Report—Key ACCC® Conductor Use Cases for New and Rebuilt Transmission Line Projects

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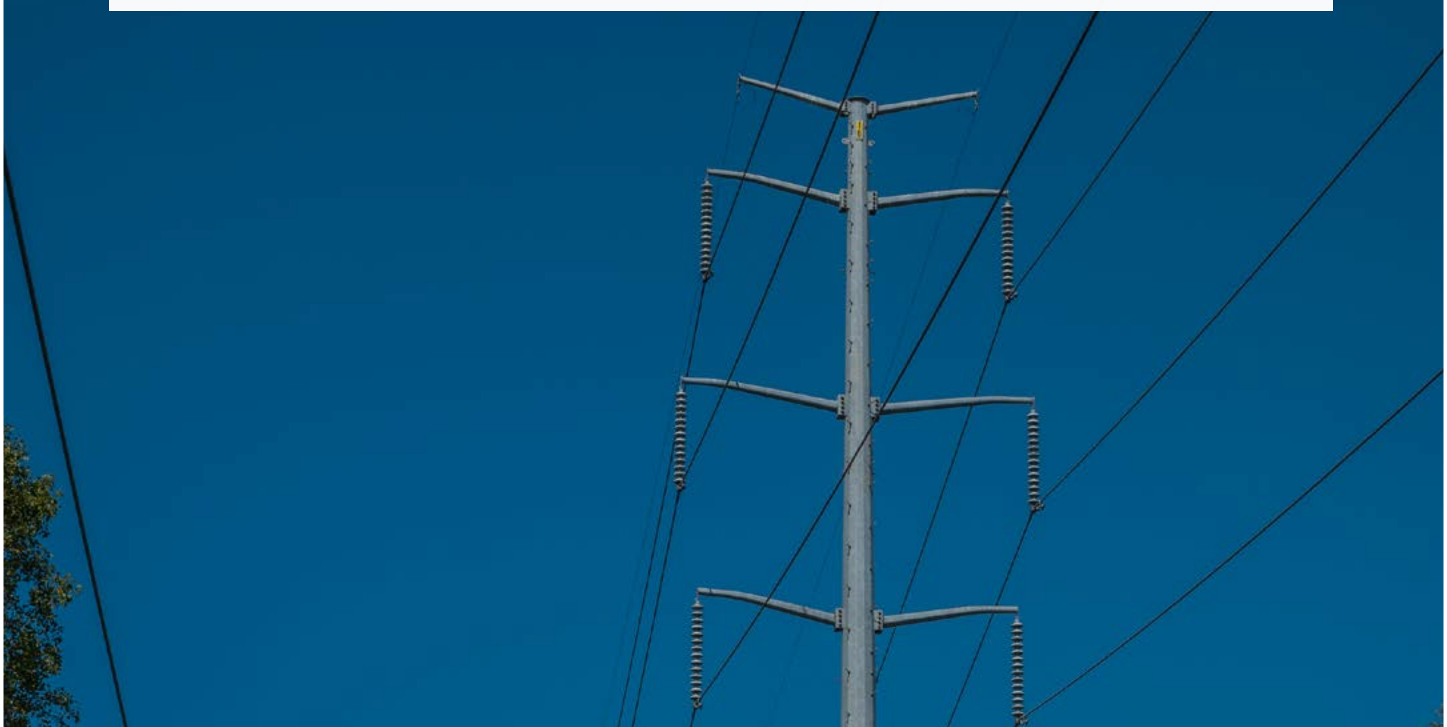

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Executive Summary

POWER Engineers, Inc., member of WSP (POWER), performed a high-level conceptual conductor selection analysis comparing the costs and performance of ACCC® Conductor options to traditional counterparts with the goal of highlighting key ACCC Conductor use cases for new or rebuilt lines. This report summarizes the methodology and results of this analysis and serves to highlight broader comparative trends using conceptual conductor comparisons.

