Planning with ATTs and State Law Compliance: Early Developments and Lessons Learned

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Grid Strategies

WATT COALITION

Est. 2017

- Trade association for Grid Enhancing Technologies
  - Dynamic Line Ratings
  - Advanced Power Flow Control
  - Topology Optimization
- Vendors, generators, investors, utilities
- www.watt-transmission.org

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AMP COALITION

Est. 2023

- Trade association for High Performance Conductors
  - Composite-Core
  - Superconductors
- Vendors and suppliers
- www.ampcoalition.org

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What are Advanced Transmission Technologies?

Advanced Transmission Technologies (ATTs) are technologies that can cost-effectively increase the capacity, efficiency, reliability and/or safety of power lines faster than traditional grid infrastructure and at lower cost or with higher net benefits.

There are two types of ATTs…

Grid Enhancing Technologies (GETs)

- Dynamic Line Ratings
- Advanced Power Flow Control
- Topology Optimization

WATT COALITION

High Performance Conductors (HPCs)

- Carbon Core Conductors
- Superconductors

AMP COALITION

New major deployments

Entergy

DLR deployments in Texas, Louisiana and Arkansas in January 2026 (link)

Ameren

DLR pilot announced in late March! (link)

PG&E

APFC deployment unlocks 100MW+ of capacity – fully operational this summer (link)

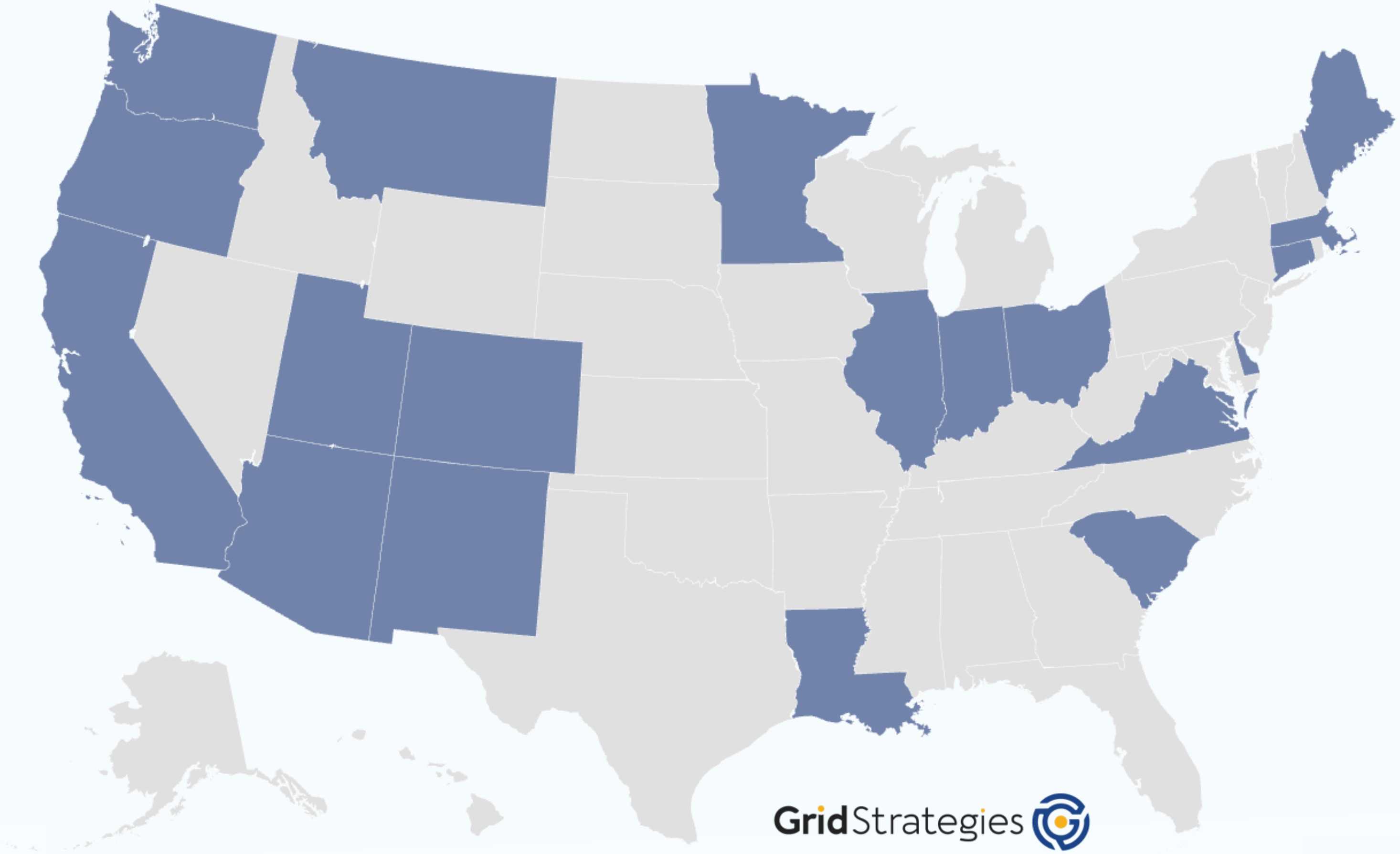
Georgia Power

21 APFC modules across 230kV circuits, and expecting another deployment in 2028, similar scale of results as PG&E (link)

MISO improves grid reconfiguration valuation, and ERCOT and SPP stand up similar processes

MISO improved its estimation of the value of grid reconfigurations, now saying that the benefits from customer-requested topology changes in 2025 were $113 million and in just January and part of February 2026 (link), the benefits were $55.5 million. ERCOT and SPP are setting up similar processes.

