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March 2, 2026  
Via E-Filing

Ms. Sasha Bergman  
Executive Secretary  
Minnesota Public Utilities Commission  
121 7th Place E, Suite 350  
St. Paul, MN 55101

**In the Matter of the 2025 Minnesota Biennial Transmission Projects Report  
RE: Grid Enhancing Technologies Report**

**PUC Docket Number: E999/M-25-99**

**I. Introduction**

The Working for Advanced Transmission Technologies (“WATT”) Coalition appreciates the opportunity to provide comments to the Minnesota Public Utilities Commission (“PUC” or “Commission”) on the 2025 Grid Enhancing Technologies Report (“GETs Report”) contained within the 2025 Biennial Transmission Projects Report. These comments address the following questions identified in the Commission’s Notice of Comment issued on November 12, 2025:

- a. *Should the Commission approve, reject, or modify Minnesota Transmission Owners’ GETs implementation plans?*
- b. *For future GETs Reports: should the Commission add or modify the filing requirements?*

WATT reviewed the GETs Report under a nondisclosure agreement, because it was filed as a trade secret document. Our intention is to provide general comments that point to specific opportunities. If the PUC requires future GETs reports, we encourage them to require more of the analysis to be publicly available, where possible.

## **II. About the WATT Coalition and Grid Enhancing Technologies (GETs)**

The WATT Coalition advocates for policy that supports the wide deployment of Grid Enhancing Technologies (GETs) to accelerate lower energy costs and enable economic growth. GETs are hardware and/or software that increase the capacity, efficiency, and maintain the reliability of the electric grid. Dynamic Line Ratings (DLR) measure and calculate the true carrying capacity of transmission lines – often finding 20% or more capacity than assumed. Advanced Power Flow Control (APFC) redirects power to lines with extra capacity, preventing overloads and balancing the use of the grid. Transmission Topology Optimization (TTO) is software that finds the best use of grid infrastructure to redistribute power and unlock more capacity. WATT’s membership includes DLR, APFC, and TTO vendors, as well as independent power producers, investors, and utilities. Learn more at [watt-transmission.org](http://watt-transmission.org).

## ***III. Should the Commission Approve, Reject, or Modify Minnesota Transmission Owners’ GETs Implementation Plans?***

### **a. GETs Report Structure and Requirements**

The WATT Coalition supports the MTO’s approach to submit a single joint GETs Report. In other jurisdictions, GETs deployments have not been feasible because neighboring transmission owners would not agree to use DLR, for instance. By studying constraints in the state holistically, the MTO are more likely to be able to scope solutions that fully address grid congestion.

The requirements of the study appear reasonable. The 168-hour congestion threshold found 66 qualifying constraints, with 12 of them meeting the payback threshold and 7 others requiring further analysis. This indicates that the criteria efficiently identified a number of cost-effective GETs deployments. 17 of the constraints that met the hours threshold were based on temporary outages or operating conditions. This indicates that using GETs in the operational planning timeframe may unlock ratepayer savings, which is also useful information for stakeholders and regulators.

The disclosure of line rating methodologies was illuminating, though incomplete. We note that the variation in effective wind speed assumptions and seasonal rating methods across transmission owners is a sign that differences in line ratings on the same conductor could be causing congestion at seams between transmission owners. Conductor emissivity and absorptivity assumptions were not reported, though those are key inputs in the IEEE standard 738-2023 that sets line rating methodologies. The assumptions for line emissivity can also vary widely across transmission owners and affect line capacity. In addition, line emissivity changes significantly over the course of the conductor's life, doubling or tripling as the conductor ages.<sup>1</sup> Factors like this are why sensor-informed full DLR is the only way to get an accurate picture of line capacity.

#### **b. Inconsistency in Identifying Cost-Effective Implementation Plans**

WATT finds that while the MTO did identify constraints that could be resolved by GETs, they did not consistently investigate solutions to the constraints nor develop sufficient implementation plans to solve them.

Minnesota Session Laws, 2024, Chapter 127, Article 42, Section 52, Subdivision 2 requires that the MTO include in their report information that “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.” When the MTO did identify a specific GETs solution with a payback period, it was exclusively a DLR (which includes wind speed) or Ambient Adjusted Rating (AAR) (usually based on only temperature and solar irradiance) solution. The GETs Report notes that some Minnesota transmission owners are still evaluating DLR vendors and setting up their DLR capabilities. The customer value identified in this report should encourage transmission owners to be prepared to deploy DLR on any lines that experience significant congestion. Many of the constraints are driven by outages, and by deploying DLR quickly in response to changes in grid topology, the MTO could avoid significant congestion.

While APFC was mentioned as a potential solution for several constraints, the MTO stated that additional analysis would have to be done to confirm the solution and its cost-effectiveness. As WATT noted in our completeness comments, this analysis would have been part of a true modeling effort to evaluate a potential APFC deployment. Per the

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<sup>1</sup> See page 38 of “IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors,” IEEE Std 738™-2023

report, TTO was not considered to solve any of the constraints. However, there are constraints listed in the report for which TTO reconfigurations have either been implemented or approved by MISO for future use. Absent the reconfigurations that have been implemented, the congestion costs cited in this report would have been significantly higher.

The decision not to study congestion on binding interfaces also leaves value on the table. GETs can address stability constraints, and TTO and APFC are ideal for managing constraints that include multiple elements. Candidate reconfigurations were submitted to a Minnesota transmission owner in 2024 to mitigate congestion on one of the listed interfaces; these have not been analyzed to date. There are both tools available for the MTO to efficiently evaluate all commercially available GETs solutions to address constraints and consulting firms with expertise in doing so.

Similarly, Minnesota Session Laws, 2024, Chapter 127, Article 42, Section 52, Subdivision 2 requires that the MTO include in their report information that “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.” This was inconsistently performed, with timelines and cost estimates for potential DLR deployments but not for potential APFC deployments.

The WATT Coalition concludes that the 2025 GETs Report is incomplete. The Commission could either

- 1) reject the GETs Report until further revisions are made, showing a sufficiently thorough analysis of all GETs solutions and implementation plans commensurate with the scope and intent of the law
- 2) OR accept the 2025 GETs Report and require a recurring GETs Report alongside the Biennial Transmission Projects Report going forward.

We recommend the second option. The 2025 GETs Report could be accepted as an interim step, with the clear expectation that the next Report will fully study all GETs and that all transmission owners will be prepared to deploy DLR. Transmission owners will be able to iteratively build on lessons learned and develop increasingly stronger implementation plans to address congestion constraints that are increasing costs for ratepayers. The WATT Coalition expects new tools for studying APFC to be released this summer, which should help the MTO complete future studies more easily.

