2024 ANNUAL VIOLATION RELAXATION LIMIT ANALYSIS INTEGRATED MARKETPLACE

Market Support and Analysis

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REVISION HISTORY

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EXECUTIVE SUMMARY

This report provides the annual analysis of the Integrated Marketplace violation relaxation limits (VRLs). The effectiveness of the VRLs and their values on reliability and pricing were evaluated. While the historical analysis focused primarily on the previous three years (July 2021 – June 2024), the sensitivity analysis used Real-Time Balancing Market (RTBM) studies ranging from July 2023 to June 2024.

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. Analysis will primarily focus 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 2021 – June 2022	July 2022 – June 2023	July 2023 – June 2024	July 2021 – June 2022	July 2022 – June 2023	July 2023 – June 2024
Spinning Reserve	0	0	0	1,502	567	402
Operating Constraint	*774	*406	*131	80,212	71,648	40,282
Operating Constraint M2M Shadow Price < 1st VRL block	0	8	41	115,727	83,921	61,136

**Day-Ahead Market constraint breaches are primarily due to phase shifter constraints that breach when the equipment is out of service. These instances have a $0 Shadow Price and no pricing impact, as a result they were excluded from the total. They account for 271 of the 1,045 instances of breached DAMKT constraints in the 2022 reporting year, and 0 instances of the 414 breached DAMKT constraints in 2023 reporting year, and 66 instances of the 238 breached DAMKT constraints in 2024 reporting year.*

RECOMMENDATIONS

Based on the analysis presented in this report, SPP is not recommending any changes to the Operating Constraint (OC) VRL blocks. The analysis presented 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 is not recommending any changes to the Spin VRL. When comparing the current $250 spin 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 is not recommending any changes to the VRLs related to Resource Capacity, Power Balance, and Ramp since these VRLs are rarely employed.

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 those situations, SPP will apply VRLs in the MCE solution. VRLs and their associated values attempt to achieve a reasonable balance between honoring operating requirements and constraints while mitigating large price excursions or other extreme prices. In other words, balance reliability and cost.

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

In the course of 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 needed to meet 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. Spinning Reserve Requirement
2. Operating Constraint – including:
    a. Manual
    b. PNode
    c. Watch List
    d. Flowgate
    e. Real-Time Contingency Analysis (RTCA) constraints
3. Resource Ramp Constraint
4. Global Power Balance Constraint
5. Resource Capacity Constraint

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 is:

- 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 Spinning Reserve Requirement at the expense of resolving a Transmission Constraint.

The report, analysis, sensitivities, and recommendations are due to the appropriate working groups by August 1st. Each year, prior to November 1st, 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. The analysis primarily focused on Operating Constraint and Spinning Reserve VRLs. Since the analysis and reporting requirements outlined in the protocols stipulated August 1st as the due date for this report, the study focused on the previous 12 months of data (July of previous year through June of current year). Data referred to by reporting year follows the convention defined below:

- Reporting Year 2022: *July 2021 – June 2022*
- Reporting Year 2023: *July 2022 – June 2023*
- Reporting Year 2024: *July 2023 – June 2024*

BINDING IN THE INTEGRATED MARKETPLACE

The charts shown in Figure 1 and 2 below illustrate the relative distribution of the binding[1] constraints in the RTBM and DAMKT, grouped by shadow price. Day-Ahead Market has a majority of binding occurrences in the [$0-$100]/MW shadow price range, while RTBM has a wider distribution. This is expected, as the RTBM has additional price volatility with changing real-time conditions and shorter ramping intervals (five minutes in the RTBM versus one hour in the DAMKT). 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.

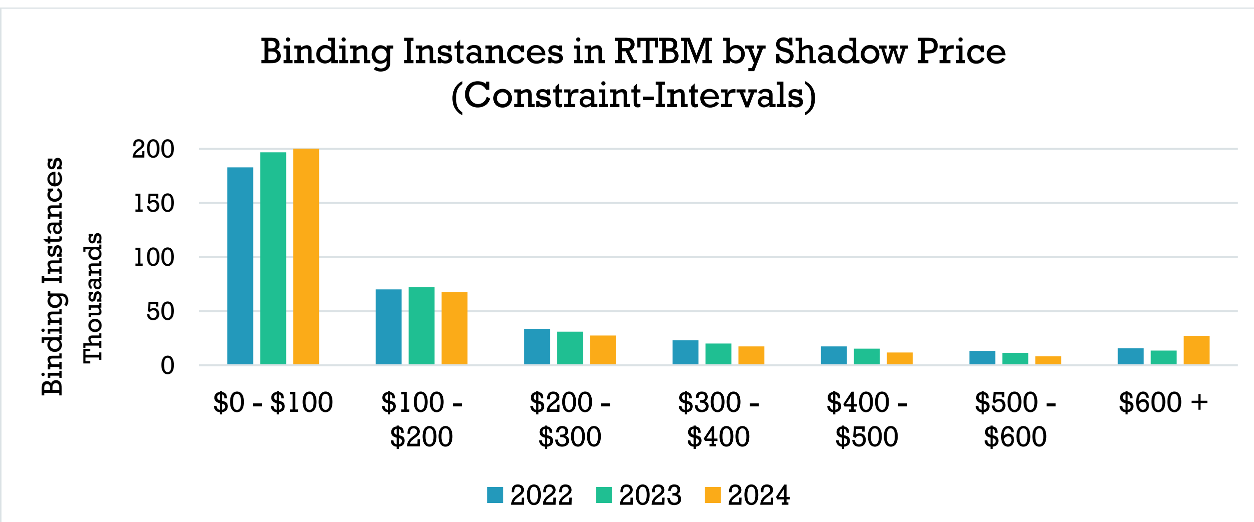

Figure 1: Binding instances in the Real Time Balancing Market

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

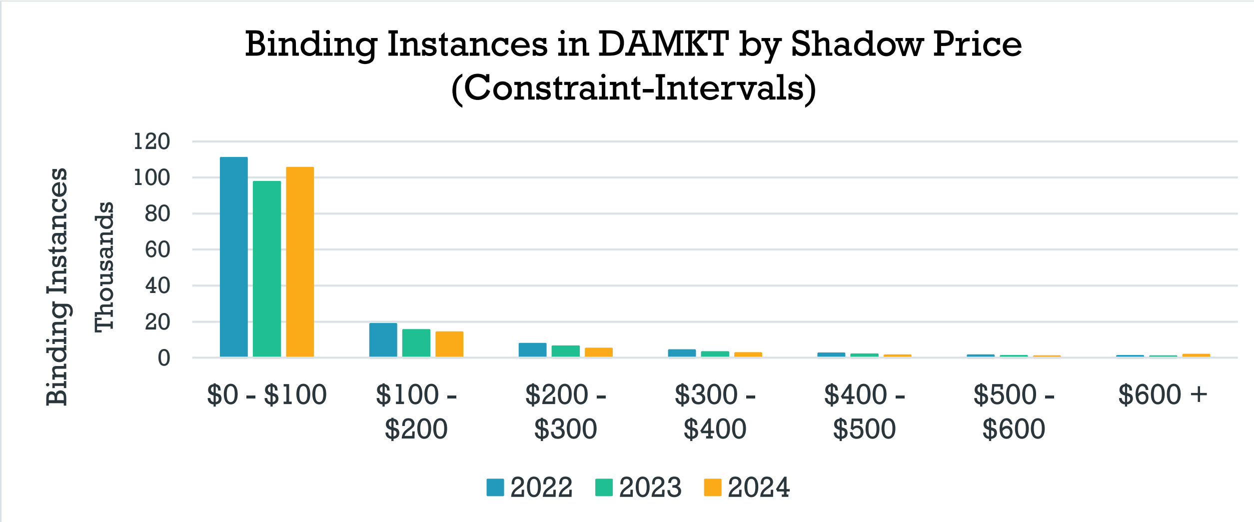

Figure 2: Binding instances in the Day-Ahead Market

Figures 3 and 4 illustrate the distribution of binding intervals in the RTBM and DAMKT grouped by shadow price. These distributions follow historical trends, shown in Figures 5 and 6.

When inspecting the binding instances by shadow price as a percent 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.

