2025 ANNUAL
VIOLATION RELAXATION
LIMIT ANALYSIS
INTEGRATED MARKETPLACE

Market Support and Analysis

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REVISION HISTORY

DATE	AUTHOR	CHANGE DESCRIPTION	COMMENTS
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CONTENTS

EXECUTIVE SUMMARY

This report provides the annual analysis of the Violation Relaxation Limits (VRLs) in the Integrated Marketplace. It evaluates how VRLs and their values affect system reliability and prices. While the Data Analysis of Current VRLs section focuses on the previous three years (July 2022 – December 2024), the Sensitivity Analysis for Operating Constraint VRLs and Spinning VRLs used Real-Time Balancing Market (RTBM) studies from the 2024 calendar year. As an update for this analysis, the 2025 reporting year encompasses the full 2024 calendar year.

Table 1 below summarizes the VRL instances in the RTBM and the Day-Ahead Market (DAMKT) for the SPP Integrated Marketplace during the last three reporting years. Note that the RTBM instances account for a 5-minute interval while the DAMKT instances account for a 1-hour interval. Multiple VRL instances can occur per interval if there is more than one constraint with a VRL application in that interval. The Analysis primarily focuses on the Operating Constraint and Spinning VRLs due to the large number of instances in those categories.

Table 1: Summary of VRL instances in the RTBM and DAMKT.

	DAY-AHEAD			REAL-TIME		
	July 2022 – June 2023	July 2023 – June 2024	January 2024 – December 2024	July 2022 – June 2023	July 2023 – June 2024	January 2024 – December 2024
Spinning Reserve	0	0	0	567	402	628
Operating Constraint	406*	131*	234*	71,648	40,282	37,891
Operating Constraint M2M Shadow Price < 1st VRL block	8	41	34	83,921	61,136	84,077

*Phase shifter constraints that breach while the equipment is offline carry a $0 shadow price and no pricing effect. These cases were excluded from the totals. They made up 0 of the 406 Day-Ahead Market (DAMKT) constraint breaches in 2023, 66 of 197 in 2024, and 66 of 300 in 2025.

RECOMMENDATIONS

Based on the analysis presented in this report, SPP does not recommend any changes to the operating constraint (OC) VRL blocks. The analysis did not show an operating constraint sensitivity that reduced both the cost and the number of breaches. Given this, SPP believes that the current VRL block, which is a uniform block of $1,500, provides a proper balance between economics and reliability.

SPP does not recommend any changes to the Regulation-up plus Spinning Reserve VRL. When comparing the current $250 Regulation- up plus Spinning Reserve VRL to the other sensitivities, there is not enough change in pricing and shortage/scarce amounts to warrant a change in the current base value.

SPP does not recommend any changes to the VRLs related to Resource Capacity, Global Power Balance, or Resource Ramp since these VRLs appear to be effective.

BACKGROUND

When generating a solution, the market clearing engine (MCE) attempts to enforce all constraints. This may result in a solution that is not feasible. In these situations, SPP will apply VRLs in the MCE solution. VRLs attempt to achieve a reasonable balance between honoring operating requirements and constraints while mitigating large price excursions or other extreme prices. In other words, VRLs balance reliability and cost.

While running the security constrained economic dispatch (SCED) for DAMKT and RTBM cases, constraints are optimized to determine the most efficient and reliable solution. At times, system limitations may cause the shadow price of a constraint to exceed a defined VRL. In this situation, the constraint's limit is relaxed, and the shadow price is replaced with the VRL penalty allowing the SCED to solve more economically.

The five VRL constraint/categories are:

1. Regulation-up plus Spinning Reserve
2. Operating Constraint – including:
    a. Manual
    b. PNode
    c. Watch List
    d. Flowgate
    e. Real-Time Contingency Analysis (RTCA)
3. Resource Ramp
4. Global Power Balance
5. Resource Capacity

In the Marketplace, there also exists unavoidable trade-offs in applying VRLs of the constraint type categories where a higher VRL value is an indication of the relative priority for enforcing the constraint type. The SCED solution priority for the Day-Ahead Market and Real-Time Balancing Market are:

- Regulation-up plus Spinning Reserve Requirement is relaxed before an Operating Constraint
- An Operating Constraint is relaxed before a Resource Ramp Constraint
- A Resource Ramp Constraint is relaxed before the Global Power Balance Constraint
- The Global Power Balance Constraint is relaxed before a Resource Capacity Constraint

In practice, lower shift factors/sensitivities on an operating constraint could lead to a resource meeting the Regulation-up plus Spinning Reserve Requirement at the expense of resolving a transmission constraint when it is more economical to do so.

Table 2 contains the VRL constraints and values currently in place, as listed in the SPP Open Access Transmission Tariff.

Table 2: VRL constraints and values

CONSTRAINT TYPE	DESCRIPTION	VRL
Resource Capacity	The minimum and maximum MW dispatchable output of a Resource as indicated in a Resource Offer.	$100,000
Global Power Balance	Energy needed to balance Resources and load.	$50,000
Resource Ramp	The ramp capability of a Resource as indicated in the Resource plan.	$5,000
Operating Constraint not subject to Market-to-Market coordination	A MW limit that can be imposed on SPP related to MW flow across a market node, a manually identified transmission constraint, a Watch List transmission constraint, a flowgate constraint, or a transmission constraint identified by SPP's Real-Time contingency analysis.	$1,500 when the loading is greater than 100% and less than or equal to 101% at each network constraint at each Operating Constraint.
		$1,500 when the loading is greater than 101% and less than or equal to 102% at each network constraint
		$1,500 when the loading is greater than 102% and less than or equal to 103% at each network constraint
		$1,500 when the loading is greater than 103% and less than or equal to 104% at each network constraint
		$1,500 when the loading is greater than 104% at each network constraint
Operating Constraint subject to Market-to-Market coordination		MISO's Shadow Price as further defined in Section 3.1 of Attachment 2 of the SPP-MISO JOA
Regulation-up plus Spinning Reserve Constraint	A MW value representing the sum of the Regulation-Up requirement and Spinning Reserve requirement.	$250

Each year, the analysis and a set of proposed VRLs must be reviewed by the applicable working groups and committees and reviewed and approved by the SPP Board of Directors as described in the Market Protocols and SPP Open Access Tariff. Sources for these requirements are found in:

- Integrated Marketplace Protocols 4.1.4 - Violation Relaxation Limits
- SPP Open Access Transmission Tariff - Attachment AE section 3.4 - Violation Relaxation Limit Reporting and Addendum 1

DATA ANALYSIS OF CURRENT VRLS

The following section provides an overview and analysis of the VRL usage in the SPP Integrated Marketplace, which primarily focuses on Operating Constraint and Regulation-up plus Spinning Reserve VRLs. The analysis and reporting timeline requirements outlined in the Tariff and Protocols were updated this year to align with the SPP Board approval process (RR671). Data referred to by reporting year follows the convention defined below:

- Reporting Year 2023: *July 2022 – June 2023*
- Reporting Year 2024: *July 2023 – June 2024*
- Reporting Year 2025: *January 2024 – December 2024*

BINDING IN THE INTEGRATED MARKETPLACE

The charts shown in Figures 1 and 2 below illustrate the relative distribution of the binding[1] constraints in the RTBM and DAMKT, grouped by shadow price. The Day-Ahead Market experiences more binding occurrences in the [$0-$100]/MW shadow price range, while the RTBM experiences a wider distribution. This is expected, as the RTBM has additional price volatility due to changing real-time conditions and shorter ramping intervals (five minutes in the RTBM versus one hour in the DAMKT). The DAMKT also has flexibility with virtual bids/offers providing more options to solve at a lower shadow price and different resource offer and dispatch behavior than the RTBM.

[1] A constraint is binding when the market clearing engine requires re-dispatching resources to maintain flows at the constraint's limit.