19 states have passed ATTs laws as of May 2026



Policy momentum driven by:

- **Affordability:** Transmission congestion and rising power prices for ratepayers
- **Load growth:** Bipartisan interest in "speed-to-power" for data centers and advanced manufacturing
- **Federal mandate:** FERC Order Nos. 881, 2023, 1920, and open rulemaking on DLR

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Three main archetypes of ATTs state legislation emerged in 2025

Type	Sub-categories	Example states, from 2025 bills introduced
1 **Study Requirements** *Outlining opportunities*	Addressing congestion/constraints	CA, IL, IN, MN, NM, OH, OR, TX
	Other benefits (i.e. generator interconnection, wildfire mitigation, etc.)	CA, CO, IN, IL, ME, NM, NY, OR, OH, TX, UT
	Survey of available technologies	CO, IN, ME, OH, TX
2 **Reporting requirements** *Integrating into utility workflows*	Transmission planning	CO, NC, NJ, SC, TX, WA
	Infrastructure siting/permitting	CT, IL, MA, MD, MT, NC, NM, OH, RI, UT, VA, WA
	Integrated Resource Planning	CO, IN, NM, OH, OR, UT, VA, WA
	Grid modernization plans	NJ
3 **Motivating deployment** *Driving speed to action*	Incentives	RI, MA, MT, WA, CO
	Cost recovery	IN, NM, UT, WA

Implementation examples: California and Minnesota

California (SB1006, 2024)

- *Progress:* Utilities submitted ATTs reports required by legislation. These reports identified specific lines that would be prime candidates for ATT deployments.
- *Next steps:* More robust evaluation of all ATTs in a systemwide manner; better integrate with CAISO planning processes and deploy more quickly

Minnesota (HF 5247, 2024)

- *Progress:* Utilities conducted congestion mitigation studies and submitted reports on GETs solutions / implementation plans.
- *Next steps:* Recurring cadence for study, more robust evaluation of all ATTs, and greater transparency of data and modeling practices

California SB 1006: Overview

Requires TOs to study GETs every 2 years and HPCs every four years

The study shall be designed to identify projects using GETs or reconductoring with HPCs that can achieve one or more of the following:

(A) Increase transmission capacity.

(B) Reduce transmission system congestion.

(C) Reduce curtailment of renewable and zero-carbon resources.

(D) Increase reliability.

(E) Reduce the risk of igniting wildfire, by means of investments that are consistent with the transmission utility's approved wildfire mitigation plan.

(F) Increase capacity to connect new renewable energy and zero-carbon resources.

(G) Increase flexibility to reduce risks surrounding technology and permitting uncertainties in statewide electrical system planning and improve optionality for load-serving entities.

California SB 1006: Methodology

Study inputs

Combination of Annual Transmission Reliability Assessment (ATRA), CAISO Transmission Planning Process (TPP) cases (22-23, 24-25, & 25-26), TPP Economic Assessments, address a thermal overload during NERC planning events P0-P7, and historical (6 years) and forecasted (10 years) congestion and curtailment data

Project level screening criteria

The studies continued in the model of individual project feasibility screening, rather than seeking system-wide optimization

- **APFC/TTO:** Excluded radial circuits or circuits that became radial under N-1 contingencies, or lines without additional capacity available on parallel paths to re-route power flows
- **HPCs:** Circuits projected to experience 20–100% thermal overloads by 2035. Lines already operating at circuit breaker limits, containing series capacitors, located underground, classified as aging or deteriorated, or have planned projects.

Limited scope of evaluation

While there was some good progress made above, a majority of the evaluation was still done on a case-by-case basis for solutions that had already been developed

- PG&E: 10 reliability-driven transmission upgrades considered for the current TPP study for TTOs/APFC
- SDGE: 1 project each for TTOs/APFC; 5 projects for reconductoring

California SB 1006: Results and lessons learned

Technology	Southern California Edison	Pacific Gas and Electric Company (PG&E)	SDGE
Transmission Topology Optimization (TTO)	No TTO opportunities were identified	No TTO opportunities were identified	No TTO opportunities were identified
Advanced Power Flow Control (APFC)	No APFC opportunities were identified	No APFC opportunities were identified	Determined one APFC alternative would be feasible, but too costly (no benefits evaluated)
Dynamic Line Rating (DLR)	9 candidates showed at least 15% capacity increase on avg.	Identified 14 lines that are strong candidates	software only DLR
High Performance Conductor (HPC)	Identified 56 candidate projects	Identified 6 lines as high potential for reconductoring	1 of 5 projects selected (may have already been selected prior)

Lessons learned

1. **Reliability and economics should be evaluated together:** *TTO for economic needs; consider LMPs and renewable curtailment*
2. **Whole-system thinking is important because line-by-line screening can miss network benefits:** *TTO and APFC as bridge solutions or modular deployments*
3. **Utilities should screen projects for greatest net-benefits, not just lowest upfront cost:** *Explore how multiple technologies, such as combining DLR, APFC, and advanced conductors, can be deployed together*

