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Ramp Rates for Battery Energy Storage System Facilities

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Territory Acknowledgement

The IESO acknowledges the land from where we are delivering today's webinar is the traditional territory of many nations including the Mississaugas of the Credit, the Anishinaabeg, the Chippewa, the Haudenosaunee and the Wendat peoples, and is now home to many diverse First Nations, Inuit and Métis peoples. We also acknowledge that Toronto is covered by Treaty 13 with the Mississaugas of the Credit First Nation.

As we have attendees from across Ontario, the IESO would also like to acknowledge all the traditional territories across the province, which include those of the Algonquin, Anishinaabeg, Ojibwe, Cree, Oji-Cree, Huron-Wendat, Haudenosaunee, Métis, and Inuit peoples.

Engagement Principles

This engagement is conducted in accordance with the IESO's External Engagement Framework, which includes the following principles:

- **Purposeful** – Initiate meaningful conversations that move the sector forward
- **Inclusive** – Invite many voices and diverse perspectives to the table
- **Timely** – Seek input and insight when it can have the most impact
- **Accessible** – Ensure we meet people where they are on their energy journey
- **Traceable** – Allow everyone to follow the path that is being taken
- **Transparent** – Show how engagement helped shape the final outcome

Shared Commitment to Respectful Participation

To support a focused and constructive discussion:

- We will take questions one at a time; please use the raise-hand feature to enter the speaking queue
- We encourage concise and focused comments to allow time for multiple perspectives
- Participants are encouraged to raise relevant points during the discussion and provide more detailed feedback through the written submission process
- We ask that all participants maintain a respectful and professional tone throughout the session
- Facilitators will guide the discussion and manage participation to stay aligned with today's focus and agenda
- Where necessary, we may disable a participant's microphone to manage participation

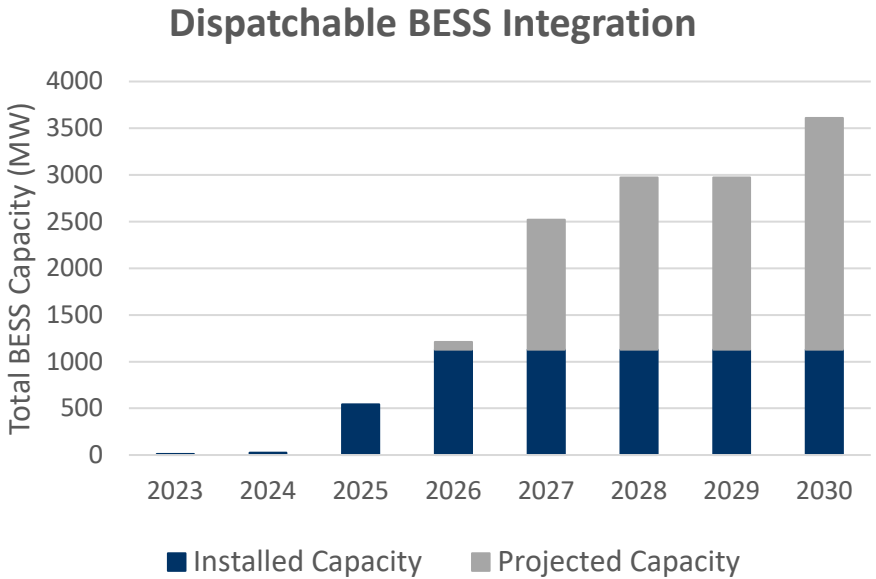
Agenda

- Introduction
- Context Setting: IESO Mandate & System Balancing
- Deeper Dive: How is System Balancing Maintained?
- Fast Ramping Capabilities & Impacts to System Balancing
- Ramp Rate Instruction for Electricity Storage Facilities
- Stakeholder Concerns and IESO Response raised during ERP
- Market Rule Impacts
- Conclusion & Next Steps

Introduction

Introduction

- Ontario's electricity grid is undergoing significant change with ~3,600 MW of new Battery Energy Storage Systems (BESS) expected to become operational by 2030
- BESS, like all resources, play a critical role in supporting system reliability and overall adequacy.



Introduction

- Near-instantaneous ramping characteristics are beneficial for quick response to system contingencies; however, they can pose challenges to system stability under normal operating conditions. Such behavior can negatively impact the Area Control Error (ACE), which the IESO must manage in accordance with North American Electric Reliability Corporation (NERC) standards.
- While near-instantaneous ramping is currently not the sole or primary cause of ACE challenges in Ontario, the impact of this characteristic on ACE is expected to significantly increase as more fast-ramping resources begin operating on the IESO-controlled grid (ICG).