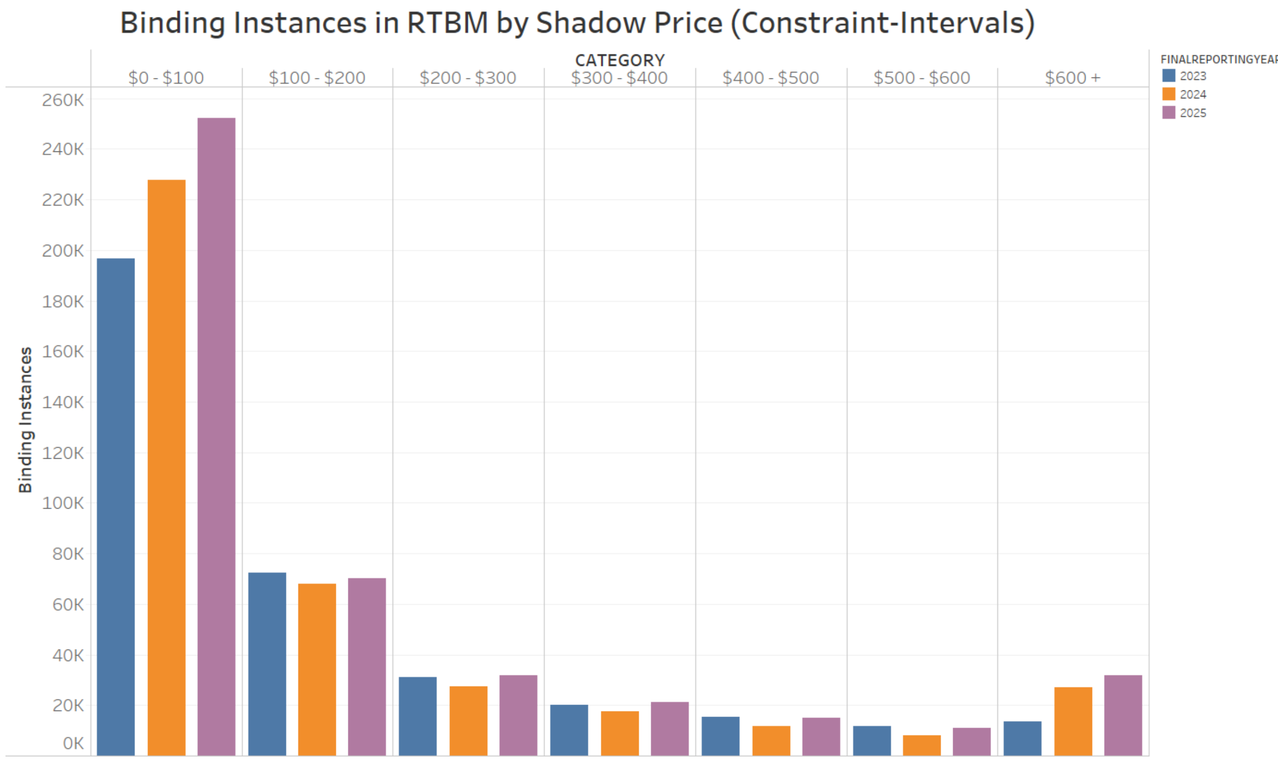

Figure 1: Binding instances in the Real Time Balancing Market

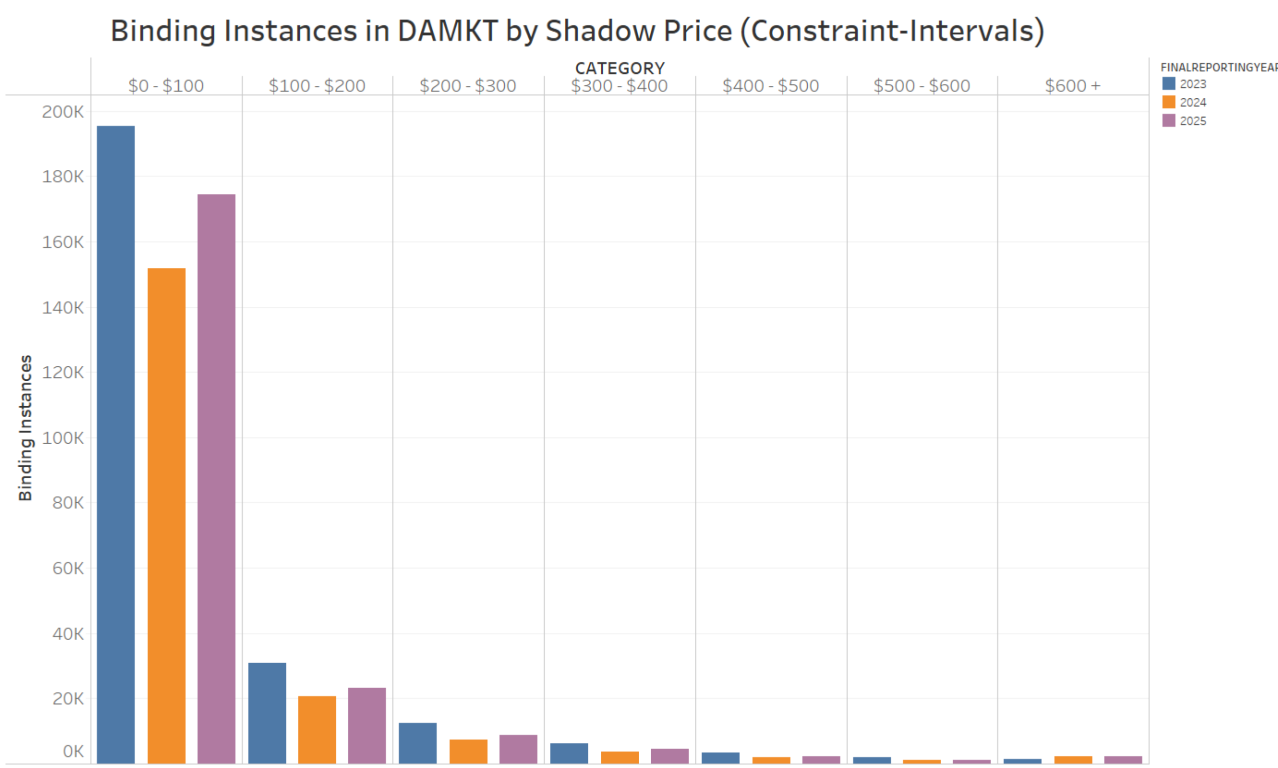

Figure 2: Binding instances in the Day-Ahead Market

Figures 3 and 4 illustrate the distribution of binding intervals in the RTBM and DAMKT as a percentage of all binding instances grouped by shadow price.

When inspecting the binding instances by shadow price as a percentage of all binding instances, notice there is a higher concentration of DAMKT binding instances in the $0 - $100 shadow price range. This is expected due to less volatility in the DAMKT than RTBM.

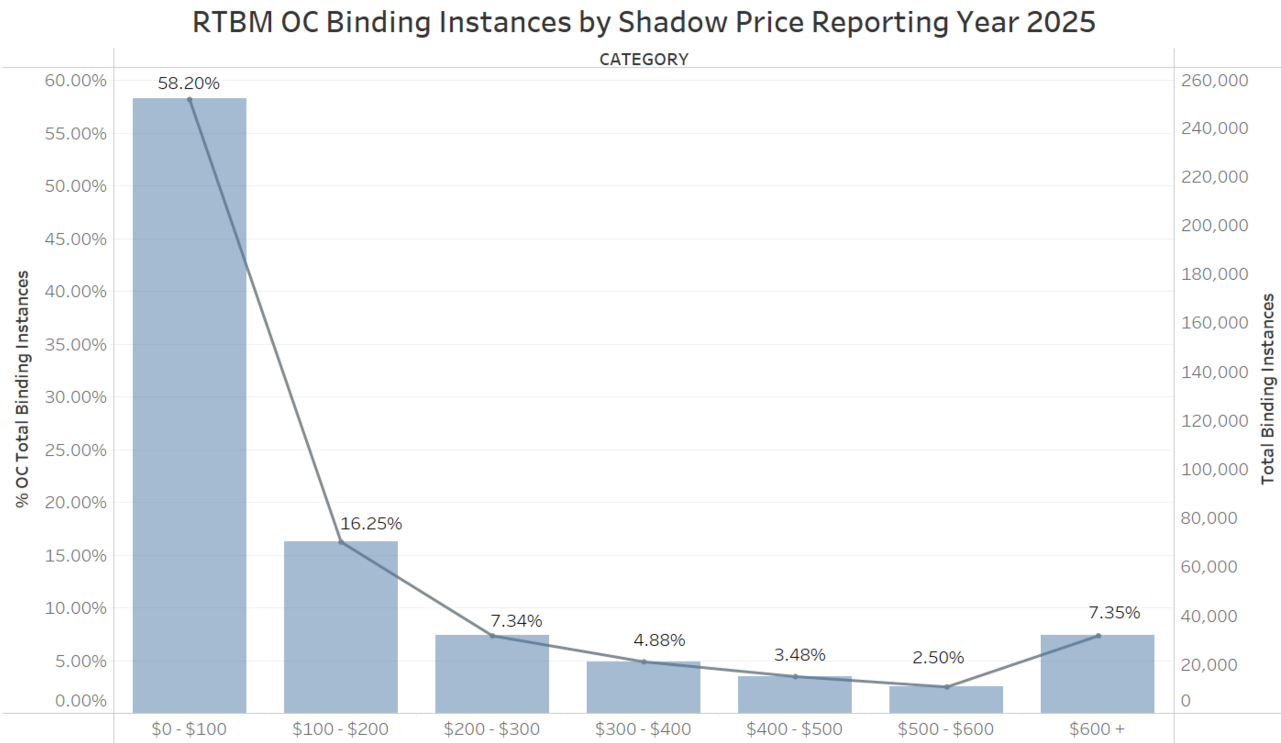

Figure 3: RTBM OC Binding Instances by Shadow Price for Reporting Year 2025

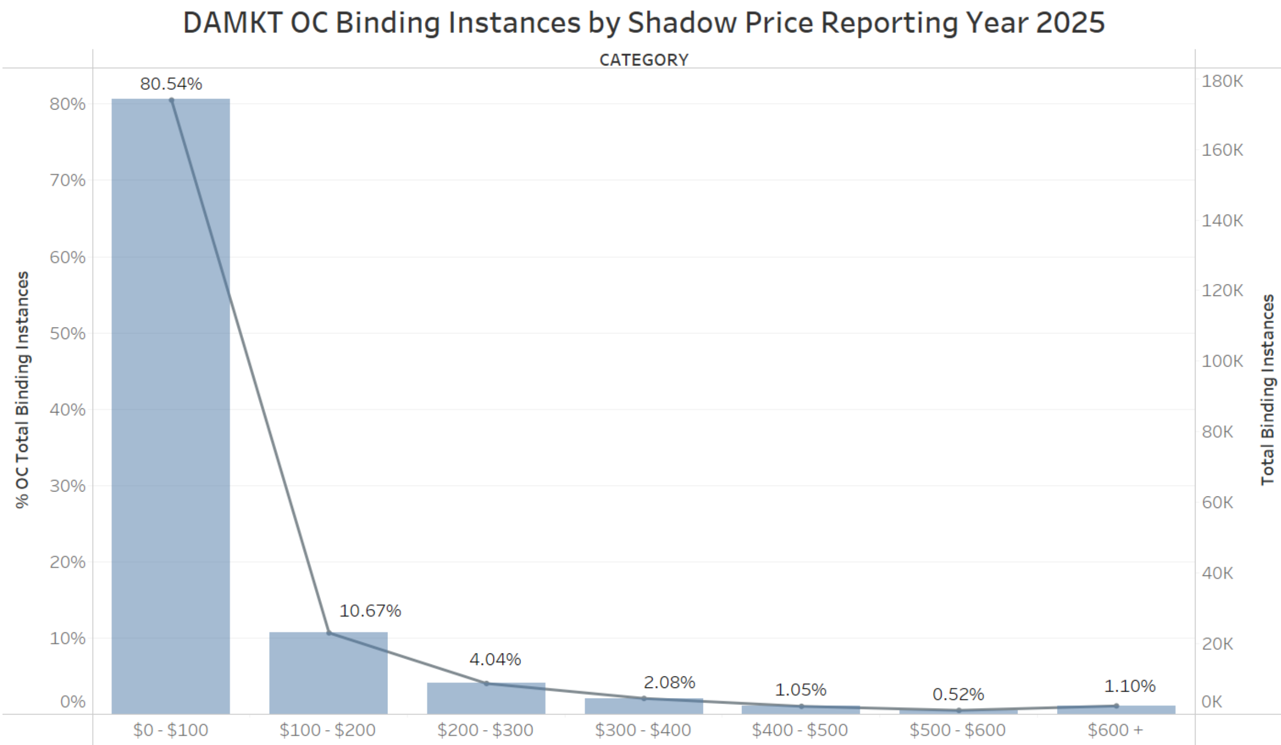

Figure 4: DAMKT OC Binding Instances by Shadow Price for Reporting Year 2025

As shown in Figures 5 and 6 below, both RTBM and DAMKT binding instances have followed very similar distributions for the past three years.

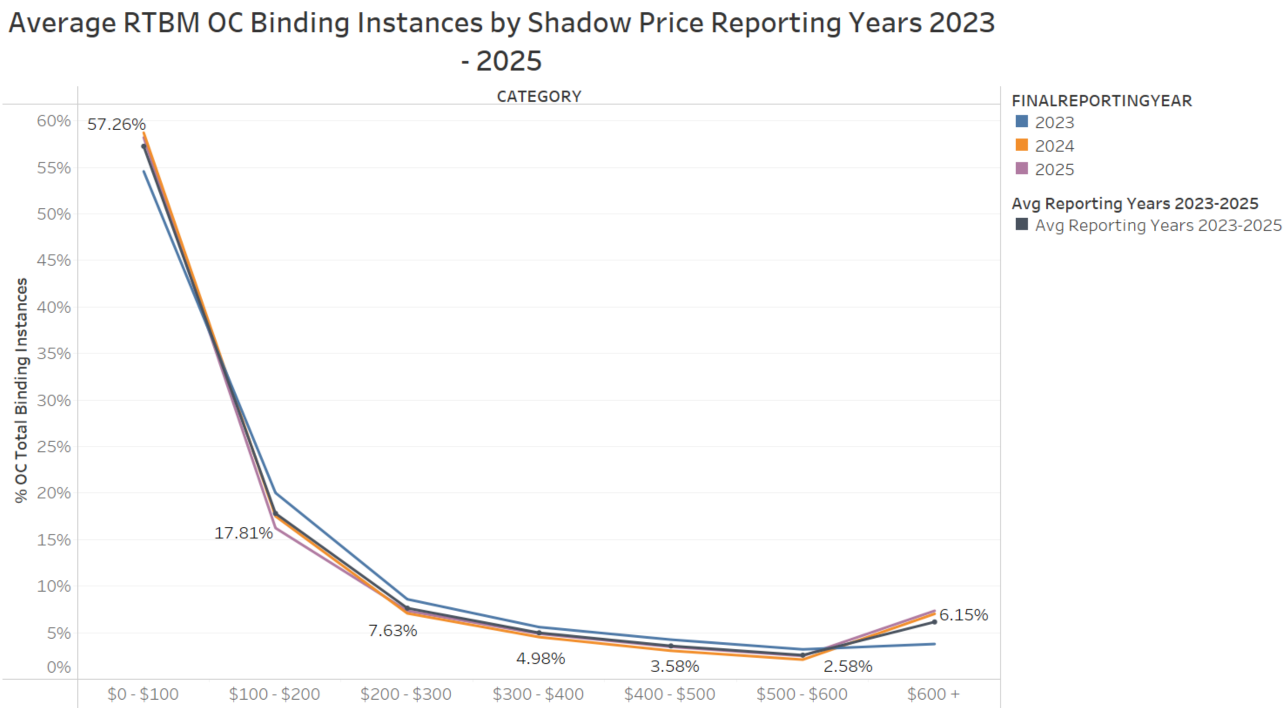

Figure 5: Average RTBM OC Binding Instances by Shadow Price for Reporting Years 2023-2025

