

Enabling Resources Program: Storage and Hybrid Integration Project

Optimization Design Engagement

Memo 2.0

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Engagement Topic: Optimization Design Element for Storage Resources

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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
IAM	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
MP	Market 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
RTM	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:

- 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.

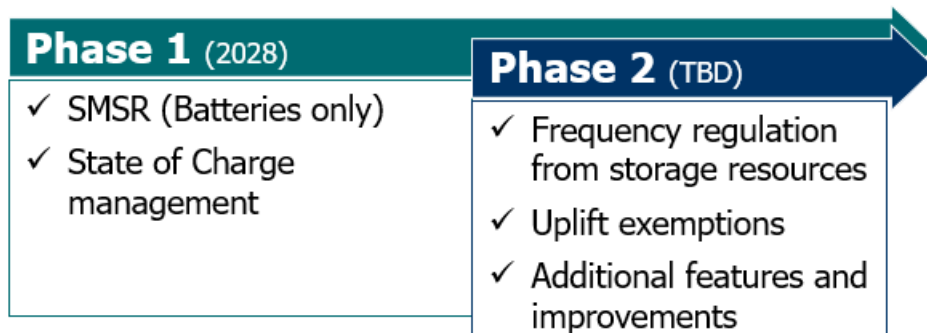


Figure 1: Project Scope

The IESO is targeting a 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.

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.

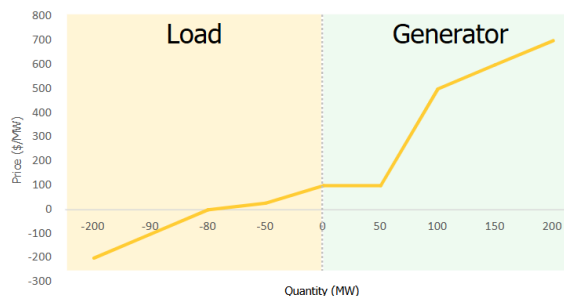
	Design Module	Design Element
Batch 1	Grid and Market Operations	• Optimization (Energy & Operating Reserve)
Batch 2	Connection and Registration	• Connection Assessment and Approval • Market Registration
	Grid and Market Operations	• Dispatch Data and Other Inputs • Operations Integration
	Market Power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

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 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

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 calculated or telemetered values.

Optimization Background

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 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.

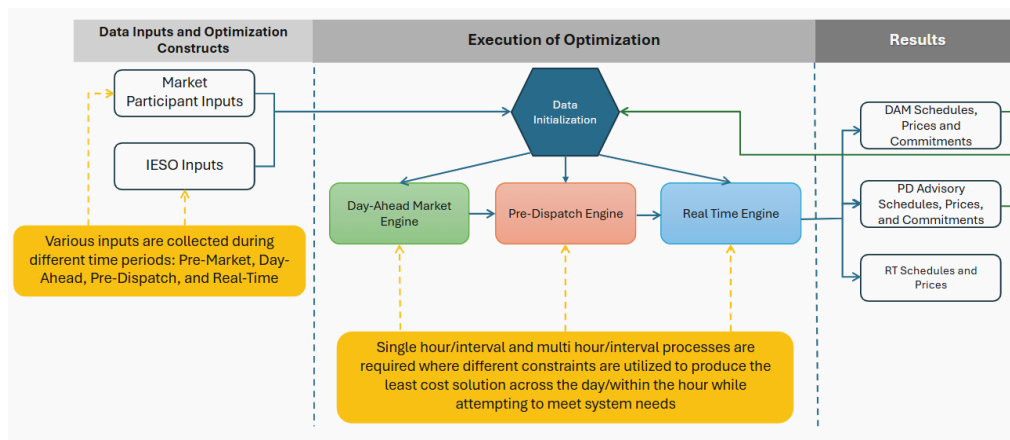


Figure 4: Optimization Process

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 value for the next dispatch day, or a telemetered value;
 - Min/Max SoC limits – Max and min that a battery resource may be scheduled or dispatched to;
 - Cycle 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.

