



AEP INTERSTATE PROJECT: 765 kV or 345 kV Transmission

I. Executive Summary

American Electric Power (“AEP”) has proposed a national vision of an advanced interstate electrical transmission system that delivers wholesale power efficiently within a competitive market while enhancing regional reliability and reducing overall environmental impact. This vision will feature proven power delivery facilities with the highest transmission capacity now available in the U.S. The result would be the launch of a “transmission superhighway” system modeled after President Eisenhower’s national interstate highway transportation plan.

To achieve this goal, AEP has proposed several major transmission line projects. The projects will function as a transmission backbone, strengthening existing electrical power systems both within and outside of AEP’s traditional service area. When evaluating and planning these projects, AEP carefully considered modern transmission technologies, including alternating current (“AC”) solutions, direct current (“DC”) solutions and a variety of solutions involving different transmission voltage classes. AEP’s guiding principle is to provide the reliable, efficient, environmentally acceptable transmission capacity and operating flexibility needed for a competitive electricity marketplace.

This paper highlights the performance, design and cost advantages of 765 kilovolt (“kV”) as compared to 345 kV transmission. It is presented for consideration in the AEP-ITC technical study of potential 765 kV development in Michigan¹. While this paper focuses on the interstate projects planned by AEP, it is relevant to any electric transmission infrastructure.

Key advantages of AC transmission technology are its flexibility, expandability into a high-capacity grid and ease of integration with the existing systems. By contrast, traditional DC technology is best suited for specialized applications, such as point-to-point transmission.

It has been well established through engineering analysis and practice that a single 765 kV line can carry substantially more power than a similarly situated 345 kV line. Generally, about six single-circuit (or three double-circuit) 345 kV lines are required to achieve the load carrying ability, or loadability, of a single 765 kV line. Furthermore, experience indicates that transmission systems designed for 765 kV operation are inherently more reliable than those operating at lower voltage levels. With up to six conductors per phase, 765 kV lines are virtually free of thermal overload risk, even under severe operating conditions. Moreover, outage statistics show that 765 kV circuits, on average, experience significantly fewer forced outages than their 345 kV counterparts, and there have been no multi-phase faults recorded at 765 kV in normal operation².

This performance record suggests a lesser likelihood and severity of disruptions at 765 kV, and an opportunity to apply effective remedies to further improve the line (and thus system) reliability.

The higher operating voltage and large thermal capacity of 765 kV offer an added advantage of markedly greater transmission efficiency relative to 345 kV. It can be demonstrated that a 765 kV line incurs only about one-half of the power losses of the six-circuit 345 kV alternative, both carrying the same amount of power.

One of the most sensitive issues in siting a modern day electrical transmission line is its impact on the visual landscape. When comparing the impacts of 765 kV and 345 kV construction, the former clearly has numerous advantages. The right-of-way requirements for 345 kV construction are up to 4½ times greater than for a single 765 kV circuit to move the equivalent amount of power. With fewer transmission lines and less right-of-way necessary, the reduced impact of 765 kV transmission on the visual landscape is significant. Moreover, a typical double-circuit 345 kV structure is actually taller than a 765 kV tower.

Per-mile costs of a 765 kV line and a double-circuit 345 kV line are estimated at \$2.6 million and \$1.5 million, respectively. With three double-circuit 345 kV lines required to match the loadability of a single 765 kV line, an equivalent cost for 345 kV construction is \$4.5 million per mile. When considering construction costs, electrical properties, reliability, land use and visual impact, it is apparent that 765 kV offers significant advantages over the competing technologies for use in a modern interstate transmission system.

II. Introduction

The electric power grid in the eastern U.S. today is characterized by mature, heavily-loaded transmission systems. Both thermal and voltage-related constraints affecting regional power deliveries have been well documented on systems operating at voltages up to and including 345 kV and 500 kV. While various measures to mitigate those constraints are under consideration, and in some cases have been implemented, those measures are largely incremental in scope and aimed at addressing specific, localized network limitations. Incremental measures are a tactical means of shoring up an existing system in the near term. In the long term, a mature system facing continued growth demands can be strengthened most effectively by introducing a proven, higher voltage technology that can provide the transmission capacity and operating flexibility necessary to achieve the goal of a robust, competitive electric marketplace.

In November 2006, AEP signed a memorandum of understanding with ITC Transmission, a subsidiary of ITC Holdings Corp (“ITC”), to perform a technical study to evaluate the feasibility of extending AEP’s 765 kV transmission system through Michigan. The study, now under way, explores the benefits of building 765 kV transmission in Michigan’s Lower Peninsula and linking it to AEP’s 2,100-mile 765 kV transmission system in the Midwest. Results of that study will be shared with the Michigan Public Service Commission, Midwest ISO, PJM Interconnection LLC and other parties to help determine the best way to serve Michigan’s future electric energy needs.

AEP has considered different transmission technologies for the interstate projects, including AC extra-high-voltage (EHV) transmission options from 345 kV through 765 kV and DC. Higher AC voltages, up to 2,000 kV, also received consideration based on AEP's prior research and successful testing, but they remain unproven in commercial operation. The attributes of these technologies -- transmission loadability, reliability, losses, right-of-way requirements, line design and field construction challenges, visual impact and cost -- are discussed below.

