"Underground Transmission"

Practical Information and Issues for Consideration by Rural Electric Systems

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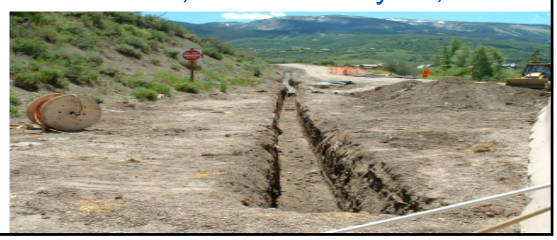


Underground Transmission Issues

Will cover the following topics:

- What are the relevant factors to consider?
- What types of underground cable are available?
- What are their relative costs compared with overhead?
- Installation methods and accessories?
- Possible methodologies being used for cost recovery?
- What your electric cooperative might consider doing?

Rationales for Consideration

- Increased local pressure to place all utilities underground, if possible.
- Limited right-of-way available for specific overhead lines.
- Densely populated areas.
- Address localized constraints, i.e. airport, river crossing, etc.
- Conservation easements that preclude overhead utilities.
- Scenic attributes that are desired to be mandated by a community.
- Requirement by some states to evaluate underground alternative.
- NIMBY concerns.
- Extent of need for new transmission lines, which face public opposition.

Critical Need for Transmission

- Attention to the future needs of the U.S. transmission grid have been insufficient
  - No major new transmission investments in the last 15 years
  - Majority of transmission lines are over 20 years old
  - Average transmission project payback is 28.5 year

- Source: Edison Electric Institute

Underground vs. Overhead Factors

Overhead	Underground
More visible	Less visible which affects level of acceptance
70 to 150 ft. ROW	20 to 75 ft. ROW; easement cost considerations
Less costly	Capital costs can be 3 to 10 times higher, or more, depending upon a host of factors
Subject to Weather (ice, wind, tornado)	Less susceptible but can be impacted by dig-ins
Span environmentally sensitive areas	Requires excavation or alternative routing
Lower repair costs which can be completed more quickly	Higher repair costs (when necessary) along with longer outages required for repairs
Any length of line	Generally short sections to address specific, localized constraint

Routing and Siting Issues

- On the one hand, it may be possible to route an underground transmission line in areas that an overhead line might not be permitted including highly urbanized areas, near airports and water crossings, and potentially along a shorter route than might be available for a more indirectly routed overhead line.
- On the other hand…

Underground Constraints

- An underground transmission line, however, has its own set of constraints, that must be addressed, which definitely limits its application.

- These include significantly higher costs and who will bear this responsibility, the need for a highly engineered system that is much different than designing underground distribution facilities, greater construction impacts, restrictions on what can be sited above the underground line, and costly repair issues.

Distinctions between Underground Distribution and Transmission

- For those who are familiar with applying underground distribution, the transition to underground transmission involves **MANY** special engineering aspects including:
  - Cable ampacity is limited by the deepest point of its alignment or when placed within a steel casing, due to heating considerations. It is critical to calculate this current limiting aspect to avoid overloading.
  - Use of special low thermal resistant backfill assists in reducing heating through better dissipation in the surrounding soils.
  - It may be necessary to utilize a larger conductor size for sections that are enclosed in steel casing or require placement at greater depths.
  - Summer soil ambient temperature conditions for the particular location.
  - Configuration of the cables within the duct bank or steel casing.

Use of Copper or Aluminum Conductor

The overall cost of the cable system will be impacted by commodity prices at the time of purchase.

Bidding is needed to determine whether to utilize copper or aluminum conductor, due to their fluctuating metal market costs.

A copper conductor will be smaller in diameter than an equivalent aluminum conductor which then influences the extent and cost of insulation required (a greater amount of insulation is required for aluminum due to its larger overall size, with insulation costs affected by other commodity prices).

Need for Engineering Expertise

- One should think of an underground project as an overall "system" which must factor in not just the type/spec of cable to be installed, whether it is to be direct buried or installed in a duct, local soil conditions, potential changes in depth of installation, the need for road crossings and how this will be handled.

- It is critical that this underground "system" be designed by those with adequate engineering expertise.

Repairs When They are Needed

- When damage occurs to underground facilities, both the costs of the repairs as well as the time to do so are MUCH greater than with overhead transmission.

  It is critical that spare reels of cable be available to the system. If installed in duct, the time to replace can be reduced, but at higher installed cost than if direct buried.

  Most underground repairs involve multiple days including weeks, depending upon availability of skilled crews, compared with hours or a few days with overhead transmission in most cases.

