CONGESTION MITIGATION WITH GRID-ENHANCING TECHNOLOGIES

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AGENDA

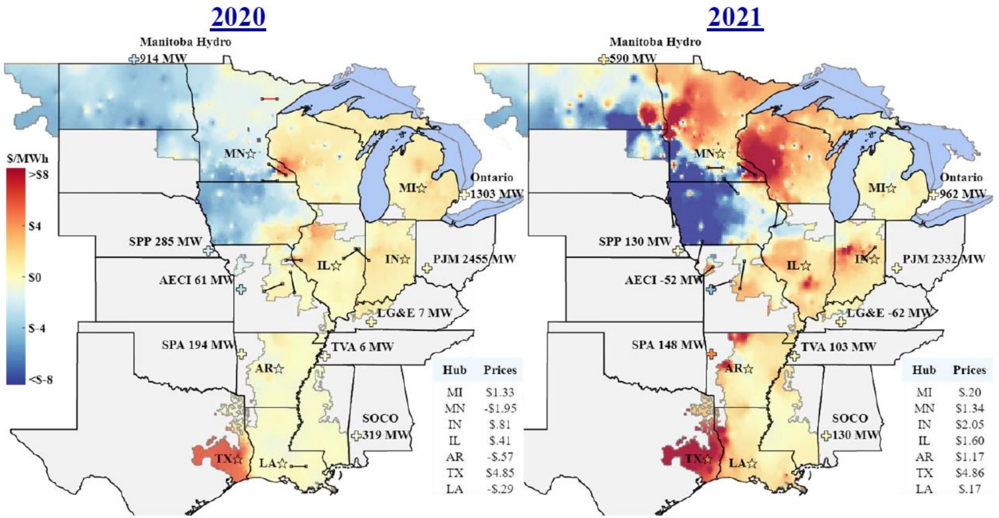
- Congestion Management Background
- Grid Enhancing Technologies
- Dynamic Line Ratings
- Advanced Power Flow Control
- Topology Optimization
  - Background
  - Impacts on Market Prices and Flows – SPP Case Studies
  - Topology Optimization with Power Flow Control – NGESO Case Study
  - A Path for Incremental Implementation
  - Reconfiguration Requests Experience and Impacts – MISO Case Studies

TRANSMISSION CONGESTION MANAGEMENT

Traditional congestion management treats the transmission grid as a fixed asset

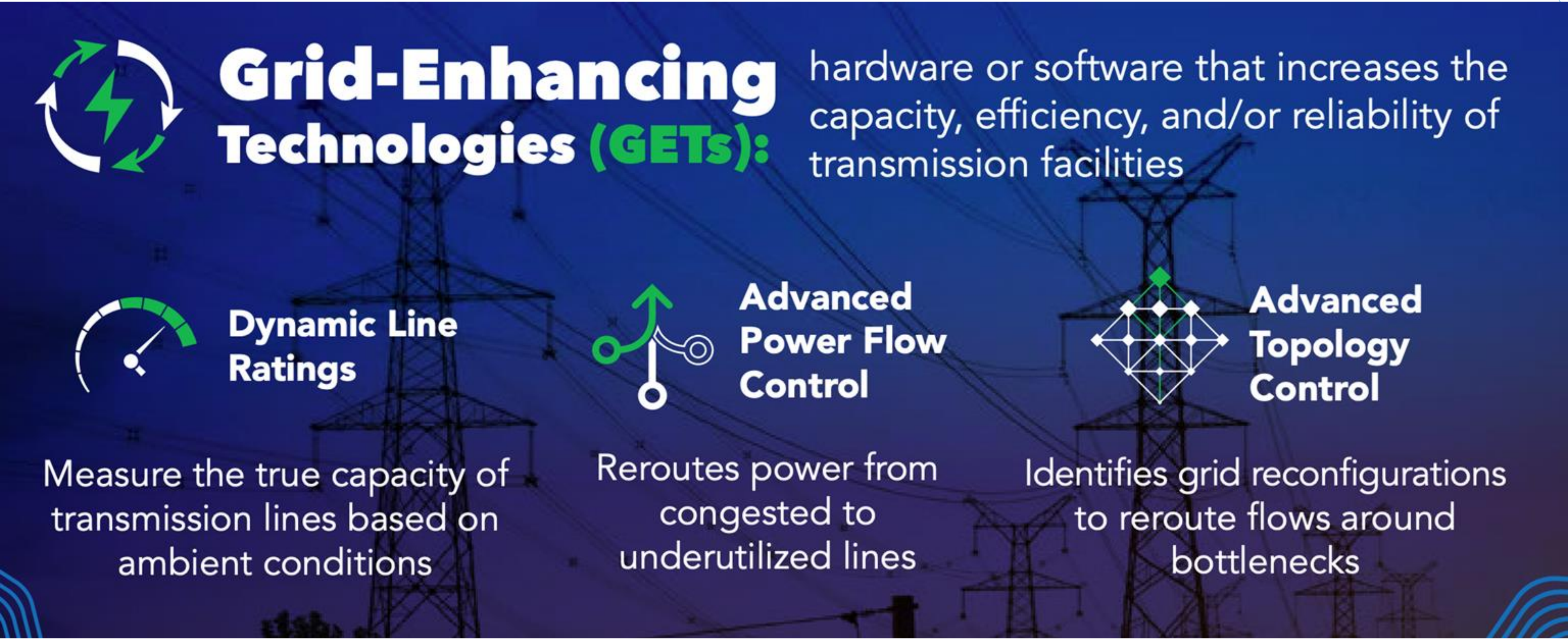
- Congestion management approach: redispatch - "*increase the tolls!*"
- MISO congestion costs in Spring 2022: over $1 billion [1]
- Frequent overloads, customer outages during extreme events [2]