III. AC versus DC Transmission

Regional system requirements and proven transmission technologies strongly influenced the conceptual design of the possible transmission development in Michigan. The existing 345 kV AC transmission system in Michigan, introduced as an overlay in the 1960s, was designed to facilitate coordinated operation of the state's generating stations and provide interconnections for energy and capacity transactions between Michigan Electric Coordinated System and other Midwest utilities. Rising demand and infrastructure underinvestment over the years have caused Michigan's transmission system to become congested and unable to transport low-cost Midwestern generation to large load centers, such as the Detroit metropolitan area. The system is now mature and facing challenges similar to those experienced some four decades ago.

Key advantages of AC transmission technology are its flexibility and widespread use by electric utilities. AC would facilitate future additions of intermediate stations, acting like exit and entrance ramps on an interstate highway, to serve local load centers and/or provide transmission access for new generation that may locate along the way. The ease of AC connections would encourage siting of fuel-diverse, newer technology and environmentally-friendly generators. Also, the use of AC technology would enable expansion into a high-capacity transmission overlay that can be readily integrated with the existing systems where so required. Integration can be achieved using commonly available step-down autotransformers or generator step-up transformers, offering the benefits of enhanced operating flexibility and reduced system losses.

By contrast, traditional DC technology is best suited for specialized applications, such as point-to-point transmission traversing sparsely populated areas or where the systems being connected do not operate in synchronism. Examples include underground/undersea cables, long-distance overhead transmission serving as outlets for generating stations, and asynchronous links between two systems that have either no ties or very weak ties. While DC offers freedom from line charging currents and simpler line design with only one (monopolar) or two (bipolar) power conductors, it requires DC/AC conversion at each terminal to integrate with the existing system.

The complexity of DC/AC converters can adversely affect station reliability, posing special concerns at critical system locations. Also, such converters consume large amounts of reactive power and produce current harmonics on the AC side (and voltage harmonics on the DC side) requiring application of remedial measures. Because of the high converter cost, DC generally is not competitive with AC for transmission distances less than 300 miles.

A robust, integrated AC transmission grid with ample capacity and flexibility for future growth will provide a solid foundation for reliable service and ease of access to all users.

IV. Loadability

To assess the loadability of a high-voltage transmission line, planning engineers commonly use the concept of Surge Impedance Loading (SIL). SIL, a loading level at which the line attains reactive power self-sufficiency, is a convenient “yardstick” for measuring relative loadabilities of lines operating at different nominal voltages.

It has been shown that, when loadability is expressed in terms of SIL, a single curve known as the “St. Clair curve” can be used to estimate the maximum permissible loading for a given line length³. Reflecting practical considerations and experience, the curve has been a valuable industry tool since its publication in 1953, when the highest transmission voltage in commercial service was 330 kV. The curve was subsequently supported with analytical methods and extended to voltages beyond 330 kV, at which system parameters play an increasingly important role⁴.

Figure 1 shows the extended St. Clair curve. The curve is accompanied by a listing of common transmission line designs and associated SIL values found on the AEP System in the 1970s. The figure does not include AEP’s latest 765 kV design with six-conductor phase bundles, employed for the 90-mile line from Wyoming Station (West Virginia) to Jacksons Ferry Station (Virginia). SIL of this new line is about 2,400 megawatts (“MW”).

As shown, loadability of a 150-mile transmission line, typical of proposed line lengths in the AEP-ITC study, is approximately 1.6 SIL. For a 765 kV line (SIL=2,400 MW) the loadability would be 3,800-3,900 MW. The corresponding value for a 345 kV line built with bundled conductors (SIL=390 MW) is 620 MW, or 1,200-1,300 MW for a double-circuit design.

It is apparent that a 765 kV line, 150 miles in length, can carry substantially more power than a similarly situated 345 kV line. Generally, about six single-circuit (or three double-circuit) 345 kV lines would be required to achieve the load carrying ability of a single 765 kV line.

Apart from its considerably higher loadability, the low-impedance 765 kV grid would help to unload the underlying transmission system, reducing losses and providing much needed margin for local power deliveries. Building 765 kV transmission would represent a strategic decision to strengthen the system beyond near-term needs with ample capacity to accommodate both future load growth and operating uncertainties intrinsic in competitive markets.

The generalized line loadability characteristic in Figure 1 incorporates a set of assumptions with regard to system parameters and performance criteria. These assumptions reflect a well-developed system at each terminal of the line and operating criteria designed to promote system reliability. As helpful as the loadability characteristic and simplified analyses are in providing estimates of the amount of power that can be transferred over a well-designed transmission system, they cannot be viewed as a substitute for detailed studies. Such studies are generally required to account for the actual structure of the network, including influence of voltage control sources, and to evaluate the system performance during contingency operation. Detailed studies are beyond the scope of this discussion.