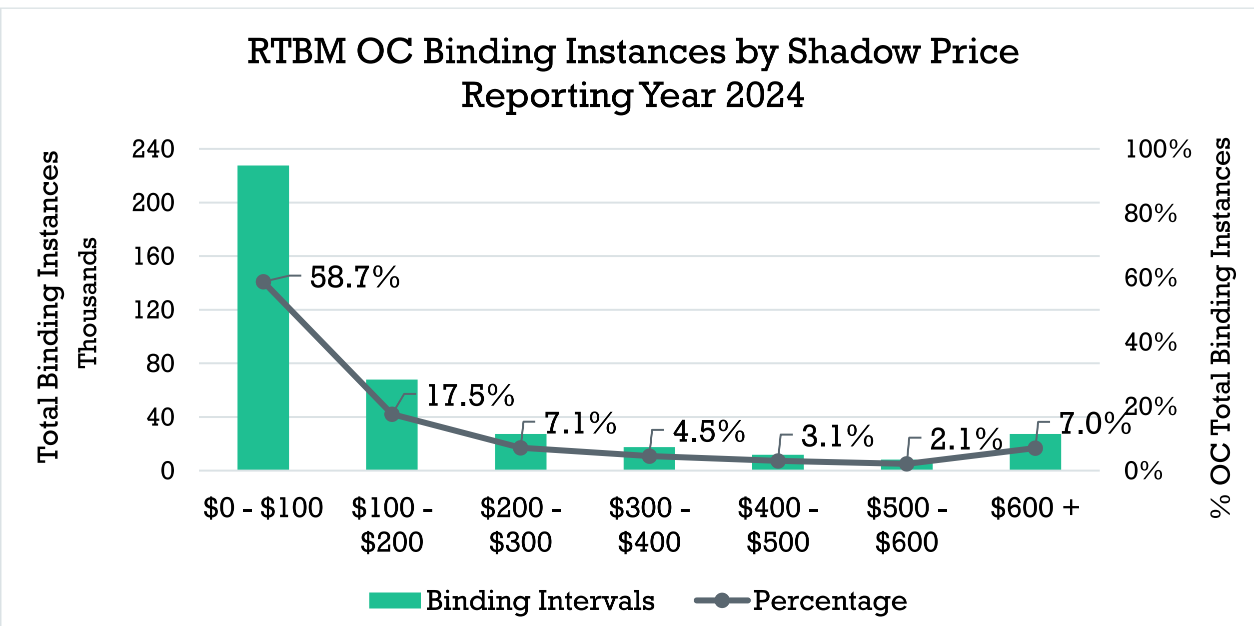

Figure 3: RTBM OC Binding Instances by Shadow Price for Reporting Year 2024

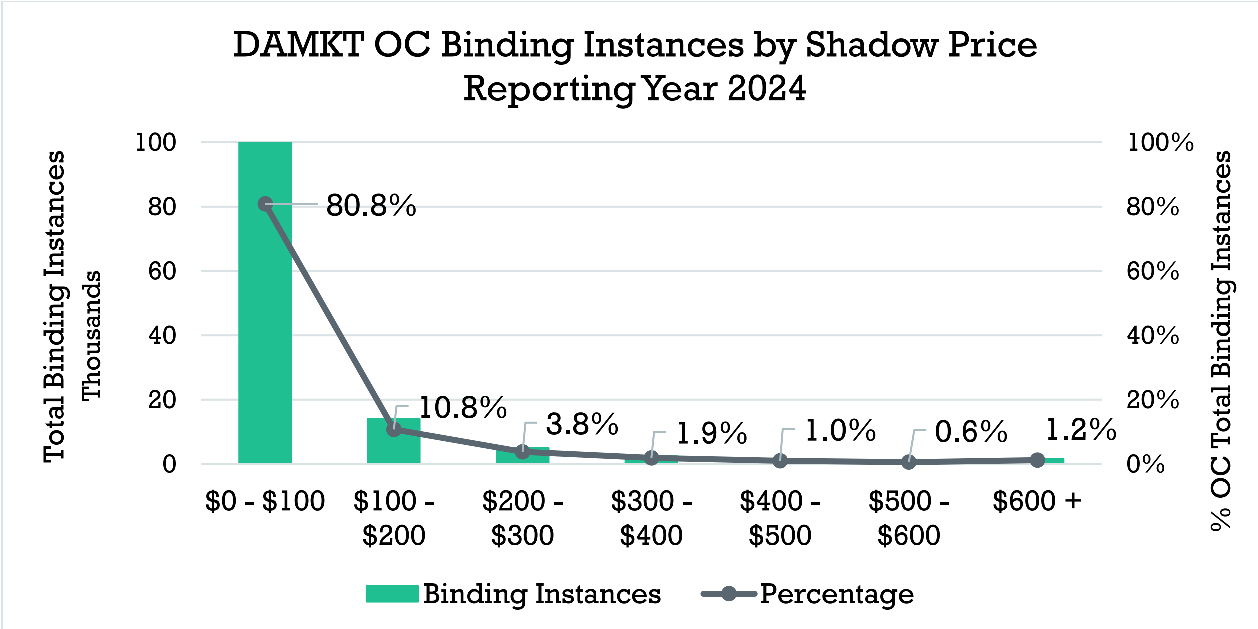

Figure 4: DAMKT OC Binding Instances by Shadow Price for Reporting Year 2024

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

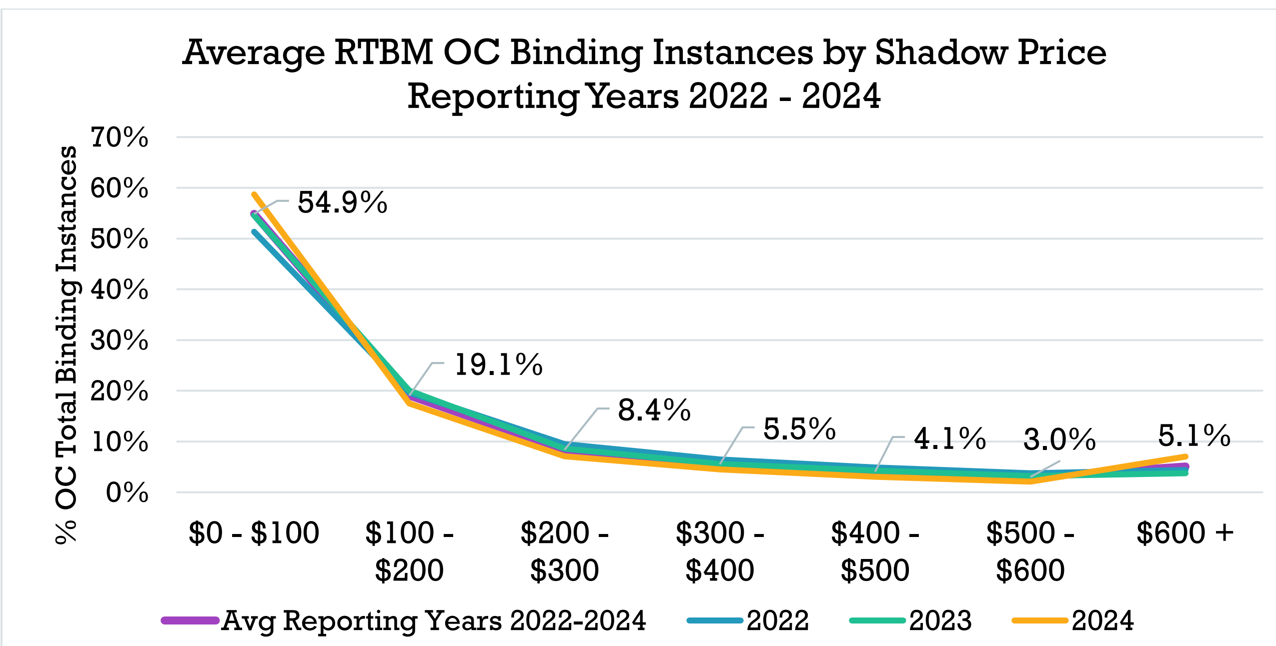

Figure 5: Average RTBM OC Binding Instances by Shadow Price for Reporting Years 2022-2024

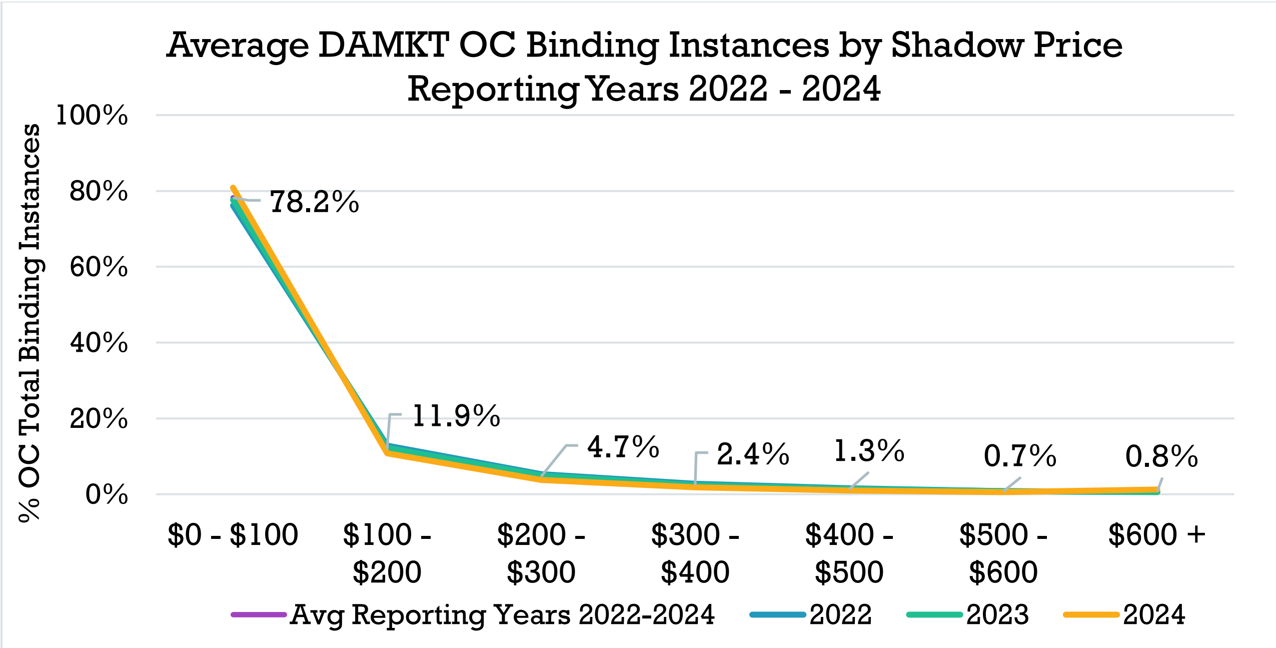

Figure 6: DAMKT OC Binding Instances by Shadow Price for Reporting Years 2022-2024

BREACHING IN THE REAL-TIME BALANCING MARKET

During the 2024 reporting year, SPP observed a decrease in breach events. This decrease can be attributed to the change in the set of VRLs on June 1st, 2023 and a decrease in the cost of Energy available to redispatch due to normalizing gas prices. It is worth noting in this section that breached instances are excluded from Figure 7 where SPP was not controlling the constraint in Market Flow Control (such as external M2M or congestion from TLR to meet market relief assignment).

