Enabling Resources Program: Storage and Hybrid Integration Project

Optimization Design Engagement

Memo ~~1~~2.0

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Engagement Topic: Optimization Design Element for Storage Resources

Date: ~~October 16, 2025~~May 6, 2026

Purpose

The purpose of this memo is to provide updated information since the October 16, 2025 stakeholder engagement on the IESO's market design work on the Optimization design element for the enhanced storage participation model. This memo discusses the updated design decisions and their rationale that are relevant to stakeholders for the enhanced storage participation model.

Initial design decisions on Optimization were made and then presented in the external stakeholder engagement sessions on July 24, 2025 and discussed further on October 16, 2025. The objective of this design memo is to conclude design decisions on those design topics and supplement the information presented.

The IESO will utilize this document and materials from subsequent design modules and elements to support the implementation of the design work for the Storage and Hybrid Integration Project. This will be captured in future changes to Market Rules, Market Manuals, software interfaces with the IESO and internal IESO systems and processes. These external changes will be reviewed for input with stakeholders. Any material changes to this design resulting from implementation will be discussed with stakeholders.

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List of Abbreviations

Abbreviation	Definition
ADE	Availability Declaration Envelope
BESS	Battery Energy Storage System
CE	Cycle Efficiency
CR	Control Room
CROW	Control Room Operations Window
CycleDEL	Cycling Daily Energy Limit
DA	Day Ahead
DAM	Day-Ahead Market
DSO	Dispatch Scheduling and Optimization
EOP	Economic Operating Point
ERP	Enabling Resources Program
ESR	Energy Storage Resource
HOL	High Operating Limit
~~ISL~~IAM	~~Internal Service Load~~IESO-Administered Market
ICG	IESO-Controlled Grid
ISoC	Initial State of Charge
LMP	Locational Marginal Price
LOL	Low Operating Limit
MaxSoC	Maximum State of Charge
MGBDT	Minimum Generation Block Down Time
MGBRT	Minimum Generation Block Run Time
MinSoC	Minimum State of Charge
MIO	Multi-Interval Optimization
MLP	Minimum Loading Point
~~MF&I~~MP	Market ~~Forecasts and Integration~~Participant
MPM	Market Power Mitigation
MPM-CD	MPM Conduct Test
MPM-IP	MPM Impact Test
MRP	Market Renewal Program
MWP	Make-Whole Payment
NCED	Network Constrained Economic Dispatch
NCUC	Network Constrained Unit Commitment
NSA	Network Security Assessment
OR	Operating Reserve
PD	Pre-Dispatch
PD-INI	Pre-Dispatch Initialization
P-Q	Price-Quantity
RAS	Remedial Action Scheme
RT	Real-Time
~~RTE~~RTM	~~Round-Trip Efficiency~~Real-Time Market
RT-MIO	Real-Time Multi Interval Optimization
SMSR	Single Model Storage Resource
SoC	State of Charge

Background

ERP's Storage and Hybrid Integration Project is focused on developing an enhanced participation model for storage resources and co-located hybrid facilities. During the Design phase, the IESO started with the core Optimization element within the Grid and Market Operations module. The Optimization element is the main precursor to design decisions that support other design modules and elements as per the scope noted in the Scope of Impact for Phase 1 section below. The design elements under the Grid and Market Operations module clarify how the storage facility participates in energy and Operating Reserve (OR) markets. This includes what the IESO needs to dispatch resources and consider them in the optimization engine across all timeframes.

Phased Approach

The Storage and Hybrid Integration Project is adopting a phased delivery approach to expedite and prioritize the implementation of essential functionality, including:

- ~~Bi-directional single resource model~~
- Single Model Storage Resource (SMSR);
- State of Charge (SoC) Management.

As seen in Figure 1 below, subsequent design phases will implement:

- Regulation service;
- Uplift exemptions;
- Any required enhancement resulting from Phase 1 implementation.

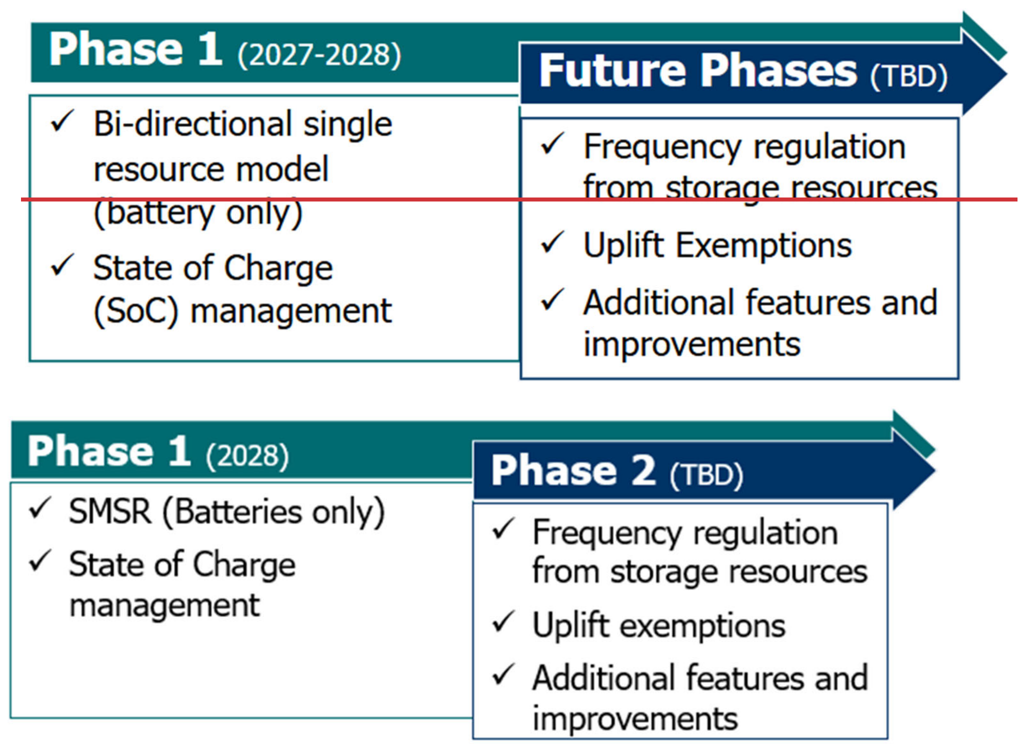

Figure 1: Project Scope

The IESO is targeting a ~~2027~~ 2028 Phase 1 implementation date.

Scope of Impact for Phase 1

For Phase 1 of the enhanced market design, the IESO will focus on Battery Energy Storage Systems (BESS), i.e., resources whose sole purpose is withdrawing electricity from the electricity system, storing that electricity and re-injecting it into the electricity system. In subsequent phases, the IESO will consider the applicability of other types of storage technologies and potential nuances that may require additional/different parameters.

The IESO's focus is on single-site, dispatchable storage resources greater than 1 MW. As registered facilities in the IESO-Administered Markets (IAMs), each BESS facility should directly interface with the IESO and may be transmission or distribution connected.

~~This enhanced market design will support recent storage procurements, including the Oneida facility and those procured via Long-Term 1 (LT1) and Expedited Long-Term (ELT) procurements. Some of these BESS facilities are/will have achieved their Commercial Operation Date before the enhanced participation model is live; the transition of these facilities to the enhanced model will be discussed with stakeholders at a later date. Further assessment is required for existing resources that have Energy Storage Facility Agreement (ESFA) contracts if they will be subject to the new storage design or will continue participating as with the foundational two-resource model in the IESO Administered Markets (IAMs) until their contracts expire.~~

The Enabling Resources Program (ERP) will require the transition of all dispatchable BESS resources into the SMSR participation model. This includes ESFA contract holders of dispatchable resources who may wish to continue operations after the conclusion of the contract. The requirement for Non-BESS technologies, such as compressed air and pumped storage facilities, to transition to the SMSR participation model, will be assessed on a case-by-case basis.

Design Methods and Outcomes

Principles

The ERP market design principles guide design decision criteria to verify that the design meets the needs of the IESO and market participants (MPs). These principles were derived from the foundational Market Renewal Program (MRP) and were considered as part of the long-term vision for storage.

- **Efficiency** - Deliver efficient market outcomes to benefit consumers;
- **Competition** - Provide open, fair, non-discriminatory competitive opportunities to enable MPs to meet evolving system needs;
- **Implementation** - Collaborate with our stakeholders to evolve the market in a feasible and practical manner;
- **Certainty** - Maintain enduring market-based mechanisms that send clear, efficient price signals;
- **Transparency** - Accurate, timely and relevant information is available and accessible to MPs to enable their effective participation in the market;
- **Operability** – The new participation models will improve the IESO's ability to plan/forecast the operational needs of the grid and provide accurate signals to BESS resources.

Method

The design and integration of storage will be organized in a build-to-bill format called modules (representing larger functions) and elements (more specific functions within a module). The build-to-bill modules and elements are specific to the MP and IESO processes to support the end commissioning stages/testing to bring new resources onto the grid and facilitate their participation in markets and services. Design modules and elements will be engaged based on project dependencies and priorities (i.e., not in a chronological format regarding a typical build-to-bill decision-making process).

The Optimization element is the first and fundamental design element that will drive all other design decisions, design modules and elements.

Optimization Element

Figure 2 below shows the scope of Phase 1 of the Storage and Hybrid Integration Project, with the focus of this design memo on the Optimization design element for storage.

~~The IESO is first proceeding with the 'Optimization' element within the 'Grid and Market Operations' module, which is the core design element and a necessary precursor to design decisions to support other design modules and elements. The design elements under 'Grid and Market Operations' module clarify how storage resources participate in the IAMs within energy and Operating Reserve (OR) markets or other functions that support the reliable operation of the grid. The Optimization element explicitly deals with the requirements needed by the IESO's calculation engines across all timeframes - Day-Ahead (DA), Pre-Dispatch (PD) and Real-Time (RT) - to be able to effectively dispatch resources~~

	Design Module	Design Element
Batch 1	Grid and Market Operations	• Optimization (Energy & Operating Reserve)
Batch 2	Connection and Registration	• Connection Assessment and Approval • Market Registration
	Grid and Market Operations	• Dispatch Data and Other Inputs • Operations Integration
	Market Power Mitigation	• Ex-Ante • Ex-Post
	Settlements	• Market Settlement
	Contracts	• Contract Impacts
Batch 3	Hybrids	• Market rules need to be adjusted for the co-located hybrid model with the integration of the new storage model

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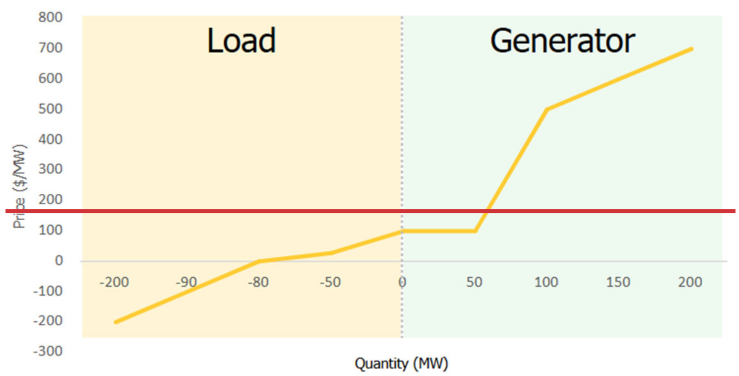
Figure 2: Market Design Modules in Phase 1

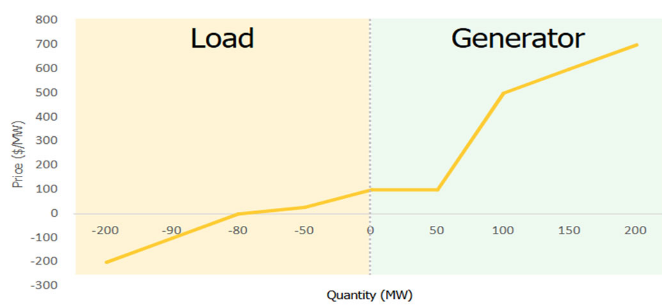
Outcomes of Optimization Design

The anticipated outcome of the Optimization design is the cost-effective use of battery storage resources to support system reliability, utilizing the unique capabilities of storage. The outcomes of optimization will support key decision-making across all other design elements and modules. The Optimization design will implement its key design decisions through:

- **A Single Resource Model** – The IESO will implement a single-resource model for energy storage which means that the load (withdrawal/charging) and generation (injection/discharging) aspects of the storage resource will be modeled as a single resource. Specifically, the IESO will implement a ~~'bi-directional generator model'~~Single Model Storage Resource (SMSR) meaning that a single resource can provide positive MWs, as an injection, and negative MWs, as a withdrawal. The single-resource model will be utilized by the IESO's optimization tool, the Dispatch Scheduling Optimization (DSO) tool, and other supporting tools. Figure 3 below shows an example of a bid-offer curve of a hypothetical battery storage resource.



Example: Capacity 200 MW, Energy Limit 800MWh



Example: Capacity 200 MW, Energy Limit 800MWh

Figure 3: Example Bid-Offer Curve for a Storage Resource under the SMSR

State of Charge (SoC) Management – SoC information will be collected, initialized, calculated and incorporated as a constraint into the optimization processes for all market timeframes, namely, Day-Ahead Market (DAM), Pre-Dispatch (PD) and Real-Time (RT). Seamless SoC management will support feasible scheduling and dispatch and the IESO's awareness of the storage resource's operational capability. To verify SoC across the different engines and passes, the IESO will utilize various ~~estimates~~calculated or telemetered values.

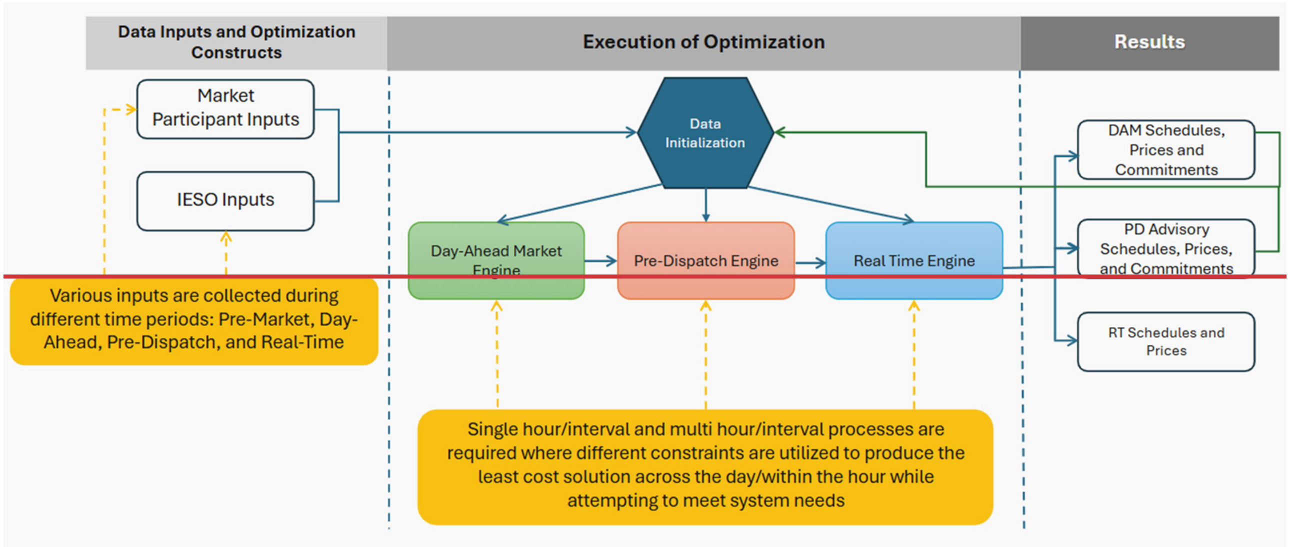
Optimization Background

~~Optimization refers to the process of making something as efficient as possible, improving performance, and achieving the best possible outcome. More specifically, in the case of a~~In the wholesale electricity market, optimization functions to maximize the gain from trade, which is the difference between the value to consumers of the electricity consumed and the cost to ~~suppliers of~~ electricity suppliers while considering grid security. The IESO optimizes its system using three calculation engines, DAM, PD and RT to achieve economic dispatch. The IESO uses resource data inputs, future-looking and RT operating conditions to optimize scheduled power flows on the grid. The IESO's calculation engines set the schedules, economic dispatch and Locational Marginal Prices (LMPs).