Minnesota HF 5247: Overview

Requires utilities to report on system congestion, and where GETs might cost effectively address it

1. An entity that owns more than 750 miles of transmission lines in Minnesota must include in that report information that:
    1. Identifies, during each of the last three years, **locations that experienced 168 hours** or more of congestion, **or the ten locations** at which the **most costly congestion occurred**, whichever measure produces the greater number of locations;
    2. **Estimates the frequency of congestion** at each location and the **increased cost to ratepayers** resulting from the substitution of higher-priced electricity;
    3. Identifies locations on each transmission system that are likely to **experience high levels of congestion during the next five years**;
    4. Evaluates the **technical feasibility and estimates the cost** of installing one or more grid enhancing technologies to address each instance of grid congestion identified in clause, and projects the grid enhancing technology's efficacy in reducing congestion;
    5. Analyzes the **cost-effectiveness of installing grid enhancing technologies** to address each instance of congestion identified in clause (1) by using the information developed in clause (2) to **calculate the payback period** of each installation, using a methodology developed by the commission;
    6. **Proposes an implementation plan, including a schedule and cost estimate**, to install grid enhancing technologies at each congestion point identified in clause (1) at which the payback period is less than or equal to a value determined by the commission, in order to maximize transmission system capacity; and
    7. Explains the transmission owner's current line rating methodology.

2. Commission must review plans **issue an order requiring implementation** of an approved plan and **may approve cost recovery**.

Minnesota HF 5247: Methodology and Results

Eight Minnesota utilities jointly developed the GETs report

Study inputs

Used MISO Day-Ahead reports (2022-2024) to identify **66 constraints** that showed **168 hours or more of congestion** which were then screened into seven categories

Project level screening criteria

Study evaluated whether GETs, traditional upgrades, or combinations of both could cost-effectively address the identified constraints under a payback period of five years established by the Minnesota PUC.

- **RESULTS:** The report identified **12 constraints** where a solution met the required payback period and included associated implementation plans. An additional **seven constraints** were identified for further analysis.

Limited scope of evaluation

Study was not comprehensive in their identification of ATT solutions to the constraints nor implementation plans to solve them, with some technologies like APFC and TTO not fully evaluated or even mentioned as options to address the constraints.

Note State regulators have a critical role in enforcing statutory requirements

What does it mean to "study" ATTs potential? (1/2)

Integrating system topology, power flow, and economics to identify where specific ATTs create value

Start with your goal(s)
Address reliability violations, enable load growth, reduce congestion/curtailment, sequence outages/construction, monitor asset condition, contingency/extreme scenario management

Use a "loading order" approach to problems solving – cheapest, fastest solutions first, to enable long-term solutions
Consider applicability: DLR → thermal constraints, or needing ~10-20% more average/peak capacity, APFC / topology optimization → meshed networks or ~25-100% firm capacity, HPCs → structural capacity needs, 100%+ firm capacity.

For state-mandated or Order 1920 planning studies:

Identify opportunities to solve problems
Use recent historical data as guide to top constraints. Run production cost models for projected load/generation growth and pinpoint high-value deployments.

Quantify economic value
A study must translate engineering into economic decision-making by calculating production cost benefits of ATTs, reduced line losses, and including the value of speed-to-deployment in the analysis (i.e., solving the problem in the near-term vs long-term).

Deliver actionable outcomes
A study should drive decisions, such as identifying priority deployments and recommend next steps.

What does it mean to "study" ATTs potential? (2/2)

Integrating system topology, power flow, and economics to identify where specific ATTs create value

Start with your goal(s)
California: reliability violations and avoided congestion. Maine: avoided congestion/rebuilds. Minnesota: avoided congestion.

Use a "loading order" approach to problems solving – cheapest, fastest solutions first, to enable long-term solutions
Unlocking the Queue: DLR → TTO → APFC. Idaho National Laboratory: DLR + APFC, alone and combined

For state-mandated or Order 1920 planning studies:

Identify opportunities to solve problems
Minnesota: historical and projected congestion. California: reliability violations / thermal overloads, support load growth

Quantify economic value
Maine: 9-1 BCR. Minnesota: 12 cost-effective projects identified. Unlocking the Queue: 6-month payback.

Deliver actionable outcomes
California: recommended further study by ISO, and included APFC in reliability planning.

Thank you!

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Founded in 2017, Grid Strategies works on policy to enable decarbonization and an affordable, reliable electricity system.

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Appendix

Utilities working on ATTs across silos Addressing technology, stakeholders, processes

Portland General Electric (multiple ATTs!)

Southern Company (multiple ATTs!)

PG&E (multiple ATTs)

National Grid (DLR)

Entergy (DLR)

Great River Energy (DLR)

Alliant Energy (TTO)

Central Hudson (APFC)

Southern California Edison (HPCs)

FERC Order 1920 requires transmission providers to develop long-term transmission plans

