conductors. The old standard underground substation getaways utilized 500 MCM CU, 25 kV cable while main line construction utilizes 1000 MCM AL, 15 kV cable. All new underground substation getaways, such as Totten Substation, utilize 1000 MCM AL, 15 kV cable. Most subdivisions and smaller underground radial and loop feeds utilize 1/0 AL URD, 15 kV cable. The table below represents the ampacity ratings for the above mentioned underground conductors based on their installation method. The three different installation methods evaluated are direct buried, conduit (assumes a single cable), and riser pole. IEEE Standard 830-9/94 was utilized to determine the allowable ampacities.

Ampacity Rating for UG Conductors			
	Installation Method		
	Direct Buried	Conduit	Riser Pole
Conductor Temp.	90 C	90 C	90 C
Load Factor	75%	75%	75%
1/0 AL URD - 15kV	216	171	137
750 MCM CU - 25kV	604	572	398
1000 MCM AL - 15kV	716	668	529

*Based on IEEE standard 830-9/94

A comparison of the conductor ampacity between overhead and underground conductors shows that the sizes in use at FPUA were chosen wisely in order to parallel the capacity of the conductors. The exception is the 1000 MCM AL UG cable, which is larger than the 927.2 AAAC conductor and has far greater ampacity when installed in conduit or direct bury. It appears that since the ampacity values for overhead and underground conductors in use at FPUA are similar, then no conclusions can be drawn here as to which installation method is best.

When a comparison is made between overhead and underground cables on the basis of backfeed capability and switching, it would seem that overhead conductors have a large advantage. This advantage is bolstered by the availability of large overhead conductors and the various open points that exist on overhead systems to allow for switching. Underground conductors suffer from conductor heating when installed in conduit and loaded beyond 75% of its capacity. This heating severely limits the ability to swap and carry load on these cables. In addition, it is sometimes difficult to locate and perform switching on an underground system due to its low profile and locked access.

Power Factor Correction

Power factor correction is necessary for efficient operation of the system. Conventional overhead mounted capacitor banks are a cost effective component for installation. Underground cables have self capacitance which can help improve system power factor; however, adding capacitance is difficult and can be expensive. These considerations will be evaluated on the basis of risk as it relates to wholesale power costs.

Remain Overhead

Pros: Cheap to install, visible/easy to see if operating,

Cons: Voltage rise, leading power factor

Convert to Underground

Pros: Increased self capacitances due to cables, padmounted banks are easily accessible

Cons: Expensive

FPUA utilizes both station mounted and overhead pole mounted switched and fixed capacitor banks. Typical sizes of polemounted capacitor banks used for power factor support are 300 and 600 kVAR, while some banks used for industrial loads can be sized as high as 1200 kVAR. In addition, the 69 kV transmission lines have some capacitor banks installed in order to provide additional capacity during peak loading. The station mounted capacitor banks range from 1.2 to 1.6 MVAR and are used to provide stability. FPUA expects to do a capacitor study in the fall that will evaluate present and future power factor correction needs and will focus on setting the switches on capacitor banks adequately.

Underground systems possess inherent self capacitance due to the underground cables, which reduces the systems' dependence on power factor correction capacitor banks. Capacitor bank installation and implementation is straightforward and new programming interfaces and switching options have allowed users to easily set up a switching scheme that is customized to their system. Overhead mounted capacitor banks are relatively inexpensive and can easily be installed on existing poles. Padmounted capacitor banks on the other hand are expensive and are quite a bit larger than polemounted banks. Most utilities typically do not employ padmounted capacitor banks due to their cost which can easily be 5-7 times the cost of a polemounted bank. It is expected that even if a full overhead to underground conversion were to take place, station mounted banks would still be employed and some additional padmounted banks would be necessary to maintain a target power factor of 95% or better.

System Protection

The technique used for overcurrent and overvoltage protection is similar for overhead and underground systems. The goals are different, though, due to operating conditions. The goals will be addressed, in addition to cost implications, of protecting an overhead versus underground system.

Remain Overhead

Pros: Cheap, visible after operation, readily available, installation is routine, easy to swap out fuse links, fault interruption capability

Cons: Susceptible to storm faults, line contact

Convert to Underground

Pros: Less susceptible to contact incidents, accessible inside cabinet

Cons: More expensive, difficulty of changing out fuses, fault interrupting capability

FPUA's overcurrent protection scheme is typical of most municipal electric utilities in that the majority of system overcurrent protection is provided by station mounted breakers or reclosers. These devices use ABB DPU2000R solid-state relays and the timing for station mounted breakers or reclosers are instantaneous, 15, 15, and lockout. Since most of the FPUA feeders are relatively short, typically downline hydraulic or electronic reclosers are not employed; however, the feeder that serves Harbour Branch Oceanographic Institute has a recloser installed halfway out on the feeder. Fuses are used on taps, riser pole dips, and on overhead polemounted transformers to provide additional sectionalizing and overcurrent support. Faults on the overhead system are interrupted by both vacuum and oil breakers, with oil breakers being replaced by vacuum units at a rate of 3 per year.

On the underground system, FPUA uses padmounted switchgear with SMU-20 fuses to protect 200 A taps. The 600 A taps are typically left unprotected. The padmounted transformers employ bay-o-net fuses to provide overcurrent protection. Fault indicators are installed inside of most padmounted transformers and at each riser pole. Overvoltage protection is provided by station mounted and overhead line mounted arresters as well as elbow mounted MOV's. Faults on the underground system are interrupted by both vacuum and oil breakers at the substations, with oil breakers being replaced by vacuum units at a rate of 3 per year.

The outage data provided by FPUA showed a reasonable amount of temporary outages by cause. It was also stated by FPUA that they had very low outage duration indices when the extreme storms category is excluded. The Fort Pierce area was struck by 2 major hurricanes, Frances and Jeanne, in 2004 which contributed to long outages of 3-7 days for most consumers. At Day 3 of the Hurricane Jeanne recovery, 40% of the consumers were restored and at Day 6, 95% of consumers were restored. Hurricane Frances restoration was approximately one day slower. The outage data provided by FPUA showed that there were 8,712 trouble calls which indicated a temporary outage (defined by a breaker operation) during the time period from January 2002 through May 2005. The majority of these outage were caused by animal intrusion, bad connectors, customer fuse/breaker problem, equipment failure, lightning, storms, tree contact, vandalism, vehicle contact, and miscellaneous or other. Some of these outages can be mitigated though better inspections, right-of-way trimming, and by replacing dated equipment prior to failure. While you can never eliminate all momentary outages, these techniques can help reduce the number of trouble calls.

The goals of protection for overhead and underground systems are similar in nature, but are different due to the operation of the individual systems and the cost differential. The fundamental difference lies with the installation of the system protection and the operating environment. On an overhead system, most of the faults are temporary and are caused by tree or weather contact. Underground system faults tend to be permanent due to their installation and fault types. On an overhead system, the system protection is typically polemounted and can operate in air, as in the case of most fuses, or in a vacuum or oil for reclosers. On an underground system, the fuses are typically operated under oil. Padmounted reclosers can be purchased and operate under oil or in a vacuum similar to polemounted units. These units are

Solid blade disconnects on overhead line typically larger than their polemounted cousins, but are similar in interrupting capability. Due to the increased expense of padmounted switchgear and padmounted reclosers, they are used sparingly. Most padmounted switchgear units have to be manually switched or reset in order to isolate a fault or restore service. Searching for a fault on the underground system can be tedious, but the use of fault indicators inside of switchgear and padmounted transformers can aid in reducing outage duration by allowing operators to quickly find and isolate the fault. At the other end of the spectrum, automated switchgear units (VFI) can sense a fault and operate automatically to isolate the faulted section. These units are quite expensive and are hard to justify on strictly a cost basis.

Transformer Sizing

Transformers should be "right" sized for the anticipated or actual load. This will help with operating the system at maximum efficiency and reducing losses. A general guideline will be developed to assist in the determination of proper sizing based on industry standard parameters.

<u>Remain Overhead</u>

Pros: Cheap, dependable, easier to protect, relatively safe from human contact

Cons: Aesthetics, animal contacts, congestion on pole

Overhead transformer along S. Jenkins Rd.

<u>Convert to Underground</u>

Pros: Aesthetics, easily accessible, can accommodate more services

Cons: Protection, vandalism, human contact, shrubbery blocking access

Based on our drive through and tour of the FPUA system, most transformers appear to be adequately sized to meet loading requirements. Overhead polemounted transformers are conventional and employ a bracket mounted fused cutout and arrester to provide overcurrent and overvoltage protection along with maintaining 95 kV BIL. It was noted by FPUA personnel that the ANSI standard transformer mounting bracket does not appear to be strong enough to withstand the cutting forces of the mounting head bolts when the transformer is subjected to high winds. A possible solution is being tested for mitigation. This solution utilizes a factory made standard square washer that had the bottom cut out to look like a "U". PCB testing has been done on FPUA transformers as they are removed from service and none have been found. Most padmounted

Padmount transformer in backyard

transformers are typical oil filled units that rest on concrete pads. FPUA has opted to replace existing mild steel padmounted transformer cabinets with new stainless steel (304 Alloy) units to resist corrosion and rusting due to the coastal environment. Fault indicators are typically installed at each padmounted transformer to aid in isolating faults. Underground feeds to both three-phase and single-phase padmounted transformers are typically looped, with the exception being riser pole dips to a single padmounted transformer. New commercial service is provided underground to the customer via either a three-phase padmounted transformer or polemounted three-phase bank.

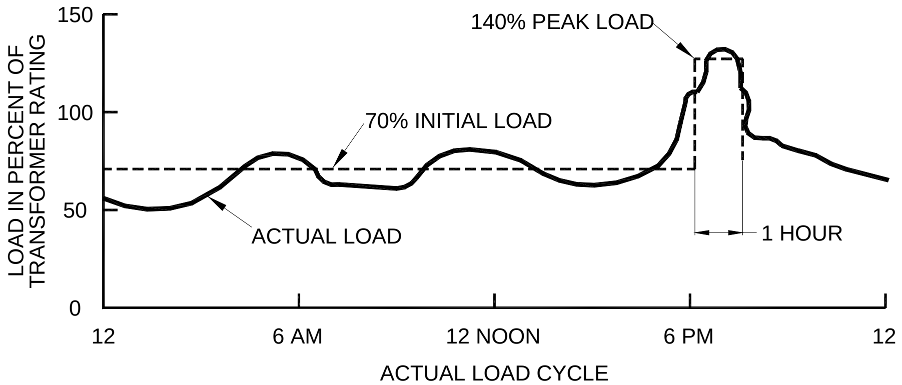
To size a transformer, it is necessary to have an understanding of the thermal loading characteristics of a transformer. ANSI C57.12.20 is the industry standard used to rate the size of a pole-mounted transformer. A transformer is designed to carry its rated load continuously over its expected lifetime at an ambient temperature of 30º C (86º F), without exceeding an average winding temperature rise of 65º C (149º F). Industry experience has shown that normal life expectancy under these conditions should be at least 30 years.

