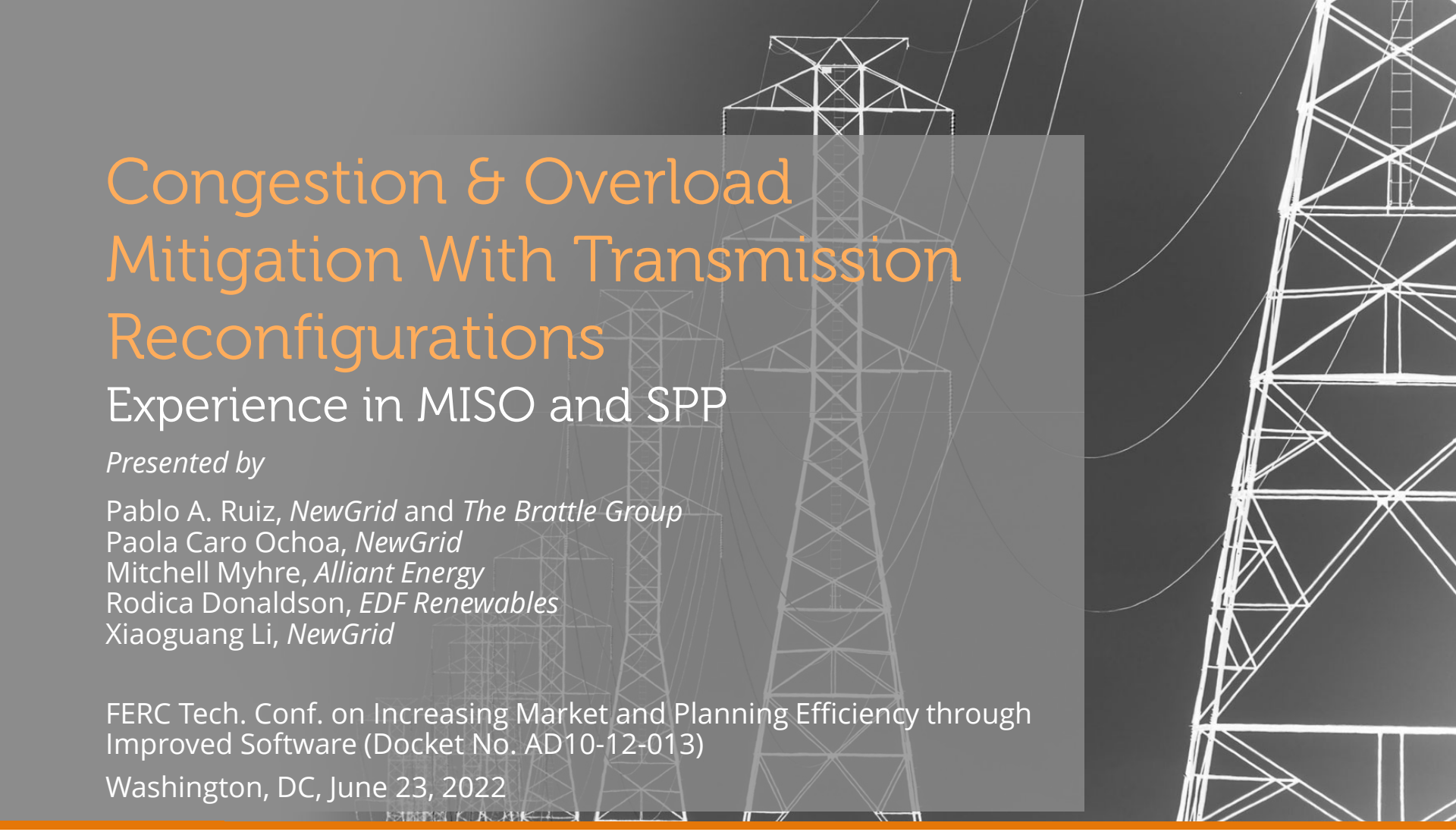


Congestion & Overload Mitigation With Transmission Reconfigurations

Experience in MISO and SPP

Presented by

Pablo A. Ruiz, *NewGrid* and *The Brattle Group*
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FERC Tech. Conf. on Increasing Market and Planning Efficiency through Improved Software (Docket No. AD10-12-013)

Washington, DC, June 23, 2022

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Agenda

- Transmission Congestion Management

  Traditionally assumes a static transmission grid, relies on re-dispatch

- Topology Optimization Technology

  Enables reliable flexible grid operations, finds reconfigurations to reroute flow around bottlenecks

  - Reconfigurations: Practice, Reliability Criteria, Types

    Reconfigurations are applied by switching existing circuit breakers

  - Applications

    Reconfigurations adapt the grid to best address system needs in operations and planning

  - An Incremental Path for Technology Implementation

    Start with simpler, offline applications to gain experience

- Optimal Reconfiguration Requests Case Studies in MISO and SPP

  Market participants make requests, RTOs & TOs validate reliability, impacts prior to implementation