#### ***IV. For Future GETs Reports: Should the Commission Add or Modify the Filing Requirements?***

If the Commission requires further GETs Reports, it could include a requirement to study GETs for modeled congestion, congestion driven by planned outages, and reduced impacts of grid construction. Cost-effectiveness studies and implementation plans were not developed for the eight constraints that only met the 168-hour threshold in forward-looking modeling. We are not sure if these overlap with the likely constraints that MISO identified in 2024 in its Near-Term Congestion Study Report,<sup>2</sup> where MISO looked at how likely construction outages would create grid congestion. The MISO report included a call for stakeholders to propose GETs solutions to reduce the impact of those construction outages. The MTO should look to mitigate projected congestion based on the GETs Report and the MISO report, at the very least. GETs can cost-effectively avoid congestion while new lines are planned and built and can be redeployed if they are no longer cost-effective on a certain line. There are frequently siting or construction delays associated with large-scale infrastructure, and putting GETs in place to reduce the impact of those potential delays protects consumers and grid users.

##### **a. How to Calculate the Payback Period**

Since many of the projects that met the payback period threshold in this Report were driven by outages, the WATT Coalition found it difficult to understand how long the constraint was expected to continue. Future GETs Reports could include more interventions that MTO made throughout the year to address such outages (including the expected payback period), so that proactive response to constraints can be recognized. Several projects noted that DLR was already deployed, which was encouraging.

It will be easier to know whether the payback period threshold is reasonable once all GETs solutions are evaluated. Considering congestion benefits alone may exclude some solutions that protect other, more expensive equipment, or that avoid larger upgrades. For the next GETs Report, we believe that five years remains a reasonable payback period for addressing grid congestion, though it will be important for forward-looking models to include planned grid construction and outages to fully capture the benefits of GETs. Once GETs are deployed as a matter of course in addressing grid constraints, we expect that

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<sup>2</sup> MISO, *2024 Near-Term Congestion Study Report* (Oct. 10, 2024), <https://cdn.misoenergy.org/MTEP24%20Near-Term%20Congestion%20Study%20Report657728.pdf>

transmission owners will find multiple continuing benefits through better asset awareness and operational flexibility, even after construction is finished or outages are resolved.

#### **b. Accounting for Financial Transmission Rights (FTR) Revenues**

The WATT Coalition urges the Commission not to include accounting for Financial Transmission Rights (FTR) revenues in future GETs Reports. As this Report demonstrates, FTRs are an imperfect hedge against congestion. Regardless of how the transmission owner hedges, the congestion still represents system inefficiency and limits. System inefficiency should be addressed, so that as much of the grid and generation is available to grid users as possible. Allowing constraints to continue because the transmission owner has hedged against them could even create a perverse incentive structure to maintain the constraint.

Congestion costs represent problems that should be solved: insufficient infrastructure to deliver low-cost power. Netting FTR revenues obscures the true magnitude of the inefficiency from regulators, ratepayers, and the public. Congestion costs identify grid constraints, and those constraints can have reliability implications if operators need more transfer capacity in outage scenarios or extreme weather. Netting FTR revenues from congestion costs is like subtracting the amount covered by insurance from the cost of a surgery to suggest that because the cost to the customer was low, the injury was small.

More fundamentally, FTRs are financial hedging instruments, not grid assets or operational solutions. Their purpose is to allocate congestion rent among market participants, not to remedy the underlying constraint. Allowing transmission owners to net this revenue conflates the financial layer of the electricity market with the physical layer, and in doing so, encourages inaction. If being financially whole through an FTR portfolio means that a transmission owner should not pursue transmission upgrades, pursue rerouting solutions, or advocate for interconnection improvements that would relieve the bottleneck, customers will not get an efficient system at the end of the day. Netting FTR revenues distorts the signal from congestion costs for where the grid is underperforming, allowing actual constraints that could be resolved to continue.

#### **c. New or Emerging GETs Technologies**

DLR, APFC, and TTO are commercially available and have been for many years. Examples of worldwide GETs deployments and their positive impacts are appended to these comments. We recommend that future GETs Reports focus on these three technologies as

low-hanging fruit until they are part of everyday utility processes. Given that the MTO did not study two out of the three technologies, WATT believes the MTO should develop effective methods to identify technical feasibility and calculate cost-effectiveness for all three before adding additional categories for study.

## **V. Conclusion**

The WATT Coalition appreciates the opportunity to comment on the 2025 GETs Report. We look forward to engaging in a productive and collaborative dialogue with the Commission and stakeholders on cost-effective GETs solutions in future supplemental comments.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Julia Selker", is positioned above a vertical line that separates the signature from the typed name below.

Julia Selker

Executive Director

WATT Coalition

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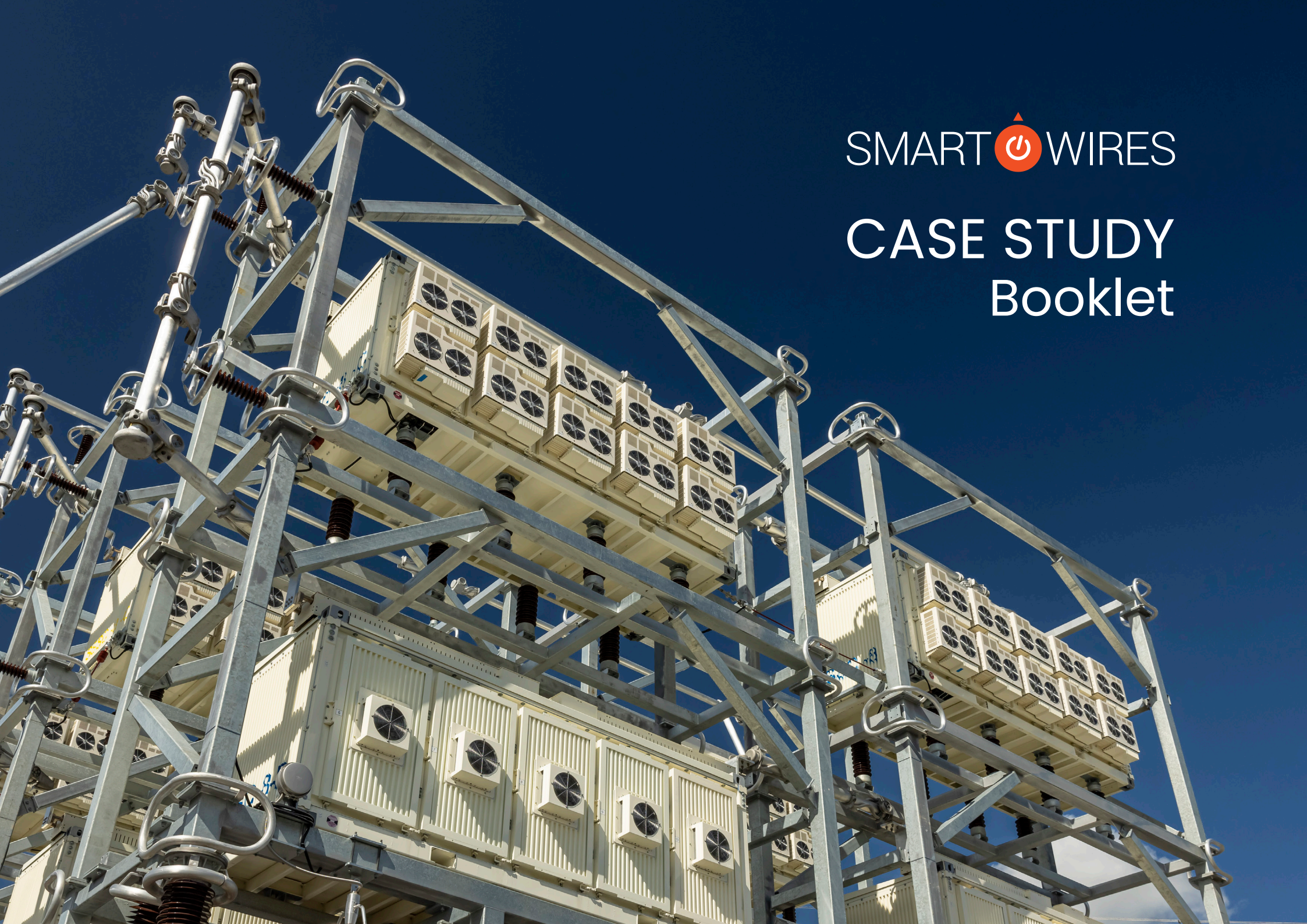
## APPENDIX A

