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Power Grab: Exploring Grid Enhancing Technologies (GETs) Maximum Reliable Transmission

January 2025

Changing the World's Energy Future

Jake P Gentle, Jonathan M. Tacke, Abby M. Neumann

Idaho National Laboratory

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January 29, 2024

Power Grab: Exploring Grid Enhancing Technologies (GETs) Maximum Reliable Transmission

CNEE Webinar

CENTER FOR THE NEW ENERGY ECONOMY
COLORADO STATE UNIVERSITY

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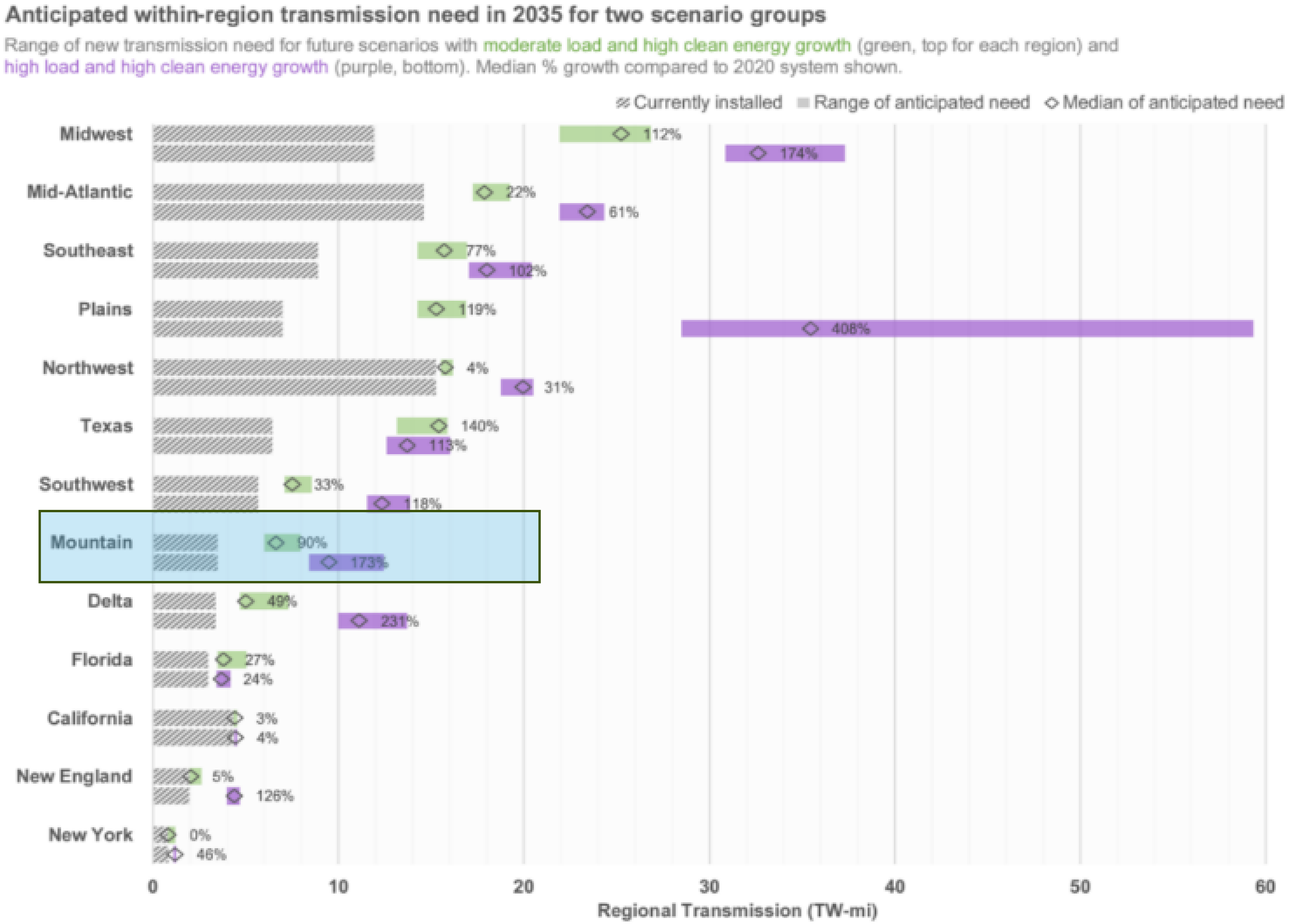
A Congested Outlook: Integrating Clean Energy

- ***Grid Transmission Capacity***
  - Aging infrastructure needs to be replaced or augmented to meet the increased power demand.
- ***Adding more Clean Energy Generation***
  - Renewable energy will address the need for clean and sustainable energy but must be integrated into the existing power grid.
- ***Geography Matters***
  - Renewable energy sources are often located far from load centers, requiring extensive transmission infrastructure to carry electricity from the generation sites to the consumers.
- ***Slow Rate of Interconnection***
  - As more renewable generation sources join the grid, congestion costs are expected to rise substantially.
- ***Cybersecurity concerns***
  - Many renewable energy systems haven’t yet matured in terms of cyber security risk management and operations because the generation technologies are still in the early stages of deployment and operations.

Transmission Capacity Is Needed

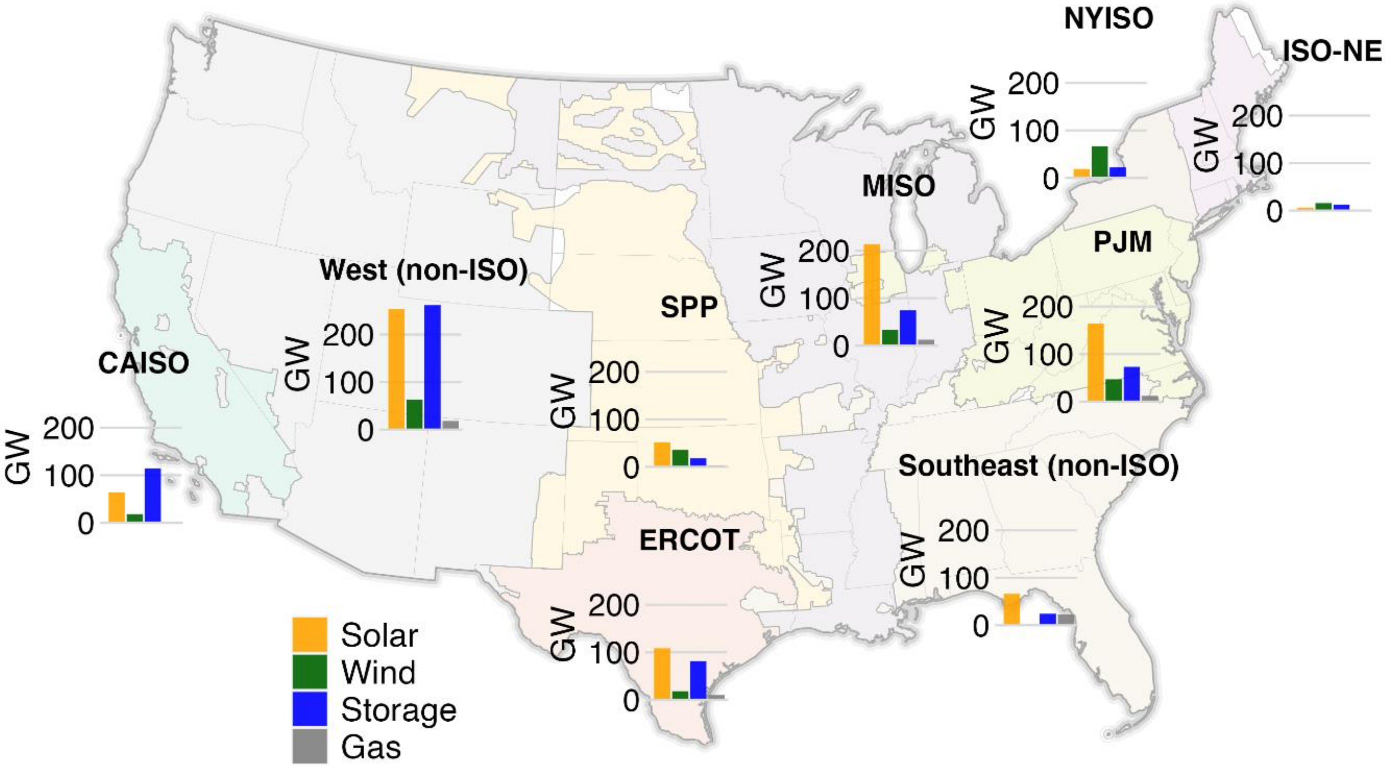


Key findings from the DOE National Transmission Needs Study (2023):

- **Mountain Region is expected to increase by 90% by 2035** assuming a moderate growth in demand and high growth in renewables.
- These 2035 deployment needs increase even more under high load growth scenarios, specifically for the **Mountain (173%)** region.