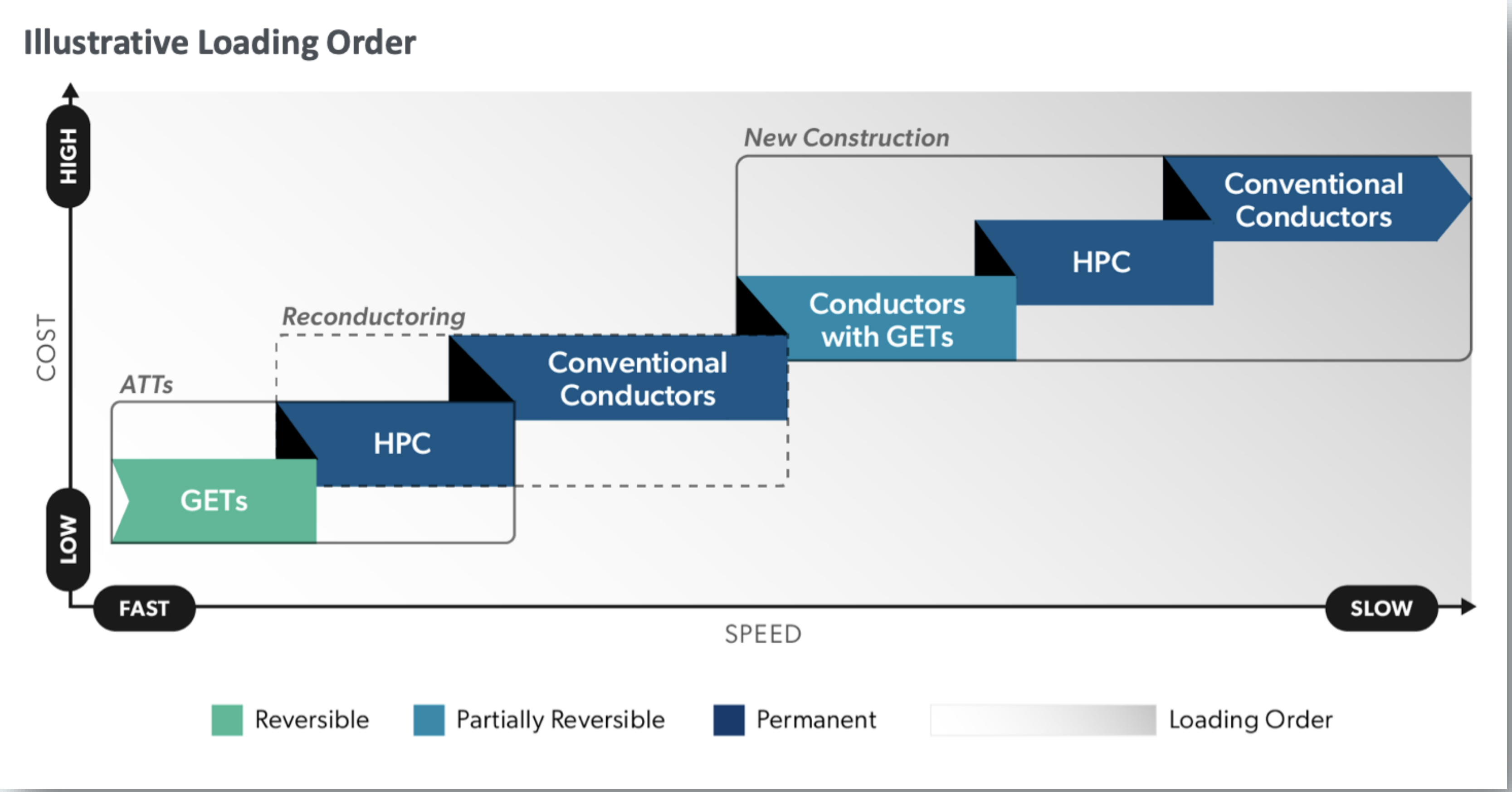
Transmission providers must quantify at least **seven reliability and economic benefits:**

1. Avoided / deferred transmission & aging infrastructure Investments
2. Loss of load probability and reduced planning reserve margins
3. Production cost savings
4. Reduced transmission losses
5. Reduced congestion due to transmission outages
6. Mitigation of extreme weather
7. Capacity cost benefits from reduced peak energy losses

	Technology	*Benefits*						
		1	2	3	4	5	6	7
1: DNV-GL PJM Study	APFC	x		x				
2: DOE Lift-off Report	GETs	x						
3: SCE HPC and Transmission Towers	HPC	x						
4: NY DLR	DLR	x						
5: DOE GETs Report	DLR, APFC	x						
6: 2018 "Bomb Cyclone" and DLR	DLR (AAR)		x				x	
7: SPP Winter Storm Jupiter	TS		x				x	
8: SPP Winter Storm Elliot	TS		x				x	
9: HPC Design and History	HPC						x	
10: Brattle SPP GETs Study	DLR, TS, APFC			x	x			
11: RMI PJM GETs Study	DLR, TS, APFC			x				
12: Transmission Switching Studies	TS			x			x	x
13: GRE DLR	DLR			x				
14: ELIA DLR	DLR			x				
15: Hydro Quebec Conductors Comparison	HPC				x			
16: APFC 2015	APFC					x		
17: EPM and AFC	APFC					x		
18: Transmission Switching Study	TS					x		
19: PJM Winter Storm Elliot	DLR						x	
20: Nevada Energy HPC	HPC						x	
21: Oklahoma Gas and Electric HPC	HPC						x	
22: California Wildfire and HPC	HPC						x	
23: Canada Icing and HPC	HPC						x	
24: Southeastern U.S. and HPC	HPC						x	
25: New York Phase Angle Regulators	APFC, TS							x