Extent of Underground Transmission in the United States

- The initial underground transmission lines in the United States were surprisingly installed in the 1920's.

  At this time, there are approximately 5,000 miles of underground transmission cable compared with 200,000 miles of overhead or 2.5% of overall mileage.

Types of Underground Systems

- High-Pressure Fluid-Filled (HPFF) pipe
- High-Pressure Gas Filled (HPGF) pipe
- Self Contained Fluid Filled (SCFF)
- Extruded Dielectric Cable (XLPE or EPR) (most typical type currently being used for voltages below 230 kV)

High Pressure Fluid or Gas Filled (HPFF, HPGF)

All three conductors are installed inside steel pipe

Insulated with either oil or nitrogen gas

In the past, this was the most typical cable type used, which continues to be the case for higher transmission voltages, along with a proven track record of performance.

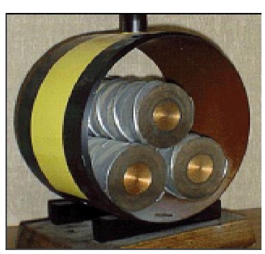


Photo courtesy PDC

Oil systems are more competitive when use for longer project lengths due to cost of the oil pressure system itself (approx. $250,000).

High Pressure Fluid or Gas Filled (HPFF, HPGF)

- Use of saturated or filled (impregnated) paper tapes for insulating qualities is typical.
- Pressures are typically 200 psi nominal, but do increase.
- Gas systems utilize nitrogen, which is naturally occurring in the atmosphere, and therefore has different environmental impacts should a leak occur than with a pressurized oil system.
- Many of these lines installed as early as in the 1930's are still in operation today.
- These systems compose ~80% of total mileage installed.

High Pressure Fluid or Gas Filled (HPFF, HPGF)

- The designs of these two types are similar except:
  - Required insulation thickness for "gas" needs to be greater than with "fluid" systems, due to the lower electrical strength of gas compared with "fluid".
  - At 115 kV, paper insulation thickness would be .485 inches for gas and .375 inches for fluid.
  - A "gas" system could be converted to an "fluid" system, at potentially a "higher" voltage, under certain cases.

Self Contained Fluid Filled (SCFF)

Most typically used for underwater installations; insulated with oil

Able to be installed to depths of 2,600 ft w/o special provisions

Each of three fluid filled cables are installed in individual pipes

Photo courtesy Prysmian Cables & Systems

Photo courtesy USI Power

Extruded Dielectric Cable (XLPE or EPR)

Offers a number of advantages compared with the previous types including the absence of pressured systems as well as the ease of splicing, resulting in a less costly installation, precluding potential for environmental risks (leaks), and lower maintenance costs, but useful life questions are more unknown compared with previous systems.

Used extensively for voltages up to 230 kV

May use either copper or aluminum conductor

Available with either XLPE or EPR insulation

CABLE TYPE AHXLMK 1750 kcmil 115 kV
MAXIMUM STRESS DESIGN

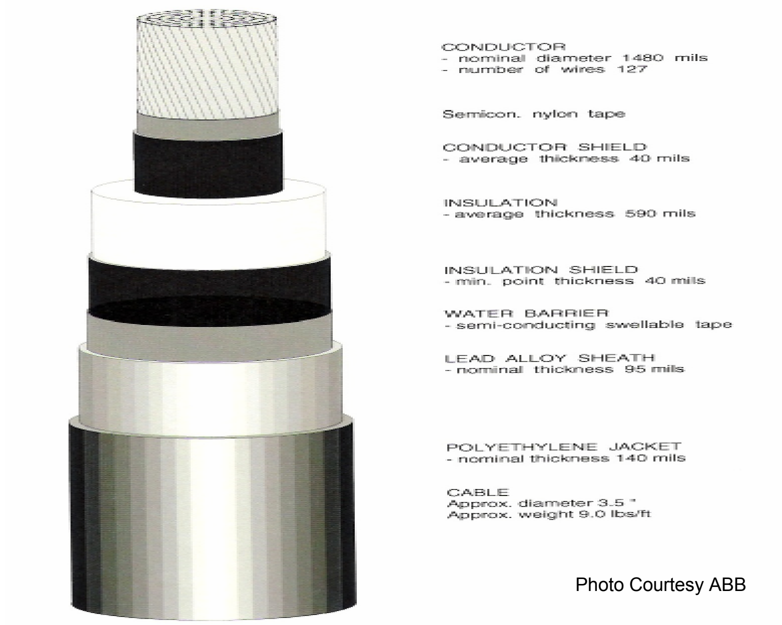
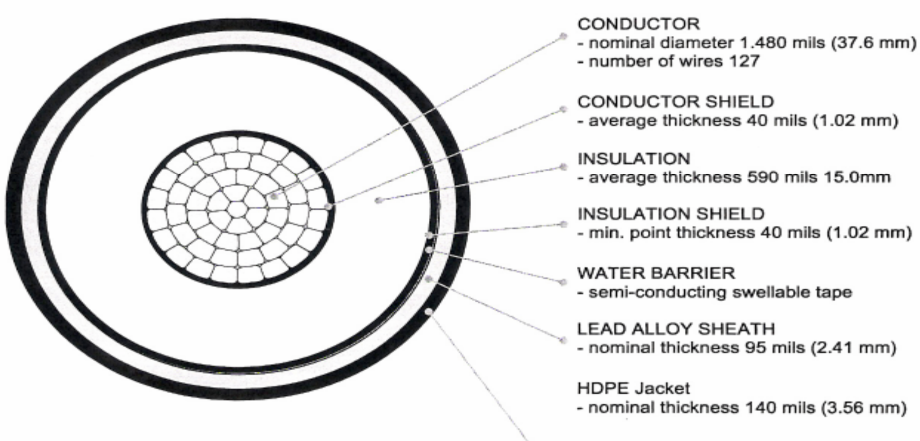