### **Sample DLR Deployments Showcasing Value and Commercial Readiness**

- [PPL Electric Utilities](#) deployed DLR for less than \$1 million, compared to \$20 million for reconductoring, and \$40 to \$60 million for rebuilding transmission. DLR would also be operational in less than 1 year with no outages, compared to 2 to 3 years with extended outages for reconductoring, and 3 to 5 years with extended outages for rebuilding transmission. The deployment saves \$20-\$60 million in congestion costs yearly, and the extra capacity from DLR was [noted for avoiding redispatch during Winter Storm Elliot by PJM](#). Also in Pennsylvania, [Duquesne Light Company found an average of 25% more capacity](#) across monitored transmission lines.
- AES partnered with DLR vendor LineVision to [install 42 DLR sensors across 5 critical lines in Ohio and Indiana](#), ranging from 69 to 345kV, to study how the technology could optimize carrying capacity. DLR demonstrated a 43% average capacity increase across the 5 lines, at a cost of 7.6% what the cost to reductor the lines would have been. The deployment avoided 2.5 months of grid outages and demonstrated to AES that DLR could be used as an effective alternative to costly system upgrades, while helping integrate large commercial customers and new generation.
- AEP installed real-time line ratings on a congested 138 kV transmission line to [avoid a \\$20 million upgrade](#) that would have quickly become a stranded asset as new lines were built to serve increased wind generation.
- Puget Sound Energy recently [deployed Heimdall Power DLR on 100 miles of transmission lines in five counties in western Washington](#). This is the largest deployment of DLR sensors in the U.S. to date, supporting growing regional demand. Another recent deployment by Heimdall Power with [Entergy installed 31 sensors across three states over just 10 days](#).
- Supported by a U.S. Department of Energy grant, Xcel's Minnesota, Wisconsin, and Colorado territory demonstrated that [DLR increased available transmission capacity 85% of the time](#) compared to static line ratings. DLR exceeded static reference ratings by 9-33% in winter months and 26-36% in summer months at the monitored sites.
- A DLR project in upstate New York will [avoid the need to rebuild 26 miles of transmission lines](#). With an estimated cost of \$3.2 million, the project budget is less than the average cost of rebuilding just a single mile of a 115 kV line in the area.

## **APPENDIX B**

### ***Sample APFC Deployments Showcasing Value and Commercial Readiness***



SMART  WIRES

CASE STUDY  
Booklet

## Central Hudson – USA



### Project overview

New York aims to achieve 70% of its electricity from renewable sources by 2030. Each year, the NYISO conducts a study to assess proposed generation projects interconnecting with the state's grid. In 2011, the study revealed a need to increase the firm transfer capacity of the UPNY-SENY interface in Central Hudson's territory by 185 MW. Central Hudson considered various network options, including the use of a Fixed Series Capacitor (FSC). Following a detailed evaluation, modular Static Synchronous Series Compensators (M-SSSCs)—SmartValve™—were selected as the preferred network option for controlling power flows on the Leeds-Hurley Avenue circuit to unlock 185 MW of transmission capacity. The SmartValve deployment offered advantages such as reduced substation work, lower overall project cost, a smaller footprint, and lower risk of sub-synchronous resonance. Additionally, as SmartValves are modular, Central Hudson can easily expand or relocate the deployment as system needs change over time, eliminating the risk of stranded assets.



Unlocks  
185 MW of  
firm capacity



Saved \$10 M  
on project  
costs



Minimal  
substation  
space used



Eliminates  
the risk of  
stranded assets



**PG&E – USA**



### Project overview

Facing a projected 700 MW data-center-driven load increase in San Jose and with a new transmission line not due until 2032, CAISO and the regional utility needed a faster solution to maintain reliability by 2025. After evaluating reconductoring and energy storage, SmartValve was selected as the most effective and timely option. SmartValve will redirect power from a limiting 115 kV facility to underutilized lines, reducing thermal overloads by up to 34% during peak scenarios and enabling to the data center. This solution fits within the existing substation footprint and is designed for rapid deployment, future expansion, or relocation as system needs evolve.



Enables 100+ MW firm power



Reduces thermal overloads by up to 34%



Deployed in under 12 months



Cost-effective vs. storage or reconductoring

# Georgia Power – USA



## Project overview

Georgia Power needed a fast and cost-effective solution to relieve constraints on two 230 kV circuits forecasted to overload from 2025. Traditional options, such as line rebuilds and new reactors, faced high costs and long lead times. After evaluating alternatives, Georgia Power selected SmartValve for its modularity, speed, and dynamic control. The deployment includes 21 SmartValves operating in various control modes to shift power flows and reduce thermal loading. Fully integrated with the EMS and operational systems, the project marks the utility's first full-scale use of advanced power flow control and supports broader long-term grid planning efforts.