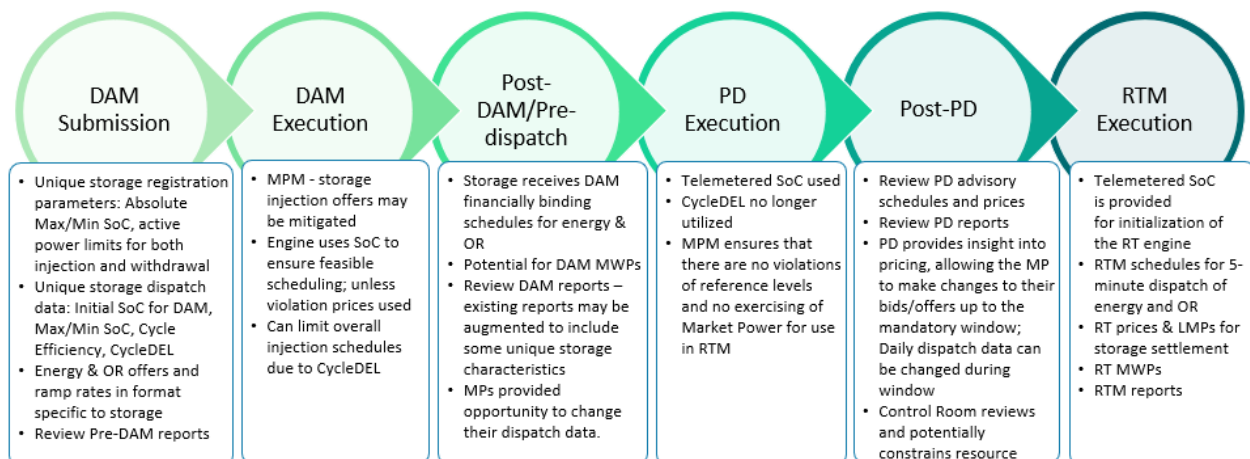


Figure 5: Storage-specific Optimization Process

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 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.
- **Commissioning of the new Model** – When commissioning the resource, the resource will utilize a 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 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 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 (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 Operating Reserve as dispatch data (note – MPs can use a combination of their max injection and max withdrawal limits for a lamination into OR, referred to as branching).
Maximum Negative Generator Resource Active Power Capability (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 Operating 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. Value will be used to validate MaxSoC submission.

Parameter	Unit	Timeframe	Definition
Absolute 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. Value will be used to validate MinSoC submission. Can be zero or another value as determined by the MP.
Minimum State of Charge (MinSoC)	MWh	Registration / Hourly Dispatch	The minimum energy amount that the electricity storage system can consistently be discharged beyond expected degradation from standard operation.
Maximum State of Charge (MaxSoC)	MWh	Registration / Hourly Dispatch	The maximum energy amount that the electricity storage system can be consistently charged beyond expected degradation from standard operation.
Cycle Efficiency ¹	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.
Bi-directional Resource Flag	Boolean (Yes/no)	Registration	Determines whether a resource has both a positive and negative dispatch range.

Data Monitoring/Telemetry Requirements

All facilities must comply with the applicable data monitoring requirements, which are listed in the IESO Market Rules (Chapter 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.

¹ 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.

Table 2: Data Telemetry Requirements

Attribute	Units of Measure	Description	Note
Active Power	MW	<p>1) MW (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility)</p> <p>2) MW (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility)</p> <p>3) MW telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.</p>	<p>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.</p>
Reactive Power	MVAR	<p>1) MVAR (withdrawn or injected) on the low side of each transformer (dependent on the number of resources in the facility)</p> <p>2) MVAR (withdrawn or injected) on the high side of each transformer (dependent on the number of resources in the facility)</p> <p>3) MVAR telemetry from each feeder. For electricity storage facilities that have been aggregated, the standard requirement shall be provided as an aggregated total.</p>	<p>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.</p>
State of Charge (SoC)	MWh	<p>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.</p>	<p>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</p>

Attribute	Units of Measure	Description	Note
			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 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 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 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 SMSR when the resource is expected to withdraw.

Resource Minimum and Maximum 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. 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.

Violation Pricing

The constraint violation² 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 optimization will apply to support the scheduling of the storage resource 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).

² 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 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.

