May 20, 2020

Storage Design Project (SDP): Long-term Design Proposals

Energy Storage Advisory Group

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Overview and Purpose

The primary purpose of this presentation is to lead a discussion of the long-term design proposals for the IESO's Storage Design Project (SDP).

Agenda

1. Project recap and next steps
2. Stakeholder feedback from March EPRI/ESAG presentation
3. The “Long-Term Period”
4. Long-Term design: SoC management
5. Long-Term design: other aspects of the design proposal
   - Market and Facility Registration
   - Offer Curve
   - Price Setting
   - Regulation Service
6. Request for stakeholder feedback

Project Recap and Next Steps

Storage Design Project (SDP) Scope

The SDP will:

1. Clarify how energy storage resources can participate in today's IESO Administered Markets (the **interim period**), and

2. **Today's focus:** Provide a vision for how storage resources will participate in the IESO Administered Markets on an enduring basis once investment in IESO tool upgrades to fully integrate storage resources are made (the long-term period)

Storage Design Project (SDP) Scope (cont'd)

3. The SDP is an important step towards ensuring energy storage can fully compete to reliably and efficiently provide needed system services

Project Scope and Deliverables

1. Design Considerations

- Answer key questions about how IESO will treat storage in IESO Administered Markets (IAMs)
- Reflect different timeframes (e.g. greater detail for interim period and a higher-level-vision for the long-term)

2. Market Rules and Manuals

- Draft, and invite stakeholder feedback on, market rule/manual language required to implement interim measures
- Produce inventory and description of future market rules/manual changes required to implement long-term design questions addressed in the project

Project Scope and Deliverables (cont'd)

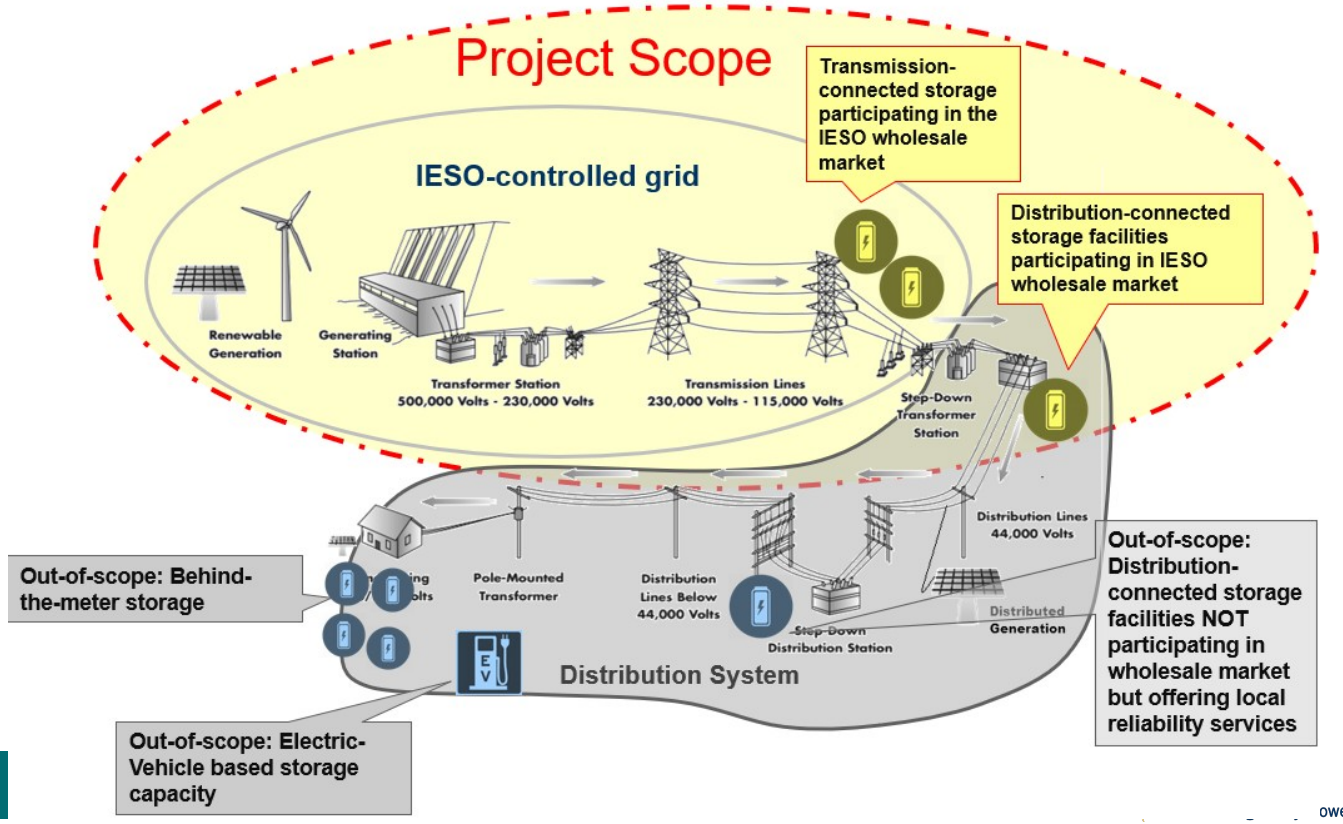
3. Inventory of IESO Tool/Process Changes

- Develop list of tools/processes that will require updating to enable design questions addressed in the project

4. Schedule for Market Updates

- Develop schedule to roll out changes that reflects dependencies on/timing of other initiatives

Energy Storage Design Project – Scope of Facilities Involved



Making Design Decisions

Adhere to Market Renewal Program principles

- Efficiency, competition, implementability, certainty, and transparency

And reflect design considerations discussed with ESAG

- Through this project we will seek design solutions that contribute to reliability, efficiency, and competition at the bulk level
- We will build on the practical experiences of other jurisdictions that are integrating energy storage resources into wholesale markets

Making Design Decisions (cont'd)

- We will seek to maximize the chances of timely implementation by:
  - Leveraging the capabilities of existing or planned software tools
  - Reducing design complexity wherever possible
  - Avoiding design by exception – i.e. ensure that we have a single framework that can be applied to the widest possible range of storage technologies