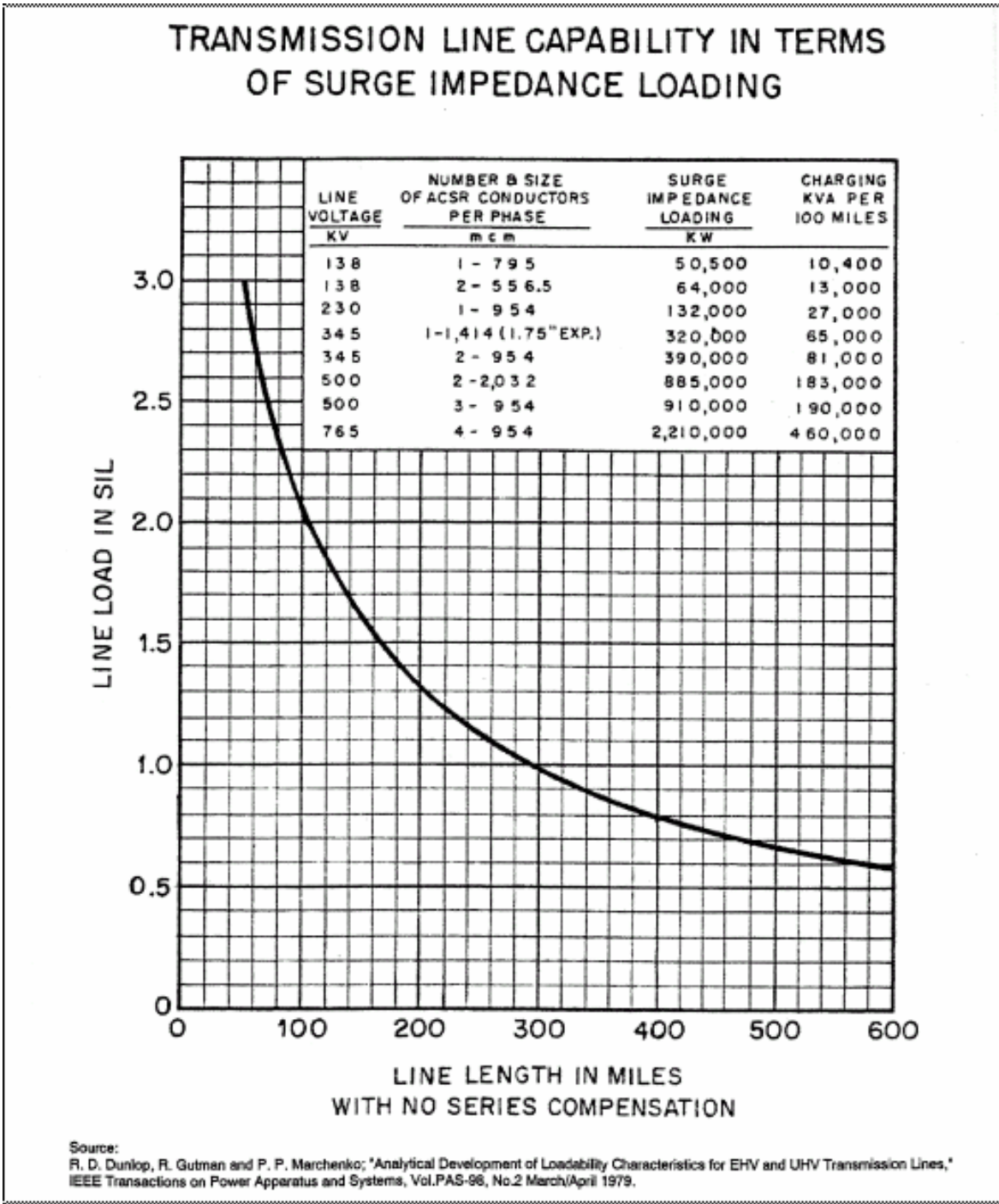


Figure 1 - St. Clair Curve

V. Reliability

A vibrant, reliable transmission system is essential to lowering the cost of electricity for all consumers. Experience shows that transmission systems designed for 765 kV operation are inherently more reliable than those operating at lower voltage levels.

The 765 kV lines are constructed using up to six conductors per phase to obtain acceptable corona and audible noise performance. Summer normal rating of a typical 765 kV line, including terminal equipment, exceeds 4,000 MVA (phase conductor bundle is rated still higher), virtually eliminating the risk of thermal overloads even under severe operating conditions. Notably, even when heavily loaded, 765 kV lines operate at near-ambient temperatures minimizing the sag effect and, thus, the likelihood of tree contact.

Outage statistics⁵ indicate that 765 kV circuits experience, on average, one forced outage per 100 mile-year. A comparable statistic for 345 kV is 1.6 forced outages per 100 mile-year. While single-phase faults are the dominant type of failures for both voltage classes, no multi-phase faults have been recorded at 765 kV in normal operation, short of tower failure. (AEP did experience 765 kV tower failures on rare occasions due to both severe icing and tornadoes.) This performance suggests a lower likelihood/severity of disruptions at 765 kV and an opportunity to apply effective mitigation measures, such as single-phase switching, to further improve the line (and thus system) reliability.

Single-phase switching (SPS) is a concept advanced and successfully applied by AEP in the mid-1980s in conjunction with the Rockport Project in southern Indiana^{6,7}. The concept has allowed integration of a 2,600 MW generating station with the system using only two 765 kV lines. SPS takes advantage of the superior outage performance of 765 kV lines by momentarily interrupting only one of three phases to clear temporary single-phase faults. This feature, made possible by the fact that 765 kV-connected station facilities (circuit breakers, shunt reactors, etc.) are built as single-phase units, enhances the line's availability and minimizes system disturbances caused by faults and associated switching operations.