Example "Rule of Thumb" approaches to evaluating transmission solutions

- **Size**: Prioritize GETs for transfer increase needs of <20% and HPCs >50% when "right-sizing" opportunities are observed.
- **Timing**: Prioritize GETs for immediate needs
- **Cost thresholds**: Pre-screening cost threshold based on a potential solution's likelihood of producing certain monetizable *Benefits*, by analyzing historical and market data

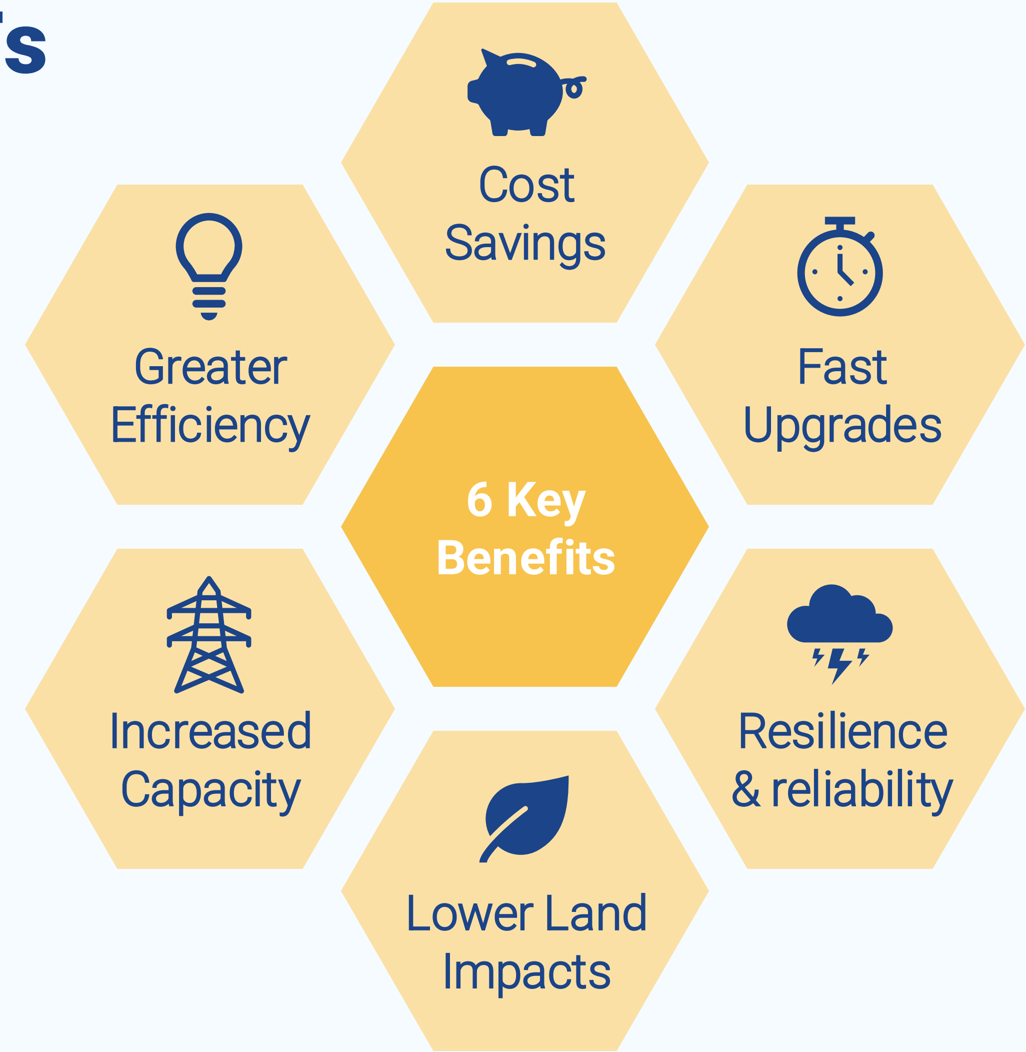


Checklist to confirm with transmission owners

- Train field personnel on installation and maintenance of ATTs
- Build internal modeling expertise for HPCs, DLR, APFC, and TTO
- Train operators on new data streams and operational procedures
- Update EMS systems to accept DLR
- Incorporate GETs in outage mitigation workflow
- Pre-study topology reconfigurations to enable faster restoration after events.

