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Ramp Rates for Battery Energy Storage System (BESS) Facilities



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Agenda

- Recap – Ramp Rate Requirement for BESS Facilities
- Technical Considerations for BESS Ramp Rate Requirement
- Updated Financial Impact Analysis
- Draft Market Rules/Market Manuals
- Conclusion & Next Steps

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Recap – Ramp Rate Requirement for BESS Facilities

- As penetration of battery energy storage system (BESS) increases, the near-instantaneous ramping capability of these resources could lead to significant system balancing and stability concerns under normal operating conditions.
- At the July 22 engagement session, the IESO proposed to amend the market rules to codify the 100 MW/min ramp rate requirement for BESS facilities when responding to 5-minute energy dispatches.
- The IESO's response to stakeholder feedback was posted on September 23; the following slides discuss specific feedback and additional information regarding:
  - Technical considerations for selecting the 100 MW/min ramp rate requirement for BESS facilities; and
  - An update to the financial impact analysis presented at the July engagement session, now covering the expanded period of May 2025 through June 2026.

BESS Ramp Rate Requirement: Technical Considerations

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Feedback Received: Technical Considerations for Ramp Rate Requirement

Theme	What We Heard
Rationale for a BESS ramp rate requirement	• Stakeholders generally understand and agree that instantaneous ramping can create over- and under-generation within 5-minute dispatch intervals, impacting the IESO's Area Control Error (ACE), overall system balancing and ability to maintain reliability.

Additional Technical Justification	• Stakeholders requested additional justification for the selection of the 100 MW/min BESS ramp rate value, including:
	  • how the 100MW/min threshold resolves the balancing concern; and
	  • sensitivity analysis identifying other ramp rates considered and their corresponding impact on ACE and NERC balancing standard metrics.

BESS Ramp Rate Requirement: Overview

- Coincident energy dispatch instructions issued to a large proportion of the BESS fleet creates the risk of significant system imbalances, resulting from the simultaneous movement of the BESS fleet outpacing changes in both market demand and other supply resources.
- BESS resources have registered ramp rates that are over 100 times faster than other resource types connected to Ontario's electricity system, including other inverter-based variable generation (i.e., wind and solar).
- With approximately 3,600 MW of installed BESS capacity procured and expected online by 2030, the IESO has determined that a 100 MW/min ramp rate requirement for the BESS fleet will be sufficient to mitigate significant impacts on ACE and overall system balancing.
- The BESS ramping requirement will be specified as 6.7 MW/4 seconds to make clear that an instantaneous step-change of 100 MW within a 1-minute period is not permitted when responding to real-time energy dispatches.
- This ramp rate requirement is comparable to the upper bound of submitted ramp rates for the vast majority of other faster-ramping resources in Ontario (hydroelectric, wind and solar).

Ramp Rates of Fast-Ramping Resources

Resource Type	Installed Capacity*	Registered Ramp Rates*	Submitted Ramp Rates*	Additional Considerations
BESS	1,050 MW	Max: 49,995 MW/min Avg: 6,587 MW/min	Max: 499 MW/min Avg: 96 MW/min	Coincident ramping impacts on ACE observed (shown on next slide).
Hydro	8,864 MW (~5,000 MW peaking)	Max: 274 MW/min Avg: 94 MW/min	Max: 105 MW/min Avg: 25 MW/min	Coincident ramping impacts on ACE observed (shown on subsequent slide).
Wind	4,943 MW	Max: 3,291 MW/min Avg: 295 MW/min	Max: 500 MW/min Avg: 32 MW/min	Coincident ramping impacts on ACE mitigated by real-time fuel (wind speed) availability and geographic diversity.
Solar	478 MW	Max: 100 MW/min Avg: 35 MW/min	Max: 11 MW/min Avg: 8 MW/min	Coincident ramping impacts on ACE mitigated by real-time fuel (solar irradiance) availability and geographic diversity.