Gridlocked: Clean Energy Interconnection Queue

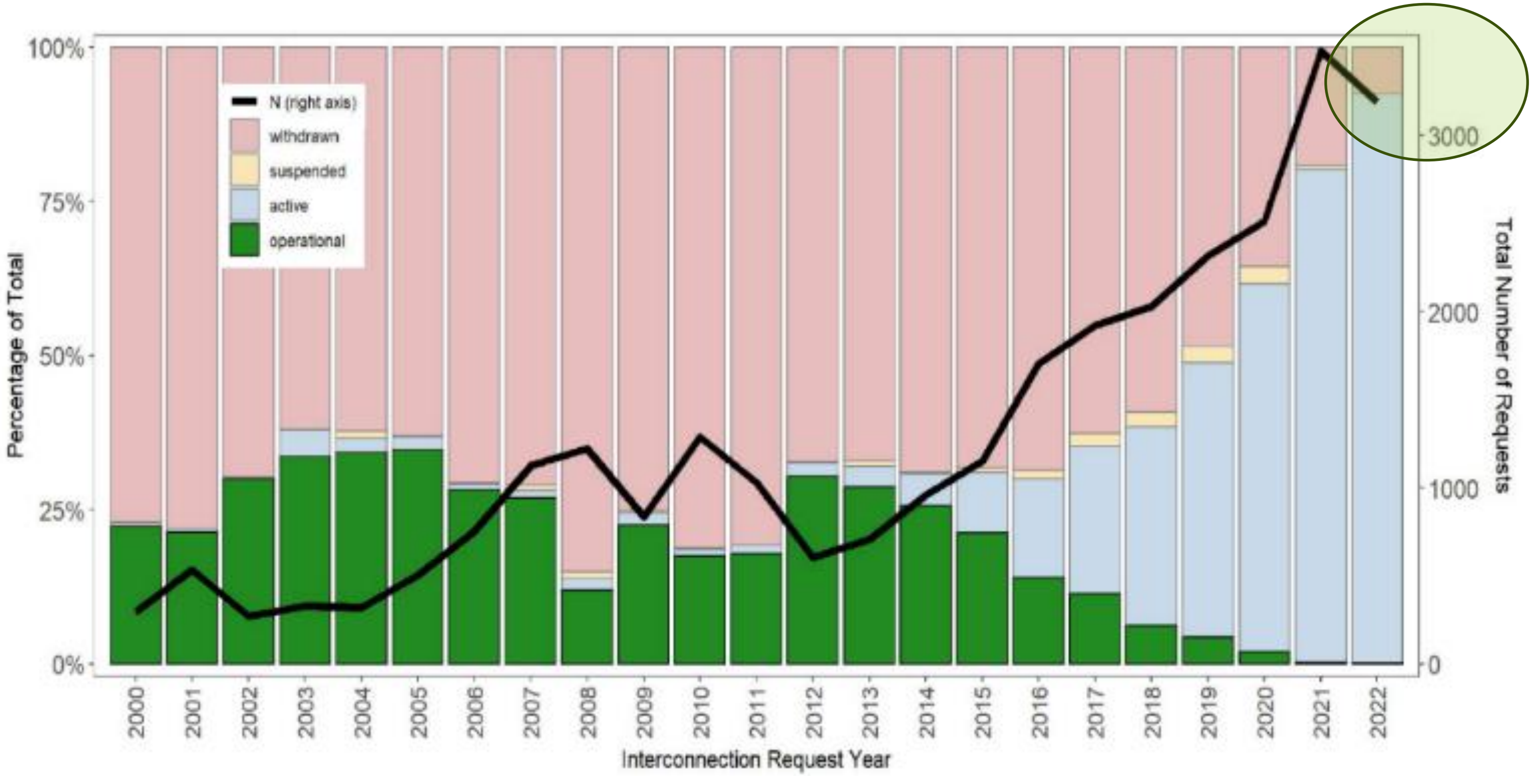
Proposed projects seeking to connect to the grid



- Interconnection is dictated by a complex network of laws, regulations, and administrative processes
- Over 2,000 gigawatts (GW) of total generation and storage capacity seeking connection to the grid
- Current interconnection procedures, however, are **not designed to accommodate** the deployment of hundreds of gigawatts.

https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf

Gridlocked: Clean Energy Interconnection Queue



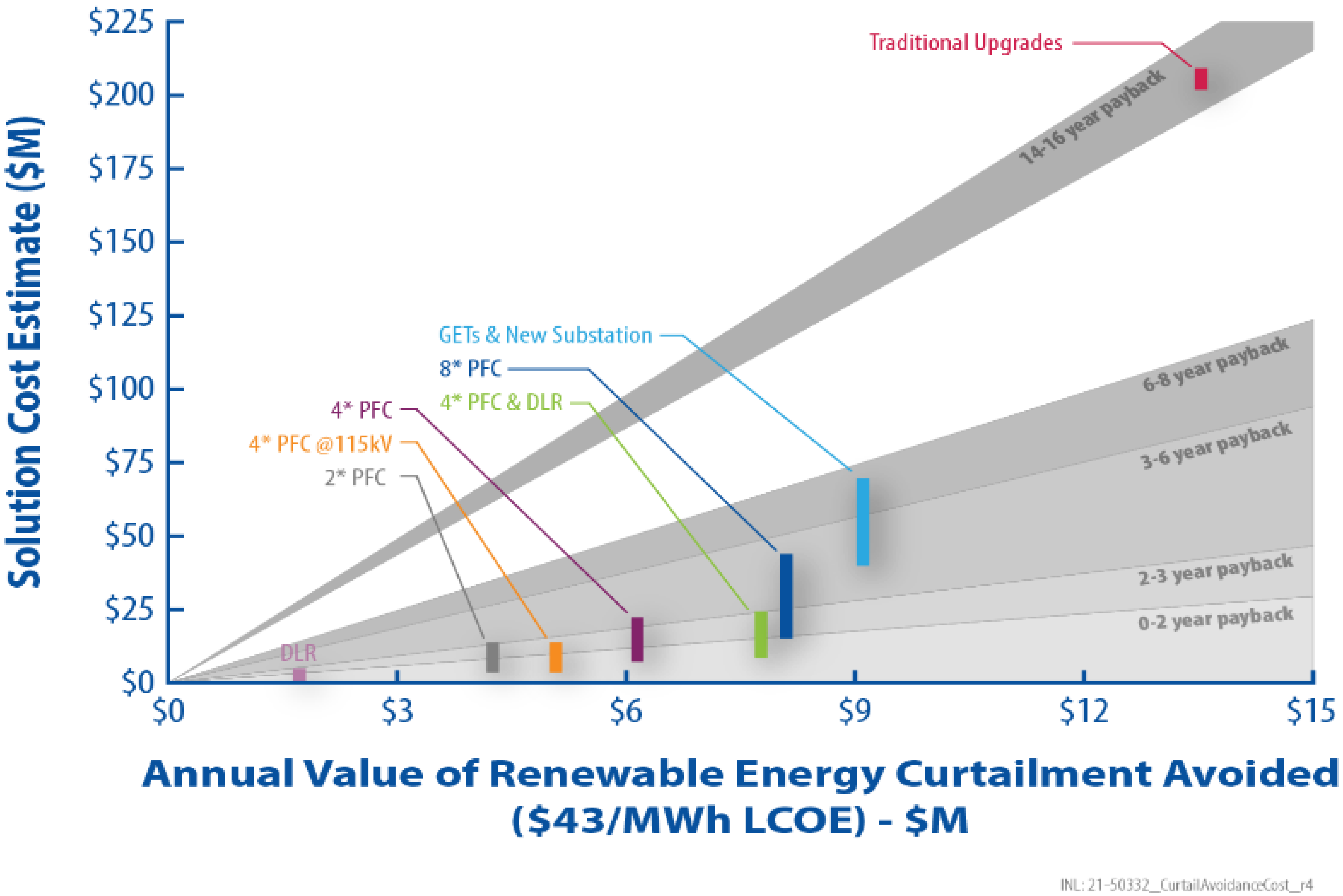
https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf

Only 21% of all projects proposed from 2000-2017 had reached commercial operations by the end of 2022

~ **72% had withdrawn from queues**

Rising interconnection costs and long queue delays for renewables may **impede clean energy goals** set at the federal and state level

GETs: Relieving Grid Congestion



https://www.energy.gov/sites/prod/files/2019/08/f66/Congressional_DLR_Report_June2019_final_508_0.pdf
https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

- GETs cases provide optionality in addressing curtailment at a fraction of the cost
- Similar story across other system economic metrics
- Payback period appears to be faster for GETs
  - GETs lifecycle shorter than traditional upgrades
- Range of costs identified for each of the GETs cases

GETs: Relieving Grid Congestion

Grid Enhancing Technologies (GETs) include, but are not limited to:

1. Power Flow Control (PFC) and optimized transmission switching
2. Storage technologies
3. Advanced line rating management
   - Ambient Adjusted Ratings (AAR)
   - Dynamic Line Ratings (DLR)
4. Advanced Conductors

Power Flow Control is a set of technologies that push or shift power away from overloaded lines and onto underutilized lines/corridors within the existing transmission network. Multiple power flow control solutions exist.

Dynamic Line Ratings (and Ambient Adjusted Ratings) Utilizes hardware and/or software used to appropriately update the calculated thermal limits of existing transmission lines based on real-time and forecasted weather conditions

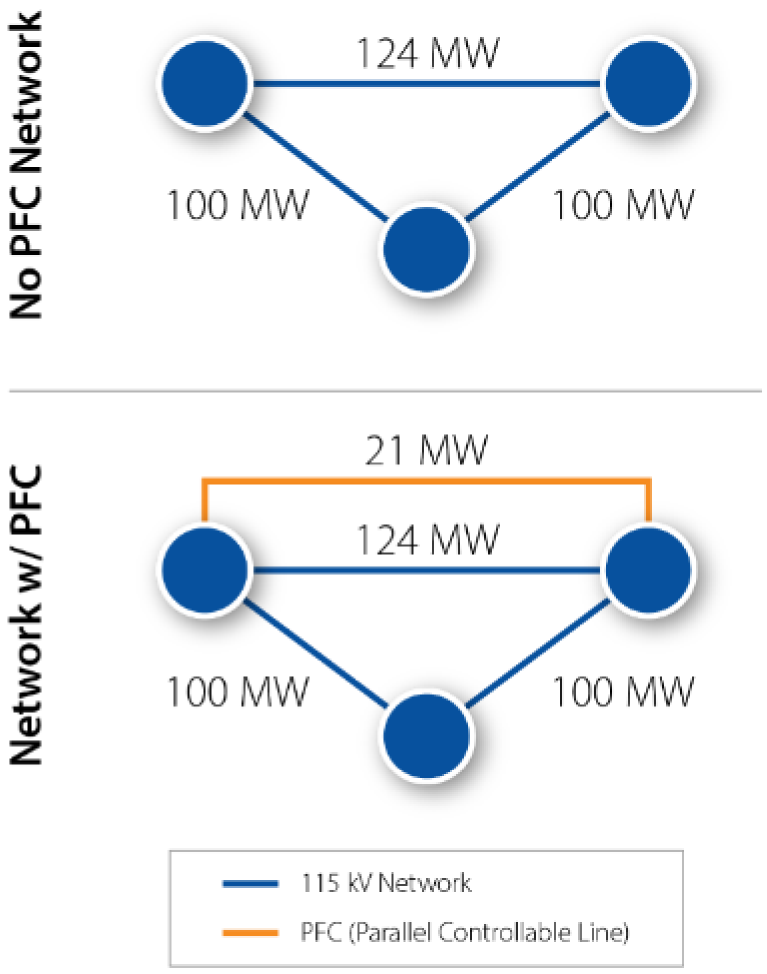
Contingency - the loss of a transmission component

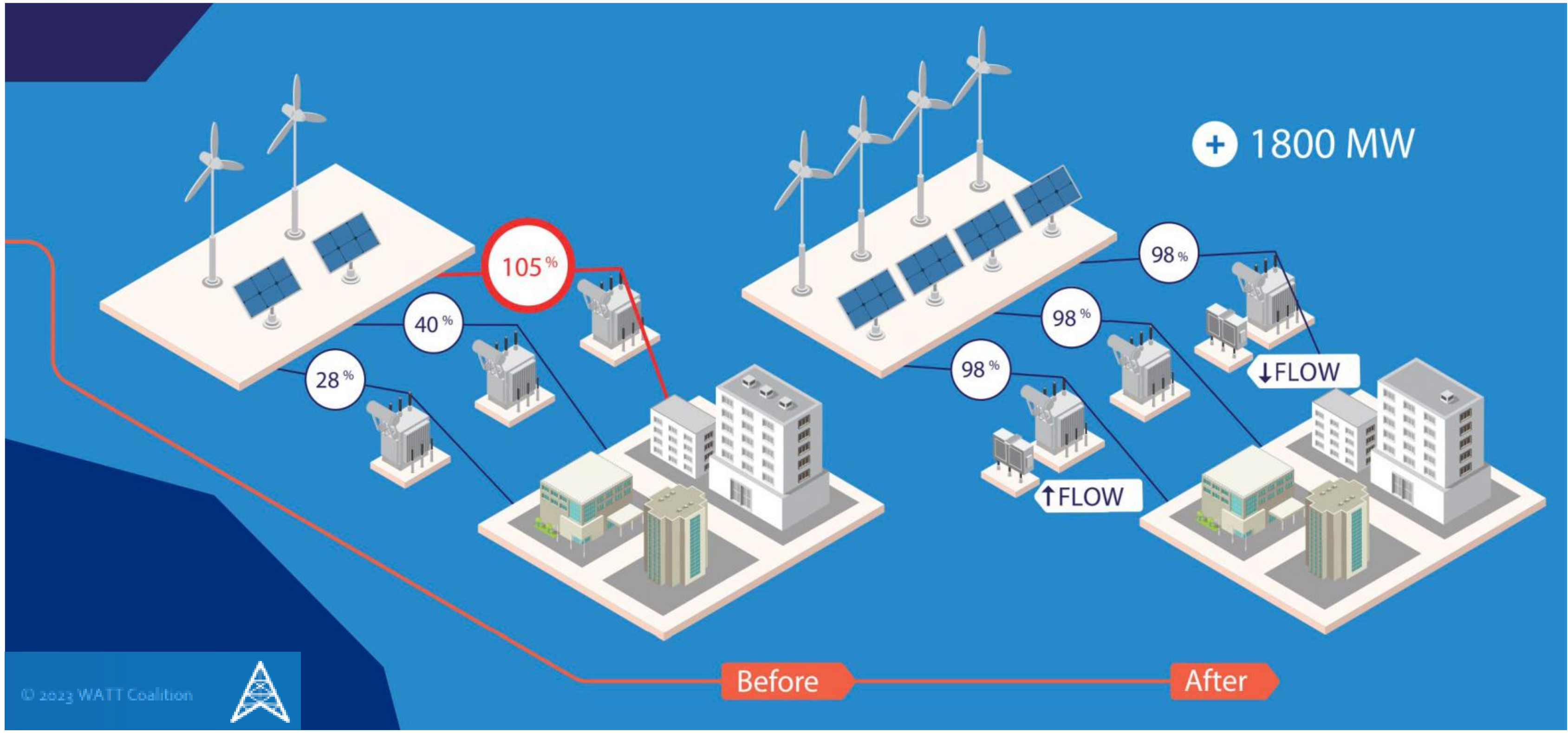
Monitored Element - the elements overloaded when a contingency happens

Flowgate – the contingency and monitored element pair that limit power transfer across the transmission system (from wind/solar to load in this example)

GETs definition from FERC Notice to Convene a Workshop on Grid-Enhancing Technologies: https://cms.ferc.gov/media/7198