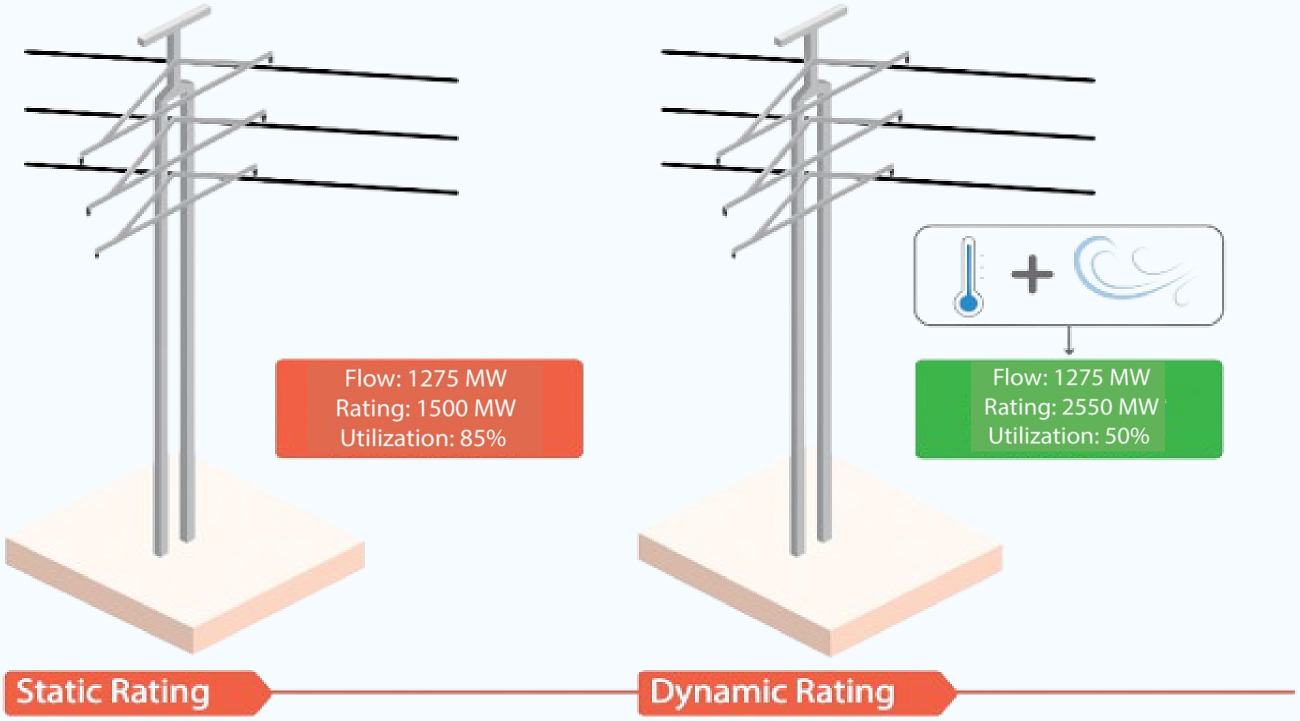
About ATTs

Benefits of ATTs



Dynamic Line Ratings

Hardware or software used to calculate the true capacity of transmission lines using real-time and forecasted weather conditions



Results from 2021 deployments across 3 states

DLR exceeded static reference ratings by 9-33% in winter, and 26-36% in summer

DLR exceeded static ratings over 85% of the time

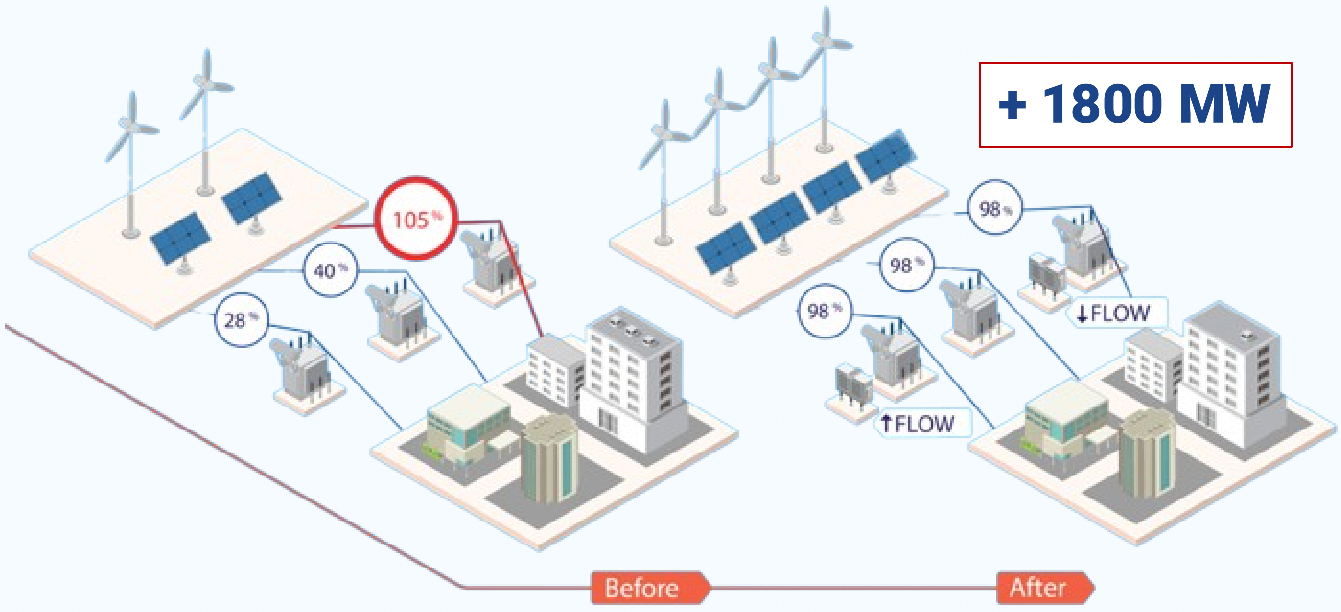
Case study examples

2022 Pennsylvania
Increased line capacity by 25% on average

2012 Belgium
Increased capacity by >20%, 90% of the time.

Advanced Power Flow Control

Hardware and software used to reroute electricity from overloaded transmission lines to underutilized transmission corridors by adjusting circuit impedance



Results from 2024 deployment in New York

APFC unlocked 185 MW of capacity to accommodate new generation

APFC offered advantages over legacy solutions, such as lower cost and smaller footprint