Next Steps

- Today – High-level proposals for most long-term design questions
  - Continuing to develop proposal for allocation of uplift charges
- Stakeholder feedback on today's proposals is due June 10
- June engagement days (June 24-26) – draft rule and manual changes for interim design
- July/August – complete set of long-term design proposals
- IESO is continuing to consider the timing for implementing the enduring vision for storage participation
  - IESO will share information at an upcoming SDP meeting as soon as it is available

Stakeholder Feedback

March ESAG Webinar

- At the March 26 ESAG webinar the Electric Power Research Institute (EPRI) provided an overview of storage integration efforts in the US
- A key focus area for the webinar was how US jurisdictions are approaching state-of-charge management
- The IESO asked for stakeholder input on what approach to state-of-charge (SoC) management they support and why

March ESAG Webinar (cont'd)

- The IESO also shared two key positions that would inform its proposal for SoC Management
  - Modelling the unique operating constraints of resource types may be appropriate when doing so supports system **reliability** and market **efficiency**
  - The IESO, through its tools and processes, will optimize schedules and dispatch instructions for all resources based on **competitive** bids and offers into the market

Stakeholder Feedback on SoC Management

- As of April 28, the IESO had received 7 feedback submissions
  - Submissions are published on the ESAG webpage
- Submissions provided support for a range of SoC management options and also outlined rationale for stated preferences
  - Submissions supported self-scheduling, self-managed, and optionality between ISO-managed/self-managed SoC

Stakeholder Feedback on SoC Management (cont'd)

- Some key themes in SoC Management feedback included:
  - A desire to ensure that storage participants can manage their own operations through their offers
  - A desire to include state-of-charge in the IESO's tools in order to drive feasible and efficient schedules and dispatch instructions

IESO Proposal for SoC Management

- In today's presentation the IESO will outline its proposal for a "SoC Lite" framework
- The IESO believes that SoC Lite provides an effective and implementable path forward that:
  - Enables storage resources to manage their own operations
  - Results in feasible schedules and dispatch instructions
  - Is based on market participant offers, which is essential for fair competition
  - Helps to drive efficient market outcomes

Other Stakeholder Feedback Themes

Noted in 2 or more responses

- Offer Curve - The long-term solution should model storage resources as a single resource (from maximum withdrawal to maximum injection)
  - Reflected in today's proposals
- Uplift - Propose storage resources should not be subject to uplift if they are providing grid services and that OEB should also review application of network charges for storage resources
  - To be discussed at a future SDP meeting

Other Stakeholder Feedback Themes (cont'd ..)

Noted in 2 or more responses

- Schedule – Expressed a desire for enduring storage design to be implemented within MRP
  - To be discussed at a future SDP meeting

The “Long-Term” Period

Other Stakeholder Feedback Themes (cont'd …)

The "Interim Period"

- **Stage 1:** Interim framework to clarify storage participation in today's IESO-administered markets
  - **Related project:** Capacity Auction

Today's focus on the next slide.

Other Stakeholder Feedback Themes (cont'd ….)

Today's Focus. Long-Term design changes.

- **Stage 2:** Changes to allow energy storage resources to provide regulation service, energy and operating reserve
    - **Related project:** SCADA EMS Upgrade (nominally targeting Q1 2022), plus additional requisite system changes to effect the use of the energy storage for regulation service
- **Stage 3:** Enduring participation model for energy storage resources enabling more efficient scheduling of energy and operating reserve
    - **Related projects:** future Dispatch Scheduling and Optimization (DSO) tool changes and Replacement Settlement Systems

The “Long-Term Period”:

- Scope:
  - Will replace most of the Interim Design Features set out in the SDP Interim Design Document
  - Commences no earlier than the implementation of the Market Renewal Program Energy Stream framework
  - Encompasses the enduring framework for energy storage integration in the IESO administered markets

The "Long-Term Period" (cont'd):

- Includes the implementation of IESO system components to:
  - Afford dispatchable electricity storage facilities the same opportunities to participate in wholesale market products as dispatchable generators
  - Afford self-scheduling storage facilities the same opportunities to participate in wholesale market products as dispatchable generators
  - Automate state of charge management for dispatchable electricity storage facilities
  - Improve the use of energy storage facilities providing regulation service

Design Issues for the Long-Term Period, as originally presented at October 28th, 2019 ESAG meeting

Design element	Design questions
Market and facility registration	How should an energy storage facility be registered into the IAMs?
Day-ahead market (DAM) bidding and scheduling of energy storage resources (ESRs)	Who should optimize state of charge (SoC) of ESRs in the DAM: the ESR, system operator, or give ESRs the choice?
SOC management in real-time (RT) energy market	Who should optimize SOC of ESRs in the RT energy market: the ESR, the system operator; or give ESRs the choice? Should SOC be included in Multi-Interval Optimization?

Design Issues for the Long-Term Period, as originally presented at October 28th, 2019 ESAG meeting (cont'd)

Design element	Design questions
RT energy and operating reserve markets: bidding and scheduling of ESRs	What offer curve shape (e.g., continuous/discontinuous) should ESRs be allowed to use to offer into the energy and operating reserve markets?
Ability of ESRs to set market-clearing price in the energy and operating reserve markets	Should ESRs be able to set the market-clearing price?
Regulation service	What are the rules for what proportion of an ESR's total capacity gets used for regulation, energy and operating reserve – both at different times and simultaneously?
Settlement and charges	How will uplift charges stipulated by the IESO Market Rules be applied to energy storage resources?

Long-Term design: SoC management decision

Recall: Combinations of Accessible Wholesale Product Participation for Storage Today

	Real-time Energy	**Operating Reserve**	**Regulation Service**	**Reactive Support and Voltage Control**	**Demand Response (to be replaced with Capacity Auction)**
Real-time Energy	Yes – but with efficiency losses	Yes – but with restrictions and efficiency loss	No	Yes – but with efficiency losses	No
Operating Reserve	Yes – but with restrictions and efficiency loss	Yes – but with restrictions and efficiency loss	No	Yes – but with restrictions and efficiency loss	No
Regulation Service	No	No	Yes – but with efficiency losses	Yes – but with efficiency losses	No
Reactive Support and Voltage Control	Yes – but with efficiency losses	Yes – but with restrictions and efficiency loss	Yes – but with efficiency losses	Yes	No
Demand Response	No	No	No	No	Yes - rules for storage to be clarified in Capacity Auction Design

Recall: Combinations of Accessible Wholesale Product Participation for Storage Today (cont'd)

- The previous slide is a matrix that depicts the combinations of wholesale market products that an ESR can participate in today. In many cases, registration to participate in a given wholesale market service product is mutually exclusive to providing another service (e.g. regulation service precludes participation in the energy and operating reserve markets). In other cases, although participation may be allowable, it may be less than optimal for both the facility operator and the market as a whole.