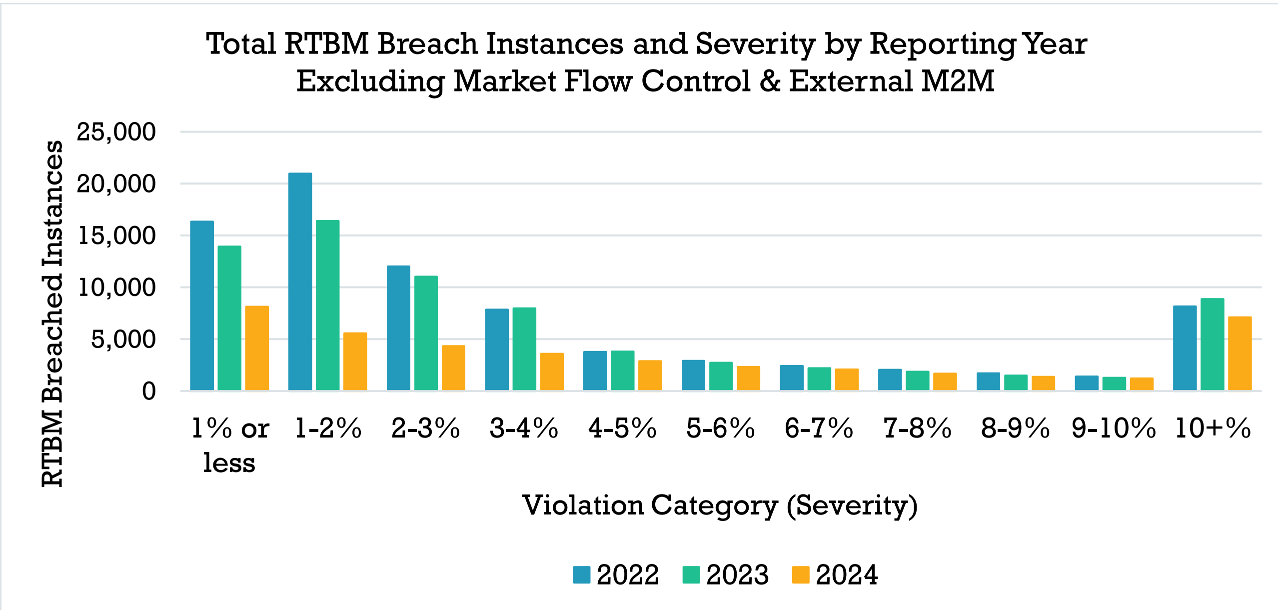

Figure 7: Total RTBM Breach Instances and Severity by Reporting Year Excluding Market Flow Control & External M2M

Figure 8 illustrates the distribution by percent of breached instances.

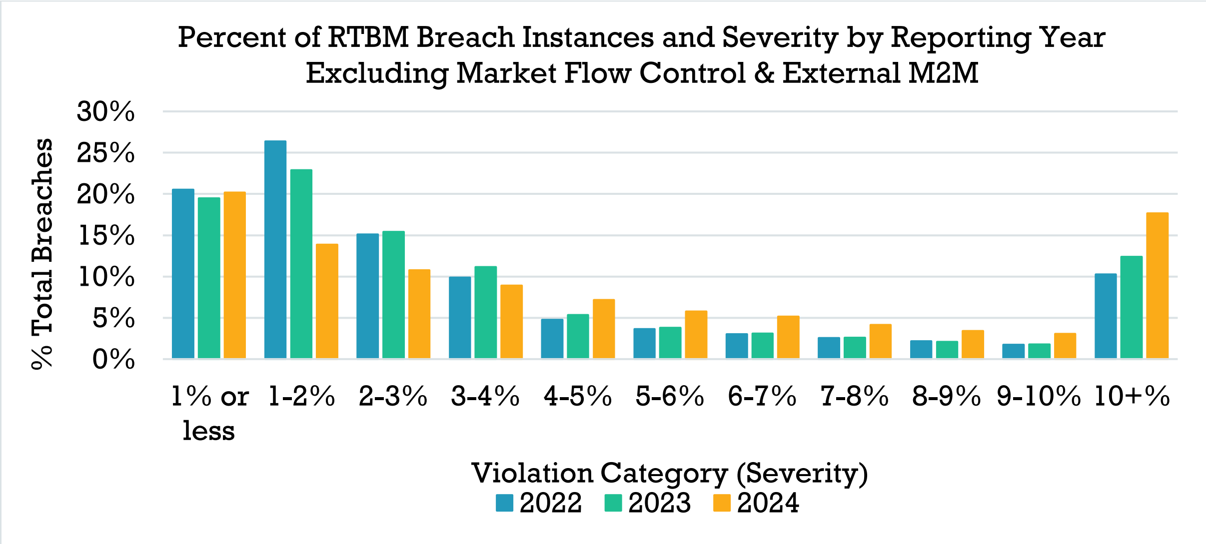

Figure 8: Percent of RTBM Breach Instances and Severity by Reporting Year Excluding Market Flow Control & External M2M

BREACHING IN THE DAY-AHEAD MARKET

The DAMKT sees far fewer breaches than RTBM, 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.

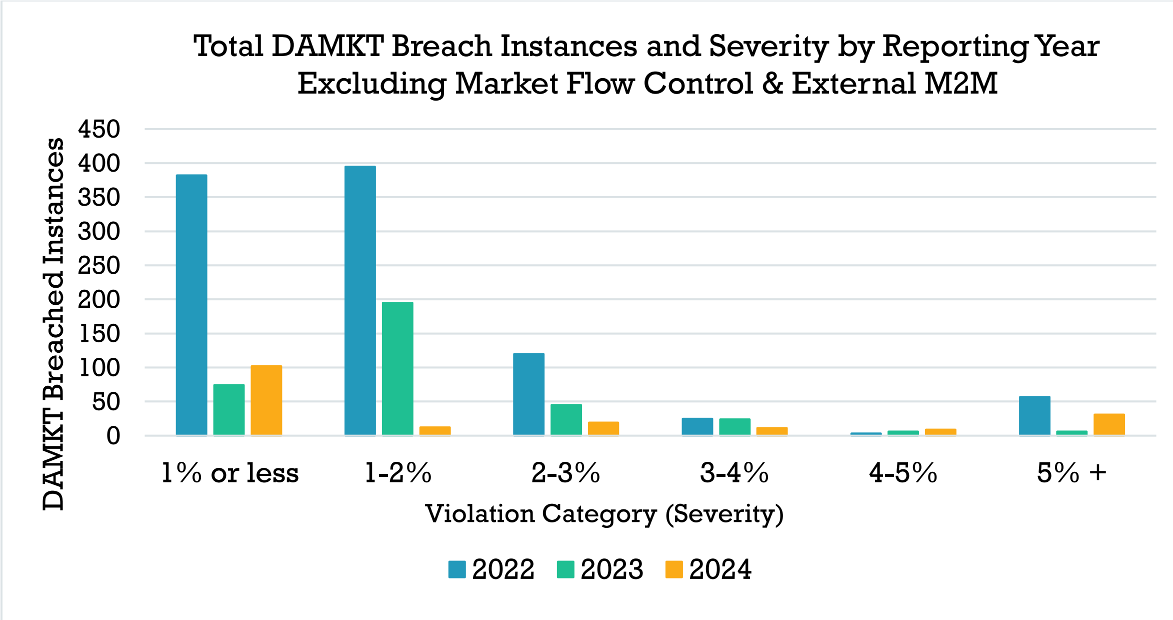

Figure 9: DAMKT Breach Instances and Severity by Reporting Year Excluding Market Flow Control & External M2M

As noted in the opening of the report, many of the breached intervals in DAMKT from the 2022-2024 reporting years are due to phase-shifter control constraints that are unable to solve when the phase-shifting transformer becomes temporarily radial due to transmission outages. These instances all resulted in a $0 shadow price and did not affect the solution but are still reported as breached.

Table 3: Day-Ahead Market Breach Events

DAY-AHEAD MARKET BREACH EVENTS			
Reporting year	**Operating Constraint**	**Phase Shifter**	**Total**
2022	774	271	1,045
2023	414	0	414
2024	172	66	238

SPINNING RESERVE SHORTAGES IN THE RTBM

The prevalence of spinning reserve shortages significantly decreased in the RTBM for the 2024 reporting year as shown in Figure 10. The occurrences of spinning reserve shortages in RTBM are primarily due to unplanned changes in obligation, larger than forecasted ramping events, and limited rampable capacity. From Figure 10, we can see a decrease in spinning reserve shortages in real time for the 2024 reporting year so far due to the increase in spin VRL pricing and decrease in natural gas prices, with the large improvement being in the 0-50 MW shortage amount category, but we can also see an improvement in the more severe shortages of over 400 MWs.

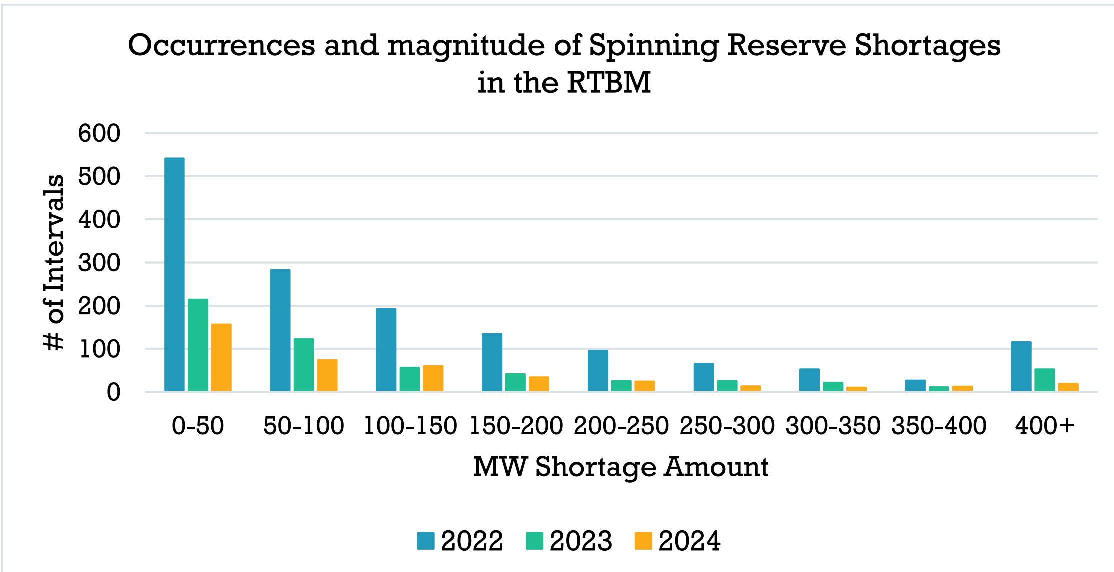

Figure 10: Occurrences and magnitude of Spinning Reserve Shortages in the RTBM

Historically, spinning reserve shortages have been concentrated in the off-peak months. These months tend to have a large amount of renewable energy penetration and conventional generation outages. 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 RTBM by month. The orange line represents the 2024 reporting year, and we can see that the number of spin reserve shortages in RTBM remains lower compared to the past two reporting years, likely due to the lower gas prices and higher VRL penalty. Overall, we see 50 or less intervals short per month from July 2023 to June 2024.