One of the important considerations to remember when applying load to a transformer is its ability to dissipate or expel the heat inside itself that is caused by the load current running through the transformer windings. The outside ambient temperature plays a significant role in cooling the transformer. So the hotter it is outside, the less the transformer can cool itself, and conversely, the cooler it is outside, the more the transformer can cool itself. Thus, it is possible to get more kVA load through a transformer in the winter than in the summer.

Other factors to consider when loading transformers include: the duration of the peak load and the level of pre-loading or initial load. An example of the effect of the duration of peak load is a truck's engine, which can be pushed past the tachometer's redline for a short period of time without damaging the engine. Similarly, pre-loading is like that same truck's engine being used for towing a heavy trailer all day, which will affect the engine's limit to be pushed over the redline.

The pre-loading for a residential transformer varies with the load on the transformer. However, an efficiently sized transformer will have pre-loading in the range of 80% to 90% based on the most recent twelve one-hour intervals prior to the peak load. The duration of the peak load is affected by the local weather conditions, which makes heating or cooling systems in a home run longer. Typical peak durations are two to three hours for residential loads as shown in the figure.

Example of Load Cycle. Source IEEE Std. C57.91-1995



When sizing a transformer, the peak load is estimated and compared to the available transformer sizes. For efficiency, it is generally recommended to fully load a transformer. In fact, it is common practice to select transformers that are anticipated to serve winter loads that slightly exceed their kVA ratings (110-120%). According to ANSI/IEEE Std. C57.91, a transformer with a four-hour peak overload and pre-loading of 90 % can be loaded to 136% of its nameplate rating in the summer (30º C) and nearly 173% of its nameplate rating in the winter (0º C). However, these high load levels (136% to 173%) are typically not used because the voltage drop through an overloaded transformer approaches the limit of allowable voltage drop. An overload of 25% in the winter and 10% in the summer is suggested herein.

Managing Losses

A discussion on the determination of sources of losses and their subsequent control will be addressed. Underground cables have losses from energizing current and capacitive currents. Unloaded cable or even lightly loaded cables still have losses. Typical sources and associated loss values will be developed from existing industry sources.

<u>Remain Overhead</u>

Pros: Large conductors reduce losses, capacitor banks are relatively inexpensive and available, polemounted transformers are typically loaded more effectively

Cons: Transformer core losses-occur even when not loaded, conductor heating reduces ampacity, many taps are only partially loaded

<u>Convert to Underground</u>

Pros: Capacitive charging currents reduce losses, underground systems are typically more right sized to prevent excess capacity, more adequate cable sizing

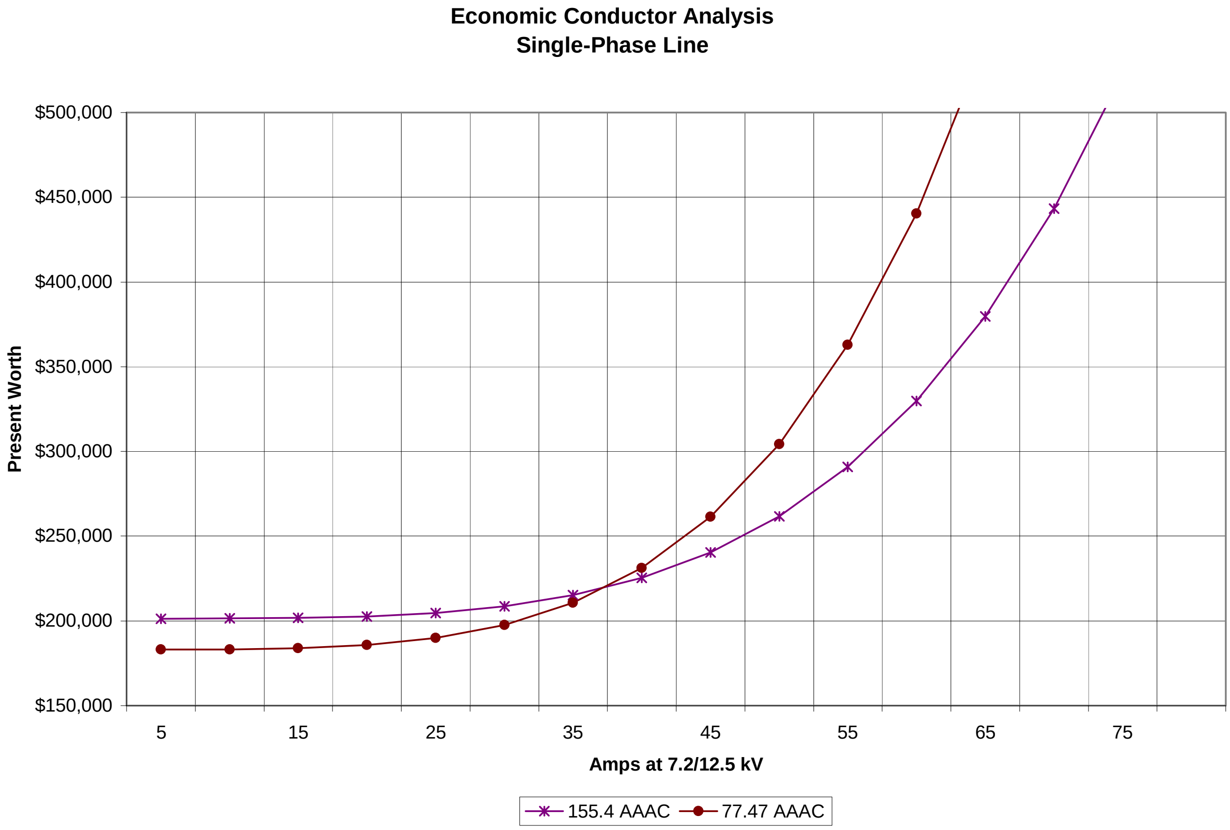
Cons: More expensive to implement power factor control, looped system may contribute to additional losses

The management of line and equipment losses is a very important subject for most utilities. Line losses represent lost kWh revenue that cannot be billed to the customer. FPUA has employed several techniques to manage system losses and to keep them to a minimum. Typical practices employed include using adequately sized conductors, the installation of station and polemounted capacitor banks, right sizing transformers, and de-energizing unloaded/abandoned line and transformers.

On an overhead system, losses can be minimized by employing prudent engineering practices. Transformers should be right sized and loading in accordance with IEEE Standard C57.91. A more detailed description of transformer loading can be found in the transformer sizing section. By following prudent loading practices and not overloading transformers for extended durations, losses can be managed effectively. It is also good practice to remove abandoned transformers as the core no-load losses can add up significantly. On overhead conductors, conductors should be right sized to the load they intend to serve. Line losses are characterized by the I^2R relationship. That means that as the current is doubled, the losses will increase by a factor of 4. Smaller conductors have higher DC resistances, which lead to increased losses over larger conductors with lower resistances. In addition, the affects of heating or cooling of the conductor affect its overall current carrying capacity. By installing conductors capable of serving the intended load and not overloading the conductor, losses can be minimized. The recommended ampacity levels of overhead conductors, based on IEEE 738, can be found in the conductor ampacity section. In addition, load should be balanced adequately across all 3 phases to minimize system losses.

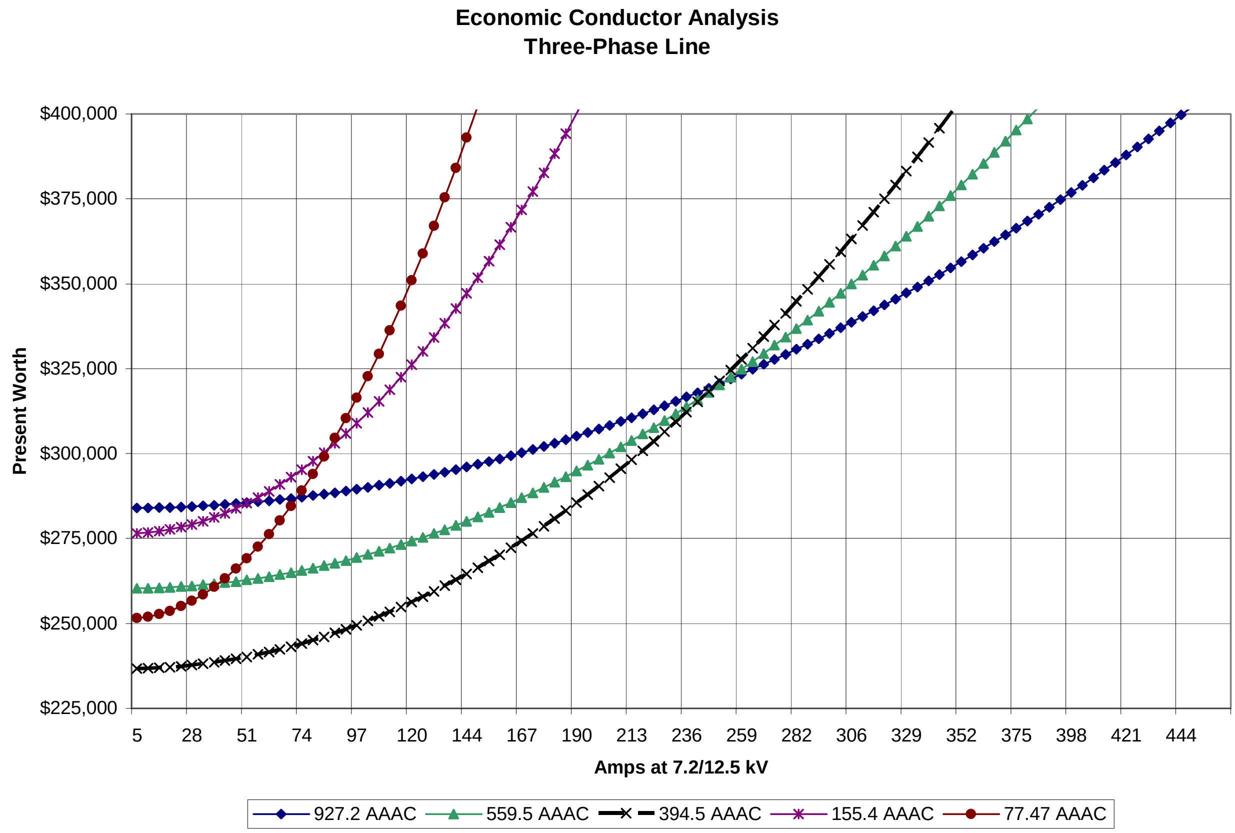
For underground conductors there are two main factors that influence the conductor ampacity, which in turn affects the amount of losses incurred on the cable. Like overhead conductors, underground conductors have decreasing DC resistances as they increase in size. In addition, copper conductors have less resistance than aluminum conductors of the same size. The affect of right sizing the conductor to match the anticipated load will once again affect the losses incurred on the affected cable. The second major factor affecting the ampacity level and losses on an underground cable is the installation method. The conductor can be direct buried in earth, installed in conduit that is direct buried, installed in concrete encased duct bank, or installed in a plastic or metallic riser pole conduit. Each of these installation methods limits an underground cable's maximum ampacity. A discussion of the allowable ampacities of direct buried cable and cable installed in conduit or in a riser pole conduit according to IEEE Standard 830-9/94 can be found in the conductor ampacity section. It is recommended that the installation method be taken into account when sizing underground cables to the specified load in order to minimize losses.