In the analysis, four key categories of use cases at voltages 345 kV and below were identified where ACCC Conductors best compete with their traditional counterparts. These use case categories include considering ACCC as opposed to:

- » Equivalent diameter Aluminum Conductor Steel-Reinforced (ACSR) conductors.
- » Equivalent diameter Aluminum Conductor Steel Supported, Trapezoidal Wire (ACSS/TW) conductors.
- » Equivalent diameter Aluminum Conductor Steel Supported (ACSS) conductors.
- » Using either smaller diameter ACCC Conductors or a fewer number of ACCC subconductors in comparison to ACSR conductors.

ACCC Conductors have a greater aluminum area than round wire conductors for the same diameter due to their trapezoidal stranding. This reduces the resistance of ACCC Conductors and provides savings in terms of line losses. ACCC Conductors also see reduced sag at their maximum operating temperature in comparison to steel core conductors. The key use cases of ACCC highlighted in this report offer varying benefits among them including reducing losses by up to 25%, reducing total project costs by up to 15%, increasing the maximum ampacity up to approximately double, reducing structure heights by 3–6 feet and reducing structure loading.

This analysis focuses on the 2024 North American market and primarily considers alternating current (AC) lines. The broader trends highlighted in this analysis could be considered applicable to both new line projects and rebuild projects. This analysis Report—Key ACCC® Use Cases for New and Rebuilt Transmission Line Projects uses estimated structure and foundation costs that are based on calculated ground line moments, considering structure heights, configurations, and line tensions.

The analysis estimates the cost of line losses based on an average line loading of approximately 40% of the lines' maximum capacity. For markets outside of North America, the design criteria and cost assumptions would need to be modified.

Typical industry prices in 2024 are the basis of this study. Changes in material prices based on future market adjustments or location-specific price inflation could impact the resulting analysis trends discussed in this report. Increases in structure material prices are likely to result in a more substantial cost impact of structure height and loading reductions.

> *This analysis focused on showing trends in how ACCC Conductor competes against traditional conductor options for new line projects and highlights situations of interest and aspects in which ACCC Conductor competes well against traditional conductor options for new line projects.*
>
> **–Kailey MacHardy, E.I.T., Engineer-in-Training**

The analysis is not intended to perfectly represent any specific project with great accuracy. Values representing differences in costs between conductor options presented in this report have been rounded to the nearest 5% to better depict the high-level nature of these results. Engineers and project designers would need a refined analysis based on detailed, project-specific data such as local environmental conditions, load forecasts, structural constraints and location-specific material costs.

Key ACCC Use Cases on New Line Projects

Various use cases where the application of ACCC Conductor can provide benefits for new line or rebuild projects are discussed in the following section.

In general, the key ACCC use cases for new lines focus on voltage levels 345 kV and below. At these voltage levels, required conductor ampacity is the primary driver of conductor selection. This allows for the benefits of the high capacity of ACCC Conductors to be best utilized.

Transmission lines at voltage levels of 345 kV and below are also often relatively short in length (less than 50 miles). Lines shorter in length typically have power transfer limits governed by conductor ampacity rather than electrical limits such as voltage drop and stability. This allows for the benefits of the high capacity of ACCC Conductors to be more fully realized.

Four key categories of use cases for ACCC Conductors are discussed below.

1. ACCC versus ACSR

One of the key use cases for ACCC Conductors on new line projects is to use ACCC in lieu of an equivalent-diameter ACSR conductor. POWER analyzed eight scenarios that compared ACCC Conductors to equal diameter ACSR conductors over a range of voltage levels between 115 kV and 345 kV. Throughout these scenarios, several analysis trends were observed showing potential benefits of applying ACCC Conductors.

ACCC conductors have a greater aluminum area than ACSR for the same diameter, which reduces the resistance of ACCC Conductors and provides saving in terms of line losses. Between 15–25% savings in line losses were observed in the analysis under average loading conditions for these scenarios. The savings in terms of line losses were observed to have the potential to decrease total project costs (which includes capital costs and line losses) by up to 15%, with less than a 10% increase in capital costs in most cases. In the scenario shown below in Figure 1, only a minor increase in capital costs of 5% was observed, while savings in losses of 20% were achieved. Specific project situations with higher average loading requirements would see greater benefit as this results in even greater savings in line losses. These trends are demonstrated in Figure 1, where the cost of losses, capital cost and total cost are graphed as a function of average line loading for a 115 kV single circuit transmission line with typical structure heights in the range of 60–70 feet. Table 1 summarizes key values from this scenario.