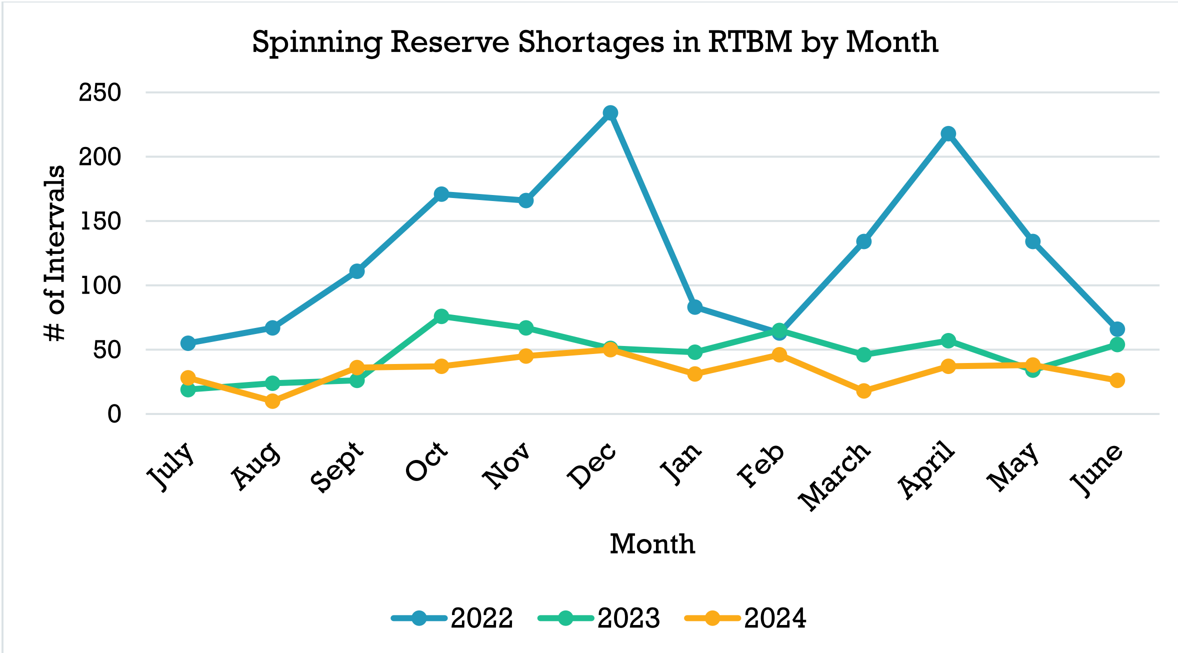

Figure 11: Spinning Reserve Shortages in RTBM, by Month by Reporting Year

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 41 operating days. These days represent a variety of congestion patterns on the SPP system as the case selection covered a wide range of operational conditions.

Table 4: Operating conditions per reporting year

	2022	2023	2024
Number of Intervals	26,132	12,033	11,808
RTBM cases ran and analyzed	+182,000	+60,165	+70,848
System load	21.6 to 51.0 GW	22.4 to 53.4 GW	22.6 to 56.1 GW
System generation	22.4 to 51.5 GW	21.5 to 52.9 GW	23.2 to 54.8 GW
System wind forecasts	0.6 to 26.8 GW	0.8 to 27.1 GW	0.6 to 29.5 GW
Net scheduled interchange	-3.0 to 5.1 GW	-2.9 to 3.6 GW	-6.7 to 3.5 GW

There were five sensitivities studied that are described in more detail below. One sensitivity has a single VRL block, and four sensitivities have increasing blocks. Combined with the base reruns, the study analyzed over 70,848 RTBM intervals.

The VRL blocks were the only input changes to the cases, but a feed-forward dispatch simulation[2] was used to reflect resource dispatch following and constraint impacts. This simulation style is the same as was used in the 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 are 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 now a flat $1,500 curve that was recommended from the previous VRL report and went in 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, so that changes in the VRL blocks can 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. **Single Blocks** – This VRL block sets a single price for every single VRL block. Table 5 lists the VRL blocks and is graphed in Figure 12.

Table 5: Penalty blocks for the Single Block Size

	Base	Sensitivity 5	If VRL passed, relax limit to
First Block	$1,500	$1,250	101%
	$1,500	$1,250	102%
	$1,500	$1,250	103%
	$1,500	$1,250	104%
Last Block	$1,500	$1,250	>104%

3. **Increasing Blocks** – These sensitivities explored the impact of increasing the size of the price jump as the market relaxed the constraint limits during the solution. Table 6 lists the VRL blocks and are graphed in Figure 10.

Table 6: Penalty blocks for the Increasing Block Size

	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	If VRL passed, relax limit to
First Block	$1,500	$750	$1,000	$750	$1,700	101%
	$1,500	$750	$1,250	$1,000	$1,700	102%
	$1,500	$1,000	$1,500	$1,250	$1,700	103%
	$1,500	$1,250	$1,750	$1,500	$2,000	104%
Last Block	$1,500	$1,500	$2,000	$2,000	$2,000	>104%

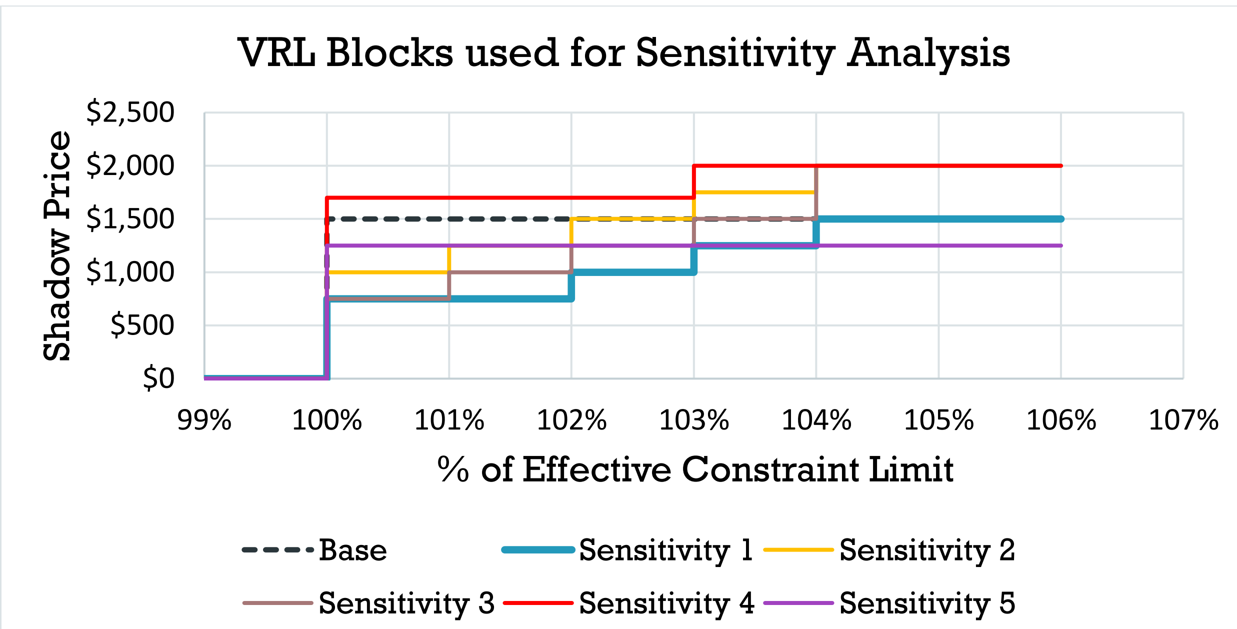

Figure 12: 2024 Constraint Sensitivity VRL Blocks

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 8.

These primary indicators are:

- Average Marginal Energy Cost (MEC)
- Average Operating Cost[1]
- Average Shadow Settlement Cost[2]
- Total number of breach constraint instances in the RTBM solutions
- Total Intervals with OR Scarcity Conditions[3]

1. *Total fuel/offer cost per interval of energy and operating reserve*
2. *Total cost to be paid to resources based on Dispatch MW * LMP + ReservesCleared MW * MCP*
3. *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.*

Table 8: Sensitivity Key Indicators- Interval Averages and Totals

Sensitivity	Average MEC	Average Operating Cost	Average Settlement Cost	Total Breach Instances	Total Market Scarcity Intervals
Base	35.98	$9,277.12	$85,855.40	5,734	758
Sensitivity1	34.38	$9,201.54	$83,586.85	7,827	747
Sensitivity2	36.47	$9,292.83	$86,484.01	6,913	756
Sensitivity3	35.73	$9,259.58	$85,482.94	7,840	751
Sensitivity4	37.54	$9,332.56	$88,016.04	5,492	762
Sensitivity5	34.71	$9,237.06	$84,072.55	6,182	753

Figure 13 shows 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 are reduced while reducing costs.