Photo Courtesy ABB

AHXLMK 1750 kcmil 115 kV

Cable sizes are usually specified in 250 kcmil increments;
i.e. 1000, 1250, 1500, 1750 kcmil, etc)



Courtesy Pirelli
(Prysmian Cables & Systems)

Factors which Influence Cost

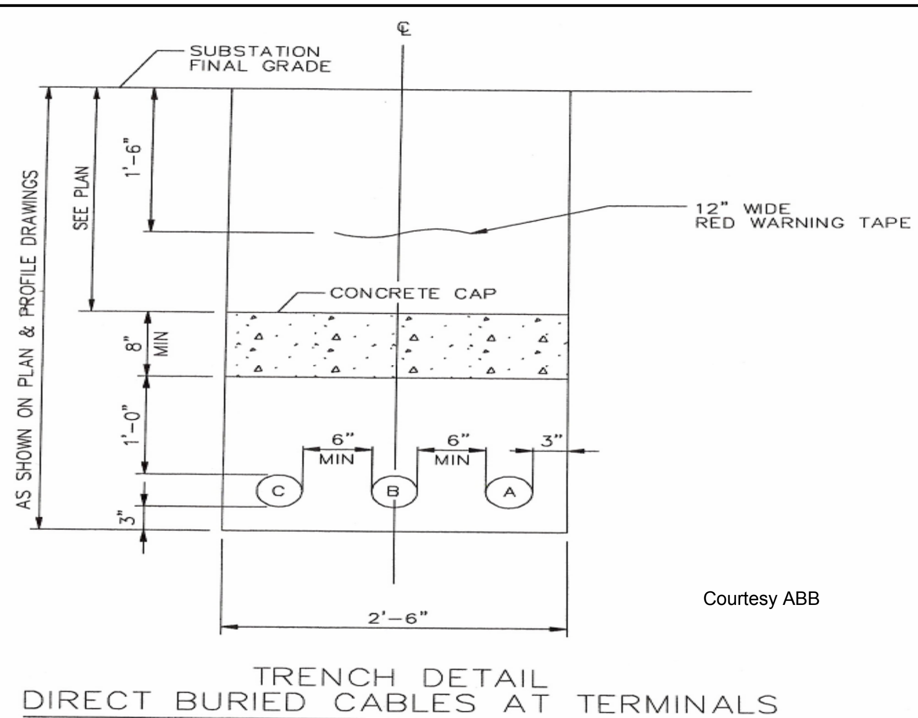
- Size and type of cable, as well as whether direct buried or in conduit
- Length of line (shorter ones are impacted by expensive termination costs)
- Terrain considerations (flat, rocky, steep)
- Presence of other underground utilities
- Number of stream or road crossings
- Need for directional boring (whose costs are significantly higher)
- Right of way costs
- Permitting requirements

