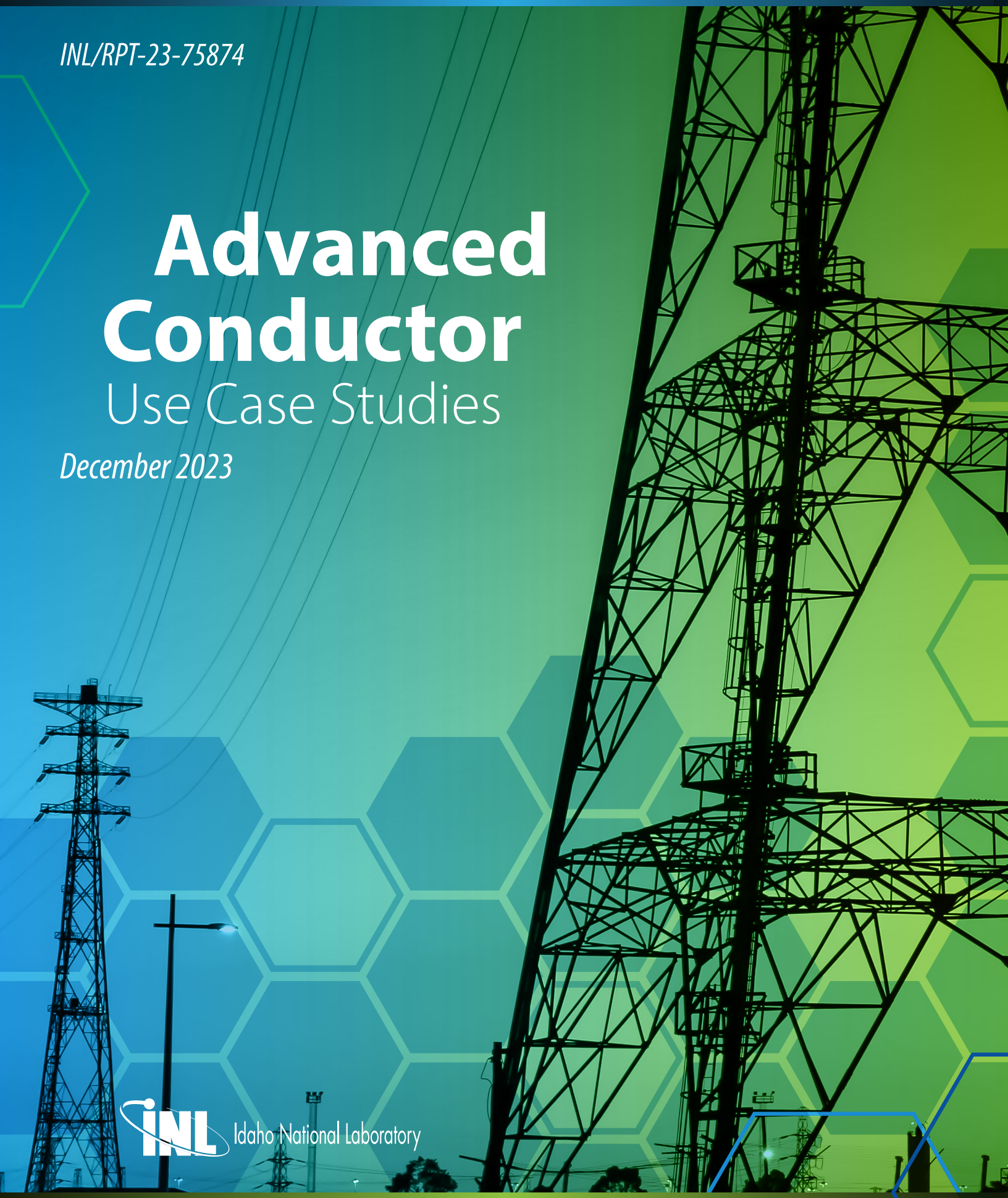
INL/RPT-23-75874

Advanced Conductor

Use Case Studies

December 2023



Idaho National Laboratory

Acknowledgments

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Contents

Utility Scan Introduction

Utility Profiles

The following document includes conductor selection profiles of 44 of the largest transmission operating utilities in the United States (U.S.). Federal power marketing agencies were also included. For each utility, available information on their conductor deployments and technology strategy is included, and exemplary project details for each conductor type are listed. Profiles are based on interviews as well as publicly available documents, such as those from regional planning processes or regulatory filings.

Conductor Application Successes

Of the profiled utilities, a high number have taken advantage of conductor technology advancements beyond ACSR. 95% of the utilities have deployed or have plans to deploy Aluminum Conductor Steel Supported (ACSS) conductors including products with ultra-high-strength steel cores. Seventy percent of utilities had deployed or have plans to deploy other advanced conductor technologies, including ACCR from 3M, ACCC from CTC Global, E3X from Prysmian, TS Conductor, and C7 from Southwire. Many utilities have installed more than one of the technologies. Figure A-1 shows adoption rates for scanned utilities.

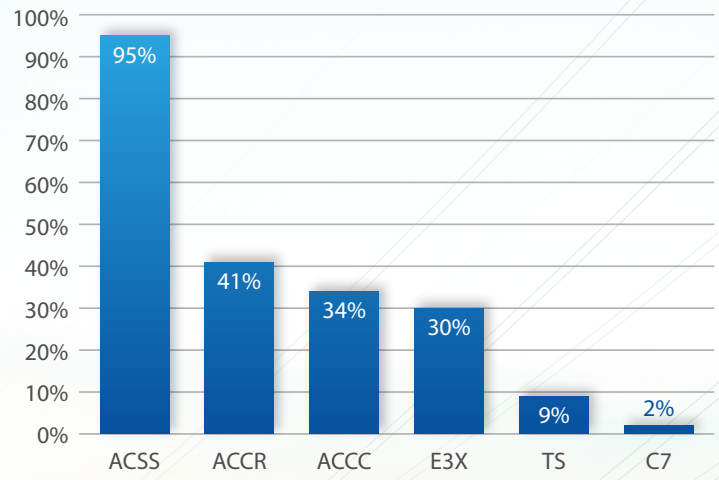

Figure A-1. Percentage of profiled utilities deploying transmission technology.

In the U.S., experience with advanced conductor technologies appears to be high, although many utilities have only limited deployments of any given technology. It seems common for a utility to perform only one or two projects with a given conductor without adopting it more broadly. Other than ACSS, 3M's ACCR was the most commonly deployed technology, followed by ACCC from CTC Global and E3X from Prysmian. Both TS Conductor and Southwire's C7 technology have relatively low acceptance, likely because of the newness of the technologies.

Utility Profile Summary

For the utilities profiled, some have standardized on a given conductor technology for a specific application, such as for a transmission voltage level or for reconductoring. Many other utilities appear to have used a technology for only one or two projects without more broadly adopting it in their system. A few utilities have used composite core conductors but no longer consider them after negative experiences either on their own projects or in the area. This indicates that U.S. utilities are willing to try a new technology but may be hesitant to widely deploy until it has a long track record of positive performance both in their network and at other utilities. The broad adoption of ACSS is likely due to the 50+ year track record, plus its continued evolution to improve performance with advancements, such as trapezoidal aluminum wires, mischmetal coated steel, ultra-high-strength steel, and availability with high-emissivity coatings. Likewise, in the two decades since introduction, composite core conductors have evolved with a proliferation of designs, including higher modulus cores, stronger aluminum alloys, high-emissivity coatings, and technologies to prevent and detect damage to the composite cores during installation and operation. The U.S. grid is built with hundreds of interconnected utilities each making their own engineering and financial decisions on what technology choices are prudent. Conductor performance in the years to come will determine which technologies become dominant and which may fade into obsolescence.

Figure A-2 shows a summary of the deployments by each of the profiled utilities.

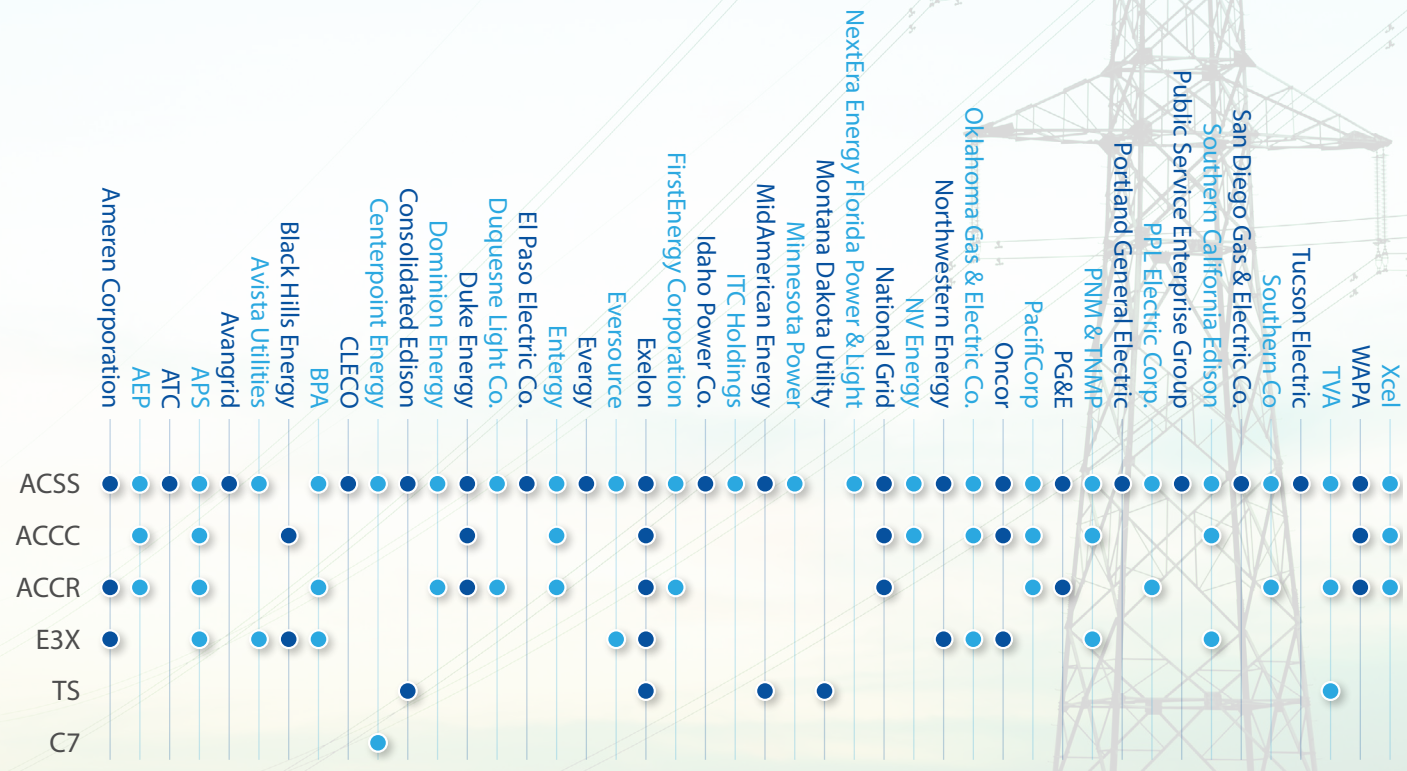

Figure A-2. Summary of the deployments by each of the profiled utilities.

Ameren Corporation

(ACSS/TW, ACCR, ACSS/E3X)

Utility Profile

Ameren Corporation serves a 64,000 mile^2 area located in central eastern Missouri and southern Illinois (Figure A-3). They serve 2.4 million electric and 900,000 natural gas customers. They operate more than 7,500 miles of transmission lines and own approximately 10,200 MW of generation capacity.

Figure A-3. Ameren cooperation service area (serves Missouri and Illinois).

Conductor Application Successes

Ameren Utilites has used ACSS extensively as well as ACCR (Figure A-4) and has designed at least one new line with ACSS with E3X. Ameren's Illinois River project spanned 375 miles and used ACSS for the new 345-kV lines. The ACCR conductor was used for the Page-Berkeley line which was reconductored to increase ground clearances and increase capacity. Ameren has proposed to use ACSS with ultra-high strength steel and E3X coating for a 3,548-foot crossing over the Missouri River.

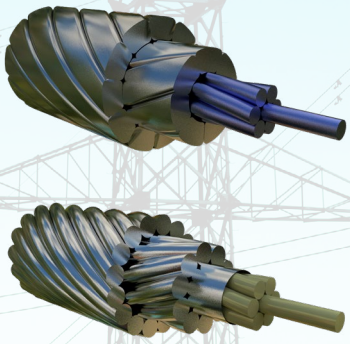

Figure A-4. ACSS conductor (top) and ACCR conductor (bottom).

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2020	Illinois Rivers	New Construction	ACSS	345 kV	375 miles	Capacity
2022	Page-Berkely	Reconductor	ACCR	138 kV	unknown	Sag, capacity
Planned	Missouri River Crossing	Rebuild	ACSS/MA5/E3X	138 kV	2 miles	Capacity

American Electric Power

(ACSS, ACCC)

Utility Profile

American Electric Power (AEP) spans over 11 states with 40,000 miles of transmission lines and serves over 400,000 residential and business customers (Figure A-5). They are also one of the largest generators of power with over 25,000 MW of power, 7100 of which is renewable energy and the largest operator of transmission lines in the U.S.

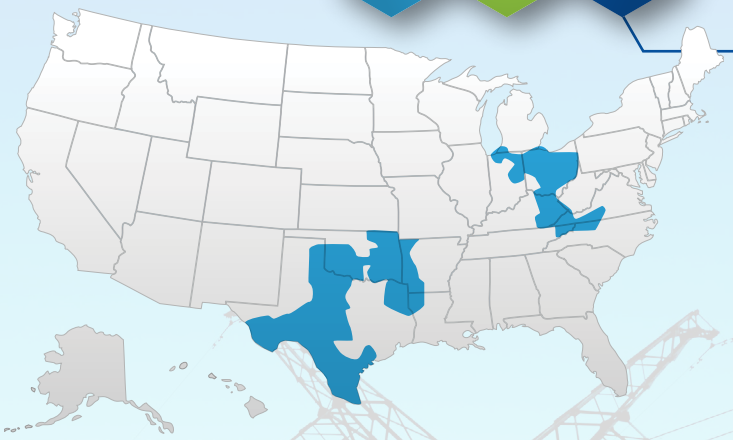

Figure A-5. American Electric Power region.

Conductor Application Successes

AEP is believed to be the largest domestic user of ACCC conductors, having installed ACCC on 26 lines for a total of 447 circuit miles of transmission. In 2015, AEP completed the largest ACCC reconductoring project in the U.S., which was 240 miles of 345-kV circuits. Because of grid constraints this reconductoring project was performed without deenergizing the existing line.

