Stakeholder Engagement Pre-Reading

Constraint Violation Pricing – November 25, 2019

The external stakeholder engagement session on November 25, 2019 will cover the following topic(s):

- Constraint Violation Pricing

The purpose of this document is to provide stakeholders with information on the detailed design for the Constraint Violation Pricing topic and set expectations for the session. These materials are required reading for the session.

Contents

Disclaimer

This document and the information contained herein is provided for information and discussion purposes only. This document does not constitute, nor should it be construed to constitute, legal advice or a guarantee, representation or warranty on behalf of the IESO. In the event of any conflict or inconsistency between the information contained in this presentation and the Market Rules, the Market Manuals, any IESO contract or any applicable legislation or regulation, the provisions of the Market Rules, Market Manuals, contract, legislation or regulation, as applicable, govern.

1. Session Objective

The detailed design engagement meetings are to be considered technical working sessions. The sessions will focus on specific topics that external stakeholders either expressed an interest in during the high-level design phase or where the IESO has identified the need for further stakeholder input to inform the draft detailed design. Each session will concentrate on the proposed design for one specific aspect of the energy market detailed design.

The IESO is publishing materials for each engagement session no later than two weeks in advance of the session. This information is being shared in advance to provide stakeholders the opportunity to review and consider the potential impacts on their organization. The material should also help stakeholders identify who from their respective organizations may be most appropriate to attend the session and provide feedback. Stakeholders are encouraged to submit questions in advance of the sessions that will be addressed either at or before the session.

Stakeholder feedback, questions or concerns can be sent directly to engagement@ieso.ca.

These sessions will allow for interactive discussions with stakeholders regarding the reading material which will be focused on the questions identified below.

Stakeholders may also submit written feedback after the session if they choose to do so. However, these engagement sessions are designed to collect stakeholder feedback in-person and to facilitate a discussion with other stakeholders on that feedback. The IESO will use the input from these sessions to inform the detailed design decisions. Following each engagement session, the IESO will publish a brief summary of the discussion and allow for a short window for feedback for those not able to participate.

In the pre-engagement session, the IESO will be asking the following questions:

- What questions do stakeholders have on the proposed methodologies?
- What questions do stakeholders have on the rationale for the proposed methodologies?
- Do stakeholders agree that the proposed methodologies are consistent with the Market Renewal principles? If not, what changes would be required to better align with the principles?

List of Principles of Market Renewal

- **Efficiency:** Lower out-of-market payments and focus on delivering efficient outcomes to reduce system costs
- **Competition:** Provide open, fair, non-discriminatory competitive opportunities for participants to help meet evolving system needs
- **Implementability:** Work together with our stakeholders to evolve the market in a feasible and practical manner
- **Certainty:** Establish stable, enduring market-based mechanisms that send clear, efficient price signals
- **Transparency:** Accurate, timely and relevant information is available and accessible to market participants to enable their effective participation in the market

2. Background

The IESO dispatches resources and determines market prices by optimizing the system to most efficiently meet energy and operating reserve requirements. However, the optimization may at times be unable to resolve all of the system constraints that are needed to ensure a reliable dispatch. For example, there may be a lack of operating reserve offers or transmission capacity available to meet demand. When unable to find feasible solution that can respect all constraints, the optimization can then attempt to achieve a solution by allowing constraints to be violated. The violation of these constraints must be undertaken to ensure reliability and be appropriately reflected in market prices.

In the IESO's current two-schedule market, constraint violations are handled differently in the constrained dispatch and unconstrained pricing schedules.

High penalty prices are used in the constrained dispatch schedule to provide the dispatch with a value for a cost of incurring a particular violation. High penalty prices ensure that all market options have been exhausted before violating constraints that are needed to maintain reliability. The penalty prices currently used are all greater than the maximum market clearing price, and are not used for market settlement. These prices have been determined with enough separation between different types of violations such that a clear priority of violations is established. The ordering signals the sequence in which the IESO will violate system constraints when no market outcomes would otherwise be found.