Target Market Access for Storage During the Long-Term Period

	Real-time Energy	Operating Reserve	Regulation Service	Reactive Support and Voltage Control	Capacity Auction
Real-time Energy	Yes	Yes	Yes	Yes	Yes
Operating Reserve	Yes	Yes	Yes ‡	Yes	Yes
Regulation Service	Yes	Yes ‡	Yes	Yes	Yes, subject to Capacity Market obligations
Reactive Support and Voltage Control	Yes	Yes	Yes	Yes	Yes
Capacity Auction	Yes	Yes	Yes, subject to Capacity Market obligations	Yes	Yes

Target Market Access for Storage During the Long-Term Period (cont'd)

- The implementation of the proposals in this presentation will afford storage facilities the opportunity to compete in all wholesale market product categories on the same footing as other dispatchable facilities.

Note: all types of dispatchable facilities providing regulation and operating reserve may face further restrictions against providing such products simultaneously at a given moment of time.

Recall: The EPRI SoC Design Spectrum

	Strong ISO Intervention in storage operations	←	→	Little or no ISO intervention in storage operations
EPRI Type	**EPRI "ISO-SOC-Management"**	**EPRI "SOC-Management-Lite"**	**EPRI "Self-SOC Management"**	**EPRI "Self-Schedule" option**
Philosophy	The system operator has more information than any individual market participant and should therefore manage all aspects of optimizing and scheduling energy storage	Let energy storage facilities react to immediate price changes – and ensure any SOC constraints are accounted for within the DSO Allow market participants to submit modified bid/offer data reflective of storage resource capabilities and/or other data to reflect SOC limitations	Let energy storage facilities react to immediate price changes – and ensure any SOC constraints are indirectly accounted for within the DSO via bid/offer changes. Allow market participants to submit modified bid/offer data in order to signal SOC limits. *{analogous to current treatment of dispatchable storage in IESO Interim Design)*	Let energy storage facilities react to immediate price changes whenever and wherever possible – and don't worry if SOC constraints can be directly seen by the DSO *{analogous to current treatment of self-scheduling storage in IESO Interim Design)*

Background: The General Trade-off Across the SoC Management Design Spectrum

EPRI "ISO-SoC-Management"	EPRI "SoC-Management-Lite"	EPRI "Self-SoC Management"	EPRI "Self-Schedule" option

Benefits of "ISO-SoC Management"

- Optimized over the system-wide informational picture seen by the system operator (i.e. seeks optimal outcome for the entire market)
- Feasible dispatch assured by IESO's dispatch engine

Drawbacks of "ISO-SoC-Management"

- Limited by the system operator's view of the storage assets and out-of-market uses for such facilities
- Potential sub-optimal use of individual storage facilities when accounting for out-of-market profit considerations

Background: The General Trade-off Across the SoC Management Design Spectrum (cont'd)

EPRI "ISO-SoC-Management"	EPRI "SoC-Management-Lite"	EPRI "Self-SoC Management"	EPRI "Self-Schedule" option

Benefits of "Self-Schedule" option

- Optimized over the complete informational picture seen by storage participant – including aspects not seen by the system operator

Drawbacks of "Self-Schedule" option

- No guarantee of feasible dispatch
- Potential sub-optimal outcome for system as a whole

Recall: The General Trade-off Across the SoC Management Design Spectrum

EPRI "ISO-SoC-Management"	EPRI "SoC-Management-Lite"	EPRI "Self-SoC Management"	EPRI "Self-Schedule" option

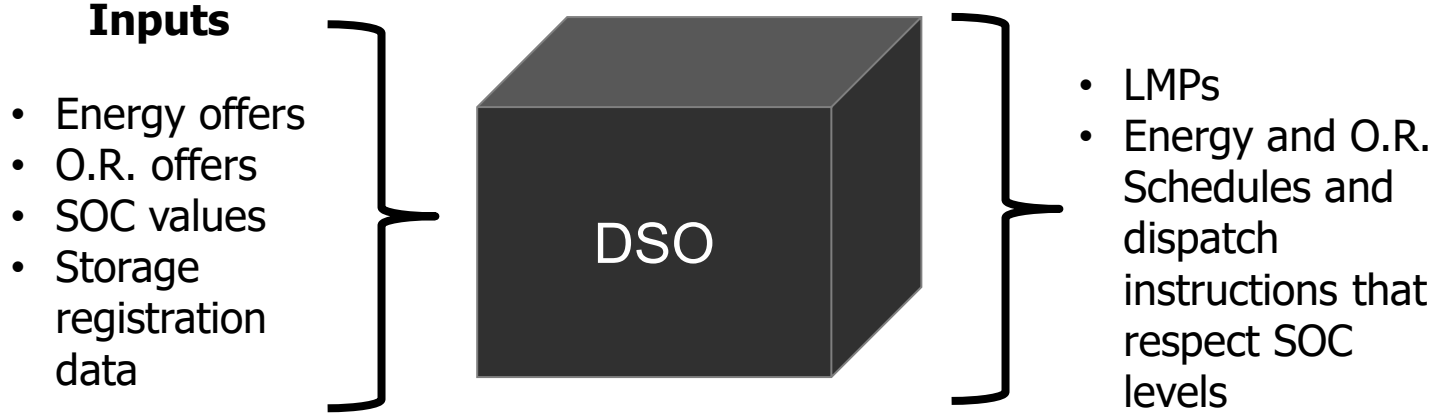
Benefits of "ISO-SoC-Management"

- Optimized over the system-wide informational picture
- Feasible dispatch assured by IESO's dispatch engine

SOC Management Lite – In One Sentence and One Picture

The same market access as a generator, and accounting for the practical operating realities of a storage facility

SOC Lite – SOC management now taken care of within the Dispatch Scheduling and Optimization (DSO)