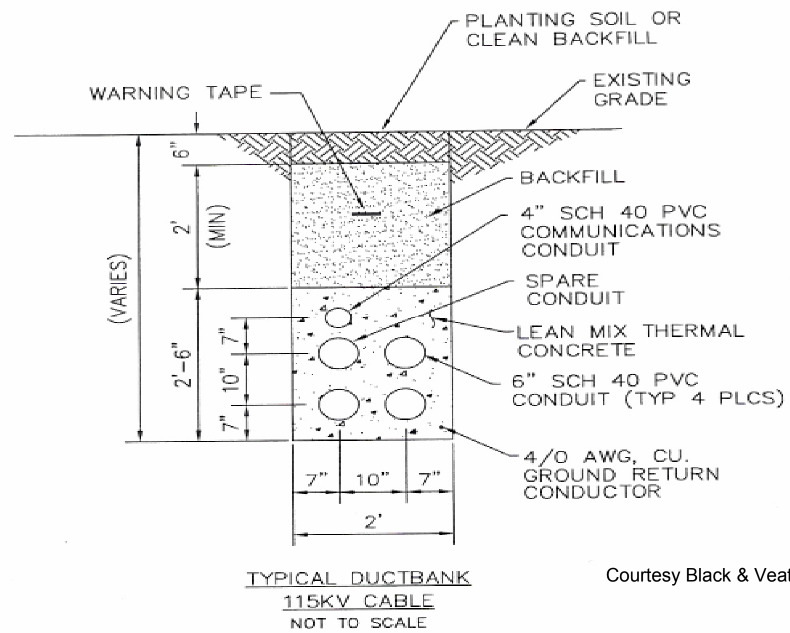
Approximate Costs of Underground Transmission

- For purposes of estimation, recognizing the numerous factors cited in the previous slide, approximate costs could be seen in the following ranges:
  - 115 kV: $1.0 - $1.5 million + per mile (installed)
  - 230 kV: $2.0 - $3.0 million + per mile (installed)

Underground Construction

- The construction process involves:
  - clearing the right-of-way
  - digging the trench
  - installing the duct bank and vaults
  - covering with thermal backfill
  - pulling cable between vaults
  - splicing cable, install termination points, dead-end structures and surge arrestors.



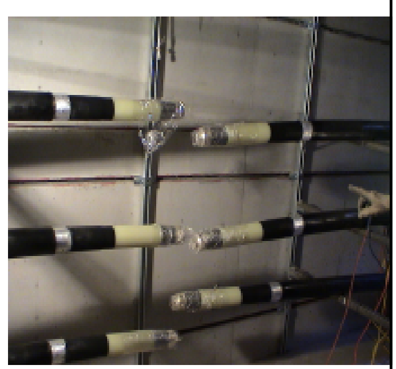


Courtesy Black & Veatch

Photos Courtesy ABB


PIRELLI

Peeling the insulation



Photos Courtesy Pirelli
(Prysmian Cables & Systems)

Photos Courtesy Tri-State G&T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CAUTION:

Manholes (Vault)

- Their <u>locations</u> will be dependent upon a number of <u>factors</u> including:
  - Cable reel limitations
  - Allowable tensile stress
  - Sidewall pressure on the cable (Tension out of Sheave divided by Radius of Sheave)
  - Elevation changes on the route
  - Access issues for a particular manhole location

Manholes are pre-cast and come in either:
- two sections (top/bottom) or
- three sections (top/middle/bottom).

After backfilling, only a cast iron lid is visible.

Manholes (Vaults) and Splices

- Cost range of a vault might range from
  $ 10,000 to $ 30,000 +
  (for a 115 kV installation).

  Cost range of splices might range from
  $ 4,000 to $ 5,000 + per phase
  (for a 115 kV installation).


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CAUTION
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Crossing Roads

Options include:

a) Jack and Bore Casing - is much more expensive than open cutting the road; however, it permits traffic to flow without interruption. Pits are excavated on either side of the road and sections of steel casing will then be "jacked" from one end to the other.

b) Open Cutting the Road - is a much less expensive option but does require traffic control and interruptions.


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Terminations (i.e. Pothead)