An analysis of the studies base and sensitivity data indicates:

- Sensitivity 1 had the second largest decrease in reliability while maintaining a minimal decrease in cost compared to the base. The average MEC decreased by 4.45% ($1.60) from the base cost, while increasing the total breaches by 36.5% (2,093) from the base count.

- Sensitivity 2 showed a slighter decrease in reliability than sensitivity 1 but at a higher cost. The average MEC for sensitivity 2 increased by 1.36% ($0.49) from the base cost, while increasing total breaches by 20.56% (1,179) from the base count.
- Sensitivity 3 was the closest in cost compared to the base, with a large decrease in reliability. The average MEC decreased by 0.69% ($0.25) from the base cost, while increasing the total breaches by 36.73% (2,106) from the base count.
- Sensitivity 4 provides a small decrease in breaches with the largest increase in cost compared to the base. The average MEC increased by 4.16% ($1.60) from the base cost, while reducing the total breaches by 4.22% (242) from the base count.
- Sensitivity 5 provides a small increase in breaches with a small decrease in cost compared to the base. The average MEC decreased by 3.53% ($1.27) from the base cost, while reducing the total breaches by 7.81% (448) from the base count.

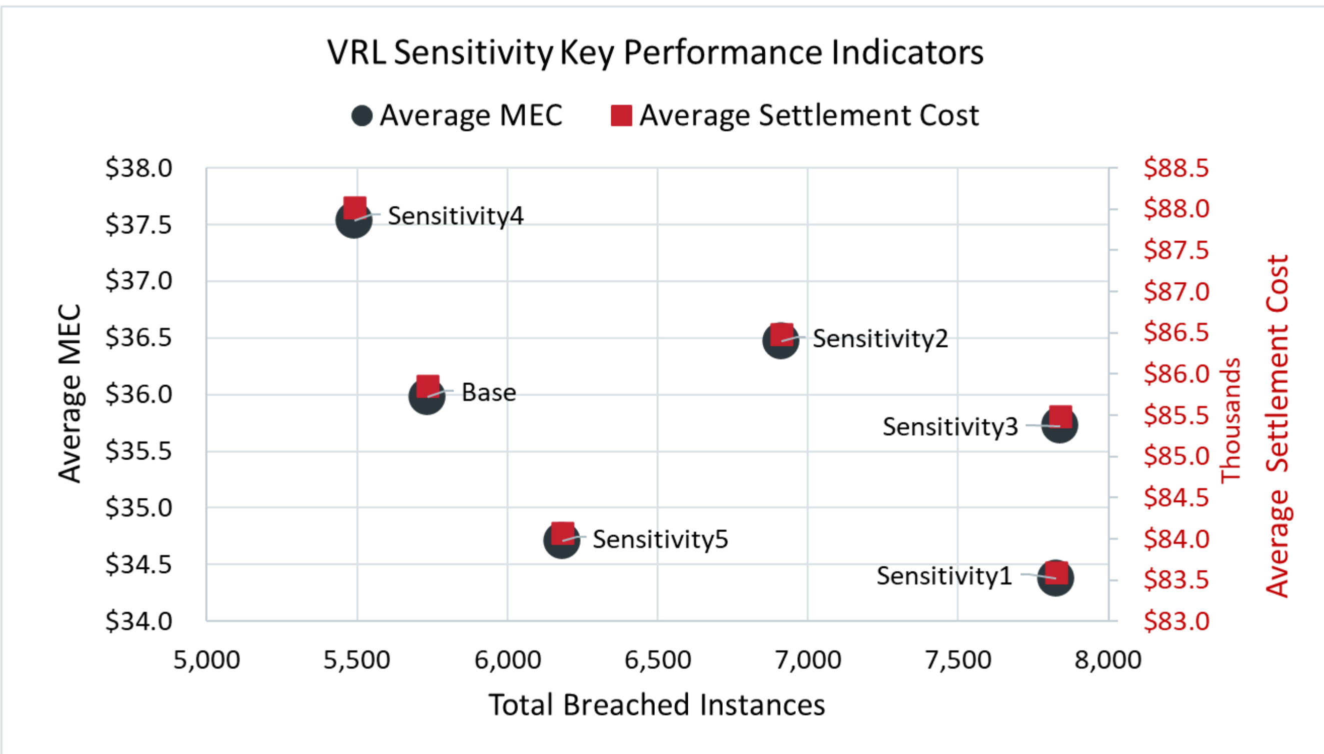

Figure 13: Key Performance Indicators of VRL Sensitivities - Interval Averages and Totals

Table 9 shows the impacts to the total Operating and Total Shadow Settlement costs.

Table 9: Sensitivity Key Indicators- Totals

Sensitivity	Average MEC	Total Operating Cost (Millions)	Total Settlement Cost (Millions)	Total Breach Instances	Total Market Scarcity Intervals
Base	35.98	$101.6	$939.6	5,734	758
Sensitivity1	34.38	$100.8	$914.8	7,827	747
Sensitivity2	36.47	$101.8	$946.5	6,913	756
Sensitivity3	35.73	$101.4	$935.6	7,840	751
Sensitivity4	37.54	$102.2	$963.3	5,492	762
Sensitivity5	34.71	$101.2	$920.1	6,182	753

In Figure 14, the effect of the first VRL penalty block on breaches is clear when we group the sensitivities as shown by the labels within the graph. Each label describes every sensitivity and their first VRL penalty value. We can see that as we increase the value of this first penalty block, we reduce the number of breaches.

Sensitivity 5 had a uniform penalty block, while sensitivities 1-4 had an incremental penalty block. Sensitivities 1 and 3 had the least expensive first block compared to the other sensitivities while the others increased in price. Additionally, sensitivity 4 was the only study that had a reduction in breach amounts from base, however, this comes at a significantly higher operating cost due to the more expensive redispatch and a higher settlement cost due to the increase in average MEC.

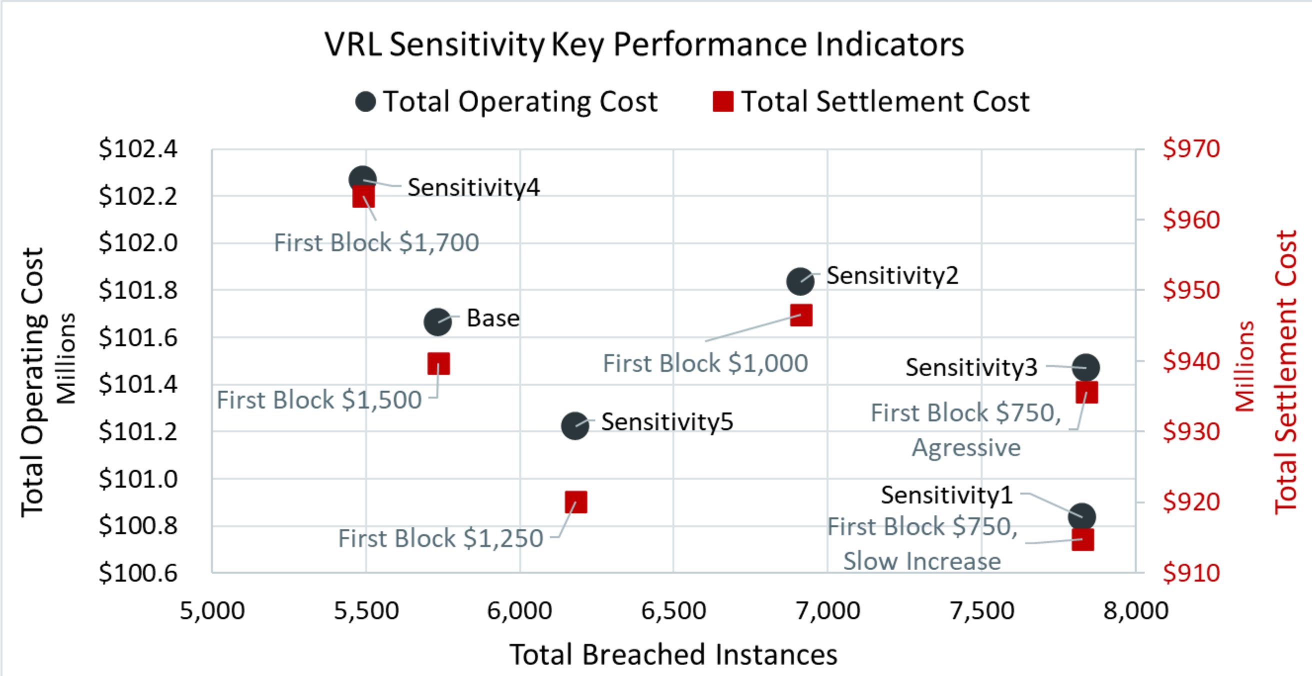

Figure 14: Sensitivity indicators grouped by first VRL penalty block

The total settlement costs shown below are grouped by minimum and maximum category level. That is, data for the days with minimum wind, minimum generation, minimum NSI, minimum load, and minimum MEC were put in one group while data for the days with maximum values were put into another. For each day where RTBMs were re-executed, each sensitivity was grouped into a category then normalized with the highest total settlement cost for that category. Figure 15 shows that the maximum category had larger differences in total settlement costs compared to the minimum category. The graph also shows that sensitivity 1 and 5 were the least expensive and sensitivity 4 had the highest total settlement cost in both categories.