Delivers constraints relief by 2025



Reduces costs vs. traditional infrastructure



Bridges gap with new transmission circuits being built



Eliminates the risk of stranded assets



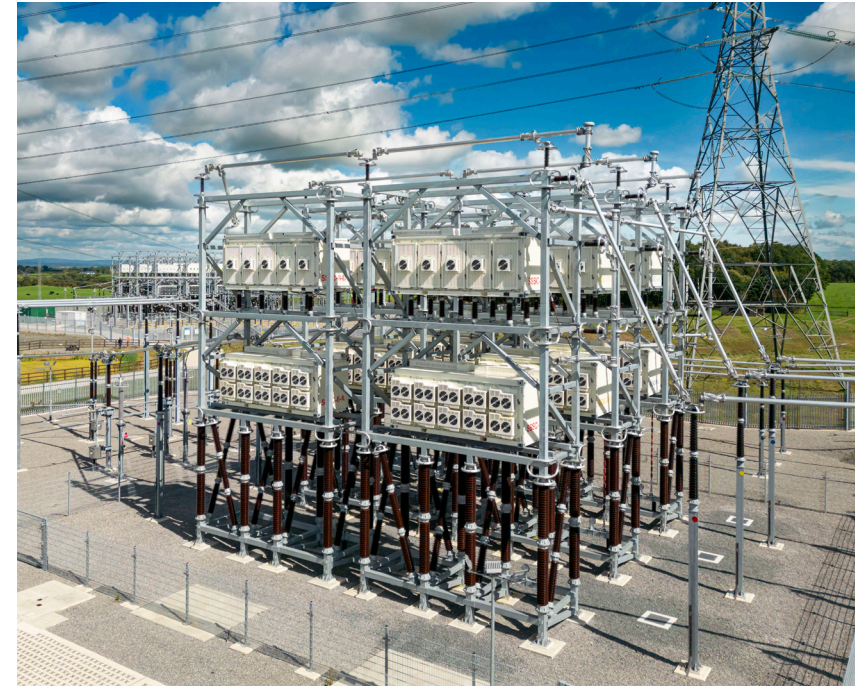


## Project overview

The UK has seen significant growth in renewable energy in recent years, which has led to rising levels of network congestion in England as power flows towards large demand centers in the south. National Grid Electricity Transmission (NGET) needed a solution that could quickly and cost-effectively resolve bottlenecks on key boundaries. After extensive analysis under the UK's Network Options Assessment (NOA) process, advanced power flow control (APFC) was recommended as the optimal solution to resolve the identified network congestion across three key boundaries, B6, B7, and B7a in 2020/2021. Alternative options evaluated included other power flow control solutions such as phase-shifting transformers and network reinforcements such as reconductoring of overhead lines and transformer replacements.

The first set of projects used APFC—SmartValve™—at three substations to balance power flows across five circuits, unlocking over 2 GW of firm transfer capacity for renewable energy and providing a quickly deployable, flexible, scalable solution that could be easily expanded as the network needs evolve over time.

**Video:** <https://youtu.be/ECT8T2A4F04>



Unlocks over 2 GW of firm capacity across multiple boundaries



Delivers £400 million savings for UK consumers over a 7 year period



Minimizes disruption to local communities and the environment



Provides operational flexibility



## Transgrid – Australia



### Project overview

Australia's electricity grid is undergoing a once-in-a-lifetime revolution as coal-fired generation retires earlier than anticipated and the shift to renewables continues to gather pace. In 2020, the Australian Energy Market Operator (AEMO) and Transgrid initiated a Regulatory Investment Test for Transmission (RIT-T) to identify a solution to increase transfer capability between Victoria and New South Wales. Smart Wires' advanced power flow control technology—SmartValve™—was selected as the preferred option due to its net economic benefits, short timeframe to recover project costs, and minimal environment impact compared with alternatives. In 2022, Transgrid deployed 15 SmartValves across two 330 kV circuits, unlocking 170 MW of firm capacity to support renewable integration and greater power flows between the states.

**Video:** <https://youtu.be/2jjxtUQluyQ>



Unlocks  
170 MW of  
firm capacity



Delivers  
AUD \$268  
savings



Improved  
security  
of supply



Boost to  
local  
employment



## ISA Atlantico – Colombia



### Project overview

With 1.5 GW of wind and solar generation already approved to connect, the Atlántico region in northern Colombia is set to experience a substantial increase in renewable injections over the coming years. The additional generation is forecast to cause overloads on multiple transmission circuits in the area, especially under N-1 or contingency scenarios. After evaluating multiple network options to resolve this need, the national planning agency UPME selected ISA TRANSELCA's proposal to deploy SmartValve™, a modular Static Synchronous Series Compensator (M-SSSC) as the optimal solution. The project involved installing 21 SmartValves across five 220 kV circuits in 2024, unlocking more than 300 MW of firm capacity and enhancing the network's ability to accommodate additional renewable generation.



Unlocks  
300 MW of  
firm capacity



Strengthens  
reliability of  
energy supply



Provides benefits  
faster than  
alternatives



Optimizes the use  
of substation  
space

## ENLAZA GEB – Colombia



### Project overview

The Termocandelaria generation plant was scheduled for expansion in 2022 to meet increasing electricity demand in northern Colombia. However, studies showed that under an N-1 contingency of nearby 220 kV circuits, congestion would limit output of the generation plant. Enlaza – GEB, the Group's electric power transmission subsidiary, considered multiple options to resolve this congestion before selecting to deploy SmartValves across two 220 kV circuits to control power flows. This solution could be installed much faster than reconductoring, avoiding curtailment at the Termocandelaria plant and providing 252 MW of firm capacity, with minimal impact on local communities in the surrounding urban area.

**Video:** [https://youtu.be/b0i0qwEGt\\_Y](https://youtu.be/b0i0qwEGt_Y)



Enables additional  
252 MW  
of generation



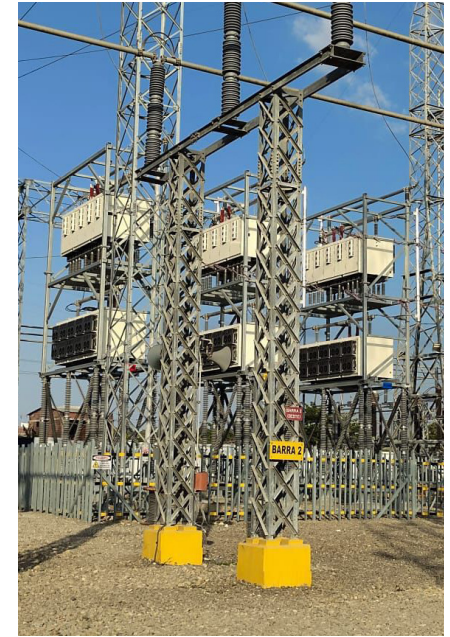
Improves  
security of  
supply



Provides flexible  
scalable  
solution



Optimizes the use  
of substation  
space





## EPM Aburra Valley – Colombia



### Project overview

Delays in the construction of critical transmission infrastructure in Colombia are putting pressure on the grid, causing bottlenecks and increasing the risk of load shedding. In the Aburrá Valley region, transmission owner EPM identified high grid congestion on three transmission lines that would limit the output of distributed hydro in future years. EPM evaluated several network options to address this congestion, including reconductoring the transmission corridor with high-temperature low sag (HTLS) conductors, before determining that the use of modular Static Synchronous Series Compensators (M-SSSCs) at two substations would be the optimal solution. This deployment of m-SSSCs—SmartValves—quickly and cost-effectively unlocked 400 MW of capacity to support increased output of distributed hydro and solar generation, without disrupting local communities and the environment.

**Video:** <https://youtu.be/HINRP8p-MEs>



Unlocks  
400 MW of  
firm capacity



Delivers cost  
savings and  
lower tariffs



SmartValve,  
flexible scalable  
solution



Eliminates  
the risk of  
stranded assets



## ISA Transelca Co-Cost Project



### Project overview

The Guajira – Cesar – Magdalena (GCM) region in northern Colombia is expected to see a significant increase in renewable energy generation in the coming years, putting strain on the existing transmission grid. In 2021, the national planning agency, UPME, identified a need to address grid congestion on 220 kV circuits to support the reliable connection of renewables, and SmartValve was selected as the preferred technology. ISA TRANSELCA deployed SmartValves across two circuits to push power off overloaded lines under N-1 conditions, unlocking 300 MW of firm capacity for renewable energy resources to be reliably connected to the grid from 2023. Alternative network options that were evaluated by UPME for this project were more costly, took longer to install, disruptive to communities and lacked the flexibility to be adapted quickly over time to meet changing grid needs.