*Data current as of Summer 2026

Coincident BESS Ramping: Impact on Area Control Error

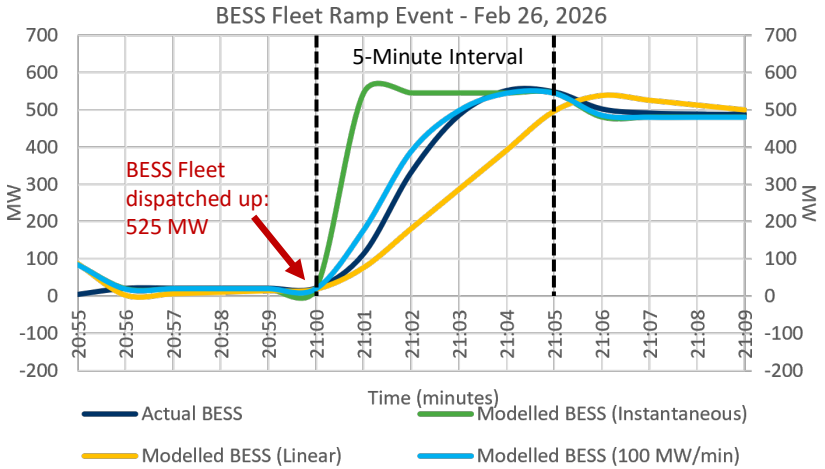
The figures provided on the next slides show:

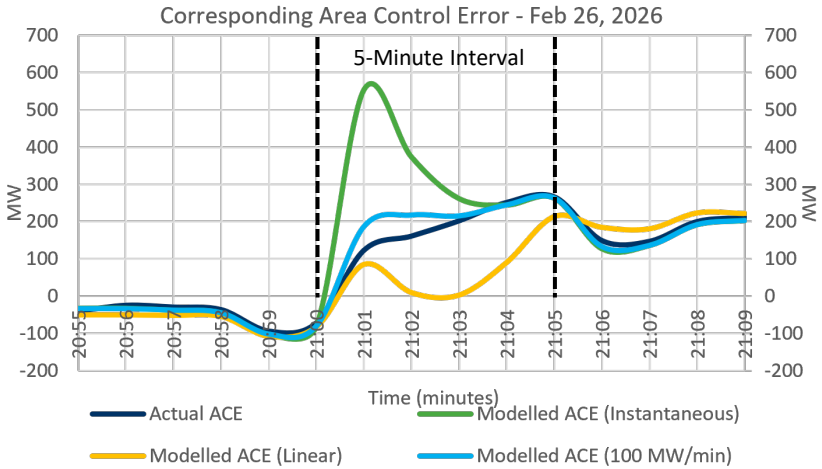
- An actual BESS ramp-up event and its impact on Area Control Error (ACE) on Feb 26, 2026, Hour Ending 22. The BESS fleet was dispatched up 525 MW.
- Modelled data representing how the BESS fleet and corresponding ACE would have behaved under different ramp rate assumptions (Instantaneous, Linear*, 100 MW/min).
- A comparison between the Feb 26th BESS ramp-up event with a similar hydroelectric resource ramp-up event, and the corresponding impacts on ACE.

* A linear ramp rate in MW/min is defined as Δ MW Dispatch divided by 5 (the number of minutes in a dispatch interval).

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Coincident BESS Ramping: Impact on Area Control Error