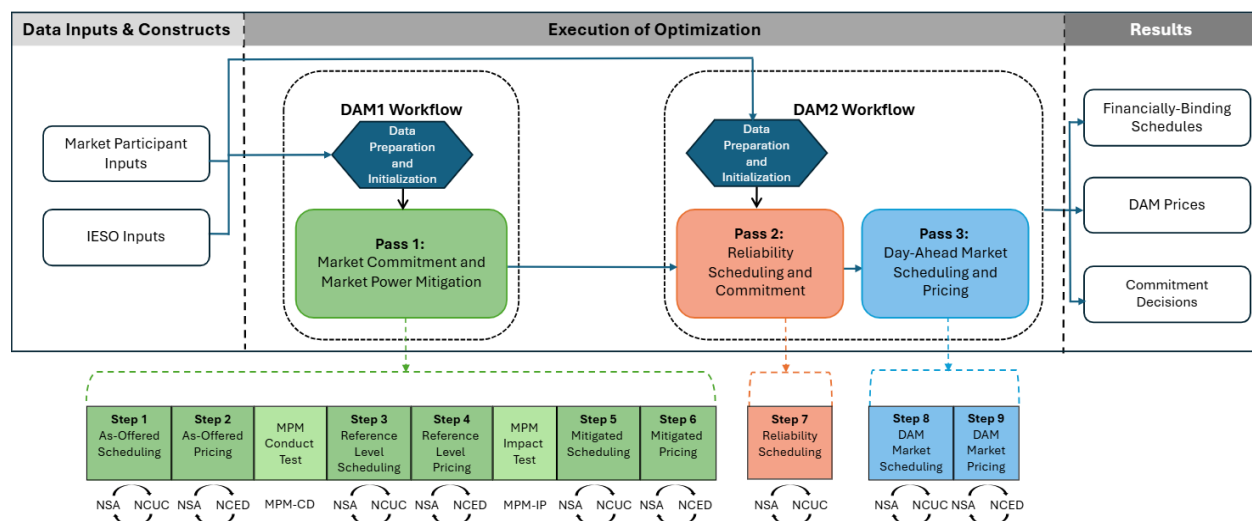


Figure 6: DAM Optimization Process

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 SMSR can submit, revise or remove hourly and daily dispatch data without restriction within this submission window. Offers can be standing offers.

Daily Dispatch Data Parameters

Table 3 below shows the daily dispatch parameters specific to the new SMSR. Some parameters may be repeated from the Registration Parameters section. Those registration parameters are used to validate the parameters in Table 3 below.

Table 3: New 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.	<ul style="list-style-type: none"> • Mandatory submission used by DAM only • Can have up to one decimal digit
Cycle Efficiency	Decimal value	A multiplier applied to withdrawals used to update the calculated SoC. Represents the combined injection	<ul style="list-style-type: none"> • Mandatory submission • Should be greater than zero and less

Attribute	Unit of Measure	Description	Note
		and withdrawal efficiencies.	<p>than or equal to one</p> <ul style="list-style-type: none"> • Can have up to two decimal digits • MPM validation
CycleDEL Cycling Daily Energy Limit	MWh (to one decimal place)	<p>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.</p> <p>To assist the MP to avoid over cycling their battery if deemed necessary to avoid degradation.</p>	<ul style="list-style-type: none"> • Optional submission used by DAM • Can have up to one decimal digit • In the absence of a submission, the default value will be 999999.9

- Initial State of Charge (ISoC):
 - Pass 1 and 3: MP submitted – This value denotes the estimated SoC in MWh of the battery resource at 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 MPs 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 in HE24.
- 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.

Hourly Dispatch Data Parameters

Table 4: New SMSR Hourly Dispatch Data Parameters

Attribute	Unit of Measure	Description	Note
MaxSoC Maximum State of Charge	MWh	The maximum energy amount to which the electricity	Mandatory submission. Can

Attribute	Unit of Measure	Description	Note
		storage system can be consistently charged without damage beyond expected degradation from normal use.	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.

Hourly Energy Dispatch Data Parameters:

- MaxSoC:
 - MPs can enter a MaxSoC up to its Absolute MaxSoC.
 - If submitting and utilizing higher than normal MaxSoC values which could limit the MP’s ability to comply with dispatch, MPs should contact the IESO³ 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 foldback⁴.
 - When submitting a lower MaxSoC up to a certain threshold (as described in the Dispatch Data and Other Inputs Design), appropriate reason codes must be 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 IESO⁵ 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.

³ 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.

⁴ 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.

⁵ 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.

- When submitting a higher MinSoC up to a certain threshold (as described in the Dispatch Data and Other Inputs Design), appropriate reason codes must be entered.
- Energy Offer:
 - 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 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 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

Example Energy offer with nine Laminations				
P/Q Pair	Price (\$/MW)	Quantity (MW)	Price to Schedule (\$/MW)	MW that could be scheduled
Pair 4	25	-50	0.01 to 25	Withdrawal 0.1 to 50
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 continue to utilize a 100 MW/min ramp rate at the facility level. The ramp restriction the IESO will be imposing applies to both injection and withdrawal when facilities are scheduled for energy. This means that if a facility has multiple resources, their combined ramp rate should total no 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 two positive breakpoints, two ramp up and two ramp down rates that are equal to or below 100 MW/min. The IESO will utilize the two positive breakpoints, duplicate and assign a negative value to interpret as the negative breakpoints for the resource.