- SOC no longer has to be managed by the no-overlap rule (SOC 1) or changes to offers in the Mandatory Window (Interim Design Feature SOC 2)
- Operating Reserve schedules automatically respect SOC (replacing Interim Design Features O.R. 1 to 3)

The Case for SOC Lite

ESAG Stakeholder feedback	SOC Lite benefit
Submissions supported self-scheduling, self-managed, and optionality between ISO-managed/self-managed SoC	• Depending on how it is used by market participants SOC Lite can leave more or less of the "SOC management" part to the system operator's dispatch algorithm
A desire to ensure that storage participants can manage their own operations through their offers	• This is the underpinning feature of SOC Lite: schedules are determined by offers that follow the same principles of other dispatchable facilities
A desire to include state-of-charge in the IESO's tools in order to drive feasible and efficient schedules and dispatch instructions	• State-of-charge is considered when producing schedules and dispatch instructions

Under SOC Lite, the extent to which SOC is ISO managed, or self-managed depends on how the participant chooses to use it

ISO-Managed	Self-Managed
Offer maximum capacity most of the time	Offer an amount of capacity that preserves SOC to the desired level
Rarely change offer prices regardless of SOC level	More frequent changes to offer prices and quantities to preserve SOC
Allow facility to run up against SOC constraint and ISO dispatch will ensure it is not exceeded	Minimize the number of times the ISO has to restrict dispatch in order to avoid a SOC violation

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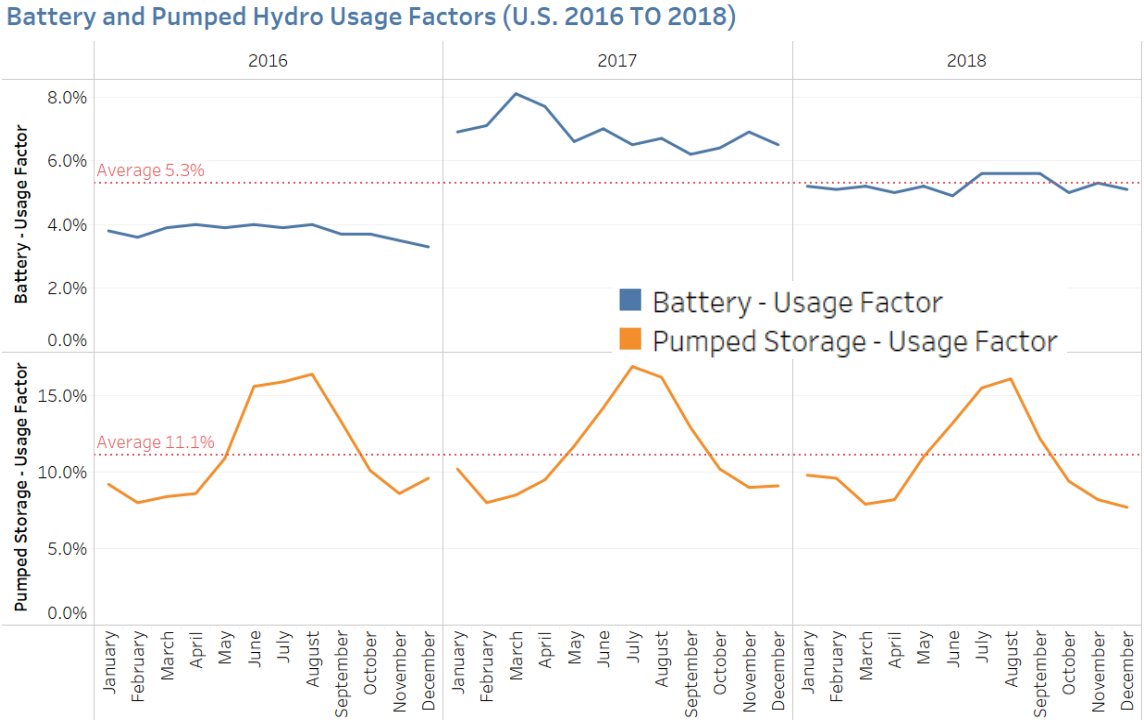
Storage Usage Factors in Practice*



* Source: U.S. Energy Information Administration, "Electric Power Annual, 2018"

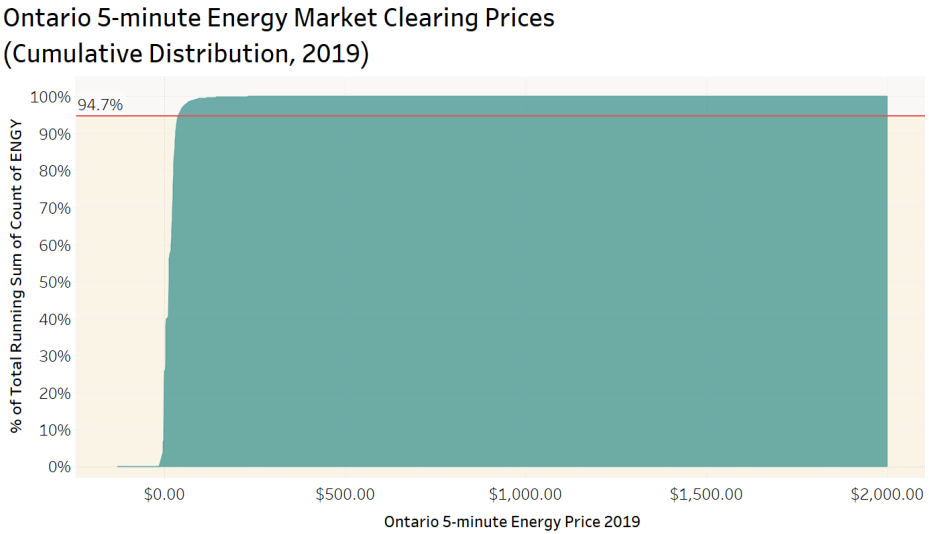
Storage Usage Factors in Practice (cont'd)

- One of the best publicly-available data series on energy storage usage factors from the U.S. Energy Information Administration shows that battery and PGS facilities have been typically used between 5.3% and 11.1%* respectively

- This implies a wide degree of freedom for storage facilities to decide how much they might rely upon the SOC management framework of the market in which they reside

