MISO

Whitepaper

MISO Transmission mitigation selection and cost estimation approach

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Network Upgrade Mitigation Strategy for DPP Phase 1

This document outlines the collaborative effort between MISO and Pearl Street Technologies to develop a robust and transparent framework for addressing transmission system overloads and voltage violations, as identified by the SUGAR software in DPP-Phase 1 studies. MISO gathered key mitigation data from several Transmission Owners (TOs), which was used to analyze and propose mitigation strategies for various upgrade types. Additionally, MISO's publicly available cost estimation guide was employed to ensure a transparent, data-driven approach to estimating network upgrade costs.

Transmission Line Overload Mitigation

Based on mitigation data shared by MISO, as well as other sources such as the MISO Cost Estimation Guide, BPM-029, and Phase 1 results from the DPP-2020 and DPP-2021 cluster studies, a comprehensive list of conductors with corresponding impedance data across various voltage levels was developed. Appendix A contains a detailed table for all voltage levels, including 69 kV, 115 kV, 138 kV, 161 kV, 230 kV, 345 kV, 500 kV, and 765 kV lines. This table serves as a reference for selecting appropriate mitigation strategies.

For a more detailed discussion of the initial objectives, challenges, and the analysis of MISO data that informed the proposed line overload mitigation approach, refer to Appendix C.

Rules for Automated Mitigation

The following rules, developed with input from TOs, guide the automated mitigation process for line overloads. These rules determine the appropriate conductor type based on post-contingency flow and ensure that the upgrades remain within the maximum allowable capacities for various voltage levels. Additionally, the rules account for terminal equipment limitations, which require verification from TOs, ensuring an efficient and cost-effective approach for mitigating transmission system issues.

For each voltage level, **maximum allowable capacity thresholds** are established based on input from TOs, terminal equipment limitations, and the current branch ratings in the MTEP models:

- The maximum allowable upgrade for 230 kV and below is 3000 A.
- The maximum allowable upgrade for 345 kV and above is 4000 A.

RULE 1: Monitored Element Post Contingency Flow < Maximum Allowable Capacity

Proposed Upgrade Type: Reconductor and Rebuild

- **Select a conductor with higher ampacity**: Based on the mitigation table and kV level, choose a conductor with MVA 1.2x above the contingency flow. A 20% buffer is added to ensure reliability.
- **Update model impedances**: The power flow model is updated to reflect the new conductor's impedance (R/mile, X/mile, B/mile) while considering the line length.
- On implementing the proposed conductor and impedance values, some newly proposed mitigations had impedances higher than those existing in the power flow model. This may be due to limited conductor data in Appendix A. To avoid increasing the impedances while selecting a conductor with higher

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ampacity, the lower of the mitigation impedances or existing impedances will be used. **Incremental upgrades**: If further increments are needed, continue to the next conductor type until reaching the maximum allowable capacity.

RULE 2: Monitored Element Post Contingency Flow > Maximum Allowable Capacity

Proposed Upgrade Type: New Line or New Circuit

Rule 2A: Add a new branch to the power flow model using appropriate conductor types from Appendix A.

- *Alternatively, if preferred by the TO, add a new branch in the power flow model, duplicating the characteristics of the overloaded line.*

- After implementing the new line or new circuit mitigation, due to the added generation, there are instances where additional iterations to solve and mitigate each identified overload may be required. To make the subsequent iteration more practical and avoid adding multiple lines in parallel, the following rule is proposed.

Rule 2B: *If the overload still exists after following Rule 2A*:

- If a new line has already been added and all lines are not fully upgraded to maximum allowable capacity, reconductor all lines to the maximum conductor rating.
- If a new line has already been added and all lines are upgraded to maximum allowable capacity, add a new branch to the power flow model using the conductor type with the maximum allowed capacity from Appendix A.
- Since this rule implementation is expected in very rare cases or only for highly overloaded lines, the mitigator will add a FLAG for TOs to review for alternative mitigation.

RULE 3: Monitored Element Post Contingency Flow < 120% Original Branch Capacity (MVA)

Proposed Upgrade Type: Reconductor and Rebuild + Flagging monitored element for TOs

- Use the modeling steps as mentioned in RULE 1 for rebuild & reconductor.
- Add a FLAG for TOs to confirm whether these monitored elements are terminal equipment limited and if there is an economical mitigation in lieu of rebuild & reconductor.