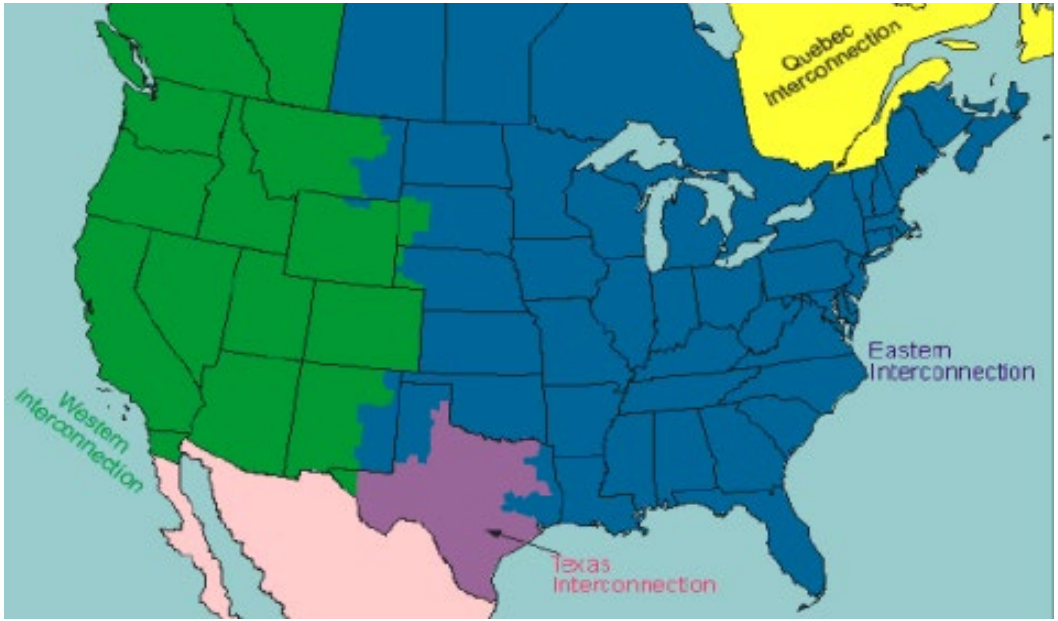
Introduction

- The purpose of today's engagement is to:
  - Provide context and rationale for BESS ramp rates
  - Facilitate an open forum for information sharing and discussion
  - Clarify the IESO's approach to BESS ramp rates
  - Describe next steps for Market Rule amendments

Context Setting: IESO Mandate & System Balancing

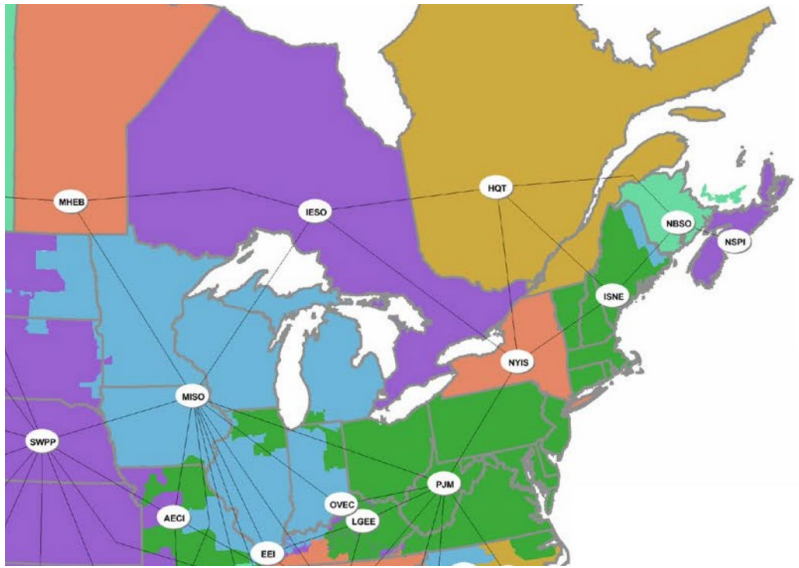
NERC Interconnections

- NERC footprint is divided into 4 major interconnections:
  - Western Interconnection
  - Texas Interconnection
  - Eastern Interconnection
  - Quebec Interconnection
- North America operates at a frequency of 60 Hz
- Frequency deviates when load ≠ generation