Example: "Set it and forget it" Strategy for a Battery in the Ontario Market

- In 2019, if a battery storage facility in Ontario had wanted to mimic the U.S. average usage factor of 5.3%, it could have placed a standing offer price of just below $39 MWh
- Following such a strategy, the number of times that a battery facility would have run up against a SOC constraint would have been a function of the facility's duration of service, and amount offered into the market



SC Lite Benefits in Summary

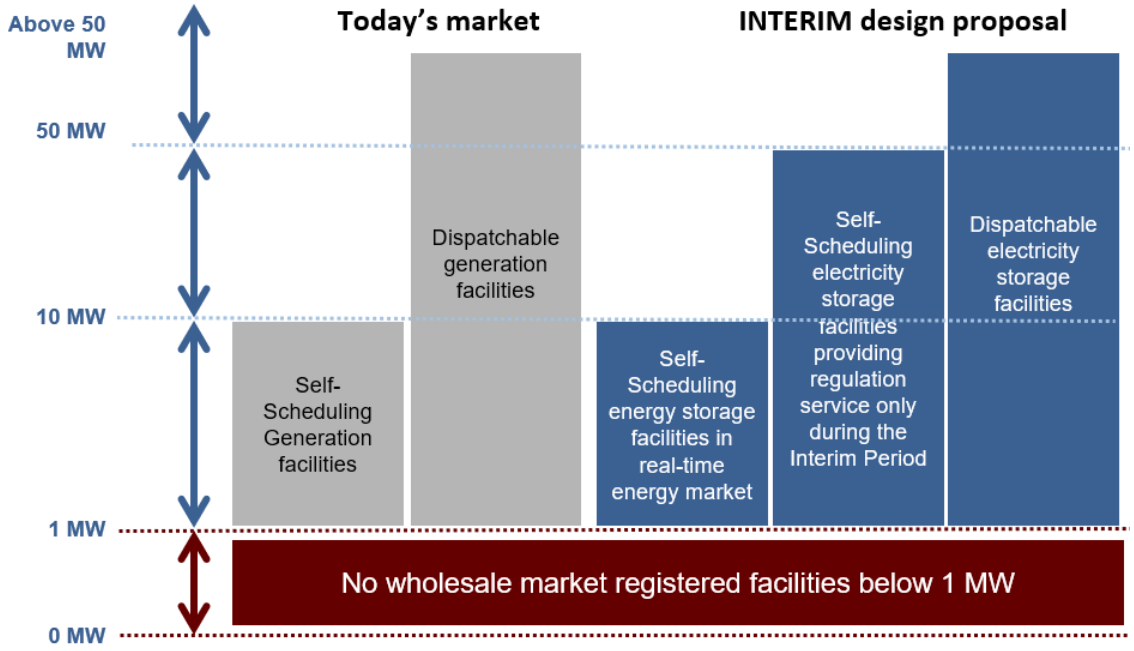
- ✓**Efficiency**: Energy storage utilization is signaled into the market via offer curves, and accounts for the SOC limit of each facility
- ✓**Competition**: Achieves the original SDP goal of providing access to wholesale market products on an equivalent footing to other types of dispatchable facilities
- ✓**Implementability**: Supported by the market platform selected by the Market Renewal Program
- ✓**Certainty**: Participant can largely control the extent to which the ISO constrains the facility's dispatch to its physical SOC limits
- ✓**Transparency**: Energy storage information disclosure to and from the market on the same basis as other types of facilities

Long-Term design: Other aspects of the design Proposal

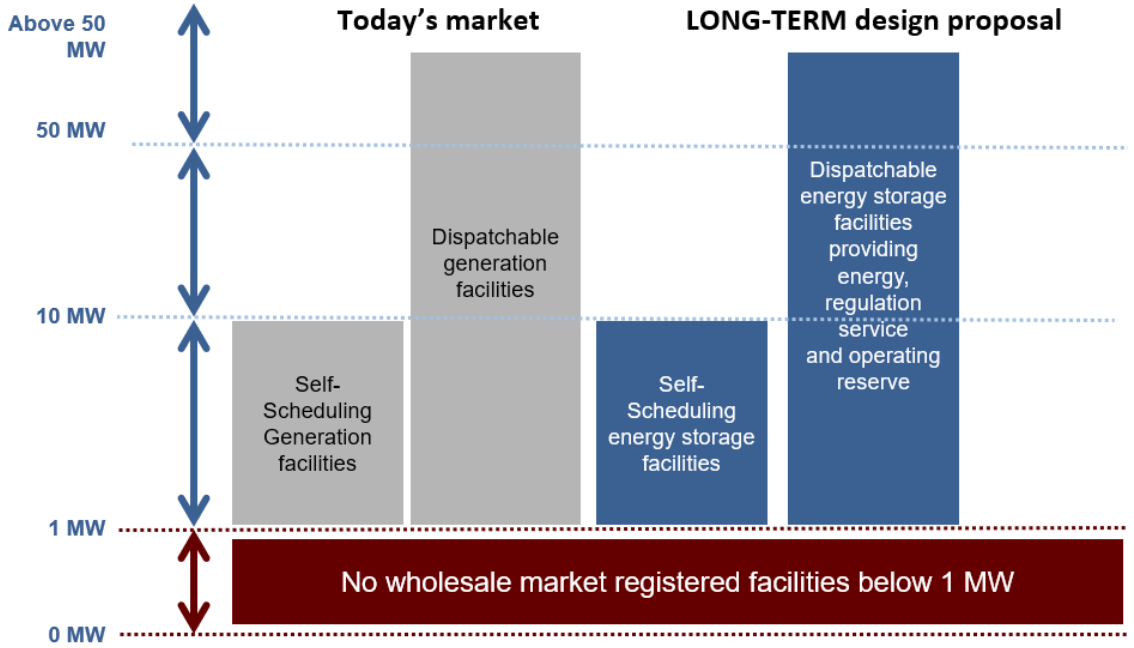
Market and facility registration

Design element	Design questions
Market and facility registration	How should an energy storage facility be registered into the IAMs?