Congestion Costs in MISO increased 3x from 2020 to 2021 [3]



1. Potomac Economics, MISO IMM Quarterly Report: Spring 2022, June 14, 2022.
2. For example, transmission congestion led to customer outages in SPP during the Arctic Blast, see Bitter cold overwhelms grid, leaves millions in dark, Edward Klump, Peter Behr and Mike Lee, Energywire, February 16, 2021.
3. Potomac Economics, 2021 MISO State of the Market Report, June 22, 2022.

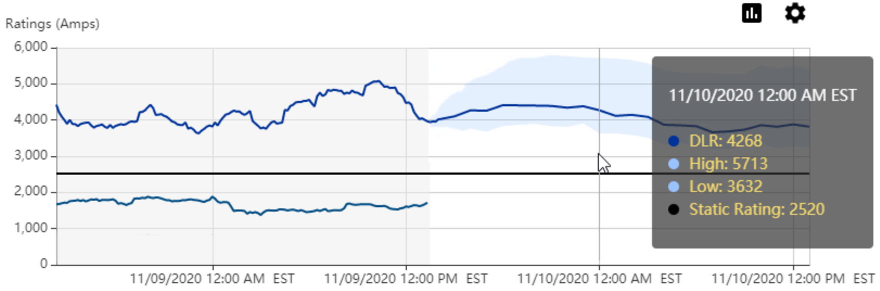
GRID-ENHANCING TECHNOLOGIES (GET)

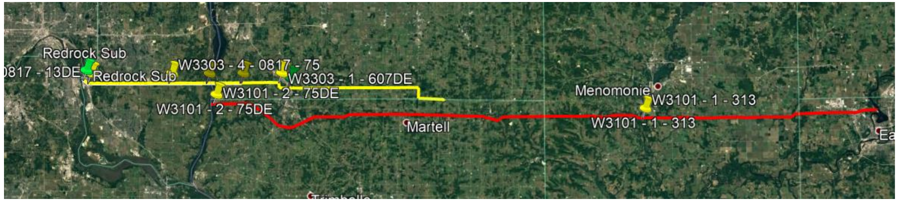


Source: The WATT Coalition.

DYNAMIC LINE RATINGS CASE STUDY IN MN AND WI

Measure and estimate accurate line ratings accounting for weather and system conditions





DLR to Static Line Rating Comparison

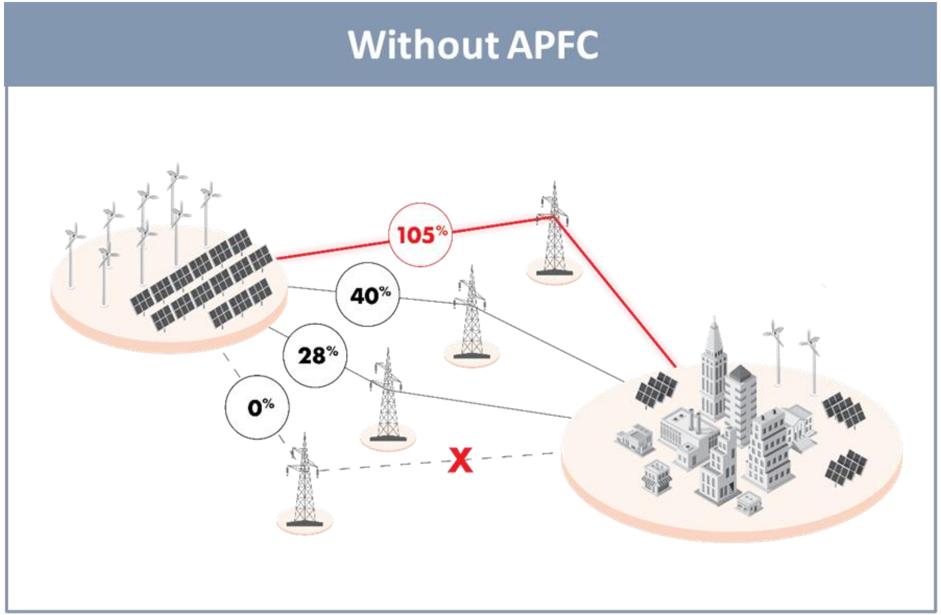
Line	Winter Static Rating	Average Winter Dynamic Rating	% Increase	Summer Static Rating	Average Summer Dynamic Rating	% Increase
0817/3303 RPO-GMT	1460	1594	9.2%	1076	1451	34.8%
3101 ASK-ECL*	2000	3661	83.0% *	1994	3358	68.4% *