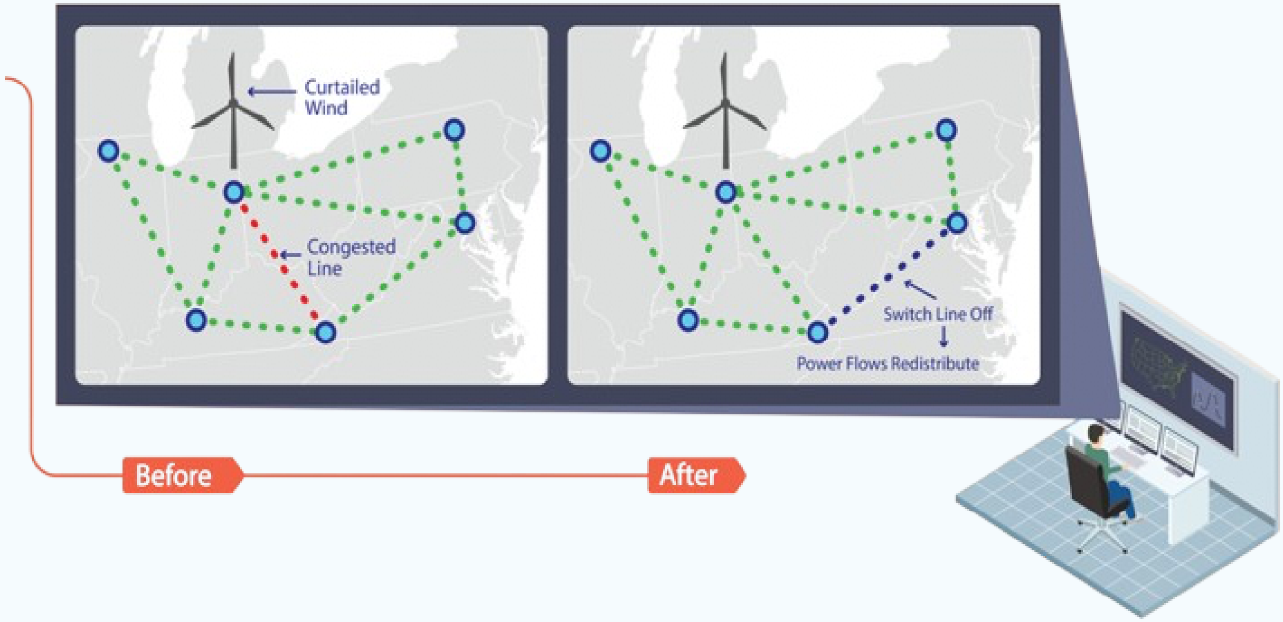
Case study examples

2024 California
Utilities identified reliability applications

2023 Vermont
Increased VT—NY transmission capacity

Transmission Topology Optimization

Technology that identifies reconfigurations of the transmission grid to most efficiently deliver power



Results from 2019 study in PJM

Topology optimization could reduce congestion costs by 50% in PJM, in ex-post study.

Results from 2021 Alliant deployment in MISO

Alliant customers saved 49% in congestion costs ($24 million) over 2 years.

Case study examples

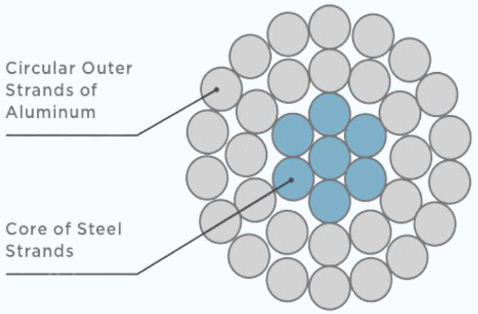
ISO-NE and SPP
Used for outage planning

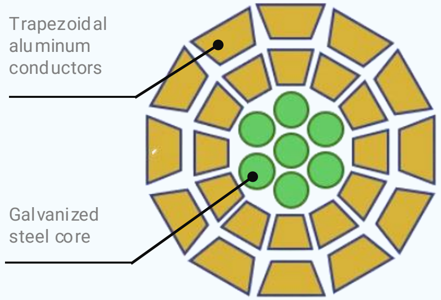
ERCOT and MISO
Allowed reconfigurations for congestion mitigation

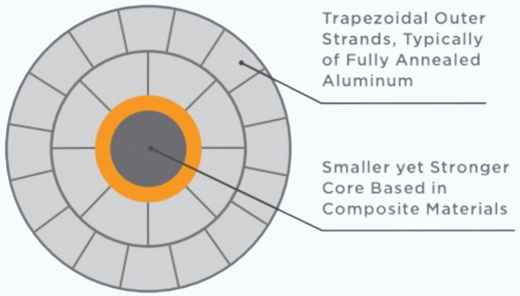
Conductor technology has evolved beyond traditional ACSR/ACSS to “High Performance Conductors” (HPCs)

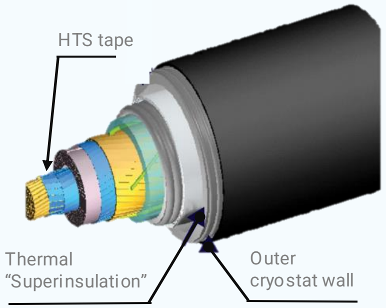
Evolution of conductors

ACSR → **ACSS (RW/TW)** → **HPCs (Carbon/composite core and superconductors)**









	ACSR	ACSS (RW/TW)	HPCs (Carbon/composite core)	HPCs (superconductors)
Additional capacity *(Compared to ACSR)*		0.75-2x	1.5-3x	5-10x
Efficiency gain *(Compared to ACSR)*		2-20%	20-40%	50-80%
Line sag *(Compared to ACSR)*	Thermal sag	Thermal sag	10% thermal sag	No thermal sag