Optimization Process

The IESO optimizes over different time periods and between electricity markets while respecting a variety of other service commitments. The IESO co-optimizes between energy and OR, where it simultaneously determines the most optimal set of resources to be utilized in both energy and OR markets.

Figure 4 below shows the overall optimization execution process where the calculation engines receive inputs from the MPs and from other internal tools to produce schedules, prices and commitments.



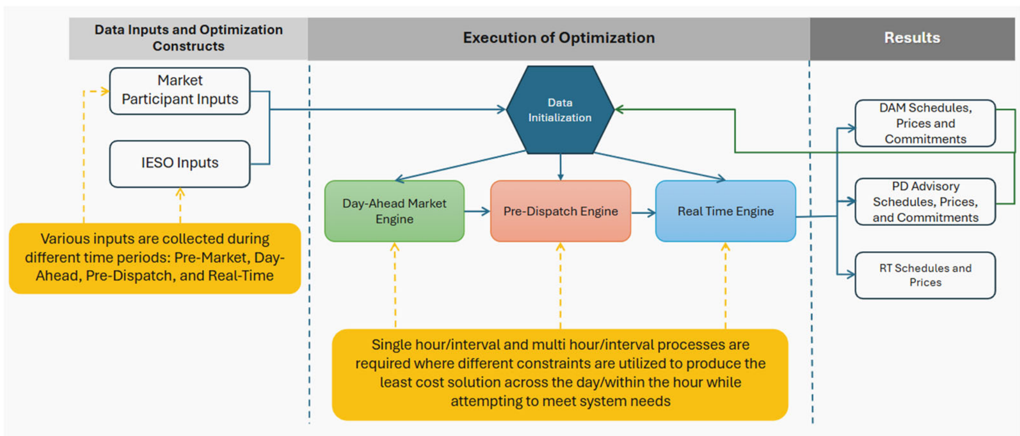


Figure 4: Optimization Process

Optimization design decisions are required across the following time periods:

- **Pre-Market** to understand impacts to pre-market requirements that are needed to support optimization in DAM, PD and RT (i.e., what could be required for connection and registration design), as well as collect some MP inputs and IESO inputs;
- **DAM** to collect relevant data, determine constraints that will impact hourly scheduling and produce DAM financially binding results;
- **PD** to collect relevant data, determine constraints that will impact hourly scheduling and produce PD advisory schedules that may impact commitments; and
- **RT** to collect relevant data, determine constraints that will impact five-minute interval scheduling and produce dispatch instructions and LMPs that will eventually be used for downstream settlement purposes.

High Level Storage Optimization Design Decisions

The following design decisions for the Optimization design element of Phase 1 will be valid for providing Energy and OR services:

- Storage will be able to participate in energy and OR from both the injection and withdrawal side of the resource, if the resource has sufficient capability. Branching from withdrawal to injection within an OR offer will be permitted, under feasible circumstances.
    - Optimization will include the entire offer range to schedule charging and discharging of storage resources for energy and OR. For energy, the offer curve will start from a negative quantity for charging and increase towards the positive direction for discharging. For OR, the offer will span from 0 MWs to positive MWs. OR offer quantities will never be negative because when the resource is discharging, it increases its MWs further to provide OR. When it is charging, it must decrease its charging MWs or stop charging to provide OR.
- The IESO will utilize the following variables to set SoC constraints:
    - SoC Tracker – a rolling total of SoC across hours or intervals~~,~~;
    - Initial SoC – MP submitted, starting PD ~~estimate to~~value for the next dispatch day, or ~~MP submitted~~a telemetered value;
    - Min/Max SoC limits – Max and min that a battery resource may be scheduled or dispatched to
    - ~~Internal Service Load – to track various facility loads that discount from the battery SoC calculation;~~
    - Cycle ~~/ round-trip~~ efficiency – energy losses resulting from dispatching the battery, applied on withdrawals.

Figure 5 below shows the high-level information on impacts/design for storage resources across the day as well as within various calculation engines and processes.

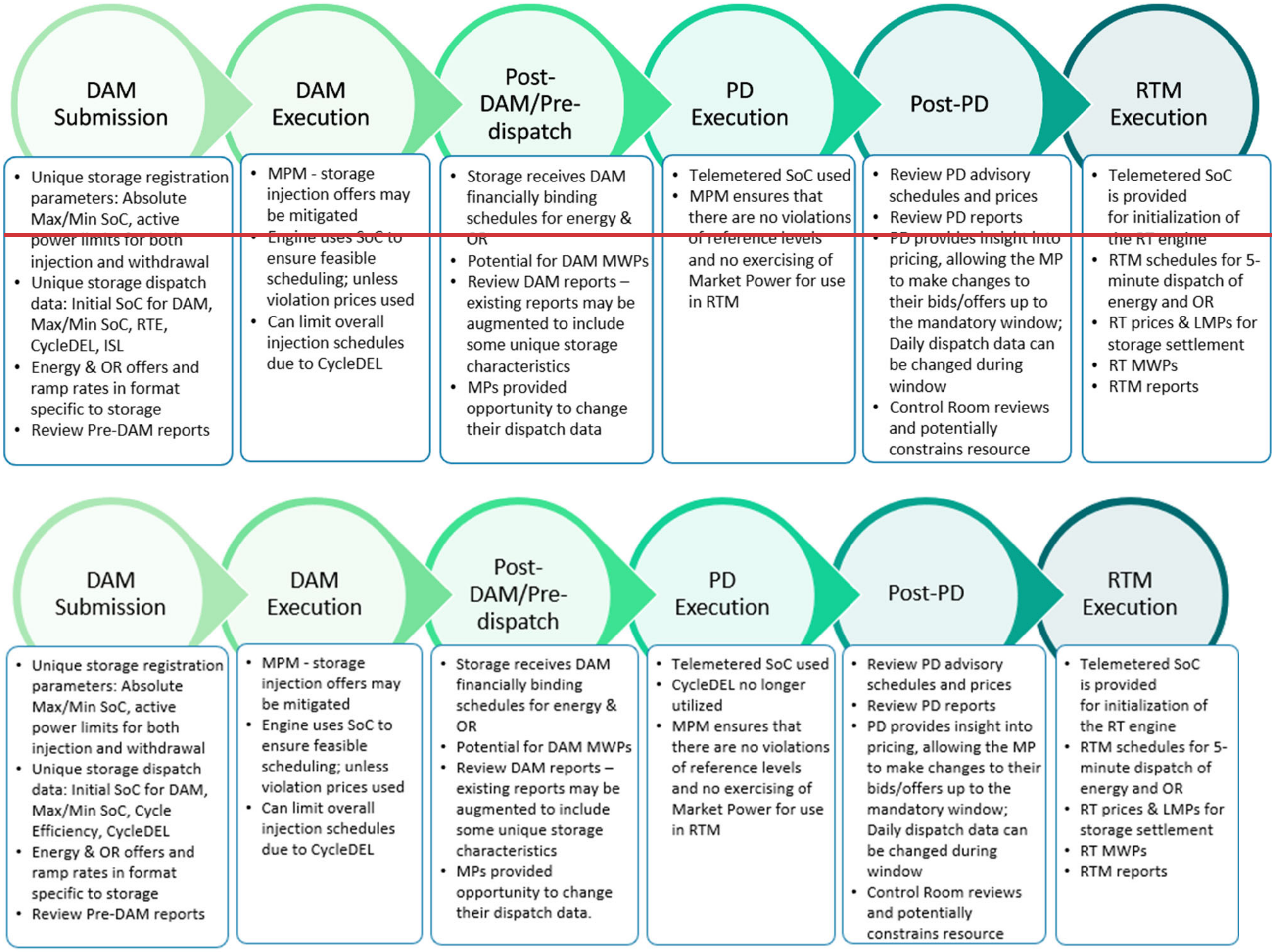


Figure 5: Storage-specific Optimization Process

Pre-Market

Many design decisions for optimization are not necessarily made for specific engines but are utilized by and are general requirements that impact all engines. Pre-market design decisions are focused on static input needs, meaning the input needs do not change frequently, and are consistent features or parameters that are applied to most or all of the calculation engines. The intention of this section is to also clarify where MPs will see impacts in value chains prior to the actual running of the engines.

MP Requirements

Pre-market design decisions related to the optimization design element are listed below:

- **Registration** – MP will register a facility as an Energy Storage Facility, which will permit the MP to select the ~~bi-directional generator resource model.~~SMSR. This registration process will enable the resource to branch from withdrawal to injection, represented as a single resource. This will require a consolidation of the generator and load requirements that were previously separated by individual resource types. The process will consider the registration needs of both a generator and load in aggregate.
- **Quick start (QS) Generator Characteristics** – This new energy storage model will be classified as a quick start generator that can produce positive or negative energy, as well as participate in providing operating reserves. This entails the same treatment within the calculation engines as existing quick~~-~~ start resources, where~~:~~ (1) there are no commitments made for schedules that carry forward into various scheduling timeframes and~~;~~ (2) certain non-quick start parameters are not available, such as minimum loading point (MLP), minimum generation block run time (MGBRT), minimum generation block down time (MGBDT), thermal states, startup costs, lead time, ramp to MLP profile, etc.
- ~~**Internal Service Load** – The IESO will request all storage MPs to provide the MW impact on the bi-directional generator resource from other facility operations such as station service and auxiliary load (if applicable), to ensure the accuracy of SoC calculations within the optimization engines. During registration, the Maximum Internal Service Load (ISL) parameter will represent the maximum hourly forecast impact on the SoC of the battery (in MW) to meet internal resource needs. It will account for the Auxiliary, Station Service, and any other marginal loads that are directly impact the resources SoC. For day-to-day operation, ISL will be a daily dispatch parameter representing the average estimated hourly MW draw on the batteries SoC to supply the same loads. ISL is considered in DAM and PD engine runs to ensure the resources are not overcommitted. The ISL is discounted from the SoC in the hourly SoC calculations. Please note, treatment of these loads is unique to each facility where different site configurations could impact various registration requirements which are outside the scope of optimization.~~
- **Commissioning of the new Model** – When commissioning the resource, the resource will ~~operate under a single resource model~~utilize an SMSR, meaning that the IESO's online model requirements will apply, although the resource will participate as a self-scheduler during this period. There will be certain exclusions and requirements to support this period of the resource's operation and to adapt the self-scheduling model for the ~~single resource model, these~~SMSR, which include:
  - The resource will participate like a self-scheduling generator but utilizing negative generator characteristics, which will introduce some nuances to existing requirements to facilitate that design. An example of a nuance is, when injecting

the resource will provide their self-schedule with a positive MW quantity, when withdrawing the resource will provide their self-schedule with a negative MW quantity.

  - LMP pricing will apply whether injecting or withdrawing during all timeframes.
  - SoC will not be modeled when entering self-schedules, the resource will manage these and must submit self-schedules that respect its own SoC limitations.

For clarity, the IESO must develop a new self-scheduling model for the commissioning of resources under the new SMSR. This model will not be used by resources who use an enduring self-scheduling two-resource storage model. Additional details on the commissioning requirements are included in the Connection and Registration Design Memo, which is posted on the ERP Storage and Co-located Hybrid Integration Project engagement webpage.

Registration Parameters

In addition to energy and OR offer curves, the IESO intends to utilize new and modified existing parameters to support feasible scheduling and dispatch of the resource. Static registration parameters are provided prior to DAM and are collected or set up within the registration phase for the resource. Static registration parameters unique to storage and expected from the storage MPs during registration are listed below in Table 1.

Note: Parameters whose timeframe is denoted as Registration/Daily Dispatch or Registration/Hourly Dispatch are intended for registering default/initial or validation values where MPs must or may have the ability to update them (within reasonable ranges and due to genuine causes) during DAM or PD data submission as daily or hourly dispatch parameters (whichever is applicable). Additionally, like other daily dispatch parameters, the parameters may be updated at any time and are not restricted by the mandatory window. Hourly dispatch data is not permitted to be updated within the mandatory window. If the daily dispatch parameters are updated prior to a new engine run being initialized, the updated parameters will be utilized by the engine. Table 1 below shows the daily dispatch data parameters used by the DSO to calculate SoC and enforce SoC limits.

Table 1: Registration Parameters

Parameter	Unit	Timeframe	Definition
Maximum Generator Resource Active Power Capability (PMax)max injection) Upper Power Operating Limit	MW	Registration	Existing parameter for dispatchable generators, but in this case refers to the maximum active **injection** capability of the resource to validate the submission of offers for energy or Operative ReservesOperating Reserve as dispatch data (note – MPs can use a combination of PMaxtheir max injection and PMinmax withdrawal limits for a lamination into OR, referred to as branching).
Maximum Negative Generator Resource Active Power Capability (PMin)max withdrawal) Lower Power Operating Limit	MW	Registration	The maximum **withdrawal** active power capability of the resource to validate the submission of offers for energy or Operative ReservesOperating Reserve as dispatch data.
Absolute Maximum State of Charge (Absolute MaxSoC)	MWh	Registration	The maximum SoC availability of the battery that could be utilized by the IESO. Indicates the MWh max that the battery will ever be charged to. Generally needed access for maintenance. Value will

Parameter	Unit	Timeframe	Definition
			be used to validate MaxSoC submission.
Absoulte Minimum State of Charge (Absolute MinSoC)	MWh	Registration	The minimum SoC availability of the battery that could be utilized by the IESO. Indicates the MWh min that the battery will ever be discharged to. ~~Generally needed access for maintenance.~~ Value will be used to validate MinSoC submission. Can be zero or another value as determined by the MP.
~~Lower Energy Limit~~Minimum State of Charge (MinSoC)	MWh	Registration / ~~Daily~~Hourly Dispatch	The minimum energy amount that the electricity storage system can consistently be discharged beyond expected degradation from standard operation.
~~Maximum Internal Service Load (ISL)~~	~~MW~~	~~Registration~~	~~The maximum amount of load consumed from the battery bank to service the resource. Expected to account for Auxiliary Load or Station Service Load that will impact IESO's SoC calculations; Submission should be a maximum value that will be utilized to validate ISL daily dispatch submission. ISL is only used in DAM and PD.~~
~~Upper Energy Limit~~Maximum State of Charge (MaxSoC)	MWh	Registration / ~~Daily~~Hourly Dispatch	The maximum energy amount that the electricity storage system can be consistently charged beyond expected degradation from standard operation.

Parameter	Unit	Timeframe	Definition
Cycle/ Round-trip efficiency (RTE)[1] Efficiency[2]	% or Decimal value	Registration / Daily Dispatch	The ratio of the energy discharged to the energy charged at the resource level. Applied at time of withdrawal and used to discount the SoC based on total efficiency losses to reinject energy back into the grid.at the resource. This should not account for ISL related items to avoid double counting impacting on SoC.
Bi-directional Resource Flag	Boolean (Yes/no)	Registration	Determines whether a resource has both a positive and negative dispatch range.

Data Monitoring/Telemetering Requirements

All facilities must comply with the applicable data monitoring requirements, which are listed in the IESO Market Rules (Chapter 0.4 Appendices, Section 4.24), and are used to ensure reliability of the grid by monitoring system conditions and resource response as well as to support DSO calculations. Table 2 below describes telemetry requirements for energy storage resources (ESRs) that should be available to the IESO on a continual basis, in accordance with the Market Rules.

Table 2: Data Telemetering Requirements

Attribute	Units of Measure	Description	Note
Active Power	MW	1) MW (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility) 2) MW (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility)	One value for active power injection and one for withdrawal (required for DSO and state estimator), net or gross depending on configuration relative to station service and auxiliary load.

[1] Please note, this value does not correspond to RTE related to payment mechanisms in the procurements. This value is for the operation timeframe to appropriately account for losses on the SoC of the resource during the operational timeframe.

[2] Please note, this value does not correspond to round trip efficiency related to payment mechanisms in the procurement contracts. The parameter in this document is meant to appropriately account for losses on the SoC of the resource during the operational timeframe.

Attribute	Units of Measure	Description	Note
		3) MW telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.	
Reactive Power	MVAR	1) MVAR (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility) 2) MVAR (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility) 3) MVAR telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.	One value for reactive power injection and one for withdrawal (only for state estimator), net or gross depending on configuration relative to station service and auxiliary load.
State of Charge (SoC)	MWh	The amount of energy available that can be injected into the grid. This is an existing parameter for storage resources currently participating in the IAMs, monitored in %. The unit of measure will be updated to MWh.	To avoid discrepancy between scheduling / dispatch and actual SoC, telemetered SoC should account for all losses and reflect MWh that could be injected into the grid. In addition, this SoC should reflect any outages towards its energy capability, in other words it should offer a true reflection of available MWh resulting from outages or derates.