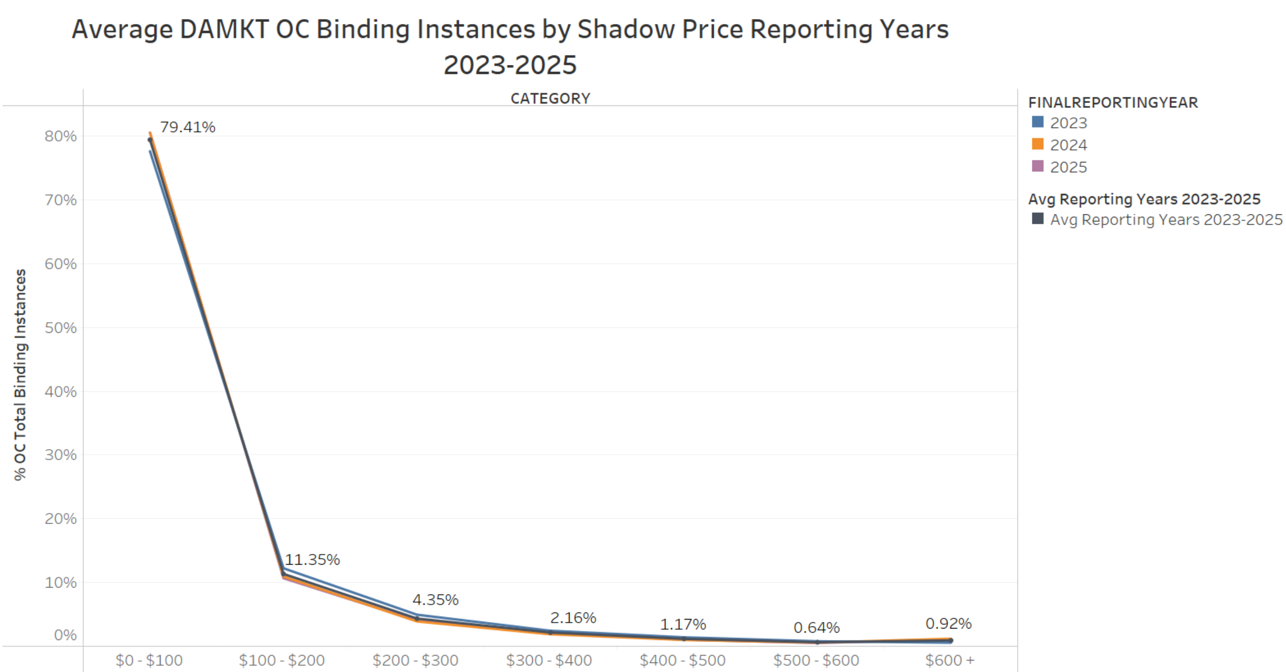

Figure 6: Average *DAMKT OC Binding Instances by Shadow Price for Reporting Years 2023-2025*

BREACHING IN THE REAL-TIME BALANCING MARKET

During the 2025 reporting year, SPP observed little change in the frequency and severity of RTBM breach events as displayed in Figures 7 and 8. This can be attributed to no changes being made from the 2024 VRL study and no significant change in the cost of Energy available to redispatch due to stabilized fuel prices. It is worth noting in this section that breached instances where SPP was not controlling the constraint in Market Flow Control (such as external M2M or congestion from TLR to meet market relief assignment) are excluded from Figures 7 and 8.

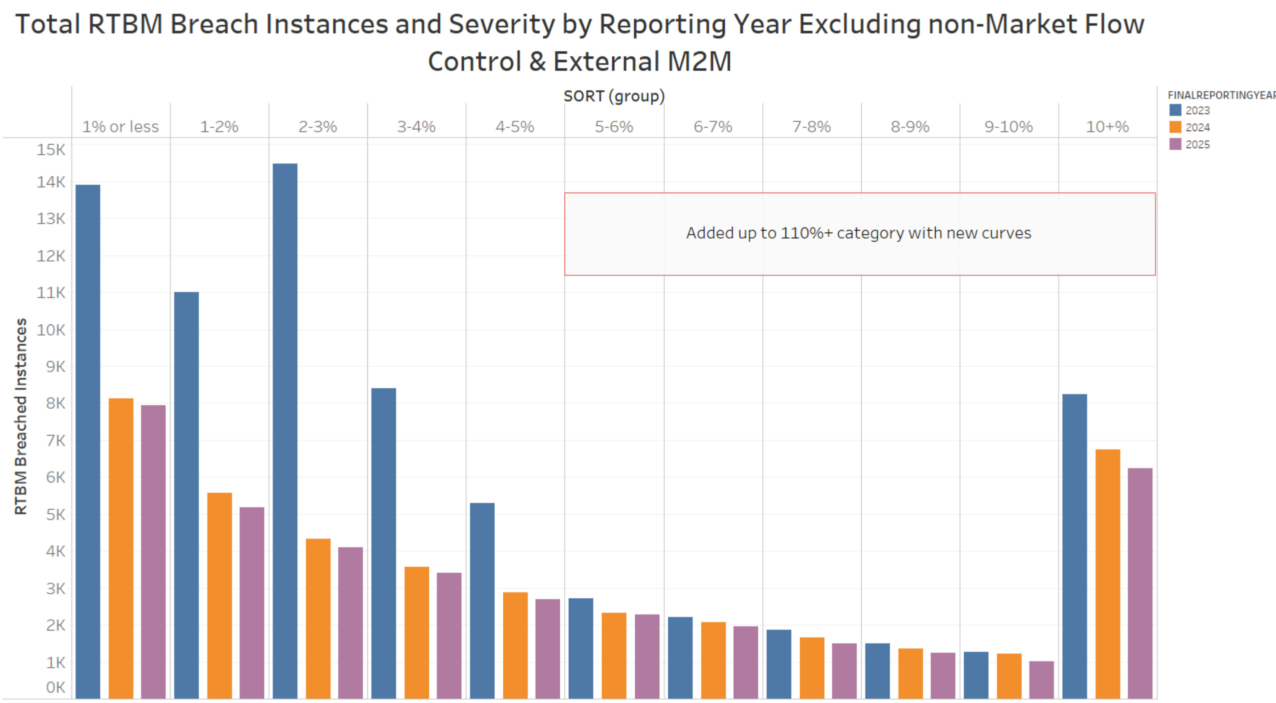

Figure 7: Total RTBM Breach Instances and Severity by Reporting Year Excluding non-Market Flow Control & External M2M

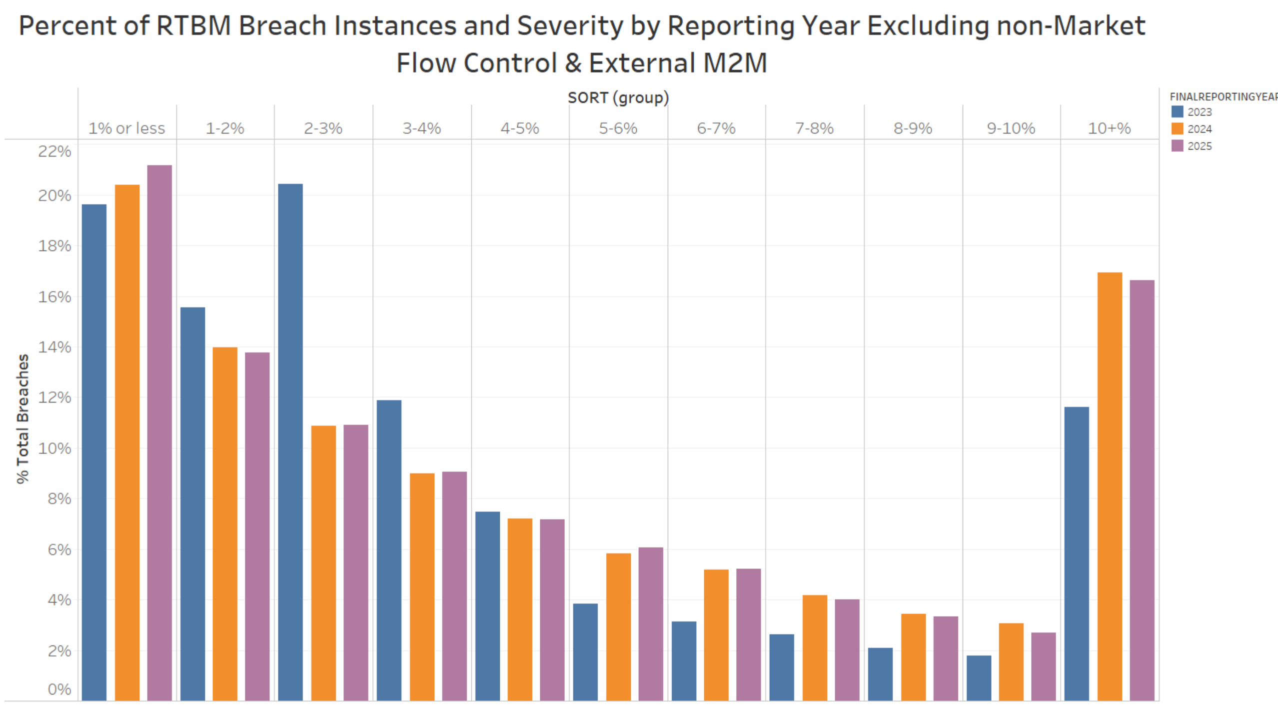

Figure 8: Percent of RTBM Breach Instances and Severity by Reporting Year Excluding non-Market Flow Control & External M2M

BREACHING IN THE DAY-AHEAD MARKET

When compared to Figure 7, Figure 9 shows the DAMKT sees far fewer breaches than RTBM. This is primarily due to:

- Less volatility and unexpected system changes
- A longer dispatch period (1 hour vs 5 minutes) to solve the constraint
- Virtual bids and offers provide more options to resolve the constraint at lower shadow prices
- Different resource offer/dispatch behavior between Real Time and Day Ahead

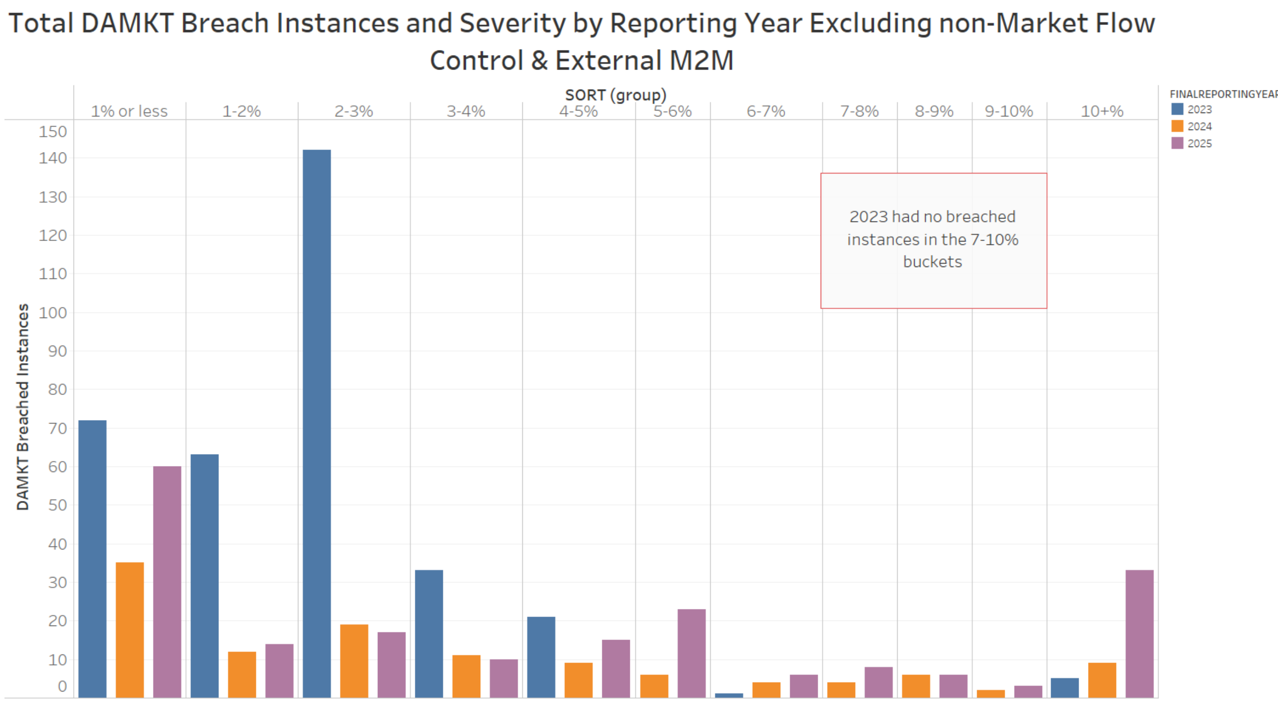

Figure 9: DAMKT Breach Instances and Severity by Reporting Year Excluding non-Market Flow Control & External M2M

As noted in the opening of the report, some of the breached intervals in DAMKT from the 2023-2025 reporting years are due to phase-shifter control constraints that are unable to solve when the phase-shifting transformer temporarily becomes a radial due to transmission outages. These instances all resulted in a $0 shadow price and did not affect the solution, but they are still reported as breached. A total of the DAMKT operating constraint plus phase shifter constraint breach events are shown in Table 3.