  - Process
  - Mitigation of Significant Constraints
  - Congestion Cost Savings

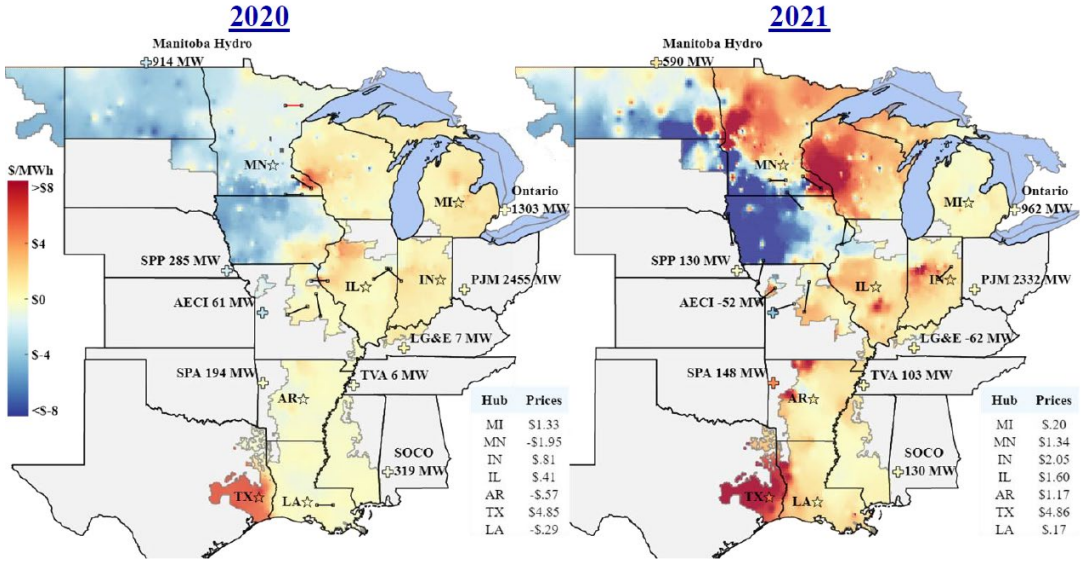
- Appendix – References

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]
- Wasted renewable production: 2-17% of system-wide potential [3]

Congestion Costs in MISO increased 3x from 2020 to 2021 [4]



[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] Wind and solar energy curtailment: experience and practices in the United States, Lori Bird, Jaquelin Cochran, and Xi Wang, NREL, March 2014; as an example, SPP wind curtailments in 2021 averaged 725 MW per hour, totaling 6.35 TWh annually, see SPP MMU State of the Market 2021.

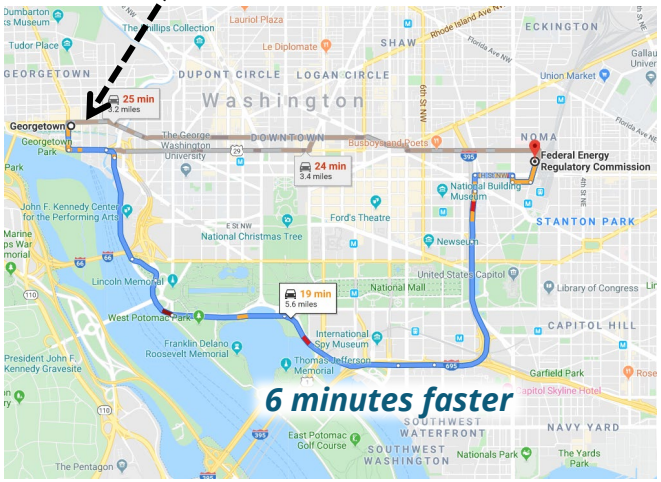
[4] Potomac Economics, 2021 MISO State of the Market Report, June 22, 2022.

Topology Optimization: Flexible Grid Operation

Topology optimization software technology, developed with ARPA-E support, 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 TO
    - Phone call between TO 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**