Total Cost Comparison—ACCC vs. ACSR
115 kV New Line

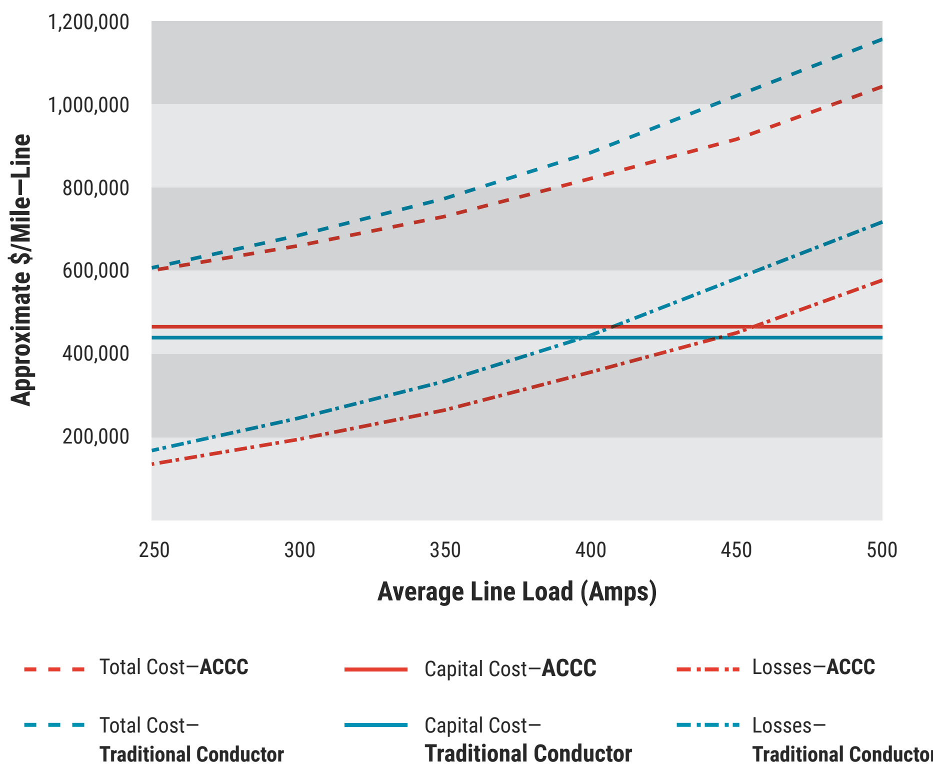

Figure 1*—Capital Cost, cost of losses, and total cost for 713.5 kcmil ACCC "Dove" and 556.5 kcmil ACSR "Dove" conductor options for a 115 kV single circuit new line.*

Table 1: ACCC vs ACSR Comparison Summary—115 kV New Line		
	713.5 kcmil ACCC Dove	556.5 kcmil ACSR Dove
Conductor Diameter	0.93 inches	0.93 inches
Conductor Max Ampacity	1417 Amps	782 Amps
Span Length	600 ft	600 ft
Change by Using ACCC		
Change in Sag	-5 ft	
Change in losses	-20%	
Change in capital costs	+5%	
Change in total costs	Up to -10%	

Additionally, ACCC Conductors provide approximately double the maximum ampacity of equivalent diameter ACSR conductors, which can provide additional value in the future if the capacity needs of a line were to increase beyond what was initially anticipated. The additional capacity of ACCC Conductors could help avoid the need for a potential future line upgrade in this scenario.

Throughout the scenarios studied, ACCC sagged approximately 4–7 feet less than the equivalent diameter ACSR option for a given span length. This reduction in sag translates to shorter structures, and a small decrease in structure and foundation costs. The decrease in structure height slightly magnified the impact for double circuit structures, in comparison to single circuit structures in terms of additional savings for structures and foundations.