Outage Information

MPs must provide outage information that accurately reflects the operational capability of resources. This impacts the high operating limit (HOL) and low operating limit (LOL) of the resource. Currently, storage resources can submit outages/derates for generation resources only. Outages must account for the capacity of the SMSR for both the injection and withdrawal ranges. The IESO will allow the resource to submit information that would independently reduce either the injection or withdrawal capacity of the resource, which will impact the high and low operating limits of the resource. For example, a storage facility rated at +/- 200 MW may submit a derate to the maximum capability down to + 185 MW impacting the HOL limiting injections by 15 MW and at the same time submit a different derate value to the minimum capability up to -190 MW impacting the LOL limiting withdrawals by 10 MW.

MPs will also be expected to provide outage information related to Max/Min SoC changes, however this information is not used by the DSO and is used for resource adequacy assessments completed by the IESO when reviewing outages.

IESO Inputs Impacted by the new Storage Model

IESO system inputs set the bounds for what the DAM engine must solve for and set system constraints to avoid operational issues from scheduling. IESO data inputs impacted by the new storage model are discussed below.

Fundamental Sets and Location Identifiers

Set of buses and delivery points within Ontario that correspond to bids and offers at locations on the IESO-controlled grid (ICG):

- Bus and Delivery Point Considerations - The IESO will model at a single delivery point and bus to support a ~~single resource model.~~SMSR. This is to ensure pricing is consistent whether injecting or withdrawing.
  - The IESO will utilize a generator bus and delivery point to support storage in the commercial model. As described above, the IESO will consider storage to be a ~~'bi-directional generator'~~ SMSR. When injecting the resource is a positive generator, and when withdrawing the resource is a negative generator. Therefore, a generator bus and delivery point can apply and provide the single pricing location.
- Within a facility, there could be multiple resources. Each dispatchable ~~bi-directional resource~~SMSR would be considered a single resource with injection and withdrawal capability, depending on the configuration of the facility.

Demand Forecasts

In DAM and PD, the IESO uses hourly average demand forecasts and hourly peak demand forecasts. In RT, forecasts represent actual total system consumption plus losses (actual demand). The IESO must ensure that demand forecasts and associated calculations accurately apply data related to a ~~bi-directional generator~~SMSR when the resource is expected to withdraw.

Resource Minimum and Maximum Constraints

~~Constraints~~Manual constraints applied by the IESO in IESO systems must allow negative and positive ranges of the resource to be constrained by the DSO.

- The IESO uses a tool to enter constraints on the resource to restrict the high and low operating limits of the resource:
  - Minimum, Maximum and Fixed constraints may be applied to storage resources in the injection and withdrawal ranges. In the withdrawal range, a Max constraint will impact the high operating limit, and a Min constraint will impact the low operating limit. (For example, for a +/- 200 MW resource with a Max constraint of -50 MW and a Min constraint of -150 MW, the generator may operate between -50 MW and -150 MW, withdrawing between 50 to 150 MWs);
  - Overlapping constraint rules remain unchanged.
- These changes also apply when an OR activation is set for the resource and must consider how branching will be implemented.
  - The IESO Control Room (CR) will set the minimum operating limit to the maximum injection range that is applicable to the OR offer.

Tie-Breaking Rules

When applicable and when scheduling storage, the standard tie-~~-~~breaking rules will apply (standard tie-~~-~~breaking for dispatchable generators/loads).

Market Power Mitigation

Reference levels and reference quantities are a set of mandatory registration requirements that the IESO determines in consultation with MPs. They are used to support the Ex-Ante, Settlement and Ex-post Market Power Mitigation (MPM) processes in the market. Ex-ante mitigation of financial dispatch data parameters takes place within the DAM and PD calculation engines. ~~Initial decisions were made for ex-ante mitigation as it occurs within some of the optimization timeframes~~Below are the changes needed to the calculation engine for the MPM process:

- Energy offers from the storage resource will be mitigated only for injections. There will be no mitigation on the load side of the energy offer submitted for consumption, except where necessary to support monotonic offer curves. For clarity, the IESO will ensure a mitigated offer meets the non-decreasing price requirement across the entire range. This means that the IESO must ensure that mitigated offers do not conflict on the withdrawal side of the offer curve and create non-viable offers for the engine to consider for scheduling. For example, if a withdrawal bid overlaps with the first injection reference pricing, when mitigated, it will be reduced to $0.01 below the mitigated injection offer to ensure a monotonic offer curve.
- ~~Generators and dispatchable loads are mitigated for providing OR on their OR supply offers for each applicable class of OR. Storage resources will have their OR supply offers mitigated, whether they are charging, discharging, or bridging an OR offer~~

between withdrawal to injection. MPM will need to support the transition to the single resource model where existing storage resource OR reference level requirements will be adapted to a single resource model. Additional changes will be considered in subsequent implementation phases of the ERP. The IESO will review its OR reference level curve per class of OR for the single resource storage model to consider all methods that a storage resource could provide OR.

Violation Pricing

The constraint violation[3] penalty curves that this resource model will utilize are listed below (specific penalty price to be determined).

- Typical violation pricing that is used in the network constrained unit commitmentoptimization will apply to support the scheduling of the storage resource when they are necessary.to avoid violations;
- For CycleDEL a similar approach for storage resources will be utilized as for existing hydroelectric resources (which use the MaxDEL constraint);
- A violation price will be utilized to bypass MaxSoC and MinSoC;
- A violation price will be set to a value higher than the standard MaxSoC and MinSoC values to bypass when MaxSoC and MinSoC are set to Absolute MaxSoC and Absolute MinSoC.

The IESO will utilize the following parameters for solution testing and will make adjustments as required based on the outcome of testing scenarios.

1. Absolute Min/Max CVPs $95,000/MWh – included in scheduling passes and pricing passes;
2. Min/Max SoC CVPs - $50,000/MWh - included in scheduling passes and in pricing passes;
3. CycleDEL CVP - $36,000/MWh - included in scheduling and multi-interval pricing passes (not in the single interval pricing).

[3] MM 4.3 Appendix A details the constraint violation penalty curves the IESO uses.

DAM

Overview

The DAM engine is the first of the three optimization and scheduling engines~~-~~ run by the IESO. At a high level, all engines operate in the same manner where data comes in, is initialized~~,~~ and run in one or more passes that comprise multiple steps to generate the results. As seen in Figure 6 below, MPs provide DAM data inputs to the IESO. MP inputs include static parameters from the registration process (described in the Pre-Market section), dynamic dispatch data submitted by the MP, or outage information. The IESO's inputs incorporate the pre-market data, in addition to relevant grid operational conditions used as constraints, various forecasts and any other IESO-submitted resource constraints. Data is initialized and ~~passed~~transferred into three different passes to execute the optimization.

This execution of the optimization in DAM produces financially binding day-ahead schedules and day-ahead prices used for settling the financially binding day-ahead schedules and setting commitment decisions for some resources that are required to operate efficiently.

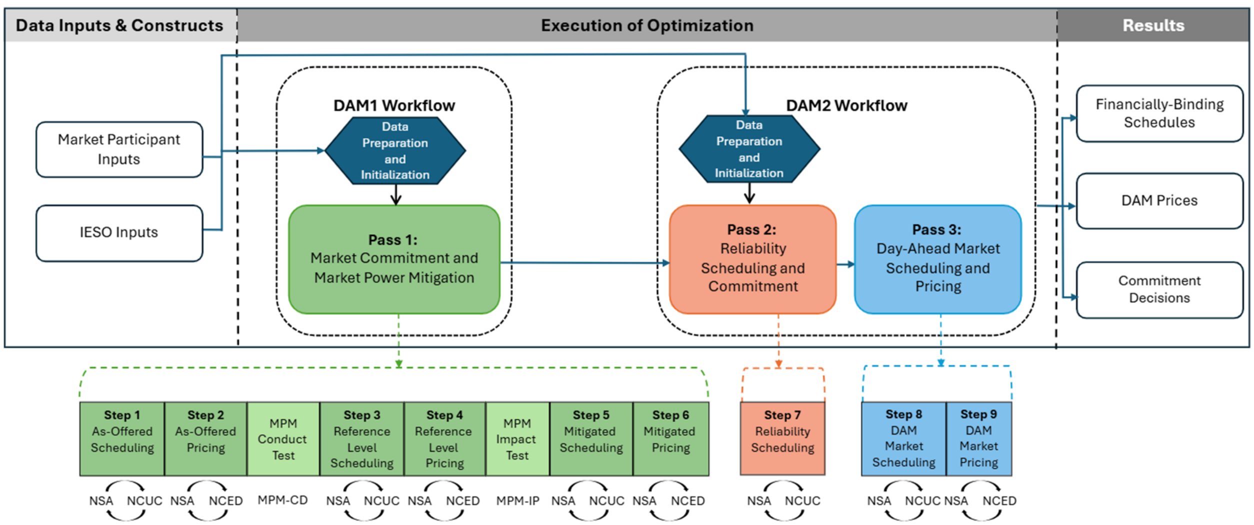


Figure 6: DAM Optimization Process

Optimization Initialization, Passes and Steps

The engines utilize passes and steps to execute the optimization. DAM utilizes three passes that support the production of initial scheduling, initial commitments, assessing and implementing ex-ante mitigation, additional commitments to support reliability and final scheduling and pricing. Below are the specific passes:

1. Market Commitment and MPM;
2. Reliability Scheduling and Commitment;
3. Scheduling and Pricing.

Each pass has multiple steps to complete the objectives of the pass. These steps utilize functions such as algorithms, assessments, unit commitments, economic dispatches, conduct tests and impact tests, which vary depending on the objectives of each step within the pass.

The following algorithms are generally utilized within various passes of all engines:

- **Scheduling algorithm:** Generates optimal solution for commitment statuses and schedules.
- **Pricing algorithm:** Uses the commitment statuses and resource schedules from the scheduling algorithm to calculate LMPs.

These require utilizing optimization functions such as the Network Constrained Unit Commitment (NCUC), Network Constrained Economic Dispatch (NCED) and a security assessment called the Network Security Assessment (NSA).

For engines that require MPM, there is the MPM Conduct Tests (MPM-CD) and the MPM Impact Tests (MPM-IP). Conduct tests are done first where additional scheduling and pricing is done, then an impact test is conducted.

Figure 6 above shows how these passes and steps run with the various other functions in the DAM engine. Each subsequent calculation engine will show its unique requirements to produce their results.

The following sections describe the design decisions that are valid and relevant to MPs for the DAM timeframe. The sections are separated into the Data Inputs, Optimization Execution and Results sections.

Data Inputs

DAM Submission Window: 06:00 EPT – 10:00 EPT: MPs utilizing the ~~bi-directional generator model~~SMSR can submit, revise or ~~withdraw~~remove hourly and daily dispatch data without restriction~~.~~ within this submission window. Offers can be standing offers~~, where the initial state of charge will be updated based on PD schedules~~.

Daily Dispatch Data Parameters

Table 3 below shows the daily dispatch parameters specific to the new ~~bi-directional storage model.~~SMSR. Some parameters may be repeated from the Registration Parameters section. Those registration parameters are used to validate the ~~MPs can override them~~parameters in Table 3 below.

Table 3: New ~~Bi-directional~~ Generator SMSR Daily Dispatch Data Parameters

Attribute	Unit of Measure	Description	Note
ISoC Initial State of Charge	MWh	Represents the total forecasted SoC, which corresponds to the amount of MWh available to inject into the grid. Value should already exclude all losses associated with withdrawal and injection.	• ~~Optional~~Mandatory submission used by DAM only~~. IESO will utilize the last available PD forecast prior~~ • Can have up to ~~the end of bid submission window if nothing submitted by the MP. If submitted it should not include~~

Attribute	Unit of Measure	Description	Note
			any ISL reductions. one decimal digit
RTE Round-trip Efficiency	% or decimal value; TBD	A multiplier applied to withdrawals used to update the calculated state of charge; Represents the combined injection and withdrawal efficiencies.	• Optional submission. Supersedes the default registered RTE value when submitted.
Cycle Efficiency	Decimal value	This value is applied to the withdrawal MWh to account for efficiency losses on both sides of the resource to provide accurate information on the MWh available. It should not account for other draw on the battery, such as auxiliary load etc.	• Mandatory submission • Should be greater than zero and less than or equal to one • Can have up to two decimal digits • MPM validation • Value between 0.00 - 1.00
MaxSoC *Maximum State of Charge*	MWh	The maximum energy amount to which the electricity storage system can be consistently charged without damage beyond expected degradation from normal use.	Optional submission. Supersedes the default registered MaxSoC value when submitted. Can enter up to Absolute MaxSoC.
MinSoC *Minimum State of Charge*	MWh	The lowest energy amount to which the electricity storage system can be consistently discharged without damage beyond expected degradation from normal use.	Optional submission. Supersedes the default registered MinSoC value when submitted. Can enter to the Absolute MinSoC
ISL *Internal Service Load*	MW (to one decimal place)	The average estimated hourly MW draw on the batteries	Optional submission between zero and the maximum ISL

Attribute	Unit of Measure	Description	Note
		SoC to supply its auxiliary load or other service loads. This discounts the calculated SoC at the beginning of each hour.	submitted during registration.
CycleDEL Cycling Daily Energy Limit	MWh (to one decimal place)	The maximum amount of daily injections that may be scheduled for energy across all hours and for feasibility on OR scheduled from the injection side. To assist the MP to avoid over cycling their battery if deemed necessary to avoid degradation.	• Optional submission used by DAM and PD. • Can have up to one decimal digit • In the absence of a submission, the default value will be 99,999.0 (consistent with Max DEL). CycleDEL is not utilized in RT to restrict dispatch and scheduling.999999.9

- Initial State of Charge (ISoC):
  - Pass 1 and 3 – PD populated/: MP submitted – the DAM engine will utilize the last valid PD run prior to DAM submission window closing. This will pull the HE24 SoC which will then be adjusted to the hour ending SoC based on the schedule of HE24. This value denotes the estimated SoC in MWh of the battery resource that they must inject into the grid andat the beginning of the dispatch day. This will be used as the initial value for scheduling of the first hour the resource is available in the DAM. The expectation is that this would be similar to what the IESO would telemeter from the resource. The market participants can override this value during the DAM offer submission window, where they canMPs must provide their own estimate with the assumed SoC the resource will have at the end of the previous dispatch day, including any other pertinent changes (such as outages or derates) and expected initial value for their dispatch data in DAM.
  - Pass 2 – the IESO will only utilize the SoC from PD advisory schedules. The IESO will pull the latest available HE24 SoC and then adjust to the hour ending SoC based on the schedule as described abovein HE24.
- Internal Service Load (ISL)
  - Considering that the calculation methodology for station service and auxiliary loads varies significantly according to several factors (e.g., season, temperature, aging), the IESO requests market participants to submit an 'internal service load' parameter information to support MPs not having to include it in the Round-Trip

Efficiency (RTE) calculation and to support an accurate SoC calculation. This is an estimate from the MP and will be subtracted from each hour's SoC at the beginning of each hour. MPs are expected to change this value if they determine a different draw on the batteries SoC as a result of various ISLs.

- Cycling Daily Energy Limit (CycleDEL):
  - This will be entered as a daily dispatch parameter. There will not be any restrictions in increase or decrease of this value.

Daily Hourly Dispatch Data Parameters

Table 4: New SMSR Daily Hourly Dispatch Data Parameters

Attribute	Unit of Measure	Description	Note
MaxSoC Maximum State of Charge	MWh	The maximum energy amount to which the electricity storage system can be consistently charged without damage beyond expected degradation from normal use.	Mandatory submission. Can enter up to Absolute MaxSoC.
MinSoC Minimum State of Charge	MWh	The minimum energy amount to which the electricity storage system can be consistently discharged without damage beyond expected degradation from normal use.	Mandatory submission. Can enter up to the Absolute MinSoC.