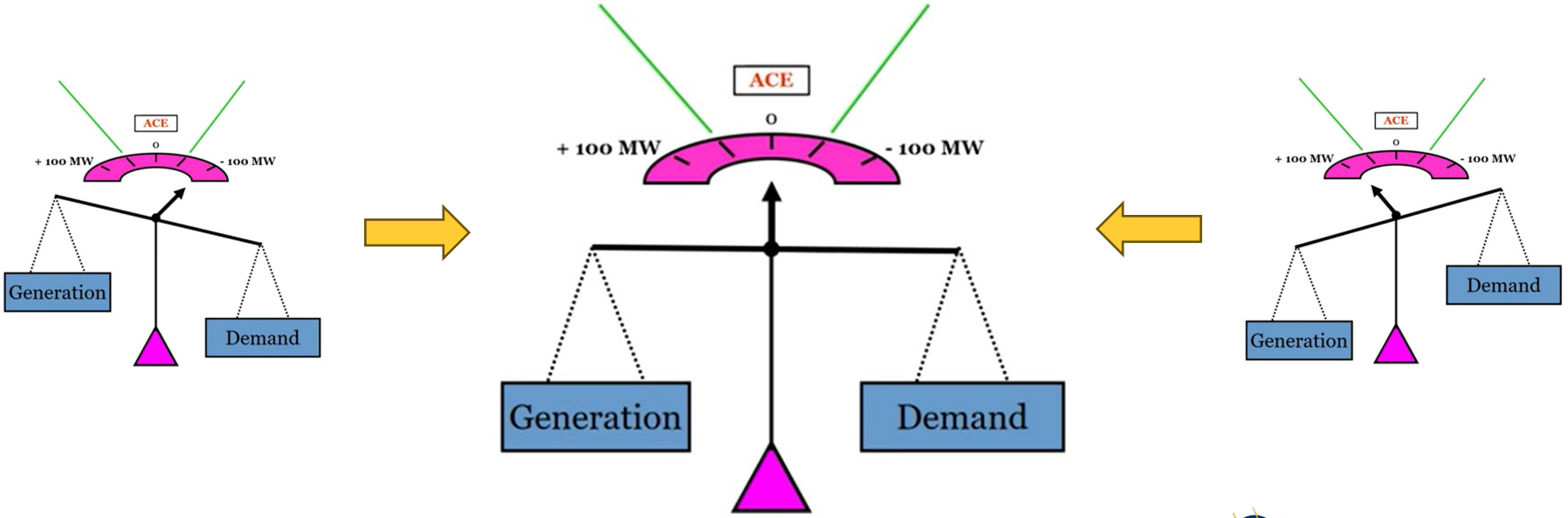
IESO and Neighbouring Balancing Authorities (BAs)

- As a Balancing Authority (BA), the IESO is obligated to manage reliability and maintain the real-time balancing of load and generation within our Balancing Authority Area (BAA)
- The IESO must operate within NERC's BAL Standards and regulate Area Control Error (ACE) to limit frequency deviation and grid disturbance.
    - ACE is a measure of the imbalance between generation and load within a BAA and its role in maintaining interconnection frequency at 60Hz



Relation between Generation, Demand and ACE

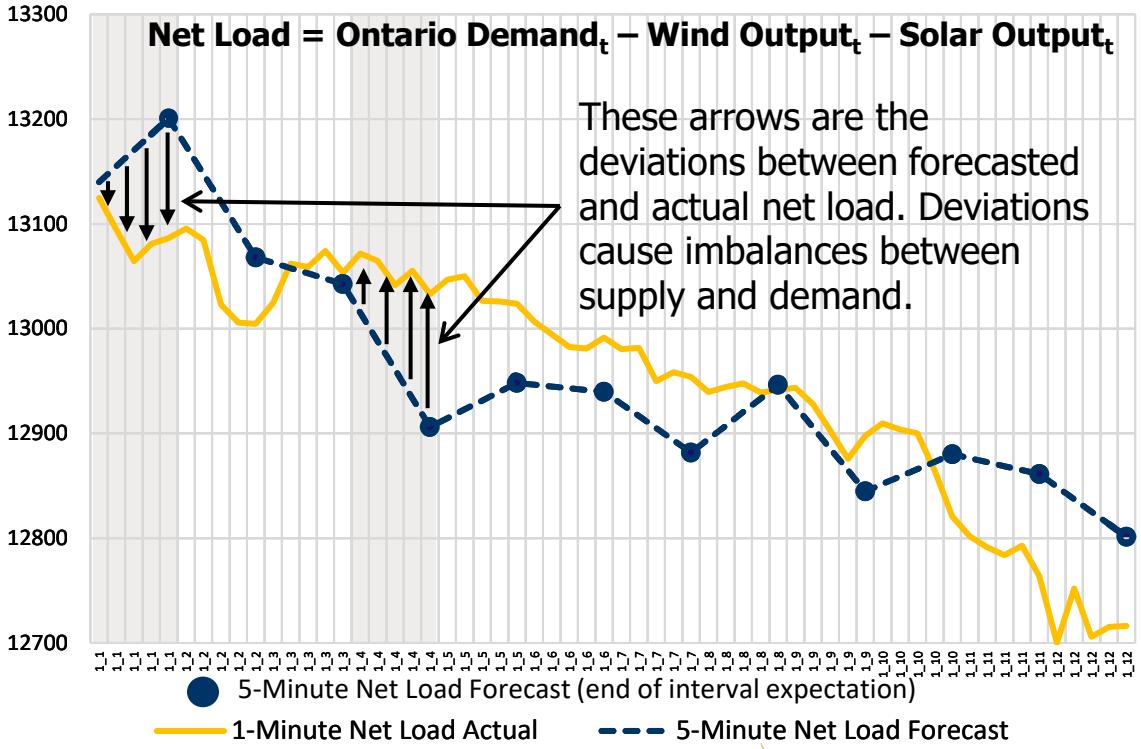
- System balance must be maintained at all times, second-to-second and minute-to-minute.



Deeper Dive: How is System Balancing Maintained?