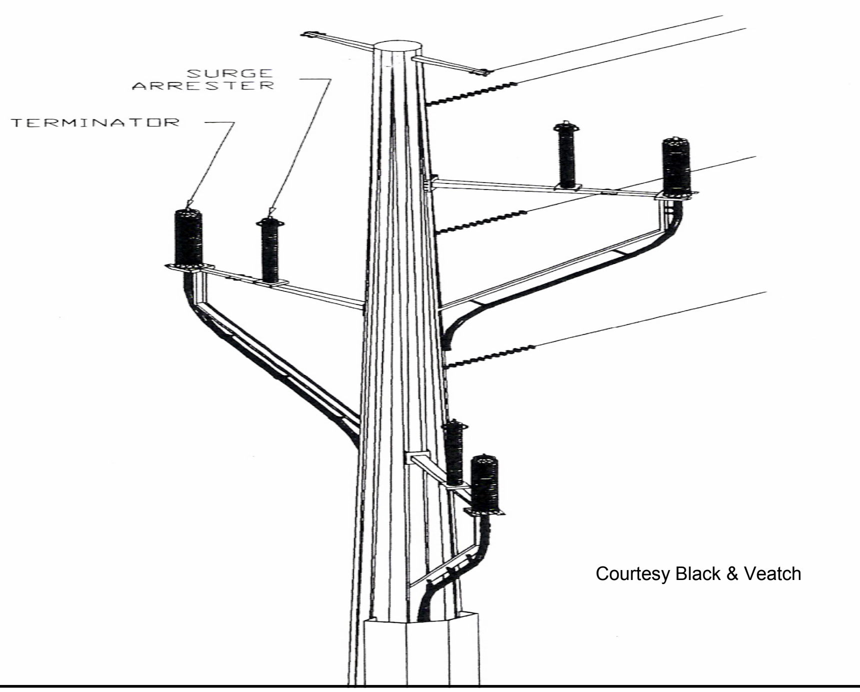
- Each end of the underground transmission line requires a termination device:

  - i.e. stress control mechanism in a sealed, electrically insulated housing.

  - it must provide external insulation between the cable conductor & ground.

- Costs can range from $ 25,000 to $ 60,000 + at each end (for all three phases, including labor), but excluding cost of required lightning arrestors and riser poles.

- Critical that these be performed by skilled workers, and warranty provisions likely to be dependent upon this.



Courtesy Black & Veatch


Photos Courtesy Holy Cross Energy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Tests Upon Installation

Tests include:

a) Phasing Check

b) Cable Jacket Integrity Test

c) 24 hour Full Line Voltage Soak Test

Electric Cooperatives with Underground Transmission

- To date, there has been a very limited amount of underground transmission constructed by rural electric cooperatives due to its high cost relative to overhead.
- I will discuss three transmission projects that have been recently completed in Colorado, including the way in which each were handled by the utility.

Colorado Underground Projects

Voltage	115 kV	115 kV	115 kV
Length	3.2 mi	1.9 mi	.5 mi
Type	Double Cir. XLPE AL	Single Cir. XLPE Cu	Single Cir. XLPE AL
Size	1750 kcmil	1750 kcmil	1750 kcmil
Routing Constraint	Scenic / Land Restrictions	Urban	Urban
U vs. O Multiplier	~ 5	~ 6	~ 4

(depending upon ROW cost and other cost allocation assumptions)

Cautionary Point

- It is very important to note that the previously mentioned ratios of underground to overhead costs can NOT be assumed for other projects.
- These ratios are totally dependent upon so many design considerations, as well as local issues, including ROW costs.
- Each potential transmission project should be independently evaluated.

Differential Cost Treatment

- Three different approaches were applied by the particular Colorado system in handling the differential costs between overhead and underground transmission facilities:
  - In one case, the amount was collected in cash from the municipality that required underground service.
  - In the second case, the amount is being collected as a monthly electric surcharge for those consumers served by the substation over its assumed life (35 years).
  - In the third case, the utility will consider the total cost as normal system expansion and collect from all consumers served. There were justifying reasons that required moving ahead with the project and the difficulty in obtaining an overhead easement.

Interesting Aspects of 2nd Option

- The town requiring underground transmission service was given the option of collecting this differential as a monthly electric surcharge calculated as follows:

  The owning cost differential between underground and overhead transmission is collected based upon either:
  - A flat charge per consumer
  - The amount of kWh used by consumers
  - The revenue paid by consumers
  - A combination of the kWh and revenue methods

  In each case, these amounts would be greatest in the initial year of service, and decrease thereafter as the number of consumers and their respective usage increased.

Cable Standards, Warranties

- Applicable standards include:

  - AEIC (CS1-90, CS2-97, CS3-90, CS4-93, CS6-96, CS 7-93, CG1-96, CG2-72, CG3-2005, CG4-97, CG5-2005, and CG6-95) depending upon type of cable;
  - ANSI/ICEA T-27-581, NEMA WC 53 (standard test methods)
  - ASTM B8/231

- These projects specified insulation thickness that ranged from 590 mils XLPE, to 800 mils XLPE (100% insulation level).

- The warranties offered by cable manufacturers typically range from 2 to 5 years, and may possibly be extended to 10 years.

- Warranties are often affected by whether the cable terminations are installed by parties that the cable manufacturer have authorized or not.

“Underground” Policies

It is advisable that any electric cooperative responsible for transmission line construction and ownership, consider adopting a line extension policy as it relates to “Underground Transmission”.