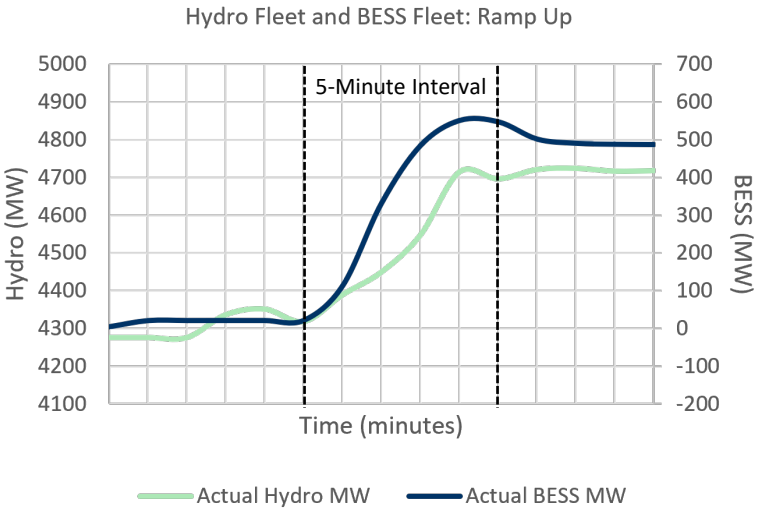


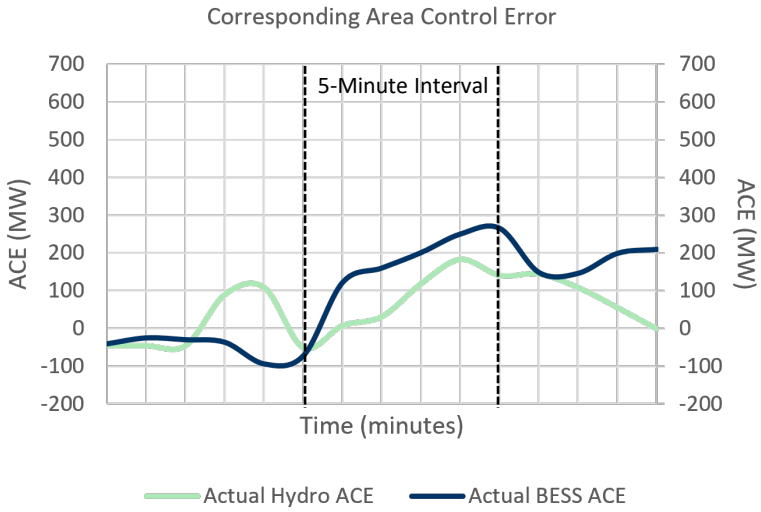
The BESS fleet was dispatched up 525 MW in Interval 1, Hour Ending 22. Modelled data shows how the BESS fleet would ramp under different ramp rate assumptions compared to actual BESS output.

An instantaneous ramp rate would result in ACE increasing to >550 MW. With the actual BESS ramp rate (100 MW/min), there is still an impact on ACE of 250 MW, which is managed by balancing mechanisms (e.g. regulation).

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BESS and Hydro Ramping: Impact on Area Control Error





The figures above show the impact on ACE of similar 5-minute ramp-up dispatches (525 MW total dispatch) to the BESS and Hydro fleets and indicate that while ramping of the hydro fleet has a direct impact on ACE, the actual impact is limited due to the ramp rates of hydro resources.

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BESS Ramp Rate Requirement: Summary

Findings

- Impact of an instantaneous ramp rate on ACE would be significant with the current BESS fleet.
- This impact is anticipated to increase significantly with 3,600 MW of BESS expected online by 2030, resulting in adverse impacts to system balancing and the overall reliability of Ontario's electricity system.
- Experience with other fast-ramping resources such as hydro indicates that the impact on system balancing of a 100 MW/min (6.7 MW/4 seconds) BESS ramp rate can be managed by available balancing mechanisms (e.g. regulation service) both now and in the future.

What was not considered

- The BESS ramp rate was not established with the intent of achieving a specific impact on ACE or meeting minimum NERC BAL-001 Reliability Standard requirements.
- Determining a maximum/definitive ramp rate requirement by isolating the impact of the BESS fleet is not practicable, as ACE and NERC reliability metrics are a function of numerous, coincident supply and demand-side variables.
- If these were the objectives, the expected increase in BESS capacity would require ongoing adjustments to the ramp rate requirement that would likely be more restrictive than the current requirement.

Updated Financial Impact Analysis

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Feedback Received: Lost Cost Opportunity Analysis

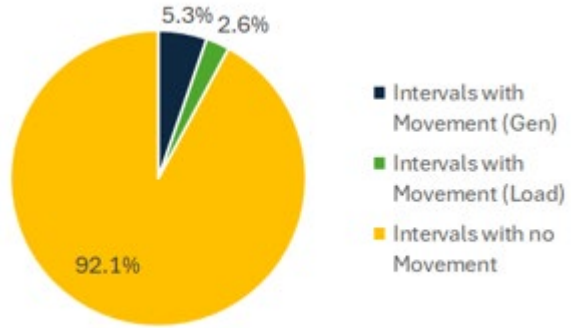
Theme	What We Heard
Additional data required	• The Lost Cost Opportunity Analysis of the BESS ramp rate requirement presented at the July 22 stakeholder engagement included a very limited set of historical data (August to October 2025) that is insufficient to represent the impact of the ramp rate restriction on BESS facilities