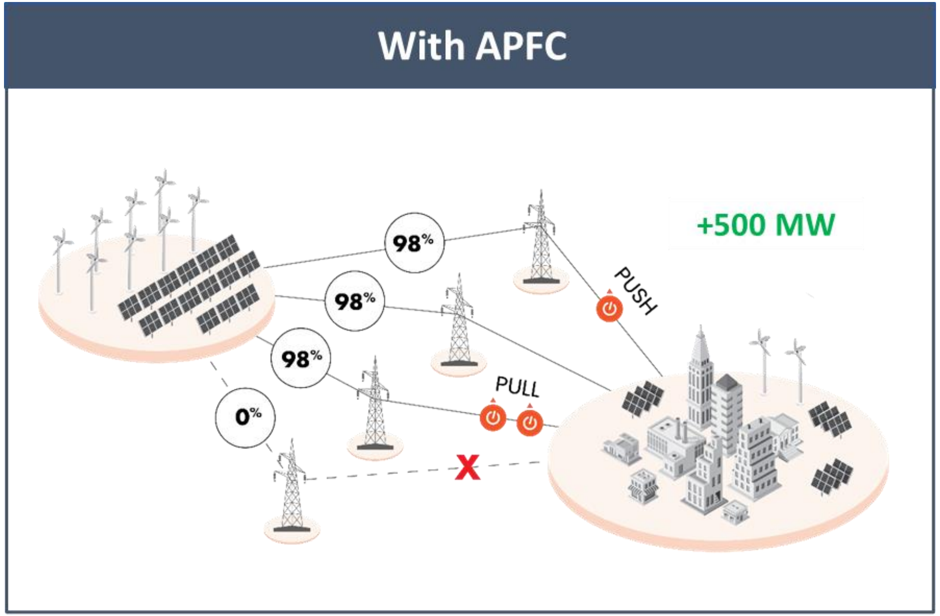
* Line 3101 ASK-ECL is clearance-limited by other spans along the line which are not monitored by LineVision.

Source: DOE Office of Electricity project Demonstration of Advanced Monitoring and Data Analytics of Power Transmission Lines.

ADVANCED POWER FLOW CONTROL (APFC)

APFC are FACTS devices that enable granular control of power flows by altering effective device reactances. Utilities typically use APFC as a planning tool to unlock grid capacity.

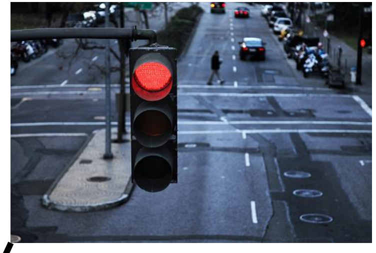


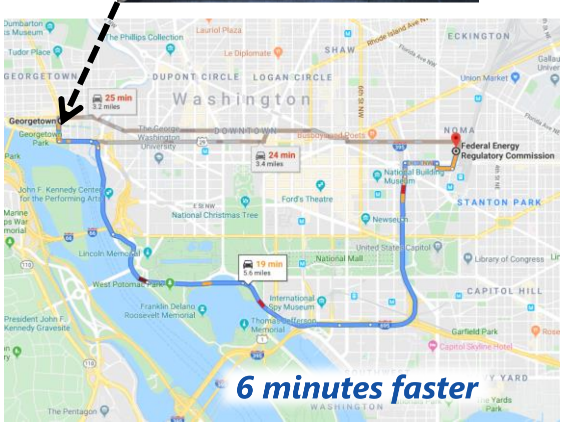


Source: Smart Wires.