2. ACCC versus ACSS/TW

The more traditional, high-temperature conductor option of ACSS/TW is another key use case for ACCC Conductors on new line projects. ACCC Conductors and ACSS/TW conductors have similar aluminum areas for a given conductor diameter, since both use compact trapezoidal outer strands. For this reason, these conductors achieve similar overall line losses and maximum ampacity ratings. ACCC Conductors are lighter weight than ACSS/TW conductors of the same diameter, due to the reduced weight of ACCC's composite core in comparison to steel cores. This reduction in weight reduces vertical loading on structures, which in turn can lower the cost of structures.

In the analysis performed by POWER, several scenarios were analyzed that compared ACCC Conductors to equal diameter ACSS/TW conductors over a range of voltage levels between 115 kV and 345 kV. Throughout these scenarios, POWER observed very similar capital and totals costs for the two conductor options. While ACCC Conductors had a higher cost per foot than ACSS/TW conductors, the ACCC Conductor option sagged on average 3–6 feet less than the ACSS/TW option at the maximum operating temperature. This results in a potential for shorter structures and savings in structure and foundation costs which offsets the higher conductor cost. As seen in Figure 2, for a 230 kV double circuit transmission line with typical structure heights in the range of 75–85 feet, the ACCC and ACSS/TW options have very similar costs in all categories (losses, capital cost and total cost). Table 2 summarizes key values from this scenario. In this case, for approximately the same cost and power transfer capabilities, ACCC provides a lower viewshed option over ACSS with 5-foot shorter structures.

Total Cost Comparison—ACCC vs ACSS/TW
230 kV New Line

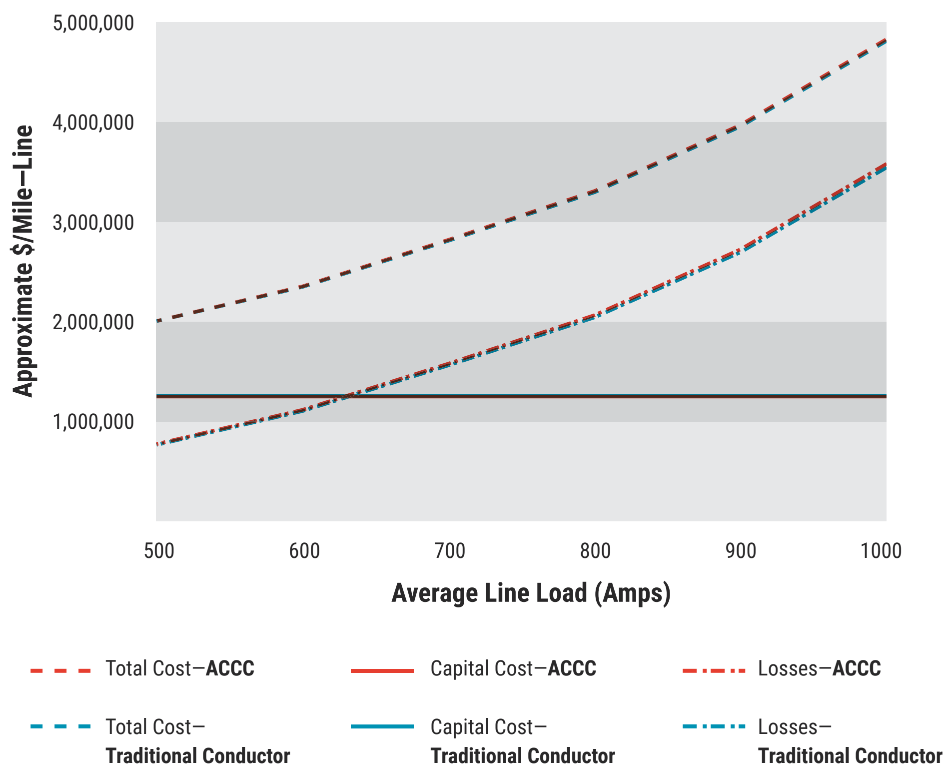

Figure 2*—Capital Cost, cost of losses and total cost for 1025.6 kcmil ACCC "Drake" and 1033.5 kcmil ACSS/TW "Curlew" conductor options for a 230 kV double circuit new line.*