Table 1 - Current IESO Penalty Prices in Constrained Dispatch Schedule

Violation	Penalty Price
Total Reserve Requirement	\$6,000/MW
10-Minute Total Reserve Requirement	\$10,000/MW
10-Minute Spinning Reserve Requirement	\$12,000/MW
Energy Balance (Over- or Under- Generation)	\$30,000/MW
Import/Export Scheduling Limit or Net Interchange Scheduling Limit	\$40,000/MW
Security Transmission Limit (Base case or Contingency)	\$60,000/MW

Relaxation is often used in the current unconstrained scheduled to determine market pricing when a violation is incurred. Its purpose is to 'relax' the constraint according to the size of the incurred violation, thereby eliminating the violation. By relieving the constraint, prices are not set by the high penalty prices as described above, but instead based on the marginal cost of the last resource dispatched before the violation would have been incurred. A shortcoming of using relaxation to resolve constraint violations is that it can result in an over- or under-relaxation of constraints. Accurately identifying exactly how much a constraint needs to be relaxed can be challenging, and lead to inaccurate market prices.

Specific pricing rules are also used by the current unconstrained schedule to calculate the energy price. For example, operating reserve prices are based on the higher of the energy price or the highest-cost operating reserve offer scheduled.

2.1. Constraint Violations in the Single Schedule Market

The future wholesale market will optimize scheduling and pricing across the day-ahead, pre-dispatch, and real-time timeframes considering all system and resource constraints. When necessary, the optimization engines will apply penalty prices when making scheduling and market pricing decisions.

The intent of an SSM is to align scheduling with market prices. To ensure this the same penalty prices would be used for determining schedules and prices. However, this approach can result in challenges.

- A high penalty price can help mitigate the violation of a given constraint by allowing relatively expensive resources to be used to resolve the violation. However, the resolution of the constraint may result in unreasonably high market prices.

  For example, to meet its NERC requirements for 30-minute operating reserve the IESO applies a $6,000 penalty price. If used for both scheduling and pricing, this penalty price could result in a 1 MW shortfall of 30-minute reserve causing a price of $2,000/MWh in the operating reserve market.

- A lower penalty price may result in market prices that more appropriately reflect the market value of the violation, but could allow a violation to persist by not scheduling higher-cost units to resolve it. This requires operator intervention to manually resolve the violation through potentially inefficient out-of-market actions.

Allowing for different sets of penalty prices for the same type of violation in scheduling and pricing can potentially alleviate these concerns.

2.2. High-Level Design Decisions

Constraints related to a reliability standard obligation, adherence is not discretionary. Therefore, applying a high penalty price for scheduling is an efficient way to ensure the IESO meets those requirements. However, for some types of constraints not directly linked to a reliability standard obligation, such as the net intertie scheduling limit (NISL), a high penalty price may not be appropriate.

A more advanced form of constraint violation pricing that applies to market prices is graduated penalty pricing or 'penalty price curves'. This approach varies the magnitude of the penalty price in proportion with the magnitude of the violation. For example, an OR violation of 5 MW would incur a lower penalty price than a violation of 500 MW. Penalty price curves therefore prevent unnecessary price volatility.

Pricing rules for constraint violations will be broken into two categories:

- For reliability-based constraints, apply the current penalty prices to ensure a reliable schedule. Use a new set of penalty prices, graduated where possible, for determining pricing; and
- For non-reliability based constraints, aim to apply a new set of penalty prices that are the same in both scheduling and pricing.

In addition to the two categories above, market settlement prices will be remain capped at the current minimum and maximum market clearing price (i.e. +/- $2,000/MWh). This is most relevant to situations where multiple violations occur and the total of the corresponding penalty prices exceeds the maximum market clearing price.

2.3. Detailed Design Proposal for Constraint Violation Pricing

The following sections provide a description of the IESO's proposed methodology for determining constraint violation pricing logic for multiple types of constraints, specifically:

- Operating Reserve Requirements
- Net Intertie Scheduling Limit
- Transmission Line Limits
- Over and Under Generation
- Import and Export Limits

For each constraint, the IESO has provided a description of the constraint and a proposed methodology outlining the applicable penalty price curves will be used for determining market prices.

To aid discussion the IESO has applied the proposed methodology to recent market results and derived sample penalty price curves for each constraint. These price curves are not definitive, but are illustrative of the types of values that the methodologies described below would produce under current market conditions.

3. Constraint Violations

3.1. Operating Reserve

3.1.1. Description

There are three classes of operating reserve, determined by the time required to bring the energy into use and the physical behaviour of the facilities that provide it:

- 10-minute synchronized (spinning);
- 10-minute non-synchronized (non-spinning); and
- 30-minute.