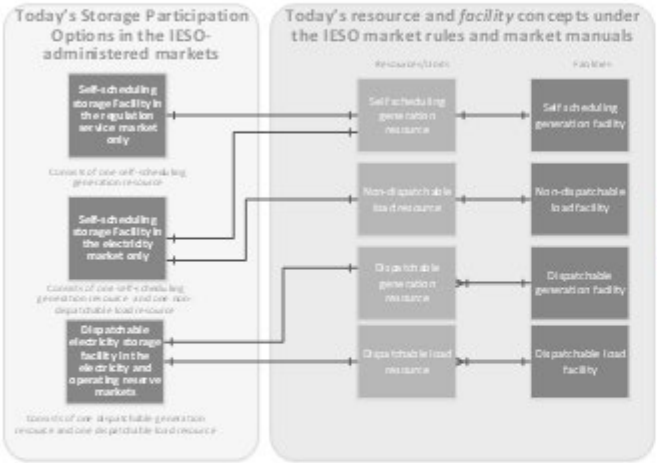
Background: Proposed Size Thresholds for Electricity Storage Facilities in the **INTERIM** Design

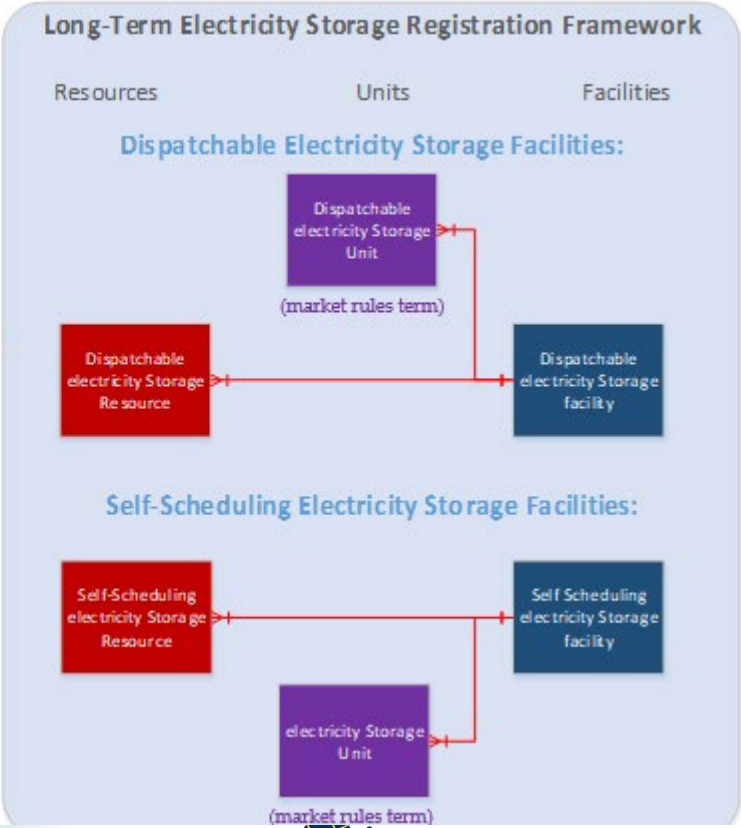


Recommendation: Proposed Size Thresholds for Electricity Storage Facilities in the **LONG-TERM** Design



Recommendation: Storage Resource Model





- SoC Lite no longer relies on a complex usage of the existing resource model
- New storage resource types now reflect the physical capability to inject, store and withdraw energy

Rationale: Storage Resource Model

A foundational design feature enabling…

- Continuous offer curves reflecting the full range of capabilities of the storage facility
- Functional parity between:
  - Dispatchable generators and dispatchable electricity storage facilities
  - Self-Scheduling generators and self-scheduling electricity storage facilities.
- The replacement of a host of manual workarounds that are part of the interim storage framework

Additional Considerations – Market and Facility Registration: Storage Resource Model

- Stakeholders expressed the need to re-examine the 10 MW self-scheduling threshold (anticipating a future with a higher penetration of distributed energy resources)
- The IESO agrees that this is a topic worth continued discussion but will not explore the issue within the SDP
  - This is a broader discussion that affects multiple resource types
- The IESO will further consider the potential timing and forum for this discussion and will report back, through the SDP, on next steps

RT energy and operating reserve markets: bidding and scheduling of ESRs

Design element	Design questions
RT energy and operating reserve markets: bidding and scheduling of ESRs	What offer curve shape (e.g., continuous/discontinuous) should ESRs be allowed to use to offer into the energy and operating reserve markets?

Background: Offer Curves for Dispatchable Electricity Storage Facilities

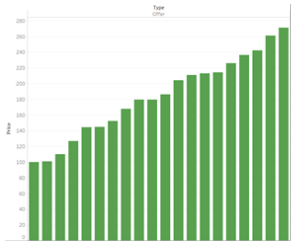
"What offer curve shape (e.g., continuous/discontinuous) should ESRs be allowed to use to offer into the energy and operating reserve markets? "

Background: Under the **interim** SDP design a dispatchable electricity storage facility may submit:

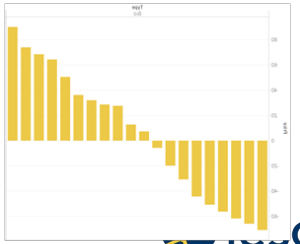
- An offer curve for the generator resource comprising the facility
- A bid curve for the load resource comprising the facility
- An Operating Reserve offer curve for either the load or generator resource

- Energy bid and offer curves may not overlap over the same price range.