How does 5-minute Dispatch Work

- The IESO uses 5-Minute Ontario Demand Forecasts and 5-Minute Variable Generation (Wind and Solar) Forecasts to determine how much additional generation must be dispatched from the fleet
- Any mismatches between the forecasts and the actuals will cause imbalances



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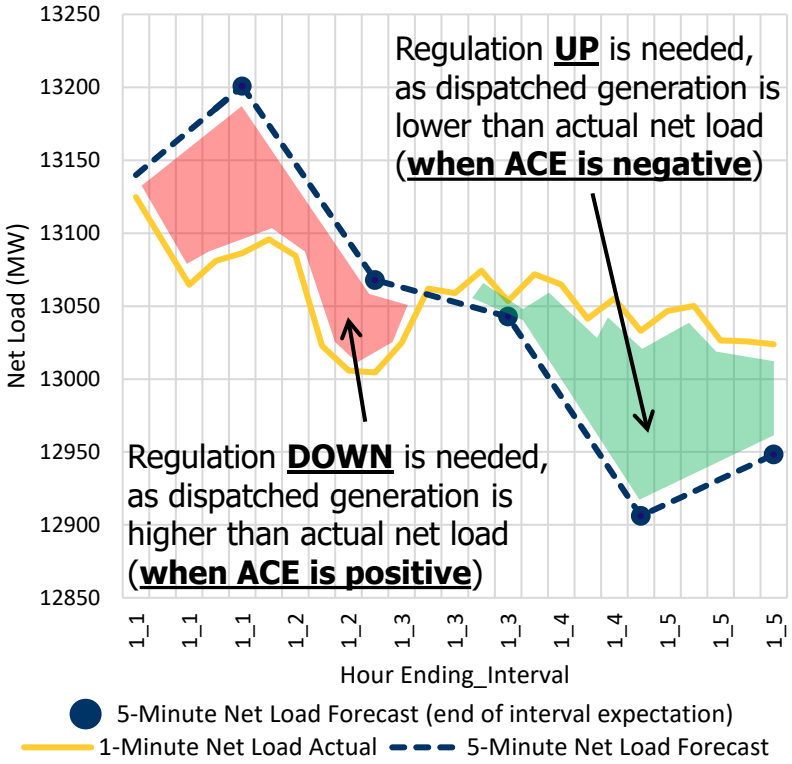
Regulation Service

- **What is it?** Regulation provides minute-to-minute balancing to ensure electricity supply matches demand and is currently provided by generation facilities with Automatic Generation Control (AGC) capability, which permits them to vary their output in response to signals sent by the IESO
- **Why is it required?** NERC BAL-001 assesses a Balancing Authority's ability to maintain Interconnection frequency within defined limits, and prescribes requirements that are meant to maintain balancing in the minute-to-minute timeframe as part of normal system operations



Balancing Products

In addition to regulation, balance between supply and demand may also be achieved via other balancing products, depending on the timing and nature of the event causing the imbalance.

Time

Mechanism	Inertial Response	Primary Frequency Response	Regulation	Operating Reserve	Ramping Capability
What is the response time?	Immediately following a system event	Within the first few seconds following a system event	Within less than 5-minutes of a mismatch between supply and demand	Within 10 minutes or 30 minutes of a system event	Five minutes to hours
How is balancing currently achieved?	Drawn from the stored kinetic energy of rotating equipment	Automatic adjustment of energy output by generators	Signal from IESO tools to a resource to adjust energy output	Activated by the IESO	Scheduled by the IESO's dispatch scheduling engine

Fast Ramping Capabilities & Impacts to Balancing

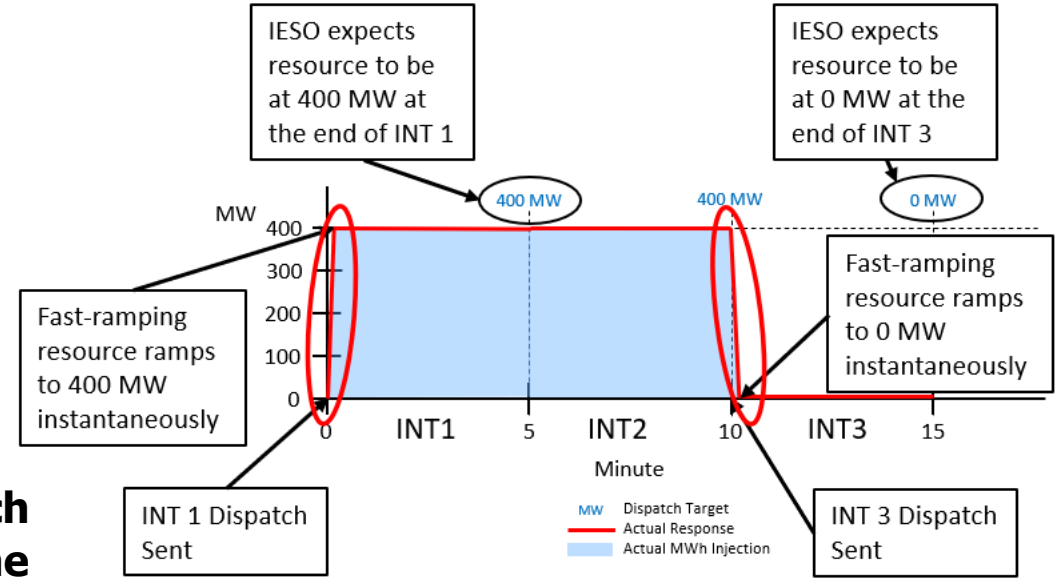
Fast Ramping Capabilities & Impacts to System Balance