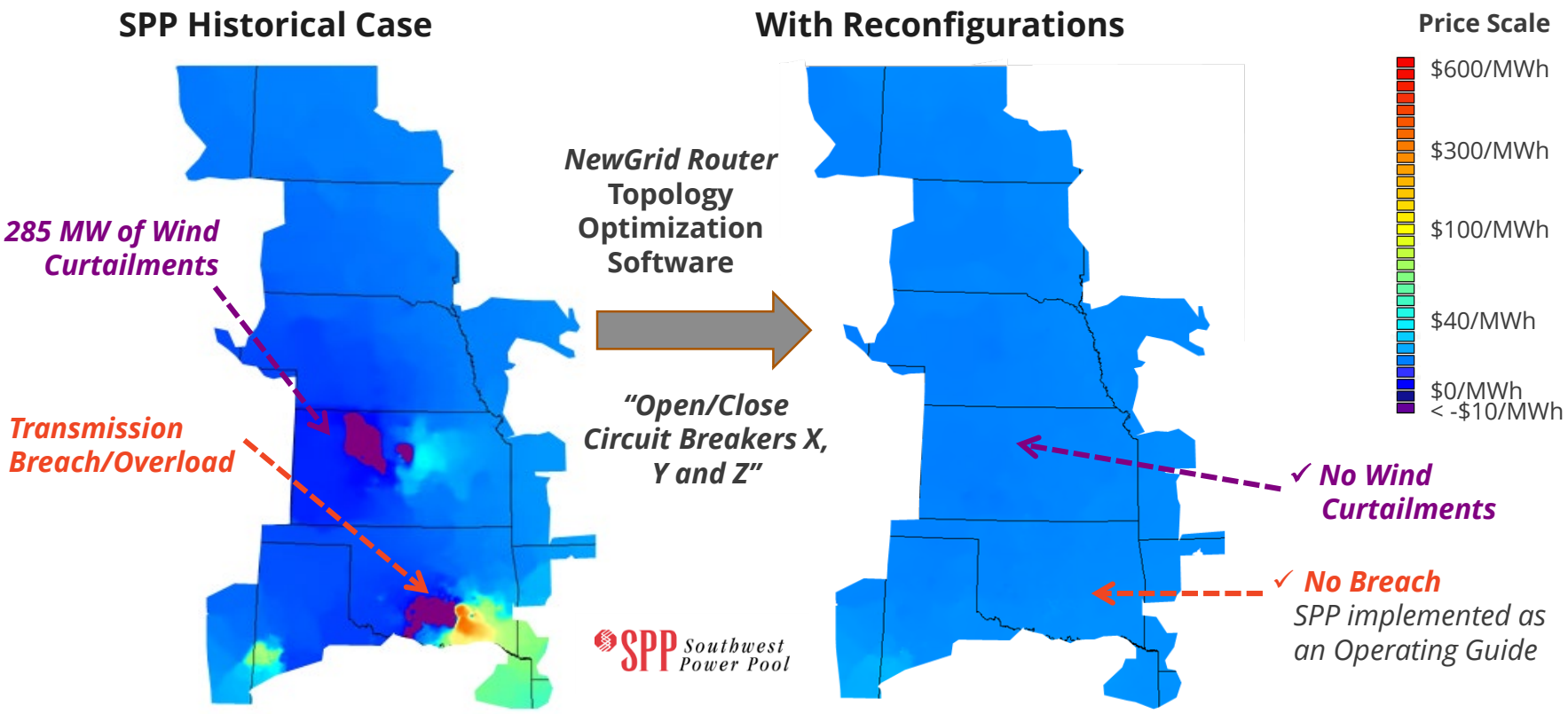
* For single-pressure SF6 breakers. Based on a CIGRE survey of 281,090 breaker-years with responses from 82 utilities from 26 countries, source: A. Janssen, D. Makareinis and C.-E. Sölver, "International surveys on circuit-breaker reliability data for substation and system studies," *IEEE Transactions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

SPP Case Study

Congestion Reduction using Reconfigurations

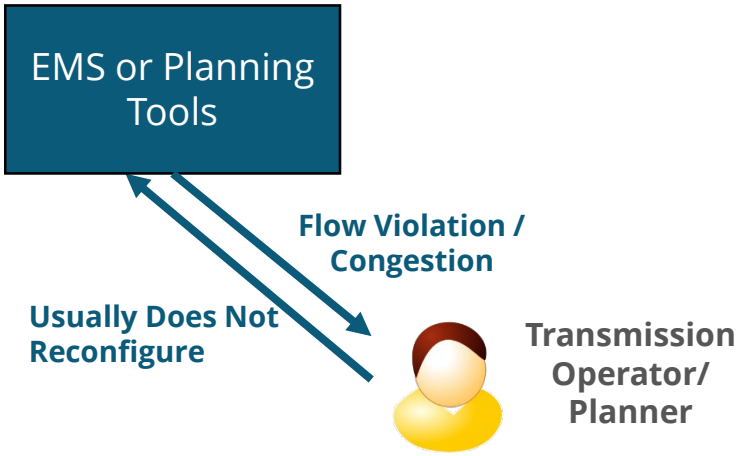
Reconfigurations identified by topology optimization can be a powerful complement to market redispatch for congestion management, materially reducing costs, improving reliability and mitigating curtailments