Table 3: Day-Ahead Market Breach Events Excluding Non-Market Flow Control & External M2M

DAY-AHEAD MARKET BREACH EVENTS			
Reporting year	**Operating Constraint**	**Phase Shifter**	**Total**
2023	406	0	406
2024	131	66	197
2025	234	66	300

REGULATION-UP PLUS SPINNING RESERVE SHORTAGES IN THE RTBM

The prevalence of regulation-up plus spinning reserve (spinning reserve) shortages showed little variation between the 2024 and 2025 reporting years as shown in Figure 10. The occurrences of spinning reserve shortages in the RTBM are primarily due to unplanned changes in obligation, larger than forecasted ramping events, and limited rampable capacity. As displayed in Figure 10, the spinning reserve VRL did not show significant change from the 2024 to 2025 reporting year since fuel prices stabilized. There is a significant decrease in spinning reserve shortages in real-time between the 2023 and 2024 reporting years. This can be attributed to the increase in spinning reserve VRL pricing and lower fuel prices. The most notable improvement occurred in the 0-50 MW shortage category, though improvements were also observed in more severe shortages exceeding 400 MWs.

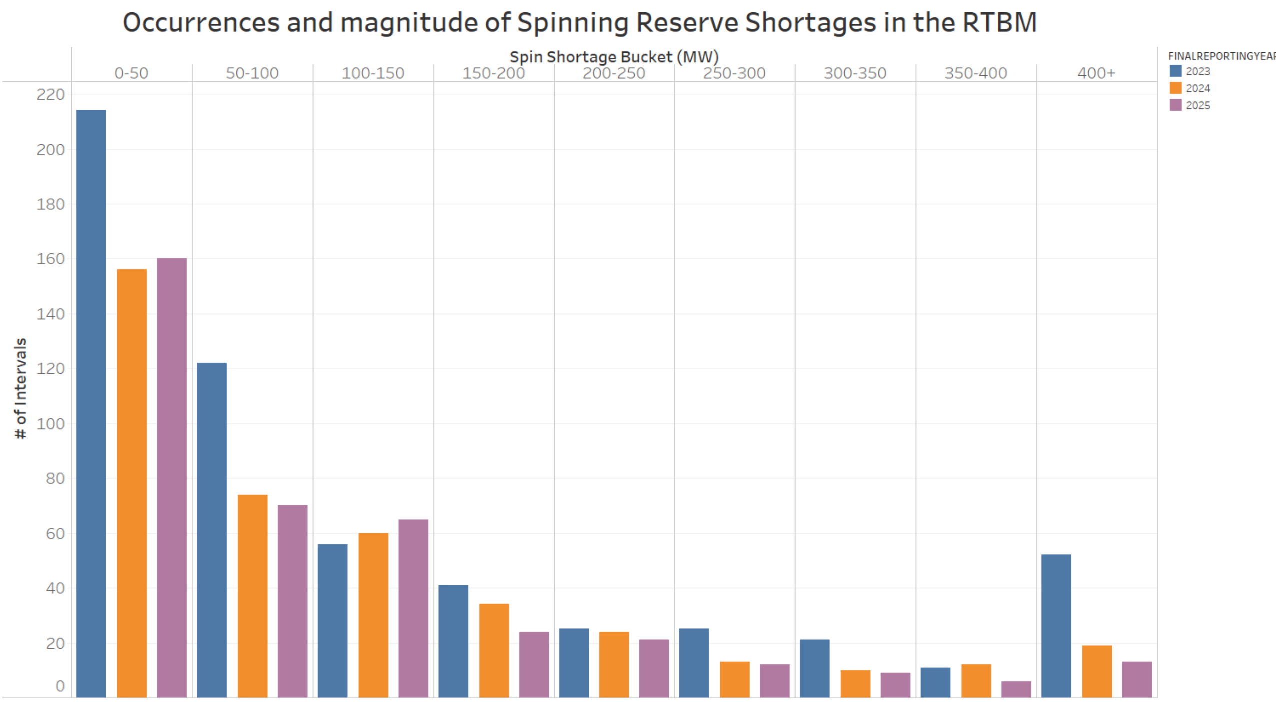

Figure 10: Occurrences and magnitude of Spinning Reserve Shortages in the RTBM

Historically, spinning reserve shortages have been concentrated in the off-peak months (Spring and Fall), and the 2025 reporting year proves to be consistent with this. These months tend to have a large amount of renewable energy penetration, conventional generation outages, and volatile weather events. This increases the likelihood that errors associated with forecastable generation will contribute to a lack of available ramping capability. Figure 11 shows the spinning reserve shortages in the RTBM by month. The purple line represents the 2025 reporting year, and it is evident that the number of spinning reserve shortages in the RTBM remains relatively similar to the 2024 reporting year, again due to the similar fuel prices and no change in the VRL penalty.

However, it still shows there are 50 or less intervals short per month from July 2023 to June 2024 due to the 2023 reporting year spinning reserve VRL values.

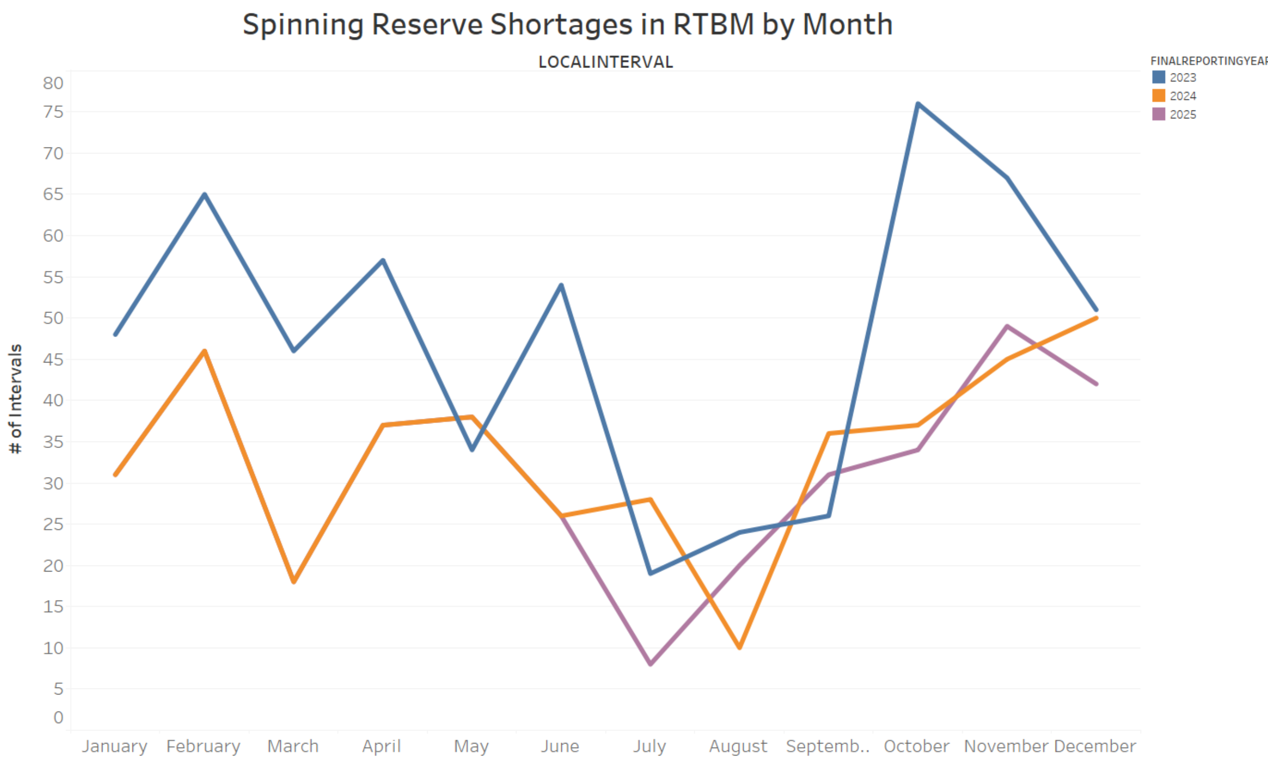

Figure 11: Spinning Reserve Shortages in RTBM, by Month by Reporting Year

SENSITIVITY ANALYSIS FOR OPERATING CONSTRAINT VRL

METHODOLOGY

This year's analysis focused on the changes in operating costs and system reliability when adjusting the VRL blocks. We assessed the impacts of the VRL changes by executing RTBM sensitivity studies for 40 operating days. These days focus on binding constraint counts; representing a variety of congestion patterns on the SPP system and covering a wide range of operational conditions. Table 4 shows the range of conditions captured from the study days for each VRL year.

Table 4: Operating conditions per reporting year

	2023	2024	2025
Number of Intervals	12,033	11,808	11,520
RTBM cases ran and analyzed	60,165	70,848	85,097
System load	21.6 to 51.0 GW	22.4 to 53.4 GW	22.6 to 56.1 GW
System generation	21.5 to 52.9 GW	23.2 to 54.8 GW	24.35 to 52.7 GW
System wind forecasts	0.8 to 27.1 GW	0.6 to 29.5 GW	1.4 to 29.5 GW
Net scheduled interchange	-2.9 to 3.6 GW	-6.7 to 3.5 GW	-6.7 to 2.4 GW

There were five sensitivities studied. All sensitivities implemented increasing VRL blocks. Combined with the base reruns, the study analyzed 85,097 RTBM intervals.

The VRL blocks were the only input changes to the cases, and a feed-forward dispatch simulation[2] was used to reflect resource dispatch following and constraint impacts. This simulation style is consistent with prior studies dating back to the 2017 VRL reporting year analysis. The results were assessed based on performance of constraint control, how many breached instances were observed, as well as system cost and pricing indicators.

[2] SPP's process for performing retroactive dispatch analysis involves feeding forward the calculated dispatch values from a forward time. For example, the dispatch calculated from Interval Ending 00:10 will be used as the actual generation when the simulation reaches interval ending 00:10.

SENSITIVITIES ANALYZED

1. **Base** – This is a flat $1,500 curve that was recommended from the 2022 VRL report and implemented on June 1st, 2023. This sensitivity is important to run due to the usage of the feed-forward dispatch simulation to represent resource and constraint movement. The base sensitivity acts as the control for the study, allowing other sensitivities to be compared to this reference. The VRL blocks used are:
    a. $1,500 when the loading is greater than 100% and less than or equal to 101% at each network constraint at each Operating Constraint.
    b. $1,500 when >101% and <= 102%
    c. $1,500 when >102% and <= 103%
    d. $1,500 when >103% and <= 104%
    e. $1,500 when >104%
2. **Increasing VRL Blocks** – These sensitivities explored the impact of increasing the size of the price jump as the market relaxed the constraint limits during the solution. Sensitivities 1-5 are ordered in general magnitude of pricing. Sensitivities 1 - 3 had the least expensive first block compared to the other sensitivities and increased in price while going up the blocks. Sensitivities 4 and 5 had a much higher first block and higher prices than the other sensitivities. The increased value for 4 and 5's final block was added to see if there could be a reduction in the count of severely breached instances (>110%). While the number of breached instances in the more severe category did go down, it came at an exceptionally high cost. Table 5 lists the VRL blocks which are also graphed in Figure 12.