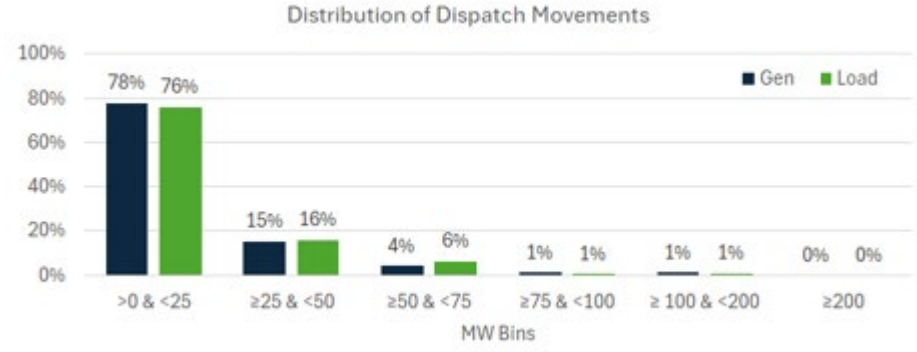
Lost Cost Opportunity and Additional Costs for BESS Resources

- BESS resources are settled based on actual energy injections and withdrawals over each 5-minute interval.
- The BESS Ramp Rate requirement can potentially result in:
  - Lost cost opportunity when BESS are injecting MWs as a generator;
  - Additional costs when BESS are consuming MWs as a load.
- Real-world experience indicates that the frequency, magnitude and financial materiality is relatively limited.

Lost Cost Opportunity and Additional Costs for BESS Resources

- **Frequency & Magnitude of Change:** A review of RT energy schedules of dispatchable BESS as a generator or load between May 2025 - June 2026:
  - Out of all intervals, ~8% of intervals required movement (either dispatched up or down)
  - 5% of intervals for BESS injections as Generator, 3% of intervals for BESS consumption as Load.
  - Out of the all intervals requiring movement, 99% of intervals required a change < 100 MW.





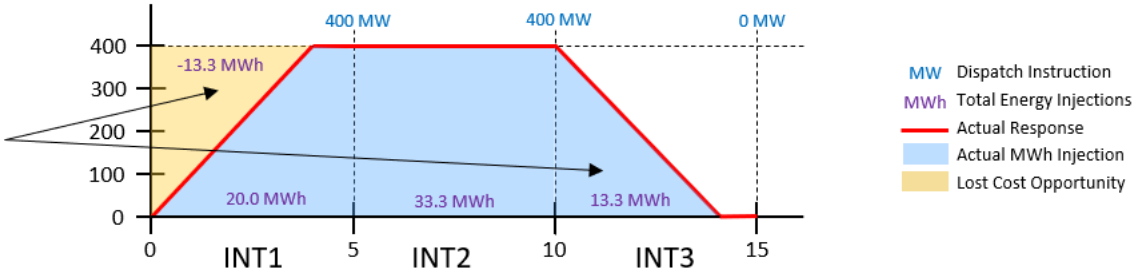
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Lost Cost Opportunity for BESS Injection

For BESS MW injections as a Generator:

- The estimated financial materiality of the lost cost opportunity identified by stakeholders was limited to ramp up intervals only. However, the ramp rate instruction applies to both the ramp up and ramp down intervals.
- Participants will be compensated for the additional energy injected during the ramp down intervals, which help offset the lost cost opportunity associated with the ramp up intervals.

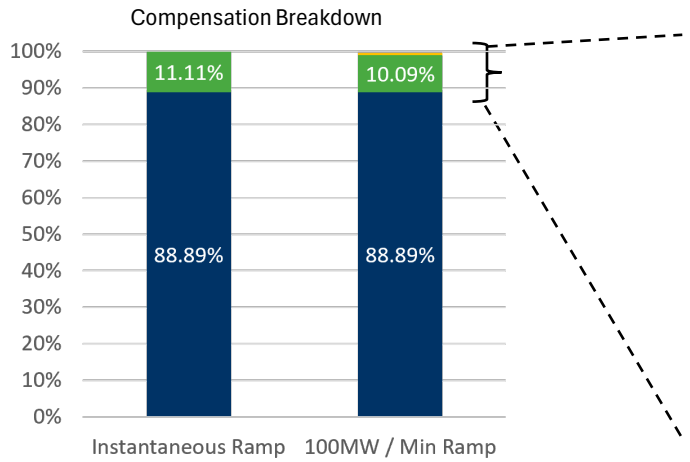
Additional revenues generated in INT3 partially offset lost cost opportunity from INT1