AEP has also used ACCR on two lines for a total of 27 circuit miles. AEP widely uses ACSS conductor for reconductoring and for new construction. In 2021, AEP also indicated a 30-mile 345-kV line reconductor with ACSS conductor (Figure A-7).

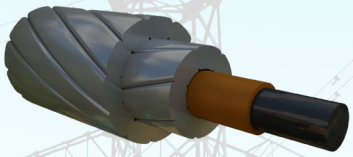

Figure A-6. ACCC conductor.

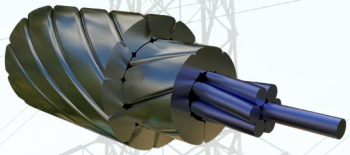

Figure A-7. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2015	Lower Rio Grand Valley	Reconductor	ACCC	345 kV	240 miles	Capacity
2021	East Lima to Maddox Creek	Reconductor	ACSS	345 kV	30 miles	Capacity

American Transmission Company

(ACSS)

Utility Profile

American Transmission Company serves parts of Michigan, Wisconsin, and Illinois (Figure A-8). They operate over 10,000 miles of transmission lines and 582 substations.

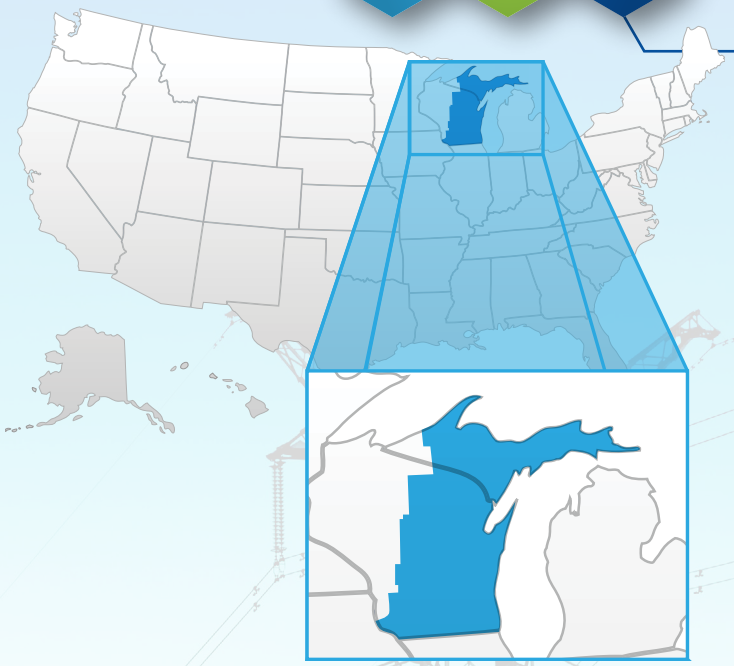

Figure A-8. American Transmission Company service region.

Conductor Application Successes

American Transmission Company constructed the 180-mile 345 kV Badger-Coulee project, which was part of the MISO region MVP project portfolio. This project was primarily constructed with twisted pair ACSR (Figure A-9, top), but portions were constructed with Aluminum Zirconium Alloy stranded ACSR, which is capable of higher temperature operations, and with ACSS (Figure A-9, bottom). Twisted pair ACSR is used to prevent conductor galloping, ACSR with aluminum zirconium alloy (ZTACSR) has higher current carrying capabilities, and ACSS has lower sag than ZTACSR and uses annealed aluminum.

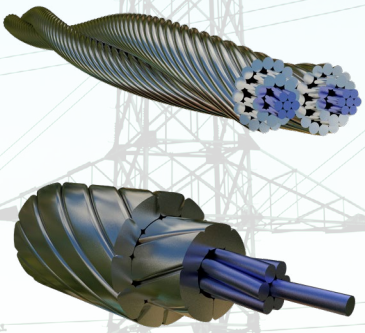

Figure A-9. Image of twisted pair ACSR (top) and ACSS (bottom).

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2018	Badger-Coulee	New construction	ACSR-TP, ACSS, ZTACSR	345 kV	180 miles	MVP project

Arizona Public Service

(ACSS, ACCR, ACCC/E3X)

Utility Profile

Arizona Public Service (APS) Provides Electric to 15 counties in Arizona. The transmission system covered for this region is illustrated in Figure A-10.

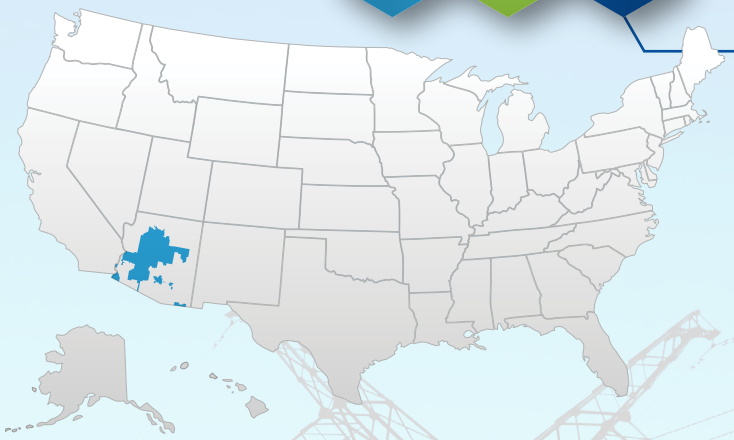

Figure A-10. APS Electric Service territory boundary.

Conductor Application Successes

APS uses ACSS and ACSR (Figure A-11) for new construction and reconductoring projects. APS has used ACCC with E3X (Figure A-12) and ACCR (Figure A-13) for reconductoring projects in dense urban environments. The urban environments to increase capacity without worrying about clearance issues and replace structures tends leading them to use a composite core conductors.

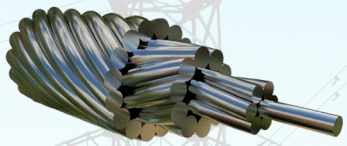

Figure A-11. ACSS/ACSR.

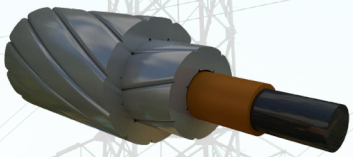

Figure A-12. ACCC.

Figure A-13. ACCR.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
Prior to 2010	Phoenix Metro Trunkline	Reconductor	3M ACCR	230 kV	5.5 miles	Capacity increase
2020	Tempe Upgrade Project	Reconductor	ACCC with E3X Coating	69 kV	2 miles	Capacity increase
2015	Palm Valley-Trilby Wash	New construction	ACSS	230 kV	16 miles	Capacity increase

Avangrid

(ACSS)

Utility Profile

Avangrid's has two main operations. Avangrid renewables, which operates renewable energy power plants over 24 different states from the east to west coasts (Figure A-14). Avangrid Networks owns and operates eight electric utilities, which serves over 3.3 million customers from New York to New England. Avangrid Renewables is the third-largest renewable energy company, which includes both onshore and offshore assets. Avangrid Networks electric utility companies include Central Maine Power, United Illuminating, New York State Electric and Gas, and Rochester Electric and Gas Company.

Figure A-14. Avangrid service area.

Conductor Application Successes

Avangrid had previously used ACSS (Figure A-15) in their system on a long span over the Housatonic River. The Derby Junction-Ansonia project is an example of how utilities have been increasing capacity on existing corridors for close to 100 years. The line had originally been built in 1924 of steel lattice towers and operated at 13.8 kV. In the 1930s, the line was upgraded to 69 kV and in the 1960's, upgraded to 115 kV. An eight-fold increase in voltage would have increased capacity by the same factor of eight. United Illuminating, the Avangrid operating company in Connecticut, considered upgrading the line one more time to further increase capacity by reconductoring with an ACSR with E3X, but upon inspection realized a high percentage of the lattice structures and foundations would need significant work and opted for a rebuild instead.

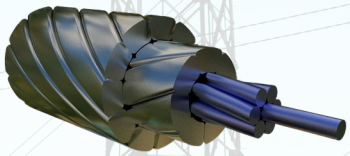

Figure A-15. ACSS conductor.

The rebuild considered ACSR and ACSS, and ultimately selected ACSR to meet future needs. Should future demands require increasing capacity again, advanced conductors will be able to double the capacity again on the same route.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
1930's and 1960s	Derby Junction-Ansonia	Voltage uprate	Copper	13.8 to 69 to 115 kV	8.2 miles	Capacity increase
Planned	Derby Junction-Ansonia	Rebuild	ACSR	115 kV	8.2 miles	Capacity increase and reliability

Avista Utilities

(ACSS, ACSS/E3X)

Utility Profile

Avista operates over 30,000 miles[2] spanning from Washington, Oregon, Idaho, and Alaska (Figure A-16). Their grid is powered by 59% of renewable energy largely due to the vast hydro resources available in the Washington area, but also has wind, biomass, natural gas, and coal.

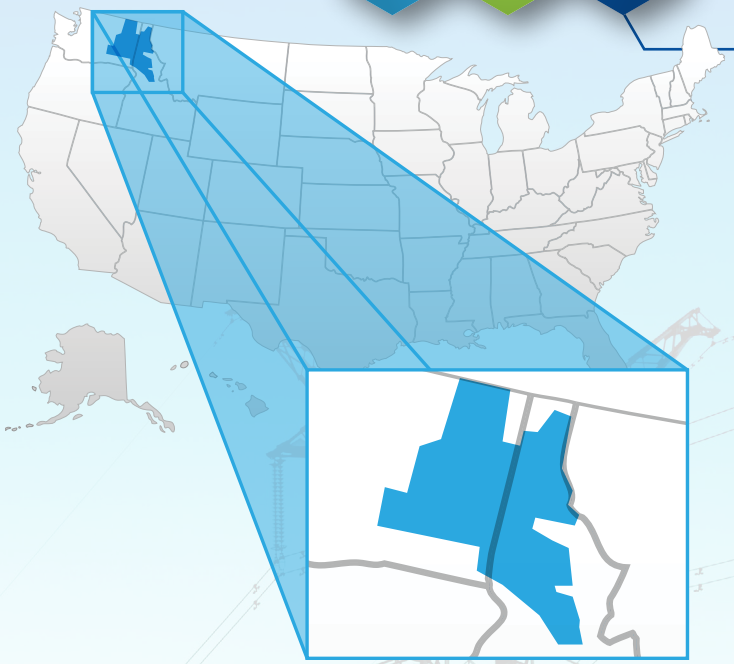

Figure A-16. Avista service area.

Conductor Application Successes

Avista Utilites has used ACSS (Figure A-17) in their system. Generally, projects considering this conductor involve building new towers to add redundancy and additional capacity into narrow corridors. E3X is a special coating placed on conductors that facilitates faster heat transfer away from the conductor. This results in the conductors being able to cool faster from electrical resistance heat generation. Thus, the E3X coating enables power lines to support power loading up to 25% beyond their normal rating. For example, ACSS without E3X coating can double power capacity in comparison to traditional ACSR. E3X can add an additional 25% capacity.

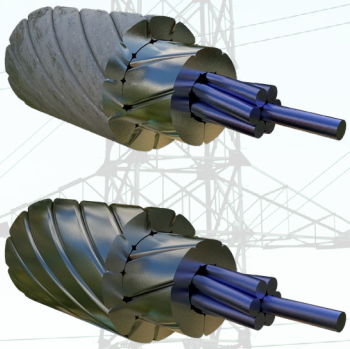

Figure A-17. ACSS cable with (top) and without (bottom) E3X emissivity coating.

Upgrading the Benton–Othello line was deemed necessary after engineering analysis revealed increased peak loading during the summer could exceed capacity. If the Benton–Othello line was lost, it could affect other areas in the system resulting in blackouts or increased system fragility.

The Ninth and Central project replaced wood poles from the 1940s while increasing line capacity through a residential area. ACSS with E3X coating was leveraged, which increased the ACSS conductor capacity by 15% beyond the upgrade the project had already planned with standard ACSS. The E3X coating dulled the wire just like a non-specular conductor (i.e., it does not reflect the sunlight) to reduce the visual impact of the new installation. The previous lines lasted over 70 years, and Avista hopes to achieve a similar longevity out of this line upgrade without disturbing the residents along the right of way.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2020	Benton-Othello	Rebuild	ACSS	115 kV	26 miles	Capacity
Ongoing	Ninth & Central-Sunset	Rebuild	ACSS/E3X	115 kV	7 miles	Capacity

Black Hills Energy

(ACCC)

Utility Profile

Black Hills Energy provides electricity and natural gas to approximately 1.3 million customers (Figure 18).

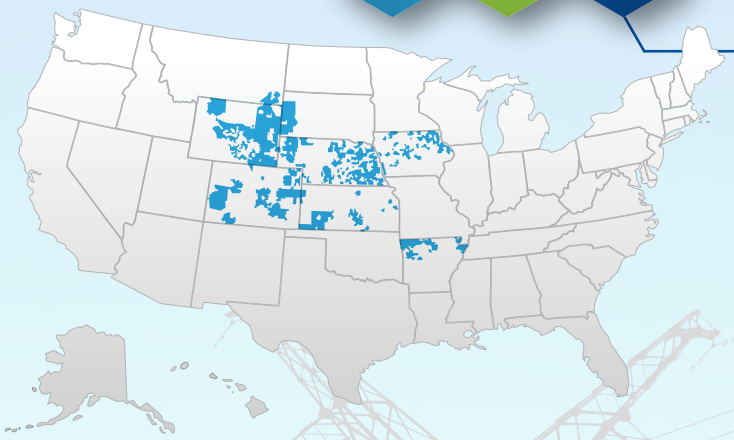

Figure A-18. Black Hills Energy region.

Conductor Application Successes

In 2014, Black Hills Energy completed their first reconductoring with ACCC to increase the capacity in Spearfish, South Dakota. The ACCC conductor (Figure A-19) provided increased capacity without the need to add new structures or reinforce existing transmission towers. In 2018, Black Hills reconductored a 115-kV line in Cheyenne, Wyoming that had been built in 2013 using ACSR. Because of heavy growth from data centers in the area, more capacity was needed.

The conductor used was ACCC with E3X coating, which was the industry's first installation of a composite core conductor with high-emissivity coating.