**Video:** [https://youtu.be/ll\\_n0OfpliE](https://youtu.be/ll_n0OfpliE)



Unlocks 200 MW of firm capacity



Delivers cost savings and lower tariffs



Improves reliability and security of supply



Eliminates the risk of stranded assets



## Project overview

To meet growing electricity demand in São Paulo and support increased renewable integration, Brazil's planning agency (EPE) and ISA Energia Brasil identified a need to relieve congestion on key 138 kV lines. Although nearby 400 kV lines had spare capacity, bottlenecks on the lower-voltage network were limiting the grid's overall ability to serve load. SmartValve was selected as the optimal solution to address near-term needs and provide a flexible path for future system expansion. In the first phase, nine SmartValves will be deployed across two 138 kV circuits in 2025 to push power onto 400 kV lines and support load growth near Ribeirão Preto. These will be relocated in 2027 to São José do Rio Preto and Votuporanga, and expanded further in 2031 to address forecast congestion.



Unlocks firm capacity for new load and renewables



Delivers benefits within one year



Relocatable and scalable solution



Supports flexible operation under N and N-1 conditions



## About Smart Wires

Smart Wires is a leading grid enhancing technology and services provider. We help electric utilities unlock capacity and solve their critical grid issues, using our solutions to create a more flexible, reliable and affordable grid. This enables a faster, more cost-efficient path to meet growing electricity demand with clean energy generation, at the lowest cost to consumers. Headquartered in the Research Triangle Park of North Carolina, Smart Wires has a global workforce of passionate and visionary industry-leading experts across four continents, who work every day to transform grids globally. In collaboration with our customers and partners, we've unlocked over 4 gigawatts (GW) capacity—enough to power over 2.5 million homes—supporting the faster integration of clean energy and new demand, enhancing security of supply and delivering cost savings to consumers.

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## **APPENDIX C**

### ***Sample TTO Uses Showcasing Value and Commercial Readiness***



## TOPOLOGY OPTIMIZATION CASE STUDIES

*January 11, 2026*

Topology optimization identifies transmission network reconfigurations to redirect power flow around transmission bottlenecks, mitigating thermal flow constraints and improving voltage and stability system performance. These reconfigurations are implemented through switching on or off existing circuit breakers.

Topology optimization is gaining traction in power networks where traditional means to congestion management become less effective and very costly as transmission systems accommodate rapid growth of electricity demand and integrate new generation sources, and to mitigate the impacts of major reliability events.

The following 25 case studies illustrate the benefits of topology optimization. These case studies are based on work by NewGrid with partners and clients in North America, Europe, and Latin America using the NewGrid Router software to identify beneficial grid reconfigurations. The reconfiguration analysis was conducted on NewGrid Router using state estimator system snapshots of regional grid operators. With an average run-time of a few seconds to a few minutes per reconfiguration solution, NewGrid Router typically identifies multiple beneficial grid reconfiguration options that relieve the identified constraints by expanding the grid's effective capability between 5% and 25% while meeting all specified reliability requirements.

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## TOPOLOGY OPTIMIZATION CASE STUDIES

### 1. Alliant Energy customers save \$24 million annually with reduced congestion costs of 50%.

Alliant Energy, a U.S. utility operating in Iowa and Wisconsin with about 1 million customers and 8 GW of installed capacity, has partnered with NewGrid to mitigate congestion events affecting customers. Using NewGrid's topology optimization software and expertise, analyses identify simple and robust regionally beneficial reconfiguration solutions to relieve congestion events while respecting system security limits. Leveraging MISO's reconfiguration request process over the May 2024 to April 2025 period, the effort delivered \$24 million in savings to Alliant customers, in addition to further regional savings.<sup>1</sup> Iowa customers have seen about 50% reduction in congestion costs, net of congestion hedging impacts.

Congestion costs would have been reduced by another 31% (\$17 million) if additional reconfigurations identified in the efforts had been implemented, for a total cost reduction estimate of 80%. Further, additional reconfigurations identified could have reduced constraint overload risks by 90%, providing significant reliability benefits.<sup>2</sup>

### 2. MISO saved \$100+ million in 2024, avoiding 66 hours of transmission overload risk and 254 GWh of solar and wind curtailments.

NewGrid monitors congestion on behalf of some MISO members on an ongoing basis and uses topology optimization technology and expertise to develop mitigation solutions for major congestion events. The solutions identified and implemented as part of the efforts have provided over \$100 million in regional congestion cost savings in 2024 by enabling more efficient use of the MISO transmission system. These solutions have avoided 66 hours of overload relief and 254 GWh of renewable curtailments.<sup>3</sup>

For example, reconfigurations implemented for 25 days in May and June 2024 to mitigate the impacts of multiple 138 kV and 765 kV outages in Illinois and Indiana avoided an estimated \$57 million of regional congestion costs, 54 hours of constraint overloads and 29 GWh of wind curtailments. The impacts were particularly high for this event because

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- 1 Mitchell Myhre, Kristie Erickson and Pablo Ruiz, [Effective Congestion Mitigation with Transmission Topology Optimization at Alliant Energy and ATC](#), FERC Tech Conf on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-016), July 9, 2025, slides 15 to 19.
  - 2 Pablo Ruiz and Mitchell Myhre, [Congestion Mitigation with Transmission Reconfigurations](#), Organization of MISO States Market and Transmission Work Groups meeting, March 11, 2024, slides 10 and 17.
  - 3 Pablo Ruiz and Sophie Leamon, [NewGrid Router Topology Optimization Package](#), Global System Operations Summit, Topology Optimization Symposium, Berlin, Germany, September 25, 2025.

the outages were at or close to the MISO and PJM border, making the resulting congestion challenging to control with traditional means.<sup>4</sup>

As another example, a two-action reconfiguration implemented to mitigate the impacts of two critical 161 kV line outages in southeast Minnesota saved the region \$24.5 million over the month-and-a-half duration of the outages in the Fall of 2024. At the same time, the region avoided an estimated 6 hours of constraint overloads and 45 GWh of wind curtailments.<sup>5</sup>

These MISO members are ongoing partners with NewGrid and expect to see similar and possibly higher savings in 2025 and beyond. These efforts leverage the reconfiguration request process that has been implemented by MISO.

### **3. Transmission Reconfigurations Mitigate Stability-Driven Constraints in MISO.**

Stability-driven transmission constraints can result in very impactful economic limitations in the power grid to avoid the risk of undesirable electromechanical and electromagnetic transient phenomena. NewGrid has successfully developed reconfiguration solutions to mitigate these stability constraints occurring under both system normal or transmission outage conditions.<sup>6</sup> The implemented reconfigurations, located in Minnesota and Wisconsin avoided 194 GWh of renewable curtailments between September 2024 and August 2025.