Daily Hourly Energy Dispatch Data Parameters:

- MaxSoC:
  - MPs can enter a MaxSoC up to its Absolute MaxSoC.
  - If submitting a high and utilizing higher than normal MaxSoC values which could limit the MP's ability to comply with dispatch, MPs should be scheduled with the IESO i.e. contact the IESO[4] to schedule such requirements. The IESO could expect

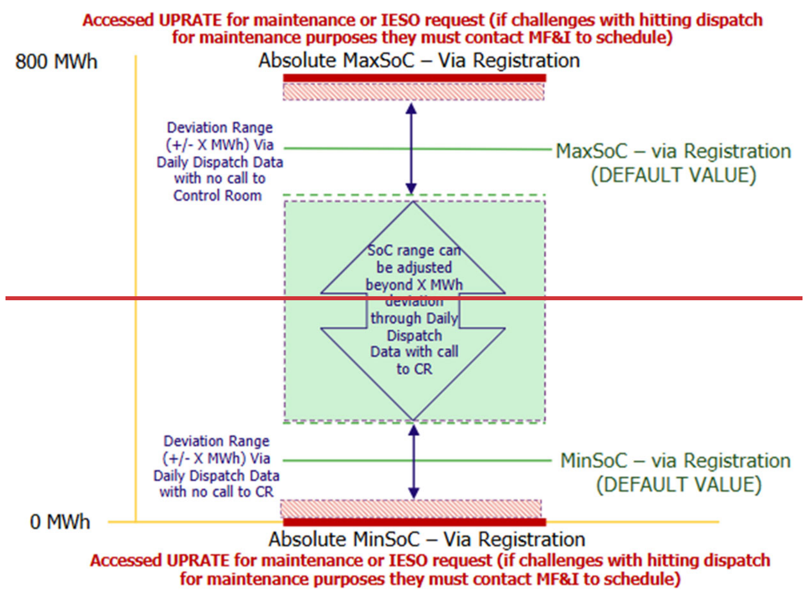
[4] Adhering to dispatch instructions is a typical requirement for dispatchable resources; if there are any issues complying with these instructions, the MP must notify the IESO.

this to occur when operating or performing maintenance on the full operating range of the resource and due to foldback~~ and to perform maintenance.~~ [5].

  - When submitting a lower MaxSoC up to a certain threshold (~~to be determined by the IESO), the IESO will request MPs to inform the IESO to verify this entry. The IESO will provide further details~~as described in ~~later design elements on how this process will~~the Dispatch Data and Other Inputs Design), appropriate reason codes must be ~~implemented, and the thresholds / conditions that will require such requirements~~entered.

- MinSoC:
  - Enter a MinSoC up to its Absolute MinSoC.
  - If submitting and utilizing lower than normal MinSoC values which could limit the MP's ability to comply with dispatch, MPs should contact the IESO[6] to schedule such requirements. The IESO could expect this to occur when operating or performing maintenance on the full operating range of the resource and due to foldback.
  - When submitting a higher ~~MaxSoC~~MinSoC up to a certain threshold (~~TBD by the IESO), the IESO will request MPs to inform the IESO to verify this entry. The IESO will provide further details~~as described in ~~later design elements on how this process will be implemented, and the thresholds / conditions that will require such requirements~~the Dispatch Data and Other Inputs Design), appropriate reason codes must be entered.

~~**Figure 7** below depicts the design for min/max SoC limits, assuming an 800 MWh battery.~~



~~**Figure 7: Design for minimum and maximum State of Charge limits**~~

- Energy Offer:

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[5] Refers to automatic, controlled reduction of active and/or reactive power output by the battery inverter when operating limits or grid conditions would otherwise push the battery system beyond safe or compliant operation.

[6] Adhering to dispatch instructions is a typical requirement for dispatchable resources; if there are any issues complying with these instructions, the MP must notify the IESO.

- Currently, MPs are allowed to submit between two to 20 price-quantity (P-Q) pairs ($/MW) for energy on a resource, which will continue to be the case for the new storage resource model. The unique feature of an energy offer curve for ~~single-resource storage model will~~ the SMSR is that it will be a single continuous/bi-directional offer curve, representing both offers for charging (withdrawal) and for discharging (injection).
- The first lamination for the resource will indicate the largest MW quantity withdrawal, utilize a negative MW value, as well as have their lowest (highest in the negative direction) price in $/MW as part of the same lamination. Each subsequent lamination will have a monotonically increasing MW quantity, and a monotonically non-decreasing $/MW price. After expressing all withdrawals, the MP must enter a zero MW quantity to denote the cutover point to injections, which will share the same $/MW value as the resource's next injection lamination (the lowest price the MP is willing to accept for an injection). Each injection will be denoted by a positive MW quantity and will also have monotonically increasing MW quantities and monotonically non-decreasing prices in $/MW. If just withdrawing, the curve goes from the largest withdrawal to zero. If just injecting, it starts at zero and goes to the highest injection capability the MP wants to express for the resource in the market.
  - The existing offer requirements for dispatchable generators that may not apply for a ~~storage~~bi-directional offer curve are~~:~~, i) The first quantity must equal 0.0 MW and ii) Prices on the first and second P-Q pairs must be the same.
- Accounting for Station Service and Auxiliary Load – There should be minimal to no error between how a resource is being dispatched, what response the IESO sees onto the grid (via the resource's telemeter) and how the IESO should add or subtract from the SoC of the resource.
- Availability Declaration Envelope (ADE) based on the MPs' energy offer - ESRs will continue to be subject to the ADE requirement. The ADE is the hourly injection or withdrawal capacity offered day-ahead for dispatchable resources. ESRs must submit their maximum injection, and maximum withdrawal offers to fully utilize that range in PD and RT through their continuous offer.

Table 5: Example of Bi-directional Energy Offer Laminations

Example Energy offer with nine Laminations				
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**	**Price to Schedule ($/MW)**	**MW that could be scheduled**
Pair 1	-200	-200	-200 or less (more negative)	Withdrawal 90.1 to 200
Pair 2	-100	-90	-199.99 to -100	Withdrawal 80.1 to 90
Pair 3	0	-80	-99.99 to 0	Withdrawal 50.1 to 80
Pair 4	25	-50	0.01 to 25	Withdrawal 0.1 to 50

Example Energy offer with nine Laminations				
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**	**Price to Schedule ($/MW)**	**MW that could be scheduled**
Pair 5	100	0	25.01 to 99.99	Idle
Pair 6	100	50	100 to 499.99	Inject 0.1 to 50
Pair 7	500	100	500 to 599.99	Inject 50.1 to 100
Pair 8	600	150	600 to 699.99	Inject 100.1 to 150
Pair 9	700	200	700	Inject 150.1 to 200

- In the example shown in Table 5 above, the MP submits nine laminations. The MP is showing a maximum withdrawal capability of 200 MW (denoted by the -200 MW quantity) and a maximum injection capability of 200 MW (denoted by the +200 MW quantity) for the resource. The MP can provide up to these values in PD and RT as per the ADE requirement. The zero quantity in the laminations indicates that this resource will not be scheduled economically between market prices of $25.01 to $99.99. Their withdrawals will start at a $25/MW market price, and their injections will start at the $100/MW market price.
- Generation without Offer - If the resource does not have any offer, the resource will be assigned a value of zero MW based on the assumption that the resource is offline and will not be charging nor injecting.

- Energy Ramp Rate:
  - Energy ramp up rate refers to increasing generation or decreasing withdrawal (MW moving in the positive direction) and will be validated against registered energy ramp rate Non-Financial Reference Levels (NFRLs).
  - Energy ramp down rate refers to decreasing generation or increasing consumption (MW moving in the negative direction) and will be validated against registered energy ramp rate NFRL. Figure 7 below depicts the energy ramp up and ramp down rates.
  - The IESO will ~~look~~continue to ~~set~~utilize a 100 MW/~~Min max requirement on its~~min ramp rate at the facility level. The ramp restriction the IESO will be imposing applies to ~~be utilized by storage resources for~~both injection and withdrawal when facilities are scheduled for energy. ~~Although this value will be entered at a resource level, based on current precedence the IESO expects storage facilities operate~~This means that if a facility has multiple resources, their ~~resources in combination~~combined ramp rate should total no ~~higher~~more than 100 MW/min.
    - Note: This 100 MW/min requirement will support more stable grid performance and supports SoC calculations throughout the different engines.
  - The resource/facility is not required to adhere to the 100 MW/min max ramping requirement when activated for OR, frequency excursions, voltage changes, or

equipment protection operations including Remedial Action Scheme (RAS) runbacks.

   - MPs can submit up to ~~5~~two positive breakpoints, two ramp up and two ramp down rates that are equal to or below 100 MW/~~Min~~min. The IESO will utilize the two positive breakpoints, duplicate and assign a negative value to interpret as the negative breakpoints for the resource.

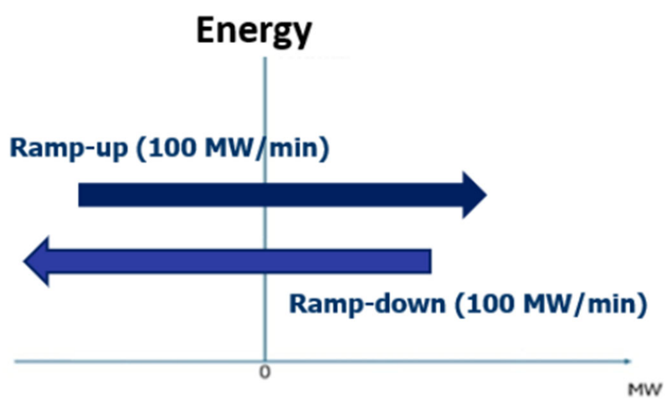

Figure 7: Energy Ramp Rates Design

Hourly OR Dispatch Data Parameters:

- Operating Reserve Offer:
   - OR offers will primarily be consistent with other resource types where:
      - MPs are allowed to submit between two to five P-Q pairs/laminations for each class of operating reserve (10S, 10N, 30R) for each dispatch hour with their OR MW quantity and $/MW price.
      - OR offer is always either zero or positive for MW quantities.
   - ~~Storage resources~~SMSRs can ~~offer~~utilize the full operating range of the resource as a net positive value~~.~~ in their offer. Specifically, this means that the MP can submit a combination of the absolute values of the withdrawal MW range and injection MW range as a single lamination for the resource into OR. This will support the resource in providing an OR activation by reducing charging and then immediately discharging, referred to as branching.

Table 6: Example of Operating Reserve Offer Laminations

Example OR offer with five laminations		
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**
Pair 1	0.1	0
Pair 2	0.1	50
Pair 3	5	80
Pair 4	10	200

Example OR offer with five laminations		
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**
Pair 5	10.01	400

- The example in Table 6 above has five laminations where the first OR offer is 50 MW and the last offer is 400 MW. If correlated to the resource's energy offer in the previous energy offer example, the MP submitted a -200 MW and +200 MW quantity offer into the market. This 400 MW OR offer accounts for the resource's capability to be consuming for 200 MW and immediately provide injection capability of 200 MW if activated. ~~To simulate this action~~If activated for OR, within the ~~MP~~permitted time (i.e., 10 or 30 min), the resource would stop their consumption and ~~immediately~~then shift to inject the 200 MW for a 400 MW swing of response.
- The optimization engine will determine the correlation between energy offers and OR to support co-optimization efforts due to OR offers expressing withdrawal, injection~~,~~ and branching opportunities.

- OR Ramp Rate (MW/min):
  - Design for ~~storage~~the SMSR will be consistent with other resources where only one value is permitted.
  - It will be validated against registered OR ramp rate NFRL.
  - Unlike energy ramp up/down rates, the OR ramp rate will not be limited by the 100 MW/Min requirement ~~but must respect~~as these are infrequent actions that are intended to replace the sudden loss of other grid supply. However, the resource's registered maximum ramp rate value must be respected, as depicted in Figure 8 below.

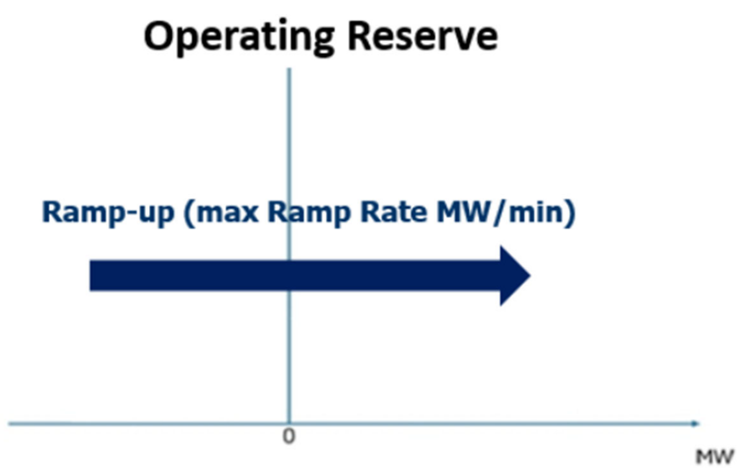

Figure 8: Operating Reserve Ramp Rate Design

- Reserve Loading Point:
  - This denotes the minimum generation level in MW at which a resource associated with a dispatchable generation facility can provide the maximum OR of the class of OR being offered.

- A reserve loading point must be zero for a single resource modelSMSR. This will accommodate the resource providing OR from a static state, the complete operational range of the resource (withdrawal to injection), while injecting, or only withdrawing.

Optimization Execution

Single-hour and multi-hour processes are required where different constraints are utilized to produce the least-cost solution across the day, while attempting to meet system needs.

Single Hour Constraints:

- The bi-directional generatorSMSR will be able to operate at any level between their HOL and LOL. There will be no forbidden regions applied to the resource. When dispatched to zero MWs, the resource is expected to not be operating/providing energy/withdrawing from the grid but can be scheduled for OR up to the HOL and depending on the various limiting factors described in this section. The HOL and LOL is based on:
  - Offer quantities – a resource's schedule will not exceed offer quantities submitted by the MP through their dispatch data for energy and cannot exceed the combination of the absolute values of max withdrawal quantity (the largest negative offernumber) and the max injection quantity (the largest positive number).
  - Derates - the MP can submit a derate on their maximum injection or withdrawal capability and scheduling will not exceed these limits.
  - Constraints entered by other IESO systems and tools that feed into the DSO - the IESO shall be able to submit Min/Max or Fix constraints in the positive or negative range of the resource. This can be entered in one hour or multiple hours.
- The above can be further constrained by:
  - CycleDEL – this could limit the schedule based on the availability of the daily energy limit value. The resource cannot be scheduled beyond this limit on the injection side only, unless violation pricing is applied. This will apply for each hour and over the entire multi-hour schedule. CycleDEL should not impact scheduling the resource for withdrawals.
    - For example, a resource that is economic to inject up to its HOL of 200 MW but with a remaining CycleDEL of less than 200 MWh, will be limited by the CycleDEL for both energy as well as OR scheduled in the injection range.
  - Ramp rate – ramp rates can constrain a schedule like for other quick start resources. For schedules that will utilize branching the resource, it will utilize both withdrawal and injection ramp rates and breakpoints of the resource for energy to determine feasibility and the OR; when ramp rate for OR. When withdrawing energy and OR, the resource will be limited by the ramp rate for energy schedules like other quick start/dispatchable load resources. For OR, the amount of 10 min or 30 minute OR cannot exceed the amount by which the resource can decrease and then increase its output over 10 or 30 minutes, as limited by its OR ramp rate which indicates a positive swing (moving in the net positive direction from the negative withdrawal to the positive injection).
  - State of charge/Min and Max SoC resources must be scheduled within these limits. Unless violation pricing is utilized, the SoC can be reduced by:

- ~~RTE~~Cycle Efficiency (CE) - losses submitted by the MP. This will be applied only on the withdrawals, even though it accounts for all losses from withdrawing and injecting.
  - ~~Internal Service Load – SoC will be discounted by the ISL estimate that was submitted by the MP at the beginning of each hour. This is required prior to any additional SoC related calculations.~~

- Changes in Min/Max SoC – Planned changes in SoC range could derive uneconomic schedules to ensure that the resource is continually scheduled within its updated Min/MaxSoC range. For example, the resource has a 100 MWh SoC and a planned outage to reduce MaxSoC from 100 MWh to 75 MWh. Without logic, the engine will assume there is an impending condition that will assume the resource must be scheduled to inject 25 MWh to avoid bypassing the new MaxSoC limit of 75 MWh. As a result, when an MP changes its resource's SoC range, scaling logic must be introduced to account for these adjustments to avoid unnecessary scheduling.
- The IESO does not have direct visibility into the battery packs themselves and how outages of packs will influence a SoC change. There could be many different scenarios and impacts to the actual SoC as a result of a change in the range. To simplify this, the logic will always assume that certain amounts of MWh of stored energy could be removed or added to the resource depending on if a resource is decreasing or increasing the range. This simulates one scenario that the MP is removing a pack with some SoC and returning a pack with some SoC. This will therefore always scale the look ahead period's SoC in the DSO.
- When the change physically happens, the SoC will revert to the telemetered SoC when it becomes available. For example, the MPs could be removing/adding a battery pack from/to service with a full SoC and schedules could happen in between returning to service that will influence the calculated SoC. When the battery pack is removed/added and the telemeter is utilized for the next dispatch/schedule the SoC will revert to this actual SoC from the telemeter to initialize scheduling.
- Figure 9 below represents a visual example and the scaling logic that is being utilized.