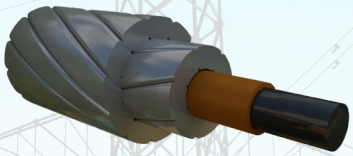

Figure A-19. ACCC conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2014	Spearfish, SD	Reconductor	ACCC	69 kV	Unknown	Capacity
2018	Cheyenne, WY	Reconductor	ACCC/E3X	115 kV	Unknown	Capacity

Bonneville Power Administration

(ACSS, ACCR)

Utility Profile

The Bonneville Power Administration (BPA) delivers hydropower produced in the Columbia River Basin to communities across the Northwest. The BPA service area is illustrated in Figure A-20.

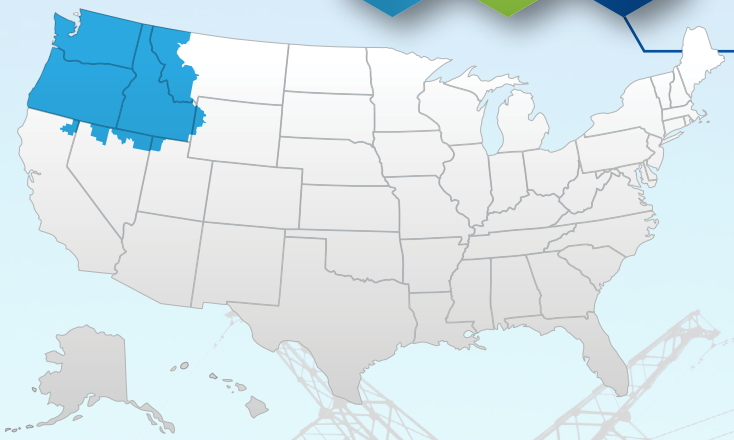

Figure A-20. BPA region.

Conductor Application Successes

BPA has installed ACSS, ACCR (Figures A-21 and A-22) for test and new construction, recognizing the importance of the application and the resulting benefits.

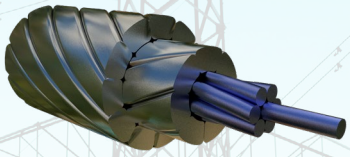

Figure A-21. ACSS conductor.

Figure A-22. ACCR conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2004	Pascal, Washington	Reconductor	ACCR	115 kV	Unknown	Test line

CenterPoint Energy

(ACCR, ACCS, ACSS/TW)

Utility Profile

CenterPoint Energy supplies electricity and natural gas to several states in the Midwest and Southern United States (Figure A-23). Their electricity footprint lies primarily in the Houston, Texas area, where transmission and distribution infrastructure provide service to approximately 2.6 million customers.

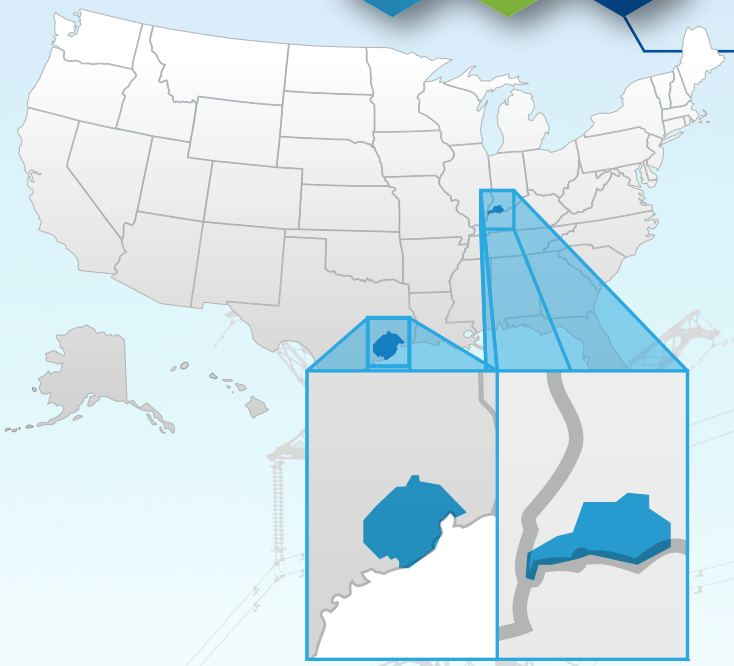

Figure A-23. Region served by CenterPoint Energy.

Conductor Application Successes

CenterPoint Energy (CPE) installed over 3000 miles of ACSS between 2000 and 2007, and in 2007 pioneered the implementation of ACSS/TW MA5 with an ultra-high strength steel core.

In 2014, CNP built projects using C7 composite core conductors. The CNP implementation used two types of conductors with a C7 core: an ACCS/TW (Figure A-24) and ACCR/TW. The ACCS/TW/C7 provided less sag at higher temperature, but the ACCS/TW/C7 (Figure A-25) provided better robustness to extreme wind and ice loads. The application provided an operational performance basis to inform appropriate application in future transmission reconductoring upgrades and new line construction.

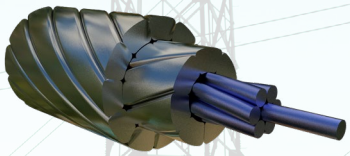

Figure A-24. ACSS/TW conductor.

Figure A-25. ACCS/TW/C7 conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Crosby-Mt Belvieu	Reconductor	ACCR/C7	138 kV	2.6 miles	Pilot project capacity addition
2013	Crosby-Mt Belvieu	Reconductor	ACCS/C7	138 kV	3.3 miles	Pilot project capacity addition
2007	Bay City-Rosenberg	New construction	ACSS/TW/HS285	345 kV	40 miles	Capacity

CLECO

(ACSS)

Utility Profile

Cleco provides electricity to serve approximately 293,000 customers in Louisiana (Figure A-26).

Conductor Application Successes

Cleco has utilized ACSS conductor (Figure A-27) within its transmission area.

Figure A-26. CLECO region.

Figure A-27. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2021	Unknown	Unknown	ACSS	Unknown	3 miles	Unknown

Consolidated Edison

(ACSS, ACSS/E3X)

Utility Profile

Consolidated Edison (ConEd) provides electricity and natural gas to New York City and Westchester County (Figure A-28). Electricity service is provided to approximately 3.6 million customers. Most of ConEd's transmission system uses underground cables; however, ConEd owns 45.7% of New York Transco, LLC, which is a transmission developer for the state of New York.

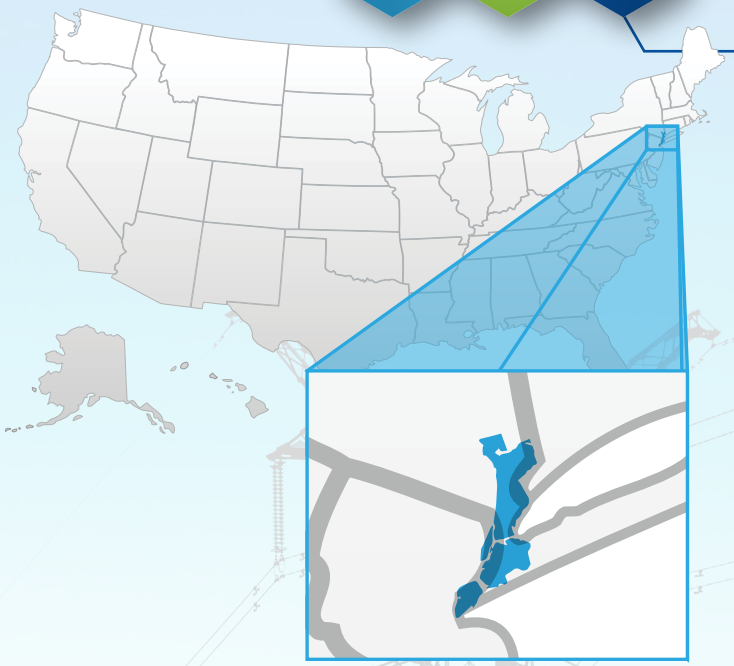

Figure A-28. Consolidated Edison region.

Conductor Application Successes

Con Edison is a partner in a 17.5-mile transmission project that ties the Cricket Valley Energy Center to one of its substations. The ACSS conductor was selected for the New York Energy Solution project and for Cricket Valley Energy Center transmission based upon consideration of construction costs, line losses, and line performance for the line rating. New York is aggressively building capacity to connect lower cost renewable generation in the upstate region to the city. NY Transco completed a 54-mile 345-kV rebuild project along existing 115-kV corridors using ACSS. ACSS/E3X was (Figure A-29) selected for a short section of the line, which enabled reconductoring of existing 345-kV structures.

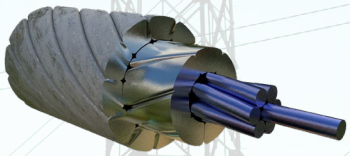

Figure A-29. ACSS conductor with E3X coating.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2017	Cricket Valley	New build	ACSS	345 kV	17.5 miles	New generation interconnection
2020-2023	New York Energy Solution	Rebuild and reconductor	ACSS for rebuild ACSS/E3X for reconductor	345 kV	54.5 miles	Capacity to connect to upstate

Dominion Energy

(ACSS/TW, ACCR)

Utility Profile

Dominion Energy operates electricity in Virginia, North Carolina, and West Virginia, and includes the dense northern Virginia cluster of data centers where power demand is expected to grow by over 200% in the next 4years. The transmission system covered for this region is illustrated in Figure A-30.

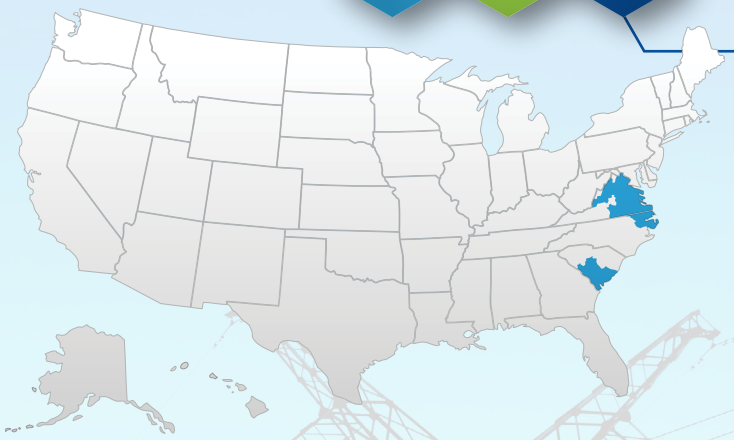

Figure A-30. Dominion Transmission region.

Conductor Application Successes

In 2009, Dominion completed the Loudoun-Brambleton line in close proximity to the Dulles airport in Loudoun County, VA. The conductor increased capacity on an existing line by 90%.

Dominion Energy has used ACSS for high-capacity lines and has a standard to use ACSS/TW (Figure A-31) for new and reconductored 230-kV circuits. Recognized benefits of using ACSS for high-capacity applications has been codified in Dominion Energy's strategy. Dominion uses triple-bundle ACSR (three conductors per phase) for construction of 500-kV lines, presumably because 500-kV systems are less likely to be thermally limited.

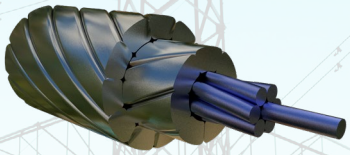

Figure A-31. ACSS/TW conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2022	Beaumeade Belmont	Reconductor	ACSS/TW	230 kV	6.7 miles	Capacity
2009	Loudoun-Brambleton	Reconductor	ACCR	230 kV	5 miles	Capacity

Duke Energy

(ACSS, ACSS/TW, ACCR, ACCC)

Utility Profile

Duke Energy is based in Charlotte, North Carolina, they support 7.2 million and own 58,200 megawatts of generation (Figure A-32). Duke Energy's service territory covers 104,000 miles^2 in IN, OH, KY, WV, VA, NC, and SC. A large majority of Dukes' power generation in the Midwest comes from coal, natural gas, or oil. In the Carolinas, a large portion (~1/2) comes from nuclear power. Duke has made a commitment to installing more renewables and is looking for ways to improve efficiency, reduce costs and reduce greenhouse gas emissions. Figure A-31 shows Duke's current Transmission line project.

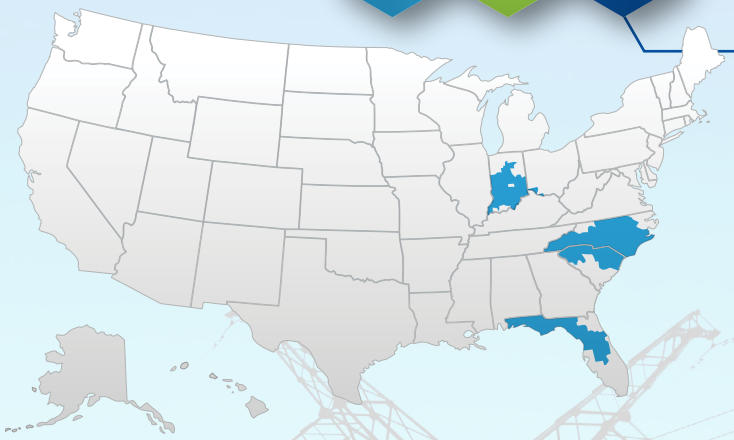

Figure A-32. APS Electric Service territory boundary.

Conductor Application Successes

Duke commonly uses ACSS (Figure A-33) and ACSS/TW. Duke has experience with ACCC (Figure A-34) and ACCR (Figure A-35) composite core conductors but in 2022, testified to the North Carolina Utilities Commission that Duke no longer considers composite core conductors due to recent installation concerns.

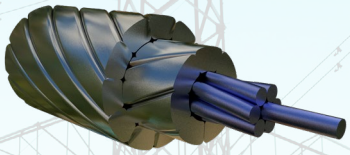

Figure A-33. ACSS conductor.

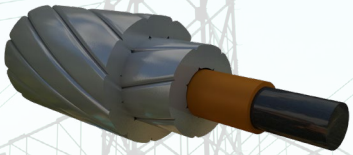

Figure A-34. ACCC conductor.

Figure A-35. ACCR conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Pisgah Tie to Shiloh Station	Reconductor	ACSS	230 kV	22 miles	Capacity
2019	North Carolina State Port Authority	Reconductor	ACCR	230 kV	2 miles	Reduced Sag for larger container ships
Unknown	Florida	Unknown	ACCC	Unknown	Unknown	Unknown

Duquesne Light Company

(ACCR, ACSS/TW)

Utility Profile

Duquesne Light company has more than 600,000 customers, 1700 employees, 7700 miles of transmission and distribution lines, and 150 EV charging stations (Figure A-36). The customer base is ~90% residential. The service area is in the Pittsburg region.