- Dispatch instructions issued by the DSO indicate the target energy output to be achieved **at the end** of the dispatch interval to meet the forecast demand.
- Resources with near-instantaneous ramp rates present unique challenges since they can ramp much faster than any other resource type and can do so at any point within a 5-minute interval, which can negatively impact system balancing.
- The following slides illustrate the challenges posed by these resources in the context of 5-minute energy dispatches and maintaining system balance.

Fast Ramping Capability: Example

A 400 MW fast-ramping resource at (MW receives the following three 5-minute dispatch instructions:

- INT1 Dispatch: 400 MW
- INT2 Dispatch: 400 MW
- INT3 Dispatch: 0 MW



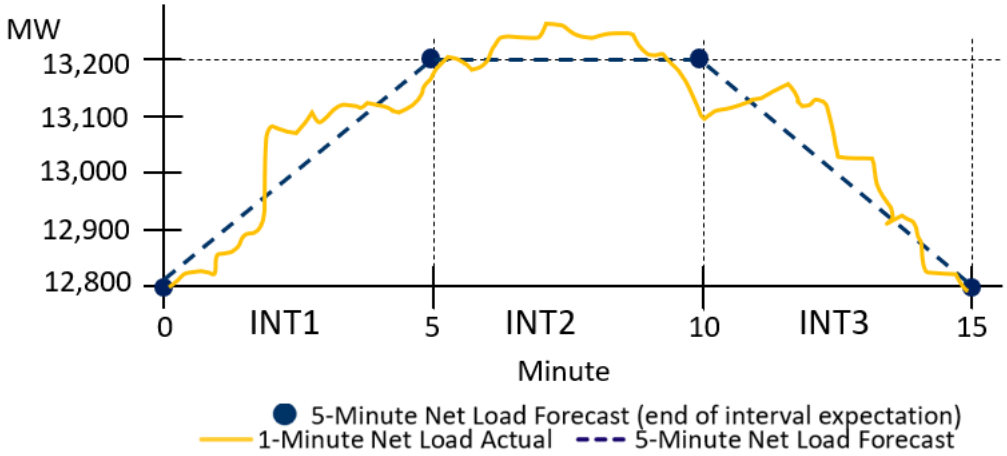
Fast-ramping resources can reach their MW dispatch well before the end of the dispatch interval.

Fast Ramping Impacts: Example

Very fast ramping can lead to over/under-generation which creates imbalances within the 5-minute dispatch interval.

Consider the following example:

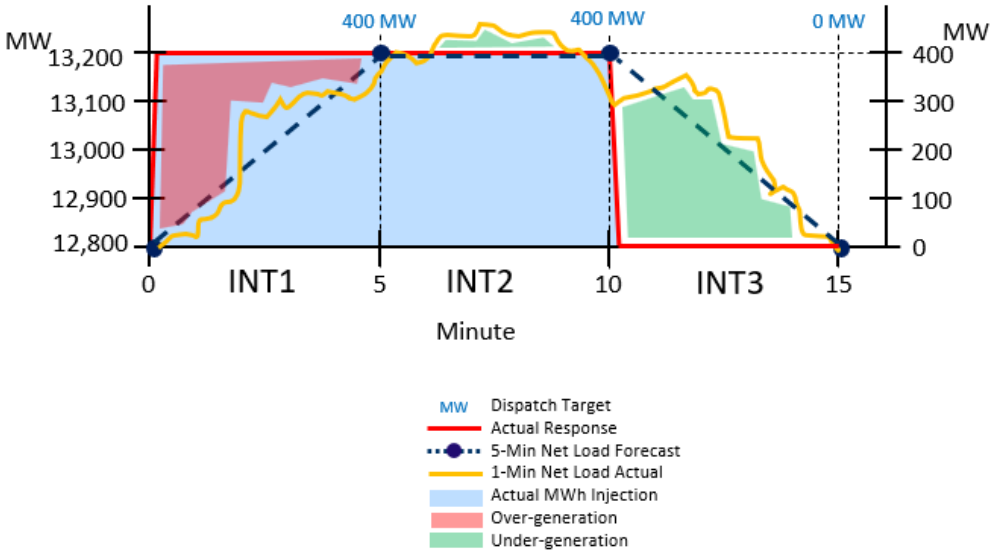
- The 5-Minute Net Load Forecast is projected to increase to 13,200 MW in INT1, remain at 13,200 MW in INT2, drop back down to 12,800 by the end of INT3
- 1-Minute Net Load Actual over this same 3-interval period is shown in yellow



Fast Ramping Impacts: Example (continued)

In response, the DSO dispatches a 400 MW fast-ramping resource from 0 MW to 400 MW in INT1, and back to 0 MW in INT3, expecting MW dispatches are reached at the end of the intervals (i.e., same dispatches as Slide 20)

Fast-ramping resources can create over- and under-generation conditions when they ramp instantaneously in response to IESO 5-minute dispatch instructions.