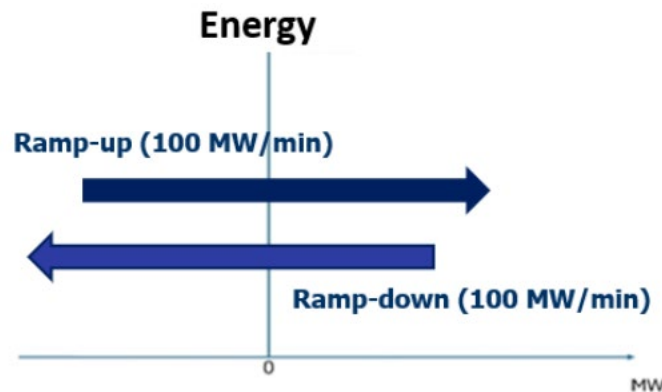


Figure 7: Energy Ramp Rates Design

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.
 - SMSRs can 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
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. If activated for OR, within the permitted time (i.e., 10 or 30 min), the resource would stop their consumption and 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 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 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.

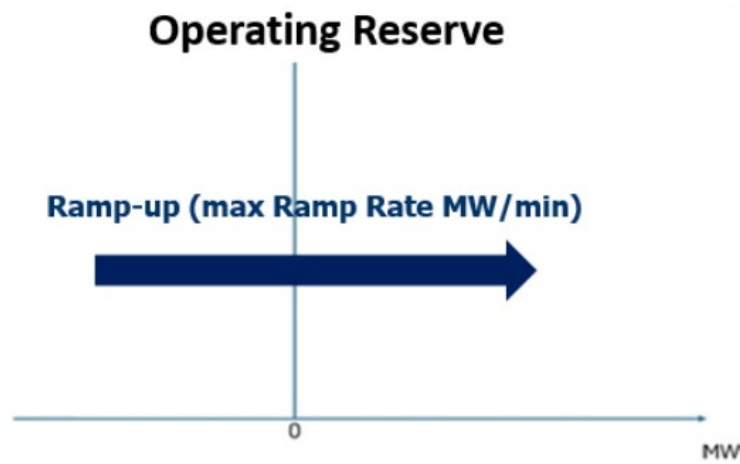


Figure 8: Operating Reserve Ramp Rate Design

- 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 SMSR. 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 SMSR 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 number) 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 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 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:
 - 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.
 - 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.

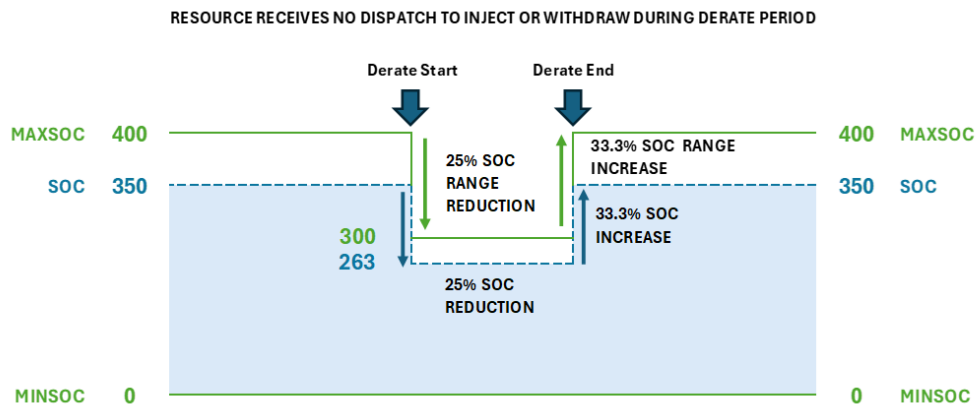


Figure 9: SoC Scaling Example

- New SoC Estimate_h: $((\text{Actual SoC}_{h-1} - \text{MinSoC}_{h-1}) / (\text{MaxSoC}_{h-1} - \text{MinSoC}_{h-1})) \times (\text{MaxSoC}_h - \text{MinSoC}_h) + \text{MinSoC}_h$
- 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.
- $((350 \text{ MWh} - 0 \text{ MWh}) / (400 \text{ MWh} - 0 \text{ MWh})) \times ((300 \text{ MWh} - 0 \text{ MWh})) + 0 \text{ MWh} = (0.875 \times 300 \text{ MWh}) + 0 \text{ MWh} = 262.5 \text{ MWh}$.

- Additional SoC Considerations⁶:
 - Energy (no reserves scheduled)
 - In any given hour, a 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.