Advanced Power Flow Control

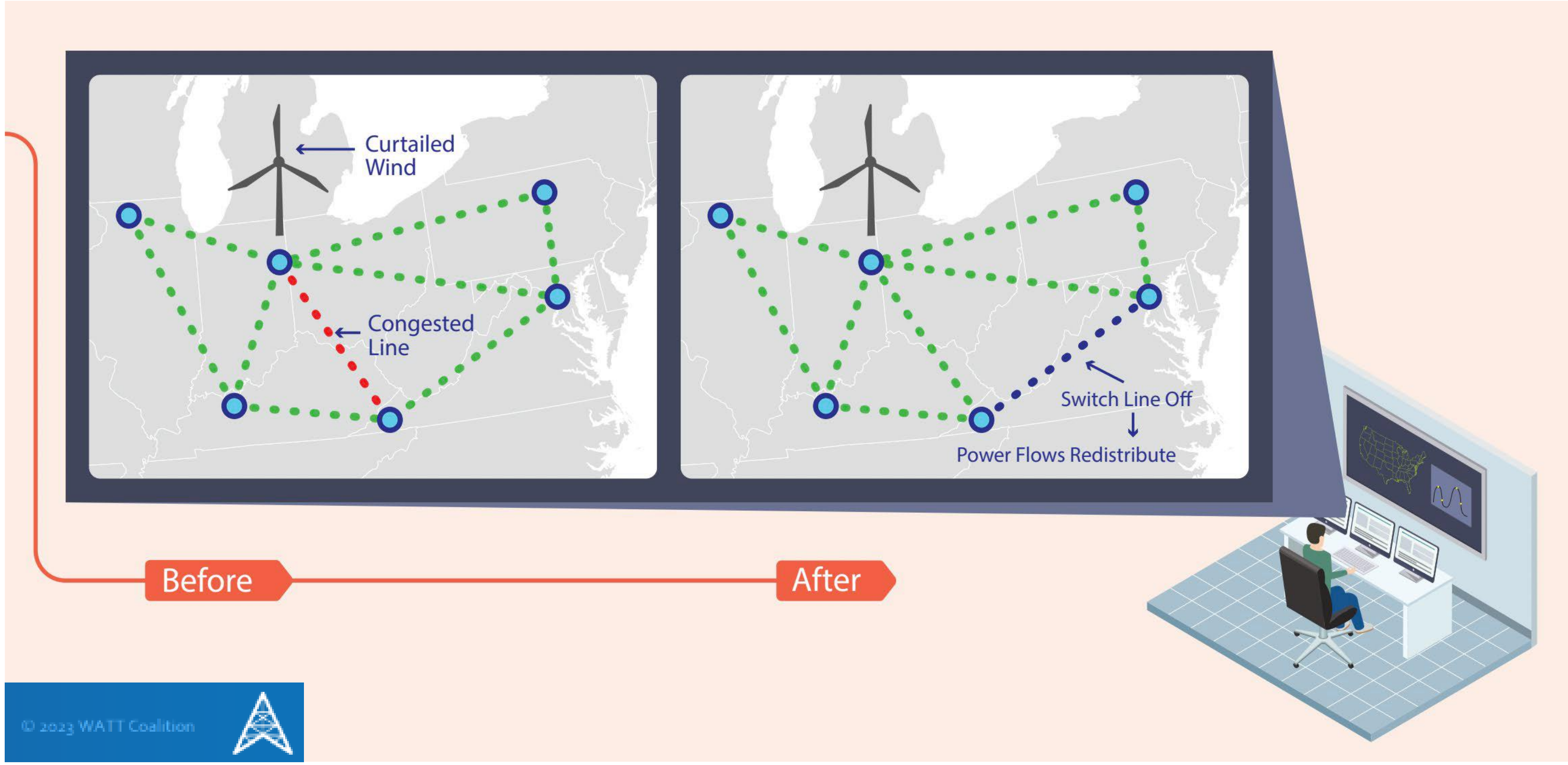




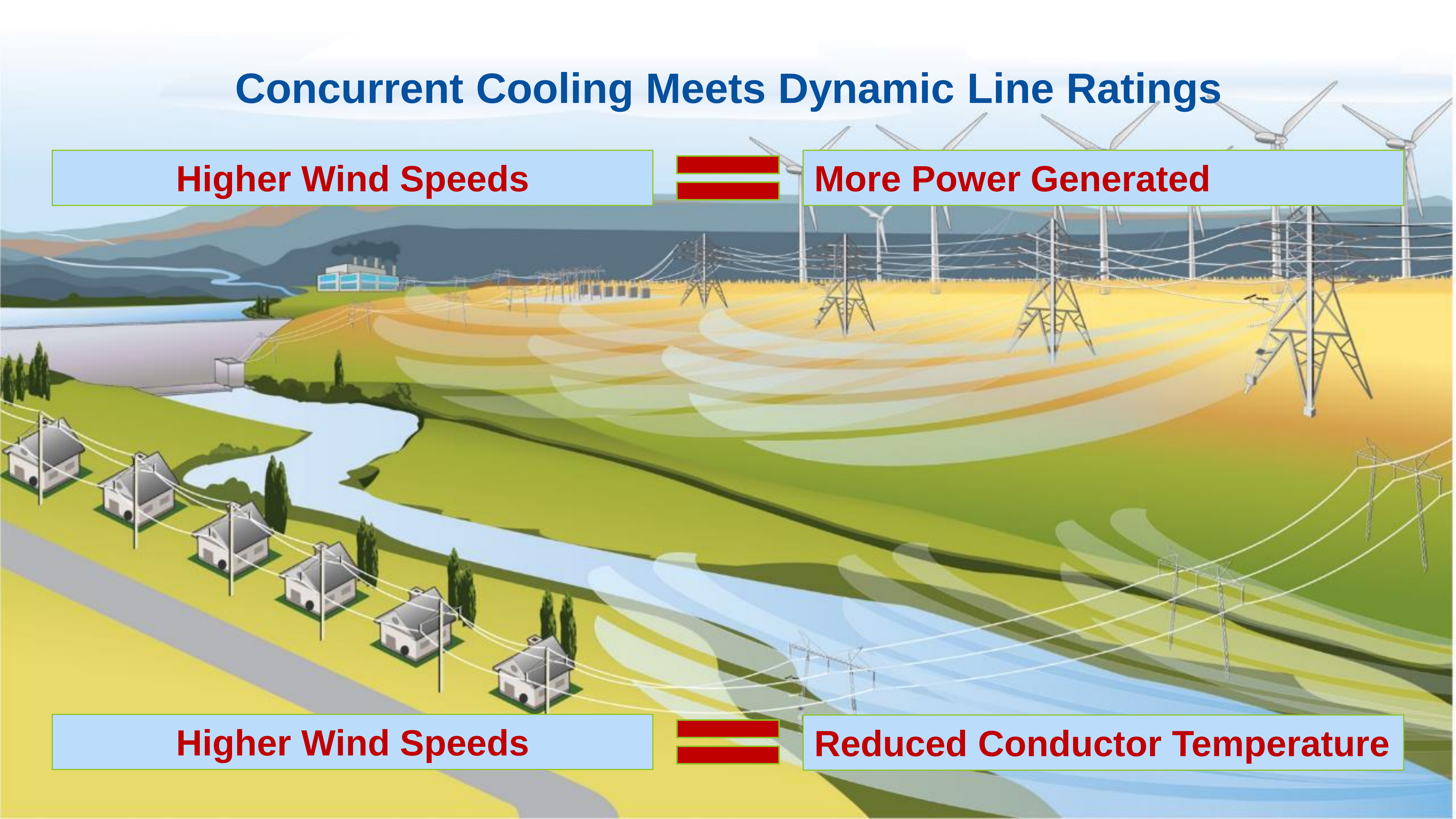
PFC allows system operator to reroute flows across the transmission network by changing line impedance

Topology Optimization

- Software finds and evaluates reliable reconfigurations to reroute flow around congestion
- Reconfigurations can be implemented by opening or closing circuit breakers.
  - Analogous to temporarily diverting traffic away from congested roads to make traffic flow smoother.
- Provides a high-level, actionable overview of whether there are reconfiguration options to mitigate the congestion patterns.