Reconfiguration Practice

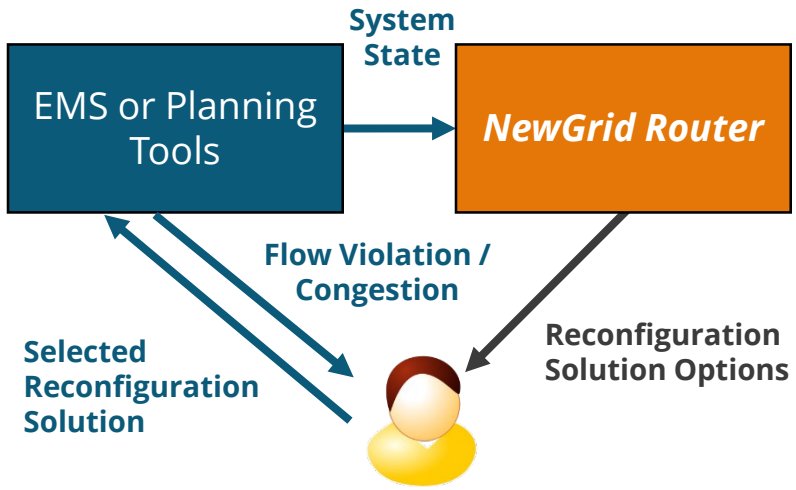
Traditional Practice

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



With Topology Optimization

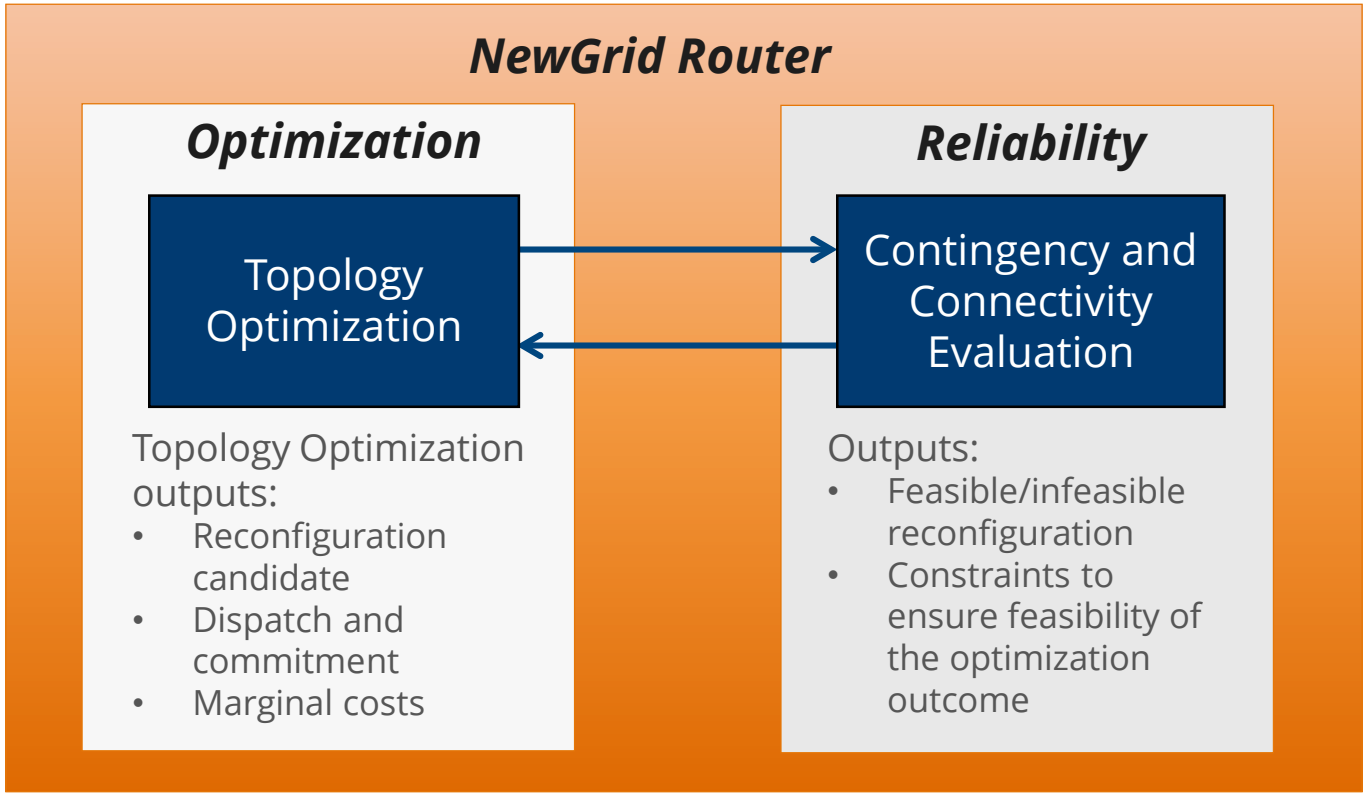
- ✓ Software finds reliable reconfiguration solution *options*
  - Fast search time: 10 s – 2 min
  - Enables all operators to optimize the grid
- ✓ Enables broad application of reconfigurations in different processes
- ✓ Knows when to restore/close open assets
- ✓ Analyzes current system conditions,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



* See list at https://www.pjm.com/markets-and-operations/etools/oasis/system-information/switching-solutions.aspx.

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.



Optimization Scope and Reconfiguration Types

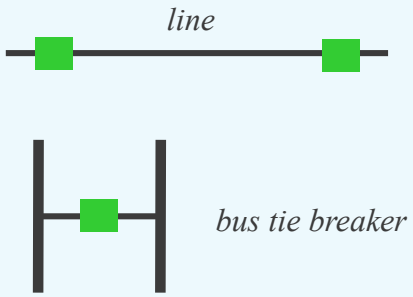
*Optimization routines search reconfigurations to relieve **one or more simultaneous constraints**, and identify **preventive or corrective solutions**.*

Reconfiguration types vary depending on system topology, system conditions and congestion problem characteristics.