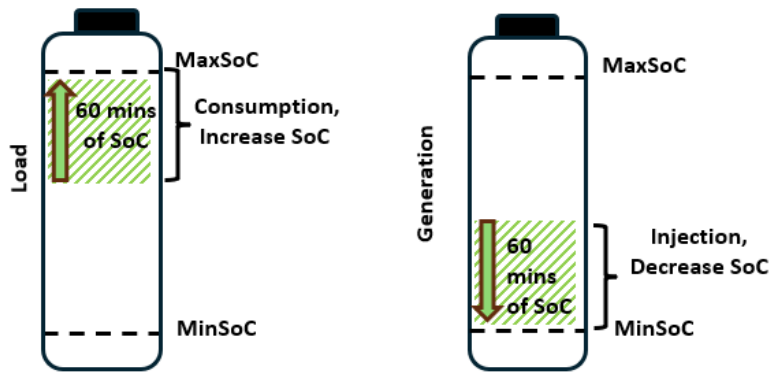


Figure 10: SoC requirement for Energy in DAM

- 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.

⁶ 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.

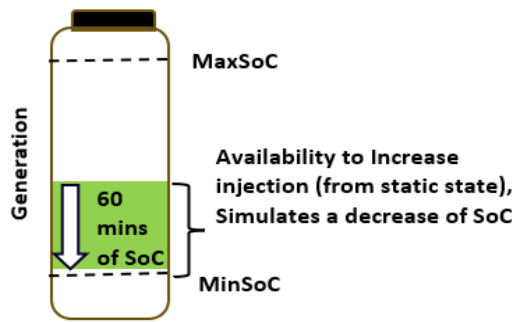


Figure 11: SoC requirement for OR in DAM

- 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 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 swinging to injecting (branching from withdrawal to injection). 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.

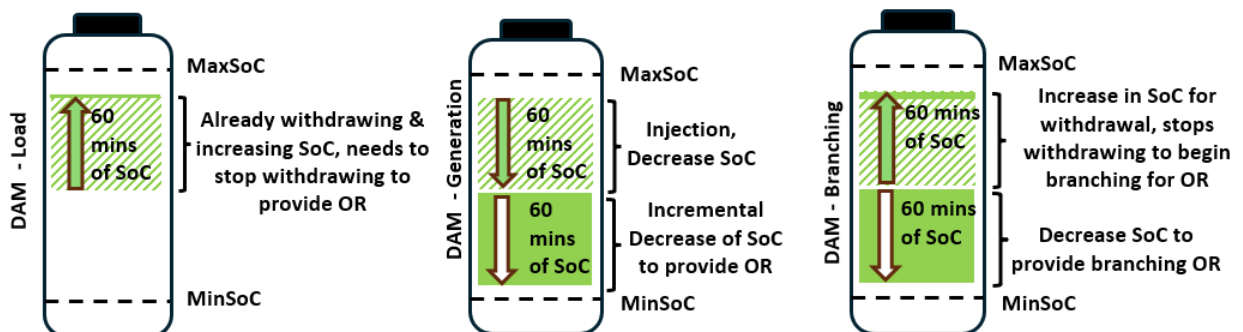


Figure 12: SoC requirement for Energy and OR in DAM

- 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 the SMSR is being modeled as a quick start generator, SMSRs will not receive commitments.
- Price setting eligibility:
 - SMSRs with a binding CycleDEL, will have their price-setting eligibility requirements treated the same as other energy 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 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.