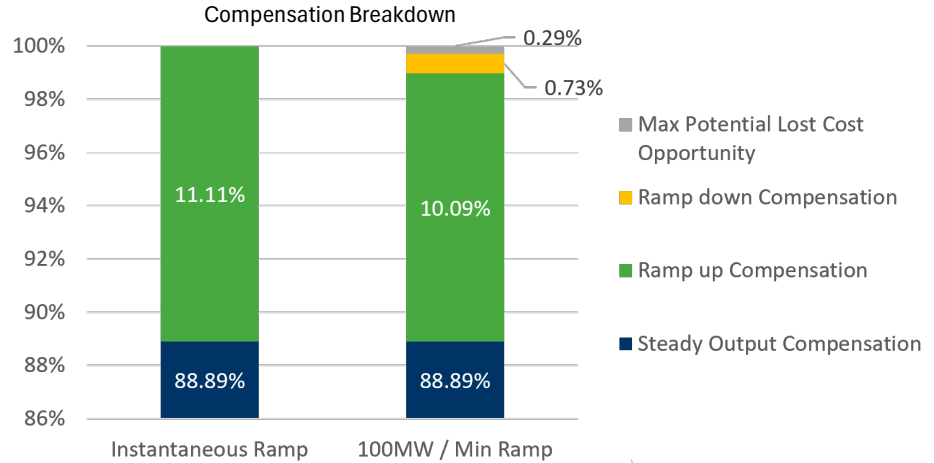


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Lost Cost Opportunity (Injections): Financial Materiality (%)

- Based on a review of Real-Time schedules and associated LMPs over the period May 2025 to June 2026, an analysis was conducted to calculate the energy revenues (i.e., MWh injections * LMP) associated with a theoretical instantaneous ramp rate versus a 100 MW/min ramp rate.
- As shown in the graphs below, there is a **maximum** lost cost opportunity of **0.29%** relative to the total compensation of BESS resources using a theoretical instantaneous ramp rate





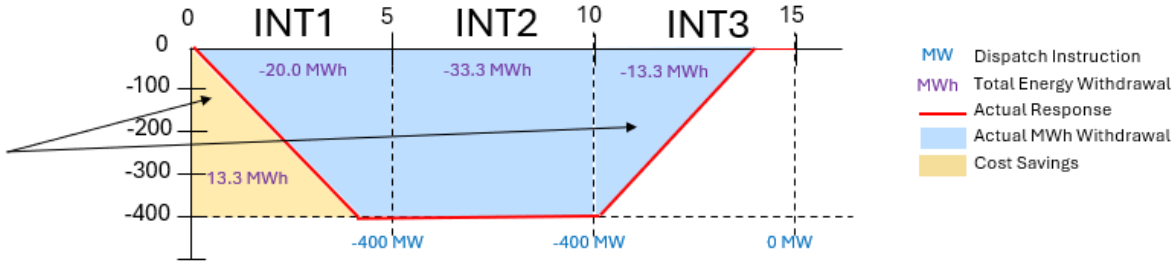
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Additional Cost for BESS Consumption

When BESS resources consume MWs as a Load, the ramp rate requirement:

- Limits the quantity of energy consumed for intervals where a BESS resource is dispatched up to consume MWs. This results in reduced costs incurred during these intervals.
- Increases the quantity of energy consumed for intervals where a BESS resource is dispatched down from consuming MWs. This results increased costs incurred during these intervals.
- The net effect may result in additional costs incurred by BESS when consuming MWs as a load.

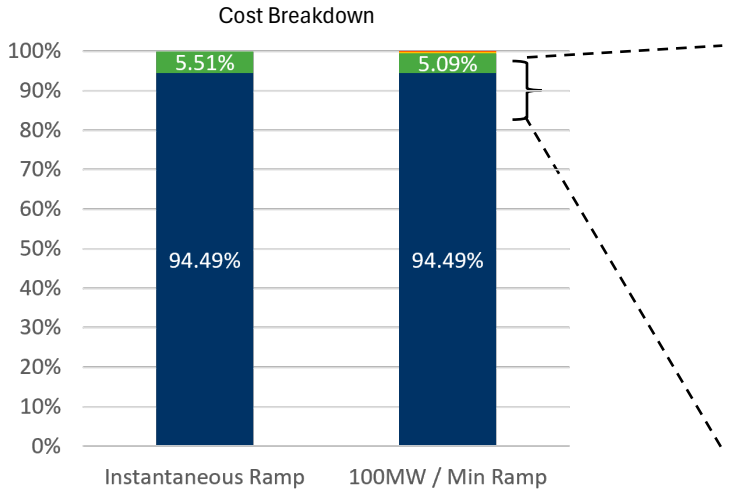
Savings in INT1 partially offset the additional charges in INT3