The advantages of 765 kV become even more apparent when considering the alternative of building multiple double-circuit 345 kV lines. With eighteen distinct phase bundles, taller structures and lower ground clearances, the 345 kV alternative would present an increased exposure to lightning strikes and tree contacts. In fact, the three double-circuit lines required at 345 kV to match the loadability of one operating at 765 kV would incur, as a group, nearly ten times more outages than the 765 kV counterpart. While these outages would only partially degrade the loadability of the 345 kV corridor, the combined outage duration in a year would be significant.

Reliability of the 765 kV system is perhaps best illustrated by the blackout experience of August 14, 2003. On that day, a large segment of the interconnected grid in the eastern U.S. and Canada collapsed in a cascade that affected service to some 50 million people. It is notable that the cascade was effectively stopped at the "doorsteps" of AEP's 765 kV transmission system, which remained intact.

VI. Line Losses

Power losses in a transmission line increase linearly with its resistance and quadratically with loading. For a transmission distance of 150 miles, discussed earlier, the maximum loading of a 765 kV line – or the 345 kV alternative of six single-circuit (or three double-circuit) lines – is approximately 3,900 MW. At this loading level, the two transmission options would be characterized by the following losses due to conductor resistance.

Table 1 – Resistive Losses of 765 kV versus 345 kV Transmission (150 Miles)		
	765 kV (1 Circuit)	345 kV (6 Circuits)
Phase Conductor Bundle	6-795 kCM ACSR 45/7 (Tern)	2-954 kCM ACSR 45/7 (Rail)
Number of Phase Bundles	3	18
Effective Resistance (%)*	0.0546	0.1052
Loading (MW)**	3,900	3,900
Total Resistive Losses (MW)	83	160
Notes:		
* Positive-sequence resistance of all circuits comprising the option, expressed on 100 MVA and corresponding kV base.		
** Maximum expected loading of a 150-mile transmission corridor.		

As shown in Table 1, the 765 kV option would incur only about one-half of the power losses of the 345 kV alternative, both carrying the same amount of power. This markedly greater transmission efficiency of 765 kV can be attributed mainly to its higher operating voltage (and thus lower current flow) and large thermal capacity/low resistance compared to 345 kV transmission. Furthermore, by unloading the underlying systems with higher resistance, overall system losses can be reduced.

VII. Right-of-Way Requirements

The width of right-of-way necessary for a transmission line is dependent upon several factors including, but not limited to, structure design, conductor blow-out conditions, future needs, topography, electric and magnetic fields (“EMF”) and static discharge considerations. Sometimes, the acquisition of additional property rights or right-of-way width will allow better control over vegetation growth and thereby improve reliability.

AEP purchases a minimum right-of-way of 200 feet for 765 kV construction. The typical industry right-of-way width for 345 kV is 150 feet. AEP would expect to purchase the same right-of-way width for 765 kV in other parts of the country unless state laws dictate otherwise. Based on the relative loadabilities of 345 kV and 765 kV -- six single-circuit or three double-circuit 345 kV lines to move the same amount of power that can be carried with a single 765 kV line -- between 2.25 and 4.5 times more right-of-way would be required at the lower voltage (Figure 2).

Note: Approximate relationship based on Surge Impedance Loading (i.e. reactive power balance point) 345 kV single circuit tower lines with two conductors per phase compared to 765 kV single circuit lines with six conductors per phase.

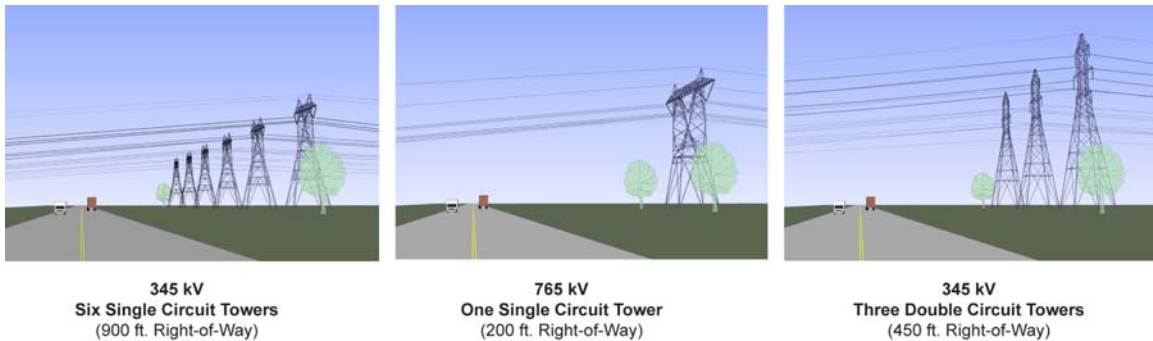
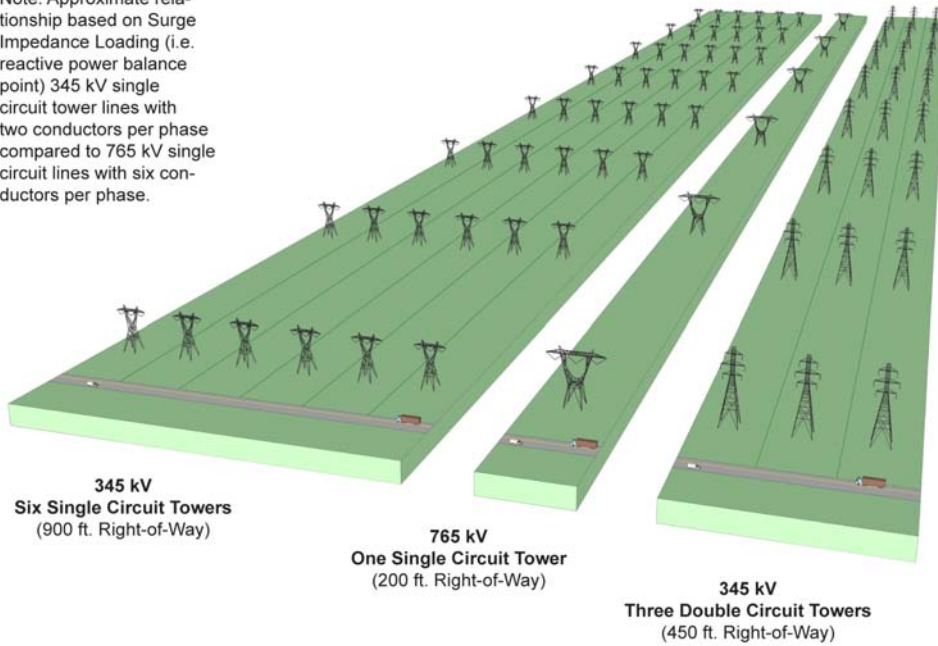