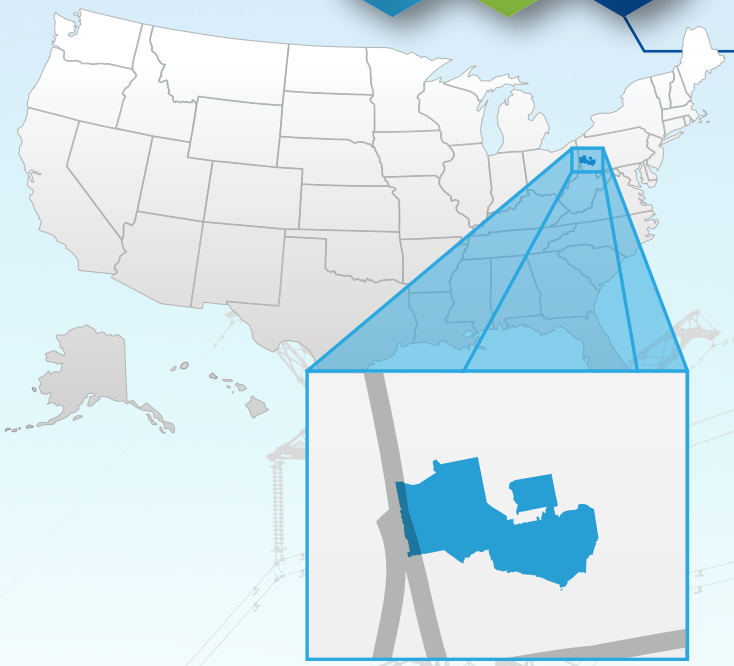

Figure A-36. Duquesne Light service area.

Conductor Application Successes

Duquesne Light has used ACSS/TW (Figure A-37) to reconductor multiple projects, including a 7-mile transmission line installed on towers constructed in the 1960s.

To solve the congestion on this line, only a single side needed to be reconductored; however the structural imbalance would have created issues with the line-to-line clearance and resulted in unacceptable mechanical loading on the towers (Figure A-38).

Replacing towers to mitigate loading issues was not desirable because the towers had not reached their end of life.

The project also had a long span with a diagonal crossing of the Ohio River. A single span was required that could stretch 3700 feet that required new structures. To comply with Federal Aviation Administration rules on tower height as well as clearance to the river below, the ACCR conductor (Figure A-39) was selected for its low-sag properties.

In this project, a mix of conductors helped match the historic mechanical loading characteristics for tower stability on existing structures while using a composite core conductor for very low-sag characteristics on the river crossing.

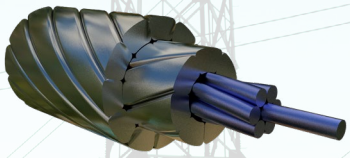

Figure A-37. ACSS/TW conductor.

Figure A-38. Tower reconductoring.

Figure A-39. ACCR conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2018	Ohio River Crossing	Rebuild	ACCR	138 kV	3700-foot span	Capacity
2018	Pittsburgh project	Reconductor	ACSS/TW	138 kV	7 miles	Capacity

El Paso Electric Company

(ACSS)

Utility Profile

El Paso Electric company is based in Texas. The generation portfolio is very diverse including, nuclear, natural gas, solar, and wind turbines. The company also has transmission, and distribution line in west Texas and southern New Mexico (Figure A-40). The company owns 2010 MW of base load generation from six generation facilities. El Paso Electric Company serves ~437,000 customers. The company's retail customers are primarily in El Paso, Texas, and Las Cruces, New Mexico.

Figure A-40. El Paso Electric service area.

Conductor Application Successes

In the El Paso Electric Company 2020–2029 System Expansion Plan, the utility has enumerated a list of projects; all the projects will use ACSR. Only a single 2-mile span has been modeled with ACSS (Figure A-41). The company seem to currently be leveraging other technologies like smart meters and improved electric vehicle infrastructure to improve efficiency, stability, and reduce emissions. The company also seems to have put a great deal of resources into developing solar generation.

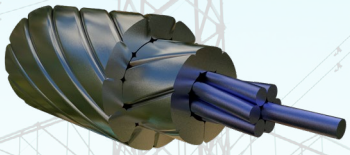

Figure A-41. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2019 planned	Newman East	New construction	ACSS	115 kV	2 miles	Capacity

Entergy

(ACCC, ACCR, ACSS)

Utility Profile

Entergy headquarters is in New Orleans and the company services areas in Arkansas, Louisiana, Mississippi, and Texas. The company provides generation, transmission, and distribution to their customers (Figure A-42).

Figure A-42. Entergy service area.

Conductor Application Successes

A reconductoring project "Hartburg-Inland Orange" using ACCC (Figure A-43) was studied by EPRI and a report was published in 2011, which showed reconductoring with ACCC reduced a project cost from $18.1 million for rebuilding with ACSS to $8.5 million with ACCC while also improving efficiency versus ACSS. A draft Entergy specification from 2021 states, "It is generally preferential to develop a custom conductor solution using an ACCR conductor in lieu of the ACCC conductors. Use of the ACCC standards will generally be limited to extension of existing ACCC lines or other similar circumstances" so Entergy appears to have changed preference from ACCC to ACCR for composite core conductors. In 2016, Entergy completed the Ninemile-Napolean reconductoring project with ACCR in the City of New Orleans.

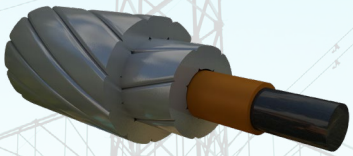

Figure A-43. ACCC conductor.

Entergy has been using ACSS (Figure A-44) at least since 2010 with projects to connect main transmission to new substations. Entergy has been upgrading much of their system for better storm resiliency. A typical example was a new substation being linked to the McLewis line and the Helbig line. Multiple projects of this kind are present in the public record. One of the more interesting documents from Entergy is a recently released scope book for solar generation providers, giving guidance on how to link to Entergy. In this book there is a fairly comprehensive enumeration of conductor technologies presented as viable options for use.

Figure A-44. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
Prior to 2011	Hartburg-Inland Orange	Reconductor	ACCC	230 kV	4 miles	Capacity
2016	Ninemile-Napolean	Reconductor	ACCR	230 kV	12 miles	Capacity and decreased sag
2018	Southeast Louisiana Improvement Project	New construction	ACSS	230 kV	10 miles	Capacity and reliability

Evergy

(ACSS, ACSS/TW)

Utility Profile

Evergy is an electric utility serving Kansas and Missouri formed by the combination of Kansas City Power and Light and Westar in 2019. The company serves ~1.7 million customers including residential, commercial, and industrial (Figure A-45). Evergy has a generating capacity of 16,000-megawatt electricity in Kansas and Missouri. Evergy owns >10,100 miles of transmission and ~52,000 miles of distribution.

Figure A-45. Evergy service area.

Conductor Application Successes

In 2003, Evergy predecessor company KCP&L performed a live line reconductoring using ACSS on a 32-mile line connecting the LaCygne power station. The project used an ACSS/TW conductor (Figure 46) to replace the existing ACSR conductor. The cost savings of the added transmission capacity paid for the cost of the upgrade in 14 months. There are other reconductoring projects in the queue for Evergy along with several historic use cases. The Maryville to Creston 161-kV Rebuild (GIA-61) (143691) is a typical case and is a reconductoring effort for 62.4 miles using 556.5 ACSS Parakeet conductor costing ~$14,900,000. Evergy has made their analytic process for selecting candidate corridors and technologies for reconductoring open to the public. The company is clearly forward-thinking regarding new technology but is looking for the best design fit for their system and geography.

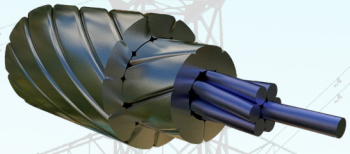

Figure A-46. ACSS/TW conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2003	LaCygne to Stillwell	Live reconductor	ACSS/TW	345 kV	32 miles	Capacity

Eversource

(ACSS ACSS/E3X)

Utility Profile

Eversource covers several states in the Northeast (Figure A-47) with electricity and natural gas. Within this region approximately 4 million customers are served.

Conductor Application Successes

Eversource uses ACSS (Figure A-48) in transmission systems and had previously standardized on its use. Eversource prefers to use ACSS instead of ACSR because of the increased current carrying capacity. In 2023, Eversource and Prysmian announced that Eversource would be using ACSS with E3X coating as an enhancement to the ACSS for improved efficiency.

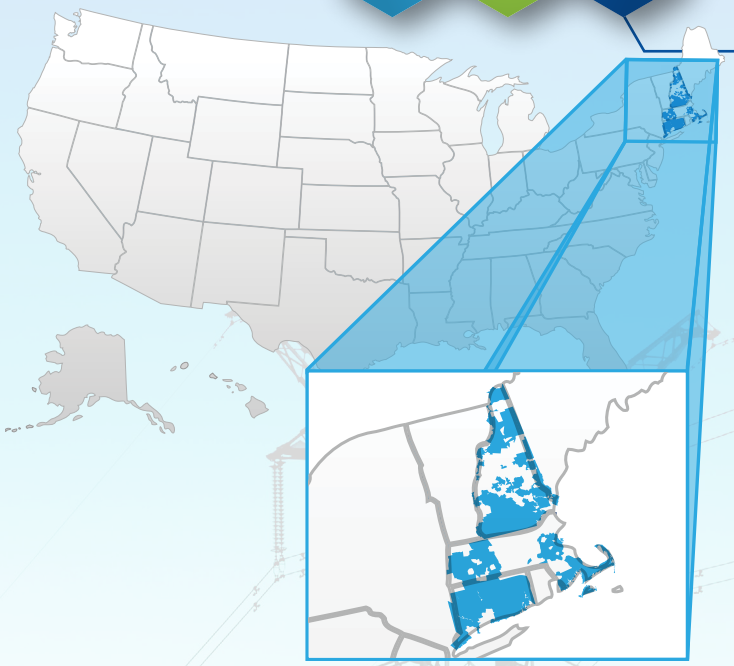

Figure A-47. Eversource region.

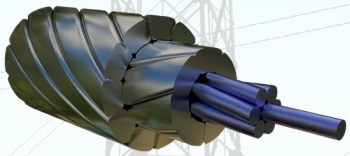

Figure A-48. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
Prior to 2022	Various	Rebuild and new construction	ACSS	115 kv 345 kv	Various	New capacity and wood pole replacement
2023	Various	Rebuild and new construction	ACSS/E3X	115 kv 345 kv	Various	New capacity and wood pole replacement

Exelon

(ACSS, ACSS/TW, ACCC, ACCR, E3X)

Utility Profile

Exelon covers a family of companies across several states in the Midwest and Northeast (Figure A-49) with electricity and natural gas. These companies include Commonwealth Edison (ComEd), Philadelphia Electric Company (PECO) and others. Within this region approximately 8.8 million electric customers are served. Exelon has adopted a wide range of different transmission technologies to increase capacity on transmission lines.

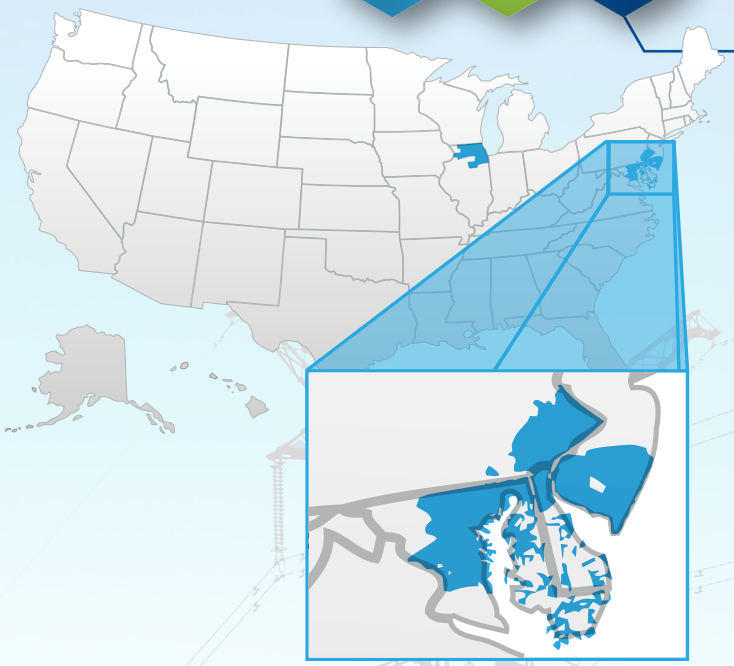

Figure A-49. Exelon region.

Conductor Application Successes

Exelon has used ACSS conductor (Figure A-50) and ACSS/TW and has it listed as an optional conductor for application, as noted in a 2006 interconnection guide, for several voltage levels.

Exelon utility ComEd used ACCC conductor (Figure A-51) on projects in 2014 and 2015 in Illinois and Wisconsin. The Rockford project used ACCC/ULS, which is the stronger carbon-fiber core option for ACCC, typically used for heavy ice load conditions. ComEd also used ACSS to reconductor 4.5 miles of 138-kV lines from the Lisle to York Tap in 2012.

ACCR conductor (Figure A-52) was used for a large reconductoring project connecting two Exelon utilities, PECO, and Baltimore Gas and Electric. Reconductoring occurred on a 500-kV line that was 54 years old.

TS Conductor also notes that TS Conductor has been installed by Exelon.

Exelon has demonstrated an interest in advancing the application of transmission conductors and has continued to innovate in this field. Exelon has been working with Prysmian to retrofit existing transmission lines with E3X coating using robots. E3X works by improving heat dissipation and can increase line ratings on existing lines without reconductoring (Figure A-53).

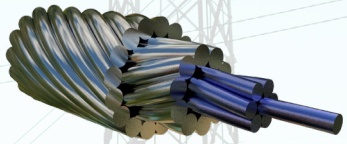

Figure A-50. ACSS conductor.

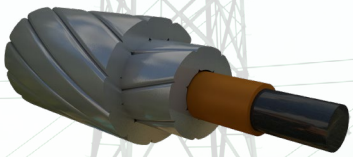

Figure A-51. ACCC conductor.

Figure A-52. ACCR conductor.

Figure A-53. E3X robot.

Exelon

(ACSS, ACSS/TW, ACCC, ACCR, E3X)

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2014	T Line 1607	Reconductor	ACCC	138 kV	3 miles	Capacity
2018	Conastone Area projects	Reconductor	ACCR	500 kV	26.4 miles	Capacity
2015	Lisle to York Tap	Reconductor	ACSS	138 kV	4.5 miles	Capacity
2021	ConEd	Robot E3X retrofit	ACSR	138 kV	1 mile	Pilot

FirstEnergy Corporation

(ACSS, ACSS/TW, ACCR)

Utility Profile

FirstEnergy Corporation covers several states in the Midwest/Eastern United States. (Figure A-54). Within this region, approximately 6 million electric customers are served.