TOPOLOGY OPTIMIZATION: FLEXIBLE GRID OPERATION

Topology optimization software technology finds reliable reconfigurations to reroute flow around congestion (“*Waze for the transmission grid*”)





- Reconfigurations are implemented by switching circuit breakers (open or closed)
  - Analogous to temporarily diverting traffic away from congested roads to make traffic flow smoother
- **Reconfigurations are implementable today!**
  - Switching infrastructure is already in place:
    - Most breakers are controlled remotely over SCADA by the TOP
    - Phone call between TOP and RTO to coordinate operations
  - Circuit breakers are capable of high duty cycles & extremely reliable
    - Two designs: 2k or 10k switching cycles per overhaul
    - Some breakers are switched very frequently today, e.g., those connecting generating units with daily start and stop
    - Failure occurs less than once in 20,000 switching cycles*
  - Low cost: usually $10-$100 per switching cycle**

* For single-pressure SF6 breakers. Based on a CIGRE survey of 281,090 breaker-years with responses from 82 utilities from 26 countries, source: A. Janssen, D. Makareinis and C.-E. Sölver, "International surveys on circuit-breaker reliability data for substation and system studies," *IEEE Transactions on Power Delivery*, v. 29, n. 2, April 2014, pp. 808-814

** All-in cost of maintenance overhauls for single-pressure SF6 breakers rated 72.5-362 kV.

RELIABLE RECONFIGURATIONS

The reconfigurations are reliable under all specified contingencies (e.g., do not introduce new problems, and are consistent with mitigating the ongoing risks in operations) and do not radialize load beyond a user-specified value. They can be validated for transient and/or voltage stability performance as needed using existing software tools.

NEWGRID ROUTER

OPTIMIZATION

TOPOLOGY OPTIMIZATION

OUTPUTS

- Reconfiguration candidate
- Dispatch and commitment
- Marginal costs

RELIABILITY

CONTINGENCY AND CONNECTIVITY EVALUATION

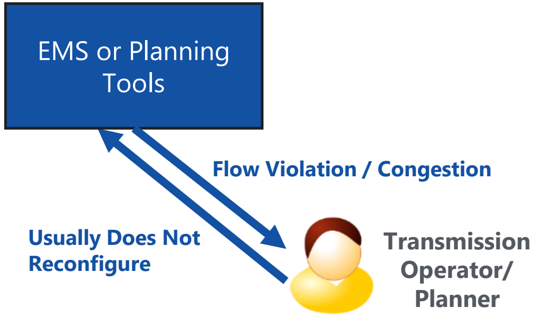
OUTPUTS

- Feasible/infeasible reconfiguration
- Constraints to ensure feasibility of the optimization outcome

RECONFIGURATION PRACTICE

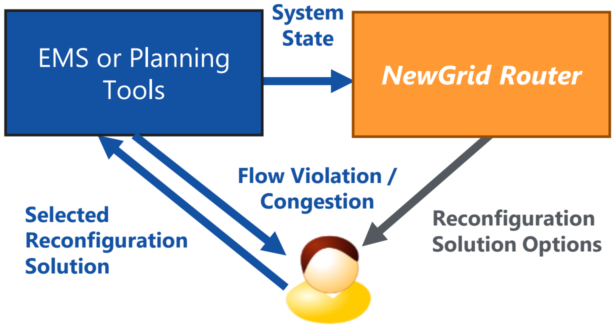
Traditional Practice

- Reconfigurations identified based on staff experience
  - Time-consuming process
  - Depends on expert operators
- Already employed to a limited extent, on an ad-hoc basis
  - Operating Guides
  - Remedial Action Plans
- Solutions are blunt instruments, they are not developed for current system conditions
- Transmission grid flexibility underutilized