By doing so, the board and management will have had the opportunity to develop appropriate considerations and requirements for potential cost sharing, prior to any inquiry that surfaces.

Just as most electric cooperatives have such policies as they relate to underground distribution, it is advisable to address transmission, should questions arise during project development.

Cost Responsibilities

- Many electric cooperatives as well as other utilities have reached the conclusion that any special requirements beyond that normally provided by the utility should be borne by the specific community that dictates such need.

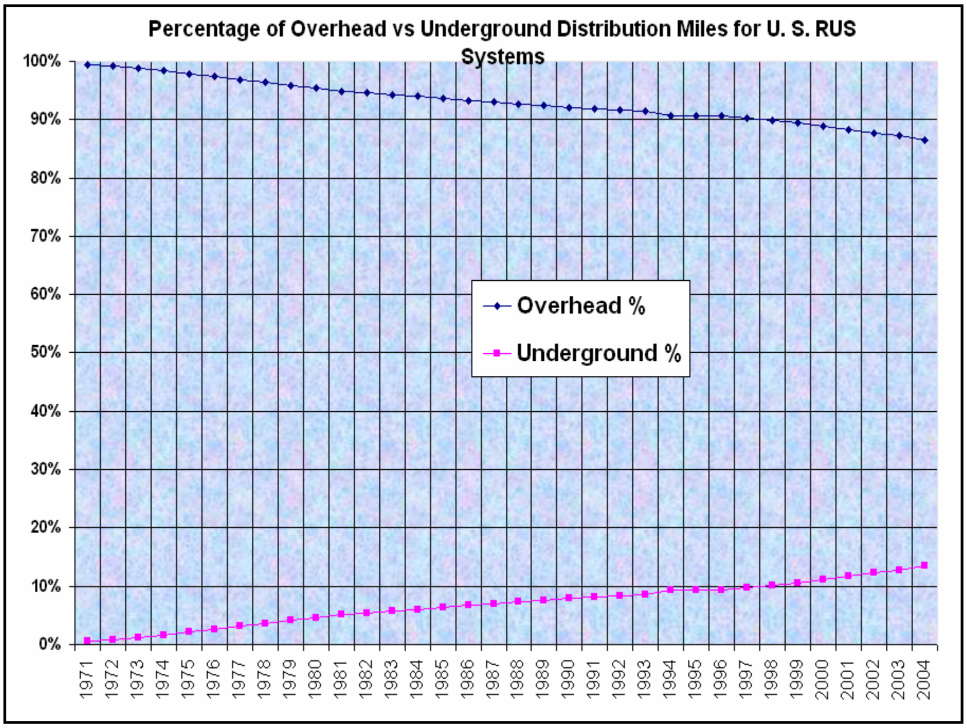
  This is based upon the belief that underground is not universally required, or desired, and should not be the cost responsibility of those portions of the system which do not impose such requirements.

Other Factors to Consider

- It is important that the following aspects be considered when an underground transmission project is being evaluated or developed:
  - Utilize Engineering Expertise qualified to design and ensure proper installation
  - Appropriate Cable Testing upon manufacture & installation (ANSI/ICEA T-27-581, NEMA WC 53)
  - Need for Spare Parts (1 cable reel, 1 cable terminator, 2 cable joints, 1 surge arrester)
  - Maintenance Costs (periodic inspections and jacket integrity tests)
  - Life Expectancy (solid dielectric cables are assumed to have a useful life of 35 years; historic HPFF underground systems continue to be operational well beyond that period).

Underground Transmission?

- The ultimate decision is left to each individual system after recognition of all relevant factors including available options for routing, cost of construction including easements, possible cost sharing, ability to afford such higher costs, as well as numerous other factors mentioned.
- Many formally rural systems are being impacted by issues that have driven greater use of underground distribution construction.
- However, it is a MUCH bigger step to implement underground transmission and will continue to only be seen in rare instances for many years to come.