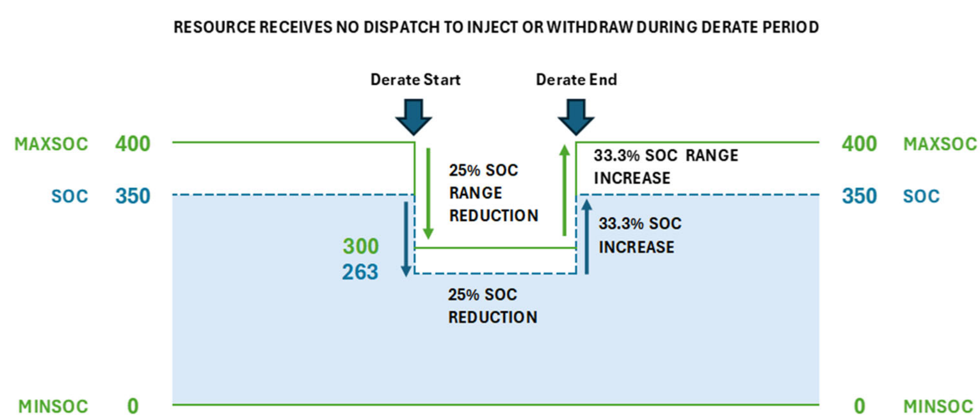

Figure 9: SoC Scaling Example

        - New SoC Estimate$_h$: ((Actual SoC$_{h-1}$ – MinSoC$_{h-1}$) / (MaxSoC$_{h-1}$ – MinSoC$_{h-1}$)) x (MaxSoC$_h$ – MinSoC$_h$)) + MinSoC$_h$
        - For example, in h-1 if the resource has an SoC of 350, a MaxSoC of 400 MWh and a MinSoC of 0 MWh, the MP is adjusting the Max SoC to 300 MWh in h. If there is no logic, the engine will see a difference of 50 MWh that must be scheduled to ensure that 300 MWh MaxSoC is achieved in an upcoming hour or interval. Therefore, in this example we scale the estimated SoC down by 0.875 to accommodate the change and avoid that scheduling.
        - ((350 MWh – 0 MWh) / (400 MWh – 0 MWh)) x ((300 MWh – 0 MWh)) + 0 MWh = (0.875 x 300 MWh) + 0 MWh = 262.5 MWh.
- Additional SoC Considerations[7]:
    - Energy (no reserves scheduled)
        - In any given hour, a ~~storage resource's~~SMSR's SoC, considering its energy schedule for the hour, should always be less than or equal to its maximum energy storage capacity and greater than its minimum energy storage capacity.
        - The SoC capability must ensure that the resource can feasibly provide energy for the full hour scheduled for injection or withdrawal. The highest economic energy offer will set the initial limit, unless SoC is not available for injection or SoC is too high to support a withdrawal for a full hour based on this offer, the resource can be scheduled for the max of their SoC/energy capability for the hour (i.e., if SoC available is 100 MWh, but their power capability is 200 MWs, the resource is available to only inject 100 MWs for the hour). For injection, this will be SoC availability up to the Min SoC, for withdrawal this is difference between the Max SoC and existing SoC.

[7] Please note that the requirements described in this section, as well as similar sections in PD and RT, can be bypassed when the DSO requires the usage of constraint violation prices.

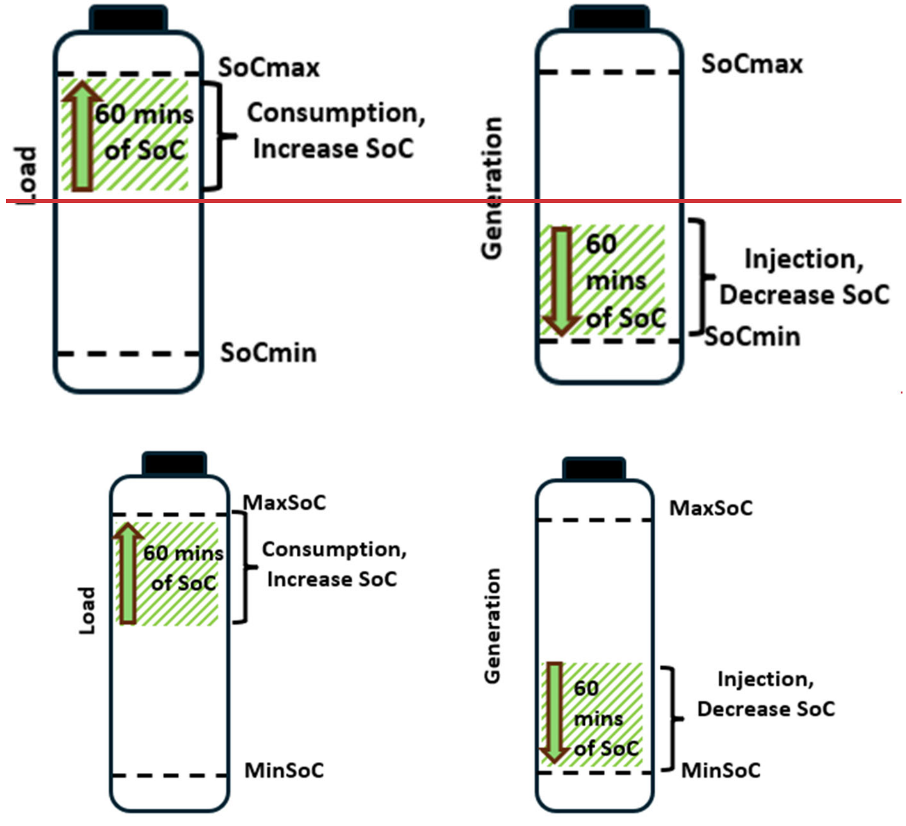

Figure 10: SoC requirement for Energy in DAM

- Operating Reserve – With no energy schedule:
  - OR only schedules can only be achieved by the injection capability of the storage resource. Therefore, to provide OR only, the resource must have a zero energy schedule and to achieve the OR activation, it requires the resource to inject energy into the grid.
  - As there is no energy schedule, the expectation is that a storage resource can have their OR schedule limited to a value that ensures 60 minutes of SoC availability and this value cannot exceed the MinSoC. This is to simulate the ability to have an OR activation that can be met at any point over the hour without bypassing the lower SoC limit set by the MP.

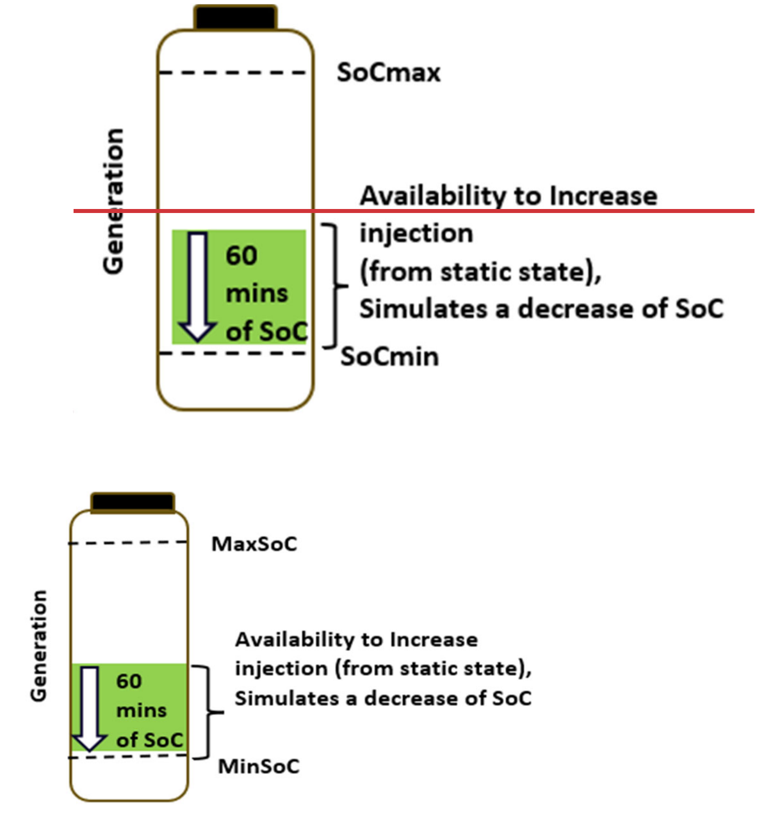

Figure 11: SoC requirement for OR in DAM

- Operating Reserve - With an Energy and Operating Reserve Schedule:
  - Withdrawal based energy and OR – to be scheduled to consume energy, the DAM engine must ensure the resource's schedule can receive energy/can consume for a 60 minute period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption, therefore, will not exceed what can be consumed over a 60 minute period, which is the same limit as energy withdrawal.
  - Injection based energy and OR – to be scheduled to inject energy, the DAM engine must ensure that the resource's schedule is capable of injecting energy for 60 minutes as well as have an additional 60 minutes of stored energy to contribute an incremental increase in energy from an OR activation, in addition to not exceeding the ~~SoC Min~~MinSoC.
  - Withdrawal based energy and branching OR – to be scheduled to consume energy, the DAM engine must ensure the resource's schedule can receive energy/can consume for a 60 minute period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption and then ~~immediately~~swinging to injecting (branching from withdrawal to injection~~), therefore~~). The OR schedule will not exceed what can be consumed over a 60 minute period, which is the same limit as energy withdrawal, but must also have 60 minutes of injection capability without exceeding the MinSoC. The energy schedule is limited to this withdrawal capability, and the OR schedule is limited to both the stated withdrawal and injection requirements with the start of the hour SoC being the worst case assumption.

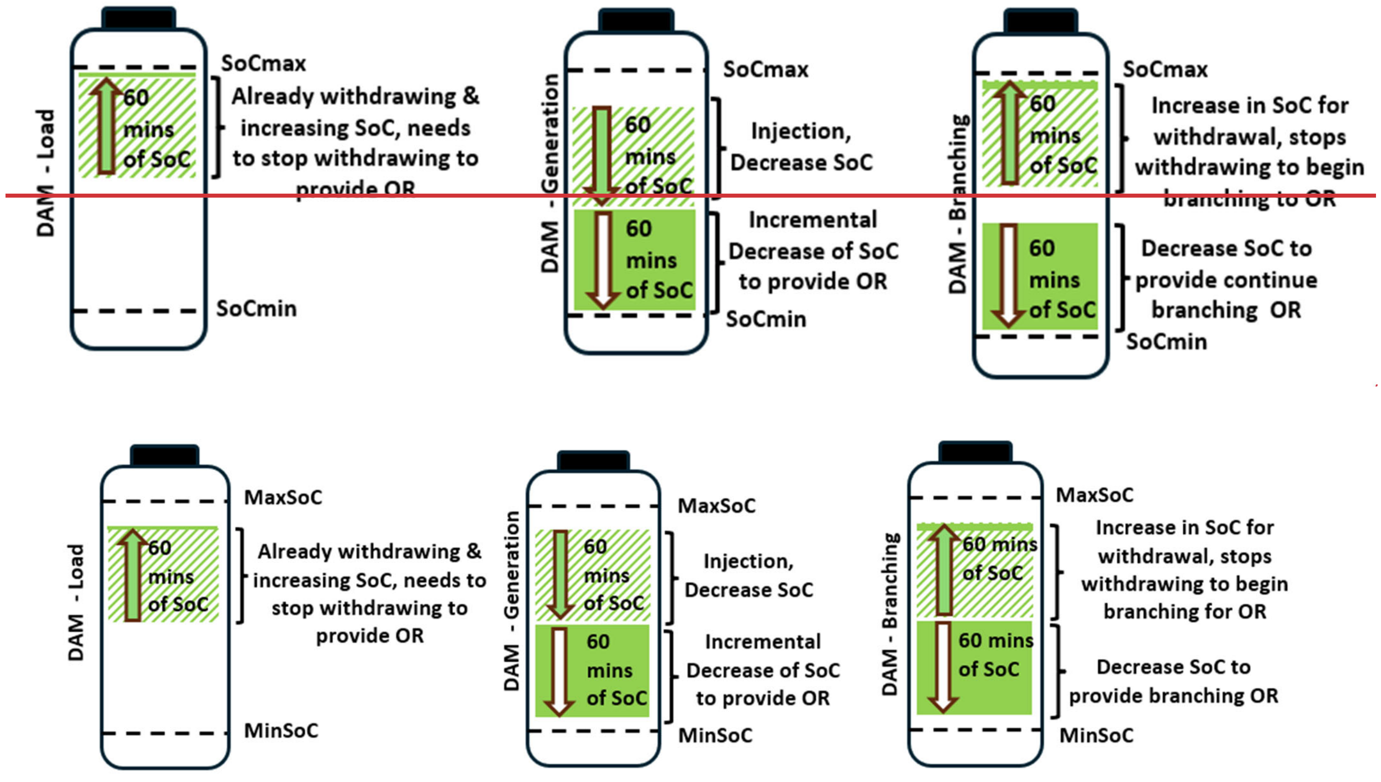

Figure 12: SoC requirement for Energy and OR in DAM

- Energy and OR Joint Optimization Considerations:
  - Energy offers and OR offers will be co-optimized. OR offers will only be scheduled if the corresponding energy offers will promote a feasible action by the resource. If other OR quantities must be achieved by having the corresponding energy MW schedule, a specific example is branching in OR, where the resource must be scheduled to withdraw by a certain MW quantity to enable this action.

Figure 10, Figure 11 and Figure 12 depict the SoC requirements in DAM of a battery while providing energy only, OR only and co-optimized energy and OR, respectively.

Results

Results for the resource in DAM include typical financially binding DAM schedules for energy and OR, based on LMPs. In addition, the IESO has made the following design decisions that will impact the results:

- Since ~~storage~~the SMSR is being modeled as a quick start generator, SMSRs will not receive commitments.
- Price setting eligibility:
  - ~~Bi-directional generator resources~~SMSRs with a binding CycleDEL, will have their price-setting eligibility requirements treated the same as other energy ~~limit~~limited resources with a binding MaxDEL.
  - When scheduled up to the Max/MinSoC, this will also limit a resource's ability to set prices.
  - The same price-setting requirements should be leveraged for ~~bi-directional generator resources~~SMSRs as other resources on the following constraints:
    - Ramping Constraints;

    - Manual Constraints applied by the IESO (via Contract Manager) or from derates submitted by the MP (via the Control Room Operations Window (CROW)).
- Make-Whole Payments (MWPs) are determined in the Settlements design module.

Pre-Dispatch

Overview

The PD engine is the second of the three optimization and scheduling engines that is run once every hour. Data inputs come from the MPs, the IESO and commitment decisions from the DAM results. MP inputs are static parameters from registration (described in the Pre-Market section), or dynamic dispatch data submitted by the MP. The IESO's inputs incorporate the pre-market data inputs, in addition to relevant grid operational conditions, various updated forecasts, as well as real-time operational telemetry from relevant resources. After the initialization is complete, these inputs are integrated into the specific PD hours and input into the singular pass of the PD engine to execute the optimization. The execution of the optimization run in PD produces advisory schedules and prices for MPs to plan their operations and the IESO to plan the grid for the future hours. It also includes schedules for intertie resources one hour prior to real-time, as well as scheduling hourly demand response resources. Finally, the PD engine also produces additional advanced commitment decisions needed for specific resources to prepare their operations for real-time.