Figure A-54. FirstEnergy Corporation region.

Conductor Application Successes

Allegheny Power, which is now part of First Energy, installed 3M ACCR on a 1.7-mile line in West Virginia. The conductor increased capacity while matching sag of the ACSR to maintain clearance to the distribution lines on the same structures. FirstEnergy has utilized ACSS (Figure A-55) and ACSS/TW (Figure A-56) in several different reconductoring, rebuild, and new applications. ACSS conductor was designated for projects noted in 2016, 2017, 2019, 2022, and 2023 for lengths under 20 miles on 138-kV and 345-kV transmission lines. On the Dowling-Midway project, a 336.4-kcmil ACSR conductor was replaced with a 336.5-kcmil ACSS conductor without replacing the existing lattice structures. This indicates the existing structures had sufficient clearance for the higher sag from the ACSS. On the Black River-Carlisle-Lorain project, a 954-kcmil ACSR was replaced with a smaller 795-kcmil ACSS/TW. It was noted in planning documents that while the ACSS conductor was physically smaller, it had larger current carrying capacity. It is not noted but can be concluded the smaller ACSS conductor would have higher line losses than the larger ACSR it replaces.

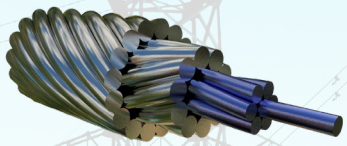

Figure A-55. ACSS conductor.

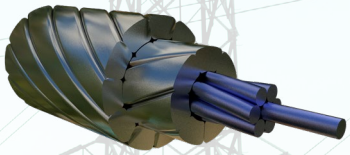

Figure A-56. ACSS/TW conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2016	Black River-Carlisle-Lorain	Reconductor	ACSS/TW	138 kV	6 miles	Capacity
2017	Dowling-Midway	Reconductor	ACSS	138 kV	15 miles	Capacity
2007	Bedington-Nipetown	Reconductor	ACCR	138 kV	1.7 miles	Capacity

Idaho Power Company

(ACSS)

Utility Profile

Idaho Power Company (IPCo) is a vertically integrated utility that covers southern Idaho and eastern Oregon. (Figure A-57). Within this region approximately 620,000 electric customers are served.

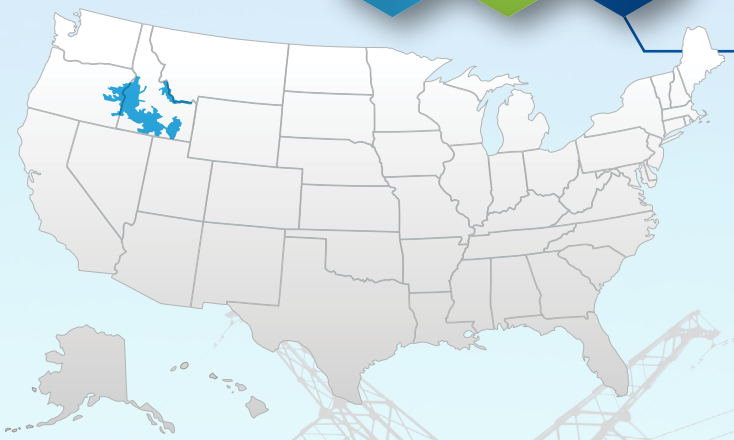

Figure A-57. Idaho Power region.

Conductor Application Successes

There is some indication from community sources that IPCo has used ACSS (Figure A-58) in transmission systems. As with other users, ACSS has been available in various versions for years, and as such, it has been an option for use in various reconductoring applications.

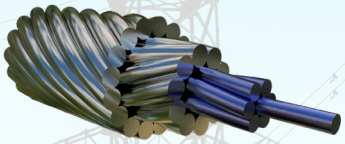

Figure A-58. ACSS conductor.

ITC Holdings

(ACSS)

Utility Profile

ITC Holdings provides electric transmission in several states in the Midwest United States (Figure A-59).

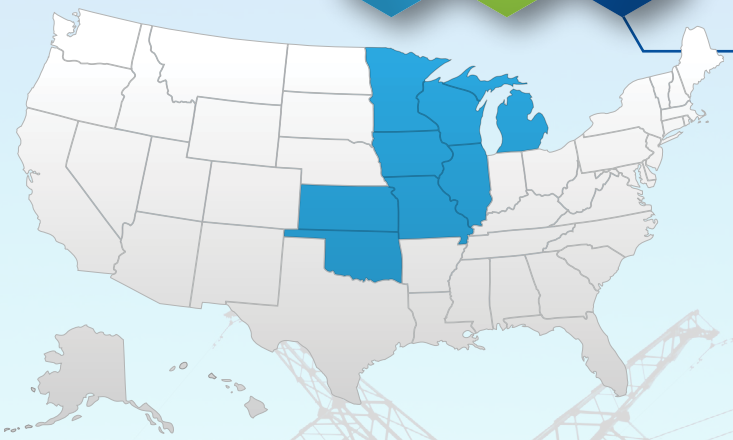

Figure A-59. ITC Holdings service area.

Conductor Application Successes

ITC Holdings has used ACSS conductor (Figure A-60) for some time and has future plans to continue using ACSS conductors on many lines in Michigan. The Wayne-Newburgh project in the Detroit area was previously constructed with a 795-kcmil ACSS conductor has now been rebuilt with a much larger 2156-kcmil ACSS conductor.

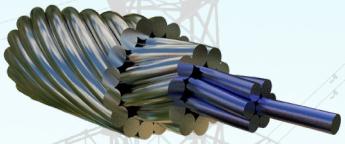

Figure A-60. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2022	Wayne-Newburgh #1	Rebuild	ACSS	120 kV	2.7 miles	Increased capacity

MidAmerican Energy

(ACSS, TS Conductor)

Utility Profile

MidAmerican Energy is a Berkshire Hathaway Energy company that operates across the Midwest in the states of Iowa, South Dakota, and Illinois (Figure A-61).

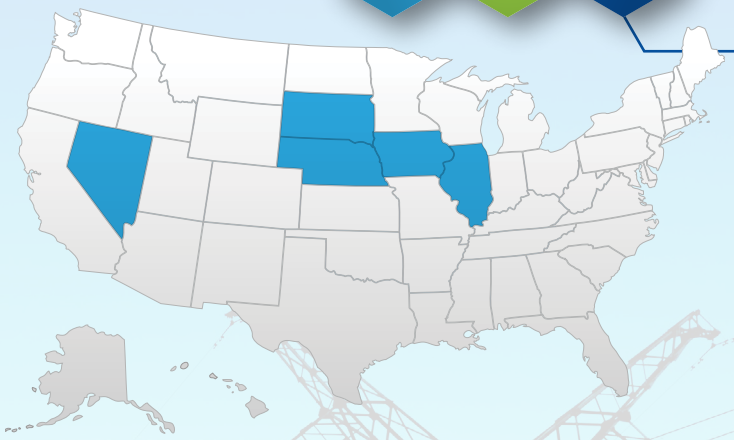

Figure A-61. MidAmerican Energy region.

Conductor Application Successes

MidAmerican's area of operation is in the portion of the upper Midwest that experiences both high winds as well as freezing rains. These concurrent weather conditions can cause the damaging impact of conductor galloping, where suspended conductors can vibrate with very large amplitudes, causing outages and damages to lines. Because of this, many of the conductors used by MidAmerican are T2 twisted pair conductors, where each conductor is composed of two individual ACSR conductors, twisted together in a loose helix. The varying profile and low-lateral stiffness of the conductor prevents galloping. MidAmerican has installed small amounts of both ACSS (Figure A-62) and recently completed a project with TS Conductor (Figure A-63) crossing the Mississippi River.

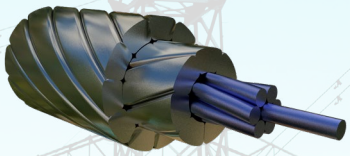

Figure A-62. ACSS conductor.

Figure A-63. TS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2023	Iowa-Illinois Border	River Crossing	TS conductor	Unknown	Unknown	Unknown

Minnesota Power

(ACSS)

Utility Profile

Minnesota Power serves over 150,000 residential and commercial customers in a 26,000 mile^2 area in northeastern Minnesota (Figure A-64). They operate over 3,000 miles of transmission voltages ranging from 500 kV to 115 kV and over 6000 miles of lines less than 115 kV. Minnesota Power operatesa variety of energy generation plants, ranging from coal, biomass, hydro, wind, natural gas, and solar.

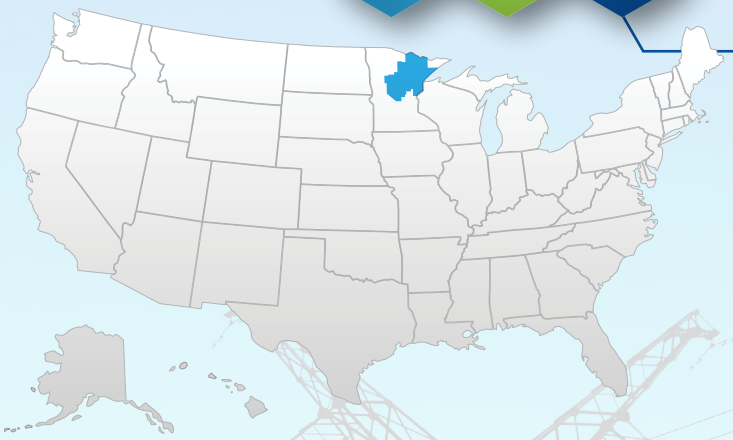

Figure A-64. Minnesota Power service area.

Conductor Application Successes

Minnesota Power has used ACSS (Figure A-65) on several projects and plans to use it on the upcoming 115-kV Duluth Loop project. Generally, projects considering this conductor involve building new towers to add redundancy and additional capacity into narrow corridors, such as the Elk River-Beck area. Concerns regarding the predicted load growth on Elk River area have spurred Minnesota Power to consider increasing power flow capacity. If not addressed and loads grow high enough, the loss of a power transformer could impact other parts of their grid. ACSS has been used in the industry for over 40 years and is widely considered a good option when building new towers as it has more capacity than traditional ACSR.

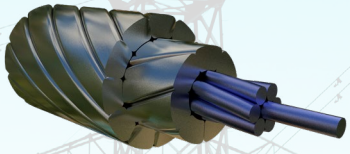

Figure A-65. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
Planned	Duluth Loop	New and rebuild	ACSS	115 kV	14 miles	Reliability

Montana Dakota Utility

(ACSS, TS)

Utility Profile

Montana Dakota Utility (MDU) is a vertically integrated utility that covers a four-state region, which includes electric and natural gas service and coal and renewable generation (Figure A-66). Within this region approximately 144,000 electric and a total of 431,000 customers are served.

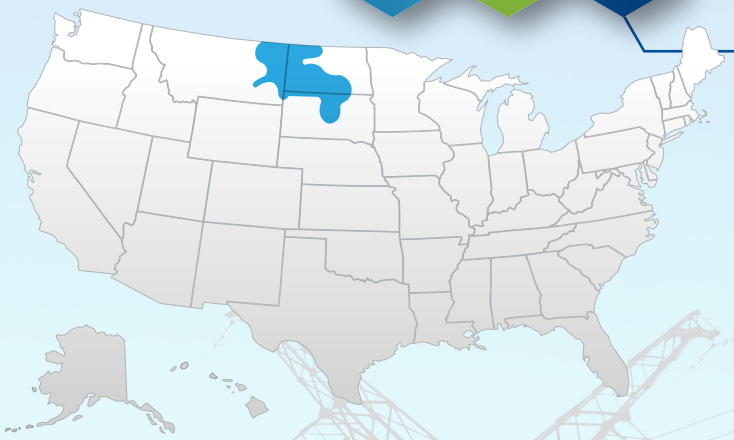

Figure A-66. MDU region.

Conductor Application Successes

MDU was the first utility to use TS Conductor (Figure A-67) in the U.S. The Bismark to Napolean project used TS for an 11-mile section, which allowed the project to reuse 60 existing structures. Reconductoring saved $1.8 million and a year of construction time versus rebuilding.

Figure A-67. TS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2021	Bismark to Napolean	Reconductor	TS conductor	230 kV	11 miles	Renewable energy

National Grid

(ACCC and ACCR)

Utility Profile

National Grid (NG) supplies electricity and natural gas to portions of Massachusetts and New York in the Northeastern U.S. (Figure A-68), as well as portions of England and Wales in the United Kingdom. In the U.S., they serve ~20 million utility customers.

Figure A-68. National grid Region.

Conductor Application Successes

In 2022, NG commenced an upgrade of 157 miles of transmission line from Edic to New Scotland and from New Scotland to Leeds with 954-kcmil ACSS Cardinal and 795-kcmil ACSS Drake conductors. The upgraded line is set to enter service in 2023.

In 2018, NG rebuilt the Somerset-Fall River line which had originally been constructed in 1923. In addition to being 100 years old, the very large structures were occupying a large amount of valuable real estate on the Taunton River. During the rebuild, smaller structures were used that not only took up less space on the ground but were also considerably shorter, which reduced the risk to aviation. To enable the shorter, smaller structures, NG evaluated multiple conductor types and selected 3M ACCR because of its light weight and low-sag profile.

National Grid Ventures is an investor in the startup advanced conductor provider, TS Conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2018	Sommerset-Fall River	Rebuild	ACCR	115 kV	< 1 mile	Reduced Sag, reduced tower height
2023	Edic-New Scotland-Leeds	Reconductor/rebuild	ACSS	345 kV	157 miles	Regional upgrade
2005	Packard-Zimmerman	Reconductor	ACCC	230 kV	1 mile	Unknown

NextEra Energy Florida Power & Light

(ACSS)

Utility Profile

NextEra Energy Florida Power and Light (NEFPL) is a utility company primarily based in the coastal regions of Florida. Florida Power and Light (FPL) Company provides electricity to approximately 5.8 million accounts, or more than 12 million people.

NextEra also has several divisions focused on energy generation and transmission assets across the country. NextEra has a transmission only called LoneStar Transmission, which operates in Texas.

Figure A-69. Region served by NextEra FPL Energy.