An analysis of the overhead conductors in terms of present worth economics was performed. There are many variables that influence the results of this analysis, but the main variables are the conductor resistance at 50 degrees C, wholesale kWh and kW prices, carrying cost, and discount rate. Other variables include operating voltage, growth rate, power factor, load factor, and initial loading. Analysis was performed for single-phase 200 A construction, which is typically constructed using 77.47 AAAC and 155.4 AAAC. A graph is included below to show the present worth analysis:



The analysis shows that the most economic conductor to use for single phase 200 A construction on the overhead system is 77.47 AAAC for loads up to 40 Amps. For loading beyond 40 Amps, 155.4 AAAC is recommended.

An analysis for three-phase construction using both 200 A and 600 A conductors was performed as well. FPUA builds their 200 A taps using 77.47 AAAC and 155.4 AAAC, while 600 A main trunk lines are constructed using 394.5 AAAC, 559.5 AAAC, and 927.2 AAAC. A graph is included below to show the present worth analysis:



By examining the graph above, we can see that 394.5 AAAC has the lowest present worth for all conductors up to about 240 Amps. Beyond 240 Amps, 927.2 AAAC becomes the most economical choice, thus bypassing the 559.5 AAAC conductor completely. It is recommended that three-phase 200 A construction utilize the larger 394.5 AAAC conductor, rather than the smaller 155.4 AAAC conductor, even though it will be oversized.

Analysis on the cost per mile estimates included in the “Costs” section of the report shows some interesting disparities between overhead construction types. This disparity is believed to be caused by the assumption that average spans for the 200 A overhead construction were estimated to be 100 feet, while 600 Amp spans were estimated to be 150 feet. This disparity in spans may be the reason why 200 A three-phase construction is more expensive than 600 A three-phase construction.

FPUA uses two primary sizes of underground cable: 1000 MCM AL UG and 1/0 AL URD. The larger 1000 MCM AL UG cable is used primarily for main feeder trunk lines while the smaller 1/0 AL is the cable used for looped and radial subdivision feeds as well as smaller commercial and industrial primary riser pole feeds. Since these two cables are used specifically for different applications, no economic conductor analysis was performed.

Substation Design

Substation design incorporating the possibility of underground sourcing will be discussed. Also, typical design alterations that can be applied to FPUA's existing stations will be investigated.

Remain overhead

Pros: Ease of operation, ease of repair, greater capacity with smaller cable

Cons: Exposure to severe storms, aesthetically displeasing to the eye

Convert to underground

Pros: The placing of the feed underground would allow for a lower profile structure thus improving aesthetics, more space could be made available for parks, playgrounds, or for other limited use

Cons: All transmission lines supplying Fort Pierce Utilities Authority are overhead no reliability improvement, extremely high cost to place facilities underground

Currently, the configuration for the majority of Fort Pierce Utilities Authority's distribution substations consist of a transmission line supplying the substation fed overhead and the 12 kV low side bus exiting the substation underground and rising on poles outside the substation. Some substations have the low side bus rise up on a pole within the constraints of the substation fence.

Although the possibility of placing the transmission supply feed underground exists, the process, however, has pros and cons. On the plus side, the placing of the feed underground would allow for a lower profile structure thus improving aesthetics. Depending on the location of the riser pole, more space could be made available for parks, playgrounds, or for other limited use. The buried section would not be exposed to the effects of high winds, heavy thunderstorms, or hurricanes. The problem though, is that the entire transmission system is not underground; therefore, the lack of exposure on the underground portion is nullified by the exposed portion of the system.

The cost involved in feeding the transmission system underground into a substation can rise rapidly. Several methods could be employed to bring a once overhead transmission feed underground but requires either major modification to the existing structure or installation of a new structure with moderate modifications to the existing structure. Another method is available for bringing an underground feed into the substation but is very costly and

Substation congestion limits construction possibilities places FPUA in a contingent situation. The method is the demolition and rebuild of an existing structure to accommodate an underground feed. This option will have the substation out of commission for several weeks while the work is performed, possibly placing FPUA in a very unpleasant position.

If the process of placing overhead transmission lines underground into substations was to be undertaken, the method that may have the least system impact could be the construction of a new structure in front of the existing structure. This will allow for the substation to continue operation while work is performed with only a short outage required to change over the feed. This will only work if the substation has sufficient room for an additional structure while clearances set by the National Electrical Safety Code are maintained.

Projects to underground transmission feeds into substations are not recommended. The benefits of doing this project are far less than the detriments. Reliability will not be positively impacted; most of the system remains overhead. Maintenance will not be any easier and longer outage times may occur if a cable fails. The cost of the endeavor would be high when factoring in the cost for cable, conduit, and trench. Adding in the cost of modification of the substation bus or possible erection of a new structure and the cost becomes much greater. In areas of high congestion, the placing of overhead transmission facilities underground may make sense; however, no such areas were discovered in Fort Pierce Utilities Authority service territory.

Ease or Difficulty of Construction in the Various Scenarios within the Service Territory

Safety Issues

Safety issues are very important concerns not just to the individuals that work on power systems, but also to the public that can come in contact with power systems. This issue becomes more important when converting overhead utilities to underground since the potential dangers are more exposed to the public.

Remain Overhead

Pros: Line is always visible, lines are above ground and generally away from the public, line crews are familiar with construction

Cons: Contact incidents can occur with ground problems, problems with pole failure or collisions with structures, sectionalizing equipment can fail to de-energize a downed line, susceptible to hurricane damage

Safety is always an issue

Convert to Underground

Pros: Conductor and equipment is typically below ground and locked in cabinet, insulation on cable offers some protection from accidental contact incidents if exposed, generally is less susceptible to hurricane wind damage

Cons: Cable can become exposed by vehicle accidents, hurricane storm surge can cause exposure of cables and cabinets to float, secondary cable faults due to storm surge

FPUA takes both employee and public safety very seriously. FPUA employees, especially linemen, are trained in the proper safety procedures which must be followed in order to ensure a safe working environment. Safety to the public is enhanced through monthly newsletters, word of mouth, and through the use of signs and stickers to make the public aware of the potential dangers that exist if contact is made with the electric distribution system. In addition, FPUA follows the safety practices outlined in the Safety Manual For An Electric Utility, 13th Edition, 2004. This manual outlines safety practices and procedures for electric utilities. Since FPUA does not have to adhere to OSHA safety requirements, this manual serves as a good guideline to keep crews safe.

FPUA employs linemen who are well trained in the safety procedures required for work around energized equipment. While most of the FPUA electric distribution system is overhead, there is a fair amount of underground located in office parks and subdivisions. Since overhead lines are strung high off the ground and away from the public, they are typically not a hazard as long as they are functioning properly and adequately grounded. It is important for the linemen to be aware of the safety considerations that come along with operating both overhead and underground equipment.

Overhead line safety is fairly straight forward due to the visible nature of the system and the familiarity with the construction. Most work on the overhead system is performed by linemen in insulated bucket trucks using cover up, grounding bonds, insulated shotgun sticks, and insulated hot line sticks to perform maintenance and construction. Vehicle contact incidents involving poles or low hanging wires can lead to energized lines becoming accessible to the public. It is important to remedy these situations as soon as possible to safeguard the public in case the overcurrent devices do not operate and energized conductors are exposed.

Guys on overhead lines can be hazardous to drivers

Underground systems on the other hand, are not as visible due to their installation. Since 90% of an underground system is below ground, it is easy to forget that contact incidents are not only possible, but they are likely if proper safety procedures are not followed. Above ground cabinets should be grounded properly and linemen should always use an insulated shotgun stick with elbow puller/installer when performing maintenance and construction while the line is energized. Underground systems are also not immune to vehicle contact and public intrusion. It is important to ensure that above ground cabinets are properly secured using the factory installed pentahead bolt and an approved locking device such as a padlock. While it is not possible to prevent vehicle contact with above ground equipment, the designer can help reduce the chance of an occurrence by employing prudent design techniques. These techniques include avoiding locating cabinets close to curbs, intersections, or curves along the roadway as well as maximizing allowable distance between cabinets. If the decision is made to convert the overhead system to underground, more line personnel will need to be trained to work on underground equipment and the public should be informed of the ever present potential dangers that underground cabinets and cables represent. The public should also be cautioned to not touch underground equipment and to not plant shrubbery or landscape around underground equipment. A safe distance around the underground device should be maintained so crews can safely operate the equipment as well as make repairs. Safety procedures should follow industry accepted guidelines.

Time to Construct

This issue is very important because it is necessary to reduce the frequency and duration of construction related pre-planned outages. It is generally accepted that underground construction takes longer than overhead construction, but there are several factors that can affect the efficiency and time involved in construction. These issues will be addressed in the report.

Remain overhead

Pros: Typically faster construction times do to the nature and familiarity with the work, ability to more easily adapt to construction impediments such as rough soil conditions

Cons: Location of pole may require a lineman to work from hooks

Convert to underground

Pros: Work is at ground level

Cons: Obstacles encountered during digging or boring, close proximity of equipment when making connections (secondary compartment of padmounted transformer may be tight), possible encounter with another utility which was miss marked

The amount of time required to construct either an overhead or underground line varies. As to be expected, the industry typically sees longer construction times for underground lines than overhead. Factors influencing the time of construction disparity include: familiarity with work, nature of work, subterranean excavations, restricted working space, and equipment involved.

Familiarity with work is a temporary hindrance to time required to complete tasks. Most linemen are familiar with overhead line work and have performed many similar tasks throughout their careers. Often, linemen have less experience with underground construction which relates directly to less efficient construction. However, as underground work becomes more prevalent and training increases, efficiency will increase, narrowing inconsistency between overhead and underground construction times.