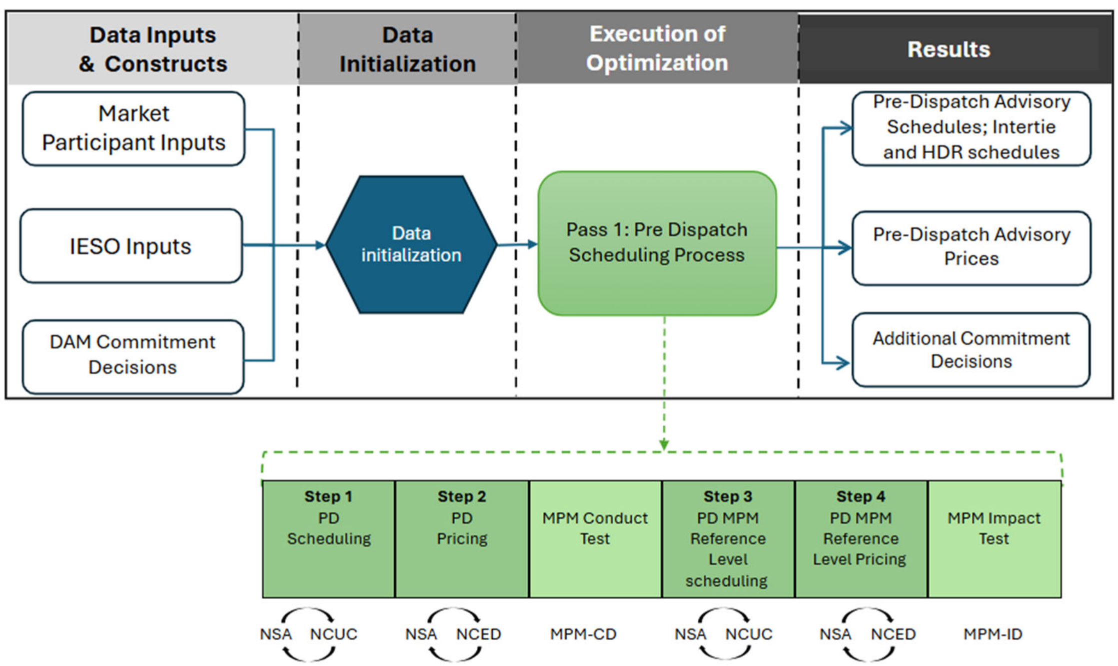

Figure 13: Pre-Dispatch Optimization Process

Optimization Initialization, Passes and Steps

There is a significant data initialization phase conducted for this engine. This is referred to as Pre-dispatch initialization (PD-INI), where the initialization process requires a simulation of the RT hour, mimicking a Real-Time Multi-Interval Optimization (RT-MIO) calculation engine. This estimate could be different than the RT-MIO engine as these engines are run to consider slightly different information. PD-INI runs seven-minutes before PD begins, starting at xx:55, calculates resource initial schedules for the hour preceding the PD study period and uses the output to determine the PD initial conditions.

There is only one pass in the PD engine that determines where there is scheduling, pricing and any applicable MPM outcomes. Like DAM, for each scheduling/pricing step during PD execution, the NSA and NCUC/NCED functions iterate until convergence and the MPM conduct test and impact test ensure that there are no violations of reference levels and no exercising of market power. The RT-MIO engine uses mitigated-for-impact offers produced by the PD engine. Figure 13 above shows how these passes and steps run with the various other functions in the PD engine.

Considering that the DAM's first pass and PD's only pass have similar steps, and both are hourly, much of the relevant information collected from the MPs, the IESO and the DAM engine requires the same design to consider storage in the PD engine. The information below provides the relevant differences in design from DAM.

Data Inputs

- Initial State of Charge (ISoC):
  - No longer will be an MP submitted estimate, but willWill utilize the last telemetered SoC prior to the start of the PD engine run to set the initial value.
- The MP can update their daily dispatch data at any point and it will be utilized in the PD run if entered prior to the engine starting its run. This specifically includes the Min/MaxSoC; RTE, ISL, and
- Max/MinSoC:
  - MPs can adjust these hourly parameters as required.
- CycleDEL - will not be used to constrain the resource of its scheduling in PD. MPs are responsible for submitting their dispatch data in a way that can support limitations in operation.

Offers:

  - The MP will be subject to the mandatory window restrictions, where updates are limited to PD-2 (two hours prior to RT).
  - Availability Declaration Envelope (ADE) based on the resource's energy bid and offer - The MP will not be permitted to submit any laminations that will exceed the max and min MW quantities in their resource's offers that were submitted in DAM. In other words, if submitting a 200 MW injection offer and a -200 MW withdrawal offer, the MP will not be able to submit an injection offer in excess of 200 MW, or withdrawal below -200 MW.

Optimization Execution

PD-Initialization – the initial value is the telemetered SoC but. PD-INI does not usepasses this telemetered value directly since bi-directional storage facilities are by default energy limited by CycleDEL and SoC. As a result, to the initialization of these parameters will follow similar methods as MaxDEL where it will takePD engine. PD-INI also takes schedules based on the average of the RT-MIO advisory schedules to reduce the CycleDEL and either add or subtract from the SoC. In addition, considering CycleDEL is not enforced in RT, it will not be enforced in the initialization so that the starting value for PD-1 (one hour prior to RT) is as accurate as possible with the best available information.the PD engine. This process also considers cycle efficiency if adding to the SoC.

Results

- Like most other resources, ~~storage~~SMSRs will receive advisory schedules and forecasted LMPs.
- ~~Storage~~The SMSR is being modeled as a quick start generator, therefore, it will not receive commitments from PD decisions. ~~Considering that there are no commitments and PD produces advisory decisions, this can result~~ However, the IESO ~~taking~~could take manual operator actions, as required, to ensure that the energy limitations of storage are managed, and to ensure there is resource availability for situations the CR deems necessary~~.~~ to maintain reliability. This is similar to how the IESO may manage other energy limited resources. Make-whole payment considerations of these actions will be discussed in the Settlement module.

Real-Time

Overview

The RT engine is the third of the three optimization and scheduling engines run by the IESO. Data inputs come from the MPs, the IESO and commitment decisions from the DAM and PD engines, and the PD intertie schedules (from PD-1). MP inputs are static parameters from registration (described in the Pre-Market section), or dynamic dispatch data submitted by the MP which was submitted prior to the mandatory window during pre-dispatch (PD-2 specifically).

The IESO's inputs incorporate the pre-market data inputs, in addition to relevant grid operational conditions, various updated forecasts, as well as RT operational telemetry from relevant MPs. Data is initialized where it is adapted for specific intervals and input into one pass to execute the optimization. This execution of the optimization in RT produces RT dispatch schedules for the next interval, and advisory interval schedules for the next 11 intervals. This also includes locational prices for each interval.

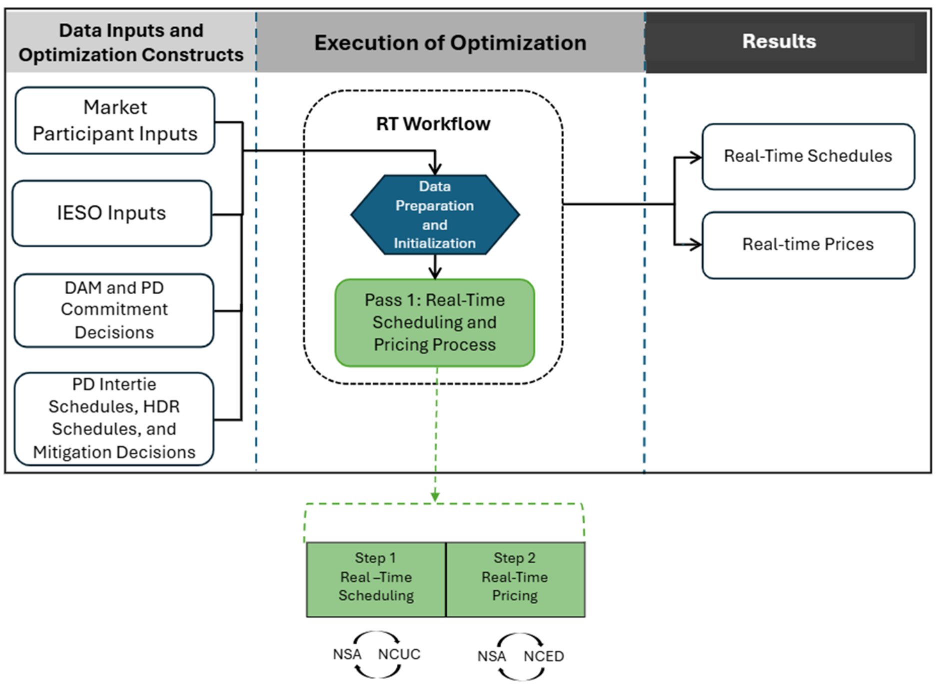

Figure 14: Real-Time Optimization Process

Optimization Initialization, Passes and Steps

The initialization is focused on the next five-minute intervals and the immediate study horizon of the engine. Some initializations must happen to account for the previous five-minute dispatch that occurred. Many inputs are also created during the PD timeframe and used as initial information. PD scheduling decisions are only passed to RT in the form of:

- Constraints applied by the IESO for specific scenarios;
- NQS commitments, hourly must run, and when MinDEL is binding;
- MPM mitigation decisions.

The RT engine is composed of a single pass, RT Scheduling and Pricing, which calculates both dispatch schedules and LMPs, utilizing the same algorithms as the DAM and PD engines. Figure 14 above shows how these passes and steps run with the various other functions in the RT engine. The first step is a scheduling step that finds the optimal resource dispatch schedules and the second step is a pricing step that calculates the LMP for each interval. Similar to DAM and PD, for the scheduling step, the NSA and NCUC functions iterate until convergence and for the pricing step, the NSA and NCED functions iterate until convergence.

The RT engine execution provides relevant information for the production of five-minute dispatch energy and reserve schedules as well as prices that will eventually be used for additional settlement purposes.

The incremental changes that are required for the RT engine are discussed in the sections below. From a ~~storage~~SMSR MP's perspective, RT requires that ~~they prepare~~the SMSR prepares for physical dispatches and other actions required by the IESO to support reliability. Many of the actions outside of this requirement are generally the same. The RT engine considers offers that were submitted during PD prior to the mandatory window. Although offers are hourly, the offers are utilized for the five-minute interval dispatches and advisory schedules.

Data Inputs

- CycleDEL - will not be used to constrain the resource of its scheduling in RT. MPs are responsible for submitting their dispatch data in a way that can support limitations in operation.
- ~~Internal Service Load (ISL) – this estimate will not be utilized by the RT engine to account for service loads that would impact the bi-directional generators SoC. This is because the IESO will collect telemetered SoC for each run of the RT engine, therefore this will avoid potentially double counting service load.~~
- Other daily dispatch parameters that have been submitted prior to any run of the RT engine~~,~~ and pass validations ~~in MIM,~~ must be applied.
- Telemetered SoC is used to manage the resource. The latest telemetered value prior to any run is used by the RT engine.
- The RT-MIO engine will use any mitigated offers for the impacted offers produced by the PD pre-process module.

Optimization Execution

- ~~Storage resources~~SMSRs that are economic in RT intervals will be dispatched regardless of their DAM or PD schedules ~~as it does not~~since the SMSRs don't have any commitments from DAM or PD.
- Initialization of the SoC - RT-MIO uses the telemetered SoC and will calculate the interval ending SoC for the interval prior based on the recent dispatch up to the ~~target~~study interval. This value will be used by the ~~target~~study interval to constrain energy and OR scheduled in the injection range to the MinSoC and to prevent withdrawals scheduled to exceed the MaxSoC.
- SoC calculations will be adjusted with MP submitted parameters to support ~~interval~~the study period and look ahead to interval calculations. This includes cycle efficiency and ramping impacts of the resource based on the submitted ramp rate as part of the dispatch data.

Constraints:

- Ramp constraints:
  - Energy and OR ramp rates can be limiting factors in the RT engine like other quick start resources.
  - The amount of 10 or 30 minute (injecting or withdrawing) OR cannot exceed the amount by which the resource can shift its withdrawal/output/withdrawal state through to output over 10 or 30 minutes, and OR ramp rate for its additional reserve schedule.
  - The RT engine can utilize branching the resource, such that the ~~tools it~~calculation engine will utilize both the withdrawal and injection capability of the resource for energy and OR. When withdrawing, the schedule will be limited by ramp for energy schedules like other quick start/dispatchable load resources. The branching OR mechanism indicates a positive swing (moving in the net positive direction, from negative withdrawal to the positive injection).
- Energy (no reserves schedule):
  - In any given five-minute interval, a ~~storage resource's~~SMSR's SoC should always be less than or equal to its maximum energy storage capacity and greater than its minimum energy storage capacity.
  - The SoC capability must ensure that the resource can feasibly provide energy for the interval when it is activated for injection or withdrawal. If the SoC available is 100 MWh, and the power capability is 200 MW, the resource is available to inject 200 MW for the interval. If the resource has a five MWh SoC, the resource would not be feasibly able to inject 200 MW for the interval, and therefore their injection will be limited to how much can be feasibly achieved for that five-minute interval considering the ramp rate of the resource to get up to that injection. For injection, this will be SoC availability up to the ~~Min SoC~~MinSoC, for withdrawal this is the difference between the ~~Max SoC~~MaxSoC and existing SoC.

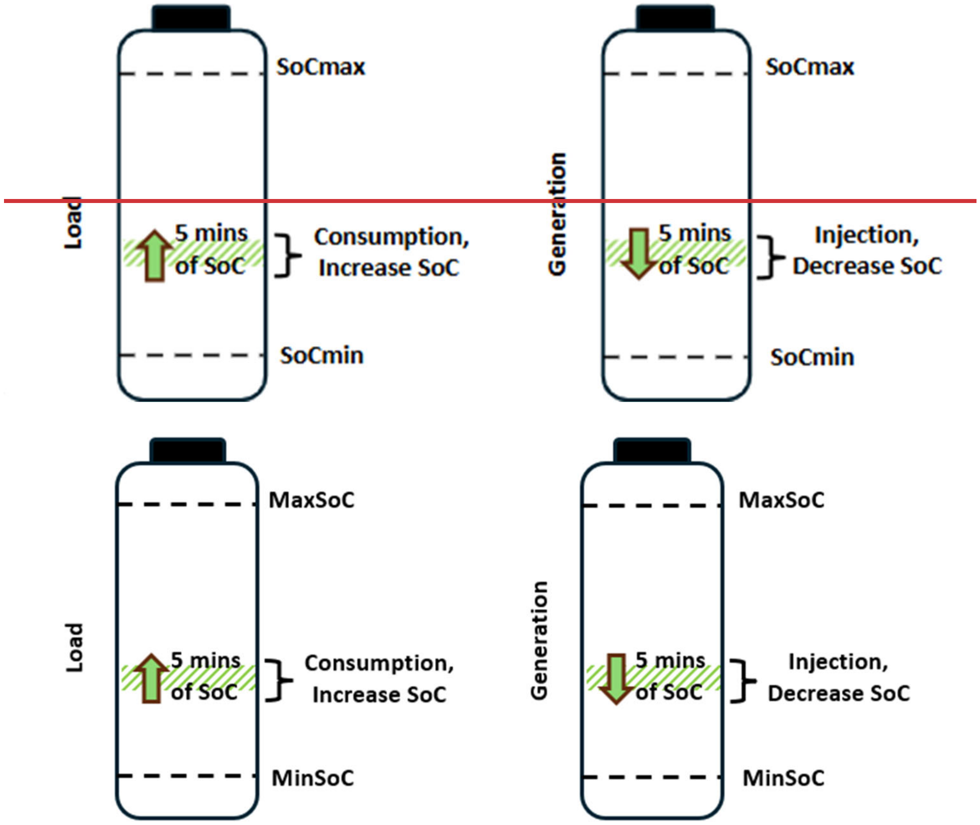

Figure 15: SoC requirement for Energy in RT

- Operating Reserve (no energy schedules):
    - Like DAM and PD, OR only activation can only be achieved by the injection capability of the ~~storage resource.~~SMSR. Therefore, to provide OR only, the resource must have a zero-energy dispatch. To achieve OR activation, it would require the resource to inject energy into the grid.
    - As there is no energy dispatch, the expectation is that a storage resource can have their OR schedule limited to a value to ensure 60 minutes of SoC availability (as in the case of DAM and PD timeframes) and this value cannot exceed the MinSoC.