Figure 2 - Relative Right-of-Way Requirements of 345 kV and 765 kV

Right-of-way and structure requirements to move equal amounts of power over long distances (greater than 100 miles)

VIII. Line Design and Construction

Structures and Foundations

AEP has experience with several tower types on its 765 kV network, including 4-legged lattice structures, guyed-V lattice towers and tubular pole structures (Figure 3). Over a nearly 40-year history of building 765 kV lines, AEP has been very successful at matching these different structure types with the various terrain and land uses encountered in the Company's service area. For future 765 kV projects, AEP will use its current designs whenever possible and take advantage of each tower's individual characteristics in order to achieve the best fit for the proposed location.

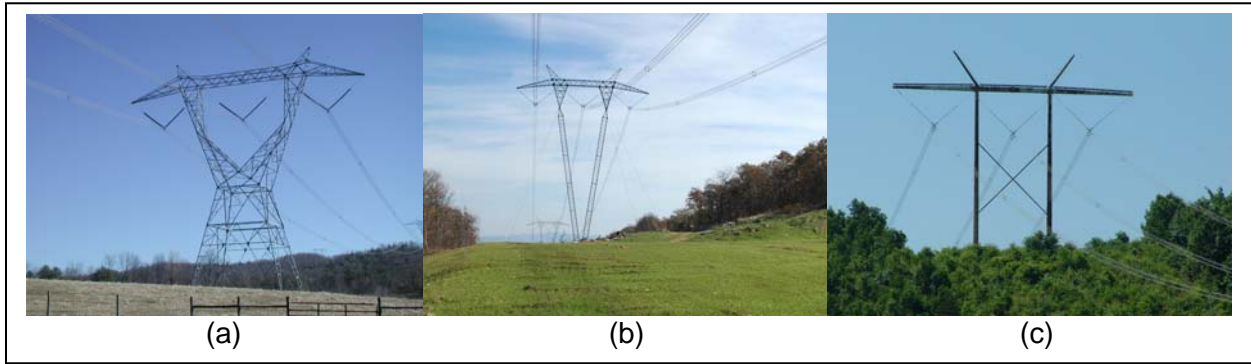


Figure 3 - Typical 765 kV Transmission Structures on AEP System

(a) 4-legged lattice steel self-supporting tower; (b) Guyed-V lattice steel tower; (c) Tubular steel structure

AEP evaluates several variables to determine the optimal structure configuration for a project, including the topography or landscape where the project will be constructed, visual impact of the structure type, structure configuration and its effect on EMF, material costs and associated lead times, and construction techniques. While AEP is capable of constructing both 345 kV and 765 kV in either tubular or lattice designs, advantages of each are highlighted below.

Lattice towers and tubular poles offer different qualities and advantages when the engineering and siting teams are selecting a design. Lattice towers are designed and constructed with steel angles that can be packaged and delivered to the structure site and assembled in place. Tubular poles usually involve a single or multiple pole shaft that occupies a smaller footprint than lattice towers, and can be easily erected in the field.

For a new 345 kV double-circuit line, AEP would most likely utilize a combination of lattice steel and tubular steel designs. The selection would again be based on the variables AEP considers for other transmission lines to find the best fit for the terrain at each tower location.

Tubular poles have advantages over lattice towers, such as a faster design, detailing and fabrication process. Because the tubular pole is a simplified design, its capability is more predictable and full-scale tests may not be necessary. New lattice tower designs, however, always require full-scale testing to check the complex connection designs. However, once lattice tower designs are tested the tower family can be easily reused on other projects. With the testing costs spread over several projects, testing costs may become insignificant.

Tubular assembly and erection is relatively simple and requires fewer labor hours overall, but it also requires expensive, heavy equipment. Depending on the terrain, a single crew can erect multiple poles in one day. As a result, tubular construction may provide a time advantage but not necessarily a cost advantage. Lattice tower assembly and erection is more complex and can take one or two weeks to erect a single tower. However, contractors erect steel based on a cost per pound and, since lattice towers are

generally lighter than an equivalent tubular design, using lattice towers will usually result in lower construction costs on large projects.