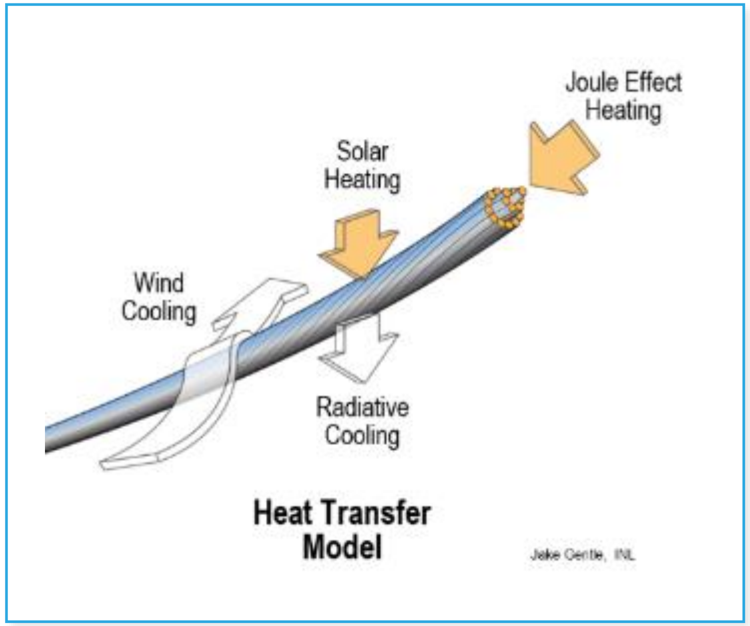
Concurrent Cooling Meets Dynamic Line Ratings

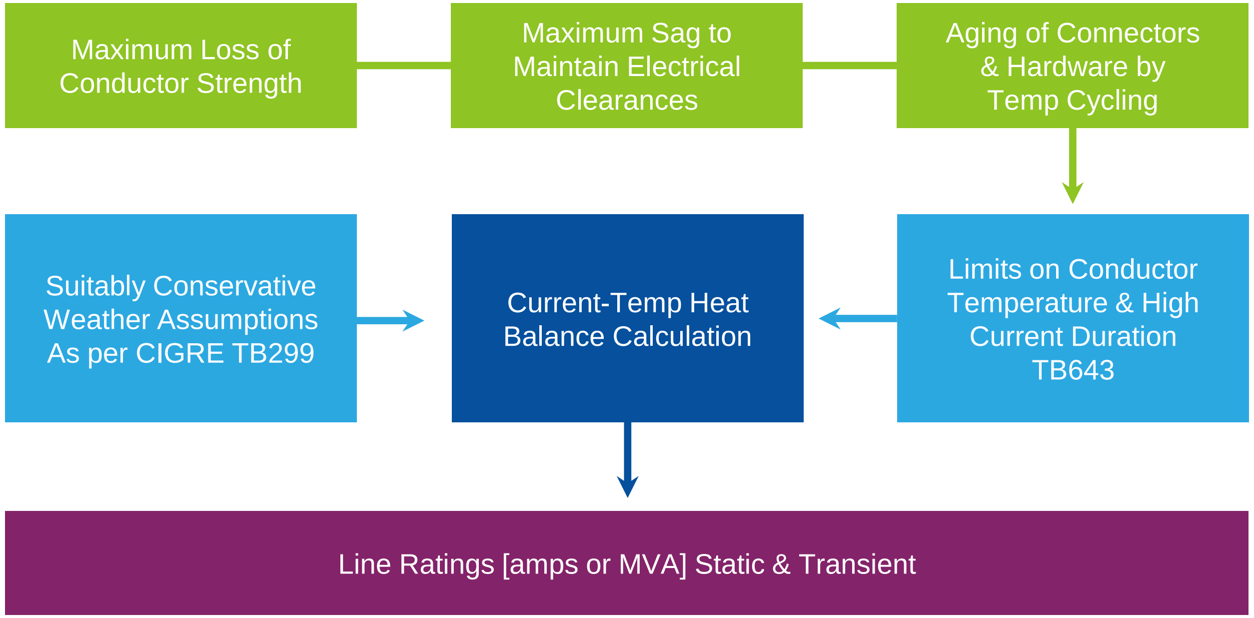


Higher Wind Speeds = **More Power Generated**

Higher Wind Speeds = **Reduced Conductor Temperature**

What is a Line’s Thermal Rating?



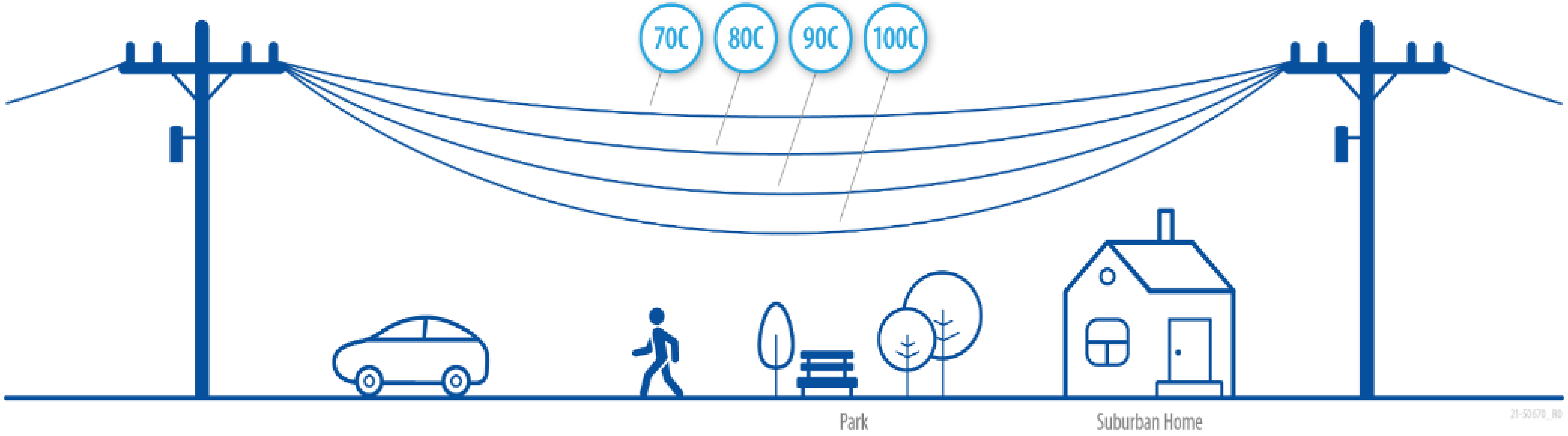


Dale Douglass, DPC

- **Maximum current a line can carry** where the resulting line conductor temperature doesn’t exceed a specified maximum conductor temperature.
- The maximum conductor temperature is calculated **to limit cumulative damage** to the conductor system **assuring minimum electrical clearances** are maintained.

Ratings Come Down to Only a Few Things

Clearances



Roger Renwick, AltaLink

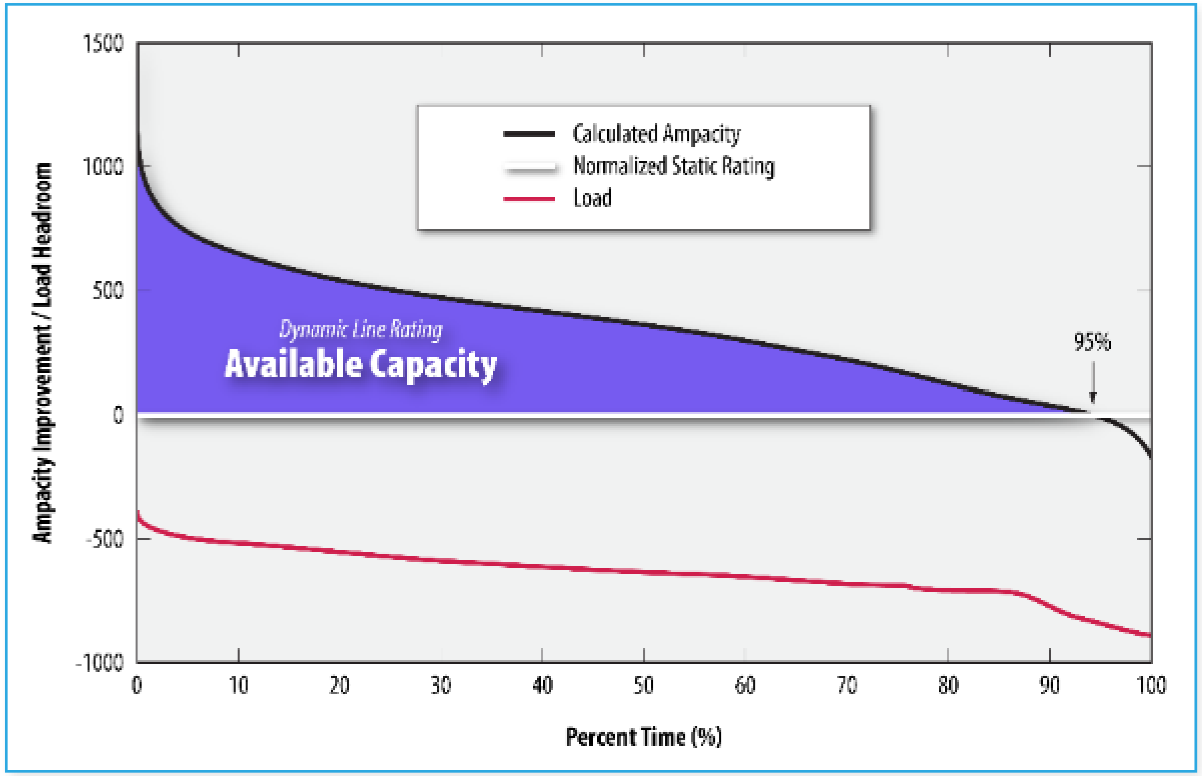
Why Should We Increase Our Ratings?