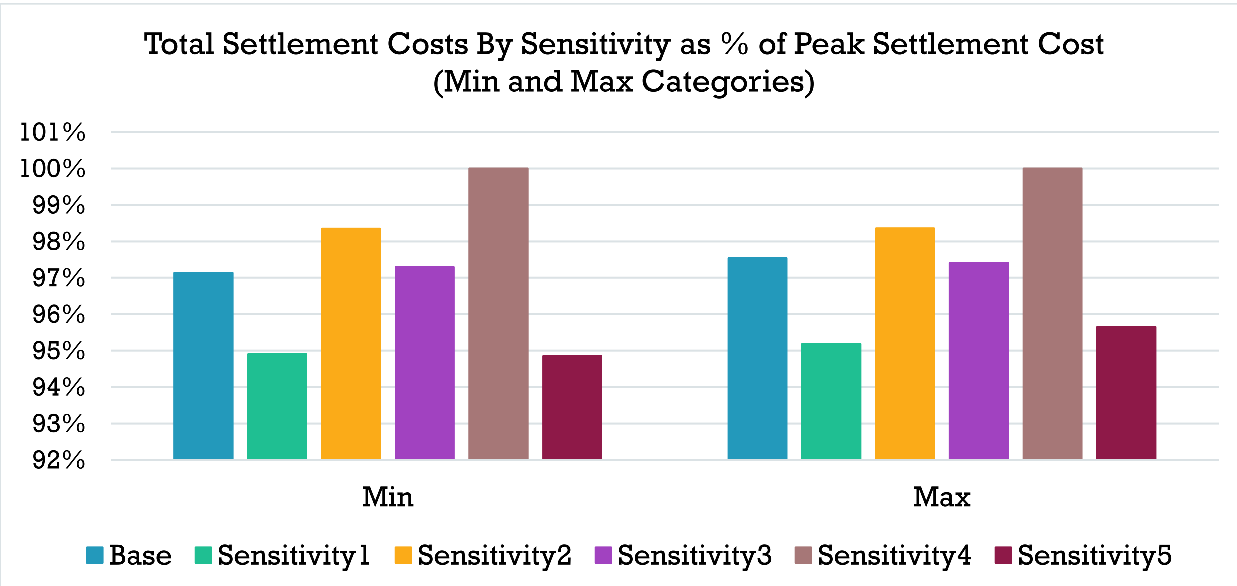

Figure 15: Daily Settlement Cost comparison of VRL Sensitivities by Min/Max Categories

By looking at the individual VRL blocks, it is possible to see where the changes in relaxation occurred for the different sensitivities. This is shown in Figures 16 and 17. Figure 16 looks at all VRL instances, while Figure 17 removes Market Flow control and external M2M in the same fashion as earlier in the report. 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%) breaches occur when the constraint is in Market Flow Control or external M2M.

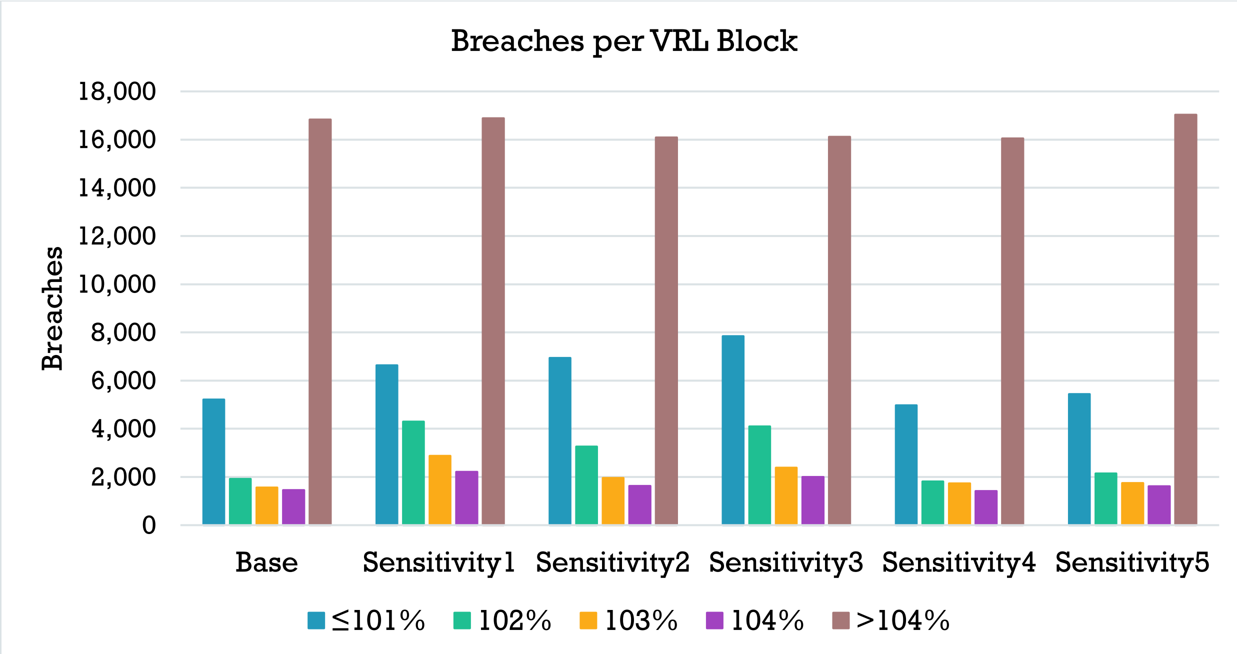

Figure 16: Breaches per VRL Block – MCE flow vs Effective Upper Limit

Table 10: VRL Instance Breakdown by Sensitivity, All Instances

VRL Block	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	5,216	6,638	6,945	7,843	4,978	5,436
102%	1,916	4,297	3,265	4,097	1,818	2,145
103%	1,567	2,871	1,965	2,389	1,737	1,741
104%	1,458	2,218	1,633	1,996	1,415	1,620
>104%	16,834	16,886	16,087	16,116	16,049	17,032

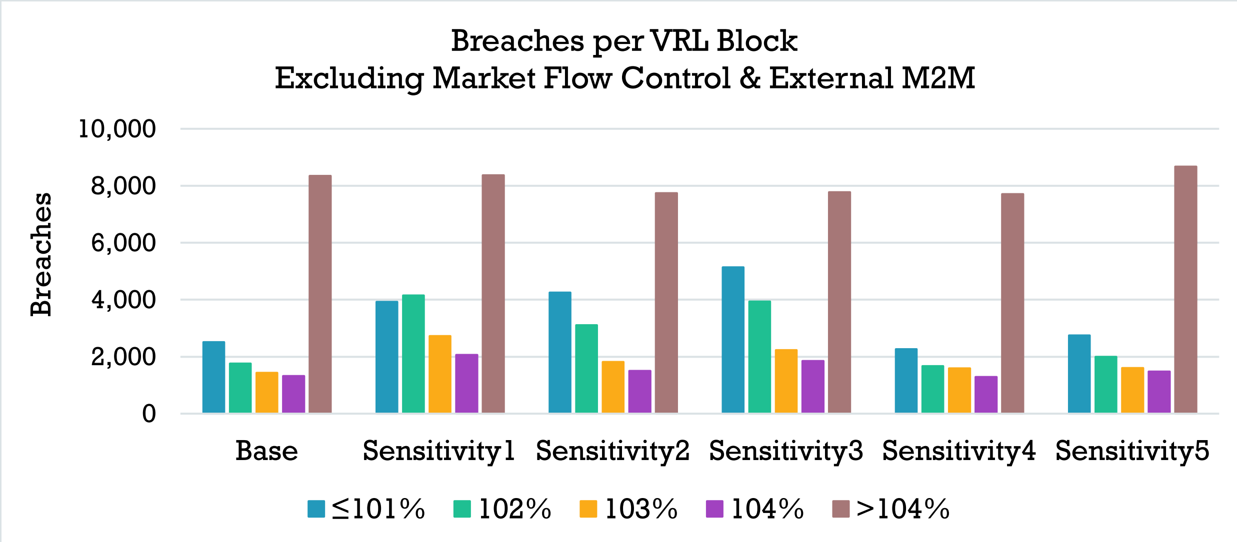

Figure 17: Breaches per VRL Block Excluding Market Flow Control and External M2M

Table 11: VRL Instance Breakdown by Sensitivity- Excluding Market Flow Control and External M2M

VRL Block	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	2,514	3,923	4,246	5,140	2,270	2,751
102%	1,762	4,150	3,104	3,936	1,672	2,000
103%	1,434	2,728	1,816	2,233	1,591	1,597
104%	1,322	2,066	1,496	1,850	1,287	1,481
>104%	8,342	8,372	7,743	7,774	7,708	8,673

As previously shown, Figures 13 and 14 focus on the count of total breached instances, however Figures 16 and 17 show that not all breaches are equal, where some breaches are more severe than others. To view the sensitivities by the instances of breaches in their severity block, a weighted calculation was applied. For VRL Blocks ≤101% to 104% were weighted 1- 4. For VRL Block >104% a weight of 8 was given to represent the more severe breaches that could be approaching the source operating limit. Reminder that these VRL violations are based on the effective limit and not the source operating limit.