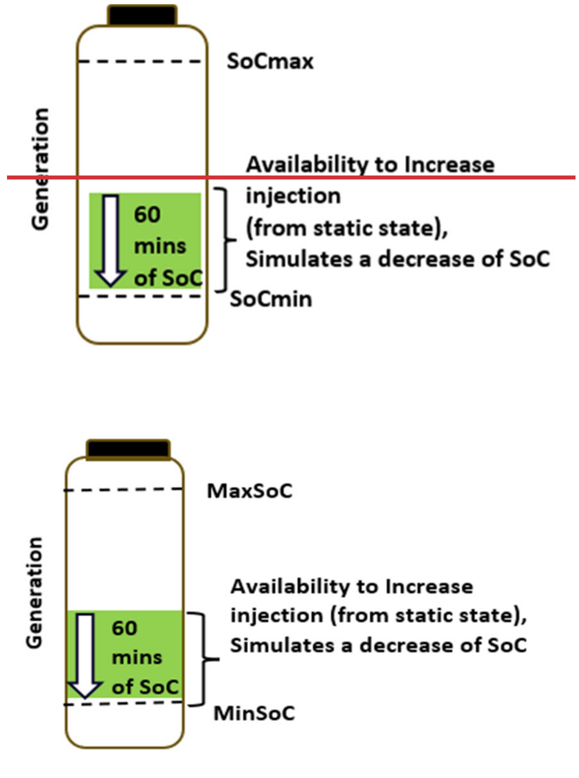

Figure 16: SoC Requirement for OR in RT

- Energy and Operating Reserve Schedules:
  - Withdrawal based energy and OR - to be dispatched for withdrawing energy, the calculation engine must ensure the resource's schedule can receive energy/can consume for a five-minute period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption, therefore, will not exceed what can be consumed over a five-minute interval, which is the same limit as energy withdrawal.
  - Injection based energy and OR – to be dispatched for injecting energy, ~~it~~the optimization must ensure that the resource's schedule is capable of injecting energy for five minutes, can maintain that output for 60 additional minutes (can be activated at end of interval), as well as have 60 more minutes of stored energy to ~~simulate~~provide an incremental increase in energy from an OR activation~~,~~, (OR schedules are incremental to energy and both must be maintained for 60 minutes if activated), in addition to not exceeding the ~~SoC Min~~MinSoC.
  - Withdrawal based energy and branching OR – to be scheduled to consume energy, the RT engine must ensure the resource's schedule can receive energy/can consume for a five-minute period without bypassing the MaxSoC of the resource. OR is provided by reducing consumption and then injecting (branching from withdrawal to injection), therefore, will not exceed what can be consumed over a five-minute period, which is the same limit as energy withdrawal, but must also have 60 minutes of injection capability without exceeding the MinSoC.

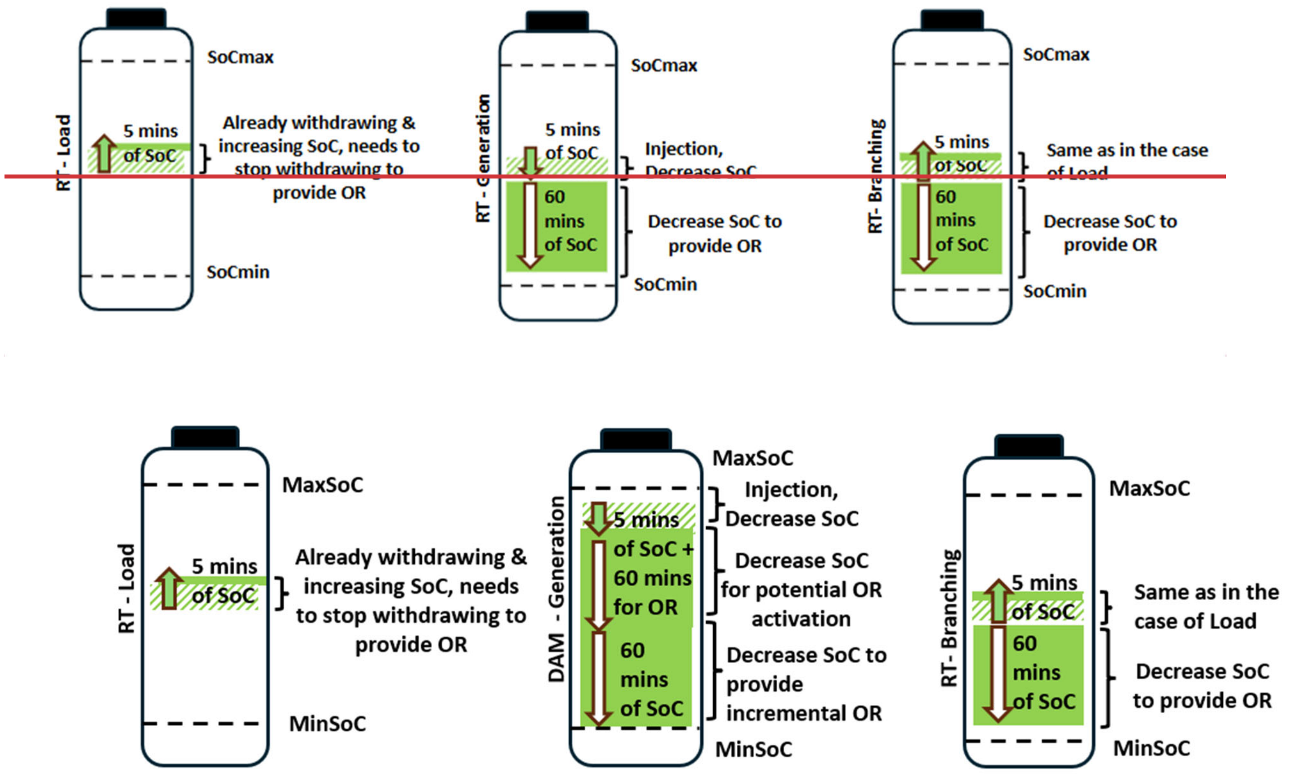

Figure 17: SoC requirement for Energy and OR in RT

Figure 15, Figure 16 and Figure 17 depict the SoC requirements in RT of a battery while providing energy only, OR only and co-optimized energy and OR, respectively.

Results

- The results include the RT dispatch (note, if there is no change to the schedule, no dispatch is sent but still considered an RT dispatch to hold at current output) and advisory schedules for the next 11 intervals.
- MWP and economic operating point (EOP) considerations are determined in the Settlements design module.

Day in the Life

This section illustrates how key features of the Optimization market design are intended to function together in the 'day in the life' of a battery storage market participantSMSR, commencing with DAM submission and concluding with Real-Time Market (RTM) execution. The examples here are intended to mimic various situations to demonstrate the outcomes of the design. These examples are for illustrative purposes only. The scenarios in this section may not occur and are being presented for educational and illustrative purposes to better demonstrate key concepts of the optimization design features.

For the examples, we are considering a resource with the characteristics listed in Table 7 below.

Table 7: Example Resource Characteristics

Parameter Name	Short Name	Unit	Parameter Value
Maximum Injection Rating	Pmax-	MW	200
Maximum Withdrawal Rating	Pmin-	MW	-200
Maximum State of Charge	MaxSoC	MWh	900
Minimum State of Charge	MinSoC	MWh	50
Cycle Efficiency	CE	% or decimal	0.9
Round-trip Efficiency	RTE	% or decimal	0.9
Initial State of Charge	Initial SoC	MWh	50
Internal Service Load	ISL	MW	3
Ramp Rate	Ramp Rate	MW/min	100
Cycling Daily Energy Limit	CycleDEL	MWh	700

Consider this MP submits the energy offer for all hours of the day listed in Table 8 below.

Table 8: Example of Energy Offer Laminations All Hours of Day

Example Energy offer with Nine laminations				
P/Q Pair	Price ($/MW)	Quantity (MW)	Price to Schedule ($/MW)	MP's Intended Action
Pair 1	-200	-200	-200 or less (more negative)	Charge 200 MW if price is -$200 or below
Pair 2	-100	-90	-199.99 to -100	Charge 90 MW if the price is between-$100 and -$199.99
Pair 3	0	-80	-99.99 to 0	Charge 80M W if the price is between -$99.99 and $0

Example Energy offer with Nine laminations				
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**	**Price to Schedule ($/MW)**	**MP's Intended Action**
Pair 4	25	-50	0.01 to 25	Charge 50 MW if the price is between $0.01 and $25
Pair 5	100	0	25.01 to 99.99	Do nothing if price is between $25.01 and $99.99
Pair 6	100	50	100 to 499.99	Inject 50 MW if price is between $100 and $499.99
Pair 7	500	100	500 to 599.99	Inject 100 MW if price is between $500 and $599.99
Pair 8	600	150	600 to 699.99	Inject 150 MW if price is between $600 and $699.99
Pair 9	700	200	700	Inject 200 MW if price is $700 or above

Table 9 below outlines the DAM prices to show how the various features will be utilized for scheduling purposes.

Table 9: Example of DAM Prices

Hour Ending (HE)	DAM LMP
HE1	$-10.00
HE2	$0.06
HE3	$-200.00
HE4	$-200.00
HE5	$-200.00
HE6	$5.00
HE7	$10.00
HE8	$15.00
HE9	$15.00
HE10	$30.00
HE11	$500.00

Hour Ending (HE)	DAM LMP
HE12	$500.00
HE13	$550.00
HE14	$550.00
HE15	$600.00
HE16	$650.00
HE17	$710.00
HE18	$~~100~~500.00
HE19	-$250.00
HE20	$500.00
HE21	$20.00
HE22	$10.00
HE23	$5.00
HE24	$5.00

DAM Scheduling

Based on the aforementioned offers and the posted DAM prices, this resource will receive the DAM Energy Schedule shown in Figure 18 below. Red values indicate a withdrawal while green values indicate an injection. Note how CycleDEL decreases throughout periods of injection. ~~Also note that in HE18 to 19 the MP has a reduction of 3 MW to account for the ISL.~~HE19s schedule impacts HE20's ~~available~~HE20's SoC. As a result, SoC shows that the ~~RTE and ISL have~~ CE has been ~~calculated~~applied, -200 MW is discounted by 0.~~9 (83~~95 (136 MW + 200 MW (0.~~9) – 3 MW = 260 MW).~~ 95) = 326 MW). Available SoC is then further discounted by the MinSoC for that hour of 100 which would result in 226 MWh.

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00

	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	-50.0	0.0	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
**STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0	734.0	776.0	818.0	860.0	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0	684.0	726.0	768.0	810.0	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Hour Ending	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00

	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
~~DAM OR SCHEDULE~~	~~200~~	~~200~~	~~100~~	~~50~~	~~50~~	~~50~~	~~0~~	~~0~~	~~0~~	~~0~~
**STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 500.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00	$ 1.00	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00

	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	0.0	0.0	0.0	100.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
**STATE OF CHARGE (SoC) (beginning of hour)	100.0	176.0	223.5	413.5	603.5	793.5	841.0	888.5	936.0	936.0	936.0	936.0	836.0	736.0	636.0	486.0	336.0	136.0	136.0	326.0
*AVAILABLE SoC (beginning of hour)	0.0	76.0	123.5	313.5	503.5	693.5	741.0	788.5	836.0	836.0	836.0	836.0	736.0	636.0	536.0	386.0	236.0	36.0	36.0	226.0

Hour Ending	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 500.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00

	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	100.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
**STATE OF CHARGE (SoC) (beginning of hour)	936.0	936.0	836.0	736.0	636.0	486.0	336.0	136.0	136.0	326.0
*AVAILABLE SoC (beginning of hour)	836.0	836.0	736.0	636.0	536.0	386.0	236.0	36.0	36.0	226.0

Figure 18: DAM Scheduling Example for Energy

The snapshot in Figure 19 below shows HE11 and HE12. Although the resource is economic and has adequate SoC in these hours for a 100 MW injection, the engine recognizes that there are greater economic opportunities in later hours and will preserve the SoC of the battery for those hours by only discharging in HE12.

Hour Ending	HE11	HE12
DAM LMP	$ 500.00	$ 500.00
	HE11	HE12
DAM ENERGY SCHEDULE	0.0	0.0
*STATE OF CHARGE (SoC) (beginning of hour)	857.0	854.0
*AVAILABLE SoC (beginning of hour)	807.0	804.0
Daily injection	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0

Hour Ending	HE11	HE12
DAM LMP	$ 500.00	$ 500.00
DAM OR LMP	$ 10.00	$ 15.00
	HE11	HE12
DAM ENERGY SCHEDULE	0.0	100.0
**STATE OF CHARGE (SoC) (beginning of hour)	936.0	936.0
*AVAILABLE SoC (beginning of hour)	836.0	836.0
Daily injection	0.0	100.0
CycleDEL Tracker (End of Hour)	800.0	700.0

Figure 19: Snapshot of HE11 and HE12 in DAM Scheduling Example (Energy)

Additionally, see HE18 in Figure 20 below. Although the resource is economic for a ~~50~~100 MW injection~~,~~ and has adequate SoC for a ~~29~~36 MW injection, the engine realizes that the CycleDEL for the day was fulfilled and will not schedule any more injections in the DAM. Note that though the resource withdraws 200 MW to charge in HE19, the CycleDEL does not increase as outlined in Figure 20 below, but it is reflected in the SoC in HE20.

	HE18
Hour Ending	HE18
DAM LMP	$ 100.00

	HE18
DAM ENERGY SCHEDULE	0.0
*STATE OF CHARGE (SoC) (beginning of hour)	136.0
*AVAILABLE SoC (beginning of hour)	86.0
Daily injection	700.0
CycleDEL Tracker (End of Hour)	0.0

Hour Ending	HE18	HE19	HE20
DAM LMP	$ 500.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 4.00	$ 4.00	$ 4.00

	HE18	HE19	HE20
DAM ENERGY SCHEDULE	0.0	-200.0	0.0
DAM OR SCHEDULE	0	50	0
**STATE OF CHARGE (SoC) (beginning of hour)	136.0	136.0	326.0
*AVAILABLE SoC (beginning of hour)	36.0	36.0	226.0
Daily injection	800.0	800.0	800.0
CycleDEL Tracker (End of Hour)	0.0	0.0	0.0

Figure 20: Snapshot of HE18 in DAM Scheduling Example (Energy)

The following examples will discuss the co-optimization of the resource. Table 10 below dictates the OR offer laminations submitted by the resource.

Table 10: Example of Operating Reserve Offer Laminations

Example OR offer with Five Laminations		
P/Q Pair	**Price ($/MW)**	**Quantity (MW)**
Pair 1	0.1	0
Pair 2	0.1	50
Pair 3	5	80
Pair 4	10	200
Pair 5	10.01	400

Energy and OR Co-optimization

When co-optimizing for OR, the engine looks at the OR offers submitted and schedules the resource based on their SoC and scheduled action for that hour. Based on the OR offers submitted above, co-optimized with our Energy offers, we receive the Energy and OR schedule in the DAM as shown in Figure 21 below.

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 100.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00	$ 1.00	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00
	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	-50.0	0.0	0.0	0.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
~~DAM OR SCHEDULE~~	~~50~~	~~116~~	~~50~~	~~50~~	~~400~~	~~250~~	~~50~~	~~50~~	~~50~~	~~200~~	~~200~~	~~200~~	~~100~~	~~50~~	~~50~~	~~50~~	~~0~~	~~0~~	~~0~~	~~0~~
*STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0	734.0	776.0	818.0	860.0	857.0	854.0	851.0	748.0	645.0	492.0	339.0	136.0	133.0	310.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0	684.0	726.0	768.0	810.0	807.0	804.0	801.0	698.0	595.0	442.0	289.0	86.0	83.0	260.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	200.0	350.0	500.0	700.0	700.0	700.0	700.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6	HE7	HE8	HE9	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00	$ 10.00	$ 15.00	$ 15.00	$ 30.00	$ 500.00	$ 500.00	$ 550.00	$ 550.00	$ 600.00	$ 650.00	$ 710.00	$ 500.00	-$ 250.00	$ 500.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00	$ 1.00	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 15.00	$ 15.00	$ 4.00	$ 15.00	$ 10.00	$ 10.00	$ 4.00	$ 4.00	$ 4.00
	HE01	HE02	HE03	HE04	HE05	HE06	HE07	HE08	HE09	HE10	HE11	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	HE20
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0	-50.0	-50.0	0.0	0.0	0.0	100.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
DAM OR SCHEDULE	50	126	50	50	400	250	50	50	50	200	200	100	100	50	50	50	0	0	50	0
**STATE OF CHARGE (SoC) (beginning of hour)	100.0	176.0	223.5	413.5	603.5	793.5	841.0	888.5	936.0	936.0	936.0	936.0	836.0	736.0	636.0	486.0	336.0	136.0	136.0	326.0
*AVAILABLE SoC (beginning of hour)	0.0	76.0	123.5	313.5	503.5	693.5	741.0	788.5	836.0	836.0	836.0	836.0	736.0	636.0	536.0	386.0	236.0	36.0	36.0	226.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	200.0	300.0	450.0	600.0	800.0	800.0	800.0	800.0
CycleDEL Tracker (End of Hour)	800.0	800.0	800.0	800.0	800.0	800.0	800.0	800.0	800.0	800.0	800.0	700.0	600.0	500.0	350.0	200.0	0.0	0.0	0.0	0.0

Figure 21: DAM Scheduling example for Energy and OR

Figure 22 below shows three examples of branching for OR.