To safely increase line utilization

- Power Flow Optimizations
- More access to lower priced generators
- Contingency analysis

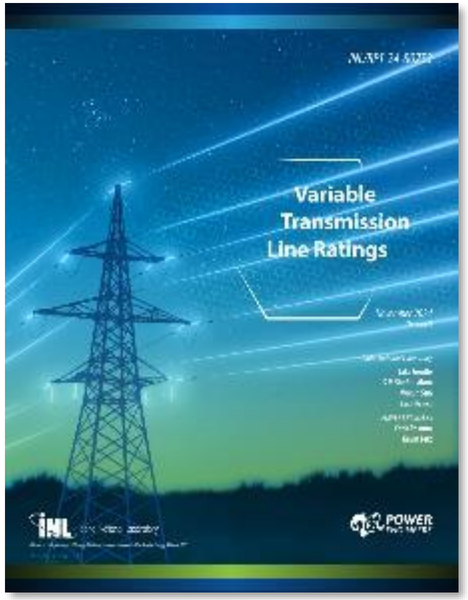
DLR accurately reflects the real-world

- Risk mitigations (equipment failure/fatigue)
- Safety & reliability

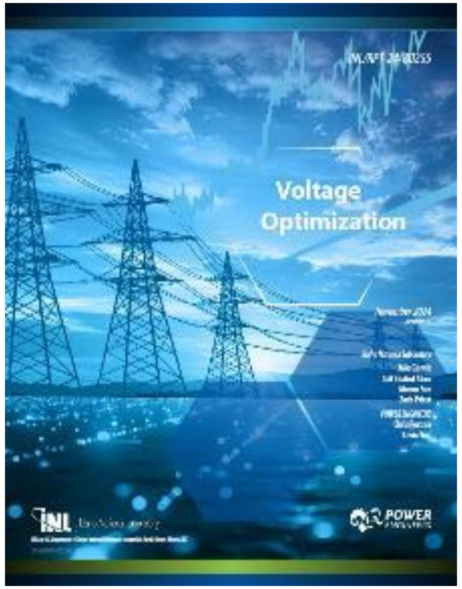


Industry Driven Literature on GETs Integration and Control

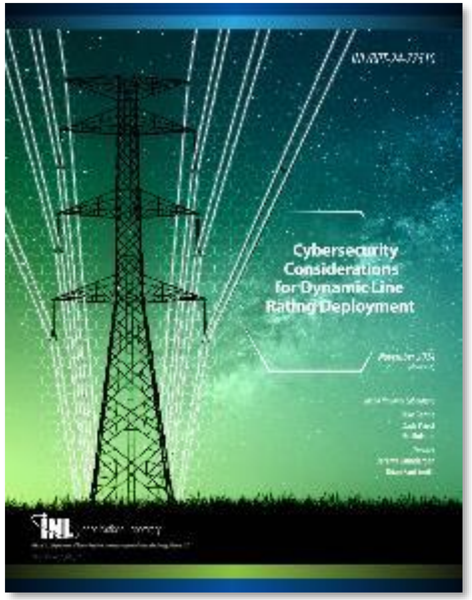
The Basics



The Control



Cybersecurity



nature reviews clean technology

https://doi.org/10.1038/s44359-024-00001-5

Review article

Check for updates

Grid-enhancing technologies for clean energy systems

Tong Su[1], Junbo Zhao[1], Antonio Gomez-Exposito[2], Yousu Chen[3], Vladimir Terzija[4] & Jake P. Gentle[5]

Abstract

Renewable energy source integration into energy systems can contribute to transmission congestion, which requires time-consuming and capital-intensive upgrades to address. Grid-enhancing technologies (GETs) can increase the capacity of grids with minimal investment, preventing congestion and curtailment of renewable energy. In this Review, we discuss the principles and uses of GETs, which use software and/or hardware to interpret real-time conditions to better use the existing capacity of grid assets. GETs include dynamic line ratings, dynamic transformer ratings, power flow controls, topology optimization, advanced conductor technologies, energy storage systems, and demand response. These GETs can enhance system performance individually, but the deployment of multiple GETs together would greatly increase their effect on the grid capacity and stability by removing multiple capacity bottlenecks in parallel. Infrastructure for real-time data acquisition, transmission and analysis is key to successfully deploying GETs but requires further development and commercialization for broader deployment.

Sections

Newest Publication!

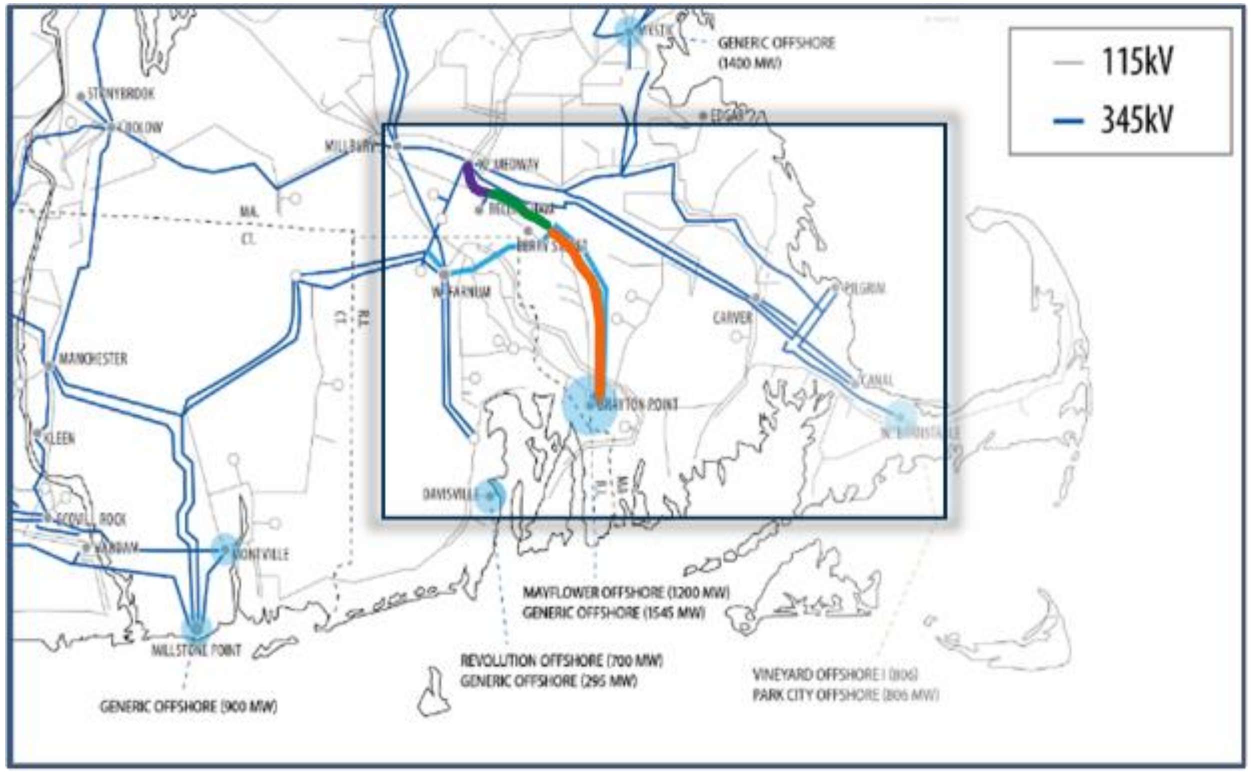
Nature Reviews Clean Technology

Grid Enhancing Technologies for Clean Energy Systems

Su, T., Zhao, J., Gomez-Exposito, A., Gentle, J., *et al*. Grid-enhancing technologies for clean energy systems. *Nat. Rev. Clean Technol.* **1**, 16–31 (2025).