Total operating reserve is the sum of these three types of reserve.

10-Minute Reserve

The IESO must have enough 10-minute reserve to cover the largest single contingency that can occur; a common example is the loss of Ontario's largest single generation unit. In this case, if the largest generator on the IESO-controlled grid is 945 megawatts (MW), the IESO must schedule at least 945 MW of 10-minute operating reserve. The total requirement for 10-minute reserve is referred to as 10T. A portion of the 10-minute reserve requirement must be 'spinning' or synchronized to the grid (referred to as 10S). The remainder of the 10-minute reserve requirement is non-synchronized (referred to as 10N).

30- Minute Reserve

The 30-minute reserve requirement is equal to the greater of: half of the second largest single contingency, or the largest commissioning generating unit. This type of reserve does not have to be synchronized and is referred to as 30R.

Reserve Requirements in Calculation Engine

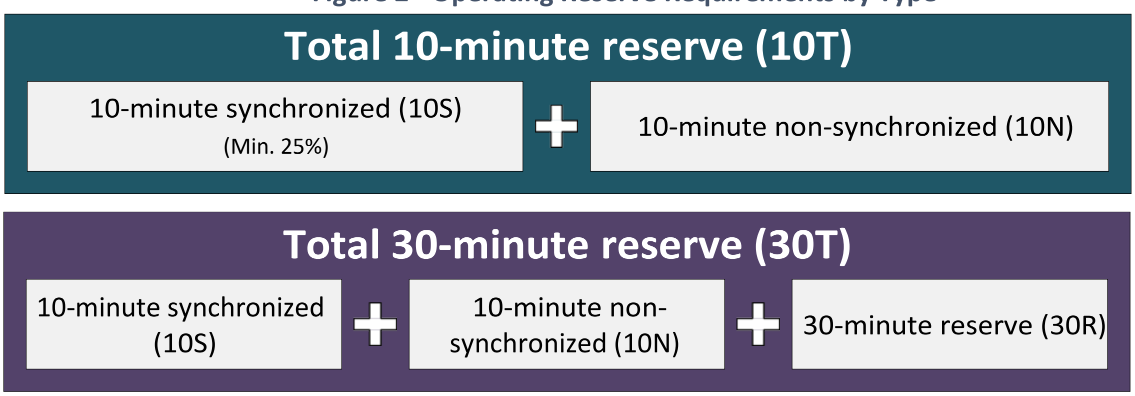
The IESO is required to carry each type of reserve (10S, 10N and 30R). However, when procuring these reserves, the IESO has the flexibility to satisfy any reserve requirement with the most economic combinations of reserve types that provides a level of reliability that is equal to or exceeds the reliability of that reserve requirement. This creates a cascading relationship where:

- the 10S requirement can only be satisfied using supplier offers for the 10S reserve product,
- the 10N requirement can be satisfied using a combination of offers for the 10S and 10N reserve product, and
- the 30R requirement can be satisfied using a combination of offers for the 10S, 10N and 30R reserve product.

This cascading relationship is reflected in scheduling through a cascading set of reserve requirements[1] that are restated as a requirement for 10S, 10T and 30T, where:

- The 10S requirement is set to the requirement needed to satisfy 10-minute synchronized requirement,
- The 10-minute total requirement (referred to as 10T) is set to the requirement needed to satisfy the sum of the 10-minute synchronized and non-synchronized requirements,
- The 30-minute total requirement (referred to as 30T) is set to the requirement needed to satisfy the sum of the 10-minute synchronized, 10-minute non-synchronized and 30-minute reserve requirement.

Figure 2 - Operating Reserve Requirements by Type



As illustrated above in **Figure 2**, the 10T requirement can be satisfied by 10S and 10N reserve. The 30T requirement can be satisfied by 10S, 10N and 30R. The cascading relationship allows reserve to be substituted "down" between reserve types in order to meet the reserve requirement using the most economic combination of offered reserve.

This cascading relationship also creates a relationship where the market price for a reserve product that provides a higher level of reliability is additive to the previous one. It also must be equal to or higher than the market price for a reserve that provides a lower level of reliability.