One of the most important variables in selecting a structure type is the foundation design required for a particular structure and the accompanying topographic challenges faced in the installation of different types of foundation. Tubular pole foundations are generally reinforced concrete piers. Lattice towers can be installed on concrete piers or steel grillage foundations. Steel grillage foundations are usually advantageous in mountainous terrain when the travel time to the job site eliminates concrete as an option. If the project area is in accessible terrain and in close proximity to concrete batch plants, concrete pier foundations gain a significant advantage. Tubular poles are very successful in these areas but require an efficient means to optimize the foundation design dimensions at each structure. This can be achieved with a thorough plan to obtain appropriate subsurface soil investigations and geologic reports prior to the design phase.

A comparison of the various structures needed to support each delivery system is presented below for multiple lines using a double-circuit 345 kV design with two-conductor bundles (2-954 kCM ACSR 45/7, Rail) and a single-circuit 765 kV with six-conductor bundles (6-795 kCM ACSR 45/7, Tern).

Structural Loads

Structural loads for a single-circuit 765 kV line and a double-circuit 345 kV line are shown in Table 2. This tabulation assumes 2,000-ft vertical and 1,300-ft transverse spans with 25 lb/ft² wind.

Table 2 - Conductor Wind and Weight Loading		
	765 kV Single Circuit (A)	345 kV Double Circuit (B)
Conductor Type	795 kCM 45/7 ACSR (Tern)	954 kCM 45/7 ACSR (Rail)
Conductor Diameter (in)	1.063	1.165
Conductor Weight (lb/ft)	0.896	1.075
Conductors per Phase Bundle	6	2
Bundles per Structure	3	6
Transverse Wind Load (lb)*	51,821	37,863
Vertical Weight Load (lb)**	32,256	25,800
(B)/(A) Wind Load Ratio	0.73	
(B)/(A) Weight Load Ratio	0.80	
Assumptions:		
* 1,300-ft horizontal span & 25 lb/ft ² wind (Load = Cond. diameter x #Cond./phase x #Phases x 1,300 ft x 25 lb/ft ²)		
** 2,000-ft vertical span (Load = Cond. weight x #Cond./phase x #Phases x 2,000 ft)		

As shown in Table 2, structural loads (i.e., transverse wind load and vertical weight load) for a single-circuit 765 kV tower are higher than those for a double-circuit 345 kV structure. To withstand the higher loads, 765 kV towers are designed with more structural capacity. Nevertheless, because of the vertical layout of the phases required for a double-circuit 345 kV structure design, the 765 kV towers are shorter over the same terrain, thus reducing the overall visual impact. This is particularly significant considering that three double-circuit lines would be required in the 345 kV alternative to match the power carrying capacity of a single 765 kV line.

In addition to the obvious aesthetic benefit, the single-circuit 765 kV design would carry only a slightly larger cost premium for the stronger towers. The cost premium is directly proportional to the steel structure weight, which can be estimated as the cube root of the wind and weight load ratios (the cube root of the wind and weight load ratios is proportional to the section modulus of a regular polygon).

$$\begin{aligned} \text{Pole weights and foundation size} &= \sqrt[3]{(0.73)} = 0.90 \\ \text{Arm weights and horizontal bridge weight} &= \sqrt[3]{(0.80)} = 0.93 \end{aligned}$$

Line construction contractors generally base their labor and equipment costs on structure weight. Therefore, the erection costs are only slightly greater for 765 kV construction compared to 345 kV construction. With three double-circuits required in the 345 kV alternative, its cost premium over 765 kV would be substantial. More details are provided in Section X (Cost).

IX. Visual Impact

Visibility

Double-circuit 345 kV towers are historically built in a vertical phase-over-phase configuration as opposed to 765 kV towers where the phases are in a horizontal, side-by-side configuration (Figure 4). Vertical 345 kV construction produces towers that are approximately 25% taller than 765 kV towers. Clearly, three 345 kV power lines using taller structures will result in a vastly greater overall visual impact, affecting significantly more property owners and critical viewsheds, than a single 765 kV line. Figure 5 demonstrates the differences in visual impacts of 765 kV and 345 kV construction.