Today's bid/offer construct for a dispatchable energy storage facility

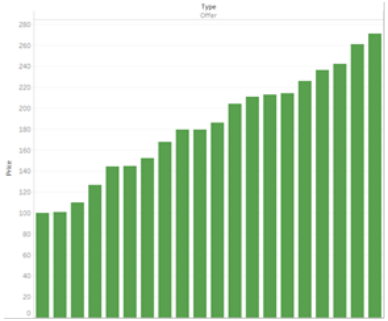


Offer curve (discharging)

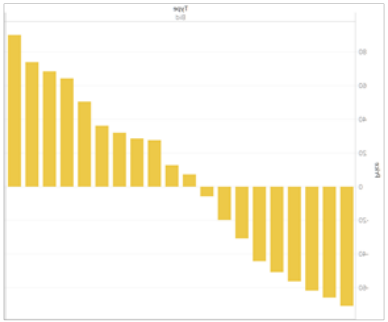


Bid curve (charging)

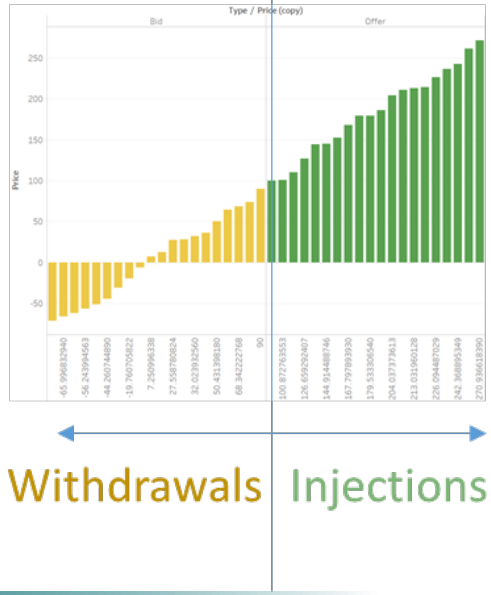
Recommendation: Energy Offer Curves for Dispatchable Electricity Storage Facilities



Offer curve (discharging)



Bid curve (charging)



Continuous price curve (bid curve inverted to show withdrawals and injections on the x-axis)

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Recommendation: Energy Offer Curves for Dispatchable Electricity Storage Facilities (cont'd)

- **Recommendation:** Energy storage offer curves will be continuous over the charging and discharging range
- **Rationale:**
  - Reflects the full operating range of the facility
  - Implicitly and automatically enforces the no overlap rule already in place under the SDP Interim Design
  - Eliminates the possibility of simultaneous/infeasible dispatch instructions to charge and discharge

Ability of ESRs to set market-clearing price in the energy and operating reserve markets

Design element	Design questions
Ability of ESRs to set market-clearing price in the energy and operating reserve markets	Should ESRs be able to set the market-clearing price?

Recommendation and Rationale: Storage Resources Setting Clearing Prices

- **Should ESRs be able to set the market-clearing price?**

Recommendation

- Yes, dispatchable electricity storage resources should be able to set the market clearing prices for energy and operating reserve by virtue of being able to submit offers into those markets

Recommendation and Rationale: Storage Resources Setting Clearing Prices (cont'd)

Rationale:

- Consistent with the current SDP Interim Design
- An implicit feature of the SOC Lite design construct, which is predicated on signaling value of energy and operating reserve via offers
- Consistent with MRP principles of enhancing competition across all market product categories

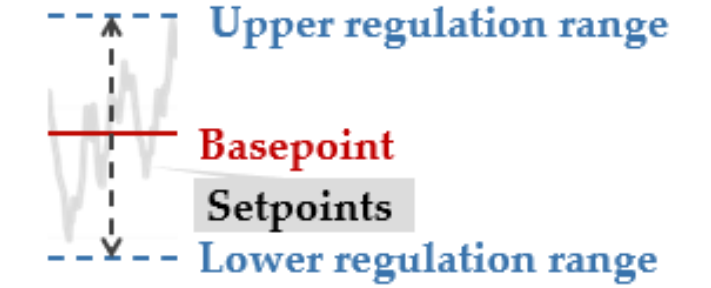
Regulation service

Design element	Design questions
Regulation service	What are the rules for what proportion of an ESR's total capacity gets used for regulation, energy and operating reserve – both at different times and simultaneously?

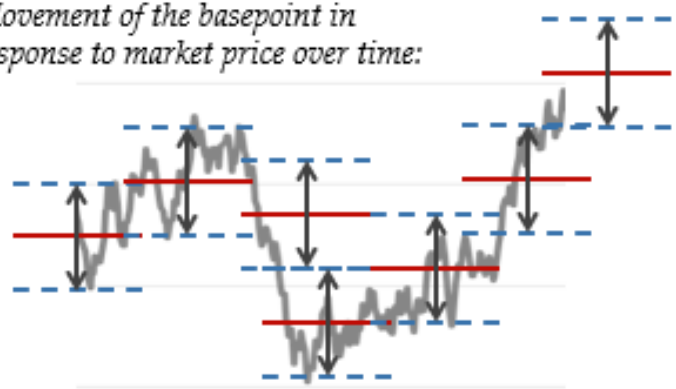
Background: Regulation Service for **Generators** Today

- Today, the Dispatch Scheduling and Optimization (DSO) engine moves the basepoint of a generator up and down its feasible operating range, and according for market economics in response to prices

- The Automatic Generation Control (AGC) system then sends out regulation "setpoint " signals, that respect the upper and lower bounds of the regulation range being provided by the facility



Movement of the basepoint in response to market price over time:



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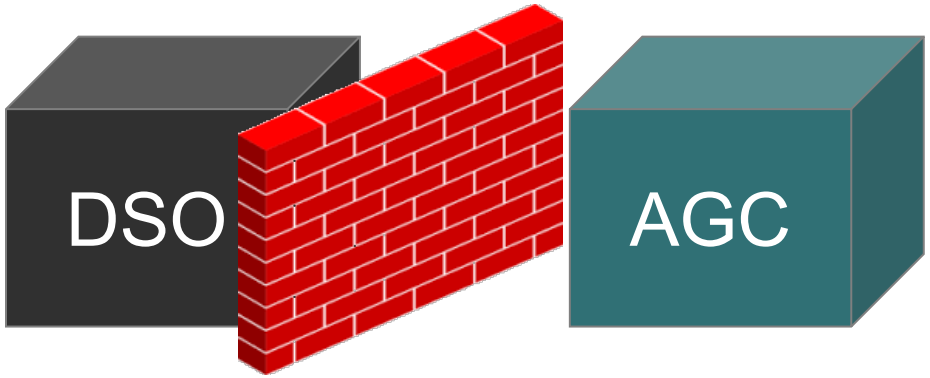
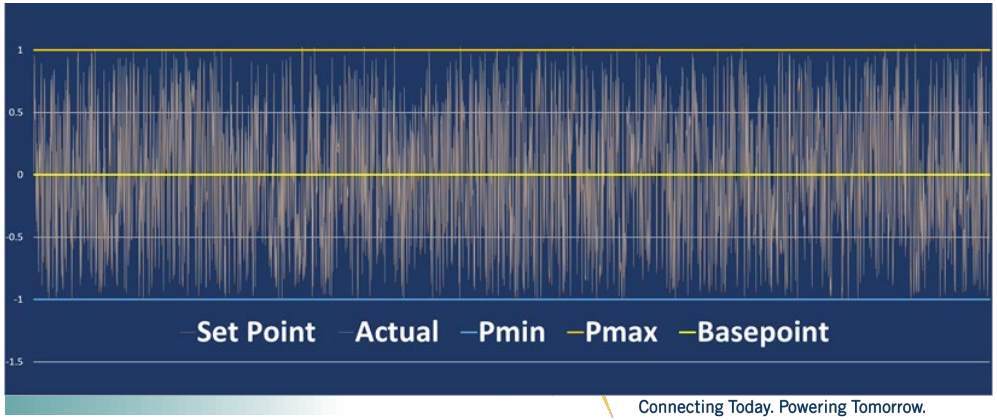
Background: Regulation Service for **Energy Storage Facilities** Today