After implementing a mitigation per RULES 1–3, the mitigated line will, by default, have the same nominal and emergency ratings (i.e., Rate A and Rate B) as specified in the mitigation table (column: MVA). This approach is consistent with previous MISO Phase 1 mitigation upgrades and associated IDV files. Alternatively, if a TO proposes their preferred conductor types, including different Rate A and Rate B MVA values, the mitigated lines within that TO's territory will be based on those different ratings.

Example

Table 1 below presents the proposed conductor characteristics for 161 kV lines. When the study model shows a final contingency flow of 200 MVA on a 161 kV monitored element, which results in an overload, the automated process follows RULE 1. The system first calculates the required conductor capacity by adding a 20% buffer to the contingency flow. In this case, the minimum required capacity becomes 240 MVA (200 MVA x 1.2). The automation then recommends an upgrade to a **new conductor and rebuilds the transmission line** to handle

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this increased flow. A conductor capable of handling at least 240 MVA, such as the 666 ACSR conductor, which has a capacity of 246 MVA (as shown in Table 1), is selected to provide sufficient margin.

The system also checks the maximum allowable capacities for each voltage level, as defined in the rules. For example, RULE 2 ensures that for 161 kV upgrades, the cap is set at 3000 A or 837 MVA. If the final contingency flow exceeds this cap, the automation adds a **new line or circuit**.

Table 1: Mitigation for 161 kV line

Conductor Type	MVA	Amperes	R/mile	X/mile	B/mile
336 ACSR	160	573.76	0.001162	0.003102	0.001388
666 ACSR	246	882.16	0.000692	0.002898	0.001482
954 ACSR	309	1108.08	0.000486	0.002851	0.001528
1272 ACSR	364	1305.31	0.000375	0.002776	0.001562
1600 A	446	1599.37	0.000305	0.002714	0.001592
1272 ACSS	551	1975.9	0.000444	0.002776	0.001562
3000 A (Max cap)	837	3000	0.000215	0.002013	0.002154

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Mitigation Cost

MISO provides exploratory cost estimates for AC transmission projects, including new single circuits, rebuilds, and reconductoring, using $/mile costs defined by voltage class and, in most cases, the state where the project is to be developed. This data is used to calculate network upgrade costs as follows:

For RULE 1:

- **Line Cost:** The rebuild single circuit $/mile cost provided in Table 4.1-3 is used. This unit cost is multiplied by the line length to determine the network upgrade cost for the relevant voltage level.

For RULE 2:

- **Line Cost:** The new single-circuit transmission line $/mile cost from Table 4.1-1 is used. This unit cost is multiplied by the line length to estimate the network upgrade cost for the applicable voltage level. TO (or

Area Number) to state mapping, as provided by MISO, helps identify the appropriate $/mile value by state.
    - For line mitigations added based on Rule 2B, the new double-circuit transmission line $/mile cost from Table 4.1-2 is used instead of the new single-circuit transmission line $/mile cost.
- **Substation Addition Cost:** Voltage-specific costs are used from the MISO cost estimation guide (Table 4.2-1). As new line costs do not cover substation upgrades, the "Upgrade - Add One Position (Breaker-and-a-Half Bus)" configuration is applied to represent the cost estimate.

Key Assumptions in Line Network Upgrade Costs:

1. **For RULE 1 and RULE 3** (until TO confirms whether the monitored element is terminal equipment-limited or not), the proposed upgrade type is Rebuild and Reconductor. The cost estimation guide's "rebuild - single" cost is used. For 345 kV, 500 kV, and 765 kV, where rebuild costs are not provided, the "new-single" cost is applied. (Alternatively, reconductor costs for the entire TO territory or specific voltage levels may be used if preferred by the TO).
2. **For RULE 2B**, since the cost estimation guide does not provide "new-double" costs for 500 kV and 765 kV, the "new-single" cost per circuit is applied.
3. Any additional line added under **RULE 2B** will use the above cost estimation without any changes. These mitigations are flagged for TO review if alternative mitigations are available instead of adding multiple lines in parallel.
4. **For upgrades spanning multiple states**, the average upgrade costs across those states are used.
5. **For area or state intertie upgrades**, a 50% change of ownership is assumed, and average upgrade costs from TOs are applied, contingent on receiving TO-specific unit cost data.
6. **For Line Lengths:** The values provided in the power flow models are used. If line lengths are missing, the SUGAR Mitigator estimates the lengths using impedances. The mitigation results will include information on which line lengths were calculated by the SUGAR Mitigator for cost calculation purposes, so stakeholders can verify and confirm.
7. **For Zero Impedance Lines:** If the line length is not specified in the power flow model, a distance of 0.1 miles is considered for cost calculations.