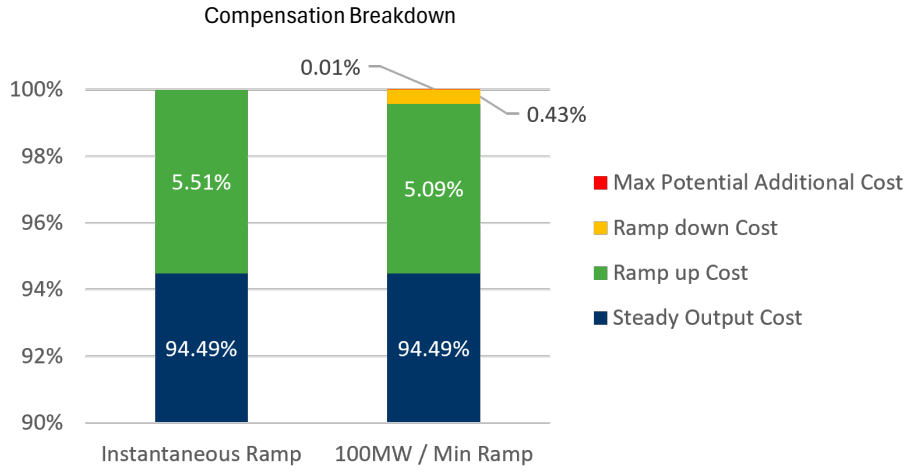


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Additional Cost (Consumption): Financial Materiality (%)

- Based on a review of Real-Time schedules and associated LMPs over the period May 2025 to June 2026, an analysis was conducted to calculate the energy costs (i.e., MWh consumption * LMP) associated with a theoretical instantaneous ramp rate versus a 100 MW/min ramp rate.
- As shown in the graphs below, there is a **maximum** additional cost of **0.01%** relative to the total compensation of BESS resources using a theoretical instantaneous ramp rate





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Draft Market Rule & Market Manual Proposed Language

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Market Rules and Manuals

- Market rule amendments and market manual changes will be required to integrate these ramping requirements into our system while avoiding the potential adverse impacts on reliability that they may cause.
- The market rule and manual changes are consistent with the ramp rate instruction currently applied to storage facilities.
- The market rules and manuals can be found on the stakeholder engagement page.

Market Rule Amendments

Rule	Section Title	Description
Ch.7 s.3.5.7.4A	Submission of Dispatch Data	Establishes the ramp dispatch data constraint, both up and down, for battery storage facilities of 100 MW/minute
Ch.7 s. 7.5.1.1	Compliance with Dispatch Instructions	Requires a smooth ramp across the full minute by stating requirement in increments of 4 seconds, which matches the telemetry readings. Requirement is at the facility level, allowing for flexibility in response in real time, provided the ramp constraint at the facility level is adhered to.
Ch.4 Appendix 4.2	New section: 13.Ramping	Requires directly connected battery storage facilities to have the capability to operate with a ramp constraint.
Ch.4 Appendix 4.3	New Section: 13.Ramping	Requires battery storage facilities embedded in a distribution system to have the capability to operate with a ramp constraint.

Market Manual Changes

Market Manual	Description
4.1- Submitting Dispatch Data in the Physical Markets	New additions on both section 2.1.4 and 3.1.3 provides clarification that the ramp rate constraint applies to energy market offers, and that operating reserve offers need not adhere to the same constraint.
4.3- Operation of the Real-Time Market	Edits in section 5.1 provides additional detail on the how the ramp rate constraint should be responded to in real time.

Next Steps

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Next Steps

Timing	Engagement Activity
~~July 22, 2026~~	~~First public engagement session~~
~~November 10, 2026~~	~~Technical Panel (TP) Education~~
November 25, 2026	Second public engagement session
January 12, 2026	TP Vote to Post
February 2, 2027 (TBD)	TP Vote to Recommend
March 12, 2027	IESO Board Consideration
Q2, 2027	Target Implementation

Next Steps

- Pending stakeholder feedback and IESO response, the IESO intends to present Market Rule and Market Manual amendments to the Technical Panel for posting in January 2027

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