Open/close branch

Branch types

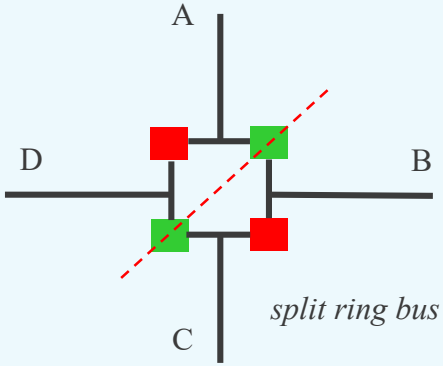
- Lines
- Transformers
- Bus tie breakers
- Reactor by-pass breakers



Bus split/merge

Bus may be split under a range of substation arrangements, such as

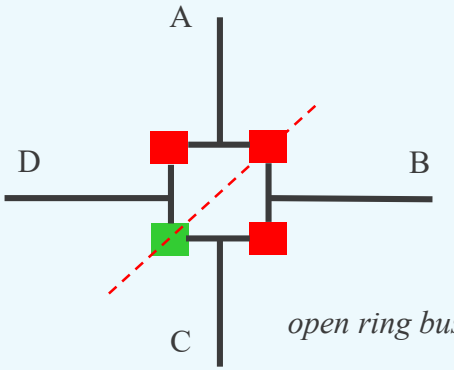
- Ring bus
- Double bus double breaker or disconnect
- Breaker and a half



Contingency-change

Substation reconfigurations

- Bus normally connected
- Split bus or disconnected element under specific contingency conditions



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**
Intra-Day	– Minimize RUC and manual unit starts for constraint management – Unlock capacity from export-constrained areas – **Minimize congestion costs** in the real-time and day-ahead markets – **Reduce renewables curtailments**
Day-ahead	– Help **manage constraints at the RTO seams** – Pre-position the system topology to match expected conditions – Support outage scheduling and coordination (enable conflicting tickets)
Weeks Ahead	– **Mitigate the expected congestion impacts of planned outages** – **Develop Op. Guides** for extreme events that minimize load shedding
Long-Term	– Adjust underlying system topology when new projects are energized – Maximize the benefit-to-cost ratio of new projects – Identify preferred base system topology for long-term planning analyses

This presentation provides MISO and SPP examples of the applications listed in **bold**.

Incremental Technology Implementation

Simplest ↕ *Highest benefits*

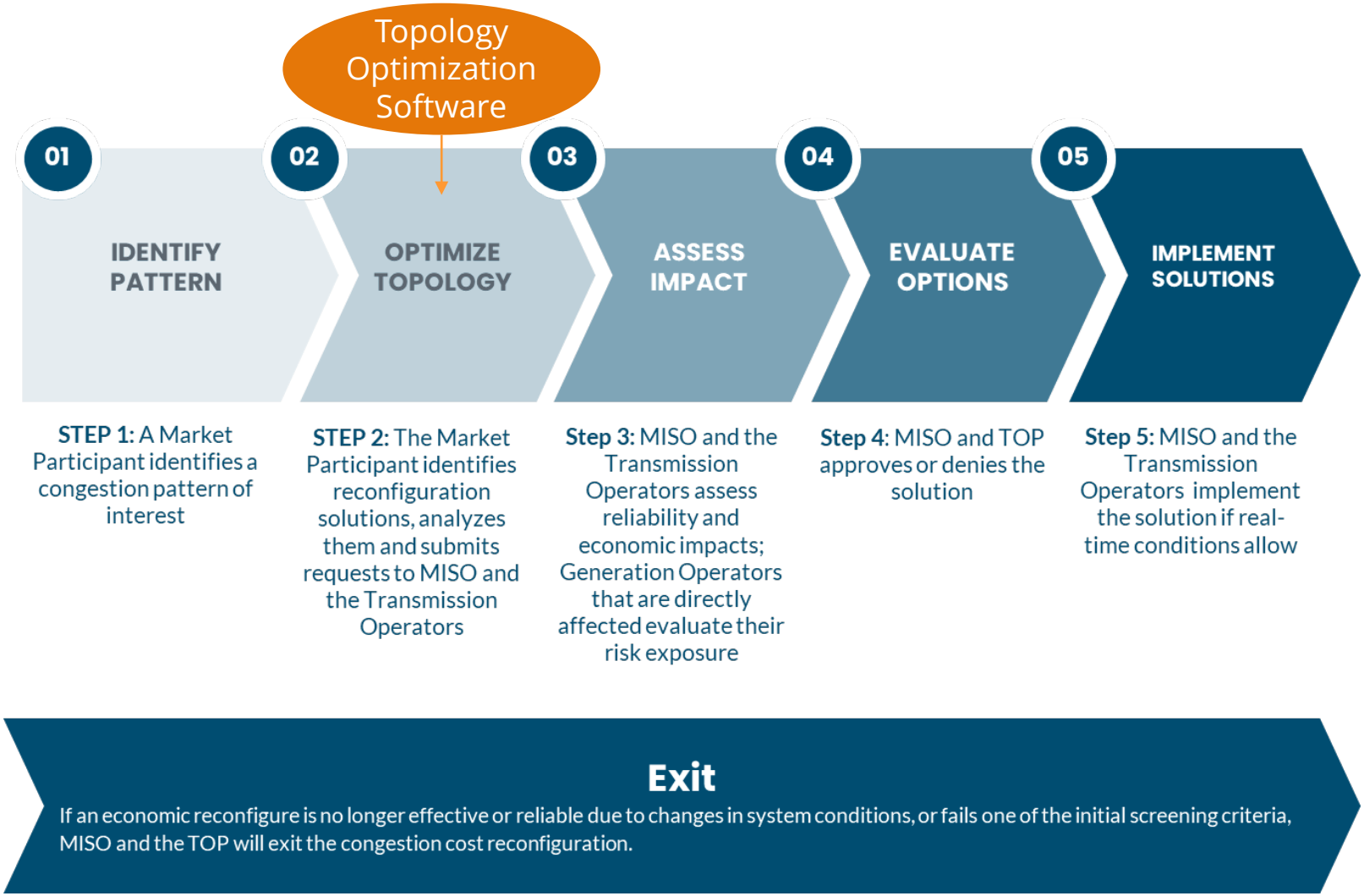
Process	Technology User	Application	System Integration	Timeframe
Step 1 **Reconfiguration Request Process**	**Market Participants** (RTOs, RCs and TOs have the software needed to evaluate requests)	mitigation of expected constraints	none	days / weeks / months
Step 2 **Operations Planning Support**	**RTO, 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 discuss recent experience and updates on reconfiguration requests in the rest of the presentation