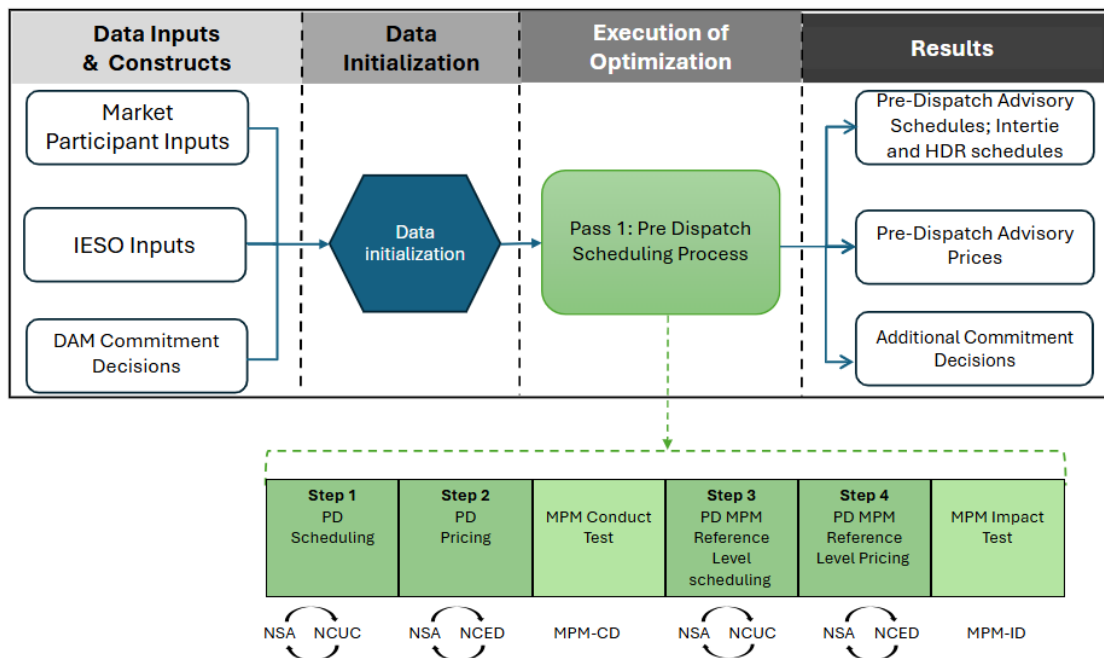


Figure 13: Pre-Dispatch Optimization Process

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):
 - Will 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.
- 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. PD-INI passes this telemetered value to the PD engine. PD-INI also takes schedules based on the average of the RT-MIO advisory schedules to either add or subtract from the SoC in the PD engine. This process also considers cycle efficiency if adding to the SoC.

Results

- Like most other resources, SMSRs will receive advisory schedules and forecasted LMPs.
- The SMSR is being modeled as a quick start generator, therefore, it will not receive commitments from PD decisions. However, the IESO 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.

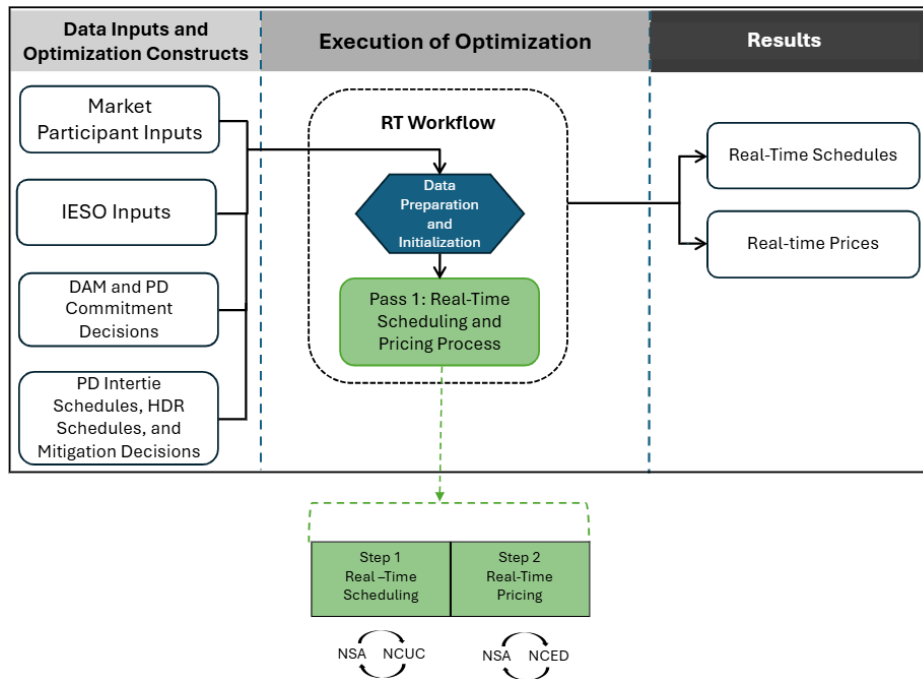


Figure 14: Real-Time Optimization Process

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 SMSR MP's perspective, RT requires that 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.
- Other daily dispatch parameters that have been submitted prior to any run of the RT engine and pass validations 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

- SMSRs that are economic in RT intervals will be dispatched regardless of their DAM or PD schedules 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 study interval. This value will be used by the 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 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 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 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 MinSoC, for withdrawal this is the difference between the MaxSoC and existing SoC.