[1] Each of the cascading reserve requirements (10S, 10T and 30T) will also require a complementing operating reserve demand curve (ORDC)

When the scheduling engine determines reserves prices it does so for the cascading set of reserve requirements (10S, 10T and 30T). These shadow prices[2] are then applied according to the following rules in order to establish the market prices in each of the reserve markets:

- the market clearing price for the 30R market is equal to the shadow price of the 30T cascading reserve requirement;
- the market clearing price for the 10N market is equal to the sum of the shadow price of the 10T and 30T cascading reserve requirement; and
- the market clearing price for the 10S market is equal to the sum of the shadow price of the 10S, 10T and 30T cascading reserve requirement.

Area Operating Reserve

The IESO currently has operating reserve areas, within which exist 10-minute operating reserve minimum and overall maximum requirements. Reserve areas are used to ensure the operating reserve is distributed appropriately and can be activated when called upon without violating transmission limits. Maximum reserve area restrictions are used to signify that no more than given MW quantity of OR can be supplied within an area. Minimum reserve area requirements signify a minimum amount that must be scheduled within an area.

3.1.2. Methodology

Different OR penalty prices will be applied for scheduling resources and determining market pricing. The existing penalty prices for OR will be used for scheduling. This helps the IESO to meet its reliability obligations. Operating reserve demand curves (ORDCs) will be introduced to determine settlement prices. An ORDC will allow settlement prices to be set based on offered energy and OR costs without charging excessively high prices for minor violations.

Operating Reserve Demand Curve

An ORDC contains a set of price-quantity pairs whose price decreases as the OR quantity increases to cover the full range of OR requirements. When there is a sufficient quantity of offers to meet the OR requirement at a price less than that specified by the ORDC, the price will be set by the marginal offer. When there is an insufficient quantity of offers priced less than the ORDC, the price would be set by the ORDC.

Any additional offered MWs that are scheduled to meet the OR requirement and were offered at a price above the ORDC would receive make-whole payments. The steps of the ORDC are intended to be high enough to significantly reduce the need for make-whole payments without causing unnecessarily high market prices for minor OR shortfalls.

Figure 3 includes an example of an ORDC curve – the values discussed below are illustrative only and are not being proposed by the IESO.

From 0 MWs to 300 MWs the price is set at $500/MW. From 301 MWs to 600 MWs the price is set at $250/MW. In this example, there is more than enough offers to meet the required quantity at a price below the ORDC. Therefore, the requirement is met and the price is set by the marginal offer; approximately $50/MW.

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[2] Shadow price is the incremental change in the objective function for an incremental relaxation of the constraint.