The nature of underground electrical work is in part responsible for increases in construction time. Formation of connections and terminations require expertise, and, if improperly put together, can result in early, usually disastrous, equipment failure. As well as longer construction time, additional preparation work is required prior to making connections. The work is highly skilled and the worker needs to be meticulous in the installation process. Overhead line construction is a highly skilled job as well, but does not entail the greater detail required by underground installations. This aids in quicker completion times with overhead lines. As technology continues to advance, underground installations will become easier and less meticulous. This has already been observed with underground terminators. Before newer technology, underground terminators were hand made with silicone tape. Terminator construction was an art and required great attention to detail. The old method has been replaced by new technology that allows a lineman or underground installer to apply a terminator using a cold shrink terminator kit. What once took eight hours or more to complete can be accomplished in approximately one hour.

Subterranean excavations are likely the single most time consuming aspect of underground installation. Great deals of preparation and safety procedures are required as many dangers exist beneath the soil. When considering other underground utilities, it is important to remember that there is a possibility that the pipe or cable may have been marked in the wrong location. It is also possible that the exact location of some utility may not be known. Disturbance of underground utilities can also occur with an auger from a digger/ derrick truck; however, the auger is typically eighteen inches or less and is concentrated in one area. When excavating for underground installations, buckets are typically wider and longer, thus having a greater chance of encountering incorrectly marked buried utilities.

Where an overhead line requires multiple bores in many locations to anchor poles, the underground installation will typically be a continuous trench over a greater distance. If rock or other complicated soil condition is encountered, changing the location of a pole to another area would most likely be easier than moving a trench. Even worse, if a trench has been dug for some length prior to encountering difficult soil conditions, the change in the trench direction may create a cable pulling issue. As a result, the utility might incur greater costs by having to place some type of transitioning device in the location of the turn and begin another pull.

Many challenges not impeding overhead lines can arise from trenching, digging with backhoes, and even boring. Each of these occurrences adds time and cost to a project. These unknowns, along with underground congestion, are a possible setup for project frustration. Some of these conditions can be avoided with adequate pre-planning, such as test bores along the cable route, utilization of topographical maps, and choosing routes on opposite sides of heavily congested areas if practical.

The working space afforded by overhead lines is much greater than underground construction. Most times, an aerial device or digger/ derrick truck can access the pole line. If they cannot, the lineman can climb a pole and work off his hooks. Even if there are joint attachments, the spacing on the pole is such that a clear area is available for the lineman to access. With underground construction, the installer is working either in a trench, manhole or padmounted equipment. All these are restrictive in nature, causing the installer to be cramped in making connections. The lack of working space can be an impediment to quick installation of underground components or connections.

Even the equipment, and connections to it, can influence the time to complete tasks in the overhead and underground systems. Access to equipment connections and ability to get tools into locations is much easier in the overhead equipment. A multiple service tap connector for an overhead transformer is easier to handle and install than a z bar multiple service connector on a padmounted transformer. The secondary compartment of the transformer, although somewhat open, has no where near the access afforded a lineman installing the same type connector on an overhead transformer.

These differences can account for very little time or can cause a project to run over; however, one thing is certain, the time to construct is greater for underground installations than overhead installs.

Costs

The cost of construction is probably the single most important factor when deciding to convert an overhead system to an underground system. Traditionally, the cost to construct an underground system is at least double that of an overhead based system. Several factors can influence cost determinants and these will be discussed in terms of approximate unit prices for major equipment components in the report. These factors can be used to determine which design is more cost effective in terms of construction.

Remain Overhead

Pros: Cheap, easy to replace, readily available materials, minimal special equipment is required,

Cons: Frequent replacement after storm damage, frequent replacement due to damage from vehicles or vandalism,

Convert to Underground

Pros: Less likely to be damaged by storms, aesthetics can help offset costs in the publics mind,

Cons: High cost, components have longer lead time, cable pulling limitations can drive up costs,

Cost issues are some of the most challenging obstacles facing electric distribution designers today. The rising cost of copper, steel, and even wood and plastic continue to be a large factor in deciding which design approach to take. This is especially true when deciding to convert an overhead system to an underground system. Past experience has shown that underground construction typically runs at least double the cost of a comparable overhead system.

FPUA personnel have done extensive cost estimating to examine the cost differences between overhead and underground construction on both 600 Amp main trunk line circuits and 200 Amp taps. His research and estimates show that it might be feasible to construct new 200 Amp taps, both single and three phase, underground for approximately less or the same cost as overhead construction. Conversely, the estimates show that this is not true for the 600 Amp main trunk lines, of which are considerably more expensive to construct using underground construction equipment and techniques. A breakdown of these estimates is included below:

	Material Cost*,**	Labor and Equipment Cost*,**	Engineering Cost*,**	Total Cost*,**	Total Cost (per mile)**
600 Amp Segments					
Overhead 3Ph	$ 9.75	$ 10.33	$ 1.52	$ 21.60	$ 114,058
Underground 3Ph	$ 53.87	$ 29.09	$ 1.52	$ 84.47	$ 446,022
200 Amp Segments					
Overhead 3Ph	$ 8.70	$ 12.71	$ 1.52	$ 22.94	$ 121,107
Overhead 1Ph	$ 5.08	$ 10.11	$ 1.52	$ 16.70	$ 88,201
Underground 3Ph	$ 6.22	$ 5.57	$ 1.52	$ 13.31	$ 70,254
Underground 1Ph	$ 2.74	$ 4.31	$ 1.52	$ 8.57	$ 45,262

*All values are per foot
**Transformers not included

It should be noted that this analysis doesn't include the cost of transformers. If transformers are included, it is expected that the cost per mile pricing gap between overhead and underground 200 Amp construction would shrink. This increase in underground construction cost would be caused primarily by the increased equipment cost for padmounted transformers over conventional polemounted units and the increased cost to install cable terminations. In addition, it is believed that the estimate for underground assumes radial feeds. If looped feed construction is used, the pricing should go up for underground construction. Also, analysis on the cost per mile estimates shows some interesting disparities between overhead construction types. This disparity is believed to be caused by the assumption that average spans for the 200 Amp overhead construction were estimated to be 100 feet, while 600 Amp spans were estimated to be 150 feet. This disparity in spans may be the reason why 200 Amp three-phase construction is more expensive than 600 A three-phase construction.

Existing Underground Congestion

Underground congestion is a major problem when installing a new underground power system. There is only so much space available within a right-of-way. By placing the electric distribution system underground, the designer must maintain vertical and horizontal clearance requirements as well as depth requirements in relation to other utilities. Severe congestion can lead to the use of expensive concrete encased duct bank to meet these requirements, which can be very cost ineffective. Comments regarding techniques to minimize this risk will be addressed along with the affect of this congestion on restoration.

<u>Remain overhead</u>

Pros: Can locate pole line outside areas of congestion

Cons: May place you outside of the road right of way thereby requiring obtaining an easement

<u>Convert to underground</u>

Pros: Aesthetically pleasing, joint trench possibilities

Cons: Prescriptive rules of the NESC, high cost which may be escalated by concrete encasement requirement, more likely to have a dig in

The amount of space available underground is yet another factor to consider when measuring the feasibility of placing overhead electric distribution lines below the ground. Many other utilities which are typically overhead have made strides to place their facilities underground. This coupled with the customary utilities found below surface such as water, wastewater, and natural gas has led to underground congestion.

The National Electrical Safety Code (NESC) Part 3 Safety Rules For Underground Lines, Section 32 Underground Conduit Systems, Rule 320.B. addresses separation from other underground installations. According to the NESC, "The separation between a conduit system and other underground structures paralleling it should be as large as necessary to permit maintenance of the system without damage to the paralleling structures."

The separation between the electric conduit and conduit used by communications companies is three inches of concrete, or four inches of masonry, or twelve inches of well packed earth. Where a conduit crosses a sanitary sewer or storm drain, the NESC requires suitable support for the conduit on either side of the pipe. Where a conduit crosses a water line, the conduit should be installed as far away from the water main as possible as to prevent undermining of the conduit system by a water leak and aid in the prevention of accidental dig in when repairing a water line. When a conduit is in proximity to natural gas or other fuel lines, the separation should be large enough to allow for maintenance equipment utilization without adverse impact to the surrounding natural gas or other fuel pipe.

If the cable is direct buried, it should be located "so as to be subject to the least disturbance practical." When cables are installed near other underground facilities, NESC Rule 353 or 354 will be applicable. NESC Rule 353.A.1. applies to "...radial separation of communications cable or conductors from each other and from other underground structures such as sewers, water lines, gas and other fuel lines, building foundations, steam lines, etc., when separation is equal to or greater than twelve inches."

The separation should be great enough to allow for maintenance equipment utilization without adverse impact to the surrounding underground structures. When a cable crosses under another underground utility, "...adequate support may be provided by installing the facilities with sufficient vertical separation." When the cables are parallel to other underground utilities, adequate vertical separation is required to allow for maintenance equipment utilization without adverse impact to the surrounding facilities.

Underground congestion creates unpleasant scenery and possible touch potential issues

Taking into account NESC requirements, space decreases very quickly. The adequacy of separation will determine whether or not to underground and what alternatives exist. Some alternatives to the high congestion issue are encasement of duct banks in concrete, directional bore deeply to be below all other underground facilities, obtain easement on private property outside the congested area, or leave the overhead system as is. The least cost method for resolution of high congestion areas is to leave the overhead distribution line as is. The most costly resolution is to obtain an easement outside the road right of way. The next most costly would be encasement of the duct bank in concrete. Directional boring would fall in between encasement and leaving the existing overhead line.

Fort Pierce Utilities Authority has an advantage over most, as the provider of all municipal services (water, wastewater, and electric) congestion issues may be easily resolved. In addition, any new work performed will be known and use of joint trench may be explored for cost savings in the placing of overhead facilities underground.

Maintenance of Traffic

The maintenance of traffic is an item of great importance because it impacts a large portion of the public within the City. In order to reduce traffic related delays and create a safer work zone, the industry accepted Manual on Uniform Traffic Control Devices (MUTCD) Part VI Construction, Maintenance, Utility and Incident Management is a good guideline.

Remain overhead

Pros: Work is typically quicker reducing time of inconvenience to the public and exposure of the worker to traffic hazards

Cons: Typically the work requires equipment to be in the roadway, workers in an aerial device are more susceptible to injury from errant drivers (cannot move out of the way), the work can be at night creating a new set of difficulties and hazards

<u>Convert to underground</u>

Pros: Most of the work occurs outside the roadway on a shoulder, impediments to traffic are minimal, and directional boring reduces the impact on traffic even further

Cons: Workers are closer to traffic, may be in the trench not aware of hazards approaching

Compared to surrounding areas, The City of Fort Pierce, Florida is experiencing a higher than normal growth rate. The growth has increased traffic along its already busy roadways. In addition to the many busy local roads, FPUA also has major county and state roadways running through its service territory. The influx of traffic poses logistic and safety concerns for crews installing facilities along these roadways.