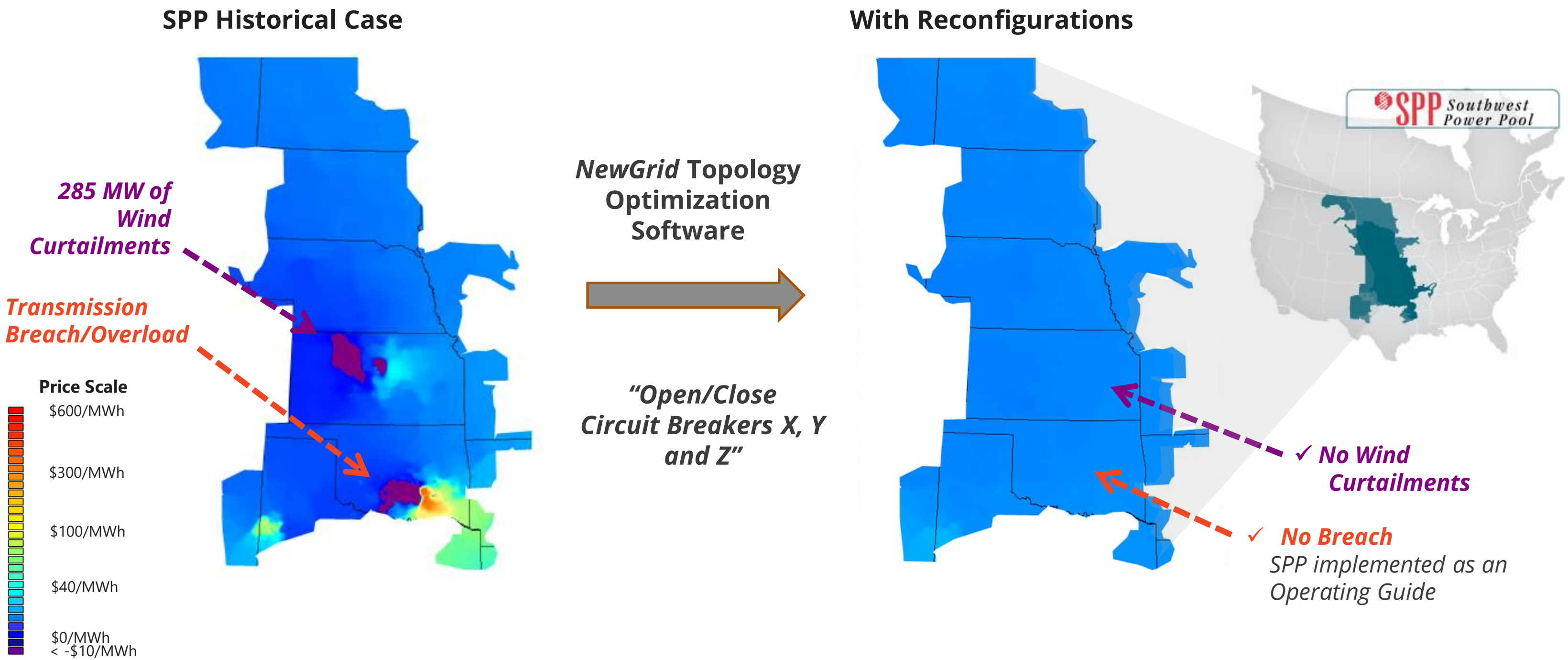
With Topology Optimization

- ✓ Software finds reconfiguration solution *options*
  - Fast search time: 10 s – 2 min
  - Enables all operators to optimize the grid
- ✓ Enables broad application of reconfigurations in different processes
- ✓ Know when to restore/close open assets
- ✓ Analyzes current system conditions, continue to optimize as conditions change
- ✓ Take full advantage of grid flexibility

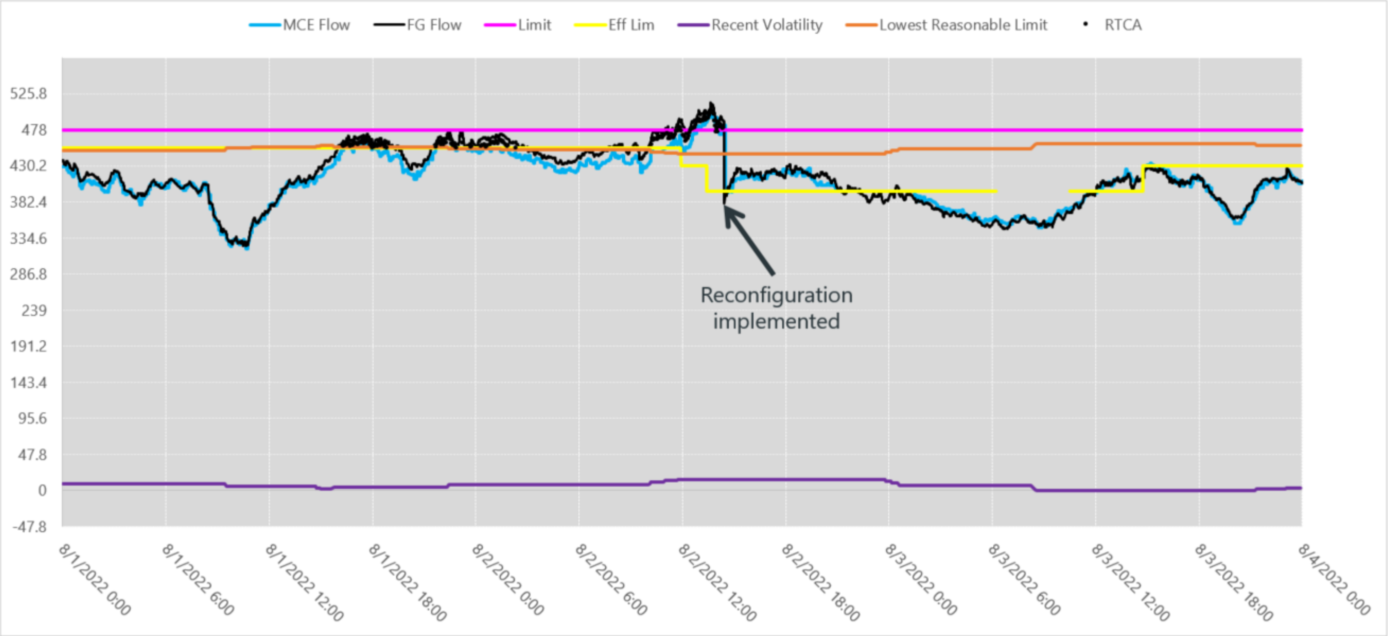


CONGESTION REDUCTION USING RECONFIGURATIONS

Topology optimization can be a powerful complement to market redispatch for congestion management, materially reducing costs, improving reliability and mitigating curtailments