Table 2: ACCC vs ACSS/TW Comparison Summary—230 kV New Line

	1025.6 kcmil ACCC Drake	1033.5 kcmil ACSS/TW Curlew
Conductor Diameter	1.11 inches	1.13 inches
Conductor Max Ampacity	1797 Amps	1816 Amps
Span Length	600 ft	600 ft
Change by Using ACCC		
Change in Sag	-5 ft	
Change in losses	Equal	
Change in capital costs	Equal	
Change in total costs	Equal	

Future market adjustments on the price of materials could impact the outcome of these comparisons, as an increase in raw steel material prices would result in greater capital cost benefits being observed for reducing structure heights and weights.

There are many different perspectives to take when comparing two different conductors, and many nuances in the analysis. It has been interesting to identify broader analysis trends and understand where ACCC fits in best.

–Lisa Deppa, P.E., Transmission Line Engineer

3. ACCC versus ACSS

As an alternative to ACSS conductors on new line projects, ACCC Conductors will provide additional savings in losses when compared by diameter to ACSS conductors. Additional savings in losses up to 20% were observed for these scenarios. POWER observed structure height savings of approximately five feet for the ACCC option in the scenarios studied comparing these conductors. Considering both the savings in losses and savings due to reduced structure heights for these cases, total cost savings were up to 10% for the ACCC option in these scenarios. Figure 3 demonstrates these results, where the cost of losses, capital cost and total cost are graphed as a function of average line loading for a 345 kV single circuit transmission line with typical structure heights in the range of 100–110 feet. Table 3 summarizes key values from this scenario.