Table 12: VRL Instance Weighted Breakdown by Sensitivity- Excluding Market Flow Control and External M2M

VRL Block	Weight	Base	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
≤101%	1	2,514	3,923	4,246	5,140	2,270	2,751
102%	2	3,524	8,300	6,208	7,872	3,344	4,000
103%	3	4,302	8,184	5,448	6,699	4,773	4,791
104%	4	5,288	8,264	5,984	7,400	5,148	5,924
>104%	8	66,736	66,976	61,944	62,192	61,664	69,384
Total		82,364	95,647	83,830	89,303	77,199	86,850

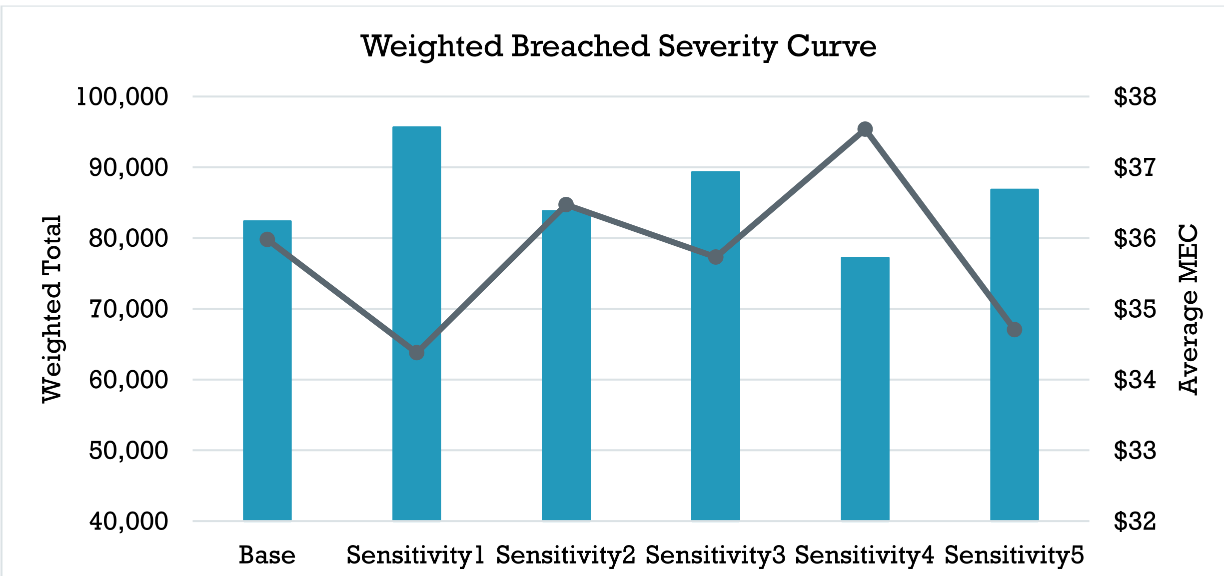

Figure 18: Breaches weighted by VRL Block Excluding Market Flow Control and External M2M

CONCLUSION

Overall, relative to our base VRL block:

- Sensitivities 1, 2 and 3 had a significant increase in the overall number of breached instances across the board ranging from 20.56% (1,179) to 36.73% (2,106). Sensitivities 1 and 3 had a slight decrease to MEC, average settlement cost, and average operating cost while sensitivity 2 had an increase compared to base values. At a maximum, the average MEC decreased by 4.45% ($1.60). Due to sensitivity 2 showing almost no benefit, it should not be considered.
- Sensitivity 4, which had increasing blocks ranging from $1,700 to $2,000, showed the largest improvement in the number of breaches compared to the base but at a higher cost than the other four sensitivities. The average MEC was 4.16% higher than the base cost ($1.60). The reduction in breaches compared to base was 4.22% (242).
- Sensitivities 5, which had a single block of $1,250, showed an increase of 7.81% (448) in total number of breaches compared to the base count while the MEC decreased by 3.53% ($1.27) from the base cost.
- There was no significant change in the number of market scarcity intervals between the five sensitivities (with a maximum change of 11 intervals).
- For the sensitivities that had minimal cost decreases with significant increases in breach instances (Sensitivity 1, 3, and 5), there is not enough benefit on the cost side to warrant a VRL curve changes from base. Sensitivity 2 showed no benefit in cost savings or reliability. Sensitivity 4 did show slightly increased reliability, but not enough to warrant the extra cost that comes along with it.

SENSITIVITY ANALYSIS FOR SPINNING VRL

Sensitivities for the spinning reserve constraint were re-run this year by adjusting the VRL price from the current value to our selected spin 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 a spin shortage, for a total of 402 intervals.

METHODOLOGY

The study was run without performing the full feed-forward simulation, since a continuous dispatch through spin 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 spin 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, scarcity of operating reserve and constraint breach events moved in the direction expected:

- The number of scarce intervals slightly decreases as the value placed on meeting the spin VRL requirement is increased. At a maximum, the spin VRL value showed an improvement in reducing the number of scarce intervals by only 1% (4) compared to the base, while most scenarios ($150, $200, $250) stayed at the same value of 402.
- Regulation down shortages did not change as the value placed on meeting the spin VRL requirement increased. All spin VRL sensitivities had an equal regulation down shortage MW value.
- Regulation up, spin and supplemental shortages decreased as the value placed on meeting the spin VRL requirement increased. The spin shortage total decreased by 4.94% with the $600 spin VRL and increased by 3.77% with the $150 spin VRL value when compared to the base spin VRL value. A $300 spin VRL value showed a slight improvement in spin shortages. The improvement compared to the $250 spin VRL value was minimal (0.81%).
- A rise in flowgate breached instances occurs with higher spin VRL sensitivities due to the increase in spin value relative to the operating constraints VRL values.

Table 13: 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	402	145	32,697	49,284	4,816	919
$200	402	145	32,192	48,420	4,804	929
$250	402	145	31,652	47,495	4,804	930
$300	399	145	31,525	47,110	4,801	938
$350	398	145	31,302	46,744	4,791	951
$600	398	145	30,778	45,149	4,769	989

The results may be more enlightening when viewed as a line chart. Figure 19 shows the number of scarce intervals by VRL spin sensitivity. As shown below, there is a small drop in scarcity intervals when the spin VRL increases. The reduction of scarce intervals is minimal (around 1%) when increasing the current spin VRL sensitivity to a value of $350 or $600.

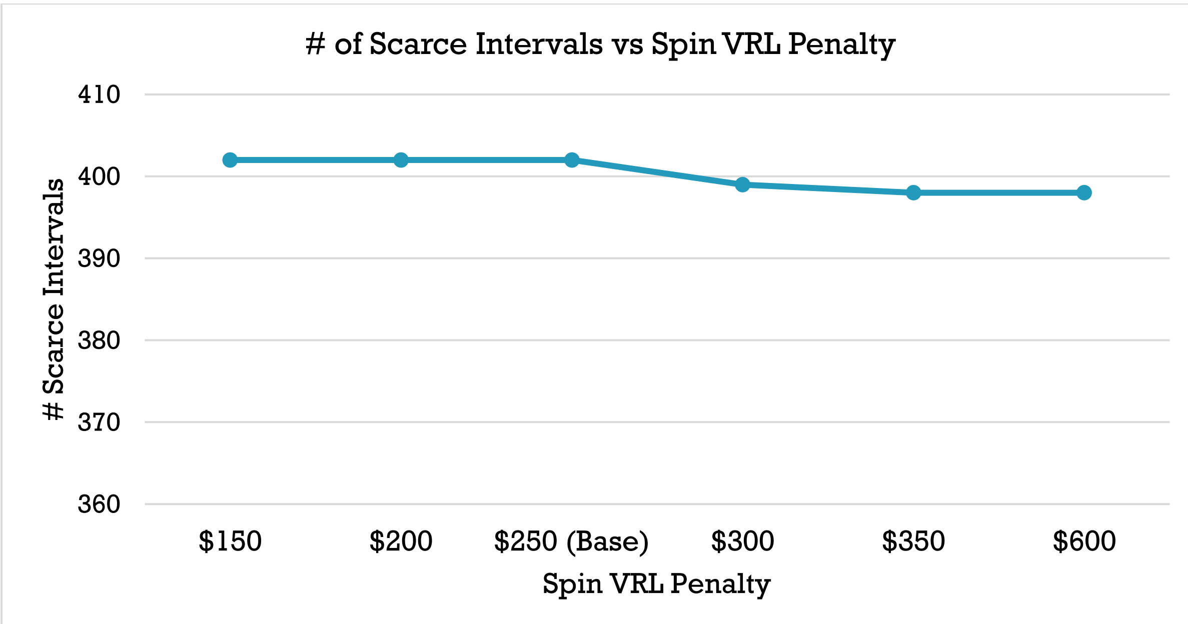

Figure 19: Number of Scarce Intervals for each Spin VRL Penalty

ECONOMIC INDICATORS

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

- There was little impact to regulation down and supplemental MCPs.
- Spin MCPs increased as the spin VRL sensitivity increased. The $600 spin VRL value showed an increase of 67.02% in average MCP compared to the base spin VRL, while the $300 spin VRL value had a 9.1% increase in average spin MCP.
- The MECs followed a similar path, since most shortages of spin involve competition with energy. The $600 spin VRL value showed an increase of 21% in average MEC compared to the base spin VRL, while the $300 spin VRL value had a 2.83% increase in average spin MCP.
- Regulation up saw an increase in MCPs as product substitution allowed it to compete with spin. With higher spin VRLs, spin 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 spin.
- The LMP spread, maximum LMP minus minimum LMP in the SCED, increased with the rise in the spin VRL.
- The congested shadow prices on constraints followed a similar pattern.

Table 14: Spin 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	$350.65	$935.15	$0.72	$36.40	$13.71	$7.64	-$557.06
$200	$362.01	$941.62	$0.73	$38.11	$15.60	$7.64	-$556.58
$250	$371.05	$938.97	$0.74	$39.47	$17.04	$7.57	-$558.48
$300	$381.54	$938.12	$0.74	$40.99	$18.59	$7.57	-$556.36
$350	$392.21	$942.04	$0.74	$42.53	$20.18	$7.57	-$557.18
$600	$448.91	$966.48	$0.75	$50.56	$28.46	$7.38	-$559.47

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 Spin VRL value increases.