RECONFIGURATION IMPLEMENTATION EXAMPLE

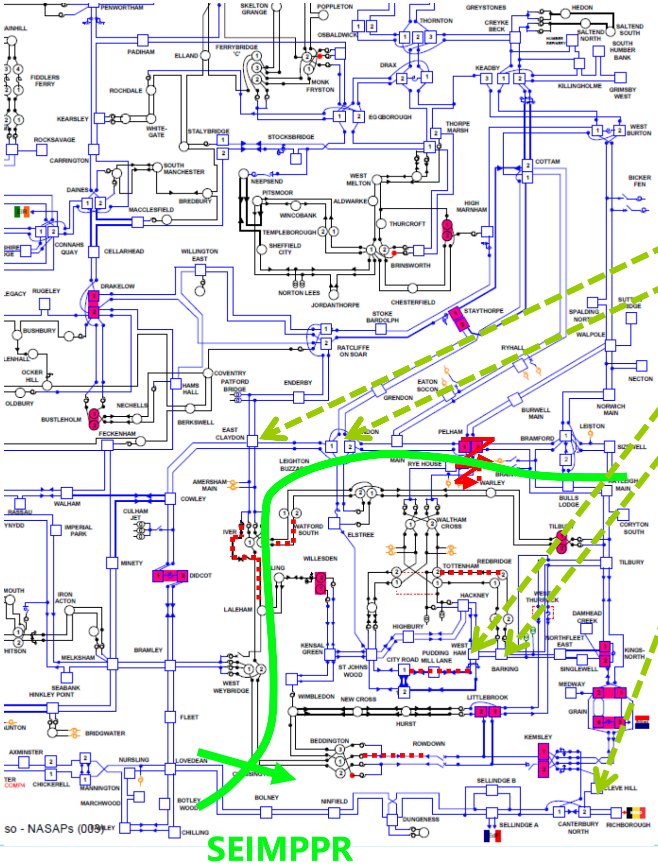


- Effective limit was reduced very low, but does not provide effective relief
- Constraint is fairly stable from a RT/RTBM difference perspective (low volatility)
- Keeping the low effective limit resulted in unnecessary congestion and extra issues in RUC studies

SPP 10

Source: Kathryn Dial, Flowgate Metrics & Congestion Management Discussion, SPP ORWG September 28-29, 2022 Meeting.

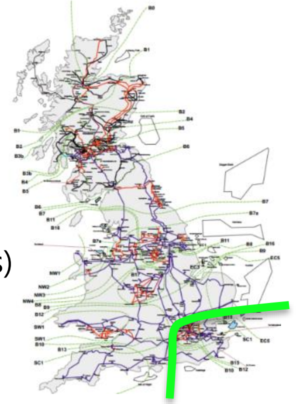
INCREASED TRANSFER CAPABILITY: +550 MW (8.4%)



NGESO identified scenario with key outages and thermal limits active on large “boundary constraints.”

Solution with substation reconfiguration + flow control *

- Close 400 kV Breaker
- Open 400 kV Breaker
- Open 400 kV Breaker
- Open 275 kV Breaker
- Open 400 kV Breaker
- Change taps at four Quad Boosters (phase shifters)



NGESO Solution Criteria

- No load radialisation
- Max six topology changes per solution
- Min 10 MW relief per topology change

… *Topology Optimization alleviates extreme operating limits*

* The actions provide incremental relief. A partial solution implementation would be feasible and beneficial.

APPLICATIONS

Topology optimization can support business processes across many scales.

Real-time

- **Adapt to emergency system conditions**, increasing grid resilience
- Relieve N-1 flow violations
- Minimize RUC and manual unit starts for constraint management

Intra-Day

- Unlock capacity from export-constrained areas
- **Minimize congestion costs** in the real-time market
- Reduce renewables curtailments

Day-ahead

- Pre-position the system topology to match expected conditions
- Minimize congestion costs in the day-ahead market
- Support **outage scheduling and coordination** (enable conflicting tickets)

Weeks Ahead

- Mitigate the expected congestion impacts of outages
- **Develop Op. Guides** for extreme events that minimize load shedding
- Adjust underlying system topology when new projects are energized

Long-Term

- Optimize transmission expansion portfolio
- Maximize the benefit-to-cost ratio of new projects