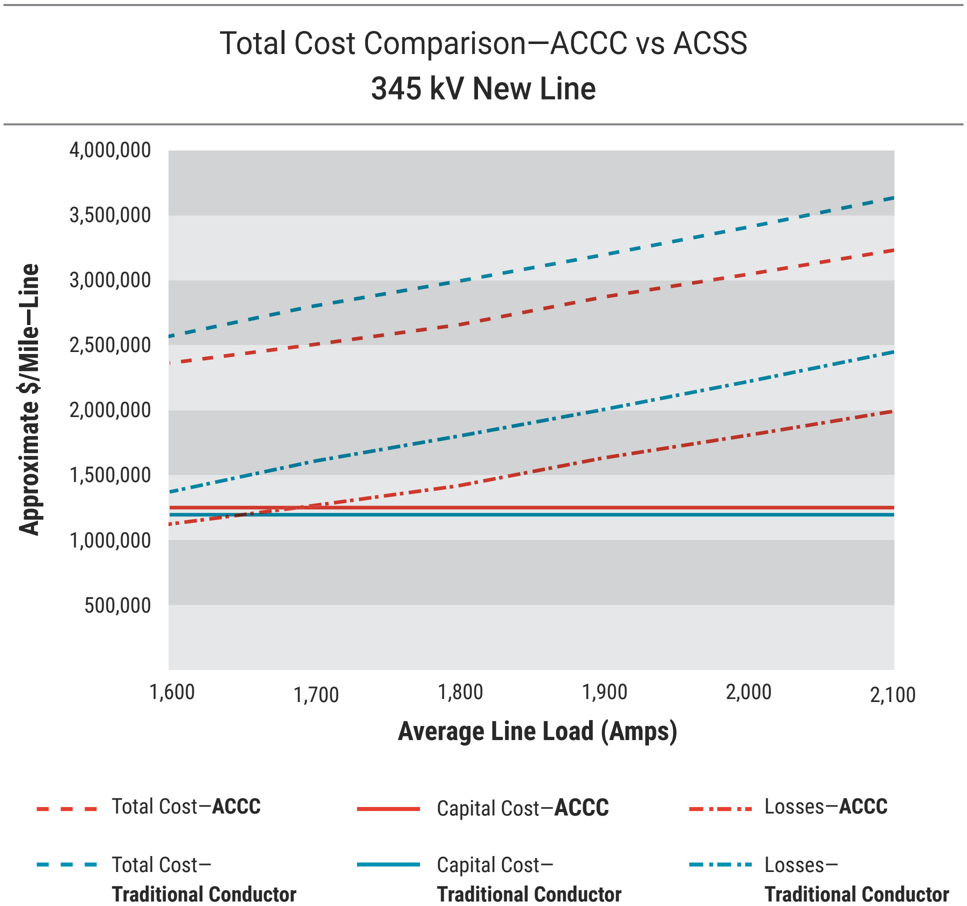

***Figure 3**—Capital Cost, cost of losses and total cost for double bundle 1948.9 kcmil ACCC "Lapwing" and 1590 kcmil ACSS "Lapwing" conductor options for a 345kV single circuit new line.*

Table 3: ACCC vs ACSS Comparison Summary—345 kV New Line

	1948.9 kcmil ACCC Lapwing	1590 kcmil ACSS Lapwing
Conductor Diameter	1.50 inches	1.50 inches
Conductor Max Ampacity	5388 Amps (double bundle)	4745 Amps (double bundle)
Span Length	1000 ft	1000 ft
Change by Using ACCC		
Change in Sag	-5 ft	
Change in losses	-20%	
Change in capital costs	+5%	
Change in total costs	Up to -10%	

4. Smaller or Fewer ACCC Conductors

The high capacity of ACCC enables the use of smaller diameters or fewer subconductors compared to ACSR on new lines. ACCC can achieve the same capacity as ACSR conductors using a smaller aluminum area due to its increased maximum operating temperature. This allows for decreased structure loading and capital costs on new line projects. POWER's analysis compared scenarios involving either a smaller ACCC Conductor versus an ACSR conductor or one larger ACCC Conductor to two smaller ACSR conductors over a range of voltage levels between 115 kV and 345 kV. For both conductor configurations, ACCC can achieve the same or greater capacity as the ACSR option, with a lower overall loading on the structure. ACCC may have similar or greater line losses depending on the relative conductor sizes due to the reduction in conductor aluminum area.

There is a tradeoff between increased line losses and decreased structural loading when choosing a conductor for a transmission line. Reducing conductor size or subconductor quantity will reduce structure loading and upfront capital costs, while increasing the lifetime cost of conductor losses, due to a decrease in conductor aluminum area. This relationship can be studied on a project specific level to help determine the most cost-effective conductor size for a transmission line that balances reduced capital costs with the corresponding conductor losses. Projects with high structural material prices may see greater benefit from reducing structural loading, whereas projects expecting high average-current loading may see greater benefit from a larger conductor size that can reduce conductor losses.

Other Considerations and Omissions

The analysis performed by POWER was high level in nature, with the goal of identifying broad comparative trends between ACCC and traditional conductors.

POWER broadly considered the North American market. However, regional nuances and project specific details may impact the results discussed here. Specific regions that see generally higher material prices compared to the rest of North America, such as California, could potentially see greater capital cost savings due a reduction in structure heights for the ACCC option than what was observed in this analysis. Similarly, a general increase in structural material prices could lead to reduced structure heights, which have a more substantial cost impact. In addition to reducing structure heights, the key use case discussed above of using smaller/fewer ACCC Conductors could also see more substantial benefits in project specific cases with high structure or foundation material costs. The lower structural loading this option provides reduces both structure weights and foundation sizes.

Quotes for ACSS and ACSS/TW conductors were not available for the analysis performed by POWER. POWER leveraged data from the 2024 MISO Transmission Cost Estimation Guide to determine approximate prices for these conductors in conjunction with the ACSR baseline data obtained through CTC's authorized manufacturer partner (AMP) network. Conductor pricing regularly fluctuates with the market and can vary by location and vendor. It is important to obtain conductor pricing quotes when comparing conductors for a specific project, as the relative difference in price between different conductor options plays an important role in the outcome of comparisons. Varying import reliance and potential tariffs of different conductor materials within the United States has the potential to affect the relative price between different conductors in the future.