Figure 3 - Example 1: Operating Reserve Demand Curve

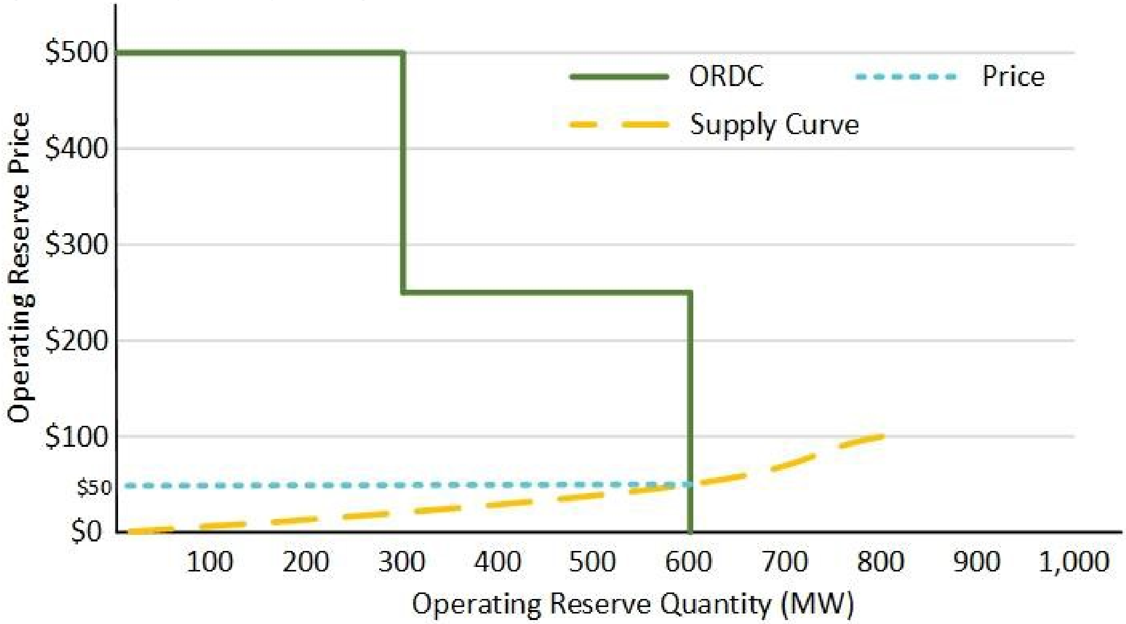
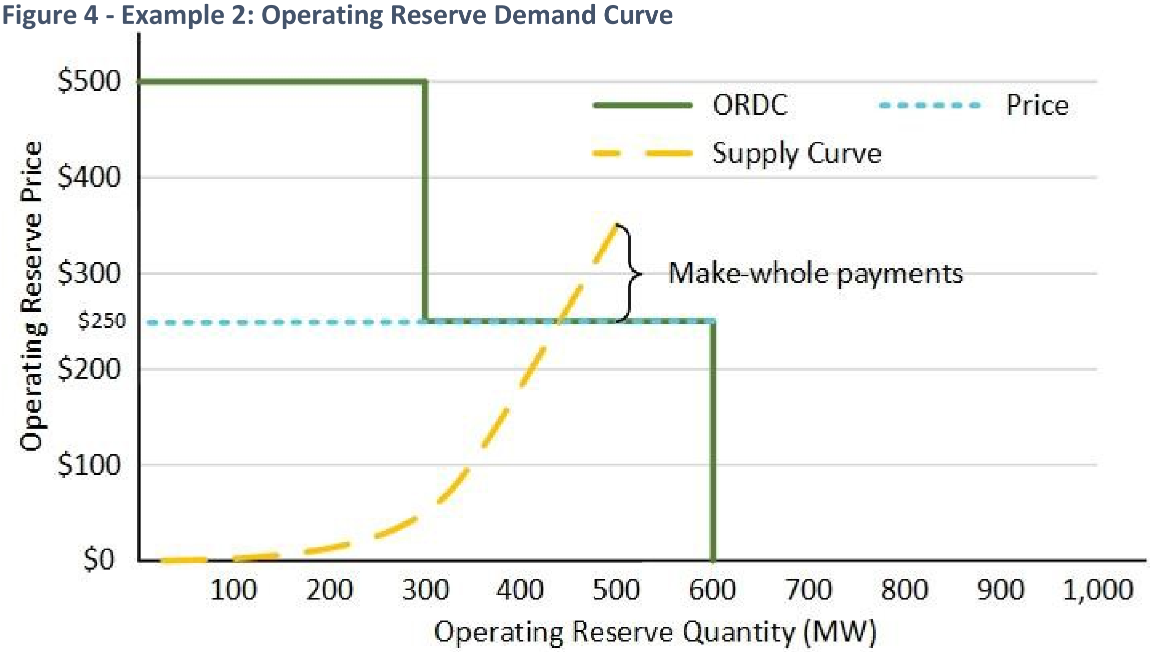


Figure 4 uses the same ORDC as **Figure 3**, but this time there is a supply shortfall – there are only 500 MWs of OR offers. In this example, the 600 MW requirement would not be met and the price would be set by the ORDC at $250/MW. The small amount of OR scheduled at prices above the ORDC would be eligible for make-whole payments.

Figure 4 - Example 2: Operating Reserve Demand Curve



3.1.3. Penalty Prices

Scheduling

The existing penalty prices for OR will continue to be used in scheduling. These prices are outlined in **Table 2**.

Table 2 - Operating Reserve Penalty Prices (Scheduling)

Operating Reserve Requirement	Cumulative[3] System-Wide Price ($/MW)	Individual[4] System-Wide Price ($/MW)	Minimum Area Price ($/MW)	Maximum Area Price ($/MW)
Total	$6,000	$6,000	$4,000	$60,000
10-Minute Total	$10,000	$4,000	$4,000	$60,000
10-Minute Spinning	$12,000	$2,000	$4,000	$60,000

The system-wide penalty prices were originally selected for the current market to ensure that all valid combinations of energy and operating reserve offers would be utilized prior to not meeting the operating reserve constraints. The prices also reflect the recognized higher value of 10S over 10N, and 10N over 30R. Having high penalty prices for scheduling reduces the potential need for operators to manually commit units to resolve OR shortfalls.