Conductor Application Successes

FPL has a proven track record of power system reliability, having been recognized numerous times in recent years with various industry rewards. In 2021, FPL won the ReliabilityOne® National Reliability Award for the sixth time in 7 years and has been in the process of upgrading and rebuilding much of the Florida grid. FPL customers have seen a 45% improvement in reliability because of these grid hardening efforts. Consequently, this region has not experienced many issues with congestion and there has been no need to deploy advanced conductors to uprate existing lines in Florida. Lonestar built 330 miles of the 345-kV Texas CREZ lines using ACSS. NextEra has also invested venture capital funds in the startup, TS Conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	CREZ	New build	ACSS	345 kV	330 miles	Renewable energy transmission

NorthWestern Energy

(ACSS/TW)

Utility Profile

NorthWestern Energy is a utility company providing electricity to western Montana and eastern South Dakota. They have approximately 750,000 customers throughout this region (Figure A-70).

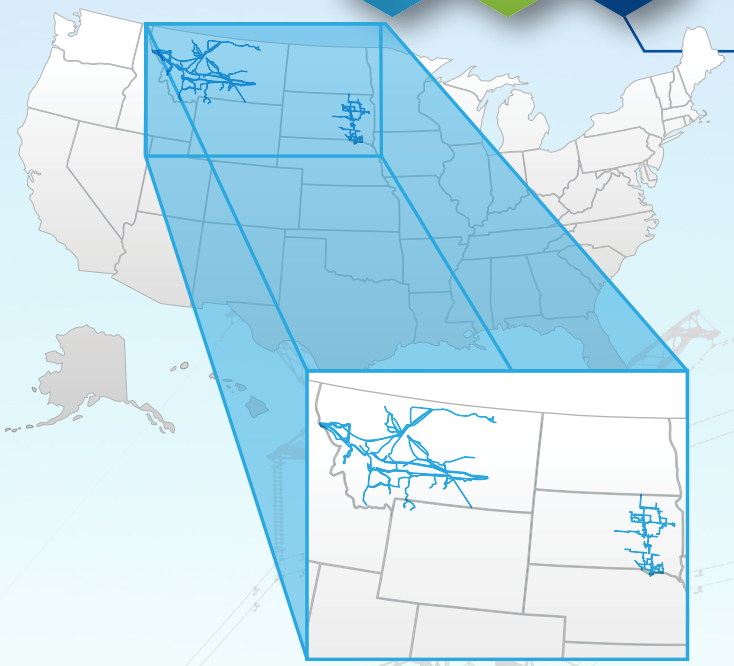

Figure A-70. NorthWestern Energy service area.

Conductor Application Successes

One 20-mile section of a 100-kV line between the cities of Great Falls and Two Dot was constructed with an ACSS/TW/MA5 conductor with ultra high-strength steel in a project, which has received national media attention as an example of a utility choosing a lower loss conductor. The annealed aluminum of the ACSS conductor increases conductivity compared to ACSR and the trapezoidal shaped wires allow more aluminum to be packed in the same diameter as a traditional ACSR. This project was undertaken in 2021. One of the primary motivating factors for the project between Great Falls and Two Dot was wildfire prevention. The ~20-mile section was through a heavily wooded area so the reduced sag of the ACSS conductor, in addition to the use of modern steel structures, reduced the risk of fires in this historically wildfire prone region.

Additionally, the conductor has increased efficiency, which provides more value to the utility and ratepayers. It was estimated if the entire 105-mile line was replaced with this ACSS/TW conductor the total savings could be as much as $440,000 per year. This project was recently used as an example for state regulators to argue for increased incentives for utilities to adopt advanced conductors in the state of Montana.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2021	Great Falls-Two Dot	Rebuild	ACSS/TW/MA5	100 kV	20 miles	Capacity and reliability

NV Energy

(ACCC, ACSS)

Utility Profile

NV Energy is a Berkshire Hathaway Energy company serving the state of Nevada (Figure A-71).

Figure A-71. NV Energy region.

Conductor Application Successes

NV Energy has performed at least 25 installations of ACCC conductor (Figure A-72) on 128-circuit miles starting in 2009 and has reported excellent experience with the conductor. This experience includes conductors surviving a wildfire that destroyed the wooden poles that were supporting. The applications include segments for 69 kV and 120 kV. NV Energy reports using ACCC for both reconductoring as well as new builds. To accommodate the large industrial end-user growth in the Reno area, NV Energy is using ACCC for new lines, which installation crews prefer to install versus multiple conductor bundles per phase. NV Energy has continued to apply ACCC for enhanced capacity where reconductoring or new line is desired at voltages 120 kV and under. This has been especially important where modification of structures would normally be required through sensitive areas, whereas reconductoring with ACCC allows for reuse of the existing structures and less disturbance to the environment.

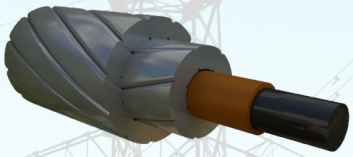

Figure A-72. ACCC conductor.

NV Energy has also used ACSS conductor (Figure A-73) in other applications and plans to continue using it for reconductoring.

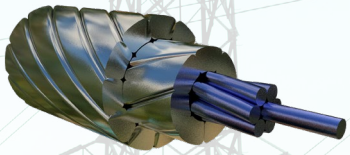

Figure A-73. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2009	107 Line	Reconductor	ACCC	120 kV	17.9 miles	Capacity
2020	Wild Horse to Comstock Meadows	New build	ACCC	120 kV	Unknown	Capacity
2023	Northwest to El Capitan	Reconductor	ACSS	138 kV	Unknown	Capacity for solar project interconnection

Oklahoma Gas & Electric Company

(ACCC, ACSS, ACSR/E3X)

Figure A-74. Region served by Oklahoma Gas and Electric Company.

Utility Profile

Oklahoma Gas and Electric (OG&E) is a utility covering most of central Oklahoma and part of Western Arkansas (Figure A-74). OG&E has ~890,000 customers and operates just over 7 GW of generation. They own ~5200 circuit miles of transmission lines and over 55,000 circuit miles of distribution lines.

Conductor Application Successes

OG&E installed a 35-mile section of ACCC Drake on a section of line between Oklahoma City and the McClain power plant in 2006. In 2013 an F5 tornado passed directly over the stretch of ACCC conductor OG&E had strung in 2006. During this event, it is surmised that a piece of flying debris struck one of the steel monopole structures, leaving it bent at a 45-degree angle. The tension placed on the conductor as a result caused the aluminum strands to snap in one location. However, the composite core remained fully intact (Figure A-75). Line crews were able to repair this section within 24 hours and ultimately bring the entire line back into service within about a week. OG&E was also the first utility to pilot E3X technology in 2013 and the first to use it on a major line in 2015.

Figure A-75. Damaged conductor following the 2013 tornado.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2006	OKC- McClain	New construction	ACCC	138 kV	35 miles	Unknown
2015	Cimarron-Matthewson	New construction	ACSR/E3X	345 kV	16 miles	Unknown
2013	Five Tribes-Pecan Creek	New construction	ACSR/E3X	161 kV	4 miles	Unknown

Oncor

(ACCC ACSS/TW, ACSS/TW E3X)

Utility Profile

Oncor is a public utility company located in the northern part of Texas. They operate over 140,000 miles of transmission and distribution lines and serve more than 400 communities in 98 counties. This service area encompasses more than 3 million people (Figure A-76).

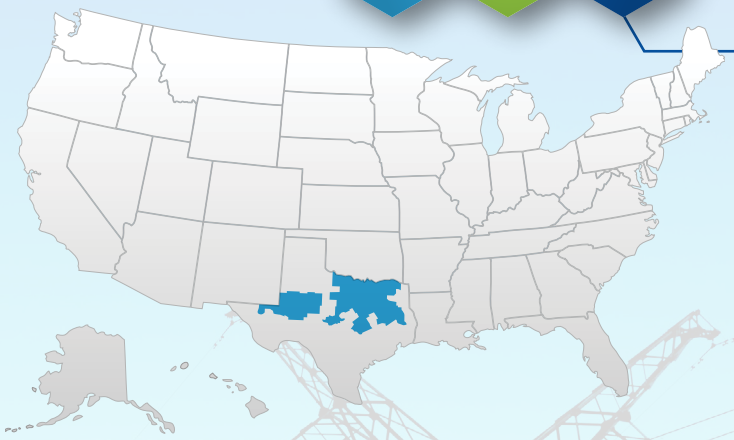

Figure A-76. Region served by Oncor.

Conductor Application Successes

In 2013 Oncor undertook a project to reconductor a 138-kV line from Odessa to Odessa North with ACCC.

Oncor has also experienced success with the use of ACSS/TW conductor in reconductoring and new lines. Additional examples include Old Country 345 kV, Ivy League 138 kV, Flat Iron–Barr Ranch 138 kV, Nacogdoches Southeast–Redland 345 kV, Ramhorn Hill–Dunham 345 kV, Sandlake–North McCamey 345 kV, and Redland–Lufkin 345 kV.

Oncor has also deployed ACSS/TW with E3X coating on several projects for reconductoring, new lines, and rebuilds. Most recently this was done on the Keller Wall Price – Keller Magnolia 138-kV project. Oncor performed a pilot project, installing DLR equipment on parallel lines to validate performance of the E3X coating. Results were favorable and presented at IEEE. Benefits noted were extra capacity and risk management of thermal line rating variables, as heat dissipation varies significantly over the life of standard conductors but with E3X the surface conditions are expected to have insignificant change with aging.

Oncor built approximately 850 miles of new transmission lines as part of the Texas Competitive Renewable Energy Zone projects, known as CREZ. This was state wide project to proactively increase transmission capacity across the state which resulted in several thousand miles of new transmission and helped enable Texas to become the leading renewable energy producer. Oncor used ACSS/TW for their portion of these project.

Oncor found reconductoring with ACCC to provide the best trade-off between cost and capacity improvement to relieve congestion in the Odessa region. Other options like Dynamic Line Rating (DLR) were considered, but ultimately due to the projected long-term load growth, they found reconductoring was the cheapest option for providing the needed capacity increase.

Within Oncor's service area ACSS/TW has become standard. Indeed, every ongoing Oncor project as of this writing is using the ACSS/TW conductor.

These projects range in purpose from improving system resilience following disturbances to meeting increased customer demand as a result of population growth and new customers. Where additional capacity beyond ACSS/TW is required for project growth, ACSS/TW/E3X is used

Oncor

(ACCC ACSS/TW, ACSS/TW E3X)

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Odessa North	Reconductor	ACCC	138 kV	Unknown	Unknown
2018	Apollo-East Richardson	Reconductor	ACSS/TW with E3X	138 kV	Unknown	Capacity increase for data centers
2015	Various CREZ lines	New construction	ACSS/TW	138 kV 345 kV	850 miles	Renewable energy interconnection

Otter Tail Power

(Twisted Pair)

Utility Profile

Otter Tail Power (OTP) is an investor-owned electric utility that provides electricity and energy services for approximately 133,000 residential, commercial, and industrial customers across 70,000 miles^2 in Minnesota, North Dakota, and South Dakota (Figure A-77).

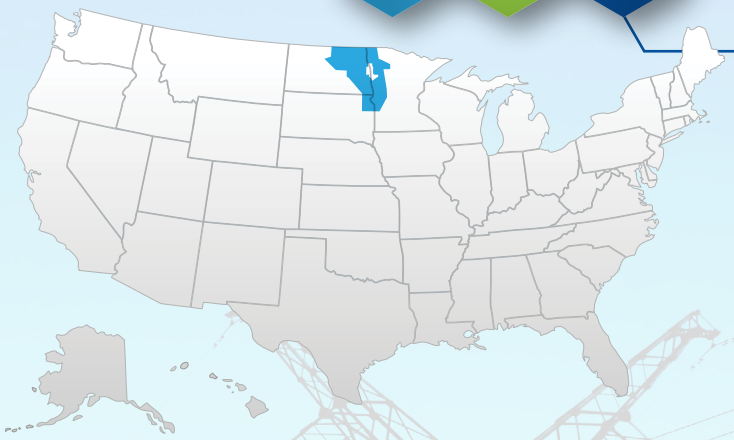

Figure A-77. Region Served by OTP.

Conductor Application Successes

OTP has largely not used HTLS conductor technologies in reconductoring projects. OTP has used a vibration resistant conductor known as Twisted Pair or T2 ACSR for both new construction and reconductoring. This variation on ACSR is constructed in a cable manufacturing process that twists two ACSR conductors into a single conductor and is known by the trade names of T2 or VR2. It is used widely in the ice prone region from the panhandle of Texas throughout the upper midwestern states. Twisted Pair ACSR is designed to prevent a phenomenon called galloping where conductors move violently in the wind, with the entire span of conductor, possibly weighing thousands of pounds moving up and down with amplitudes of up to 40 feet. Galloping can cause outages when conductors from different phases contact if not sufficiently spaced. Over time, galloping can break insulators and transmission towers. The reconductoring projects found for OTP replaced round conductor with T2 twisted pair conductor for reliability reasons.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Buffalo-Enderlin	Reconductor	Twisted Pair ACSR (T2)	115 kV	7 miles	Reliability

Pacific Gas & Electric Company

(ACSS, ACCR)

Utility Profile

Pacific Gas and Electric Company (PG&E) provides Electric in the Northern two-thirds of California, from Bakersfield to northern Santa Barbara County. The transmission system covered for this region is illustrated in Figure A-78.

Figure A-78. PG&E Electric Service territory boundary.

Conductor Application Successes

PG&E ACSR and ACSS (Figure A-79) are commonly used conductors. For reconductoring PG&E has many projects where they have used ACSS and ACCR (Figure A-80). PG&E may make modifications to existing structures or may replace a portion of line structures when reconductoring with ACSS.

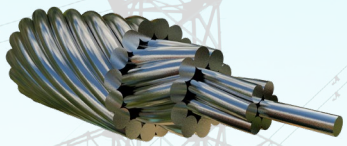

Figure A-79. ACSR/ACSS.

Figure A-80. ACCR.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
Prior to 2010	NRS to Scott	Reconductor	3M ACCR	115 kV	<1 mile	Capacity increase
Unknown	Morro Bay-Midway	Reconductor	ACSS	230 kV	35 miles	Solar project integration

Pacificorp

(ACCC, ACSS/TW)

Utility Profile

Pacificorp is a Berkshire Hathaway Energy company that consists of Rocky Mountain Power and Pacific Power (Figure A-81).