Federal landscape

Federal leaders are pushing for ATTs

I think we need to squeeze every megawatt out of the existing grid that we can. Whether that's Dynamic Line Ratings, whether that's Grid Enhancing Technologies of any types, and I can't endorse one over the other, I think we need to do a better job of being efficient with the grid we already have in addition to building new transmission. So you're going to see more from me in the coming months in that regard.

- *Commissioner LaCerte, Senate Energy and Natural Resources Committee hearing on February 25, 2026 (@ 1 hr 35 min)*

How will utilities like Duke take advantage of cost effective solutions such as Advanced Transmission Technologies to get more juice out of the existing system?

- *Rep. Latta (R-OH), House Energy & Commerce hearing "AI and the Grid: Meeting Growing Power Demand While Protecting Ratepayers" on April 29, 2026 (@ 1 hr 16 min 50 sec)*

What is in the power of the Congress to make sure our existing infrastructure is more efficient? Getting GETs, and getting utilities to uptake reconductoring? We can direct FERC, we can make changes to PURPA, maybe set different incentives. What do you recommend?

- *Rep. Castor (D-FL), House Energy & Commerce hearing "AI and the Grid: Meeting Growing Power Demand While Protecting Ratepayers" on April 29, 2026 (@ 1 hr 19 min 40 sec)*

FERC policies for Advanced Transmission Technologies

Order No. 881

Dec 2021

Line ratings: Mandates that RTOs accept dynamic line ratings, and utilities use Ambient Adjusted Ratings. PJM as submitted compliance. RTOs have asked for extensions.

Order No. 2023

Jul 2023

Generator interconnection: Requires the consideration of APFC and HPCs in generator interconnection processes; TTO and DLR as optional. All RTOs submitted compliance filings in May 2024.

Order No. 1920

May 2024

Transmission planning: Requires APFC, DLR, HPCs and transmission switching to be studied in regional plans and deployed if it would make transmission assets more cost effective; also includes a “right-sizing” requirement.

DLR ANOPR

Jun 2024

DLR Ruling: Proposes requirements that transmission owners must deploy dynamic line ratings on highly constrained lines.

Broader federal landscape for ATTs

U.S. Congress

.**Six (6) ATTs bills currently introduced,** including bills for ATTs incentives, requirements, permitting, and studies

Department of Energy

Speed to **P**ower through **A**ccelerated **R**econductoring and **K**ey Grid Upgrades ("SPARK" Funding) has approx. $3B to award to utilities and states to deploy ATTs

White House

AI Action Plan from Jun. 2025 had three pillars, including "optimize the grid"

White House memo determines HPCs as critical for national defense under the Defense Production Act

7 bills introduced in Congress in 2026

Democrat | Republican | Bipartisan

	Bill	Category: Study	IRP / planning	Siting / CPCN	Cost recovery	Mandate	Sponsorship
GETs	Advancing GETs Act				✓		Sen. King, Rep. Castor
HPCs	High Capacity Grid Act					✓	Rep. Fedorchak
	SPEED Act			✓			Rep. Westerman
Both GETs and HPCs	Electric Supply Chain Act	✓					Rep. Latta
	SURGE Act				✓		Rep. Casten
	REWIRE Act	✓		✓	✓		Sens. Welch, McCormick
	ATTs to Reduce Rates Act		✓	✓			N/A

States can apply for $1.9 billion in federal funding for ATT deployment through the SPARK program

There are three funding topic areas…

1. Topic Area 1: Grid Resilience
2. Topic Area 2: Smart Grid (states can apply)
3. Topic Area 3: Grid Innovation Program (2 or more states can apply)

…for which DOE is prioritizing projects that…

1. Reconductor with advanced conductors;
2. Use ATTs that can increase the usable capacity of existing assets in real time; and
3. Involve large-scale, cross-regional transmission upgrades and coordinated planning.

Timelines are fast! If you submitted a concept paper in April, your full application is due May 20, 2026.

Please reach out if you would like to be connected with application partners and / or technical assistance opportunities.

Regional updates

All regions are seeing progress, but piecemeal

ISO/RTO	ISO-NE	Uses TTO software to support their transmission outage coordination process; Is adding a position to evaluate ATTs for asset condition projects
	MISO	Allows grid users to propose TTO reconfigurations
	PJM	Accepts DLR into both real-time and day-ahead market operations
	SPP	Will allow grid users to propose TTO reconfigurations
	ERCOT	Will allow grid users to propose TTO reconfigurations
	CAISO	Calls out ATTs in transmission plan, with utilities each doing studies per 2024 legislation
Non - ISO/RTO	Southwest	Limited HPC adoption
	Northwest	PSE, BPA, PGE beginning DLR deployments; PacifiCorp and NV Energy deploying HPCs
	Southeast	Southern Company has APFC, DLR and HPC projects announced; originates GETs projects from planning, real-time operations, and maintenance teams. Duke proposing DLR pilot.