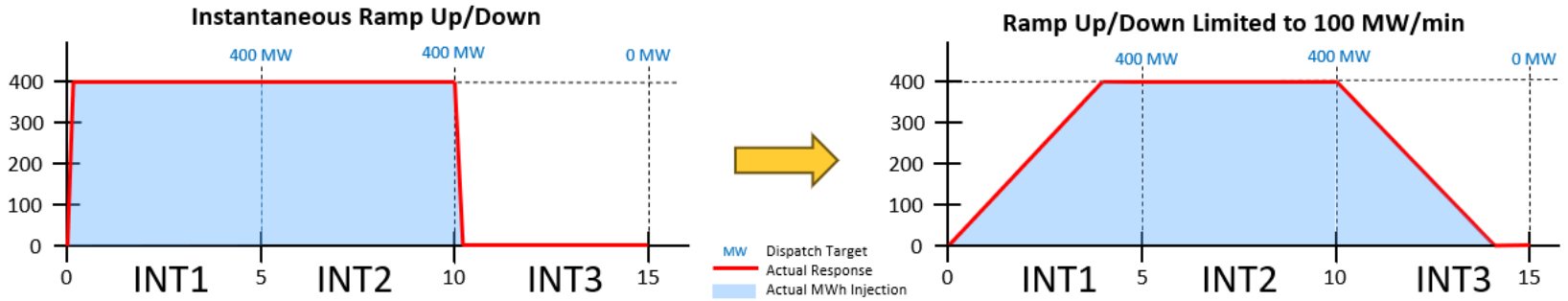


Fast Ramping Impacts: Mitigations

- To manage these imbalances, the system must rely on regulation services for minute-to-minute balancing between supply and demand (currently at +/- 130 MW)
- When regulation is insufficient, the IESO needs to activate other balancing products such as the activation of operating reserve (10-minutes) to account for under-generation.
- This is not ideal, as these are out-of-market actions, and those products should be used for what they are intended (i.e., recovering from a contingency)
    - Although not a balancing product, one-time dispatches can also be issued to reduce generation when there is over-generation or to increase generation when there is under-generation. This too, is an out-of-market action.
- These out-of-market actions are not as effective in the minute-to-minute regulation balancing timeframe since they are typically in the "OR" and "Ramping Capability" timeframes as described on slide 17

Fast Ramping Impacts: Mitigations

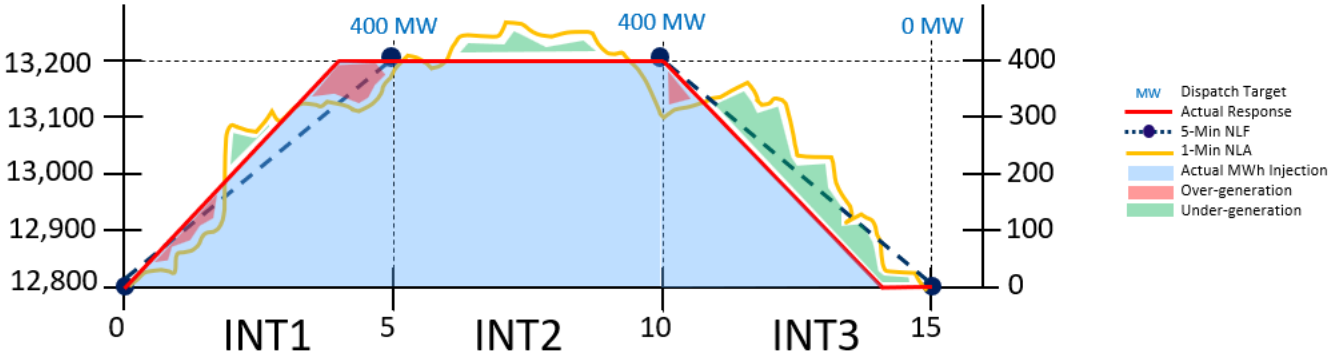
- With over 3,600 MW of fast-ramping BESS expected in the coming years and responding similarly to price signals, this represents a **significant** potential for system imbalance.
- As a result, a need for a ramp rate limitation was identified to dampen BESS' near-instantaneous response to 5-minute energy dispatches to mitigate impacts to ACE and reliance on AGC



Fast Ramping Impacts: Example (continued)

Consider the following example:

- Same 5-Minute Net Load Forecast, 1-Minute Net Load Actuals and dispatch assumptions as before, but this time the fast-ramping facility follows a ramp rate of 100 MW/min.
- Relative to the previous ramp example, the amount of over-generation and under-generation observed in INT1 & INT3 is mitigated by the 100 MW/min ramp rate limitation.