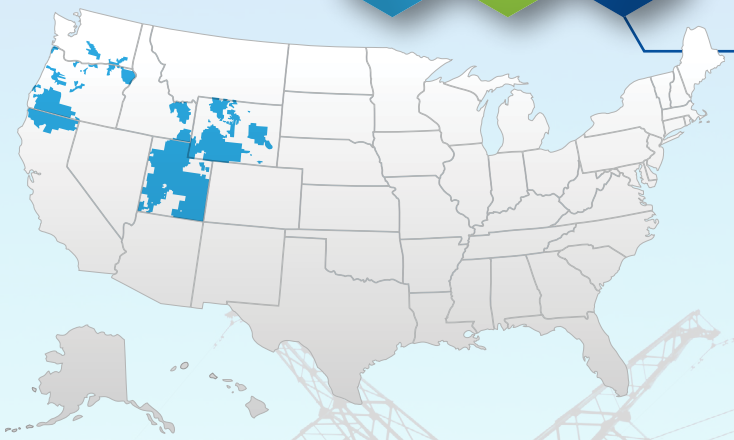

Figure A-81. PacifiCorp region.

Conductor Application Successes

PacifiCorp widely utilizes ACSS conductor including for its new Aeolus Shirley Basin 230-kV line that was built as part of the Energy Vision 2020 project. Their new Aeolus Freezeout 2 230-kV line will also be built with an ACSS conductor. PacifiCorp was an early adopter of ACCC conductor, energizing a 6.7-mile section in 2006 in the Salt Lake City area. Pacificorp has used ACCC conductor in multiple projects (Figure A-82), including to a roughly 20-mile section of the 345-kV Populus-Terminal project.

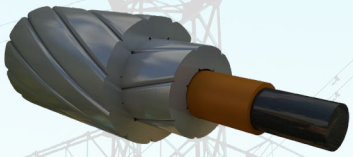

Figure A-82. ACCC conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2009	Populus Terminal	New construction	ACCC	345 kV	20 miles	Capacity
2020	Aeolus Shirley Basin	New construction	ACSS/TW	230 kV	12 miles	Capacity

PNM & TNMP

(ACSS, ACCC/E3X)

Utility Profile

Public Service Company of New Mexico (PNM) provides Electric in the Northern part of New Mexico, from Belen to Santa Fe. The transmission system covered for this region is illustrated in Figure A-83.

Texas-New Mexico Power Company (TNMP) provides electricity to more than 270,000 homes and businesses throughout Texas. They are a subsidiary of PNM.

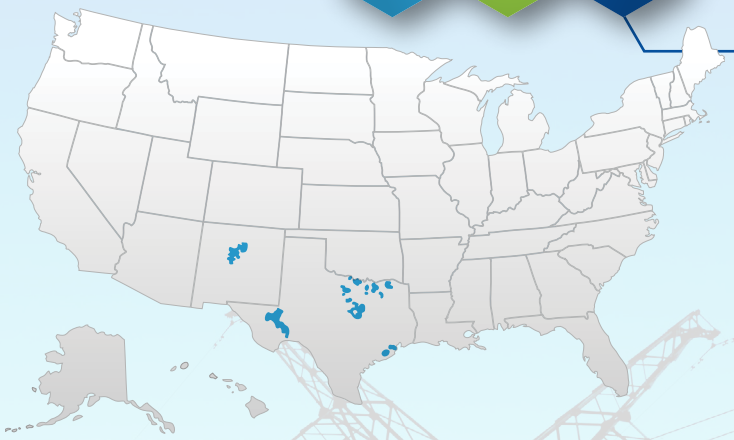

Figure A-83. PNM and TNMP coverage map.

Conductor Application Successes

PNM and TNMP both use ACSR or ACSS (Figure A-84) as their preferred conductors for new or rebuilt 115 kV and 230 kV. With the high load growth areas of their service territory, they have started using ACSS for the higher capacity. TNMP has gradually been replacing all older wooden structures with new steel structures, which will give sufficient clearance and the ability to switch to a composite core conductor if needed. TNMP is currently reconductoring an ACSR line using ACCC with E3X coating (Figure A-85). Some tower modifications are necessary as the tension required for the larger ACCC conductor used is higher than the previous ACSR. The dead-end structures are being replaced to accommodate the higher tension while the more numerous tangent structures are being reused. The E3X coating was needed to increase the capacity of the ACCC conductor to achieve the 3000-amp rating required without a complete rebuild. The ACCC conductor being used is equipped with Infocore fiber optics so the conductor can be tested for damage during production, shipping, and installation.

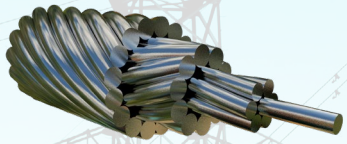

Figure A-84. ACSR/ACSS.

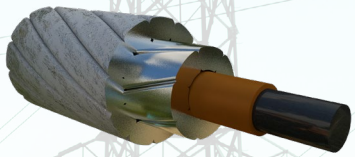

Figure A-85. ACCC.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2023	Wink-Fishhook	Reconductor	ACCC Infocore with E3X	115 kV	10 miles	Industrial load growth

Portland General Electric

(ACSS)

Utility Profile

Portland General Electric (PGE) provides power to approximately 900,000 customers in seven counties and 51 cities. PGE provides roughly 75% of the state's commercial and industrial power. The transmission system covered for this region is illustrated in Figure A-86.

Conductor Application Successes

PGE has used ACSS conductor for multiple reconductoring projects and plans to use ACSS for future reconductoring projects (Figure A-87).

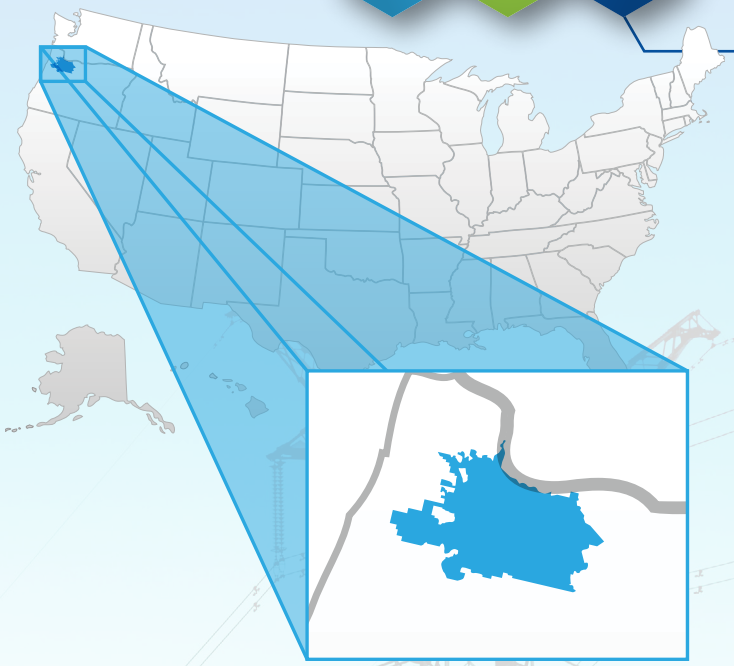

Figure A-86. PGE coverage.

Figure A-87. ACSR/ACSS.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2019	Orenco-Sunset	Reconductor	ACSS	115 kV	3 miles	Thermal overloads

PPL Electric Corporation

(ACSS/TW)

Utility Profile

PPL Electric Corporation provides power to customers in 29 counties in Pennsylvania. The transmission system covered for this region is illustrated in Figure A-88.

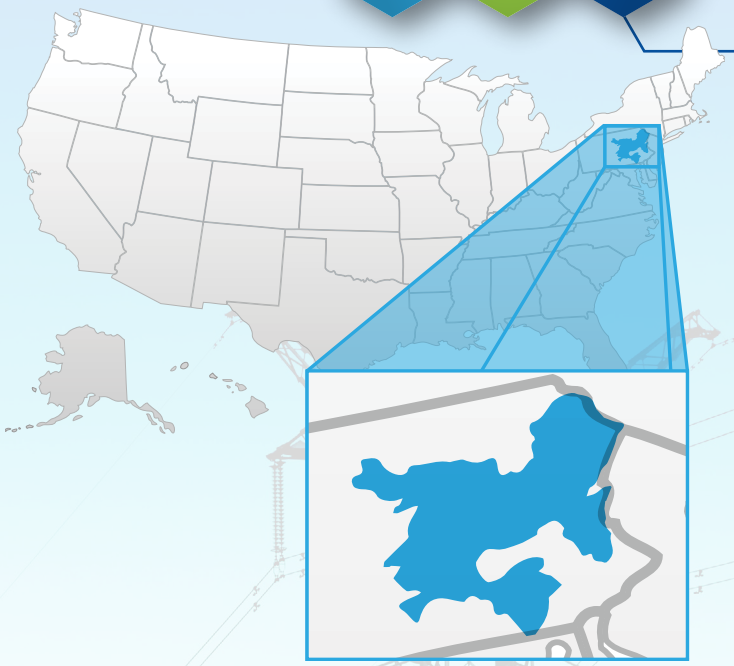

Figure A-88. PPL coverage.

Conductor Application Successes

PPL has proposed using ACSS (Figure A-89) for a reconductoring project in the PJM Interconnection. During the work they have proposed to replace the existing porcelain insulators with new glass strings of insulators, presumably because of age or deterioration of the existing insulators. Only one structure would need to be replaced out of 75 existing structures, although others would need to be reinforced. The existing shield wire will remain in place. The ACSS proposed incorporates HS285 steel (Southwire tradename), which is designated as MA5 by ASTM. Ultra-high-strength steel allows for tighter tensioning of conductors and reduced sag.

Figure A-89. ACSR/ACSS.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2023	Juniata - Cumberland	Reconductor	ACSS/TW	230 kV	14.2 miles	Unknown

Public Service Enterprise Group

(ACSS)

Utility Profile

Public Service Enterprise Group (PSE&G) covers much of New Jersey residents and businesses. The transmission system covered for this region is illustrated in (Figure A-90).

Conductor Application Successes

PSE&G has used ACSS for reconductoring projects (Figure A-91).

Figure A-90. PSE&G coverage area.

Figure A-91. ACSR/ACSS.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2007	Kittatinny-Newtown	Reconductor	ACSS	230 kV	Unknown	Unknown

San Diego Gas & Electric Company

(ZTACIR, ACSS)

Utility Profile

San Diego Gas and Electric (SDG&E) has a relatively small service area (Figure A-92), covering the southern-most parts of Orange County and spanning south to the Southern California border with Mexico. They currently serve 3.7 million customers spanning over 4,100 miles^2.

Figure A-92. San Diego Gas and Electric service region.

Conductor Application Successes

SDG&E has done several reconductoring projects. The conductors used include ACSS and ZTACIR. The projects include 607 miles of new conductor running through the Cleveland National Forest, and several smaller projects (less than 10 miles each) running around and through the cities of San Diego, La Jolla, San Clemente, and others. SDG&E is the only known utility user of ZTCIR in the U.S.. ZTCIR is known as a "heat resistant aluminum alloy conductor invar reinforced" conductor and is similar to ACSR, but uses aluminum zirconium alloy as the conductive metal and uses aluminum cladinvar steel core wire, which exhibits a low-thermal coefficient of expansion; therefore, it has low sag at high temperatures.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2016	Artesian and Bernardo	Reconductor	ZTACIR	69 kV	2.2 miles	Capacity increase
2018	Meadowlark Junction to Escondido	Reconductor	ACSS	69 kV	7.4 miles	Reliability and clearance improvement

Southern California Edison

(ACCC, ACCR, ACSS/TW)

Utility Profile

Southern California Edison (SCE) serves approximately 15 million people in southern California (Figure A-93). The utility owns its transmission infrastructure, but it has sold many of its generating assets. The company has a strong dedication to the development of green energy and embracing technologies that will secure the net zero future. From the Tehachapi Pass Wind Farm to solar contracts and solar generation development and EV rate programs, SCE is constantly searching for new technologies to improve the environment and their value for southern California.

Figure A-93. Southern California Edison service area.

Conductor Application Successes

SCE has about 300 circuit miles of lines on at least 15 projects that have been reconductored with composite core ACCC conductor (Figure A-94). They are significantly invested in CTC Global technology for reconductoring purposes. SCE also regularly use ACSS conductors (Figure A-95) for new builds and rebuilds and has also raised existing towers to increase line clearance to ground.

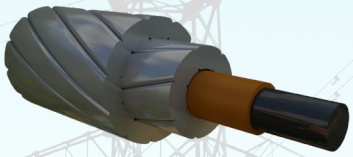

Figure A-94. ACCC conductor.

SCE used ACCR (Figure A-96) to reconductor a 3-mile section of a 500-kV line. Reconductoring and transmission line work has been done both to increase transmission capacity and to remediate approximately 11,000 safety clearance violations identified with surveys using LiDAR technology.

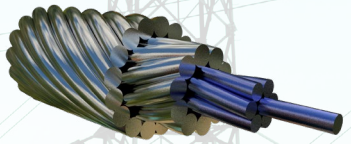

Figure A-95. ACSS conductor.

SCE has adopted ACCC and the ACSS technology and are replacing lines as they either age out or become points of congestion. Other technologies have been deployed to reduce congestion, such as the smart wires smart valves. The ecosystem of technologies provides a rich range of options that allow utilities to tailor the lowest cost solution to each unique problem.

Figure A-96. ACCR conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2018	Springville-Magunden	Reconductor	ACSS/TW	230 kV	50 miles	Unknown
2018	Victor-Aqueduct-Phelan	Reconductor	ACCC	115 kV	34 miles	Unknown
2018	TLRR project	Reconductor	ACCR	500 kV	3 miles	Unknown

Southern Company

(ACCR, ACSS)

Utility Profile

Southern Company is a parent company of several power companies covering large areas of the Southern United States (Figure A-97). Currently, they are the parent company of three electric utilities, five natural gas utilities, and five other power and telecom companies. They are currently responsible for more than 27,000 miles of transmission lines, 3,700 substations, and 300,000 acres of right of way.

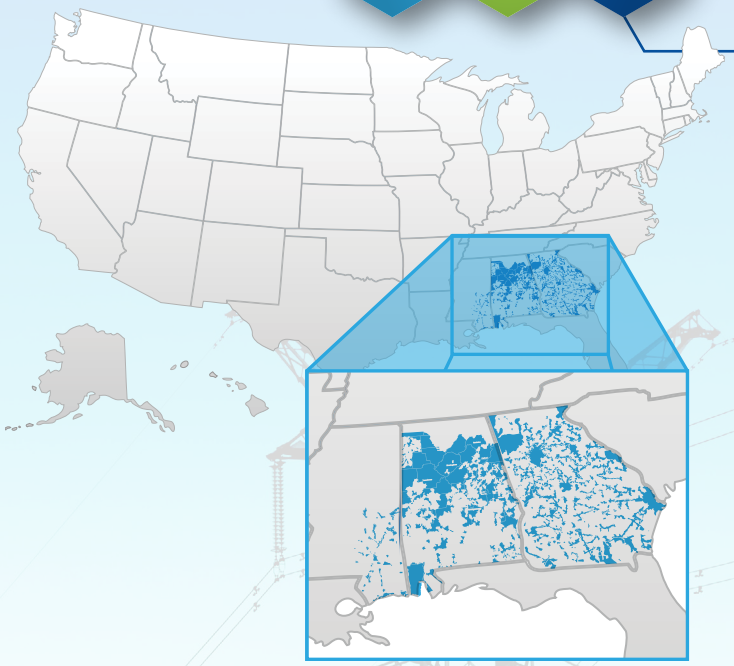

Figure A-97. Southern Company service territory.