Note

The proposed line overload mitigation rules are currently applied by default across all MISO regions and Transmission Owners (TOs). However, the SUGAR Mitigator can be supplied with TO-specific requirements. TOs may utilize the table provided in Appendix B to share their acceptable conductor types and corresponding values. This includes:

- Conductor Data: Incorporating TO-specific conductor details, as outlined in the mitigation table.
- Upgrade Types and Capacity Thresholds: Customizing upgrade types and maximum capacity thresholds for each voltage level based on TO preferences.
- Unit Costs: Adjusting $/mile costs to align with TO-specific data, ensuring accurate cost estimation.

This mitigation approach avoids "gold-plating" upgrades by preventing the assignment of unnecessarily high conductor ratings. The mitigation table recommends selecting conductors with lower or higher MVA ratings than those suggested in the MISO cost estimation guide when industry-proven alternatives can effectively resolve the

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overload. These updates ensure the automation remains flexible and adaptable to real-world variations or preferences provided by individual TOs.

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Transformer Overload Mitigation

Based on MISO mitigation data, the following automated rules and cost estimation methodologies are applied for transformer overloads for both 2-winding and 3-winding transformers.

Rules for Automated Mitigation

RULE 1: For Primary or Secondary Voltage of 69 kV:

- Replace the existing transformer with the next increment MVA transformer to address the overload.

RULE 2: For Both Primary and Secondary Voltages Above 69 kV:

- **Add a Second Transformer**: Incorporate an additional transformer into the circuit, matching the characteristics of the overloaded unit.
- **Increase Transformer Ratings**: If the overload persists, increase the rating of both the new and existing transformers to the next increment MVA.

RULE 2 Exception: In cases where two transformers already exist on the same monitored buses, avoid adding a third transformer. Instead, increase the ratings of the existing transformers to mitigate the overload, accounting for substation expansion constraints. If this rule leads to the proposal of a transformer with a capacity exceeding the maximum transformer rating (MVA) limit set by the TO, the MITIGATOR will flag such upgrades for TO review.

Mitigation Cost

Consistent with MISO's cost estimation guide, the mitigation costs include the following components:

1. **Transformer Costs:** Derived from Table 2.3-7 of the MISO cost estimation guide, which provides the cost per MVA. The transformer cost is calculated by multiplying the MVA rating of the proposed upgrade.
2. **Substation Costs**: Based on Table 4.2-1 of the MISO cost estimation guide, which outlines costs for the "Add 1 Position (Breaker-and-a-Half Bus)" configuration. These costs are included to align with MISO's exploratory cost estimation formula.

Cost Application Rules:

For RULE 1 & RULE 2 Exception: Only transformer costs are considered.

For RULE 2: Both transformer and substation costs are incorporated into the calculation.

Notes for Three-Winding Transformer:

- **Voltage Threshold**: SUGAR disregards violations involving primary or secondary winding voltages below 69 kV.

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- **Rating Selection**: When increasing ratings under Rule 2, the highest power rating (MVA) required to resolve violations among the three windings is selected.
- **Cost Estimation**: Since the MISO Cost Estimation Guide does not provide specific details for three-winding transformers, costs are calculated based on the primary and secondary voltage levels and the highest MVA values.

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Voltage Violation Mitigation

The SUGAR Mitigator automatically proposes SVCs (Static VAR Compensators) to mitigate voltage violations. To optimize costs, SUGAR will also consider discrete switched shunts (e.g., capacitor banks) as an alternative for some SVCs, wherever possible.

Based on MISO's mitigation data:

- Capacitor banks are typically assigned at lower voltage levels (e.g., 69 kV and 115 kV).
- SVCs are more common at higher voltage levels (e.g., 345 kV and 500 kV).