The Manual on Uniform Traffic Control Devices Part VI titled *Construction, Maintenance, Utility and Incident Management by the U.S. Department of Transportation Federal Highway Administration* is used by many states and municipalities as a guide for traffic control standards. The State of Florida Department of Transportation adopted the national Manual on Uniform Traffic Control Devices (MUTCD) as the minimum requirements for a uniform system of traffic control devices for the State of Florida. This manual may benefit the FPUA when working on the busy roads within their service territory. The manual, at a minimum, describes fundamental principles for the protection of workers and guidance of motorists in a clear and positive manner while approaching and traversing construction and maintenance work areas. The manual also assists in planning work zones so as not to inhibit the response of emergency vehicles. Improved motorist performance may be realized through a well prepared and complete public relations effort that covers the nature of the work, the time and duration of its execution, and its anticipated effects upon traffic. Such programs have been found to result in a significant drop in traffic; reducing the possible number of conflicts.

Based upon a site visit performed, FPUA may expect the following typical work zones: beyond shoulder, on shoulder with shoulder taper, on a two-lane roadway with low traffic volume with and without a flagger, with limited vision (curve), and a zone closing one lane of a multilane highway without a median. All these scenarios are addressed in the MUTCD with appropriate traffic control measures to maximize safety and minimize impact to the motorists.

It is important to note, traffic control is not just for the installation or repair of underground facilities. Overhead facilities, located on road rights of way, are just as susceptible to work zone dangers. There is typically more exposure to workers on the ground to vehicular conflicts as workers may not be seen as easily as overhead equipment. This is important to understand and to counteract by wearing the latest approved reflective vest.

Crossing Streets

The need for crossing streets is as necessary on the underground system as it is for an overhead system. There are several methods available for underground construction including cut and patch as well as directional boring. The merits of each of these crossing methods will be discussed in more detail in the report.

Remain overhead

Pros: Much easier to cross a roadway aerial, just need to maintain proper clearance over roadway according to the NESC

Cons: Roadway crossings detract from the scenery, may pose impediments to safe vehicle passage

Convert to underground

Pros: Multiple ways to cross a roadway (can choose least cost method)

Cons: Cost of roadway restoration, bore send and receive pits, control authority for roadways

When designing an underground electric distribution system, crossing a street is inevitable. There are several methods that may be utilized to design an effective roadway crossing depending upon some key factors. Factors to be considered include: material used to construct the roadway (gravel, concrete, or tarmac), future work planned on the roadway, and traffic patterns.

The material used in the construction of the roadway is important in determining how to traverse the designated roadway. When dealing with gravel roads the least cost method is to plow or trench. Repair to the roadway would consist of backfilling the trench and compacting the soil in 12 inch lifts. Additional material may or may not be required. The use of a directional bore is an option, and will perform the task with little or no restoration required; however, the cost of directional boring is several times greater than trenching or plowing.

As with all excavations, the controlling authority for the roadway should be consulted prior to digging and all restoration parameters discussed.

When crossing a roadway constructed of concrete, additional obstacles to excavation are present. The least cost method in this instance would be boring, due to the high restoration costs incurred when the concrete surface is broken. If a cut and patch method is utilized, a concrete saw or jack hammer may be needed to break up the concrete. Furthermore, some concrete roadways employ reinforcing rods throughout. If reinforcing rods are encountered, the use of a saw with a metal cutoff blade will assist the excavation process by easily cutting the reinforcing bars. Once this is accomplished, the trench can be excavated and conduit lain.

Restoration of the concrete roadway can be an involved process, especially if reinforcing rods are employed. Typical repairs include compaction of the soil, typically in 6 to 12 inch lifts, pouring concrete to a flush depth, and surface preparation. Floats will be required to smooth the road service. Aeration of the concrete is necessary to ensure uniformity and consistency of mixture. Proper water to aggregate mixture, known as slump, will be required; the governing agency for the roadway should be consulted for the mixture ratio required. If the roadway includes reinforcing rods, the rods will need to be replaced, being tied to existing rods using tie wires. Check with the governing roadway agency for specific requirements. If boring is utilized, many complications to the crossing are avoided. A sending pit, possibly even a receiving pit may be required to launch and receive the bore. The boring method is very cost effective for crossing concrete roadways, saving much money in restoration efforts, even though a higher initial cost exists.

As with any crossing of a roadway, restoration to original existing condition is mandated. Methods such as cut and patch, and to some extent boring, require some level of remediation. More work is required in restoring conditions to original with the cut and patch method, especially when crossing a concrete roadway, as indicated above. Remediation of bores crossing a roadway is less costly, but does require some earth work, typically reseeding. The plowing of gravel roads is not usually an issue, as much attention is not given to these road types. Any of the methods employed in crossing a roadway can involve re-work. The most common method requiring a second visit is cut and patch. With the cut and patch process, typical re-work consists of a sagging patch or insufficient patch material. This requires crews to revisit the site, take corrective action, and monitor for further issues. The most common complaint seen with boring is the washout of a sending or receiving pit. This will require a crew to revisit the site, typically add soil, smooth and possibly place some sod, or maybe some hay bales to prevent erosion. This is typically encountered on or adjacent to a sloped area.

Table 1 Matrix to Assist in Determining Least Cost and Effort Solution for Crossing Roadways with Underground Electric Facilities

Roadway Material	**Cost Level to Cross Roadway (1-Low, 3-High)**			**Level of Difficulty Crossing Roadways (1-Easy, 3-Difficult)**		
	Bore	*Cut & Patch*	*Plow*	*Bore*	*Cut & Patch*	*Plow*
Gravel	2	1	1	2	N/A	1
Concrete	2	3	N/A	2	3	N/A
Pavement	2	1,2*	N/A	2	2	N/A

* Dependent upon restoration effort required.

As evidenced in Table **1**, the least cost method for crossing a gravel roadway is plowing, followed by boring. Cut and patch is not employed, seeing there is no material to be cut. The least cost method for crossing a concrete road is boring, followed by cut and patch. The higher initial cost of boring is offset by savings found in site remediation. Plowing is a viable option only for gravel crossings. The least cost method for crossing a paved roadway may either be cut and patch or boring. The remediation of roadways to original condition may or may not exceed the higher initial cost of boring. The cut and patch process is the lower cost method when crossing a roadway slated for repaving or reconstruction. Key factors in determining the feasibility of cut and patch over boring in pavement is the roadway usage, location, and standards of restoration. The less frequently traveled roads, further from population centers, receive less complaints, and road restoration standards are more lenient.

Working in Back Yards

The need to work in backyards is not always necessary as it may be possible to locate underground equipment on property lines along the street. The pros and cons of locating facilities along the back property lines of homes will be discussed more thoroughly in the report.

Remain overhead

Pros: Customers appreciate not seeing the equipment in front of their homes, typically no other utilities present

Cons: Access is difficult at best, yard restoration costs can be high, damage may be done just by bringing a vehicle in the area, obstacles such as fences and pools to contend with

Convert to underground

Pros: Customers appreciate not seeing the equipment in front of their homes, typically no other utilities present

Cons: Access is difficult at best, yard restoration costs can be high, damage may be done just by bringing a vehicle in the area, obstacles such as fences and pools to contend with

Construction in backyards can be arduous, particularly if construction includes use of heavy machinery. Access to backyards is sometimes limited and often requires site remediation just for moving equipment behind property. Backyards often have more standing water than along roadways, as roads commonly are raised to prevent flooding. In this situation, construction along road right-of-way will save time and money spent on dewatering methods; however, if construction in a backyard is unavoidable, additional factors must be taken into account.

Common obstacles found in backyards include: fences, pools, gardens, patios, and sheds. Fences are very common and create a

Access to this transformer is limited.

boundary for linemen to work around. When a backyard is fenced, access to the area may be greatly limited. When a fence is present there may be animals loose in the backyard, this might limit line construction to only when the resident is present.

Pools are a major obstacle. Constructing lines over pools is not a recommended practice and requires adherence to more code requirements. Gardens, patios, and sheds are also considerable obstructions and must be taken into account when planning construction. Location of machinery for both underground and overhead construction may be difficult if numerous obstructions are present in the area. Mini-backhoes or bobcats with bucket attachments may be utilized if work space is limited.

Site remediation for backyard construction can be very costly. A few precautions may be taken to lower post construction costs. When working around pools, gardens, and patios, sheeting can be used to avoid contact damage and help keep areas clean. Also, in areas with soft lawns or where no lawn is present, planks can be laid to prevent path erosion.

Because the cost of site remediation in backyards can run so high, underground construction with a subterranean bore may be preferred. The bore will minimize post construction costs. In the case of equipment failure, small corrections to equipment may be easier on padmounted transformers, but if work requires replacing a transformer, or unearthing buried line, overhead lines may be preferred.

At times, building lines behind houses may be favored. If easements for backyard construction can be acquired, and if machines can be easily operated on site, backyard construction may bypass obstructions found in front yards. Driveways, especially paved, can slow trench excavation greatly and are often not present in backyards.

Need for Dewatering

Dewatering is often necessary in areas with high water tables. This technique prevents a trench from cave-in due to water penetration and allows a hole for a manhole or vault to remain open long enough to set the equipment. Dewatering is a risk variable in the cost estimate and will be address as such.

Remain overhead

Pros: Typically no adverse impact for overhead equipment

Cons: Access for vehicles to install the equipment is adversely impacted, damage to property from accessing a line through a wet area can be extensive especially if a vehicle becomes mired

Convert to underground

Pros: Typically boring operations are not adversely impacted, increases safety by decreasing chance of cave in

Cons: Trenching and open cutting is difficult, expensive pumps or methods required to remove water from area to perform underground operations

Construction in areas with high water tables or areas with extensive groundwater is often deterred by cave-ins in trenches or holes. To avoid possible collapse during construction, dewatering is used to remove excess water from the construction worksite. A few different methods for dewatering are available. Selection of methods is dependent upon location, type, size and depth of construction, as well as soil type and water level.

Main dewatering techniques include: barriers, sump and ditches, wellpoint systems, deep-well systems, and cutoffs. Consideration of dewatering devices is important in cost evaluation as a large range in price exists between dewatering methods. One approach may be as cheap as purchasing several hay bales to form barriers, while another might require excavation of a deep well for subsurface draining. If an area has a high water level on record, or if an area appears to be overly soggy, knowledge of dewatering systems will be useful.

Above-surface walls blocking runoff from nearby sources are considered barriers. In most cases, barriers are the cheapest solution to waterlogged areas; this is only effective in areas with surface water that drains adequately when a nearby source is rerouted. In areas requiring additional drainage, sump and ditch formation may be employed. A sump is a low-lying area that may be constructed to pool runoff water. A sump pump may be used to remove some water from the sump and allow for additional drainage. When digging ditches and sumps in residential areas, it is imperative to designate appropriate site remediation. If possible, ditches must be refilled after utility construction.