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6
DAM LMP	-$ 10.00	$ 0.06	$ 200.00	-$ 200.00	-$ 200.00	$ 5.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00

	HE01	HE02	HE03	HE04	HE05	HE06
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0
~~DAM OR SCHEDULE~~	~~50~~	~~110~~	~~50~~	~~50~~	~~400~~	~~250~~
STATE OF CHARGE (SoC) (beginning of hour)	50.0	119.0	161.0	338.0	515.0	692.0
*AVAILABLE SoC (beginning of hour)	0.0	69.0	111.0	288.0	465.0	642.0
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0
CycleDEL Tracker (End of Hour)	700.0	700.0	700.0	700.0	700.0	700.0

Hour Ending	HE1	HE2	HE3	HE4	HE5	HE6
DAM LMP	-$ 10.00	-$ 0.06	-$ 200.00	-$ 200.00	-$ 200.00	$ 5.00
DAM OR LMP	$ 0.10	$ 15.00	$ 0.10	$ 0.10	$ 15.00	$ 15.00

	HE01	HE02	HE03	HE04	HE05	HE06
DAM ENERGY SCHEDULE	-80.0	-50.0	-200.0	-200.0	-200.0	-50.0
DAM OR SCHEDULE	50	126	50	50	400	250
**STATE OF CHARGE (SoC) (beginning of hour)	100.0	176.0	223.5	413.5	603.5	793.5
*AVAILABLE SoC (beginning of hour)	0.0	76.0	123.5	313.5	503.5	693.5
Daily injection	0.0	0.0	0.0	0.0	0.0	0.0
CycleDEL Tracker (End of Hour)	800.0	800.0	800.0	800.0	800.0	800.0

Figure 22: Example Snapshot of HE2, HE5 and HE6 in DAM Scheduling (Energy and OR)

In HE2 the resource is dispatched for a 50 MW withdrawal and their OR offer is eligible for branching. However, since the resource is only withdrawing 50 MW and only has 76 MWh available in the battery, the total branch from withdrawal to injection is 126 MW, which is what the resource can be scheduled for.

HE5 demonstrates a full branch from the resource. The resource is scheduled for a 200 MW withdrawal, with an economic OR offer for branching. The resource also has adequate SoC to inject 200 MW. Therefore, the resource can be scheduled for a full 400 MW of OR.

In HE6 the resource has adequate SoC for a 200 MW injection of OR but is only withdrawing 50 MW. The engine recognizes that the resource can branch for 250 MW of OR.

RT Dispatch

Consider the period (HE9 INT11 – HE11 INT5) in Figure 23 below.

~~DAM Schedule~~

DAM Schedule

Hour Ending	HE9	HE10	HE11
DAM LMP	$ 15.00	$ 30.00	$ 500.00
DAM OR LMP	$ 1.00	$ 10.00	$ 10.00
	~~HE09~~	~~HE10~~	~~HE11~~
DAM ENERGY SCHEDULE	-50.(	0.0	0.0
DAM OR SCHEDULE	50	200	200
*STATE OF CHARGE (SoC) (beginning of hour)	818.0	860.0	857.0
*AVAILABLE SoC (beginning of hour)	768.0	810.0	807.0

~~RT Snapshot~~

Hour Ending	HE9 INT11	INT12	HE10 INT1	INT2	INT3	INT4	INT5	INT6	INT7
RT LMP	$ 15.00	$ 15.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 500.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	-50.0	-50.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
OR SCHEDULE	50	50	200	200	200	200	200	200	100
**STATE OF CHARGE (SoC)	771.5	775.0	778.5	778.3	778.0	777.8	777.5	777.3	777.0
*AVAILABLE SoC (beginning of Interval)	721.5	725.0	728.5	728.3	728.0	727.8	727.5	727.3	727.0

Hour Ending	INT8	INT9	INT10	INT11	INT12	HE11 INT1	INT2	INT3	INT4	INT5
RT LMP	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00
RT OR LMP	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OR SCHEDULE	100	100	100	100	100	100	100	100	100	100
**STATE OF CHARGE (SoC)	768.4	759.8	751.3	742.7	734.1	725.5	716.9	708.3	699.8	691.2
*AVAILABLE SoC (beginning of Interval)	718.4	709.8	701.3	692.7	684.1	675.5	666.9	658.3	649.8	641.2

DAM Schedule

DAM Schedule

Hour Ending	HE9	HE10	HE11
DAM LMP	$ 15.00	$ 30.00	$ 500.00
DAM OR LMP	$ 1.00	$ 10.00	$ 10.00

	HE09	HE10	HE11
DAM ENERGY SCHEDULE	0.0	0.0	0.0
DAM OR SCHEDULE	50	200	200
**STATE OF CHARGE (SoC) (beginning of hour)	936.0	936.0	936.0
*AVAILABLE SoC (beginning of hour)	836.0	836.0	836.0

RT Snapshot

Hour Ending	HE9 INT11	INT12	HE10 INT1	INT2	INT3	INT4	INT5	INT6	INT7
RT LMP	$ 15.00	$ 15.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 30.00	$ 500.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
OR SCHEDULE	50	50	200	200	200	200	200	200	100
**STATE OF CHARGE (SoC)	936.0	936.0	936.0	936.0	936.0	936.0	936.0	936.0	936.0
*AVAILABLE SoC (beginning of Interval)	836.0	836.0	836.0	836.0	836.0	836.0	836.0	836.0	836.0

Hour Ending	INT8	INT9	INT10	INT11	INT12	HE11 INT1	INT2	INT3	INT4	INT5	INT6
RT LMP	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00	$ 500.00
RT OR LMP	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OR SCHEDULE	100	100	100	100	100	100	100	100	100	100	100
**STATE OF CHARGE (SoC)	927.7	919.3	911.0	902.7	894.3	886.0	877.7	869.3	861.0	852.7	844.3
*AVAILABLE SoC (beginning of Interval)	827.7	819.3	811.0	802.7	794.3	786.0	777.7	769.3	761.0	752.7	744.3

Figure 23: RT Example 1 for Energy and OR

Assume in this situation the resource has not updated their offers in the PD window, and the original energy offer is still being used. Though the resource was not scheduled to inject in HE10 and HE11 in the DAM, since storage resources are not committed, the RT engine does not respect this DAM schedule. In HE10 INT7 we see the price spike to $500, making the resource's offer economic. This will result in a dispatch being sent to the resource, triggering a 100 MW dispatch. Since the price stays elevated into HE11, the dispatch will remain at 100 MW.

~~DAM Schedule~~

DAM Schedule

Hour Ending	HE15	HE16	HE17
DAM LMP	$ 600.00	$ 650.00	$ 710.00
DAM OR LMP	$ 15.00	$ 10.00	$ 10.00
	HE15	HE16	HE17
DAM ENERGY SCHEDUL	150.0	150.0	200.0
DAM OR SCHEDULE	50	50	0
*STATE OF CHARGE (SoC) (beginning of hour	645.0	492.0	339.0
*AVAILABLE SoC (beginning of hour	595.0	442.0	289.0

~~RT Snapshot~~

Hour Ending	HE15 INT11	INT12	HE16 INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8
RT LMP	$ 600.00	$ 600.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDUL	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
OR SCHEDULE	50	50	50	50	50	50	50	50	50	50
**STATE OF CHARGE (SoC)	254.0	241.3	228.	215.8	203.0	190.3	177.5	164.8	152.0	139.3
*AVAILABLE SoC (beginning of Interval)	204.0	191.3	178.	165.8	153.0	140.3	127.5	114.8	102.0	89.3

Hour Ending	INT9	INT10	INT11	INT12	HE17 INT1	INT2	INT3	INT4	INT5
RT LMP	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00
RT OR LMP	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDUL	150.0	150.0	150.0	150.0	200	148.0	0.0	0.0	0.0
OR SCHEDULE	50	50	50	50	0	0	0	0	0
**STATE OF CHARGE (SoC)	126.5	113.8	101.0	88.3	75.5	58.6	46.0	45.8	45.5
*AVAILABLE SoC (beginning of Interval)	76.5	63.8	51.0	38.3	25.5	8.6	-4.0	-4.3	-4.5

DAM Schedule

DAM Schedule

Hour Ending	HE15	HE16	HE17
DAM LMP	$ 600.00	$ 650.00	$ 710.00
DAM OR LMP	$ 15.00	$ 10.00	$ 10.00

	HE15	HE16	HE17
DAM ENERGY SCHEDULE	150.0	150.0	200.0
DAM OR SCHEDULE	50	50	0
**STATE OF CHARGE (SoC) (beginning of hour)	636.0	486.0	336.0
*AVAILABLE SoC (beginning of hour)	536.0	386.0	236.0

RT Snapshot

Hour Ending	HE15 INT11	INT12	HE16 INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8
RT LMP	$ 600.00	$ 600.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 650.00
RT OR LMP	$ 1.00	$ 1.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
OR SCHEDULE	41.5	29.0	16.5	4.0	0	0	0	0	0	0
**STATE OF CHARGE (SoC)	304.0	291.5	279.0	266.5	254.0	241.5	229.0	216.5	204.0	191.5
*AVAILABLE SoC (beginning of Interval)	204.0	191.5	179.0	166.5	154.0	141.5	129.0	116.5	104.0	91.5

Hour Ending	INT9	INT10	INT11	INT12	HE17 INT1	INT2	INT3	INT4	INT5	INT6
RT LMP	$ 650.00	$ 650.00	$ 650.00	$ 650.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00	$ 710.00
RT OR LMP	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00	$ 10.00
ENERGY SCHEDULE	150.0	150.0	150.0	150.0	200.0	148.0	0.0	0.0	0.0	0.0
OR SCHEDULE	0	0	0	0	0	0	0	0	0	0
**STATE OF CHARGE (SoC)	179.0	166.5	154.0	141.5	129.0	112.3	100.0	100.0	100.0	100.0
*AVAILABLE SoC (beginning of Interval)	79.0	66.5	54.0	41.5	29.0	12.3	0.0	0.0	0.0	0.0

Figure 24: RT Example 2 for Energy and OR

Consider that the resource realized they did not update their offers but wanted to respect their DAM schedule. In the PD window, MPs updated their offers to make the resource uneconomic for all hours except those scheduled for in the DAM.

Looking above at Figure 24, in HE15 and HE16 the resource is dispatched to 150 MW for both DAM and RT, and it has sufficient SoC to meet these dispatches. However, note the SoC at the beginning of HE16 and compare it to what the SoC was expected to be per the DAM. The dispatch in HE10 and HE11 has negated the ability of the resource to inject after INT2 in HE17, so the resource has not received a dispatch for ~~that~~ the remainder of the RT hour even though the resource had a DAM position. This inability to inject will be settled at the RT price in the Settlement process.

The resource could have updated their offers to become economic to withdraw prior to HE15, so that the resource will have adequate SoC to discharge in later hours. This will be allowed since CycleDEL does not apply in RT.

Next Steps

The IESO has begun work on the Phase 1 Batch 2 design work which will support decision-making across numerous modules and elements. Future engagements will take place on topics related to the Batch 2 design modules that the IESO will require feedback on to continue forward with the design work.

Phase 1 Design Scope

The scope of design modules and elements for Phase 1 design is depicted in **Table 10**.

Table 10 - Scope of Design Modules and Elements

Batch #	Design Module	Design Element
1	Grid and Market Operations	Optimization (Energy & Operating Reserves)
2*	Grid and Market Operations	Dispatch data and other inputs
	Grid and Market Operations	Operations Integration
	Connection and Registration	Market Registration
		Connection Assessment and Approval
	Settlements	Market Settlement
	Contracts	Contract Impacts
	Market Power Mitigation (MPM)	Exante
		Expost
3	Hybrid	All modules

***The IESO will run all other design elements in parallel with an attempt to expedite delivery. Where possible, the IESO will attempt to consolidate design memos and multiple engagements moving forward.**

The outcomes of design Elements such as 'Dispatch data and other inputs', 'Market Registration' and 'Exante Mitigation' feed in to the 'Optimization' design element and have been explored, to an extent, due to their high correlation with 'Optimization' design.

'Optimization' Design Element Dependencies

Other Design Elements that the 'Optimization' Design Element is dependent on are:

Dispatch data and other inputs:

This refers to daily and hourly dispatch data submitted in DAM. As described through this document, the dispatch data may be updated after submission up till 10 minutes before real time dispatch. Basic decisions related to this design element (e.g. dispatch parameters unique to storage, energy/offer curves, ramp rates) were necessary for the 'Optimization' design element. Further enhancements or more specific requirements to this element will be investigated during Batch 2 design.

Market Registration:

i) Resource Registration: This refers to constant values recorded during registration of the facility and utilized by the engines for scheduling, dispatch, and settlement. This combines existing static registration data list required for dispatchable resources and new proposed static registration parameters only required for energy storage (as described in the 'Pre-Market' section).

ii) Telemetry: All facilities must comply with the applicable data monitoring requirements, which are listed in the IESO Market Rules (Chapter 0.4 Appendices, Section 4.24), and are used to monitor system conditions, resource response, and to support DSO calculations. Some of these parameters are not required by the optimization engines but may be required for operational purposes. The IESO will continue to consider further telemetering requirements that may be required as part of subsequent modules of design including other needs to support reliability of the grid.

iii) Commissioning: For commissioning purposes only, this new storage will participate as a self-scheduling storage resource. MPs will participate in the DAM by submitting self-schedules for each hour they intend to inject or consume; they may submit either an injection schedule or a withdrawal schedule for each hour. No SoC will be modelled or submitted by MPs during this commissioning period. MPs will pay or be paid LMP. This will still utilize the negative generator model that positive is indicative of injections and negative of withdrawals. This model will mimic the existing self-scheduling generator model.

Market Power Mitigation:

Initial decisions for ex-ante mitigation were described earlier as it occurs within some of the optimization timeframes. Like ex-ante design, non-decreasing price requirement of enhanced mitigated-for-conduct offers will be respected for settlement mitigation. Ex-post mitigation for physical withholding takes place after market clearing and settlement of a dispatch day to assess potential instances of physical withholding using reference quantities. This occurs outside of the optimization engine, and it is expected that minimal changes will be made to ex-post mitigation for storage for this phase of ERP, and existing requirements will be adapted to the single resource model. Ex-post and settlement mitigation will be further explored in Batch 2 of Phase 1 design along with scenario analysis that may challenge the initial decisions made for ex-ante mitigation.

Other Impacted Design Elements:

i) Connection Assessment and Approval – Modelling of the new storage model have a limited impact with the single-resource design feature. There will be no change to completed studies and assessments.

ii) Operations Integration – Forecasting is not considered for a load in the traditional sense; therefore, modifications are required.

iii) Market Settlement:

a. Settlement outcomes are managed through the Settlements process and tools, but Economic Operating Point (EOP) tool used to facilitate Make Whole Payments (MWPs) is designed to mimic the DSO.
b. EOP tool is not currently designed to consider resources with a single bid-offer curve.

Scenario analysis will be conducted to determine where storage resources should receive make-whole payments based on the new design. This may require MWP changes or additional optimization changes (if necessary).This example also illustrates diminishing OR schedules due to diminishing SoC. In the first four intervals, the amount of OR that this resource is scheduled for decreases, since a resource must be able to provide a full hour + 1 interval of OR to be scheduled. These OR values represent the actual amount of OR that the resource can be scheduled for in that interval.