Rules can be established for specific voltage levels or adjusted based on TO preferences. The current steps for mitigation are as follows:

Steps for Automated Mitigation

Step 1: Propose SVCs with Non-Discrete Values to Mitigate Voltage Violations

- SUGAR automatically adds SVCs at the required MVAr sizes.

Step 2: Evaluate Discrete Switched Shunt Devices for Cost Optimization

- Attempt to replace the SVC from Step 1 with a discrete switched shunt.
- Replace the SVC with a capacitor bank at the bus, sized with a 20% buffer and rounded up to the nearest integer MVAr.
    - Example: If 24.2 MVAr is required, apply a 20% buffer (29.04 MVAr) and round up to 30 MVAr.
    - Assume discrete steps of 20% capacity for switched shunt devices.
        - *Alternate steps can be incorporated based on specific MISO or TO preferences.*
- The replacement is accepted if the power flow models (under contingencies) still solve without incurring voltage violations; otherwise, the replacement is rejected with the SVC still in place.

Step 3: Round the remaining SVCs to discrete values

- Round up to the nearest 100 MVAr increment.

Mitigation Cost

Consistent with the MISO cost estimation guide, the cost of voltage violation mitigation includes two components: equipment unit cost and bus position addition cost.

1. Equipment Cost: Derived from Table 2.3-8 of the guide, accounts for material, shipping, foundation, and installation expenses. To align with MISO's exploratory cost estimation practices, a 30% contingency and 7.5% AFUDC are added to the base cost.

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2. Bus position addition cost: voltage-specific costs are used from the MISO cost estimation guide Table 4.2-1. As equipment costs do not cover substation upgrades, the "Upgrade - Add One Position (Breaker-and-a-Half Bus)" configuration is applied to represent the cost estimate.

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Additional Mitigation Strategies

In addition to the automated mitigation strategies, for specific overloads and violations identified during generator interconnection studies MISO may also apply the following additional mitigation approaches:

- **Backbone Mitigation:** During study model creation, after applying dispatch rules, the study model may be infeasible due to inadequate real power transfer or local voltage collapse. SUGAR can automatically propose backbone upgrades in the form of placeholder transmission paths, modeled as phase-shifting transformers (similar to the impact of HVDC lines with real power flows in the system intact case), or SVCs in order to stabilize the network and yield a solvable model. During the result review step, MISO would either accept the placeholder backbone upgrades or use them as guidance for placing approved MTEP or Prior Queued (PQ) upgrades, or other replacements deemed more appropriate by MISO.

- **Contingency Non-Convergence Mitigation:** In some cases, there may not be a feasible solution to a contingency, yielding a non-convergence in the solver. When such non-convergence issues arise, DC loading percentages are considered in identifying the most appropriate upgrade types rather than AC loading percentages. Using DC loading percentages, SUGAR applies the same automated rules outlined in this document to identify upgrades that will fix the monitored elements and flags these cases as non-convergent. MISO, along with other stakeholders, will have the opportunity to review these proposed upgrades and suggest alternative solutions.

- **Alternate Mitigations:** Once network upgrades are identified using the automated rules outlined in this document, MISO engineers, in collaboration with TOs, Interconnection Customers (ICs), and other stakeholders, will have the ability to review the results and propose alternative mitigation strategies. These may involve leveraging existing planned upgrades (MTEP or PQ) that could address the overloads or identifying more economical alternatives compared to the automatically generated solutions. In some instances, where limited geographical information exists, a completely new line might be suggested by stakeholders to resolve multiple overloads. However, the mitigator will follow the prescribed rules for automatic identification.

MISO will provide stakeholders with a template to propose alternate mitigations, either by modifying the parameters of the already proposed upgrades or by submitting a new IDV file to address the overloaded monitored elements. The final results will include a column specifying whether the upgrade was automatically generated using the rules in this document or proposed by TOs, ICs, or MISO.