One consideration outside of the scope of the analysis performed by POWER was the impact and/or suitability of using increased tension limits. POWER used industry standard design catenary values for tension limits in this analysis. If further industry-accepted research was presented demonstrating that ACCC Conductors could utilize percent rated-breaking-strength (%RBS) limits or larger catenary values without aeolian vibration concerns, the benefits described above that utilize the decreased sag of ACCC would be further increased. Since the core of ACCC is stronger than the cores of traditional conductors, higher tensions could result in even lower conductor sags and structure heights, providing additional opportunity for capital cost savings. It is important to work closely with damper vendors to ensure that dampers can adequately provide protection against aeolian vibration for the tensions chosen on a specific project.

The analysis discussed in this report focuses on using the reduced sag of ACCC to lower structure heights, though this property can also be used to increase span lengths while maintaining the same structure height. Increasing span lengths will increase conductor blowout and structure loading and it may only be feasible in some project scenarios. Span lengths are typically chosen based on span length optimization studies for a specific project, and this type of study was not within the scope of this analysis. However, increasing span lengths without increasing structure heights could be beneficial in some scenarios where certain height restrictions may apply.

Conclusion

POWER performed a high-level conceptual conductor selection analysis comparing ACCC Conductors to traditional counterparts. This analysis achieved the goal of identifying broader comparative trends where ACCC competes well against new line projects in the North American market. Four key use cases were highlighted considering ACCC as opposed to ACSR, ACSS, ACSS/TW, and considering smaller or fewer ACCC Conductors as opposed to ACSR, at voltage levels 345 kV and below. These use cases offer varying benefits between them including reduced losses, increased capacity, reduced structure heights and reduced structure loading. From this analysis, the key takeaway is that ACCC can be competitive with traditional conductor options and is worth consideration in the conductor selection process.

Appendix

Analysis Methodology

POWER performed a high-level conceptual conductor selection analysis comparing the capital costs, cost of losses, and total costs (capital plus losses) of ACCC Conductor options to traditional counterparts. Key design considerations and methodology used for estimating the costs in this analysis are described in the sections below.

General

Each conceptual conductor selection scenario in the analysis considered a set of defined parameters for a new line including voltage level, wire type (ACCC compared to ACSR, ACSS, or ACSS/TW), circuit quantity, structure type and configuration, NESC loading zone, span length, required capacity and average line loading. In general, conductors compared in each scenario were selected based on a minimum required capacity or similar conductor diameters and/or bundle configurations. The cost comparison in each scenario considers the costs of wires, structures, foundations, hardware, construction, engineering, permitting and resistive losses. The comparison does not consider cost of land, which can vary greatly by location, and is expected to be similar between the ACCC option and the traditional conductor option.

POWER used the 2024 MISO Transmission Cost Estimation Guide to reference several cost components to support the study, such as insulators and hardware and relative price differences between ACSR and ACSS. The analysis considers sag due to maximum operating temperature and NESC Loading Zone conditions, which include ice for some regions. However, due to the high-level nature of the study, it does not consider sag due to a more extreme ice loading that some utilities may opt to use within their standards.

Tensions

Recommendations from CIGRE Technical Brochure 273 are the basis of design tension limits used in this analysis—in addition to POWER's experience—assuming Stockbridge dampers are installed on the conductors and the lines are to be installed in open, flat terrain. The tension recommendations of CIGRE Technical Brochure 273 are preferred since they are based on catenary limits. Catenary limits consider the weight of the conductor, which is more reflective of self-damping properties than the rated tensile strength. A design catenary of 2,100 meters (6,890 feet) at an average annual minimum temperature (AAMT) of 0°F has been used for all conductors and span lengths in the analysis. The guidance in CIGRE 273[i] is targeted to traditional conductor types such as ACSR and does not encompass high-temperature low-sag conductors such as ACCC. Given the lack of more targeted guidance on safe tension limits for ACCC Conductors, the recommendations in CIGRE 273 have been applied to both the ACCC and traditional conductors (ACSR and ACSS). Any impact of using ACCC at comparably higher tensions would require further investigation, which is not considered within the scope of this analysis.