INCREMENTAL TECHNOLOGY IMPLEMENTATION

Simplest ↕ *Highest benefits*

Process	Technology User	Application	System Integration	Timeframe
Step 1 **Reconfiguration Request Process**	**Market Participants** (RTOs, RCs and TOs have the software needed to evaluate requests)	mitigation of expected constraints	none	days / weeks / months
Step 2 **Operations Planning Support**	**RTO, RC, TOP**	development of operating plans	none to minimal (offline advisory tool)	days / weeks / months
Step 3 **Real-Time Operations Support**	**RTO, RC, TOP**	reconfiguration options tailored to real-time conditions	EMS	days to real-time
Step 4 **Market Clearing**	**RTO**	continuous optimization of topology as conditions evolve	EMS and MMS	days to real-time

INCREMENTAL TECHNOLOGY IMPLEMENTATION

We focus on Step 1 reconfiguration requests in the rest of the presentation

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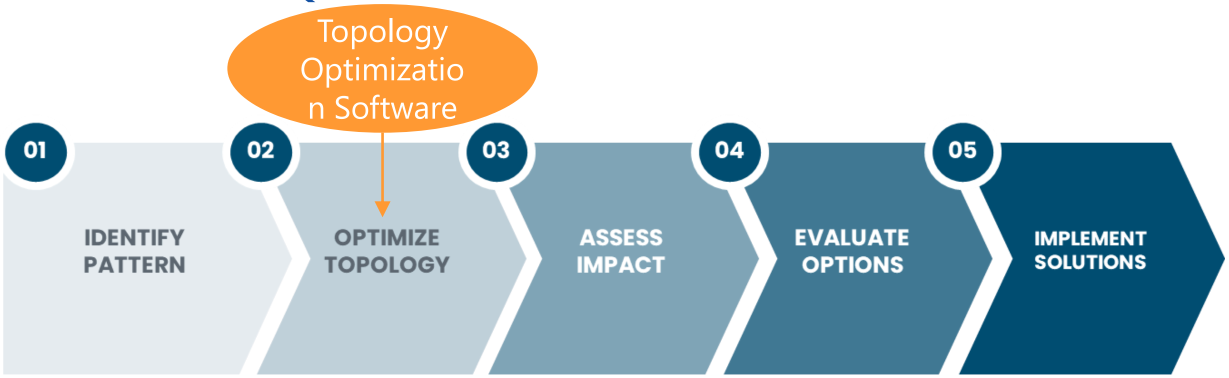
RECONFIGURATION REQUEST PROCESS



STEP 1: A Market Participant identifies a congestion pattern of interest

STEP 2: The Market Participant identifies reconfiguration solutions, analyzes them and submits requests to MISO and the Transmission Operators

Step 3: MISO and the Transmission Operators assess reliability and economic impacts; Generation Operators that are directly affected evaluate their risk exposure

Step 4: MISO and TOP approves or denies the solution

Step 5: MISO and the Transmission Operators implement the solution if real-time conditions allow

Exit

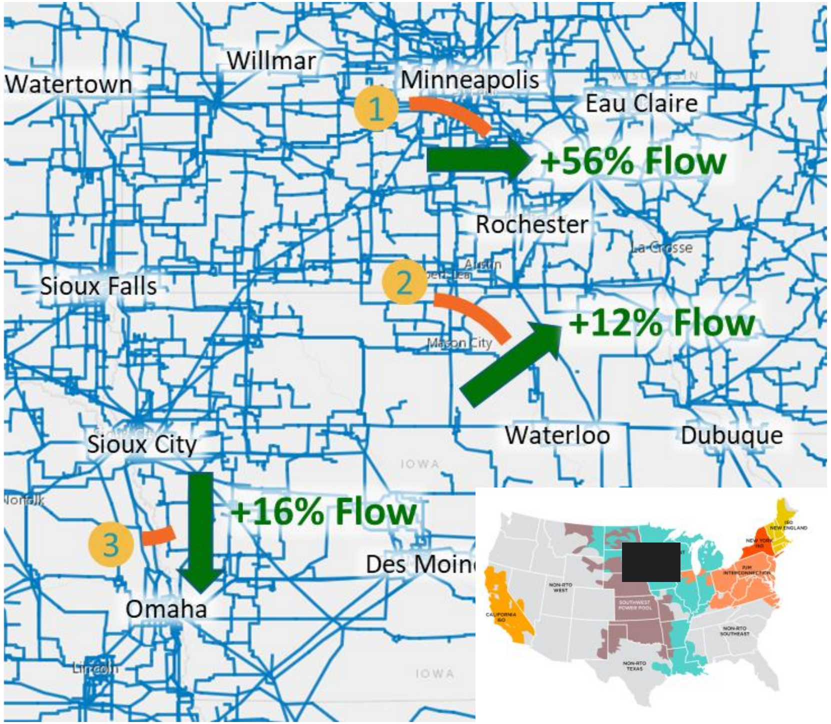
If an economic reconfigure is no longer effective or reliable due to changes in system conditions, or fails one of the initial screening criteria, MISO and the TOP will exit the congestion cost reconfiguration.