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
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Step 4 **Market Clearing**	**RTO**	continuous optimization of topology as conditions evolve	EMS and MMS	days to real-time

Process for Reconfiguration Requests

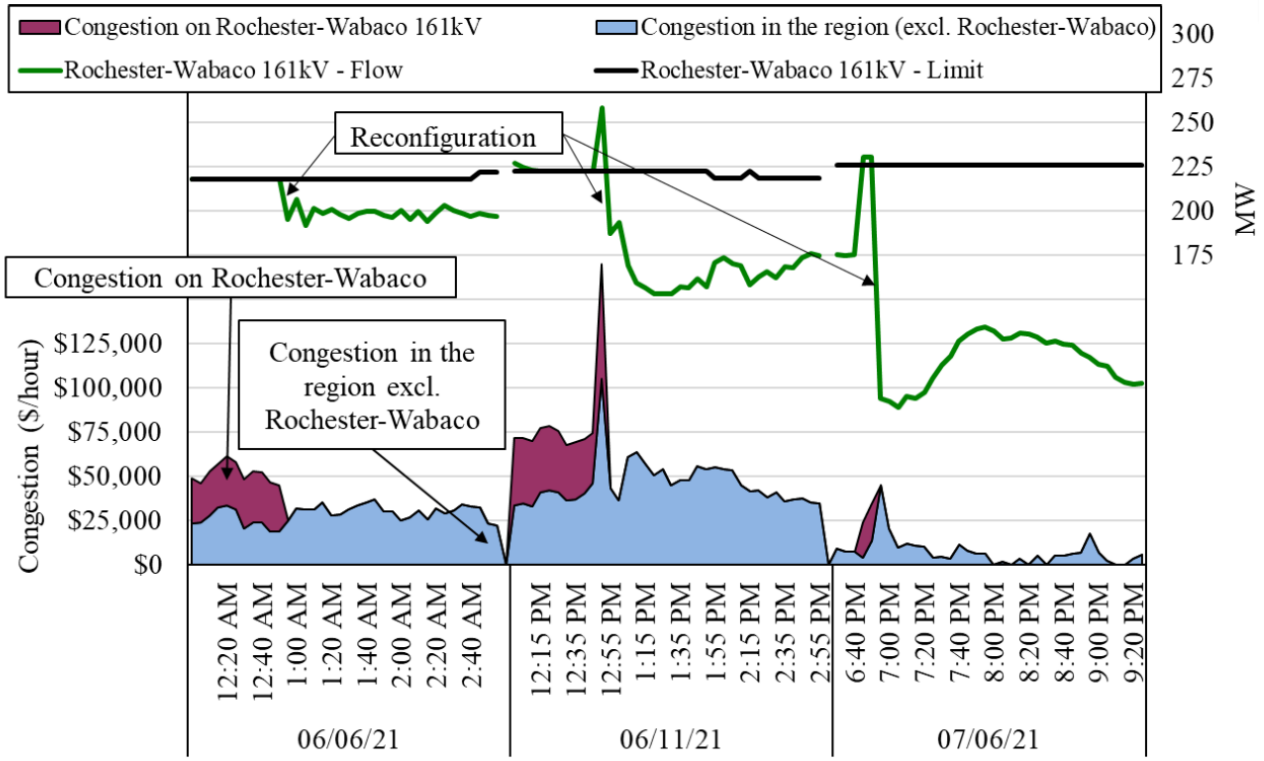


Midcontinent ISO, DRAFT Process to Support Congestion Cost Reconfigurations in the MISO footprint.

Mitigation of Standing Constraint

- Rochester – Wabaco line congestion costs over the summer of 2021: $57+ million
- When reconfigurations were used for these constraints, congestion on the line was eliminated; congestion savings over the summer would have exceeded $38 million.
- Reconfiguration enables over 25% additional throughput for this constraint

Figure 36: Impacts of Reconfiguration on the Rochester-Wabaco Line
June and July 2021