For higher water tables and areas where barriers and ditches are not effective, wellpoint drains may be constructed. These drains are, in the simplest form, 2-4 inch drain pipe with screens on the sides and an open bottom. Sections of wellpoints may vary in length. These drains may be used in tiers; each tier is possible of reducing the water level up to 15 feet. In areas with low soil permeability, wellpoints can be equipped with vacuums to ensure drainage. In locales with high water levels and extensive construction, deep-wells may need to be excavated. The use of an auger may be employed as well as some previous dewatering method to be used during well construction. The deep-well will ensure a lower water level, but will be more costly than most other dewatering methods.

Wet areas in Florida present greater risks.

Cutoffs are in effect barriers built below surface. Sheet metal driven below surface can be an effective cutoff wall for construction in small areas. Slurry wall is also a form of cutoff, but is mainly used for construction of large underground structures such as tunnels and channels.

Soil Conditions

Certain soil conditions are better suited for underground systems than others. Hi-Line will discuss construction techniques for different soil conditions in the report.

In addition to effecting underground power lines by varying water drainage, soil types have a direct effect on the ability to lay underground lines. Different soil conditions can make it harder or easier to lay underground power lines as they require different equipment. Plows, trenchers, backhoes, and subsurface bores are common machinery used to dig underground paths when laying wire. The type of machine needed should be calculated into cost analysis as well as project planning.

In areas with little ground disturbance a plow may be used to lay wire. The plow is the most efficient method for laying underground wire; however, it can only be used in areas with enough access room and with favorable soil conditions. Little ground disturbance can be classified as sand or sandy-loam with a few rocks, but nothing to interrupt the plows path. If the plow is blocked or if the plow is pushed upward, the procedure must be stopped and a sufficient length of cable inspected for damage.

Sandy conditions with small gravel

On sites with large disturbances such as boulders or with soil types of clay or gravel, a trench digger or even backhoe may need to be used. The trench digger is an efficient method of installation but does not operate as quickly as the plow. When using a backhoe for very high ground disturbances it is important to adjust the worksite to allow enough room for the large machine. Use of backhoes should be limited, as they are expensive to operate and require large crews.

Subsurface bores will minimize surface damage and therefore may prove to be more cost effective when factoring in the cost of onsite remediation. However, if the soil is rocky, the bore will require a larger rock bit; this addition will add an average of $15 per foot to the cost of subterranean boring. Boring in rough soil conditions will also be slower than boring in sand or loam.

Overall, soil conditions in Florida consist mostly of sand. Some areas in central and northern Florida have soil ranging from sandy-loam to sandy-clay. In areas with adequate room, plows may be utilized with an occasional trencher. In either case it is important to remember to surround every cable with enough compacted sand to insure proper operation and protection.

Different Types of Equipment Needed for Overhead and Underground Construction

There are several key pieces of equipment that are necessary for both overhead and underground equipment maintenance and installation.

Remain overhead

Pros: Equipment already exists, linemen are familiar with their operation and capabilities

Cons: New equipment is always coming out to make linework easier requiring additional training time

Convert to underground

Pros: Equipment costs are typically less expensive than its overhead counterpart

Cons: May require new and unfamiliar equipment or specialized training

A variety of equipment exists for construction of overhead lines. Heavy machinery mainly includes: augers, which are used to bore holes for burying poles, and bucket trucks, used as lift devices for linemen. Many types of bucket trucks are available. Different types include: telescopic boom, telescopic with material handling, telescopic articulating, and over-center and non-over-center material handling trucks. On sites with no large access point or when using a bucket truck may be of inconvenience to residents, climbing gear may be utilized to allow the linemen height and flexibility to connect wires or repair devices after the pole has been set. When pulling wire, a wire tensioner is useful in tensioning cable to set levels, limiting sag, and complying with safety and construction standards.

For underground construction a great range of equipment is also available. When building in ideal soil and water level conditions, plows are most efficient in laying cable. Plows require relatively straight lines and wide paths to operate. The next most cost effective method is normally a trench digger which may be used when space and soil type are limiting factors. Backhoes are the least cost effective method of laying cable, as they are expensive to run and require a well trained crew. In the event of a road crossing, backhoes may be required as well as a jackhammer to break road surfaces. Subsurface bores may be used. As with backhoes, bores require a well trained crew, but significantly lower the cost of site remediation. The cost of boring increases in areas with rough soil or where large rock is buried.

In addition to machinery to excavate line paths, other items must be used. When constructing and operating within a manhole, numerous instruments are required. Safety tripods to which a winch can be attached and mounted over the manhole provide safety lines to be attached to the lineman entering the hole. A ventilation system is essential in order to provide a sufficient supply of oxygen to workers below ground level.

Numerous construction and safety equipment is used on both overhead and underground work. Pole trailers are utilized to deliver poles to the construction site and take away existing poles if applicable. Skidders can be used for site preparation or for working in unfavorable soil or terrain conditions. Hot line insulator washers are available with buckets or for use at ground level. The use of washers clears insulators of debris and residue and helps maintain quality delivery service by preventing against device failure. This is especially important in areas close to salt water, where the spray can affect the insulation value and possibly cause flashover. Harnesses for pole climbing, bucket and underground work are required by OSHA; however, most municipal utilities are not governed by OSHA rules. The American Public Power Association Safety Manual requires the use of harnesses and other safety equipment further discussed in the safety section of this report.

Different Labor Skills Needed

As with any new or unfamiliar activity, new skills will need to be learned in order to maintain an underground system. However, most of the basic safety skills required to work on an overhead system still apply.

Remain Overhead

Pros: Crews are already trained, overhead is most common and thus all lineman know the construction

Cons: None

Convert to Underground

Pros: Crews will be better trained and skill sets can be increased,

Cons: Possible dangers associated with unfamiliar working environment

Both overhead and underground electric distribution system construction require different sets of labor skills in order to construct the system properly and to ensure safety. In addition basic safety skills apply to both types of construction. FPUA contracts out most major line construction for both overhead and underground projects; however, the do employ skilled linemen who are trained to work on both types of systems. This is necessary to be able to perform maintenance and repairs to both systems. It is suggested that FPUA continue annual training programs for line personnel to ensure that labor skill sets are honed and that safety is being maintained.

In addition to normal safety procedures and skill sets, a conversion to a primarily underground system will require the acquisition of several new skill sets. These skill sets include the knowledge of working on underground cable and equipment as well as confined space training and equipment. Working in confined spaces, such as vaults or manholes, require special training and equipment. It is suggested that a professional instructor be hired to conduct in depth classroom training as well as hands on field training. In addition, the following items will be needed to train linemen: gas detection unit, manhole barricade, rescue tripod & harness, blast blankets ventilation/blower, ladders, lighting, and underground tooling. Once training is complete, these equipment items can be used for actual work in the field performing maintenance and construction.

Restoration

An underground system by nature lends itself to fewer outages than an overhead system due to several factors such as less exposure to weather events and increased reliability of system components. The disadvantage of an underground system would be the inability to see the fault within a cable or piece of equipment. Because of this, an overhead outage is easier to repair and correct than an underground outage. Response time can be decreased through the use of fault indicators and a SCADA system. The pros and cons of restoration for each system will be discussed in further detail in the report.

Remain Overhead

Pros: Restoration after storm damage is enhanced due to availability of materials and labor, problems can be seen easily since overhead lines are visible, accessibility

Cons: Problems with downed power lines remaining energized, congestion, longer outage duration

Convert to Underground

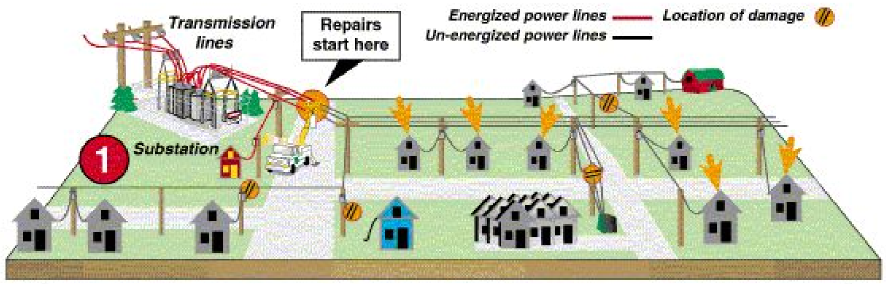
Pros: Short or no outage duration, not as susceptible to storm winds,

Cons: Susceptible to storm surge, equipment requires long lead time, difficult to repair and install while ground is flooded,

Electric utility's often say that job number one is to "keep the lights on". This old adage is certainly true and becomes extremely important in the event of an outage, when system restoration is the utility's top priority. Fast restoration of electric service keeps customers satisfied and reduces complaints. The timely restoration of service also keeps reliability indices within accepted ranges and generally promotes a sense of accomplishment for the utility.

The restoration of overhead systems is usually timely due to the visible nature of the fault cause. The use of SCADA and sectionalizing devices also enhance the chances of isolating and locating a fault quickly in order to restore service in a timely fashion. Since most overhead faults are temporary in nature, restoration times are typically lower than on underground systems. FPUA's system is primarily overhead, so their linemen are more familiar and comfortable with overhead construction which translates into a steadier work pace. Restoration work is aided by the use of detailed maps that show line routes and the location of key sectionalizing equipment. Work on primary trunk lines takes precedence while taps and services are restored in order as the crews work from the substation out. As FPUA moves forward with new construction and replacements, more and more concrete poles are being substituted for standard wood poles. These new concrete poles are stronger than conventional wood poles and tend to fare better against the hurricane force winds that are a constant threat during the summer and early fall months. A graphic of the overhead power restoration process is included on the following page:

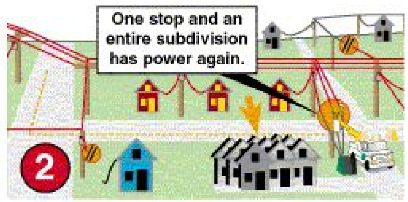
A major storm has just hit this electric distribution system. Here's a simplified look at how your utility typically goes about the task of restoring electric service.

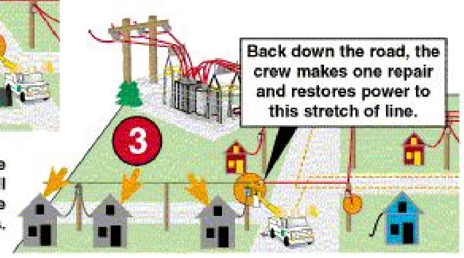


Step 1: The substation is energized but a main distribution line is damaged near the substation, leaving most members without power.