Table 5: Penalty blocks for the Increasing Block Size

If VRL passed, relax limit to	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
101%	$1,500	$750	$750	$750	$3,000	$2,000
102%	$1,500	$750	$750	$1,500	$3,000	$4,000
103%	$1,500	$1,000	$1,000	$2,250	$3,000	$6,000
104%	$1,500	$1,250	$1,250	$3,000	$3,000	$8,000
>104%	$1,500	$1,500	$1,500	$4,000	$3,000	$10,000
>110%	N/A	N/A	$3,000	N/A	$4,000	N/A

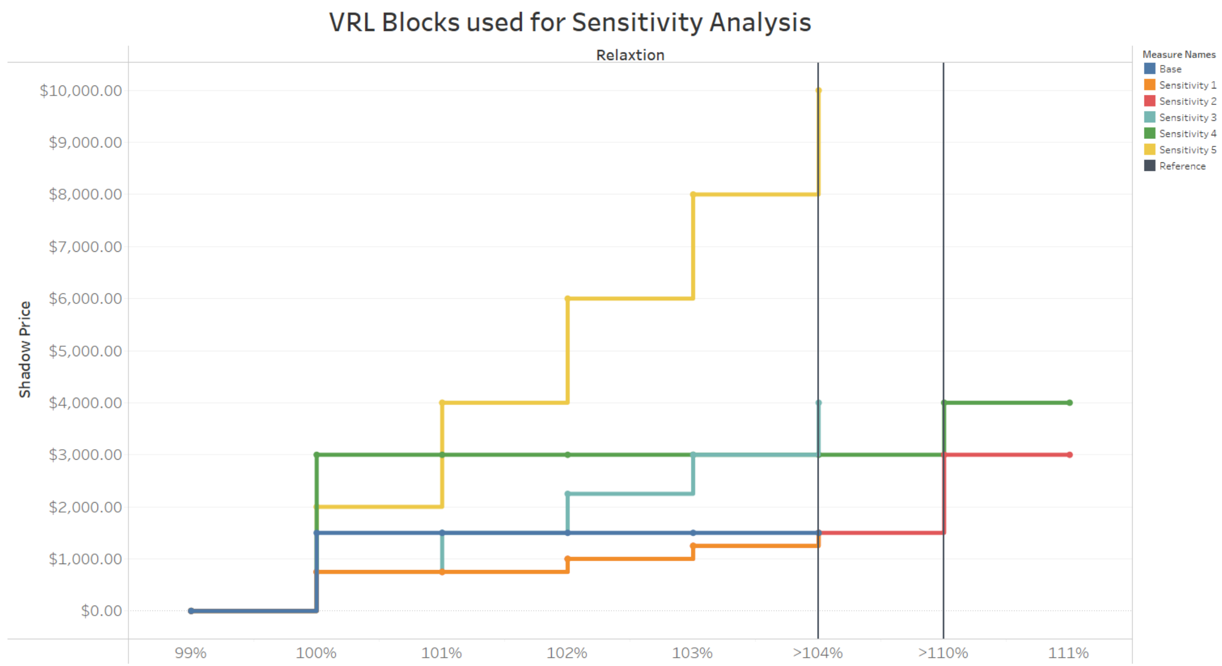

Figure 12: 2025 Constraint Sensitivity VRL Blocks

SENSITIVITY ANALYSIS RESULTS

Performance of the various VRL block sensitivities and methods were analyzed in terms of total number of breaching flowgate instances, system-level pricing, and cost indicators as detailed in Table 6.

The primary indicators are:

- Average Marginal Energy Cost (MEC)
- Average Operating Cost[3]
- Average Shadow Settlement Cost[4]
- Total number of breach constraint instances in the RTBM solutions
- Total Intervals with Operating Reserve Scarcity Conditions[5]

Table 6: Sensitivity Key Indicators- Interval Averages and Totals

Sensitivity	Average MEC	Average Operating Cost	Average Settlement Cost	Total Breach Instances	Total Market Scarcity Intervals
Base	$46.17	$-1,064.95	$83,180	14,298	617
Sensitivity1	$42.48	$-278.49	$79,699	20,095	638
Sensitivity2	$50.77	$-80.66	$90,615	20,450	661
Sensitivity3	$64.23	$889.86	$109,073	20,596	711
Sensitivity4	$70.61	$395.48	$116,511	13,004	813
Sensitivity5	$114.99	$1,581.72	$176,096	15,638	1,414

Figures 13 and 14 show the relationship between cost and reliability. There is typically a tradeoff between reduced breach events and MEC/Settlement Cost. An optimal VRL curve would place MEC and Settlement Costs on the bottom left of this scatter chart, where breach instances and costs are lowest.

An analysis of the studies base and sensitivity data indicates:

- *Sensitivity 1* had the third largest increase in flowgate breaches while showing the largest decrease in cost compared to the base. The average MEC decreased by 7.99% (-$3.69) from the base cost, while increasing the total breaches by 40.5% (5,797) from the base count.

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[3] *Total fuel/offer cost per interval of energy and operating reserve*

[4] *Total cost to be paid to resources based on Dispatch MW * LMP + ReservesCleared MW * MCP*

[5] *Includes any level of scarcity from SPP products. Product scarcity (Ramp and Uncertainty), after their respective launches in March 2022 and July 2023, would also be included.*

- *Sensitivity 2* showed the second highest increase in flowgate breaches while at a higher cost. The average MEC for sensitivity 2 increased by 9.96% ($4.60) from the base cost, while increasing total breaches by 43.03% (6,152) from the base count.
- *Sensitivity 3* continued the trend of an increased cost from the base and is the highest sensitivity in flowgate breaches. The average MEC increased by 39.12% ($18.06) from the base cost, while increasing the total breaches by 44.05% (6,298) from the base count.
- *Sensitivity 4* was the only study that provided a decrease in the flowgate breaches. The average MEC increased significantly 52.93% ($24.44) from the base cost, while reducing the total flowgate breaching slightly 9.05% (-1,294) from the base count.
- *Sensitivity 5* provided the smallest increase in flowgate breaches, but it had the largest increase in costs when compared to the base. The average MEC increased by 149.1% ($68.82) from the base cost, while the total flowgate breaches increased by 9.37% (1,340) from the base count.

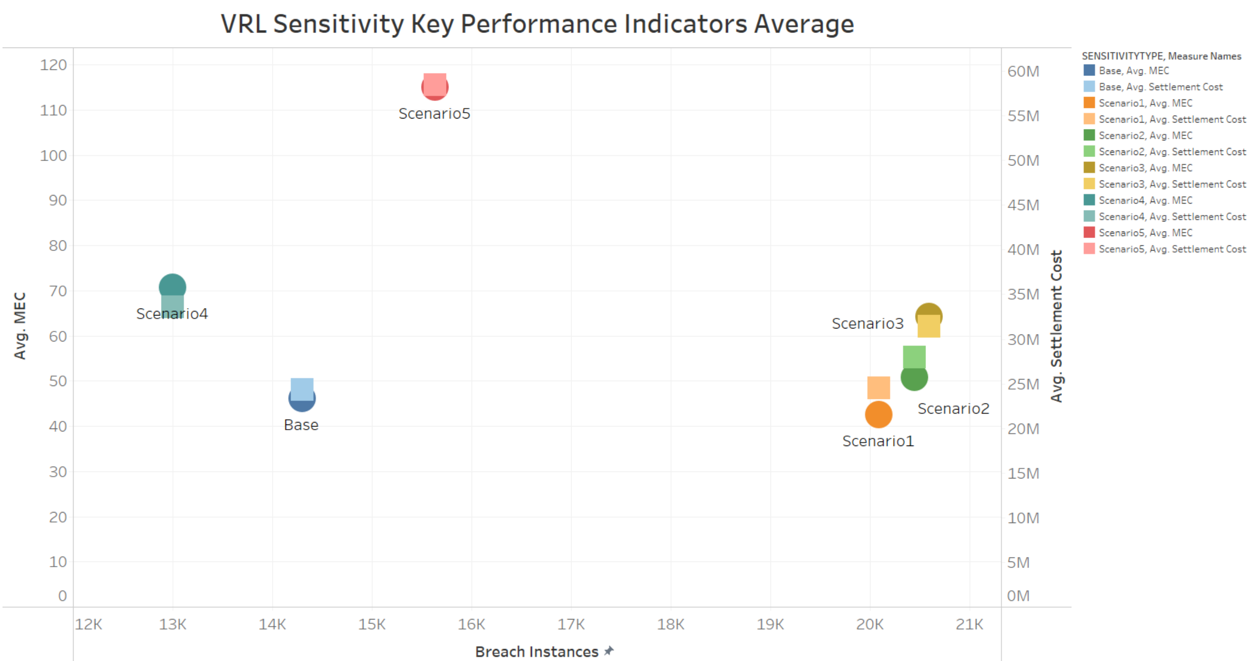

Figure 13: Key Performance Indicators of VRL Sensitivities - Interval Averages

Table 7 shows the impacts on the total Operating and Total Shadow Settlement costs. Following the same pattern as reported in Table 6.

Table 7: Sensitivity Key Indicators- Totals

Sensitivity	Average MEC	Total Operating Cost (Millions)	Total Settlement Cost (Billions)	Total Breach Instances	Total Market Scarcity Intervals
Base	$46.17	$-19.9	$0.92	14,298	617
Sensitivity1	$42.48	$-0.84	$0.93	20,095	638
Sensitivity2	$50.77	$1.49	$1.06	20,450	661
Sensitivity3	$64.23	$10.2	$1.16	20,596	711
Sensitivity4	$70.61	$5.04	$1.27	13,004	813
Sensitivity5	$114.99	$-35.8	$2.16	15,638	1,414

In Figure 14, the effect that the first VRL penalty block has on breaches is clear when grouping the sensitivities within the graph. Each label displays the sensitivity name and their first VRL penalty value. As the value of this first penalty block increases, the number of breaches is reduced. However, there is one exception to this rule, which is sensitivity 5. This is examined further in a later section.

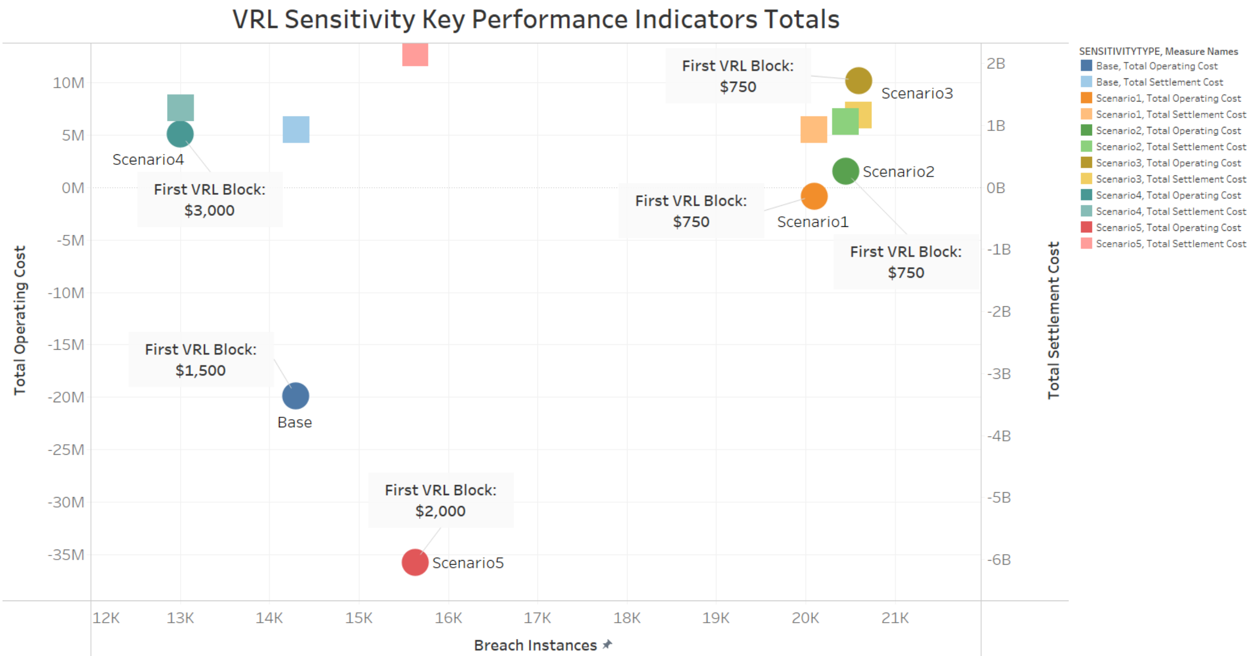

Figure 14: Key Performance Indicators of VRL Sensitivities – Interval Totals

As shown in Figures 15 and 16, it is clear to see where the changes in relaxation occurred for the different sensitivities when considering the individual breached percentages. Figure 15 looks at all VRL instances, while Figure 16 removes non-Market Flow control and external M2M in the same fashion as the historical analysis. Breaches above the first VRL block are slightly affected by the changes in the values, and most differences occur based on the value of the first VRL block. The shift between these two Figures also shows that the majority of large (>104% and >110%) breaches occur when the constraint is in non-Market Flow Control or external M2M.