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Appendix A

Table 2: Mitigation Table (including missing impedances)

Conductor	New Rating	Amps	R/mile	X/mile	B/mile
69 kV					
336 ACSR	69	577.35	0.007402	0.01566	0.000276
666 ACSR	106	886.94	0.003765	0.014839	0.000292
477 ACSS	140	1175			
1000 A	240	2008.17			
3000 A (cap)	359	3000			
115 kV					
	115	577	0.002665	0.005975	0.000717
666 ACSR	176	883.6	0.001355	0.005679	0.000756
954 ACSR	217	1089.43	0.000953	0.005588	0.00078
1272 ACSR	260	1305.31	0.000735	0.00544	0.000797
954 ACSS	297	1491.07	0.000598	0.005328	0.000814
795 ACSS	329	1650	0.001154	0.0056	0.00078
	394	1978	0.00087	0.00544	0.000797
3000 A (cap)	598	3000			
138 kV					
336 ACSR	134	560.62	0.001851	0.004149	0.001032
666 ACSR	211	882.76	0.000941	0.003944	0.001089
954 ACSR	265	1108.68	0.000662	0.00388	0.001123
1272 ACSR	281	1175.62	0.000511	0.003778	0.001147
954 ACSS	395	1652.56	0.000801	0.003889	0.001123
1272 ACSS	472	1949.6	0.000604	0.003778	0.001147
1590 ACSR	525	2196.44	0.000346	0.003067	0.001426
2-954 ACSR	530	2217.36	0.000331	0.002831	0.001523

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3000 A (cap)	717	3000			
161 kV					
336 ACSR	160	573.76	0.001162	0.003102	0.001388
666 ACSR	246	882.16	0.000692	0.002898	0.001482
954 ACSR	309	1108.08	0.000486	0.002851	0.001528
1272 ACSR	364	1305.31	0.000375	0.002776	0.001562
1600 A	446	1599.37	0.000305	0.002714	0.001592
1272 ACSS	551	1975.9	0.000444	0.002776	0.001562
3000 A (Cap)	837	3000	0.000215	0.002013	0.002154
230 kV					
	386	969.00	0.000243	0.001455	0.0029
1272 ACSR	519	1302.8	0.000184	0.001393	0.003102
1590 ACSR	540	1355.52	0.000149	0.001363	0.003161
954 ACSS	637	1599.01	0.000288	0.001433	0.003037
1272 ACSS	772	1937.89	0.000217	0.001393	0.003102
1590 ACSS	901	2261.71	0.000176	0.001362	0.003162
2-666 ACSS	1046	2625.69	0.000204	0.001063	0.003998
3000 A (cap)	1195	3000	0.000099	0.001084	0.003864
345 kV					
3000 A or 795ACSS (2) 954 ACSR (3)	1793	3000.55	0.001044	0.004128	0.001098
4000 A (Cap)	2390	4000			
500 kV					
3-666 ACSR	2165	2500	0.000017	0.00023	0.018002
3-954 ACSR	2598	3000	0.000015	0.000217	0.019936
3-1272 ACSR	3047	3518.37	0.000013	0.000214	0.020129
4000 A (Cap)	3464	4000			

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765 kV					

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Appendix B

Transmission owners may utilize the following table format to submit data pertaining to their acceptable conductor types and impedance values:

Table 3: Mitigation Table Template for Transmission Owners

Area Number	Conductor Type	Voltage	Rating A (MVA)	Rating B (MVA)	R/mile	X/mile	B/mile

Area Number: Transmission Owners Area number corresponding to their branches in the power flow models.
Voltage: Limited to 69kV, 115kV, 138kV, 161kV, 230kV, 345kV, 500kV, and 765kV.
Rating A (MVA) and Rating B (MVA): New conductor's rating. In case only one is provided, SUGAR will consider the same MVA values for both Rating A and Rating B.

Pertaining to transformers and voltage regulation, the Transmission Owner may submit their proposed set of acceptable transformer specifications and any information pertinent to the equipment sizing used in voltage mitigation efforts, inclusive of associated cost considerations.

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Appendix C

Original Approach and Challenges:

The initial scope of work to prepare mitigation rules included the following:

1. Determine the type of upgrades needed to address overloads, such as reconductoring, rebuilding, or adding additional circuits.
2. Define “maximum increase” thresholds for each type of upgrade. For instance, in the case of a 138 kV line overloaded by 100 MVA, use historical data to predict whether a reconductor, rebuild, or new circuit would best address the issue.

The analysis of MISO’s data uncovered inconsistencies, especially regarding thresholds for percentage loading that triggered different types of branch upgrades (bullet 2 above). These inconsistencies posed significant challenges to the initial scope, particularly when focusing on line upgrades.