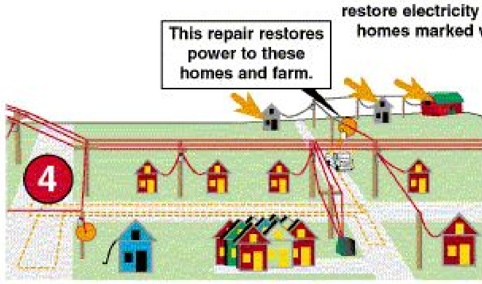
All repairs start with the main line. A large number of members (shown with orange arrows) will have power returned once the main line is fixed. All other repairs would be pointless until this line is restored as it feeds all the other lines.

Step 2: With the main line restored (now shown in red), the line crew can isolate other damage and prioritize re-pairs. Though a couple of repairs were closer, fixing the line that serves this subdivision down the road will get a larger number of consumers on more quickly.





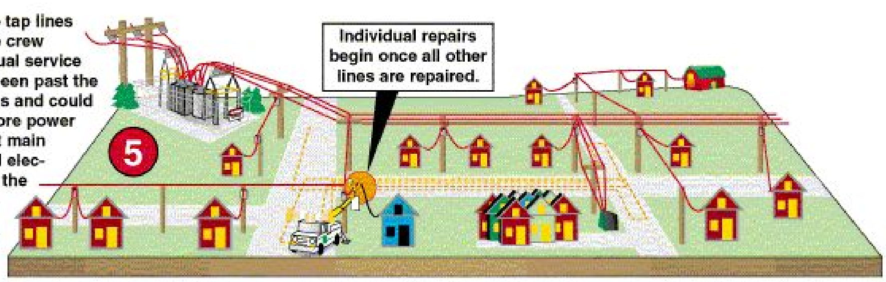
Step 3: Moving back down the road to fix this tap line will restore electricity to the three homes marked with arrows.



Step 4: A smaller tap line serving a number of homes and the farm on the hill is next on the list for the line crew. The move probably doesn't make the folks in the blue house too happy. They've seen the crew driving by their home and working right across the road. They see lights in homes of all their neighbors but they don't have power!

That's because even though electricity is coming to their pole (that happened with the first repair in Step 1), the service line from their pole to their meter is damaged. Individual repairs come after all distribution and tap lines are restored.

Step 5: Only after the tap lines are repaired does the crew start work on individual service lines. The crew has been past the blue home three times and could have stopped to restore power anytime after the first main line was repaired and electricity was flowing to the pole nearby. But it's not fair to other members for a crew to spend hours fixing one outage, when the crew can move down the road and restore power to dozens of homes in the same amount of time.



Electric Consumer graphic by Richard G. Biever

Underground systems are less susceptible to temporary faults due to their insulated design, but when faults do occur, they are permanent in nature. The restoration of service for underground components can sometimes be more time consuming due to the hidden nature of the construction. Sometimes replacement of a section of faulted cable or equipment is necessary before the system can be restored. The addition of fault indicators on riser poles and padmounted transformers can significantly decrease restoration times. It is suggested that FPUA continue its practice of installing fault indicators inside of switchgear and padmounted transformers. These devices assist in isolating the faulted section of cable and are fairly inexpensive to purchase and maintain. In addition to fault indicators, automated switchgear and padmounted reclosers can be purchased in order to aid in isolating faults and preventing fault current damage to equipment.

Alternatives for Telephone and CATV Attachment

There are typically two alternatives for the continued operation of joint use utilities after a decision has been made to convert to underground. The first most obvious choice would be for the utilities to be buried alongside the electric system during installation. The second and least desirable option would be to transfer ownership or sell remaining electric poles to the joint use utilities and allow them to maintain their facilities overhead.

Remain Overhead

Pros: Joint use agreements help offset costs, accessibility

Cons: Joint use loading reduces available pole strength, clearance issues, contact problems

Convert to Underground

Pros: Joint trench agreement offsets utility burial costs, separation is maintained,

Cons: Electric is buried while cable/phone remains on pole (aesthetics), dig ins,

Joint use attachments continue to be a major cause of problems for electric utilities. Communication attachments such as phone and cable often create clearance issues and pole loading problems. On FPUA's system, Bellsouth's cables exist on 5,305 of FPUA's poles and FPUA attaches to 4, 343 of Bellsouth's poles. As the current joint use agreement expires in 2008, it is expected that FPUA will migrate away from Bellsouth owned poles and will set new poles that Bellsouth will need to be transferred on to. Even if a conversion to underground is not planned, a formal inventory and tally of joint use attachments on FPUA poles should be completed prior to the altering or drafting of a new joint use agreement as existing agreements expire.

If a conversion of the FPUA overhead system to underground were to take place, joint use attachments would have two options. These two options include burying the communication cables in a joint trench with the electrical system, while maintaining adequate spacing and secondly, remaining attached to topped off poles that FPUA will transfer to the communication utilities once conversion is complete. Obviously, the better choice would be for all utilities to be buried underground, if it is decided that electric will be converted. As long as spacing is maintained as per the NESC, joint trench burial can be very economical because all involved utilities will share the cost. Each utility can benefit from this arrangement and aesthetics in the community, as well as property values, are increased.

Operating and Maintaining the Two Different Types of Systems

Safety

Safety issues are an ongoing concern when operating an electric distribution system. It is the utility's responsibility to make sure that a safe work environment is maintained for its workers and to ensure that the public is protected from any dangers associated with operating the system.

Remain Overhead

Pros: Away from the public above ground, lineman are familiar,

Cons: Subject to weather, car contact incidents, lines down, grounds on pole, guy wires becoming energized

Convert to Underground

Pros: Conductor is insulated and cabinets are secure, doesn't require bucket to work,

Cons: Equipment and conductor are closer to the public, access issues with shrubbery around cabinets, conductors are buried and not easy to locate sometimes, touch potential hazards

FPUA takes both employee and public safety very seriously. FPUA employees, especially linemen, are trained in the proper safety procedures which must be followed in order to ensure a safe working environment. Safety to the public is enhanced through monthly newsletters, word of mouth, and through the use of signs and stickers to make the public aware of the potential dangers that exist if contact is made with the electric distribution system. For additional information on safety, see the "Safety Issues" section of the report.

Vehicle Versus Facility Issues

The contact between vehicles and utility poles or padmounted equipment is inevitable. The best thing a utility can do is to be mindful of the location of equipment with respect to minimizing vehicle exposure. As far as debating whether or not contact with a pole or a piece of padmounted equipment is worse, one could make the point that there is less likelihood of serious injury from impacting an underground piece of equipment rather than a pole. However, the likelihood of having energized conductors closer to public during an accident, for instance with a piece of padmounted equipment, the electrocution danger is more probable than contact with a pole.

Motor vehicle versus utility pole may be dangerous

Remain Overhead

Pros: Spans can be spread out to minimize risk; stronger poles can withstand collisions,

Cons: Poles are easily compromised by vehicle contact, downed wires pose electrocution risk, and stronger poles can increase the likelihood of vehicle occupant injury if absorbing a direct collision

Convert to Underground

Pros: Hold up better to vehicle contact, cables are buried

Padmount transformers close to roadways may be dangerous

Cons: Closer to the public, fuse may not de-energize the circuit after vehicle contact

Both overhead and underground systems are susceptible to vehicle contact. Overhead systems tend to be more susceptible to vehicle contact due to their profile and quantity installed along roadways. Underground systems have a lower profile and above ground cabinets tend to be spread further apart, thus lessening their chances to be involved in a vehicle contact incident.

According to FPUA records, since January 2002, there have been 90 trouble calls where vehicles have made contact with power poles. In addition, the same time frame netted 20 low wire incidents where vehicles came in contact with fallen or sagging conductors. Conversely, there have only been 9 trouble calls where a vehicle has made contact with the underground system in the same time period. There are two main reasons for this disparity. The first reason is due to the type and quantity of equipment installed. FPUA's system is 90% overhead and 10% underground at present. Due to this, it stands to reason that there would be more overhead equipment installed along roadways than underground equipment, thus the increased number of incidents for the overhead system. The second reason is due to the "target" that the overhead poles represent over low profile switching cubicles and cabinets. Also, as spans become shorter along roadways, there is an increased chance of a vehicle contact.

There is no guaranteed method for preventing vehicle contacts with electric utility equipment, but certain design techniques can be used to minimize contact. Care should be taken when designing the layout of both overhead and underground equipment. If it is possible, the spans between poles or above ground cabinets should be spaced as far as feasible to reduce the number of “targets” in busy traffic intersections and on curves where a vehicle is most likely to leave the roadway. In addition, road crossings on the overhead system should be minimized and proper clearances should be maintained. For lighting systems, specially designed breakaway poles can be beneficial. These poles are designed to break when they come in contact with a vehicle in order to reduce the likelihood of a fatality. These poles also have special fuses/disconnects that kill the power in the standard if the pole breaks away from the base.

Switching Operations

The switching of an overhead system is typically less involved than switching on an underground system when using manual switching techniques. Overhead switching typically requires the operation of a handle on a gang operated air break switch or by using a hot line stick to open disconnects or load break fused cutouts. Underground switching can require the use of handles in switching compartments or by removing and connecting elbows inside of junction cabinets. The use of a SCADA system and downline telemetry devices on switchgear can enhance the functionality of switching by allowing remote operation. The advantages and disadvantages of switching operations for both overhead and underground systems will be covered more thoroughly in the report.

Remain Overhead

Pros: Easy to see and operate, switch devices are cheaper to install, open points are more visible, telemetry works well

Cons: Susceptible to vandalism, interrupting capability

Convert to Underground

Pros: Interrupting capability, doesn’t require bucket work or long hot stick to reset recloser,

Cons: Harder to switch due to accessing multiple cabinets, more difficult to identify open points

The ability to backfeed between circuits on an electric distribution system is very important. This ability is enhanced through the use of gang operated air break switches, disconnects, padmounted switchgear, and sectionalizing cabinets. Air break switches and disconnects are located at the open points between circuits from each of the substations. Open points on the underground system may also exist inside padmounted transformers. In the event of an unplanned or planned outage, the switches can be operated to swap feeds.

The advantages of an overhead system is that the switches are relatively accessible from the ground by using the handle mounted on the side of a pole, a hot line stick from the ground, or by using a hot stick from a bucket truck. Further flexibility can be obtained by using a SCADA system to automatically switch reclosers, automated ABS switches, or capacitor bank controls through the use of telemetry or fiber optic cable that runs on the poles. While these items are expensive to purchase and implement, power restoration can be aided by these devices, which in turn reduces outage times and keeps customers happy.

The operation of switches or the movement of elbows on the underground system typically requires the cabinet to be unlocked and then the operation performed by a elbow puller/installer. This method can be dangerous due to the close proximity of the worker while the switching is performed. Automated switchgear and padmounted reclosers can be purchased, but at great expense. These components can be controlled via a SCADA system and through the use of telemetry or fiber optic cable.