Referencing back to the increased number of breached instances in Sensitivity 5. As shown in Figure 16 and Table 9, when a high price is applied to the last few blocks of Sensitivity 5, the MCE will work hard to solve the higher breaching constraints. This will cause other previously non-breaching constraints to breach. This occurs as the system attempts to achieve the most economical solution. In other terms, to limit the constraints to lower breaching levels, the system will redistribute congestion to other constraints that were previously not congested to solve the severe constraint breaches. The effect of this trend can be better visualized in Figure 17 where the higher blocks have an increasing weight. In addition, Figure 18 shows how many unique constraints were breaching. Note that Sensitivity 5 shows a reduction in severely loaded constraints, and the flows were re-distributed to the lower blocks.

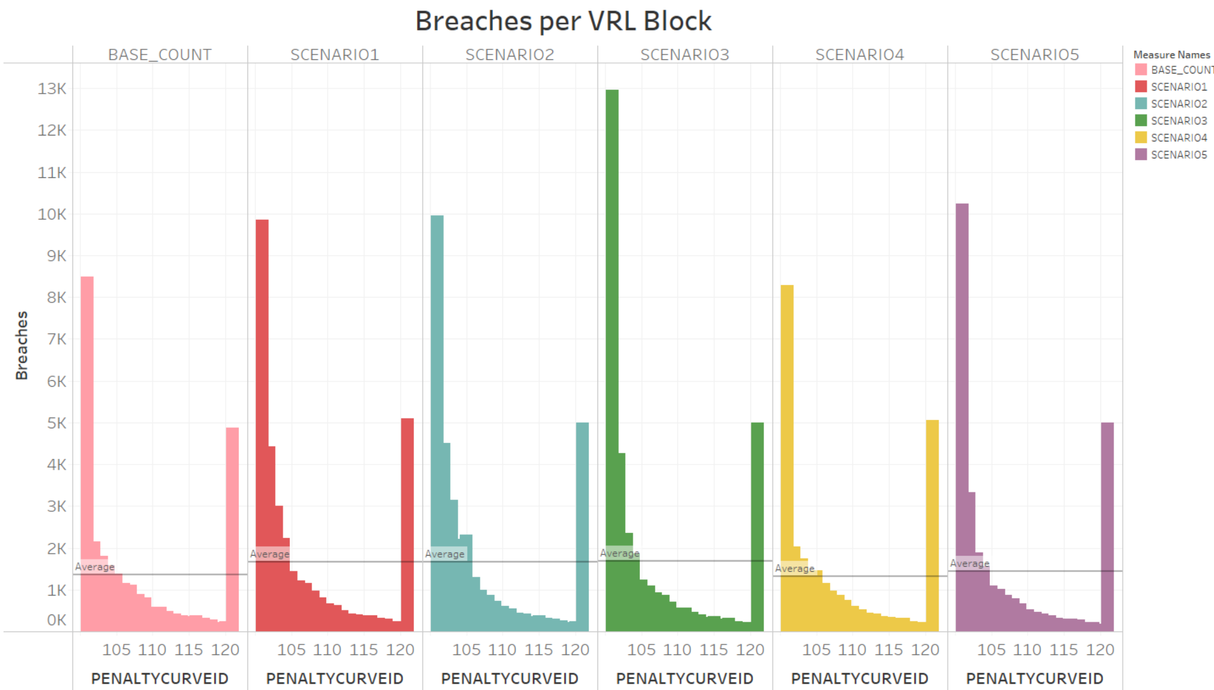

Figure 15: Breaches per VRL Block – MCE flow vs Effective Upper Limit

Table 8: VRL Instance Breakdown by Sensitivity, All Instances

VRL Block	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	8,501	9,853	9,956	12,964	8,291	10,239
102%	2,162	4,427	4,516	4,262	2,032	3,341
103%	1,812	3,008	3,150	2,354	1,749	1,897
104%	1,591	2,236	2,221	1,863	1,450	1,555
105%	1,379	1,446	2,310	1,238	1,460	1,097
106%	1,164	1,223	1,299	1,107	1,157	1,022
107%	1,121	1,151	988	938	971	865
108%	895	984	879	865	872	796
109%	814	807	738	708	751	669
110%	583	680	605	579	614	536
>110%	8,582	8,968	8,528	8,465	8,528	8,134

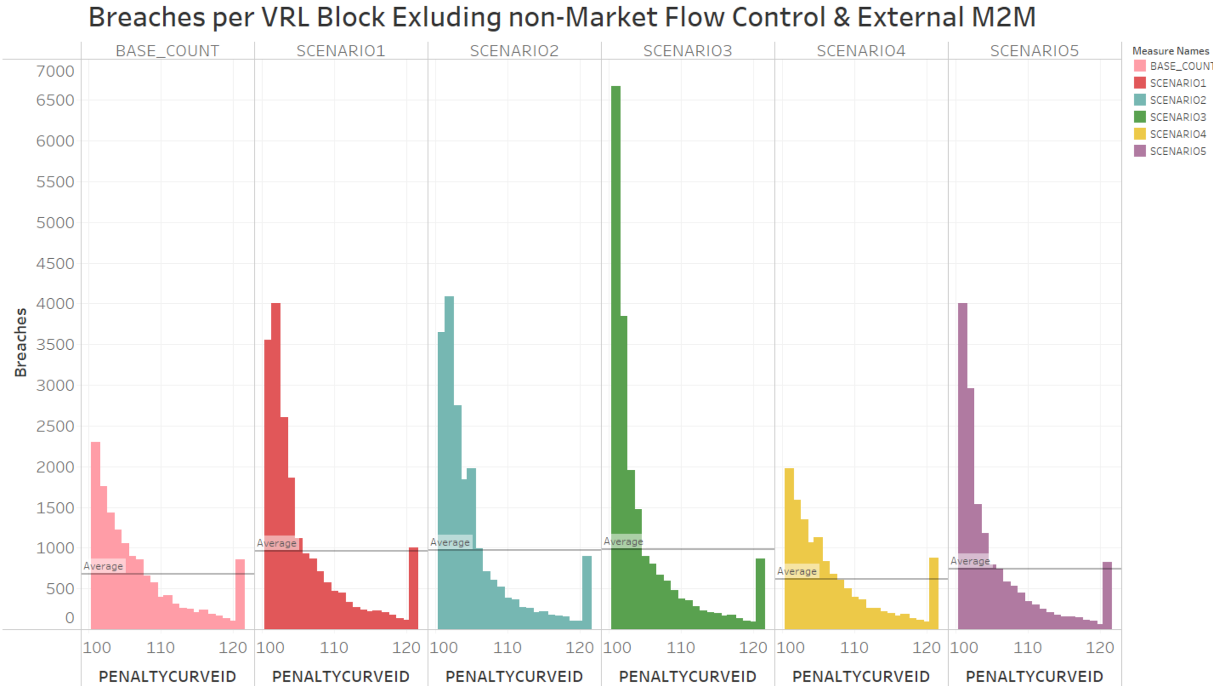

Figure 16: Breaches per VRL Block Excluding non-Market Flow Control and External M2M

Table 9: VRL Instance Breakdown by Sensitivity- Excluding non-Market Flow Control and External M2M

VRL Block	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	2,301	3,555	3,649	6,671	1,971	4,009
102%	1,758	4,006	4,089	3,844	1,592	2,955
103%	1,436	2,604	2,747	1,955	1,346	1,533
104%	1,225	1,859	1,838	1,475	1,065	1,183
105%	1,058	1,120	1,972	898	1,127	797
106%	897	930	992	803	841	739
107%	856	872	716	672	682	590
108%	659	712	604	595	603	538
109%	575	578	521	478	505	448
110%	396	467	392	377	400	340
>110%	3,137	3,392	2,930	2,828	2,872	2,506

Figures 15 and 16 show that not all breaches are equal, some are more severe than others. To view the sensitivities by the instances of breaches in their severity block, a weighted calculation was applied. VRL Blocks ≤101% to 110% were weighted 1 – 10 and for VRL Block >110% a weight of 14 was given to represent the more severe breaches that could be approaching the source operating limit as displayed in Table 10. This shows that as the VRL penalty increases, the breaches in the higher VRL blocks are reduced, resulting in a lower total with the weighted amounts.

Table 10: VRL Instance Weighted Breakdown by Sensitivity- Excluding non-Market Flow Control and External M2M

VRL Block	Weight	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	1	2,301	3,555	3,649	6,671	1,971	4,009
102%	2	3,516	8,012	8,178	7,688	3,184	5,910
103%	3	4,308	7,812	8,241	5,865	4,038	4,599
104%	4	4,900	7,436	7,352	5,900	4,260	4,732
105%	5	5,290	5,600	9,860	4,490	5,635	3,985
106%	6	5,382	5,580	5,952	4,818	5,046	4,434
107%	7	5,992	6,104	5,012	4,704	4,774	4,130
108%	8	5,272	5,696	4,832	4,760	4,824	4,304
109%	9	5,175	5,202	4,689	4,302	4,545	4,032
110%	10	3,960	4,670	3,920	3,770	4,000	3,400
>110%	14	43,918	47,488	41,020	39,592	40,208	35,084
Total		90,014	107,155	102,705	92,560	82,485	78,619

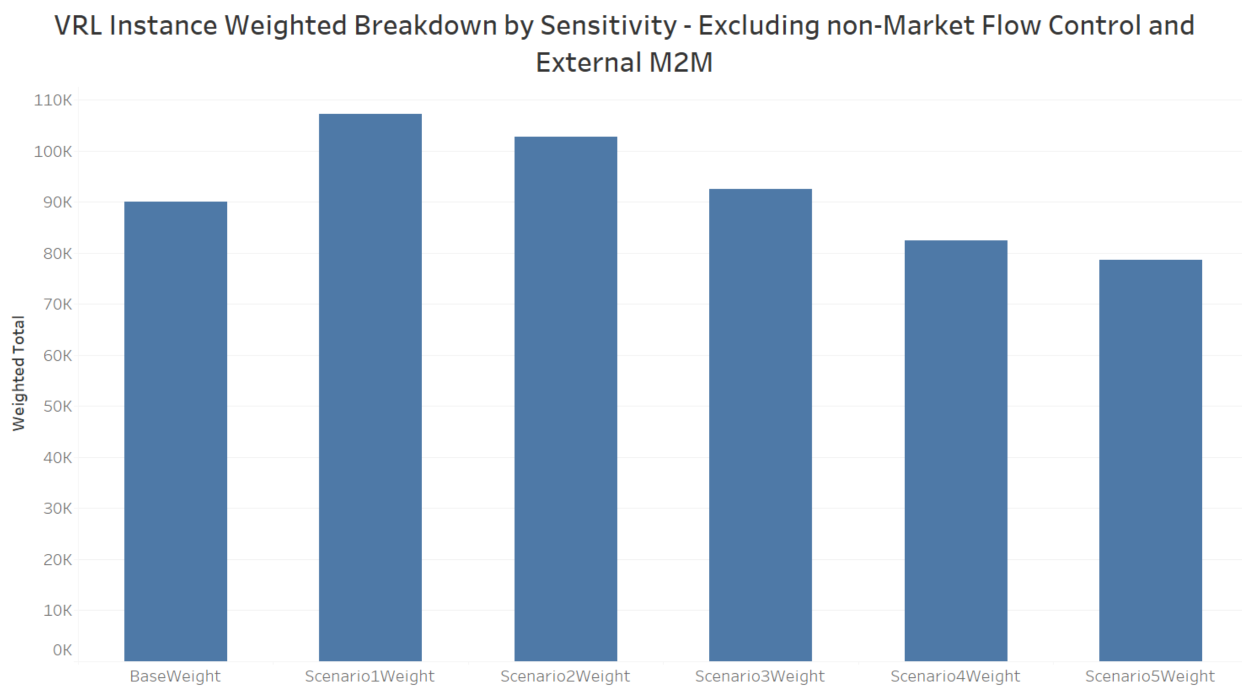

Figure 17: Breaches weighted by VRL Block Excluding non-Market Flow Control and External M2M