https://doi.org/10.1038/s44359-024-00001-5

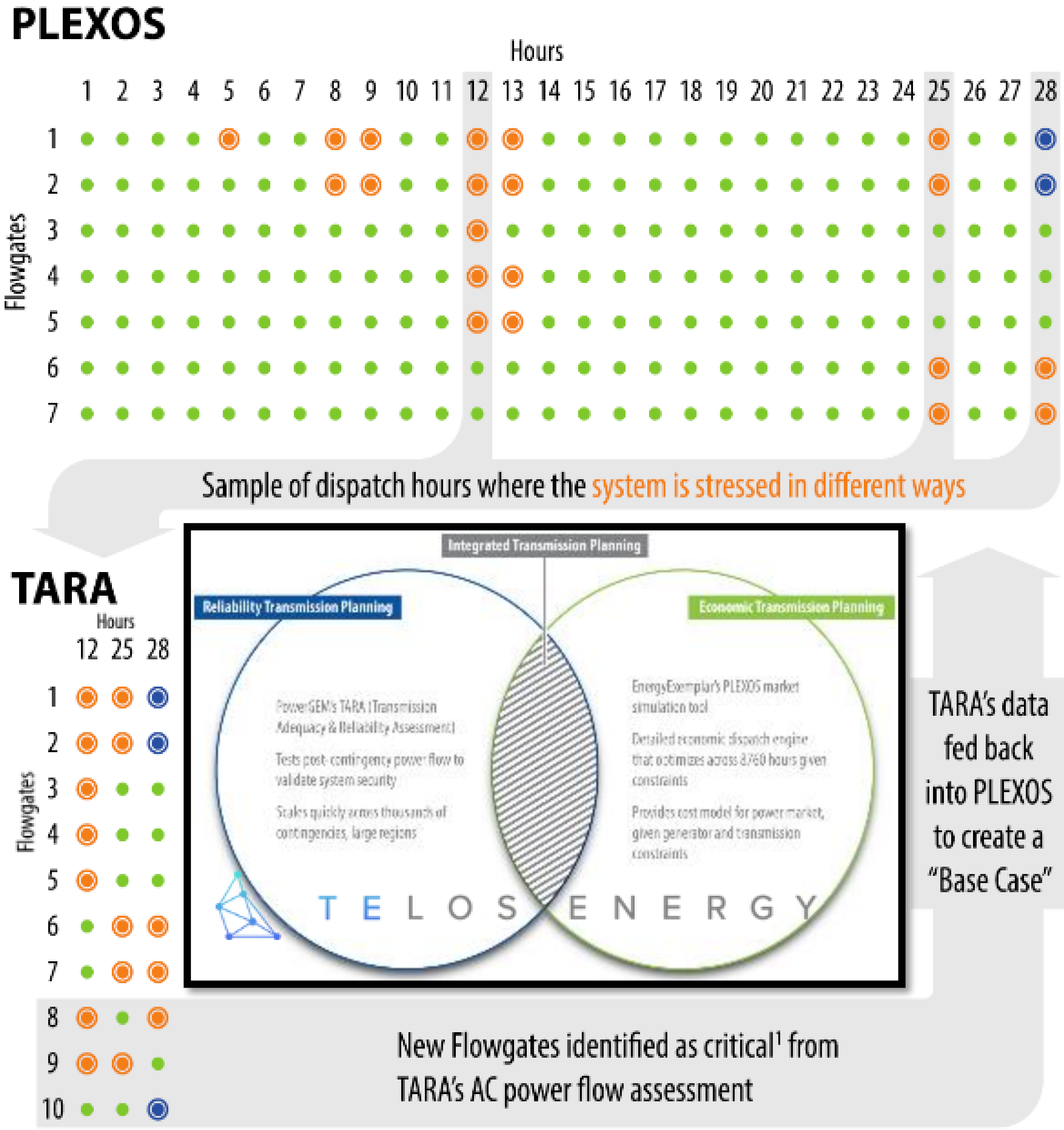
Transmission Line Ranking for PFC Implementation



Mapped PFC Locations

PLEXOS Production Cost Impact of Each PFC Location

PFC Location	Ranking	Congestion Rent Improvement ($M)	Production Cost Improvement ($M)	Total Curtailment Improvement (GWh)
Berry St – Brayton Point	1	10.4	4.3	181.8
Medway – Bellingham	2	8.0	3.1	146.2
Berry St – Bellingham	3	8.7	3.1	143.5



https://cigre-usnc.org/wp-content/uploads/2024/06/Optimized-Power-Flow-Control-Device-Siting-with-Coupled-Production-Cost-AC-Powerflow-Modeling-Presentation1.pdf

Options for Increasing Line Capacity

Change the Methodology

- Adjust Static Rating Parameters
- Apply Other Ratings
  - Seasonal
  - Ambient Adjusted
  - Dynamic Line Ratings (Real-time and Forecasted)

Change the Physical Rating

- Use Clearance Margin (if available)
- Allow Higher Temperature

Fix Clearance Limits

- Remove Obstacle
- Adjust Tension
- Modify Insulators
- Modify Structures
- Inset Structures

Reconductor

- TW Conductor
- Larger Conductor
- HTLS conductors

Increase the Voltage

- Structure/insulator modification

Rebuild the Line

- New conductor
- More circuits
- Larger voltage

Reconductoring with Advanced Conductors

Image Source: Pivotal Role: Reconductoring key to strengthening the transmission system - Power Line Magazine

Just replace the old wires with new ones…

Advantages:

- Simple
- Inexpensive
- Fast
- Low environmental impact
- More capacity (50-150%)
- Better efficiency

Traditional & Advanced Conductors

Traditional


Stranded copper (legacy technology)


All aluminum alloy conductors


Aluminum conductor steel reinforced (most used today)


Twisted pair (used in areas with high wind).