Key challenges included:

- Data Insufficiency: The available data did not sufficiently address all TOs preferences for upgrades at different kV levels.
- Inconsistent Upgrade Assignments: For monitored elements in the same area, with similar prior and new ratings, different upgrade types were assigned (e.g., reconductor vs. rebuild). This inconsistency was also reflected in the unit costs, which were sometimes the opposite of what was expected (See Table 4).
- Missing Cost Estimates: The MISO cost estimation guide did not provide rebuild costs for 345 kV lines or double-circuit 161 kV lines. Despite this, historical mitigation data showed upgrades for these types of lines.
- Higher Unit Costs: The unit costs ($/mile) derived from the upgrade information and line length calculations were generally higher than the estimates in the MISO cost estimation guide, except for 161 kV lines.

Table 4: Data from MISO mitigation information

Region	Upgrade Type	Monitored Element	Prior Rating	New Rating	Upgrade	Cost	Cost Per Mile
South (TO1)	Reconductor	[redacted]	106	176	[redacted]	$ 22M	$ 1.49M
South (TO1)	Reconductor & Rebuild	[redacted]	106	176	[redacted]	$ 7.7M	$ 0.96M
Central (TO2)	Reconductor	[redacted]	189	243	[redacted]	$ 2.26M	$ 2.00M
Central (TO2)	Rebuild	[redacted]	189	243	[redacted]	$ 8.00M	$ 1.09M

Qualitative Analysis and Determination of Conductor Characteristics:

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A qualitative analysis of the mitigation information from MISO revealed that whenever a TO proposed line mitigation and included the corresponding conductor details, there was consistency in the final line capacity and impedance per unit mile (R/mile, X/mile, B/mile).

For instance, based on MISO mitigation data, upgrading a 115 kV line to 666 ACSR conductor resulted in a new rating of 176 MVA, with impedances per mile of r=0.0014, x=0.0057, and b=0.00076. Similarly, upgrading to 954 ACSR resulted in a new rating of 217 MVA, and to 1272 ACSR, a new rating of 260 MVA, with respective impedance values. **These patterns in historical conductor selection guided the choice of conductor upgrades** and aided in preparation of effective mitigation strategies.

Additionally, the MISO cost estimation guide Table 3.1-5 highlighted typical conductors selected for circuits within each voltage class. However, it also acknowledged that specific upgrade scenarios might require different conductors than those listed, allowing for greater flexibility in addressing unique mitigation needs.

This became the basis of conductor selection via steps for each voltage level. Furthermore, this helps avoid "gold-plating" upgrades by preventing the assignment of unnecessarily high conductor ratings. The mitigation table recommends selecting either lower or higher MVA conductors than the MISO cost estimation guide's suggested levels when a different capacity conductor used in the industry could effectively resolve the overload.

Validation of Conductor Steps:

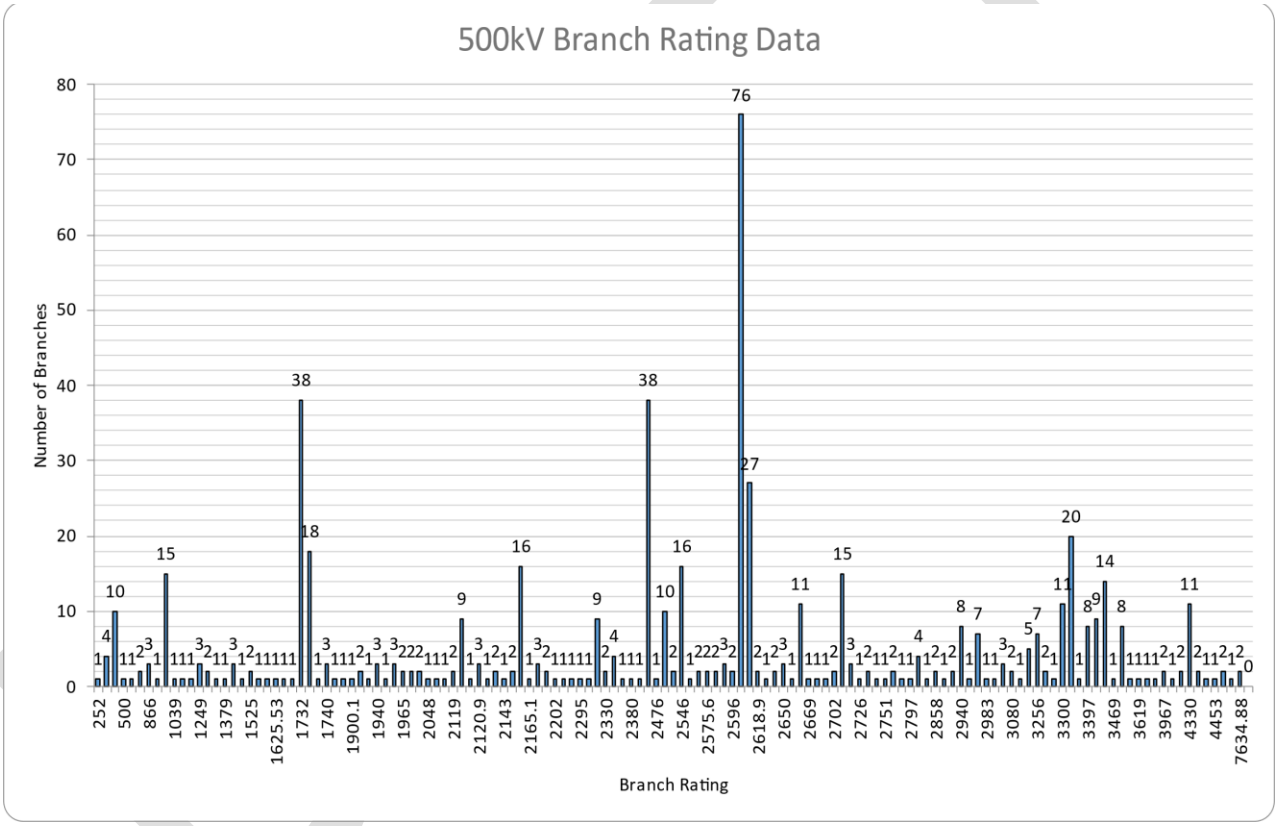
To evaluate the applicability of conductor steps and MISO's typical conductor threshold values, the existing branch ratings from the 2022 peak case were reviewed. Based on the analysis in Table 5, it was found that most voltage levels had branch ratings that were within the typical ratings outlined in the MISO cost estimation guide. Additionally, for different voltage levels, most branches showed common MVA values. For example, as illustrated in the graph below, the 500 kV branches with a 2,598 MVA rating appeared in 76 branches, matching the default MISO value in the cost estimation guide. Deviations from this value, such as 1,732 MVA and 2,395 MVA, were also observed, providing further validation for the collected MISO data and confirming the consistency of the steps in MVA ratings or conductor selection variations.

Table 5: Branch Ratings in 2022 Summer Peak case

kV	Recommended Rating (MVA)	Total Branches	Branches within Recommended Rating	Percentage
69	140	22,581	20,890	92.51%

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115	329	14,942	13,587	90.93%
138	394	12,075	10,688	88.51%
161	460	4,290	3,806	88.72%
230	657	5,725	3,555	62.10%
345	1792	2,931	2,533	86.42%
500	2598	591	286	48.39%



Preparation of Mitigation Steps:

Preparing conductor types for mitigation steps was done iteratively, incorporating inputs from MISO and TOs. The MISO cost estimation guide provided a list of typical conductor types. By analyzing mitigation

data from MISO, previous study mitigation IDV files, and feedback from TOs, the mitigation upgrade table in Appendix A was prepared:

Pass One – Initial Analysis: Incorporated MISO-shared data directly, including impedance values for line mitigation. Established preliminary rules based on existing branch upgrades and known conductor types.

Pass Two – Refinement with Additional Inputs: Supplemented MISO data with inputs from the TOs related to maximum allowable capacity. Added missing conductor types and their ratings, with the expectation that TOs would provide the missing impedance information in subsequent iterations.

Final Pass – Comprehensive Framework: Integrated data from MISO's 2020/2021 Phase 1 mitigation IDV files, along with further MISO/TO feedback. Established a detailed mitigation table based on observed trends and consistent ratings for common conductor types, removing all those conductors not yet used in any mitigation scenarios.

This systematic approach ensured that the framework developed was adaptable and reflective of MISO's standards and practical for addressing transmission overloads effectively and cost-efficiently.

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