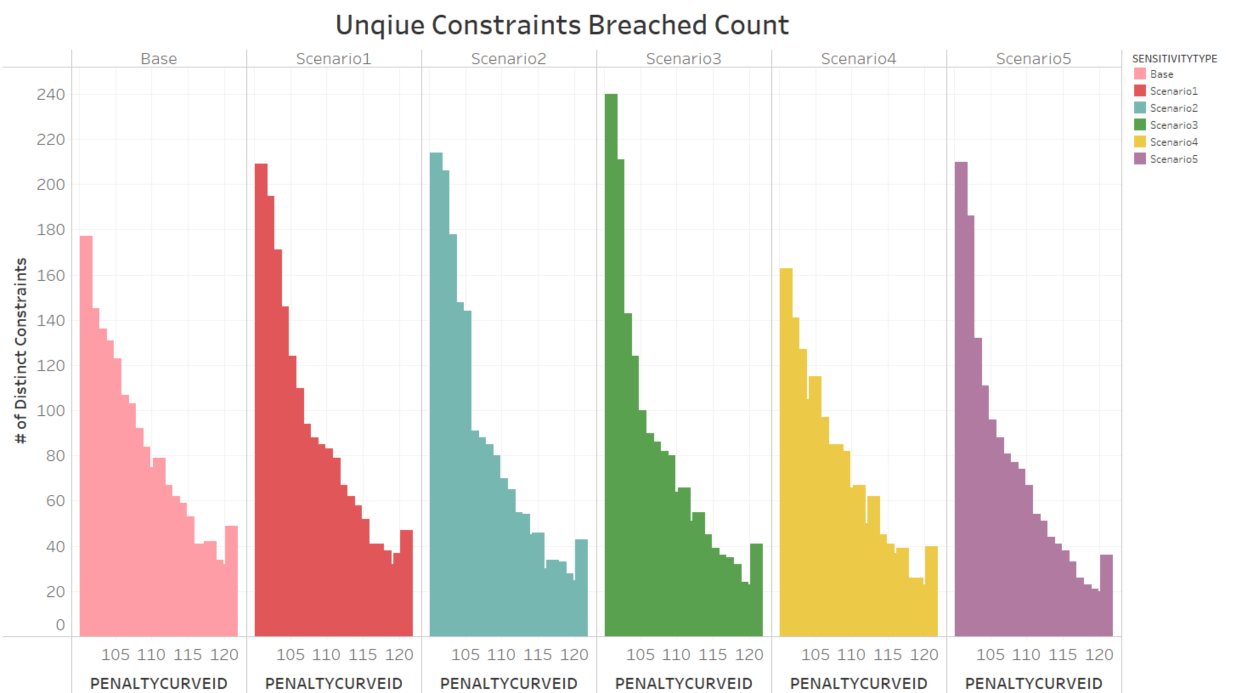

Figure 18: Unique Constraints Breached Count by VRL Block Excluding non-Market Flow Control and External M2M

CONCLUSION

In conclusion SPP does not recommend a change to the Operating Constraint VRL for the following reasons:

- **Sensitivity 1** had a slight decrease in MEC and average settlement cost. At a maximum, the average MEC decreased by 7.99% (-$3.69). Sensitivity 1 showed minimal decreases in financial benefits while decreasing reliability significantly. The total breaches increased by 40.5% (5,797) from the base count, it will not be recommended.
- **Sensitivities 2 and 3** were similar in the fact that the VRL curves started at low prices and ended at higher prices. This curve caused an increase in breaches at the lower blocks and an increase in prices since the system had to work harder to solve the high volume of breached constraints. While there was a decrease in the amount of severe breaching, a high breached count was maintained at a very high cost. These sensitivities will not be recommended.
- **Sensitivity 4** showed the largest improvement in the number of breaches compared to the base but at a significantly higher cost than sensitivities 1 – 3. The average MEC was 52.93% higher than the base cost ($24.44). While there was a reduction in breaches compared to the base of 9.05% (-1,294), it is not significant enough to offset the severe price increases and will not be recommended.
- **Sensitivity 5** showed an increase of 9.37% (1,340) in total number of breaches compared to the base count, and the MEC had the most significant increase of all the sensitivities at 149.1% ($68.82) of the base cost. While there was a noticeable decrease in the amount of severe breaching, it comes at too high of a cost and will not be recommended.
- There was a noticeable change in the number of market scarcity intervals between the five sensitivities. The amount of scarcity increased with every sensitivity, going up with the sensitivity numbers 1 – 5 (with a maximum change of 797 intervals). The base case maintained the lowest amount of scarcity intervals.

SENSITIVITY ANALYSIS FOR REGULATION-UP PLUS SPINNING RESERVE VRL

Sensitivities for the spinning reserve constraint were re-run this year by adjusting the VRL price from the current value to our selected spinning reserve sensitivities. Regulation-up is included in the analysis because of potential product substitution of regulating capacity to meeting spinning reserve requirements. This sensitivity analysis focused on 150 operating days that had intervals containing the highest spinning reserve shortages, the least severe spinning reserve shortages, and a random selection of intervals with no shortages. All these selections were based on the VRL year being split into the 4 seasons to encompass a wide range of operating conditions. This totaled out to 229 unique days and 399 unique intervals.

METHODOLOGY

The study was run without performing the full feed-forward simulation, since a continuous dispatch through spinning reserve shortage events is not expected to have a substantial impact between the base case and the re-run sensitivities.

The sensitivities were run with new spinning reserve VRL price settings of:

- $150
- $200
- $250 (Base since 6/2/2023)
- $300
- $350
- $600

RESULTS

Results of the sensitivity analysis are shown below and are broken into categories of reliability indicators (scarcity and constraint breaches) and economic indicators (MECs, MCPs).

RELIABILITY INDICATORS

The primary reliability indicators, including the scarcity of operating reserve and constraint breach events, moved in the expected direction:

- The number of scarce intervals did not change in the up or down direction as the spinning reserve VRL changed.
- Regulation down shortages and supplemental shortages did not change as the value placed on meeting the spinning reserve VRL requirement increased. All spinning reserve VRL sensitivities had an equivalent Regulation Down and Supplemental shortage MW total.
- Regulation-up and spinning reserve shortages decreased as the value placed on meeting the spinning reserve VRL requirement increased. The spinning reserve shortage total decreased by 6.46% with the $600 spinning reserve VRL and increased by 1.79% with the $150 spinning reserve VRL value when compared to the base spinning reserve VRL value. A $300 spinning reserve VRL value showed a slight improvement in spinning reserve shortages. The improvement compared to the $250 spinning reserve VRL value was minimal (0.84%).
- A rise in flowgate breached instances occurs with higher spinning reserve VRL sensitivities due to the increase in spinning reserve value relative to the operating constraints VRL values. However, the change is minimal.

Table 11: Reliability Indicators

SPIN VRL	# of Scarce Intervals	RegDOWN Shortage MW Total	RegUP Shortage MW Total	Spin Shortage MW Total	Supp Shortage MW Total	Breached FG Instances
$150	92	67	6,587	7,013	1,842	612
$200	92	67	6,544	7,000	1,842	613
$250	92	67	6,434	6,890	1,842	614
$300	92	67	6,383	6,832	1,842	616
$350	92	67	6,356	6,729	1,842	616
$600	92	67	6,215	6,445	1,842	631

The results may be more enlightening when viewed as a line chart. Figure 19 shows the number of scarce intervals by VRL spinning reserve sensitivity. As shown below, there is a no drop in scarcity intervals when the spinning reserve VRL increases.

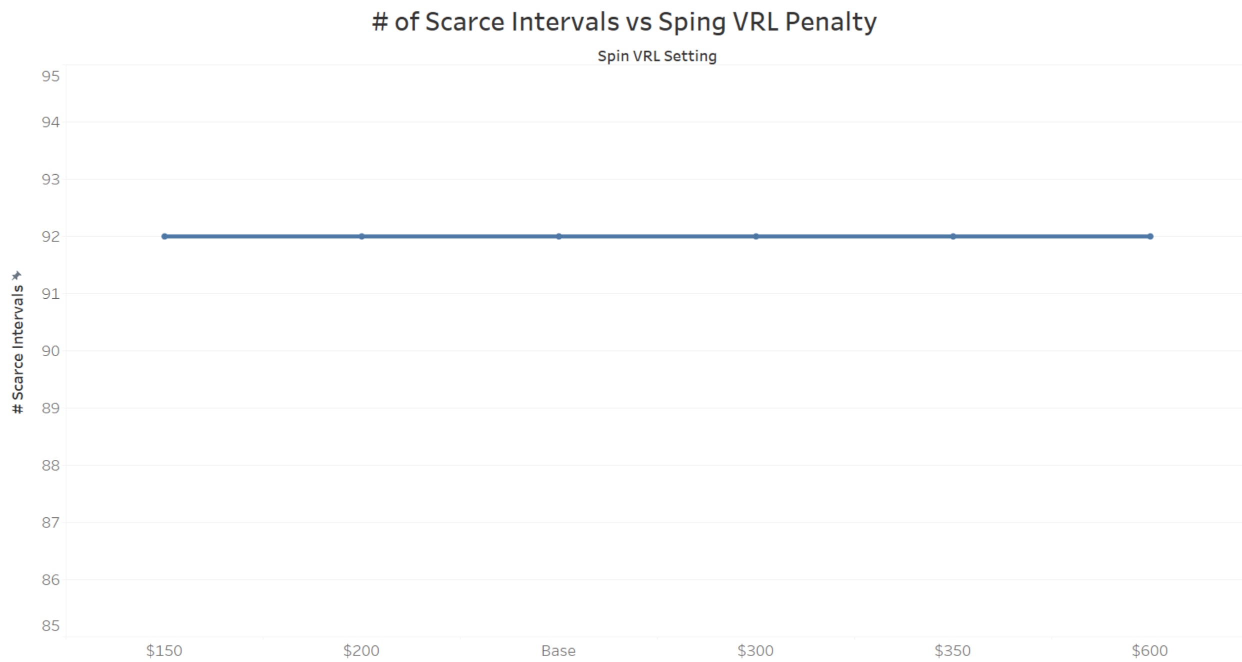

Figure 19: Number of Scarce Intervals for each Spinning reserve VRL Penalty

ECONOMIC INDICATORS

The economic indicators (LMP, MEC, MCP, shadow prices) are consistent with the reliability indicators' results:

- There was little impact ($0.01) to regulation down MCPs and no impact to supplemental MCPs.
- Spinning reserve MCPs increased as the spinning reserve VRL sensitivity increased. The $600 spinning reserve VRL value showed an increase of 70.43% in average MCP compared to the base spinning reserve VRL, while the $300 spinning reserve VRL value had a 12.4% increase in average spinning reserve MCP.
- The MECs followed a similar path, since most shortages of spinning reserve involve competition with energy. The $600 spinning reserve VRL value showed an increase of 22.47% in average MEC compared to the base spinning reserve VRL, while the $300 spinning reserve VRL value had a 3.76% increase in average spinning reserve MCP.
- Regulation-up saw an increase in MCP as product substitution allowed it to compete with spinning reserve. With higher spinning reserve VRLs, spinning reserve cleared more. There are also impacts when the system is capacity-limited and capacity can be used for 5 minutes of regulation-up versus 10 minutes of spinning reserve.
- The LMP spread, which is the maximum LMP minus the minimum LMP in the SCED, increased with the rise in the spinning reserve VRL.
- The congested shadow prices on constraints followed a similar pattern to the LMP spread.

Table 12: Spinning reserve VRL Economic Indicators

Spin VRL	Avg MEC	Avg LMP Spread	Avg RegDOWN MCP	Avg RegUP MCP	Avg Spin MCP	Avg Supp MCP	Avg Congested Shadow Price
$150	$95.95	$522.79	$0.76	$9.54	$3.75	$1.87	-$269.68
$200	$99.64	$524.32	$0.76	$10.05	$4.30	$1.87	-$267.09
$250	$100.86	$524.44	$0.76	$10.21	$4.60	$1.87	-$264.85
$300	$104.65	$525.53	$0.77	$10.76	$5.17	$1.87	-$267.26
$350	$107.45	$524.00	$0.77	$11.15	$5.58	$1.87	-$266.23
$600	$123.52	$527.51	$0.77	$13.40	$7.84	$1.87	-$265.15

The charts below illustrate the changes in system pricing. Figure 20 shows a steady increase in both average MEC and average LMP Spread as the Spinning reserve VRL value increases.