Midcontinent ISO, DRAFT Process to Support Congestion Cost Reconfigurations in the MISO footprint.

MITIGATION OF MARKET SEAM CONSTRAINTS

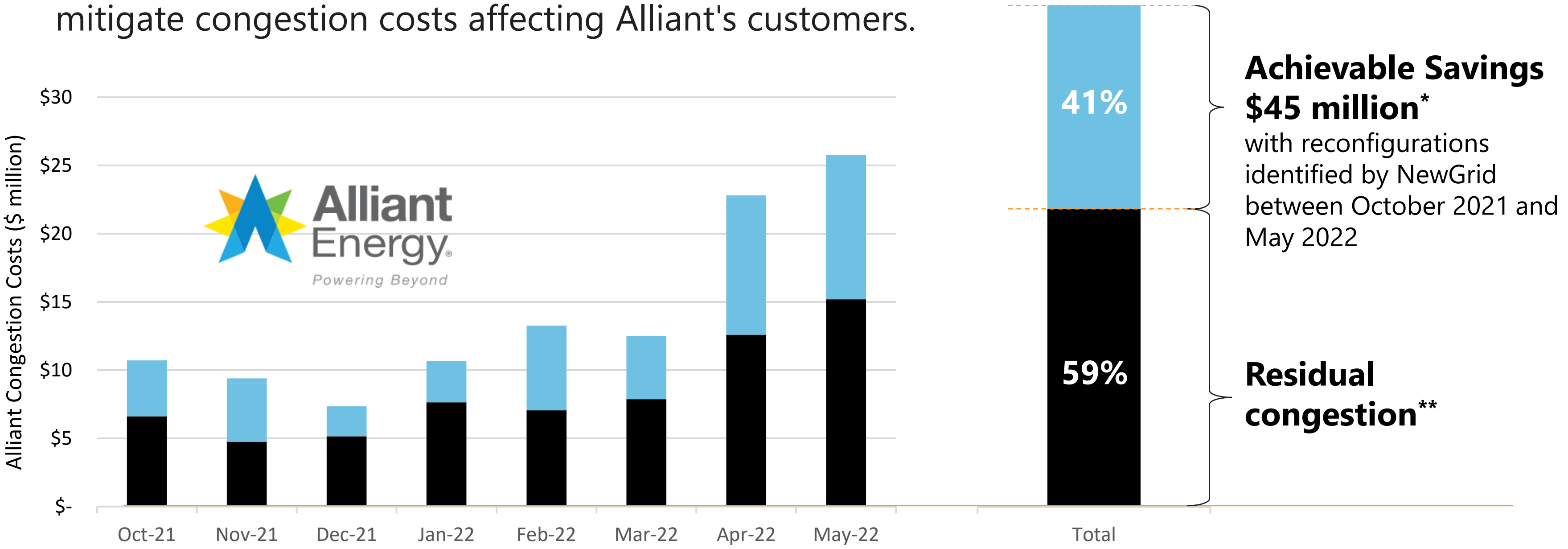
Seam constraints tend to be difficult to manage using only market redispatch, leading to high costs and inefficiencies, especially in the Day-Ahead Markets. Reconfigurations identified by NewGrid re-routed up to 56% flow on heavily binding MISO/SPP seam constraints .

1. **Chub Lake 345/115 flo Chub Lk - Hampton 345**
   - Mitigated congestion due to Helena – Scott Co. 345 kV outage in April – November 2021
   - Reliably increased throughput by up to 56%
2. **Lime Creek – Barton 161 flo Quinn – Blackhawk 345**
   - Reliably increased throughput by up to 12%
3. **Raun – Tekamah 161 flo Grimes – Beaver Creek 345**
   - Reliably increased throughput by up to 16% during the outage of Raun - Ft Calhoun 345 in February – March 2022
   - Reduced the frequency of the constraint binding by about 60% during the outage



ACHIEVABLE CONGESTION COST SAVINGS

Alliant Energy and NewGrid are conducting a topology optimization pilot, identifying and analyzing beneficial reconfigurations, and requesting and tracking their implementation to mitigate congestion costs affecting Alliant's customers.



Impacts calculated ex-post based on analyses of state estimator cases published by MISO and of historical market data.

* Partially realized, the reconfiguration request process was under development.

** Residual congestion may be reduced further, not all significant constraints affecting Alliant were analyzed during the pilot due to scope limitations.

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