The maximum operating reserve area penalty price will continue to be set at $60,000 for scheduling. This value is the same as that used for transmission penalties because it is tightly linked to respecting transmission limits. The IESO will also keep the area minimum operating reserve area penalty price equal to the current system-wide individual 10-minute total price penalty of $4,000.

Market Pricing

When setting ORDC prices, there exists a trade-off between price levels that are high enough to materially limit the frequency and magnitude of make-whole payments but not so high as to cause punitively high market prices due to relatively minor OR violations.

It is important to allow market prices to signal system conditions. ORDC prices that are set too low risk masking the price signal from OR shortages. Additionally, make-whole payments do not provide a transparent market signal and can limit efficient market participation.

Given these considerations, the proposed methodology results in ORDC penalty prices that are high enough to allow offered costs to set market prices, and therefore avoid the use of make-whole payments, 99% of the time. This 99th percentile amount will be established using a historical analysis of market prices from the IESO's constrained schedule; described in more detail below.

[3] The cumulative system wide penalty price refers to the total violation price that would set a market clearing price of a reserve market when all of the cascading reserve requirements that it contributes to are in shortage (e.g. the 10N market clearing price when 10T and 30T cascading reserve requirements are both in shortage)

[4] The individual system wide penalty price refers to the violation price that would set the shadow price for that particular cascading reserve requirement when it is in shortage (e.g. the 10T shadow price when the 10T cascading reserve requirement is in shortage).

30-Minute Reserve

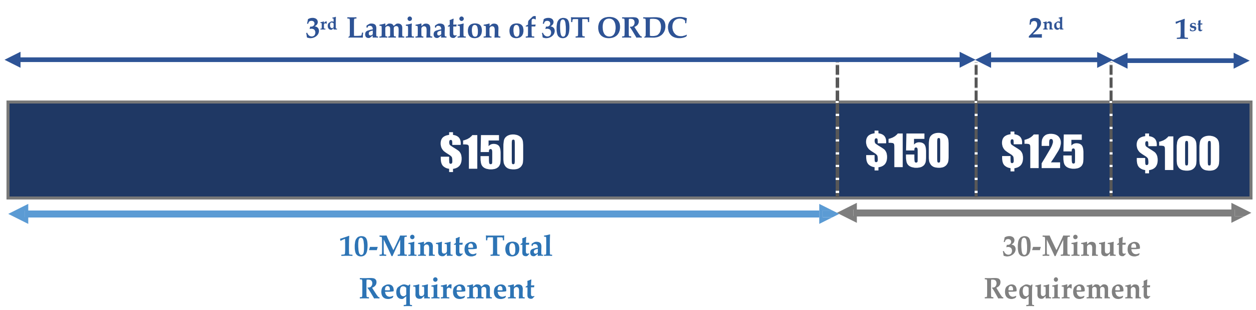
The IESO performed a historical analysis using a set of actual real-time constrained results, with CAOR offers removed. This showed that for 99% of the time, the 30R price was on average less than approximately $125. The ORDC curve for the 30T OR requirement is therefore based on a central point of $125 with additional price points both above and below. The pricing tiers are listed in Table 3 below and Figure 5 provides an illustration of the laminations.

Table 3 – 30T ORDC Penalty Prices (Pricing)

ORDC Bid Lamination (MW)	Individual Prices ($/MW) (30T Shortage) ($/MW)
0 – 1,102 (3rd)	$150
1,103 – 1,260 (2nd)	$125
1,261 – 1,418 (1st)	$100

Three equally sized steps will allow the OR price to increase gradually as the OR shortfall progresses.

Figure 5 – Breakdown of Step Sized for 30T ORDC



In practice, this means that if there is only enough OR offers to meet 1,400 MW of the IESO's 1,418 MW total OR requirement, then the market price for 30-minute reserve will be no greater than $100/MW. If available at higher prices, the 18 MW would be scheduled and eligible for make-whole payments, as necessary.

10-Minute Reserve

The 99th percentile price point for 10N was approximately $400. Consistent with the use of 99% as a central price point in the 30T ORDC, this seemed a reasonable central price point for the cumulative price of the 10T requirement. The cumulative price is the addition of the highest 30T lamination ($150) and the 10T lamination.