Percentage of Overhead vs Underground Distribution Miles for U. S. RUS Systems
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Overhead %
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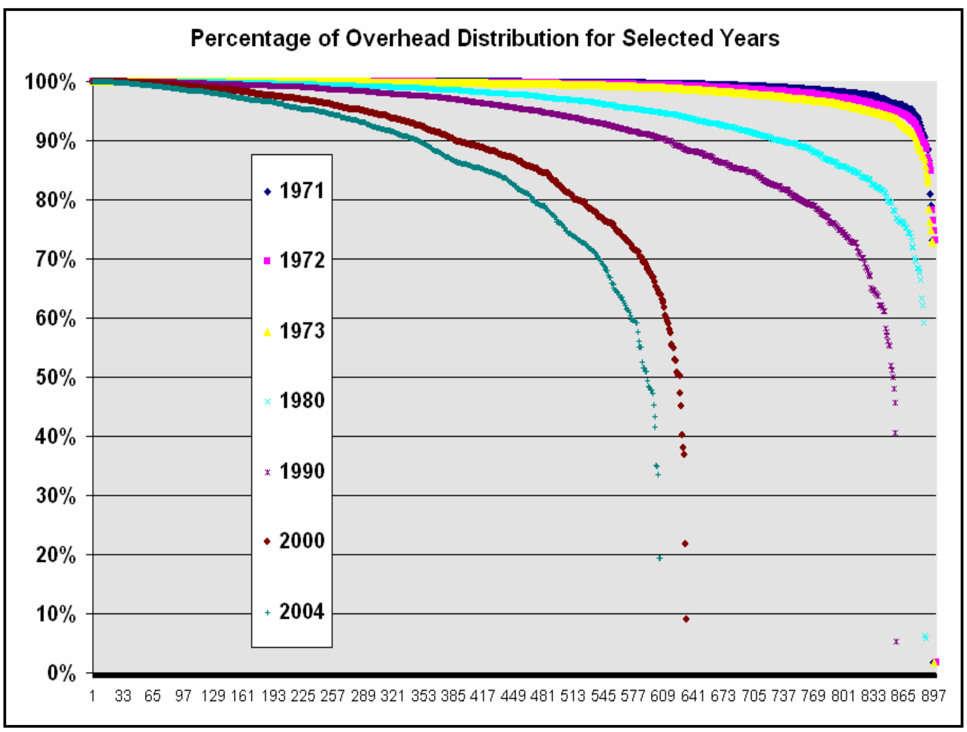

Percentage of Overhead Distribution for Selected Years
100%
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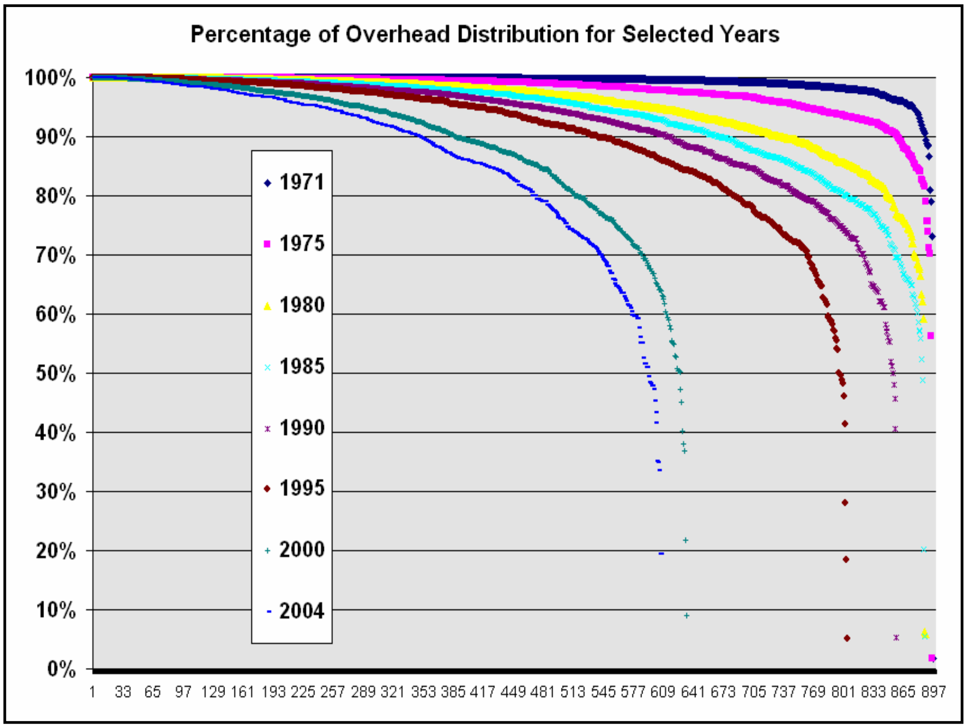