### **4. Topology Optimization Can Quickly Increase Import Capability into the Bogotá Metropolitan Area by 7%.**

Interconexión Eléctrica S.A (ISA) and NewGrid used topology optimization to develop a solution to increase import capacity into Bogotá to mitigate the impacts of transmission project delays. NewGrid Router proposed reconfigurations on two 230 kV substations allowed increased import capacity of 60 MW (7%) with the same transmission security criteria, as verified with steady state and dynamic studies. This is achieved with minimal

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4 NewGrid [Ex-Post Report 05/01-05/26: Rising – Bondville 138 kV flo Rising – Sidney 345 kV Congestion Mitigation](#), MISO Stakeholder Feedback 2024, September 17, 2024.

5 Mitchell Myhre, Pablo Ruiz, Jason Smith and Tom Butz, [MISO Economic Reconfiguration Process Value and Suggestions for Further Improvements](#), MISO Reliability Subcommittee Meeting, October 9, 2025, slides 5 and 6.

6 Pablo Ruiz, Tom Butz, Paola Caro, German Lorenzon, Rodica Donaldson, Mitchell Myhre, Ruchi Singh and Steve Leovy, [Congestion and Overload Mitigation with Optimal Transmission Reconfiguration in MISO and SPP](#), FERC Tech Conf on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-015), July 10, 2024, slides 12 to 14.

investment costs as the reconfigurations simply improve the utilization of existing resources.<sup>7</sup>

## **5. Single Transmission Reconfiguration Saves MISO \$3.5 million in Three Weeks, Reduced Wind Curtailments by 86%.**

In November 2023, a major 345 kV line across the Iowa/Minnesota border was on planned maintenance for three weeks. A reconfiguration solution developed and requested to MISO by NewGrid on behalf of MISO members was implemented and reduced regional congestion costs by \$3.5 million over the three-week outage, as evaluated ex-post using state estimator snapshots during the period. The associated additional production cost savings were \$1.1 million. During the outage, the total generation by the area wind sites was 483 GWh. The reconfiguration reduced wind curtailments by 86% (37 GWh of wind) over the three-week period.<sup>8</sup>

## **6. MISO Supports Reconfiguration Requests to Mitigate Congestion Costs.**

In support of a group of stakeholders, MISO created a formal process to verify and approve economic reconfiguration requests from MISO members to ensure that the requests are assessed in a consistent, reliable, and timely manner across the MISO footprint by MISO, Transmission Operators (TOPs) and, when applicable, Generation Operators (GOPs) and Load Serving Entities. The process has 4 phases: Initial screening, evaluation, implementation, and exit. The average time from submission to evaluation completion is expected to be 15 business days. For the period June 2023 – March 2024, MISO received 16 requests under this process and approved 6 (37.5% approval rate).<sup>9</sup>

## **7. Overload Mitigation of Major Constraint in the SPP Market.**

One of the most significant constraints in SPP in 2022 was a key transformer providing a transmission connection for a major metropolitan area. Under high load conditions, especially with medium to high wind, this constraint could overload due to limited generation options to manage it. During the summer of 2022, SPP implemented a reconfiguration identified by NewGrid to fully mitigate this congestion when the constraint

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7 Víctor A. Palacio, J. Mauricio Areiza and Germán G. Lorenzón, Mitigación de Restricciones e Incremento en la Flexibilidad Operativa Mediante Optimización Topológica, Paper C1.21\_2985, [XX ERIAC CIGRE](#), May 25-29, 2025.

8 Pablo Ruiz and Mitchell Myhre, [Congestion Mitigation with Transmission Reconfigurations](#), Organization of MISO States Market and Transmission Work Groups Meeting, March 11, 2024, slides 8 and 9.

9 Midcontinent ISO, [Process to Support Congestion Cost Reconfigurations in the MISO Footprint](#), MISO Reliability Subcommittee April 16, 2024 Meeting, RSC Liaison Report, June 30, 2023, slide 7.

was overloading and uncontrollable with redispatch. The reconfiguration provided approximately 20% reduction in flow for this constraint.<sup>10</sup>

#### **8. Full Congestion Relief on a Frequently Binding Wind Generation Constraint.**

Evergy has implemented a reconfiguration in its footprint that provided full relief on a constraint that was binding 48% of the time during high wind generation. The reconfiguration has been in place since May 2022.<sup>11</sup>

#### **9. Topology Reconfigurations Could Have Eliminated 98% of Transmission Overloads, Reducing Congestion Costs by 85%.**

NewGrid and Evergy analyzed ex post facto ten significant constraints in the Evergy footprint that are difficult to control and are thus prone to reliability challenges. The identified reconfigurations, had they been implemented, could eliminate 98% of overloads and reduce congestion costs by 85% for congestion patterns associated with those constraints, and including the impacts of further constraints once the reconfigurations are implemented.

This analysis was conducted using all state estimator system snapshots posted by SPP over a 4-month period in the spring and summer of 2022.<sup>12</sup>

#### **10. SPP Released Stranded Generation During Winter Storm Elliott with Reconfigurations.**

During Winter Storm Elliott (December 23-24, 2022), heavy congestion limited supply to a major metropolitan area in the Southwest Power Pool. SPP implemented two transmission reconfigurations that released up to 845 MW from otherwise stranded generation under Energy Emergency Alert conditions, which supplied 14 GWh of additional energy during the event.

Two complementary reconfigurations identified but not used during the storm would have released up to another 600 MW of constrained-off generation to supply an additional 9

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10 Kathryn Dial, [Flowgate Metrics & Congestion Management Discussion](#), SPP ORWG September 28-29, 2022 Meeting. Agenda item 9, slides 9-10.

11 Pablo Ruiz and Derek Brown, [Reliable and Efficient Congestion Mitigation using Transmission Reconfigurations](#), SPP SAG October 7, 2022 Meeting. Agenda item 5, slides 8-10.

12 Pablo Ruiz and Derek Brown, [Reliable and Efficient Congestion Mitigation using Transmission Reconfigurations](#), SPP SAG October 7, 2022 Meeting. Agenda item 5, slides 19-21.

GWh during the event. Together, these reconfigurations could avoid 36 hours of transmission constraints.<sup>13</sup>

### **11. Combining Grid-Enhancing Technologies to Enable Additional Renewable Connections.**

The Brattle Group’s analysis of applying a combination of topology optimization, dynamic line ratings and power flow control devices to the Kansas and Oklahoma portion of the SPP grid demonstrates that the combination of these technologies could reduce congestion and more than double the existing headroom for interconnecting renewable resources, adding 3.7 GW of headroom with a payback period of only 6 months (a \$90 million investment yielding \$175 million/year in reduced annual production costs).<sup>14</sup>

### **12. Mitigation of MISO/SPP Market Seam Constraints.**

Market seam constraints tend to be very difficult to manage using market redispatch, leading to high costs and inefficiencies, especially in the Day-Ahead Markets. Working on behalf of MISO members, NewGrid developed reconfiguration solutions for some of the most heavily binding MISO/SPP seam constraints in MISO North and they have been implemented. For example, one of these reconfigurations was implemented for over 7 months to mitigate the impacts of a major 345 kV outage in 2021. The reconfiguration re-routed flow to reliably enable increased throughput in the area by up to 56%, as measured ex-post using state estimator snapshots.<sup>15</sup>

### **13. Temporary Transmission Solutions in SPP.**

Reconfigurations can be effective mitigation solutions for constraints that are expected to bind heavily, until a transmission expansion project can be completed (usually in 3+ years). NewGrid identified reconfigurations to mitigate two such major constraints in Oklahoma identified by SPP in the ITP process as transmission needs. The reconfigurations enable 10-23% increases in flow throughput in the area.<sup>16</sup>

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13 Pablo Ruiz and German Lorenzon, [Topology Optimization for Least-Cost and Reliable Congestion Mitigation](#), FERC Tech Conf on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-014), June 29, 2023 slide 25..