- Today, energy storage facilities have been providing regulation service on an experimental basis
- The DSO tool essentially has no view of the storage facility due to its current inability to model state of charge
- A setpoint is sent from the AGC tool to the storage facility, usually holding the basepoint at a constant zero line
- The result: the storage facility is completely unresponsive to market price and is often limited by its duration of service capabilities



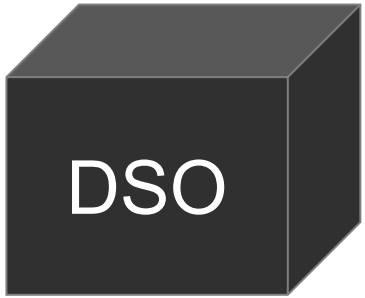


Regulation Service: Desired End State

- The SOC Lite design feature is relatively independent of the future of regulation service options for energy storage
- The overall objective is to ensure that regulation service from storage is deployed in a manner similar to generators. The only difference, is that the DSO algorithm would now send unit basepoints for regulation service that respect state of charge.
- This will improve overall efficiency for both storage facilities and the market as a whole

Regulation Service: Desired End State (cont'd)

- Energy Offers
- Agreed regulation schedules
- **State of Charge**



- Regulation Basepoints
- **State of Charge**

- Regulation set points that respect **State of Charge**

Recommendation: Regulation Service and the SDP Project

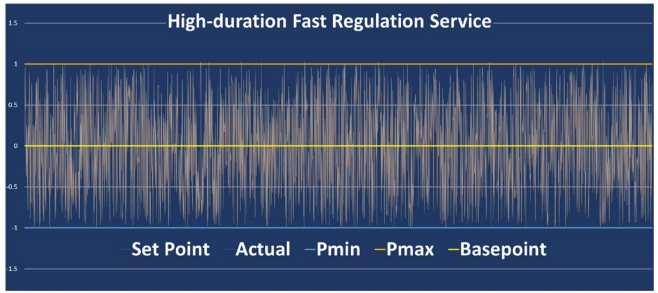
- From the outset, the SDP project has sought to level the playing field by providing the same capabilities to storage facilities as generators to provide regulation, energy and operating reserve
- The IESO's SCADA EMS Upgrade project includes a number of changes to incorporate storage facilities into the AGC tool (additional tool changes subject to IESO business planning process are also required to enable this functionality)

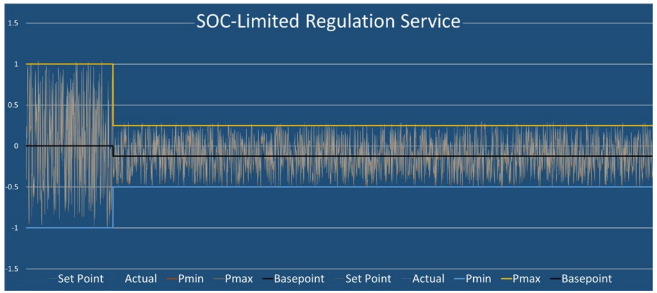
Recommendation: Regulation Service and the SDP Project (cont'd)

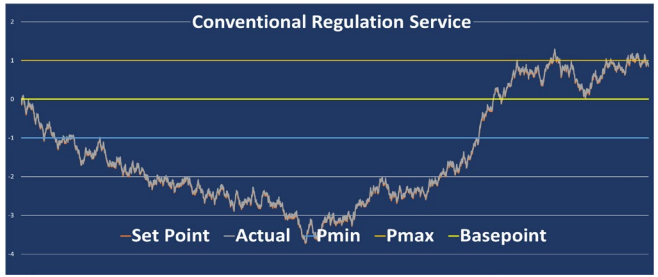
- **Recommendation:**
  - Once the above projects are completed and the long-term design is implemented, storage resources will be fully enabled to compete to efficiently provide multiple services including regulation, energy and operating reserve

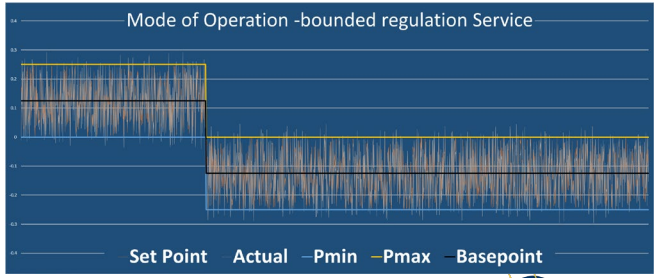
Summary and Stakeholder Feedback

…the recommended measures could enable a number potential regulation service products, of varying degrees of quality and capability, in the future, though these fall outside the scope of the SDP project.









Summary and Stakeholder Feedback (cont'd)

- Today, the IESO has presented a set of high-level proposals for the long-term participation of energy storage resources within the IESO Administered Markets
- The IESO believes the proposals captured in this presentation provide a long-term vision for storage participation that is effective and implementable

Summary and Stakeholder Feedback (cont'd..)

- The IESO is seeking stakeholder feedback on whether today's proposals offer pragmatic solutions for the participation of energy storage in IESO Administered Markets in the long-term
- Please use the feedback form that can be found under the May 20, 2020 entry on the ESAG webpage and send to engagement@ieso.ca by June 10, 2020