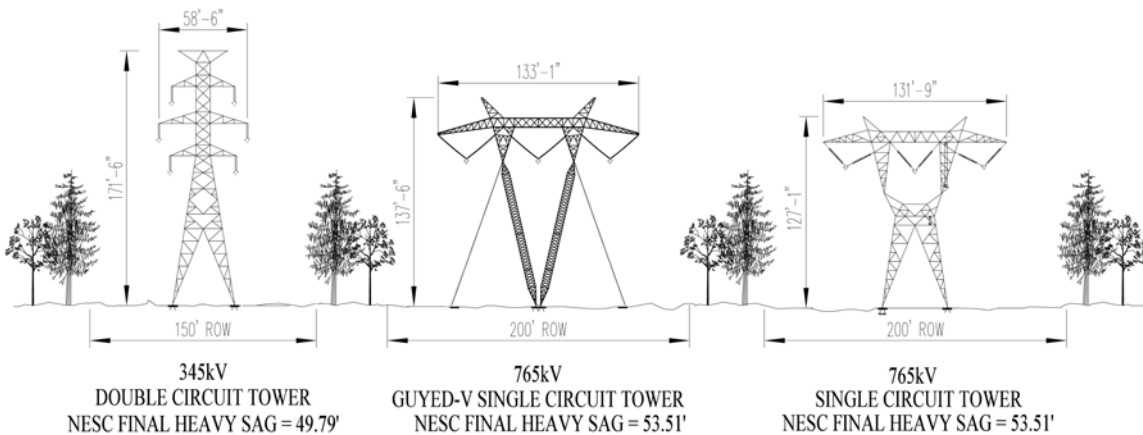


Figure 4 - 345 kV Double-Circuit and 765 kV Single-Circuit Lattice Structures

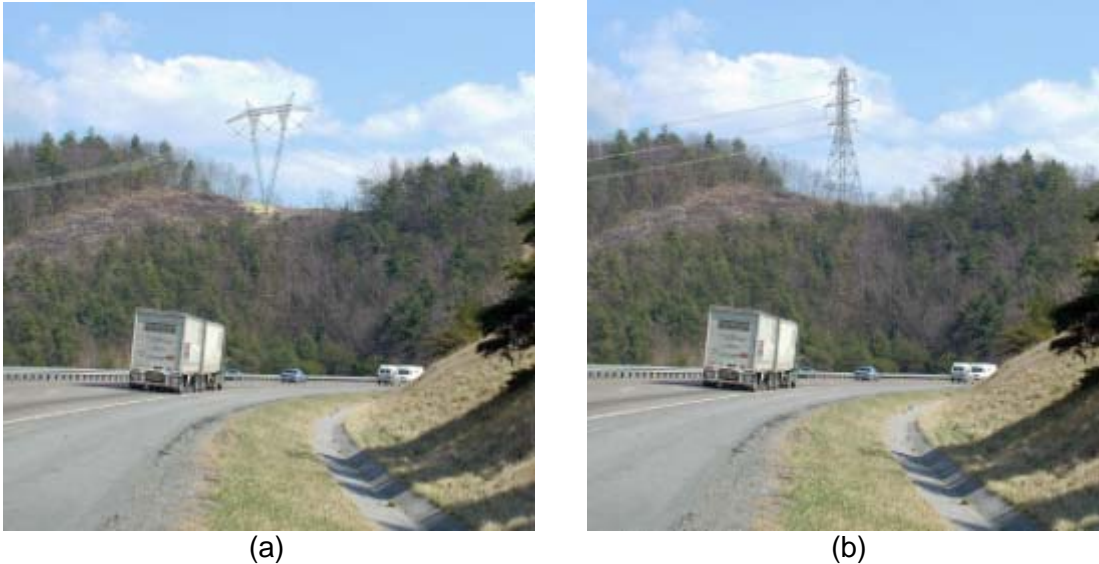


Figure 5 – Visual Effects of 765 kV and 345 kV Structures

(a) Actual 765 kV tower located in Virginia; (b) Simulation of double-circuit 345 kV tower (same location)

Visual Mitigation

In recent years, AEP has developed a rigorous visual mitigation methodology and has implemented effective measures to minimize the visual impact of its transmission lines⁸. Years ago, engineers would lay out a transmission line as straight as possible (with minimum angles) in order to reduce line construction cost. Visual impacts were an afterthought, if at all. Today, the route selection and line design process at AEP receives considerable attention and resources to reduce the overall visual impact as much as practicable.

For AEP's most recent 765 kV project, the Wyoming-Jacksons Ferry line commissioned in June 2006, landscape features such as vegetation and rolling hills or mountains were utilized to weave the line through the landscape. Visual impacts were considered during all project stages including siting, design and construction. Other commitments and methods to reduce visual impacts are highlighted below.

Non-Reflective Materials - Unlike transmission lines of yesteryear, AEP's new lines feature the latest advances in material reflectivity to darken and blend the lines into the landscape. Untreated materials reflect light and contrast with the natural scenery. The darkened effect is achieved by various treatments to the tower surface and conductors during the fabrication process. These enhancements have significantly reduced the visual impact of transmission lines (Figures 6 & 7).

Research - AEP researches existing visual impacts of transmission lines to identify effective mitigation measures. The findings influence the siting practice followed by AEP. For instance, paralleling the edges of treelines and fencelines reduces the line's visibility. This and other visual mitigation guidelines are utilized to develop study corridors to be filed with state and Federal regulatory agencies.