14 [Unlocking the Queue with Grid Enhancing Technologies](#)

15 Pablo Ruiz, Paola Caro, Mitchell Myhre, Rodica Donaldson and Xiao Li, [Congestion and Overload Mitigation Using Optimal Transmission Reconfiguration](#), FERC Tech Conf on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-013), June 23, 2022, Slide 14 .

16 Pablo Ruiz, Paola Caro, Mitchell Myhre, Rodica Donaldson and Xiao Li, [Congestion and Overload Mitigation Using Optimal Transmission Reconfiguration](#), FERC Tech Conf on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-013), June 23, 2022, Slide 15.

#### 14. Congestion Relief of Major Standing Constraint in MISO.

The Rochester – Wabaco 161 kV line drove over \$57 million of MISO congestion costs in the summer of 2021. Had reconfigurations been used to mitigate these constraints, congestion on the line would have been eliminated and area congestion costs would have been reduced by roughly 2/3rds. The congestion cost savings over the summer would have exceeded \$38 million. The reconfiguration would have enabled over 25% additional throughput for this constraint.<sup>17</sup>

#### 15. SPP Finds Reconfiguration Solutions to 55% of Constraints Analyzed with Topology Optimization in NewGrid Pilot.

SPP conducted an extended pilot with the NewGrid Router topology optimization software tool in Q3 and Q4, 2018. The pilot was conducted by the SPP Transmission Operations Analysis & Planning with a reliability focus on finding solutions consisting of a single switching action at or below 230 kV with:

- At least 5% N-1 loading reduction
- Less than 30 MW of newly radialized load
- No resultant constraint loading over 95% post-contingent.

SPP engineers evaluated 100 flowgates with congestion during real-time operations using NewGrid Router and found ‘preferred’ solutions to 55 flowgates. Some of these reconfigurations were then implemented in real-time operations.<sup>18</sup>

#### 16. Most Costly Constraint in SPP Permanently Fixed with Reconfiguration.

The first and fourth most expensive constraint in SPP in 2019 were permanently resolved with a transmission reconfiguration in 2020. Both constraints resulted from contingency limitations of a 69 kV line in Oklahoma and had been binding 16% of all the real-time market intervals in 2019, costing the market about \$25 million that year in the day-ahead and real-time markets. In addition to being costly and frequently binding, these constraints had resulted in \$30 million of TCR underfunding.<sup>19</sup>

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17 Potomac Economics, [2021 MISO State of the Market Report](#), June 22, 2022., and FERC, [Congestion and Overload Mitigation Using Optimal Transmission Reconfiguration](#), Slide 13.

18 Pablo Ruiz, Jay Caspary and Luke Butler, [Transmission Topology Optimization Case Studies in SPP and ERCOT](#), FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software (Docket No. AD10-12-011), June 24, 2020. Slides 12-20.

19 Southwest Power Pool MMU, [State of the Market 2019](#), May 11, 2020. Pages 194-195, 199 and 214.

## **17. ERCOT uses Topology Optimization Software to Support Operations Planning and Avoids Load Shedding for Outage Mitigation Plan.**

ERCOT has been using NewGrid Router topology optimization software to support their Constraint Management Plan (CMP) review and development. ERCOT engineers use the software to search for reconfigurations to replace mitigation plans that employ post-contingency load-shed.

ERCOT uses NewGrid Router to identify alternative solutions to remove post-contingency load shedding actions from the plans, to analyze, verify, and compare the most effective corrective and preventive reconfiguration plans by providing alternative switching actions, and to search for possible switching solutions for irresolvable constraints outside of the CMP Review.<sup>20</sup>

## **18. Topology Optimization Can Reduce System Operating Limit (SOL) Violation Frequency by 75% in SPP.**

In 2018, NewGrid, SPP and The Brattle Group evaluated the potential of using topology optimization to identify reconfigurations to support decision making in Operations Planning. Working with SPP transmission operations staff and using 20 selected state estimation cases with major constraints binding or overloading, the evaluation found that historical SOL violations could be eliminated for 75% for the constraints analyzed. The resulting congestion cost savings in the real-time markets were estimated to be in the range of \$18-44 million annually. Mitigation options identified during the evaluation were implemented by SPP and memorialized in Op Guides.<sup>21</sup>

## **19. Topology Optimization Avoids Load Shedding for NERC TPL-001-4 Planning Events in SPP.**

In 2018, NewGrid, SPP and The Brattle Group evaluated the potential of using topology optimization to develop Corrective Action Plans (CAP) that relied on reconfigurations and avoided load shedding for NERC P6, P7 and Extreme Event violations. SPP Planning selected three events for evaluation, one of each NERC type listed, that had CAPs

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20 Pablo Ruiz, Jay Caspary and Luke Butler, [Transmission Topology Optimization Case Studies in SPP and ERCOT](#), FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software (Docket No. AD10-12-011), June 24, 2020, slide 11., and Pablo Ruiz and Nick Steffan, [Transmission Topology Optimization Operations and Market Applications and Case Studies](#), ERCOT DSWG Nov 17, 2017. Slide 12.

21 Pablo A. Ruiz, Doug Bowman, Kathryn Dial, Xiao Li, Ryan Schoppe, Zachary Sharp, Jason Terhune, Bruce Tsuchida, [Transmission Topology Optimization Applications to Enhance System Reliability and Resilience and to Increase Market and Planning Efficiency in Southwest Power Pool](#), FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software (Docket No. AD10-12-009), June 26, 2018. Slides 13-21., and Pablo A. Ruiz, Doug Bowman, Kathryn Dial, Xiao Li, Ryan Schoppe, Zachary Sharp, Bruce Tsuchida, [Transmission Topology Optimization Pilot Study to Support Congestion Management and Ice Buildup Mitigation](#), November 15, 2018. Presentation #6, slides 16-20.

consisting of load shedding (up to 243 MW of load shed). The reconfiguration solutions identified and validated by SPP provided full relief under NERC TPL-001-4 in SPP and eliminated the need of load shed actions in those CAPs.<sup>22</sup>

## **20. Study of Winter Storm Jupiter Found that Topology Optimization Can Mitigate Overhead Transmission Line Failure Risk Due to Icing in Sunflower Electric.**