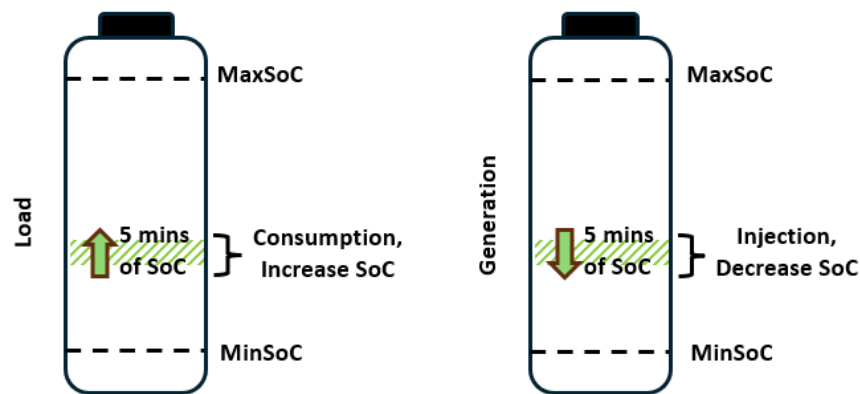


Figure 15: SoC requirement for Energy in RT

- Operating Reserve (no energy schedules):
 - Like DAM and PD, OR only activation can only be achieved by the injection capability of the 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.

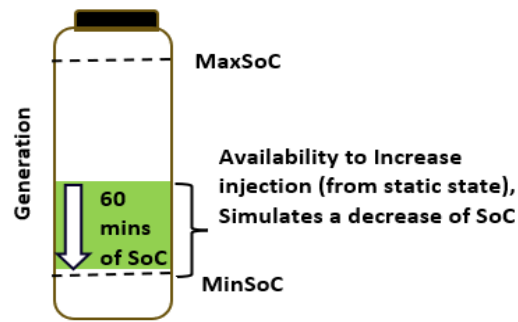


Figure 16: SoC Requirement for OR in RT

- 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, 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 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 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.

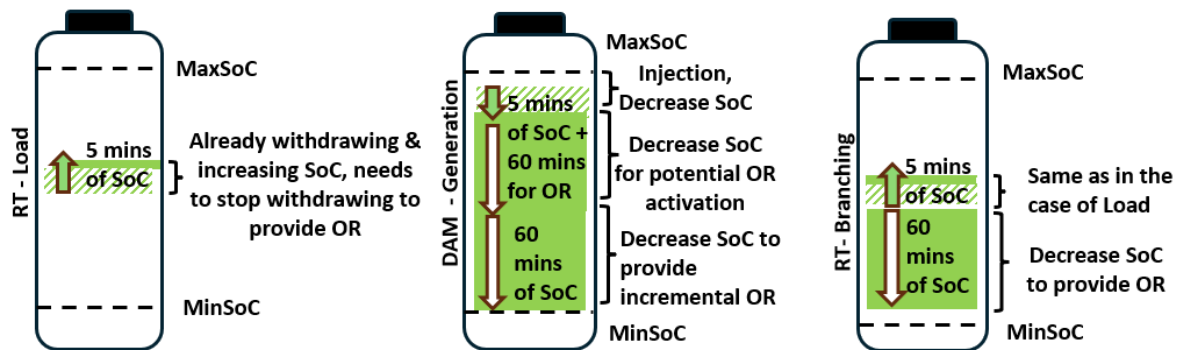


Figure 17: SoC requirement for Energy and OR in RT

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 SMSR, 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	-	MW	200
Maximum Withdrawal Rating	-	MW	-200
Maximum State of Charge	MaxSoC	MWh	900
Minimum State of Charge	MinSoC	MWh	50
Cycle Efficiency	CE	% or decimal	0.9
Initial State of Charge	Initial SoC	MWh	50
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 90M W 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
Pair 4	25	-50	0.01 to 25	Charge 50 MW if the price is between \$0.01 and \$25

Example Energy offer with Nine laminations				
P/Q Pair	Price (\$/MW)	Quantity (MW)	Price to Schedule (\$/MW)	MP's Intended Action
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
HE12	\$500.00
HE13	\$550.00

Hour Ending (HE)	DAM LMP
HE14	\$550.00
HE15	\$600.00
HE16	\$650.00
HE17	\$710.00
HE18	\$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. HE19s schedule impacts HE20's HE20's SoC. As a result, SoC shows that the CE has been applied, -200 MW is discounted by 0.95 (136 MW + 200 MW (0.95) = 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	\$ 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	-80.0	-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

DAM ENERGY SCHEDULE	0.0	100.0	100.0	100.0	150.0	150.0	200.0	0.0	-200.0	0.0
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**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
DAM OR LMP	\$ 10.00	\$ 15.00

DAM ENERGY SCHEDULE	0.0	100.0
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**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 100 MW injection and has adequate SoC for a 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.

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

Example OR offer with Five Laminations		
P/Q Pair	Price (\$/MW)	Quantity (MW)
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	\$ 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
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	125	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	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.