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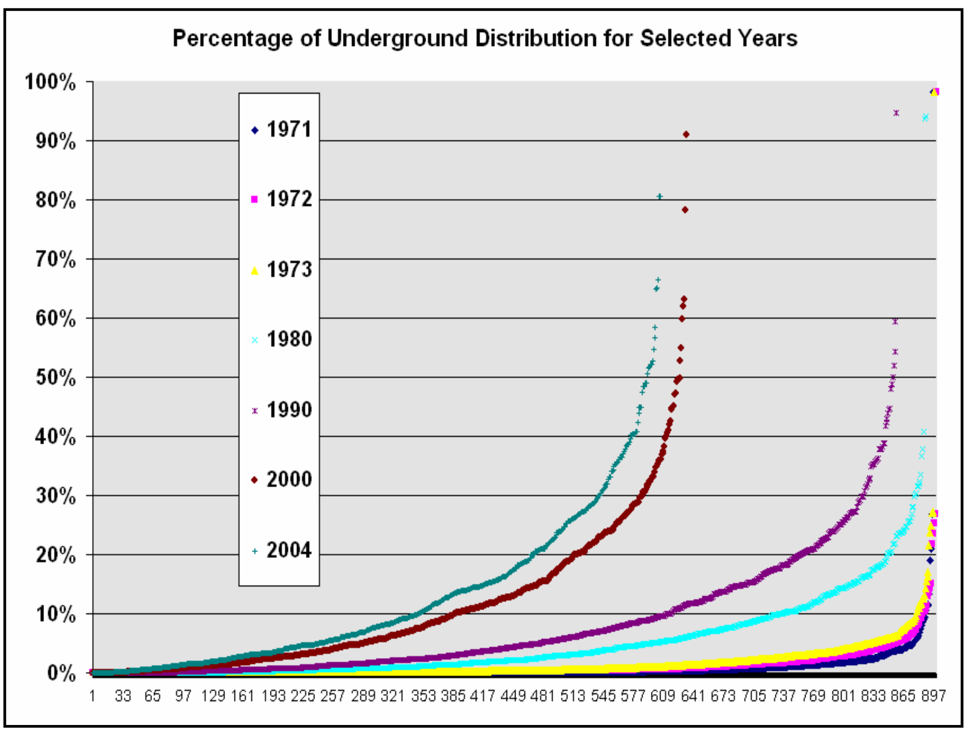

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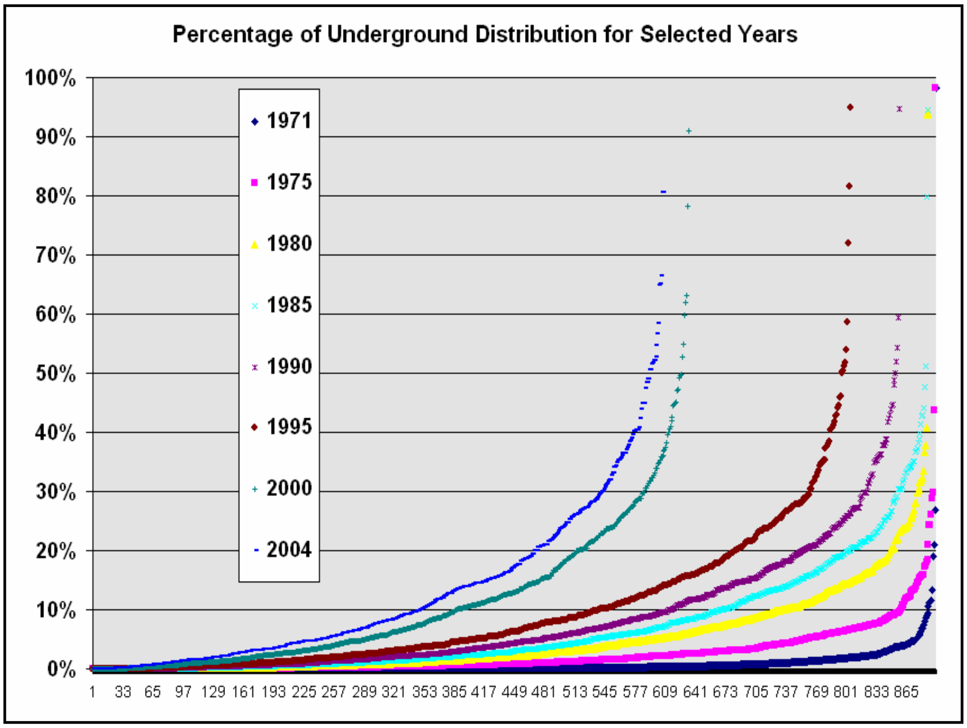

In Summary

While <u>distribution</u> underground continues to be <u>increasingly</u> utilized,

there may be <u>limited</u> <u>areas</u> or <u>circumstance</u> that underground transmission may be installed.

It certainly will <u>not</u> be the "<u>norm</u>" for rural electric systems in the United States due to its much higher costs requiring a highly engineered system.

Hope this information proves to be <u>practical</u> <u>information</u> when it is being discussed.