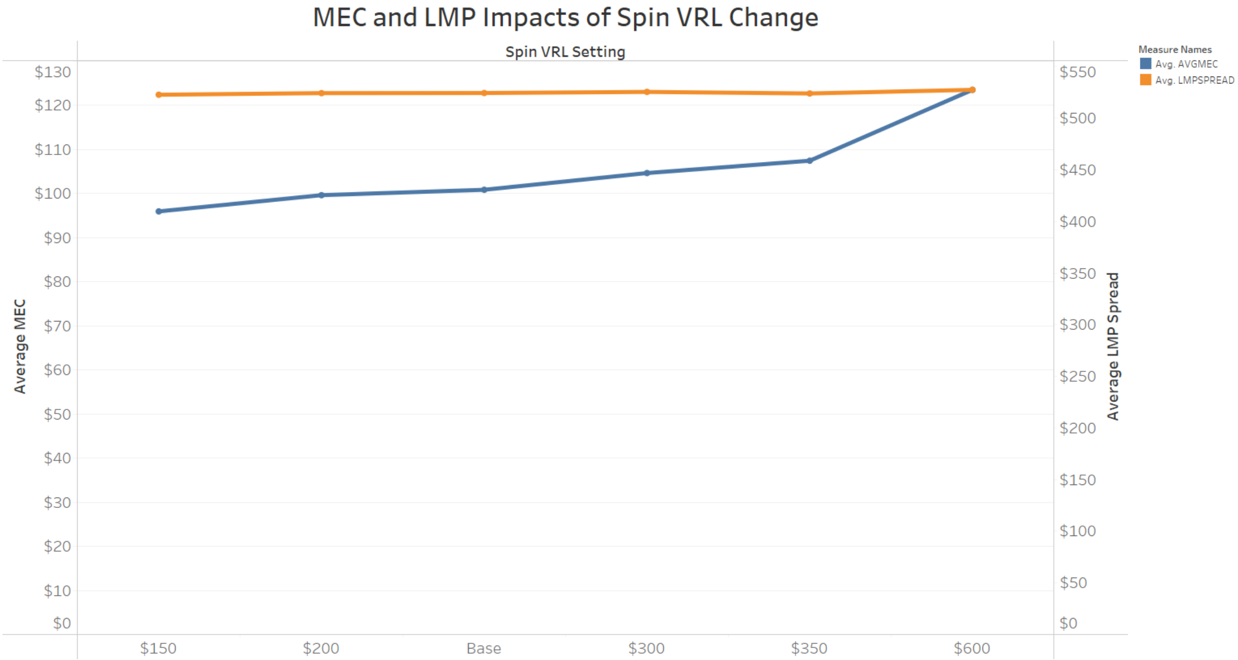

Figure 20: MEC and LMP Impacts of Spinning reserve VRL Change

MCPs for regulation-up and spinning reserve increase proportionally with the MEC as shown in Figure 21. This is consistent with previous scarcity events where regulation-up, spinning reserve, and energy are all competing, usually coinciding with low remaining online capacity. There are some ramping limitations as well.

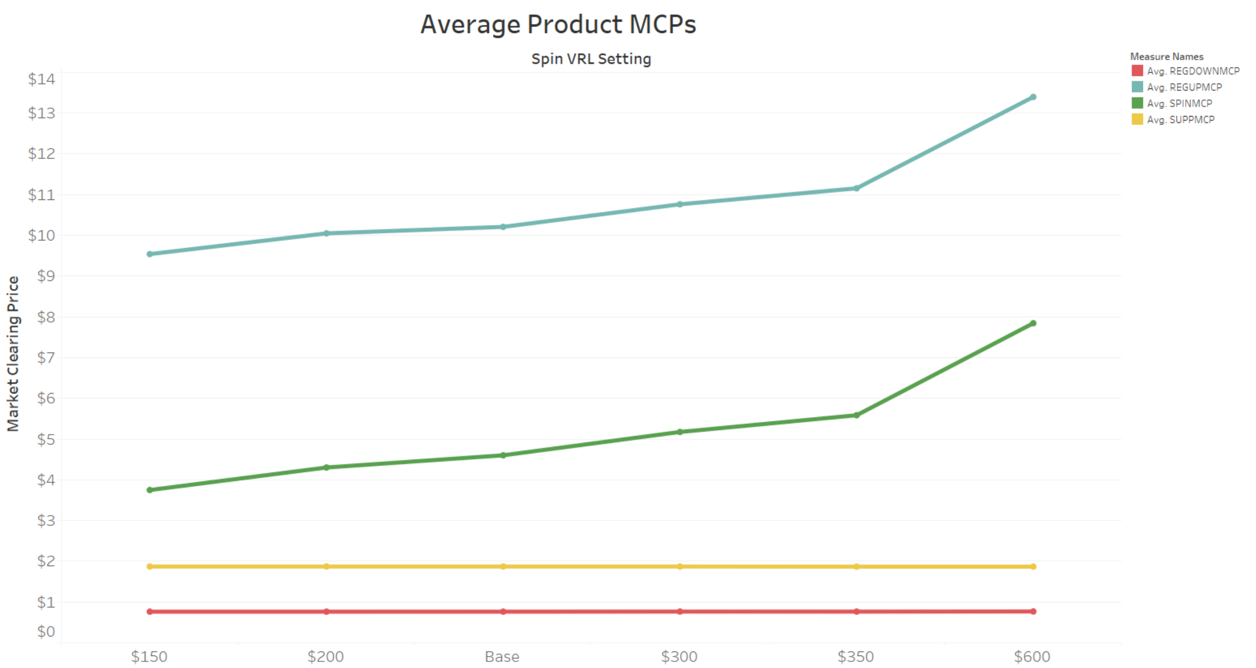

Figure 21: Average Product MCPs

Figure 22 further demonstrates some of the changes occurring around operating constraint shadow prices as the spinning reserve VRL levels increase. A more negative constraint shadow price signals higher congestion on the system.

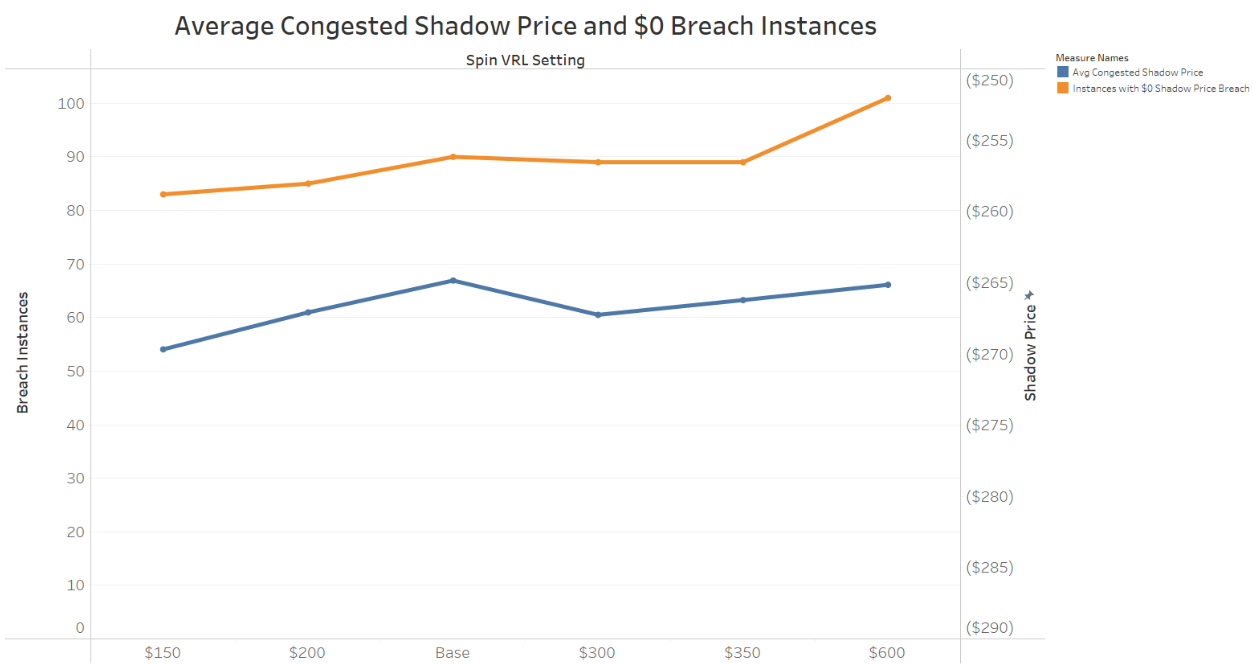

Figure 22: Average Congested Shadow Price and $0 Breach Instances

There are some instances where operating constraints can breach in the SCED with a $0 shadow price when all dispatchable relief is used to honor other obligations. This causes the average congested shadow price to appear less extreme. This explains the trend toward less extreme transmission constraint shadow pricing at higher spinning reserve VRL levels because there are more breach occurrences with $0 shadow price.

Figure 23 below plots the number of scarce intervals versus the average spinning reserve MCP for each VRL spinning reserve penalty level. As we can see from the chart, there is a steady increase in the MCP value as the spinning reserve VRL penalty is increased. Alternatively, we see a slight drop in scarcity intervals as the VRL penalty is increased. The $250 VRL spinning reserve level still offers the best decrease in scarcity for the marginal increase in MCP.

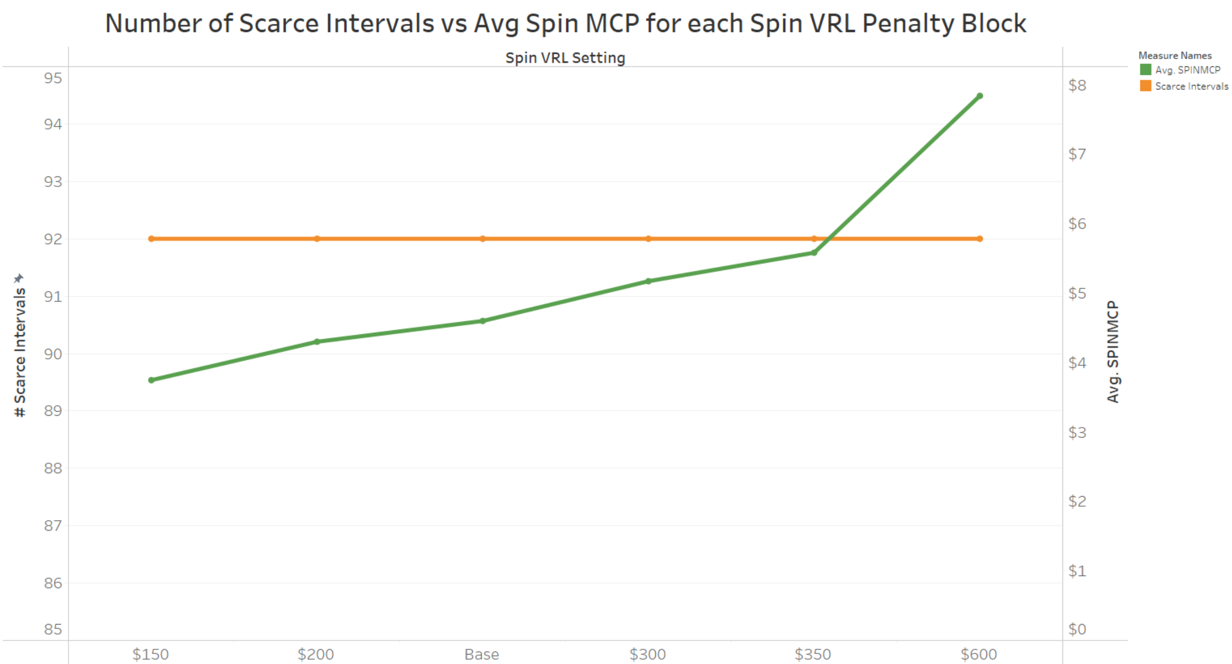

Figure 23: Average Congested Shadow Price and $0 Breach Instances

CONCLUSION

The analysis shows that for any sensitivity higher than $250, there is not a significant improvement in shortage events. Overall, while a $300 spinning reserve VRL value showed a slight improvement in spinning reserve shortages compared to the $250 spinning reserve VRL value (0.84%), it needlessly raises MCPs and MECs while having very little impact on shortage amounts and scarce intervals.

Overall, the number of spinning reserve shortages in RTBM stayed similar in the 2025 reporting year. Fuel prices were consistent with the last study, which caused average MECs to resemble the 2024 reporting year.

When comparing all other spinning reserve scenarios to the base $250, there is not enough change in pricing and shortage amounts to warrant a change in the current base value.