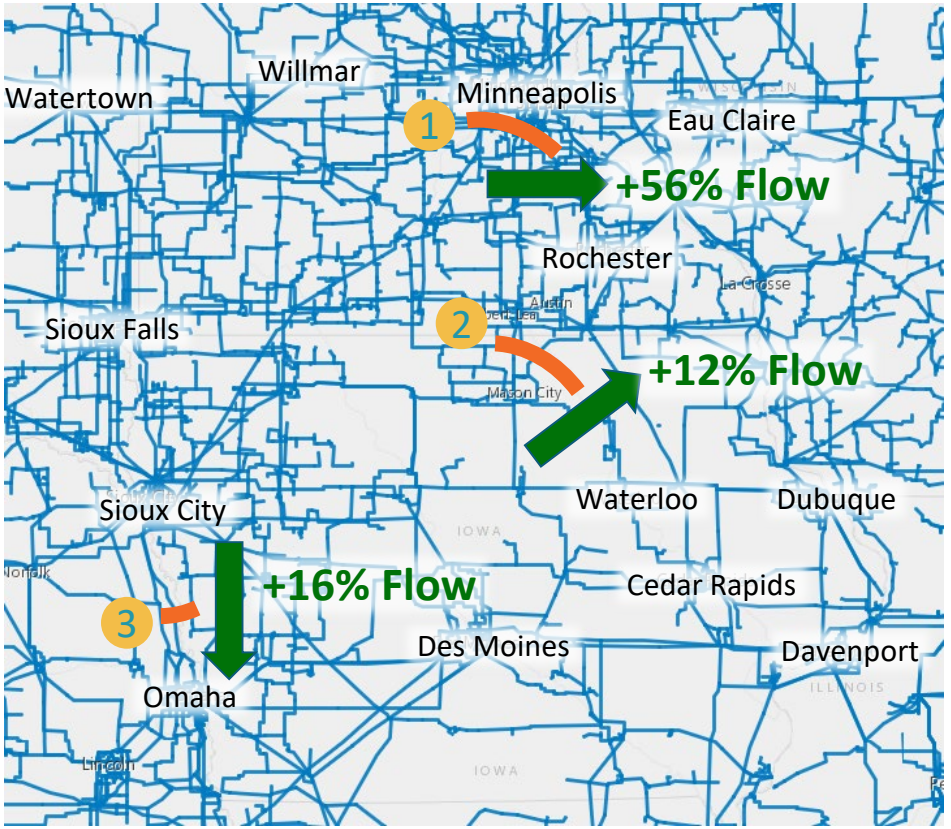


Source of figure and economic impacts: Potomac Economics, 2021 MISO State of the Market Report, 22 June 2022.

Mitigation of 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. We developed and requested reconfiguration solutions for some of the most heavily binding MISO/SPP seam constraints in MISO North.

1. **Chub Lake 345/115 kV for loss of Chub Lake – Hampton 345 kV**
   - Mitigated congestion due to Helena – Scott Co. 345 kV outage in April – November 2021
   - Re-routed flow to reliably increase throughput by up to 56%
2. **Lime Creek – Barton 161 kV for loss of Quinn – Blackhawk 345 kV**
   - Increased throughput by up to 12%
3. **Raun – Tekamah 161 kV for loss of Grimes – Beaver Creek 345kV**
   - 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



Map Source: https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::electric-power-transmission-lines/about

Temporary Transmission Solutions

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), such as these current SPP constraints.

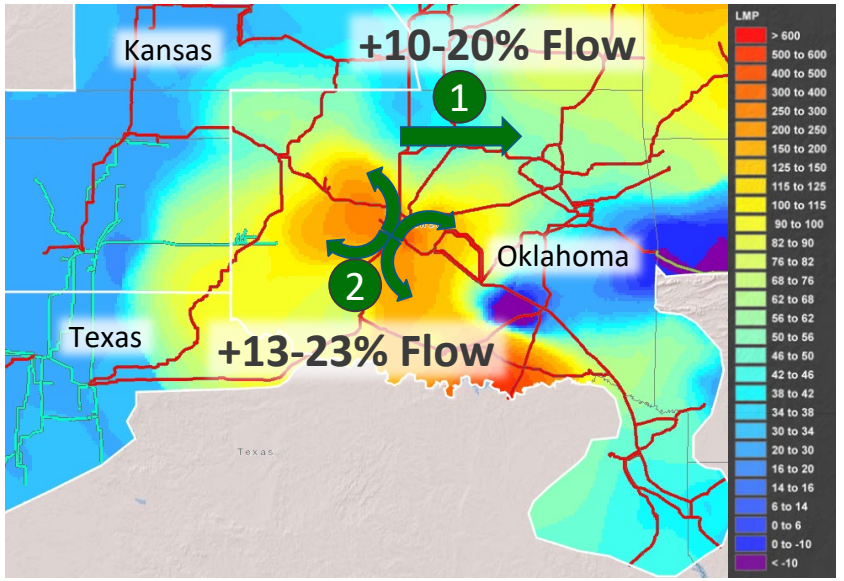
1 Osage – Webb Tap 138 kV flo Sooner – Cleveland 345 kV

- Constraint is very heavily loaded
  - Breaching or binding over 28% of all market intervals in April 2022
  - Active (high flows but not binding) over 60% of all market intervals in April 2022
- SPP identified the constraint as "overlapping Reliability and Economic need" in the 2020 ITP
- Reconfiguration enables 10-20% of increased flow