Ramp Rate Instruction for Electricity Storage Facilities

Ramp Rate Instruction

To mitigate adverse impacts and maintain balance, IESO issues the following instruction to all registering BESS facilities:

- **All Electricity Storage Facilities shall be limited to a maximum ramp rate of 100 MW/minute (1.67 MW/second) when responding to 5-minute energy dispatch instructions.**
    - This maximum rate applies equally when injecting (discharging) or withdrawing (charging) active power.
    - This limit applies exclusively to 5-minute energy dispatch signals and does not apply to the facility's response to operating reserve activations, frequency excursions, voltage changes, or Remedial Action Scheme (RAS) runbacks.
    - This requirement shall not restrict the registered ramp rate at the resource level
    - The IESO reserves the right to require further adjustments to facility ramp rates in accordance with evolving power system operating conditions

Ramp Rate Instruction – Additional Context

- The Ramp Rate instruction is applied through the registration process and is also identified in the System Impact Assessment (SIA) as a General Requirement that must be satisfied by the storage facility
- Instruction ensures that the IESO satisfies requirement to maintain system frequency and ACE within prescribed bounds. (MR Ch. 5 s. 3.2.2 and NERC BAL-001-2)
- Under the current two-resource storage model, the instruction is intended to limit the speed at which the **facility** physically responds to a 5-minute dispatch instructions only (i.e., as a controller setting); it is not meant to impact the resource's registered maximum ramp rate or dispatch data parameters.

Ramp Rate Instruction – Additional Context

- Following the implementation of ERP's future bi-directional single storage resource model, storage resources will be expected to more accurately reflect ramp rates through their dispatch data submissions for energy, in alignment with the ramp rate instruction (i.e., cannot exceed 100 MW/min). This is necessary to ensure accurate modelling and forecasting of State-of-Charge in the IESO tools & applications.
- This 100 MW/min Ramp Rate instruction is expected to be sufficient for system BESS installed capacity procured under ELT, LT-1 and LT-2 c1 (~3600 MW), and is comparable to submitted ramp rates of most other faster-ramping resources in Ontario (hydroelectric, wind and solar)

Ramp Rate Instruction – Additional Context

- BESS resources have registered ramp rates over 100x faster than other resource types on the ICG, including inverter-based variable generation (e.g. wind and solar).
- When coincident energy dispatch instructions are issued to a large proportion of the BESS fleet, this creates a risk of large-scale system imbalances resulting from the coincident movement of the BESS fleet outpacing both market demand and other resources on the ICG.
- Inverter-based variable generation exhibits fast ramping, though their output is dependent on availability of wind speed and solar irradiance. At current penetration levels, geographic diversity mitigates significant coincident ramping impacts; however, higher penetration may necessitate assessments to determine if similar ramp-rate instructions need to be applied.

Stakeholder Concerns and IESO Response raised during ERP

Stakeholder Concerns raised during ERP

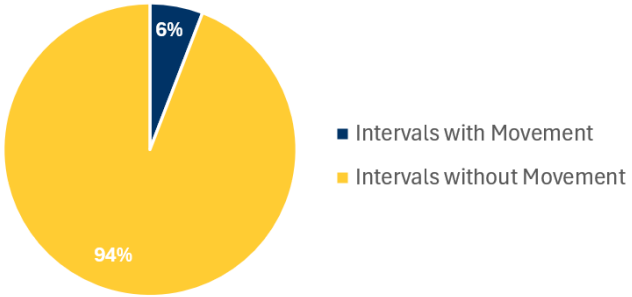
- The 100 MW/min ramp rate instruction was also identified during ERP stakeholder engagements in Q3/Q4 2025, with stakeholder feedback provided

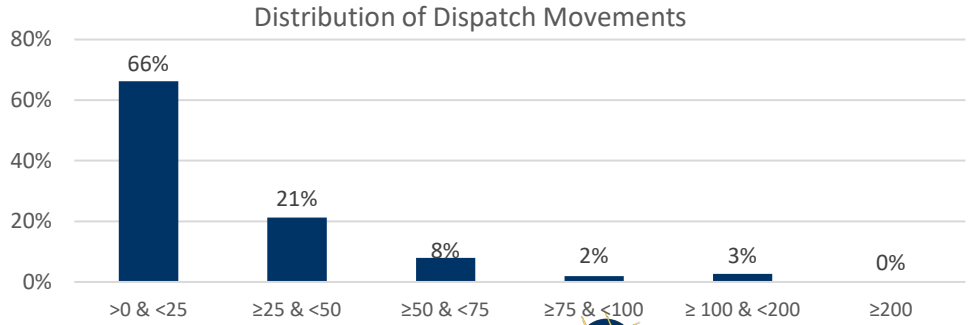
  ERP Storage and Co-located Hybrid Integration Project

- The following slides were prepared for ERP stakeholders in Dec 2025 in response to the stakeholder feedback received

Lost Cost Opportunity

- Since resources are settled based on actual energy injections over each 5-minute interval, stakeholders identified a lost cost opportunity resulting from the ramp rate limitation. Real-world experience indicates that the frequency, magnitude, and financial materiality is minor.
- **Frequency & Magnitude of Change:** A review of RT energy schedules of dispatchable BESS registered to inject between August - October 2025 during the qualifying hours (07:00-23:00EST) shows that:
  - Out of all intervals, 6% of intervals required movement (either dispatched up or down)
  - Out of the intervals requiring movement, 97% of intervals required a change < 100 MW.