In 2018, NewGrid, SPP and The Brattle Group evaluated the potential of using topology optimization during icing conditions to mitigate the risk of mechanical line failure. The analysis focused on reconfigurations to redirect flow to critical lines at risk of failure due to ice accumulation to prevent or limit ice formation. The study was performed for the January 2017 Winter Storm Jupiter conditions, which caused multiple transmission outages due to ice accumulation, and focused on the Sunflower Electric footprint in Kansas. The study identified two reconfiguration solutions that could have significantly relieved the ice buildup on selected critical lines, while meeting reliability criteria. The estimated savings of avoiding the hypothetical outages of these critical lines are \$10 to \$17 million, in addition to avoided system restoration costs.<sup>23</sup>

## **21. Transmission Reconfigurations can Increase Zonal Transfer Capacity by up to 12% in the UK.**

National Grid ESO and The Brattle Group studied the potential to increase transfer capability and reduce constraint management costs with topology optimization. The study focused on major (zonal) interface constraints that had been congested under historical outage scenarios selected by NGENSO. Topology optimization identified reconfigurations that met NGENSO criteria and provided up to 12% increase in transfer capability (1289 MW increase), as assessed by NGENSO. The reconfigurations did not radialize load and consisted of up to six topology change actions (line switching, substation reconfiguration and phase-shifting transformer adjustments).<sup>24</sup>

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22 Pablo A. Ruiz, Doug Bowman, Kathryn Dial, Xiao Li, Ryan Schoppe, Zachary Sharp, Jason Terhune, Bruce Tsuchida, [Transmission Topology Optimization Applications to Enhance System Reliability and Resilience and to Increase Market and Planning Efficiency in Southwest Power Pool](#), FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software (Docket No. AD10-12-009), June 26, 2018. Slides 23-24.

23 Pablo A. Ruiz, Doug Bowman, Kathryn Dial, Xiao Li, Ryan Schoppe, Zachary Sharp, Bruce Tsuchida, [Transmission Topology Optimization Pilot Study to Support Congestion Management and Ice Buildup Mitigation](#), November 15, 2018. Presentation #6, slides 22-32.

24 Pablo A. Ruiz and Xiao Li, [Transmission Topology Optimization to Efficiently Mitigate Congestion & Overloads, FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software \(Docket No. AD10-12-012\)](#), June 23, 2021. Slides 9-13.

## 22. Transmission Reconfigurations Relieve Congestion During Polar Vortex 2014 in MISO.

During the Polar Vortex event of 2014, The Brattle Group supported a utility in the upper Midwest to mitigate congestion and overloads under those critical conditions. Severe transmission congestion affected the upper Midwest due to record-setting high loads in MISO North and a substantial number of unplanned generation outages, both resulting from the extreme cold weather, compounded by the impacts of extended 230 kV planned transmission outages that could not be recalled during the event. The cost of electricity to customers in the area increased by over \$15 million in the first 10 weeks of 2014 due to congestion. Energy prices at load in the affected areas at times more than doubled the corresponding generation energy prices. Using topology optimization, Brattle identified reconfiguration solutions that relieved much of the congestion and overloads. The solutions were implemented after validation by MISO and the transmission owners in the area.<sup>25</sup>

## 23. Topology Optimization Could Reduce Day-Ahead Congestion Costs in PJM by 30 to 50%.

Detailed simulation of the PJM day-ahead market for representative weeks showed that the day-ahead cost of congestion could be reduced by 30 - 50% if market clearing includes topology optimization decision variables in addition to resource bids and offers. The simulation solved each day in the week sequentially, and incorporated “topology persistence” constraints, requiring that each reconfiguration be beneficial and remain in place for at least a few hours. Under 2010 market conditions, these savings would add up to \$145 million annual reduced production costs in the PJM footprint. The reconfigurations enable increases of up to 10% in transfers between PJM regions. These impacts are achieved by only using 2 - 3 switching operations per hour across PJM, which is much lower than the switching actions associated with maintenance outages.<sup>26</sup>

## 24. Financial Transmission Rights (FTR) Revenue Adequacy Improve with Topology Optimization.

Based on detailed simulation of the PJM day-ahead market for representative weeks in PJM, use of topology optimization significantly reduced congestion rent, by 30-50%. At the same time, it increased the day-ahead FTR surplus relative to the congestion rent by up to

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25 Pablo A. Ruiz and Xiao Li, [Transmission Topology Optimization to Efficiently Mitigate Congestion & Overloads](#), FERC Tech Conf on Increasing Day-Ahead and Real-Time Market Efficiency and Enhancing Resilience through Improved Software (Docket No. AD10-12-012), June 23, 2021. Slide 14.

26 Pablo A. Ruiz, Michael Caramanis, Evgeniy Goldis, Xiaoguang Li, Keyurbhai Patel, Russ Philbrick, Alex Rudkevich, Richard Tabors, Bruce Tsuchida, [Transmission Topology Optimization Simulation of Impacts in PJM Day-Ahead Markets](#), FERC Tech Conf on Increasing Market Efficiency through Improved Software (Docket No. AD10-12-007), June 28, 2016. Slides 12-17.

5%. This makes sense since the FTR portfolio tends to be consistent with least cost power transfers across the network. Revenue inadequacy results when those transfers become infeasible, for example due to outages. Topology optimization tends to increase transfer capacity and make those economic transfers more feasible, improving overall FTR revenue adequacy.<sup>27</sup>

## **25. Topology Optimization Could Reduce Real-Time Congestion Costs in PJM by Over 50%.**

Detailed simulation of the PJM real-time market for representative weeks in PJM showed that the real-time cost of congestion could be reduced by 44 - 68%, depending on the seasonal week, if market clearing includes topology optimization decision variables in addition to resource bids and offers. The simulation solved each hour in the week sequentially, and incorporated "topology persistence" constraints, requiring that each reconfiguration be beneficial and remain in place for at least a few hours. Under 2010 market conditions, these savings would add up to over \$100 million annual reduced production costs in the PJM footprint, even if unit commitment changes are not accounted for. The reconfigurations enable increases of up to 11% in transfers between PJM regions. These impacts are achieved by only using 1 - 2 switching operations per hour across PJM, which is much lower than the switching actions associated to maintenance outages.<sup>28</sup>

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27 Pablo A. Ruiz, Michael Caramanis, Evgeniy Goldis, Xiaoguang Li, Keyurbhai Patel, Russ Philbrick, Alex Rudkevich, Richard Tabors, Bruce Tsuchida, [Transmission Topology Optimization Simulation of Impacts in PJM Day-Ahead Markets, FERC Tech Conf on Increasing Market Efficiency through Improved Software \(Docket No. AD10-12-007\)](#), June 28, 2016. Slides 18-19.

28 Pablo A. Ruiz, Michael Caramanis, Evgeniy Goldis, David Hislop, Bhavana Keshavamurthy, Xiaoguang Li, Daniel Moscovitz, Russ Philbrick, Alex Rudkevich, Richard Tabors, Bruce Tsuchida, [Topology Control Algorithms \(TCA\) Simulations in PJM with AC Modeling](#), FERC Tech Conf on Increasing Market Efficiency through Improved Software (Docket No. AD10-12-005), June 23, 2014. Slides 8-20.