Conductor Maximum Operating Temperature

A maximum emergency operating temperature of 200°C has been considered for both ACCC and ACSS in the analysis, and a maximum emergency operating temperature of 100°C has been considered for ACSR.

Aluminum Compression

It is assumed that the aluminum strands of ACSR conductors will support compression at high temperatures, whereas the annealed aluminum of ACSS and ACCC will not support compression. Based on industry publications, the maximum virtual compressive stress for ACSR will be set based on a compressive strength value of 1.5 ksi for the aluminum wires.

Structure and Foundation Costs

In the analysis, structure heights are determined using maximum conductor sags from PLS-CADD (under maximum operating temperature and NESC loading conditions) combined with NESC minimum ground clearances with an appropriate design buffer. Structure geometry is calculated based on voltage level and common dimensions between phases, shield wires and the structure, based on industry references and POWER's experience. Structure geometry and height along with tensions determined in PLS-CADD were used to calculate ground line moments for each applicable load case in the scenarios for the two conductor options.

Groundline moment is an important variable in the analysis since it is correlated to structure cost. Groundline moment is a function of loading magnitude, direction, and distance from the center of the structure at the groundline. Vertical forces (weight of conductor, ice, etc.) contribute along their horizontal offset relative to the center of the structure, and horizontal forces (wind, conductor tension, etc.) contribute along their vertical offset (height) above ground. As a general statement, larger groundline moments require more material to resist the load, leading to higher capital costs. Assuming consistent structure geometry for the same applied loading, a shorter structure will result in a lower groundline moment, and for the same structure height, a lesser loading will result in a lower groundline moment. Conductor properties and tension are key parameters in applied loading and required structure heights making conductor selection a key factor in efficient line design.

The controlling groundline moment was used to estimate pole weights, based on data from past projects relating ground line moment with pole shaft and base plate weight. The cost of steel has been assumed as $2.50/lb. Foundation costs for poles are based on data published by CIGRE in Electra[ii] relating ground line moment and total foundation cost. Prices were adjusted for inflation per the Bureau of Labor Statistics CPI inflation data.[iii] Both suspension and dead-end structures are considered in the analysis. All suspension structures assume a line angle of 2° for structure loading calculations. All dead-end structures are assumed to have a line angle below 65°, with dead-end structures assumed to be controlled by the one-side-intact loading condition. The percentage of dead-end structure frequency has been assumed as 5% of the line for all cases.

Line Losses

The cost of resistive line losses has been estimated in the analysis assuming an average line loading of approximately 40% of the required capacity in scenarios where this parameter was fixed. Based on POWER's experience, this is expected to be a reasonable and simple approximation of losses, considering that estimating the percentage of time at different loading levels is difficult to achieve with accuracy. Some scenarios varied the average line loading to assess how heavier or lighter loading affects the overall cost comparison. Approximate losses per phase are calculated by squaring the stated average load (Amps-RMS) and multiplying by the resistance of the cable at the approximate temperature corresponding to this load condition. The annual cost of losses is determined assuming this loading occurs for 24 hours a day, and 365 days a year. The net present values of line losses have been calculated considering a rate of return of 7% over an estimated service life of 30 years. The cost of energy has been assumed as $47/MWh per data from the U.S. Energy Information Administration.[iv]

Conductor Pricing

Conductor costs for both ACCC and ACSR conductors are based on indicative data from CTC, sourced from CTC's authorized manufacturer partner (AMP) network in July of 2024. For ACSS/TW/MA5 conductors, a multiplier has been considered on top of the equivalent ACSR costs based on feedback from CTC's AMP network. Wire costs from the 2024 MISO Transmission Cost Estimation Guide[v] have also been referenced for pricing the steel shield wire and for determining a percentage step increase in costs between ACSR and ACSS conductors. Conductor pricing regularly fluctuates, reflecting the latest market conditions and will generally vary from vendor to vendor at any given time. Current pricing from the intended suppliers would be a key variable in any similar analysis of an actual line project.

REFERENCES

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