Outage Duration and Frequency

Overhead and underground electric systems operate nearly identically. The only difference is that the sectionalizing equipment is located in an enclosed compartment on the underground system, while it is located in plain view on the overhead system. This inherent difference is of great importance because it affects how the operator can maintain the system during an outage. Because it is sometimes hard to find underground faults due to their inherent installation method, outages can be more difficult to troubleshoot and repair. Overhead system faults can usually be located visually and then repaired. Underground faults require the use of more sectionalizing devices and fault indicators to better troubleshoot the fault. Underground outage duration is typically greater than overhead for these reasons. The repair of underground facilities usually requires more time than overhead due to specialized repair techniques or cable replacement. The pros and cons of maintaining acceptable levels of outage duration and frequency will be discussed in more detail in the report.

Remain Overhead

Pros: Faults can be located quickly and repaired, sectionalizing devices are plentiful and affordable,

Cons: More susceptible to storm damage, requires bucket truck or climbing linemen to repair

Convert to Underground

Pros: Resists storm damage, equipment is located below and just above ground so it is accessible

Cons: Difficult to locate faults, repair time is long, sectionalizing equipment is costly

There are key differences in how sectionalizing is accomplished between overhead and underground facilities. This inherent difference is of great importance because it affects how the operator can maintain the system during an outage. One key difference is that most overhead faults (as much as 90%) are temporary outages that can be cleared by the overcurrent protection system, while most underground faults are permanent in nature due to the installation method and types of faults.

Overhead system faults can usually be located visually and then repaired by utilizing system maps and drive through inspections looking for locked out equipment, whether it is a blown fuse or operated recloser. Once the fault is located, repairs can be made, fuses changed out, and equipment reset to normal operation.

Because it is sometimes hard to find underground faults due to their inherent installation method, outages can be more difficult to troubleshoot and repair. Underground faults require the use of more sectionalizing devices and fault indicators to better troubleshoot the fault. Underground outage duration is typically greater than overhead for the following reasons. The repair of underground facilities usually requires more time than overhead due to specialized repair techniques or cable replacement. The use of fault indicators can greatly reduce the time spent troubleshooting underground faults and they are inexpensive to purchase and maintain. By inspecting these devices after a fault, the trouble area can be isolated while the system is switched or repaired, allowing more customers to be restored quickly. It should also be remembered that a looped underground system will provide far greater chances of reducing outage times over a radial feed system. On a looped feed system, the faulted section of cable or device can be isolated, while the rest of the loop can be served from the same or different source. A radial system is flawed due to this inability, though it is cheaper to install.

Ease of Access

Access to overhead and underground systems can vary greatly on any utility electric system. On the one hand, since overhead lines are visible, they are totally accessible through the use of a bucket truck. If a bucket truck is unable to get to a particular pole, a lineman can climb the pole for access. However, this access can be greatly limited by traffic problems, congestion on poles, and weather conditions. Underground access is readily available for padmounted equipment and manholes, but is greatly reduced when investigating direct buried cables or cable in conduit between pieces of equipment or manholes. The pros and cons of access will be discussed further in the report.

Remain overhead

Pros: Typically easy to access for repair or installation, totally visible to the worker

Cons: Access may be hampered by traffic, the greater the number of other utilities on the pole the less able to access by climbing

Convert to underground

Pros: Equipment is at ground level for ease of access, manholes or vaults can make access easier to critical facilities

Cons: Cannot always see the complete run of the cable, equipment failure may require digger derrick vehicle to remove failed equipment and replace with new equipment, proximity to other underground utilities may cause access issues

Because overhead lines are directly visible, access is usually easy with the use of a bucket truck. If the truck is unable to reach the overhead line, linemen can climb poles to reach equipment mounted on that power pole. Bucket trucks are large and heavy and will sink easily. In large rainstorms, when power outages often occur, the danger of sinking a bucket truck in fields or backyards is high. Weather conditions also affect the ability of linemen to climb poles. In the event of lightning, work on overhead lines should be limited and safety is the paramount concern. Access to overhead lines along road right-of-way can also be limited by traffic congestion and congestion on poles.

Easily accessible underground transformer

Underground lines have access points in manholes and padmounted transformers on ground level; this makes access to vital areas of line easy. In the event of transformer failure, a bucket truck with material handling capability or digger derrick is needed to lift and replace the transformer. Access is greatly reduced when work is performed on power lines between manholes and transformers. If a line must be unearthed, heavy machinery is needed. If an underground line is behind property, away from roadways, access may be difficult and could result in remediation of access area.

Access to underground lines is further complicated if the lines are close to other utilities or lie beneath a roadway. If the line is beneath a large thoroughfare, permits for line repair may not be easily awarded. Concrete encased lines will add to the complexity of repair; however damage to the concrete encased duct bank is rare. For the most part, work done on actual cable on overhead lines is easier than excavating underground lines. Depending on conditions, work on padmounted transformers on ground level may or may not be easier than those on pole-mounted transformers.

Telemetry

Telemetry is the process by which field equipment can be remotely controlled by an operator at a central location through the use of radio waves or power line carrier technology. Typically, switching equipment can be fitted with remote operation equipment on both the overhead gang operated air break switches as well as the padmounted switchgear on the underground system. The cost is typically higher on the underground telemetry equipment and the system may be limited by reduced line of sight communication restrictions.

Remain overhead

Pros: Typically telephone lines or fiber optic cable is readily available, poles allow for mounting of radio equipment when other telecommunications media is unavailable

Cons: Protective devices required by Telephone Company to isolate power from telephone can be expensive, phone data lines may be expensive, fiber optic lines may require additional splice closures to be installed

Convert to underground

Pros: Controllers in sectionalizing devices interface well with fiber optic cable

Cons: Phone lines or radio are difficult to install, Protective devices required by Telephone Company to isolate power from telephone can be expensive, phone data lines may be expensive

Numerous sources define telemetry in different ways. One source describes telemetry as "...the wireless transmission and reception of measured quantities for the purpose of remotely monitoring environmental conditions or equipment parameters." Another source states telemetry is simply "...communicating real-time environmental data." The definition changes with how the data is transferred as "...data can be delivered via phone lines, radio waves, and the internet." A typical definition of telemetry for an electric utility derived from these two sources is to monitor equipment status and retrieve data from sources using wireless, radio, or fiber optic media.

Fort Pierce Utilities Authority appears to have limited telemetry available on its system. The substation breakers and two load tap changers are controlled by a SCADA system. Data acquisition of field devices does not appear to be utilized. Telemetry may be incorporated to: retrieve meter data from large commercial/industrial customers, check status of controlled capacitor banks and electrical parameters such as voltage and current, and monitor equipment status (open, closed, and tripped).

The data can then be localized in a central location using several methods. Radio can be an inexpensive technique to relay data; however, it is limited in transmission capabilities. The higher the frequency transmitted upon, the more necessary line of sight becomes. The use of 800 and 900 MHz spread spectrum radios are popular, but rely heavily on line of sight. The use of phone lines is another high-quality option. Generally, phone lines are on the same poles as the equipment requiring monitoring or where data is being received. Phone lines are very reliable and can transmit data relatively quickly. The downside is the cost per circuit and requirements for electrical isolation required by each phone company.

The use of fiber optic is extremely popular in the municipal market. Municipal utilities already have right-of-way they can utilize for installation of cable. Fiber optic cable can be run in the neutral area, provided only qualified personnel access it. The medium is as technology proof as possible, the cable doesn't change, but only the method of transmitting data across it. The fiber can be utilized for other applications such as a municipal area network, phone system applications, cable television, and telemetry. The cost of running fiber optic cable is very low, and the incremental costs are small up to 144 fiber count. Fort Pierce Utilities Authority has fiber optic cable on their system and could utilize it to provide telemetry in the future. The type fiber optic cable employed by Fort Pierce Utilities Authority has limitations with the number of splice points. The optical guy wire (OPGW) fiber optic cable serves two functions. The first function is a static line for the protection of the transmission line circuit. The second function is the transmission of light through the fiber optic portion of the cable. This cable is much more difficult to cut into and splice because of the dual function. In a case where OPGW is employed, and no splice juncture is available, the use of a hybrid solution may work well. The hybrid solution consists of a point where a splice closure exists on the fiber optic cable and either a laser or radio at the closure and the point to be monitored or controlled. This works well if the points are in proximity to a splice closure, but may experience issues with transmission quality in fringe areas. The use of the hybrid system can be a good solution to a control and acquisition problem given the right parameters at a very reasonable cost.

Animal Intrusion

Animal intrusion is a common concern with operating both overhead and underground electrical systems. On an overhead system, the primary concerns are squirrels getting into transformer bushings, raptors being electrocuted on the primary conductors, and woodpeckers and insects damaging the pole strength. On an underground system, the intrusion of snakes and small rodents in padmounted transformers and switching cubicles as well as ant infestations inside of padmounted equipment are of primary concern.

Remain Overhead

Pros: Raptor protection is plentiful and affordable, spacing can be increased to limit exposure to animal intrusion, ROW maintenance can reduce contact incidents

Cons: Overhead lines prove deadly for birds, frogs, squirrels, and other rodents, every pole cannot be insulated from animal intrusion no matter how much protection is installed

Convert to Underground

Pros: Cabinet provides reasonable protection from the public and most animals, easily treated to prevent insect intrusion

Cons: Susceptible to snakes and burrowing rodents which seek a warm place to live, ants and other insects cause problems as well

Squirrels often jump from trees into substations

Animal intrusion is a constant concern for both overhead and underground systems. Common problems on the overhead system include raptor contacts, squirrel or rodent contacts, and woodpecker or insect damage. On an underground system, snakes and small rodents seek out the warm protection that transformer cabinets provide, while insects like ants tend to make padmounted equipment part of their home. These intrusions may not always cause a fault, but they add to the difficulty in operation of the equipment.

Several mitigation techniques can be applied to prevent or at least stem these animal intrusions. On the overhead system, raptor protection can be applied. Several types of raptor protection exist including spike based systems, plastic guards, and rubber covers. To prevent squirrels from getting electrocuted by live bushings, rubber animal guards can be installed on the exposed parts to limit the chance of a contact in high density areas. Woodpecker damage is hard to prevent, though some success has been had by using various pole treatments, fillers, and wire meshes. On the underground system, weed killer, sprays, and poison treatments can be used to limit insect or small rodent and snake intrusion. The animal intrusion protection for overhead systems is more expensive as a whole due to its exposure and the quantity of devices needed to ensure adequate protection. On the underground system, since the cabinet provides fairly good protection, the animal intrusion mitigation techniques are less costly, though the sprays and poison needs to be added on a continuing basis, which can relate to more costly maintenance expense.