Conductor Application Successes

Southern Company states they are the largest utility user of ACCR Conductor from 3M, having installed over 300 circuit miles on many reconductoring projects. Southern Company also uses ACSR and ACSS for projects. Between 2010 and 2020, Southern Company partnered with Dalton Utilities, Power South Energy Cooperative, South Mississippi Electric, Georgia Transmission, and Municipal Electric Authority of Georgia to construct nine new ACSR transmission lines, three new ACSS transmission lines, and one replacement of an existing line with ACSS.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Kraft to McIntosh	Reconductor	ACCR	230 kV	16.7 miles	Avoiding construction in wetlands

Tennessee Valley Authority

(ACSS/TW, ACCR, TS)

Utility Profile

The Tennessee Valley Authority (TVA) works in partnership with local power companies to keep reliable public power flowing to residential and commercial electricity users throughout the seven-state Tennessee Valley region. Both municipal utilities and regional cooperatives purchase power from TVA and distribute it to consumers within their designated service areas, which are illustrated in Figure A-98.

Figure A-98. TVA region.

Conductor Application Successes

TVA has installed ACSS, ACCR, and TS conductors (Figure A-99, Figure A-100, Figure A-101) in their infrastructure, noting in particular ACCR in 2014 and more recently TS conductors. ACSS is a standard conductor for use within their infrastructure for application alongside ACSR, addressing the need for a higher capacity conductor in certain installations.

TVA has been progressive in the application of transmission technologies and advanced conductors in their infrastructure. TVA installed the world's first 500-kV transmission line in 1965 and has been using ACSS conductor since the early 1970s. TVA completed a line reconductor using ACCR on a 500-kV line in 2013, which was the world's first application of ACCR on a three-bundle 500-kV configuration. TVA is now investigating TS Conductor as a cost-effective method to upgrade existing lines without performing tower modifications.

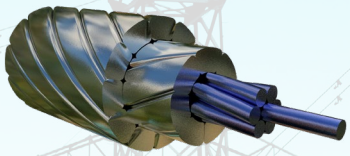

Figure A-99. ACSS conductor.

Figure A-100. ACCR conductor.

Figure A-101. TS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2013	Pinhook-Wilson	Reconductor	ACCC	500 kV	Unknown	Increased capacity
2023	Unknown	Reconductor	TS conductor	Unknown	Unknown	Increased capacity
Since 1973	Various	New and reconductor	ACSS	Various	Unknown	Various

Tucson Electric Power Company

(ACSS)

Utility Profile

Tucson Electric Power (TEP) has a relatively small service area (Figure A-102), covering the city of Tucson and surrounding areas. They own over 2,600 miles of transmission lines ranging from 46 to 500 kV. They currently serve over 442,000 customers.

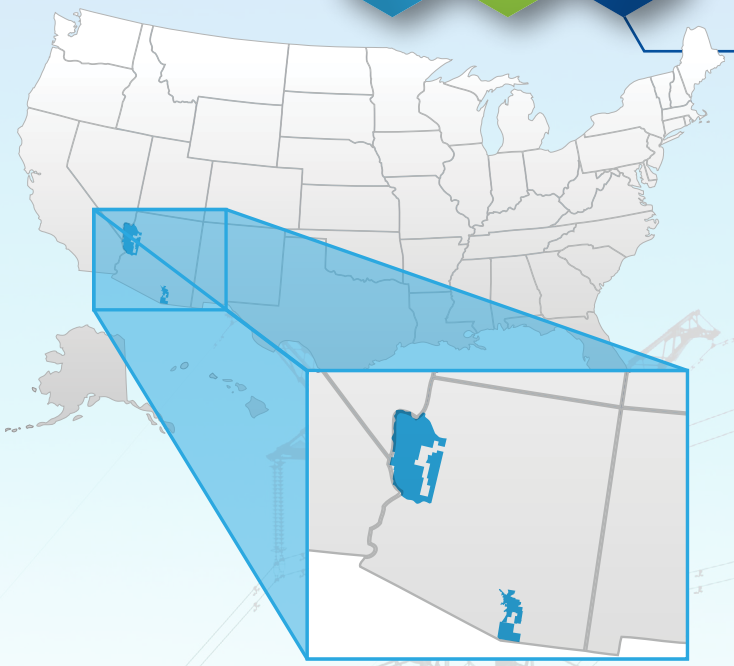

Figure A-102. Tucson Electric service region.

Conductor Application Successes

TEP uses 954-kcmil ACSS (Figure A-103) 45/7 Rail as a standard for 138-kV lines, which is rated at 2265 amps and is used for both new construction and for reconductoring. TEP used 1590-kcmil ACSR for a 500-kV new line construction that connects the Pinal Central and Tortolita substations. The total distance of the line is 40 miles and consists of a single circuit.

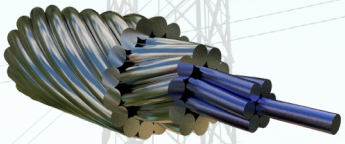

Figure A-103. ACSS conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2020	Irvington-Vail	Reconductor	ACSS	137 kV	11.1 miles	Capacity
2015	Pinal Central-Tortolita	New construction	ACSR	500 kV	40 miles	Various

Western Area Power Administration

(ACSS/TW MA5, ACCR, ACCC)

Utility Profile

The Western Area Power Administration (WAPA) is Federal Power Marketing Agency, serving as a wholesale power provider for 15 western and central states shown in Figure A-104.

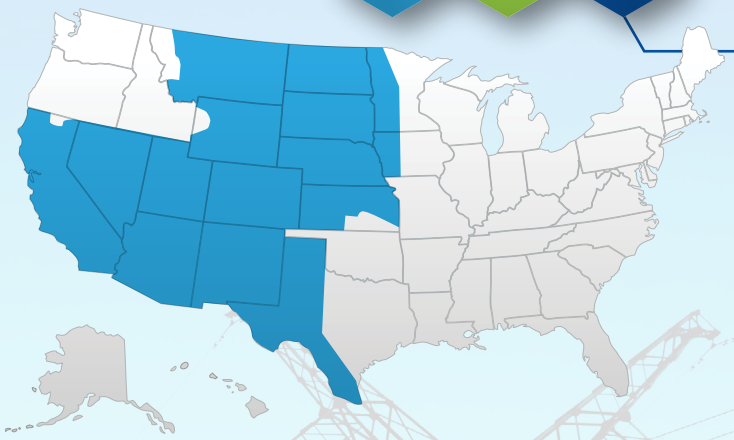

Figure A-104. WAPA region.

Conductor Application Successes

WAPA installed 1.5 thousand miles of ACSS conductor (Figure A-105) in 2008, needing to increase capacity while changing an aged ACSR line. The reconductoring performed had minimal tower modifications. A number of reconductoring and installation projects using ACSS has been noted to the current day.

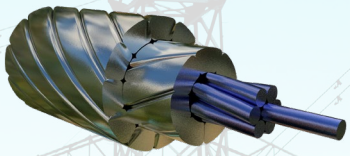

Figure A-105. ACSS/TW conductor.

ACCR (Figure A-106) has also been applied in 2006 and in other applications to boost power capacity. This included power from the Boulder Dam to increase capacity in the region and replace an aged line with minimal tower rebuilding.

Figure A-106. ACCR conductor.

ACCC (Figure A-107) was tested in 2006 in Arizona to evaluate performance against wind and other conditions.

WAPA recognized the benefits of reconductoring using the latest ACSS/TW after performing a tradeoff study of the costs with just ACSR replacement. The reduced costs of the reconductoring with ACSS with the added benefit of increased capacity, which was desired, was a driving motivation. WAPA continues this strategy.

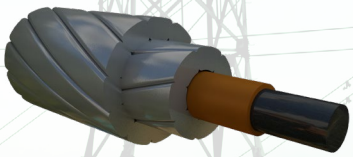

Figure A-107. ACCC conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2007	Davis Mead	Reconductor	ACSS/HS285	230 kV	61 miles	Capacity
2005	Liberty-Parker #2	Reconductor	ACCC	230 kV	2 miles	Capacity
2002	Jamestown to Fargo	Reconductor	ACCR	230 kV	1 mile	Capacity

Xcel Energy Electric Company

(ACSS, ACSS/TW, ACCC, ACCR)

Utility Profile

Xcel Energy has a service area that spans across parts of seven different states (Figure A-108). They currently serve more than 3.7 million customers and have 20,000 miles of transmission lines.

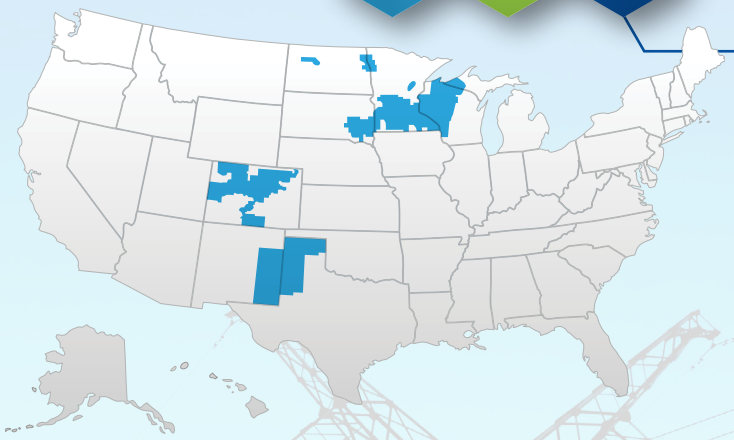

Figure A-108. Xcel Energy service region.

Conductor Application Successes

Xcel Energy uses a variety of conductor types in their transmission lines. ACSR is one of the standard types of conductors used in their transmission including twisted pair ACSR in areas prone to galloping. They currently use ACSS (Figure A-109) in approximately 20% of their new construction projects. Xcel installed the world's first commercial project for ACCR (Figure A-110) on the Black Dog-Blue Lake project as a good alternative to provide higher ampacity and less sag without rebuilding the line. Xcel was a partner along with 10 other utilities in the CapX 2020 project, which was the largest transmission project completed in the upper Midwest since the 1970s. Xcel utilized ACSS/TW on their portion of the project. During construction, the line experienced a significant problem with galloping conductors, which had to retrofit with 25-foot spacers to keep the phases separated and to inhibit the vibrations. Four of these 200-pound spacers were installed per span to mitigate the problem.

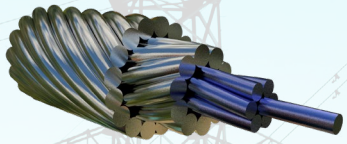

Figure A-109. ACSS conductor.

Figure A-110. ACCR conductor.

Exemplary Projects

Year	Project Name	Project Type	Conductor Used	Voltage Level	Line Length	Project Purpose
2005	Black Dog-Blue Lake	Reconductor	ACCR	115kV	10 miles	Capacity increase
2017	CapX 2020	New construction	ACSS/TW	345 kV	156 miles	Renewable energy capacity

Utility Index

Southern Company.....Pg. 49

References

1. Alabama Power
2. Mississippi Power
3. Georgia Power
4. SOUTHERN COMPANY OVERHEAD DISTRIBUTION CONSTRUCTION MANUAL
5. SERTP 2nd Quarter Meeting Preliminary Expansion Plan Meeting June 29, 2023
6. SERTP 4th Quarter Meeting Annual Transmission Planning Summit & Assumptions Input Meeting December 14th, 2022
7. SERTP 4th Quarter Meeting Annual Transmission Planning Summit & Assumptions Input Meeting December 16th, 2021
8. Major Utility in Southern U.S. Upgrades Transmission Lines
9. 3M™ Aluminum Conductor Composite Reinforced Customer Installations - Reliability
10. Alabama Power to Install 3M High-Capacity ACCR Conductor

Tennessee Valley Authority.....Pg. 50

References

1. TVA's Grid Resiliency Direction, Presentation to NESC Workshop.
2. Jeffery Phillips, "TVA Pushes More Power Down the Corridor", Transmission and Distribution World, February 2014.
3. TS Conductor Wins Public Utilities Fortnightly's 2023 Edison Pioneers Innovation of the Year Award, PRWeb, October 2023.

Tucson Electric Power Company .....Pg. 51

References

1. TUCSON - EL PASO POWER EXCHANGE AND TRANSMISSION AGREEMENT
2. AMRPWR Projects
3. Tucson Electric Power Proposed Point of Interconnection North Loop 138 kV Substation
4. Tucson Electric Power Company Sonoran Substation to Wilmot Energy Center 138 kV Transmission Line Project
5. Tucson Electric Power 138 Kilovolt Transmission Line Underground Cost Analysis

Western Area Power Administration .....Pg. 52

References

1. High-Temperature, Low-Sag Conductors Ease Ecologically Sensitive Line Upgrade
2. 2022 Annual Progress Report, WAPA
3. Composite Technology, Western Area Power Administration Organize Remote Monitoring of ACCC Grid Application, T&D World, March 2006.
4. 3M Aluminum Conductor Composite Reinforced Customer Installations - High Load Growth
5. 3M Aluminum Conductor Composite Reinforced Customer Installations - Permitting New Construction
6. 3M's New High-Capacity Overhead Conductor is Chosen by Western Area Power Administration to Boost Electricity Transmission on Key Line Along Colorado River in Arizona
7. 2022-23 Base Transmission Plan - WestConnect

Xcel Energy Electric Company.....Pg. 53

References

1. *Xcel Energy*
2. *OVERHEAD CONDUCTOR – STANDARDS*
3. *Xcel Energy Crawford Direct Final*
4. *ACCC Projects List*
5. *ROUTE PERMIT FOR CONSTRUCTION OF TWO HIGH VOLTAGE TRANSMISSION LINES AND A SUBSTATION IN SOUTHWESTERN MINNESOTA ISSUED TO NORTHERN STATES POWER CO. d/b/a XCEL ENERGY EQB DOCKET No. 03-73-TR-XCEL*