Advanced


ACSS Conductor


ACCR Conductor


ACCC Conductor

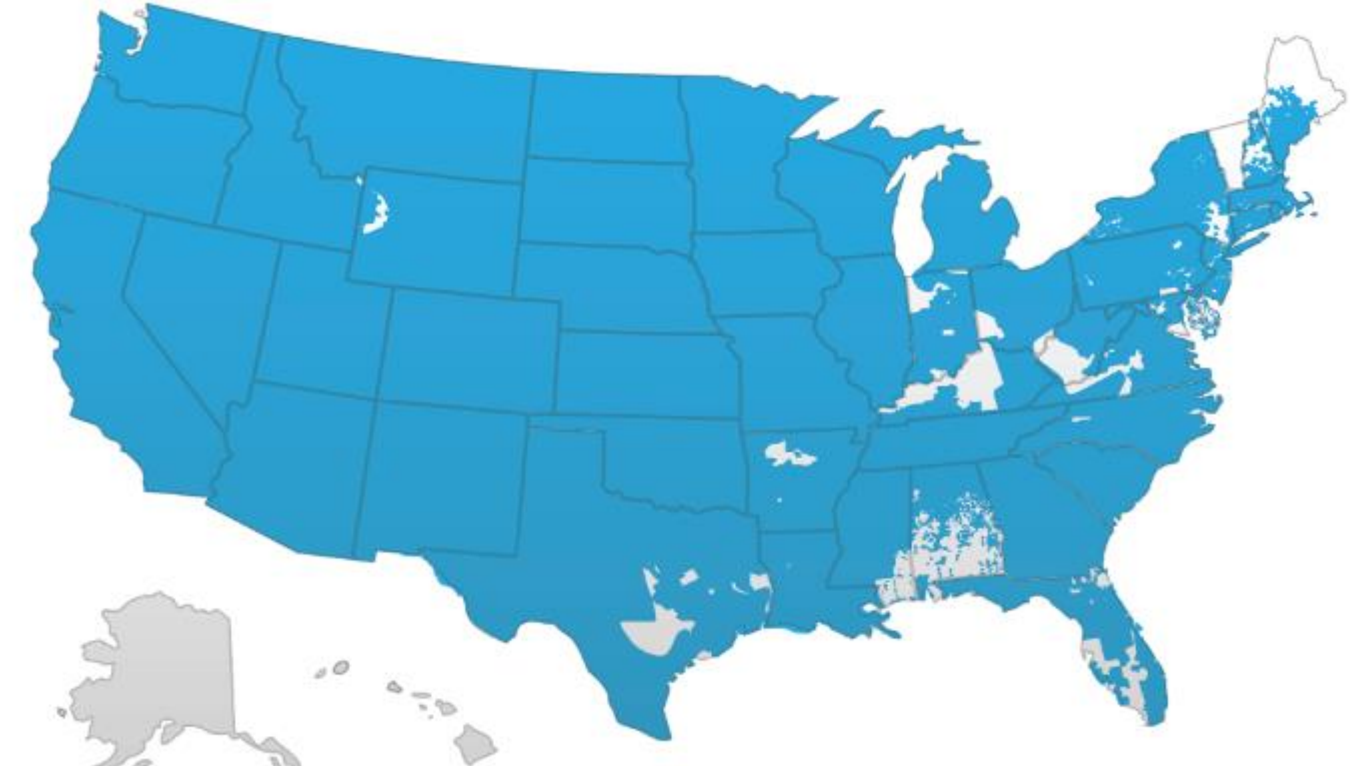

ACCC AZR (left) and ULS-AZR Conductor (right)


TS Conductor


C7 Conductor


E3X coating on ACSS Cable

Advanced Conductor Scan Report

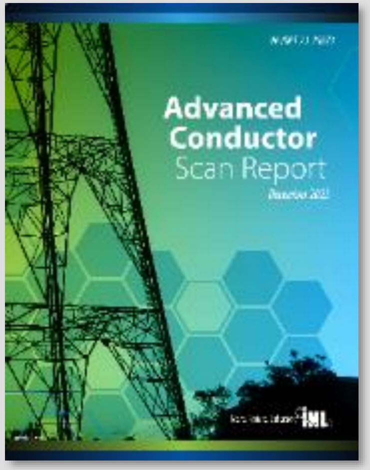


Area of the United States covered by study survey.

44 ELECTRIC TRANSMISSION UTILITIES SURVEYED

Over 70% have deployed advanced conductors

117,510 MILES OF EXISTING TRANSMISSION LINES WOULD BENEFIT FROM RECONDUCTORING WITH ADVANCED CONDUCTORS



https://inl.gov/content/uploads/2024/02/23-50856_R8_-AdvConductorszScan-Report.pdf

A Utility Serving CO, Deploys Advanced Conductor!

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.

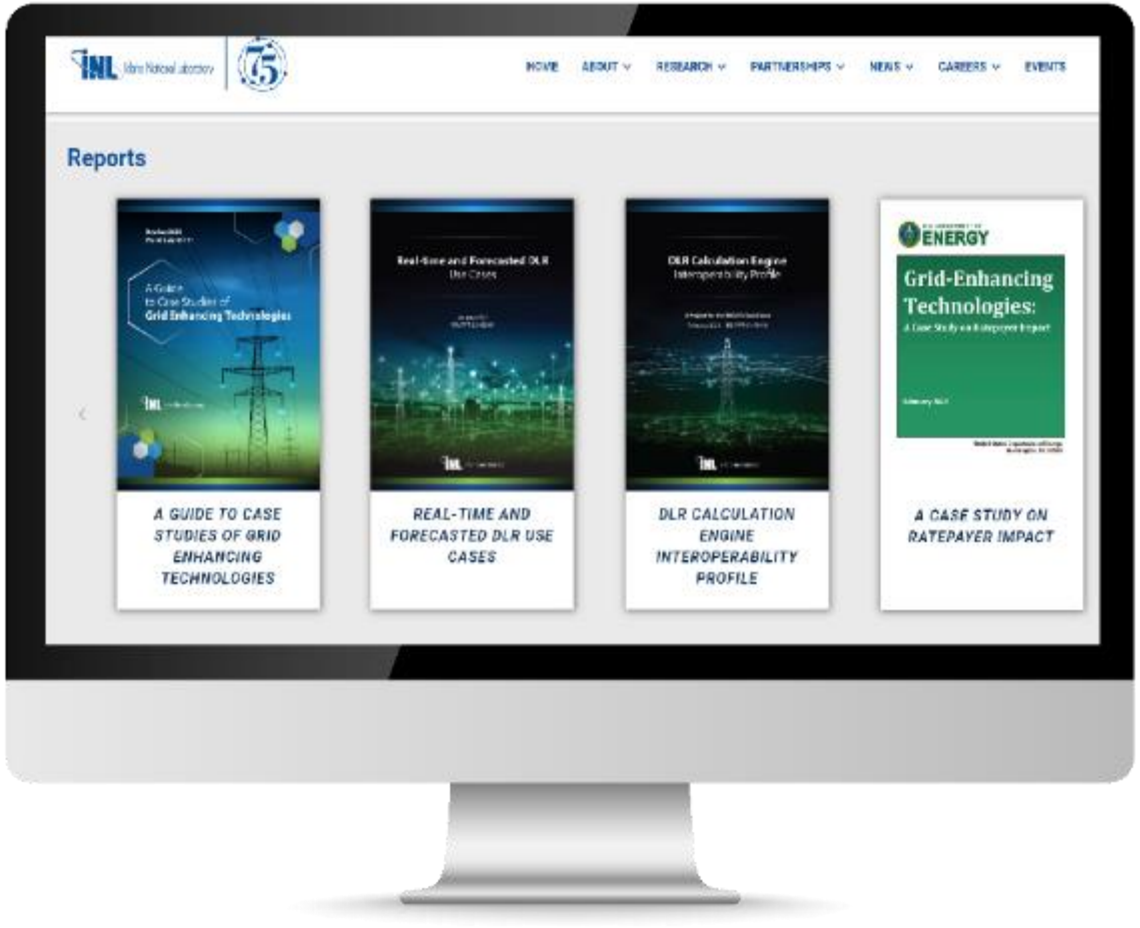
Figure A-109. ACSS conductor.

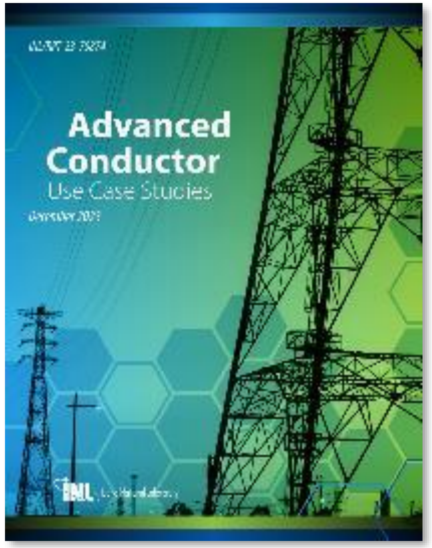
Figure A-110. ACCR conductor.

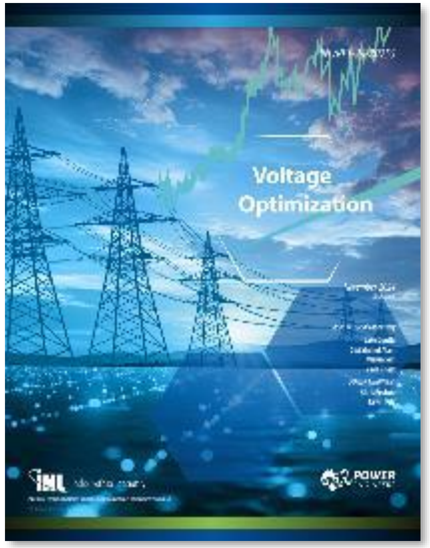
Exemplary Projects

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

Endless amounts of resources and expertise at INL







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