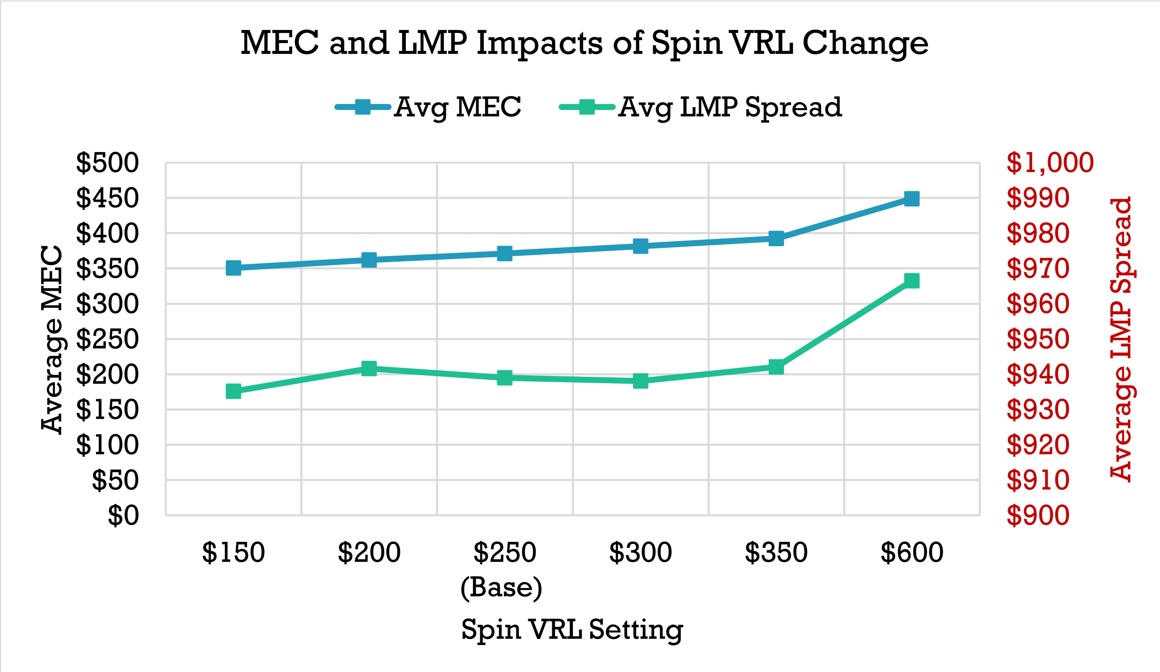

Figure 20: MEC and LMP Impacts of Spin VRL Change

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.

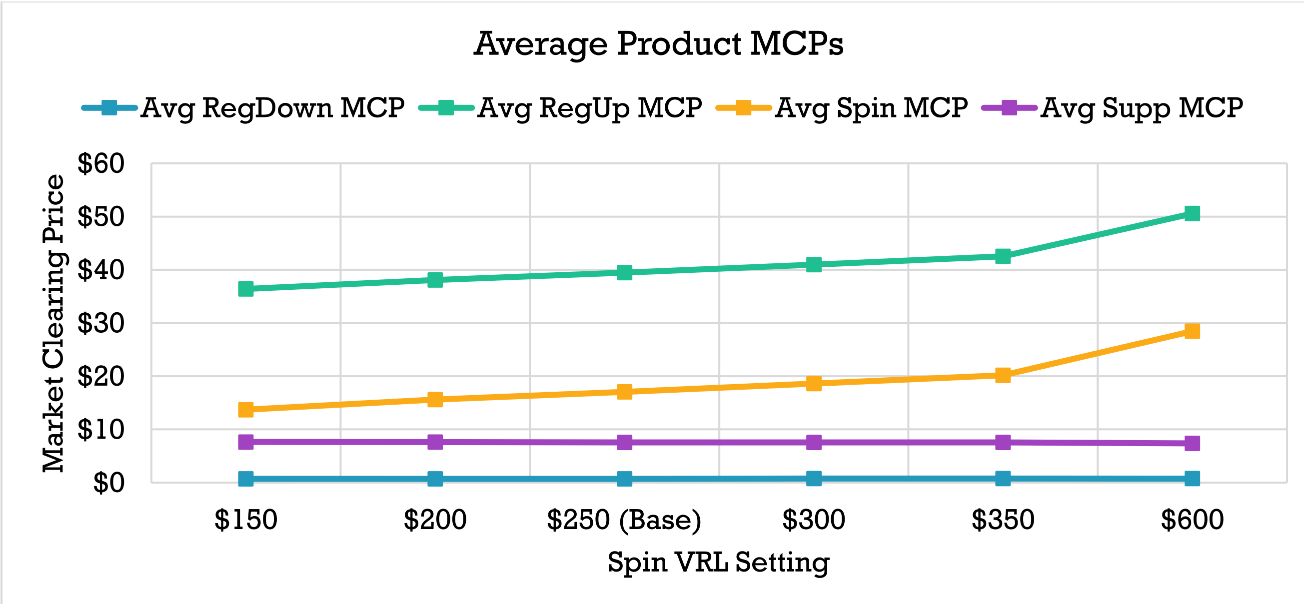

Figure 21: Average Product MCPs

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

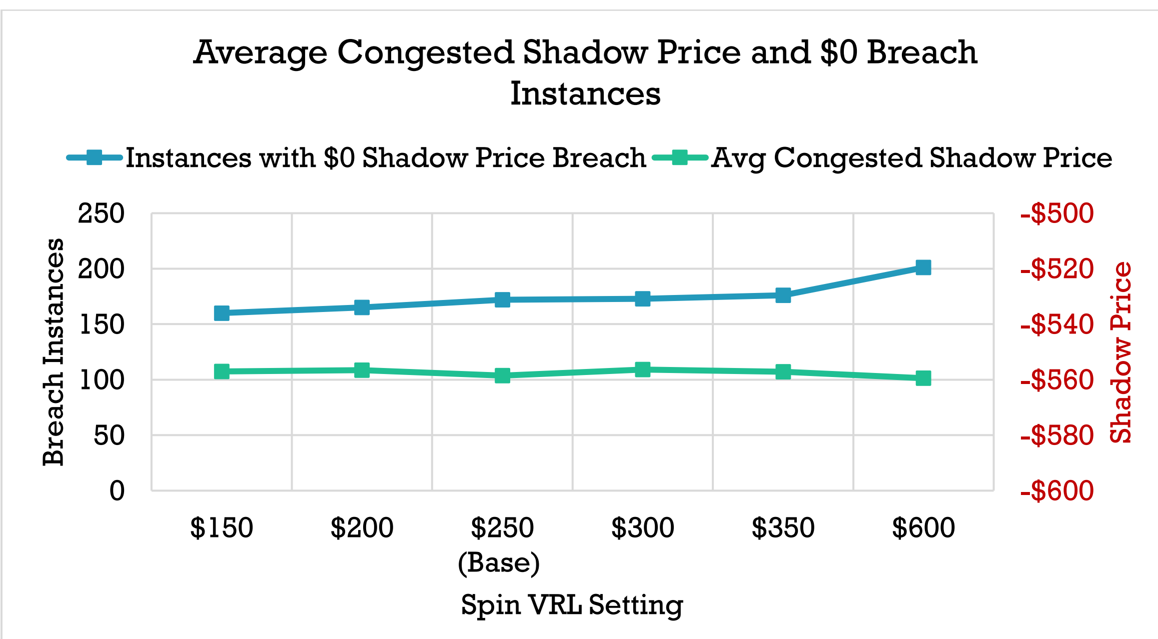

Figure 22: Average Congested Shadow Price and $0 Breach Instances

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 to less extreme transmission constraint shadow pricing at higher spin VRL levels because there are more breach occurrences with $0 shadow price.

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

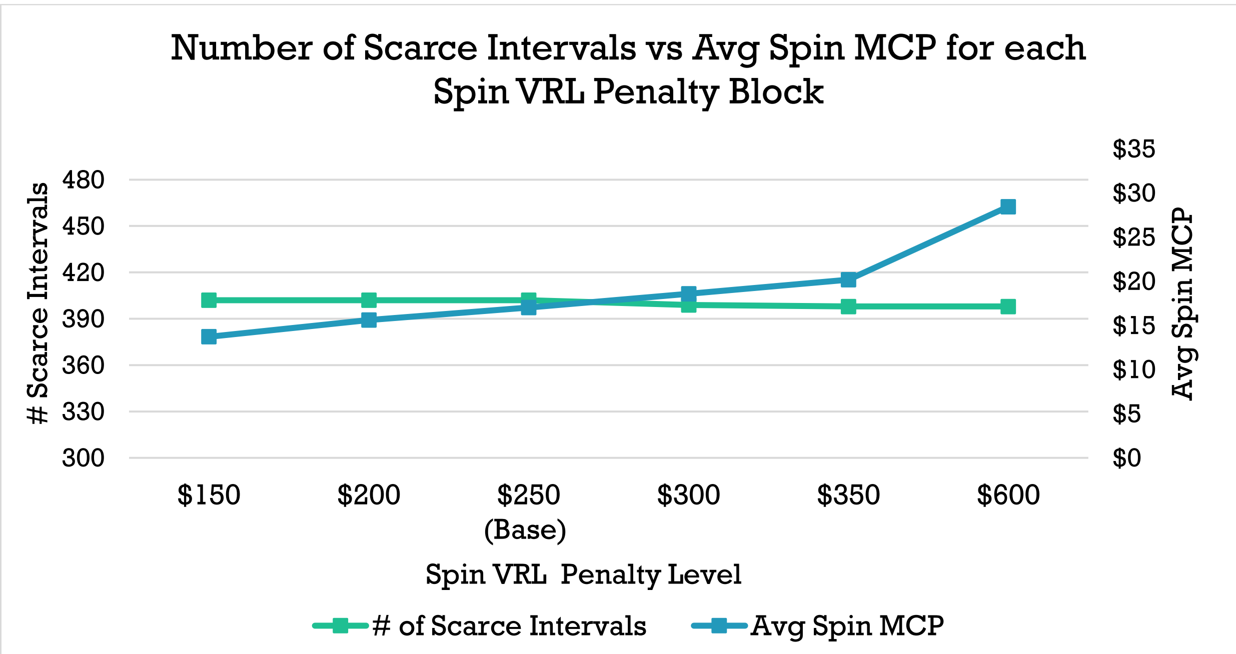

Figure 23: Average Congested Shadow Price and $0 Breach Instances

CONCLUSION

The analysis shows that for any sensitivity higher than $250, there is not a significant improvement in shortage events. Overall, while a $300 spin VRL value showed a slight improvement in spin shortages compared to the $250 spin VRL value (2.14%), it needlessly raises MCPs and MECs while having very little impact on shortage amounts and scarce intervals.

Overall, the number of spin shortages in RTBM have significantly decreased in this past reporting year. Gas prices have been relatively lower since the last study, this caused the MEC values to be lower. These conditions have partially contributed to the reduction of shortage intervals for the sensitives studied.

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