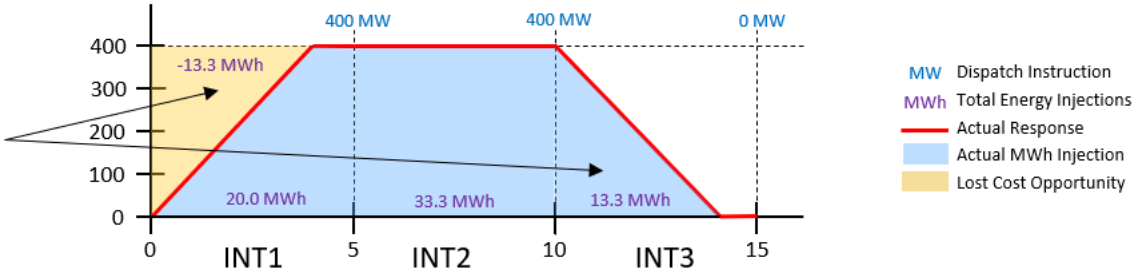




Lost Cost Opportunity (continued)

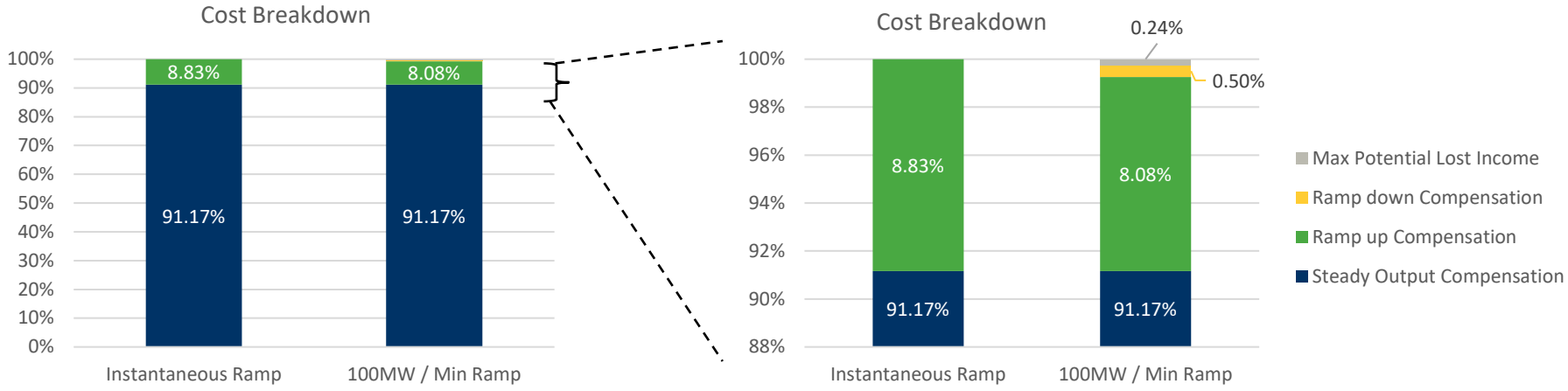
- **Financial Materiality:**
  - The estimated financial materiality of the lost cost opportunity identified by stakeholders was limited to ramp up intervals only. However, the ramp rate instruction applies to both the ramp up and ramp down intervals.
  - Participants will be compensated for the additional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

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



Lost Cost Opportunity: Financial Materiality (%)

- Based on a review of Real-Time schedules and associated LMPs over the same period (Aug-Oct), 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 opportunity cost of **0.24%** relative to the total compensation of BESS resources using a theoretical instantaneous ramp rate



Market Rule Impacts

Market Rule Impacts

The ramping constraints on storage facilities are expected to require the following market rule amendments:

1. **Chapter 7 System Operations and Physical Markets**: A ramping requirement will be structured at a facility level and applied to dispatch data submission and compliance with dispatch requirements.
2. **Chapter 4 Grid Connection Requirements - Appendices**: There will be a technical requirement for battery storage participants to have the ability to control the ramp rates of their equipment.

Conclusion & Next Steps

Conclusion & Next Steps

- The IESO issued a 100 MW/min ramp rate instruction for fast-ramping storage facilities based on the need to maintain system frequency and ACE within prescribed bounds (MR Ch. 5 s. 3.2.2 and NERC BAL-001-2).
- Pending stakeholder feedback and IESO response, the IESO intends to introduce Market Rule amendments to codify this ramp rate instruction in the Market Rules later in 2026
- The IESO intends to provide proposed Market Rule amendment language at a future stakeholder engagement session

Thank You

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