2 Cimarron XF 345/138 kV constraint

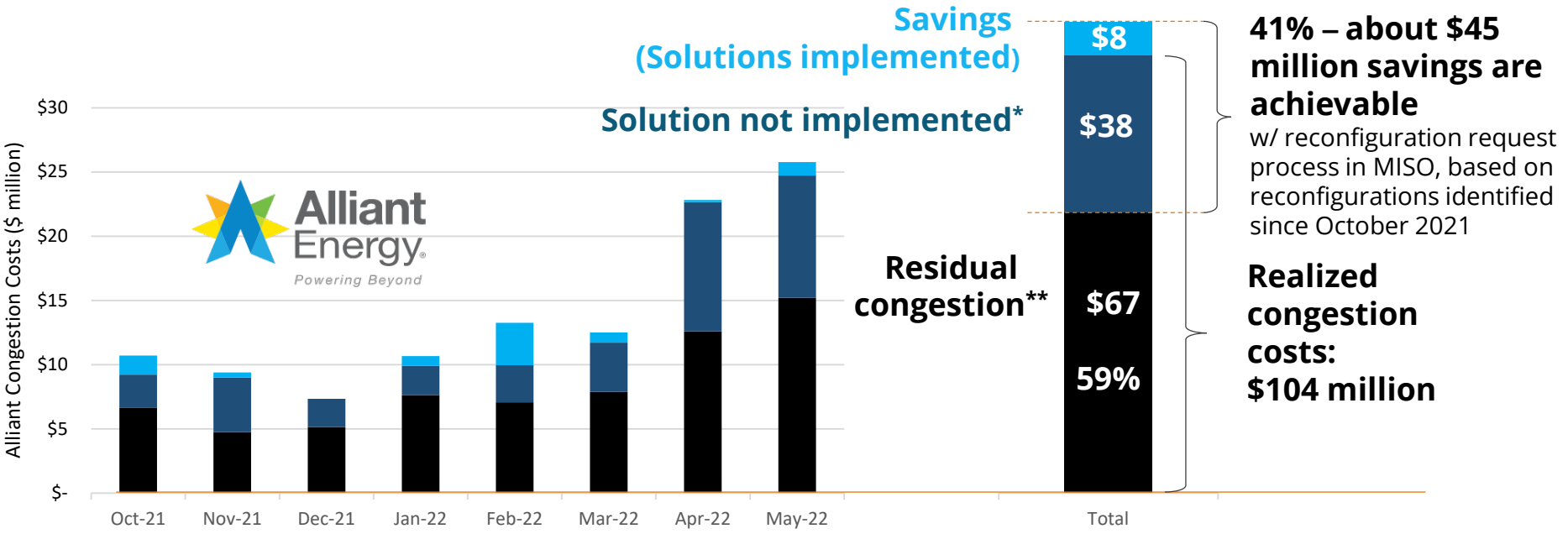
- Breaching or binding over 5% of all market intervals in April 2022, active (high flows, not binding) over 92% of such intervals
- Increases load costs in Oklahoma City (see contour map, the constraint was breaching at the time)
- SPP identified this constraint as the top "Operational need" in the 2020 ITP Assessment Report
- Reconfiguration reliably enables 13-23% increased constraint throughput under congested conditions

SPP Real Time Price Contour Map, June 21, 2022 18:50, https://pricecontourmap.spp.org/pricecontourmap/



Alliant Customer Congestion 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.



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

* Solution not implemented includes the impacts of all solutions found, requested and that were not declined on a technical basis, as well as solutions not requested due to the lack of an established request process.

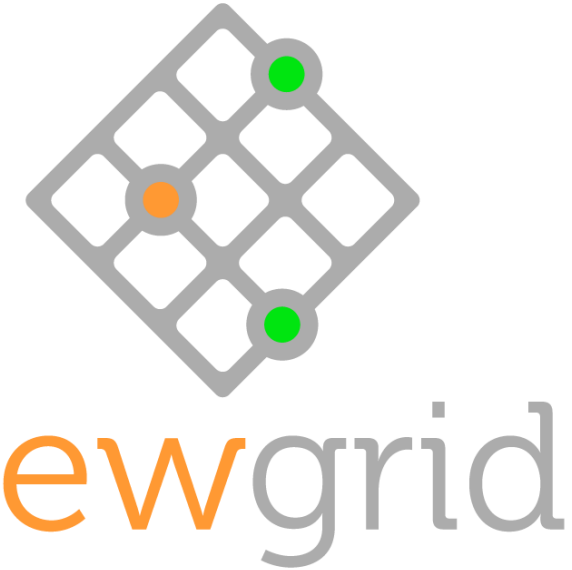
** Residual congestion may be reduced further, as not all significant constraints affecting Alliant were analyzed during the pilot due to scope limitations.

Concluding Remarks

- Topology optimization lowers risks and increases transmission system performance and utilization by rerouting flow away from heavily loaded elements to areas with additional capacity
- Reconfigurations can be very effective to lower congestion costs and improve reliable flow control on the grid, complementing redispatch
  - Reduce the congestion impacts of transmission and generation outages
  - Better manage RTO seam congestion, including in the day-ahead market where there is no effective coordination performed
  - Provide bridge transmission solutions for persistent constraints
- A reconfiguration request process can reduce transmission customer congestion costs by over 40%
  - Simplest implementation from RTO and TOP point of view, as they can evaluate requests using the systems and software they already have to schedule and coordinate outages
  - Software technology use at the RTO, RC and TOPs for system and market operations would provide additional congestion mitigation and reliability improvements

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Appendix

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