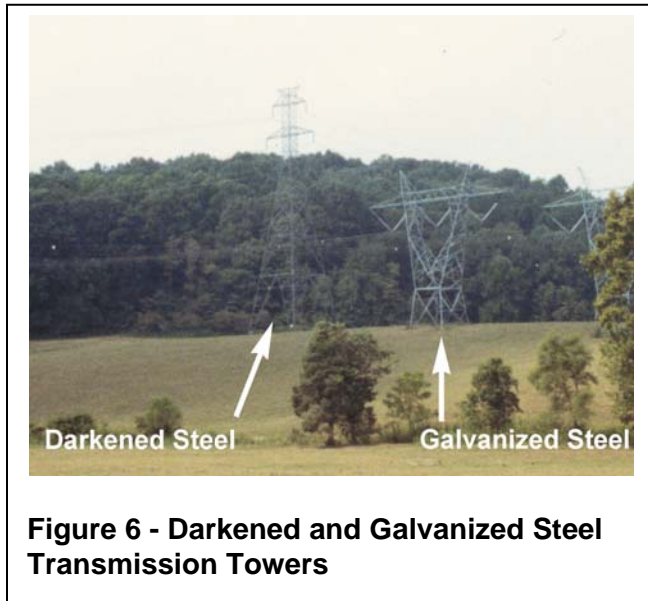


Figure 6 - Darkened and Galvanized Steel Transmission Towers



Figure 7 - Darkened Steel Transmission Towers Before Wire is Installed

Landowner and Agency Input - Communication with and input from affected landowners and state and Federal agencies is crucial. During AEP's recent 765 kV project, private landowner input was collected at public meetings to document their concerns and identify existing critical viewsheds. Later, after a preferred corridor was developed, AEP adjusted the line siting within the approved corridor to address their concerns. Also, AEP sought input from state and Federal agencies. Agency representatives possess a wealth of knowledge about the resources they administer, which can be invaluable in developing a right-of-way location that minimizes overall visual impacts.

GIS Visibility Analyses - As study corridors are identified, a viewshed analysis is performed to evaluate each corridor's visual impacts. Visibility data are generated from proposed corridor segments and key observation points using a Geographic Information System (GIS) to assess the impact on the surrounding environment.

Visual Simulations - Quantifying potential visual impacts is important for the public and planners during the line siting process. Substantial public and governmental opposition can be fueled by misconceptions of the potential visual impacts. To address these misconceptions, AEP simulates these impacts (or lack thereof) and presents them to the public and relevant government agencies. Both photographs and computer models (refer to Figure 5) are used to obtain an accurate depiction of post-construction visual effects. Visual communication can alleviate unfounded fears and help planners refine line designs to mitigate impacts.

Selective Right-of-Way Clearing - Once the line is designed, AEP prepares vegetation clearing plans and communicates them to field personnel. In a departure from past practices of typically clearing the entire right-of-way, different types of clearing (selective clearing) are specified in different situations. In many areas where ground-to-conductor

clearance exceeds 100 ft, minimal right-of-way clearing is required. Except for tower sites, clear-cutting is usually not required and low-growing compatible species, such as redbuds and dogwoods, are preserved. These minimized and selective right-of-way clearing techniques substantially decrease the line visibility. As the right-of-way is cleared and towers erected, the final stage of the visual assessment involves minimizing impacts during construction.

X. Cost

Cost estimates for any transmission line construction depend on many variables, with terrain conditions and right-of-way costs being key components. Accordingly, per-mile cost estimates will vary for different regions of the country.

Base line cost estimates for a 765 kV line and a double-circuit 345 kV line are \$2.6 million and \$1.5 million, respectively, per mile of line. These costs include siting, right-of-way and construction, but exclude the cost of terminal stations. The per-mile cost will increase from this basis depending on environmental, land use and other factors. While there is a significant premium for building a 765 kV line, this cost relationship is reversed when power transfer capabilities of the two transmission designs are taken into account. Table 3 provides the details for a typical transmission corridor considered in the AEP-ITC study, capable of carrying nearly 4,000 MW over a distance of 150 miles.

Table 3 – Transmission Cost to Deliver 3,900 MW Over 150 Miles		
	765 kV Single Circuit	345 kV Double Circuit
Phase Conductor Bundle	6-795 kCM ACSR 45/7 (Tern)	2-954 kCM ACSR 45/7 (Rail)
Number of Circuits per Line	1	2
SIL per Line*	2,400 MW	780 MW
Loadability**	3,800 – 3,900 MW	1,200 – 1,300 MW
Lines Required for 3,900 MW	1	3
ROW Width Required	200 ft	450 ft
Cost per Mile for 3,900 MW***	\$2.6 Million	\$4.5 Million (3 x \$1.5 Million)
Cost per MW-Mile	\$670	\$1,150
Assumptions:		
* SIL, surge impedance loading, is a measure of relative line loadability at the reactive power balance point without voltage support. Thermal capacities vary; e.g., 765 kV can carry well over 4,000 MW and 345 kV (double circuit) can carry over 2,000 MW.		
** Based on maximum expected loading of a 150-mile transmission corridor (approx. 1.6 SIL).		
*** Average cost in 2007 dollars; rural terrain with rolling hills. Includes siting, right-of-way and construction (but excludes station costs) for the number of lines required in each option.		

The two transmission alternatives shown in Table 3 can deliver equivalent amounts of power (i.e., 3,900 MW), with only one circuit needed at 765 kV and three double-circuit lines required at 345 kV. It is notable that, on a per-MW basis, a 70% premium would be required for the 345 kV alternative (\$1,150 per MW-mile) over 765 kV (\$670 per MW-mile). This cost advantage of 765 kV can increase further with a line design optimized for use in flat, low-elevation terrain. Apart from the cost savings, a significant reduction in the overall right-of-way requirements is possible with 765 kV transmission.

XI. Conclusion

AEP believes that 765 kV transmission is superior in many ways when compared to double-circuit 345 kV -- it offers unparalleled electrical performance, significant cost advantages and less environmental impact because fewer lines need to be constructed. As a proven, high-capacity technology with worldwide acceptance, 765 kV is the best platform on which to build a modern transmission superhighway system that meets the needs of America's economy in the 21st century.

XII. References

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