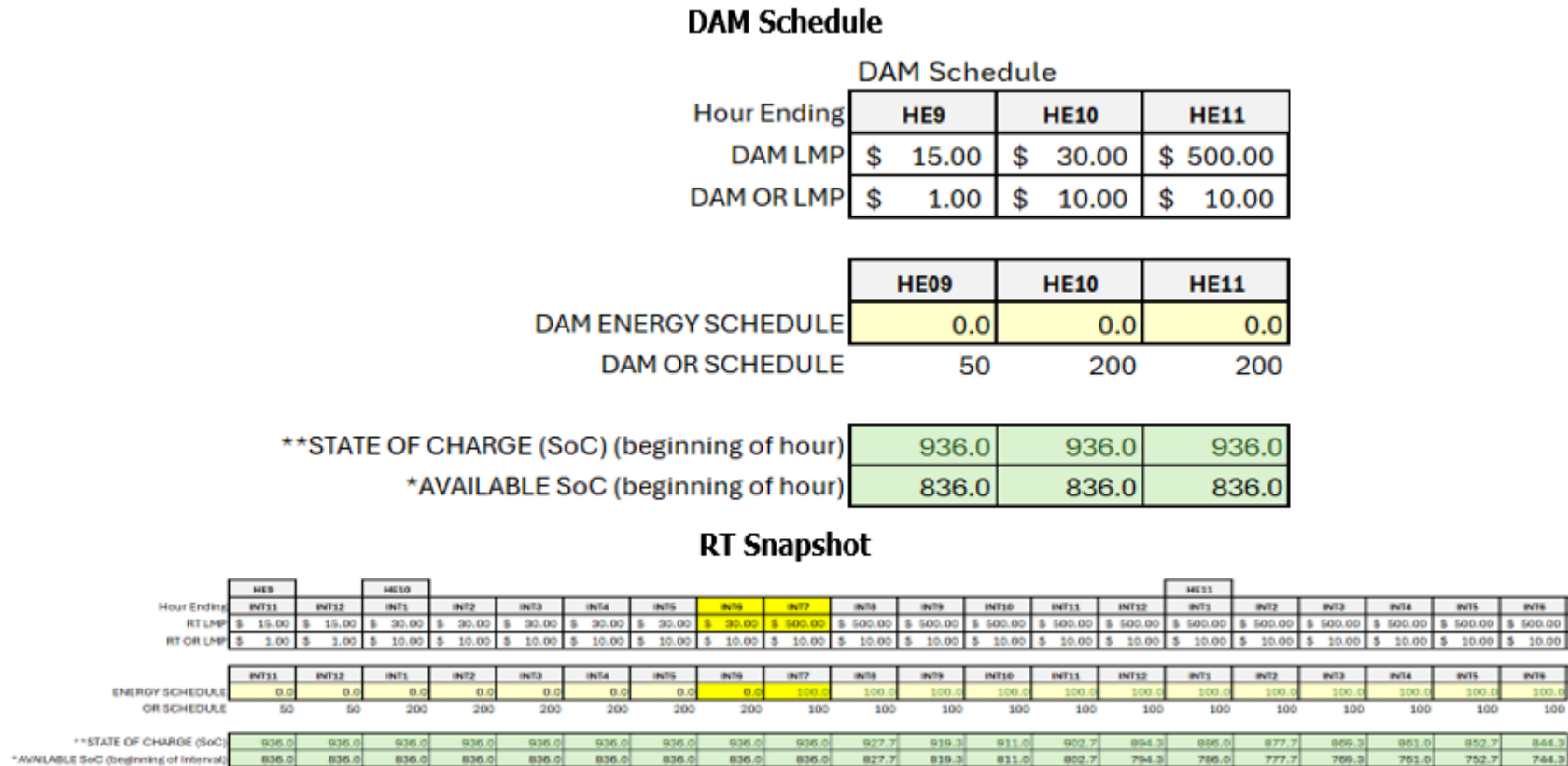


Figure 23: RT Example 1 for Energy and OR

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

DAM ENERGY SCHEDULE			
	HE15	HE16	HE17
DAM OR SCHEDULE	150.0	150.0	200.0
	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

	HE15		HE16														HE17			
Hour Ending	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8	INT9	INT10	INT11	INT12	INT1	INT2	INT3	INT4	INT5	INT6
RT LMP	\$ 600.00	\$ 600.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 650.00	\$ 710.00	\$ 710.00	\$ 710.00	\$ 710.00	\$ 710.00	\$ 710.00
RT OR LMP	\$ 1.00	\$ 1.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 10.00	\$ 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	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	200.0	148.0	0.0	0.0	0.0	0.0
OR SCHEDULE	41.5	29.0	16.5	4.0	0	0	0	0	0	0	0	0	0	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	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)	204.0	191.5	179.0	166.5	154.0	141.5	129.0	116.5	104.0	91.5	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 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.

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.