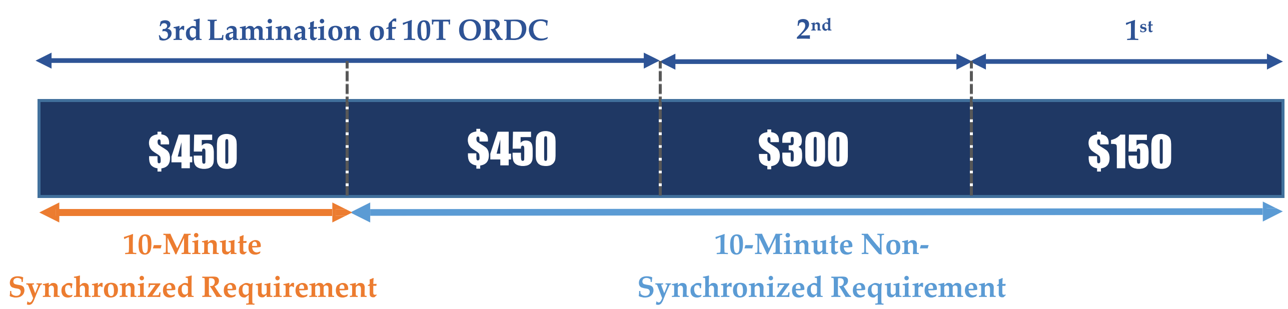
This cumulative central point was adjusted to $450 to ensure that the lower lamination of the 10T ORDC was no less than the price of the highest lamination of the 30T ORDC. Additional steps were included both above and below the central price point that achieve equal spacing in cumulative prices – as described in Table 4 and Figure 6 provides an illustration of the laminations. Similar to the 30R ORDC, the 10T curve is broken into three laminations, each with the same quantity of MW's.

Table 4 - 10T ORDC Penalty Prices (Pricing)

ORDC Bid Lamination (MW)	Individual Prices ($/MW) (10T Shortage)	Cumulative Prices ($/MW) (10T and 30T Shortage)
0 – 473 (3rd)	$450	$600
474 – 709 (2nd)	$300	$450
710 – 945 (1st)	$150	$300

Three equally sized steps will allow the OR price to increase gradually as the OR shortfall progresses.

Figure 6 – Breakdown of Step Sized for 10T ORDC



In practice, this means that if the IESO is short of 30 minute reserve and there is only enough OR offers to meet 900 MW of the IESO's 945 MW total 10 minute OR requirement, then the market price for 10N will be no greater than $300/MW.

10S is the most valuable type of operating reserve as it can be called upon from generators who are already online. As such, the 10S ORDC prices should be cumulative with the highest laminations from the 10T and 30T ORDCs. **Table 5** lists the ORDC laminations for 10S price curve. Given the smaller MW quantity relative to that of 30T and 10T two equal laminations were used instead of three.

Table 5 - 10S ORDC Penalty Prices (Pricing)

ORDC Bid Lamination (MW)	Individual Prices ($/MW) (10S Shortage)	Cumulative Prices ($/MW) (10S, 10T and 30T Shortage)
0 – 119 (2nd)	$400	$1,000
120 – 237 (1st)	$200	$800

In practice, this means that if the IESO is short of 30 minute and 10N reserve and there is only enough OR offers to meet 200 MW of the IESO's 237 MW 10S OR requirement, then the market price for 10S will be no greater than $800/MW. If available at higher prices, the required MW of 10S, 10N and 30R would be scheduled and eligible for make-whole payments, as necessary.

Summary of Potential ORDC Laminations

Table 6 provides a summary of the different laminations of the ORDC. As a reminder, these illustrative values were derived using the methodology for determining ORDC values using historical market outcomes. The methodology bases the mid-point of each ORDC lamination on the 99th percentile of 30 and 10-minute reserve market results.

Table 6 – Summary of ORDC Laminations (Pricing)

Table 6.1 – OR Class 10S

Requirement (MW)	Individual OR Class Prices ($/MW)	Cumulative Price ($/MW)
0 – 118	$400	$1,000
119 – 237	$200	$800

Table 6.2 – OR Class 10T (10S +10N)

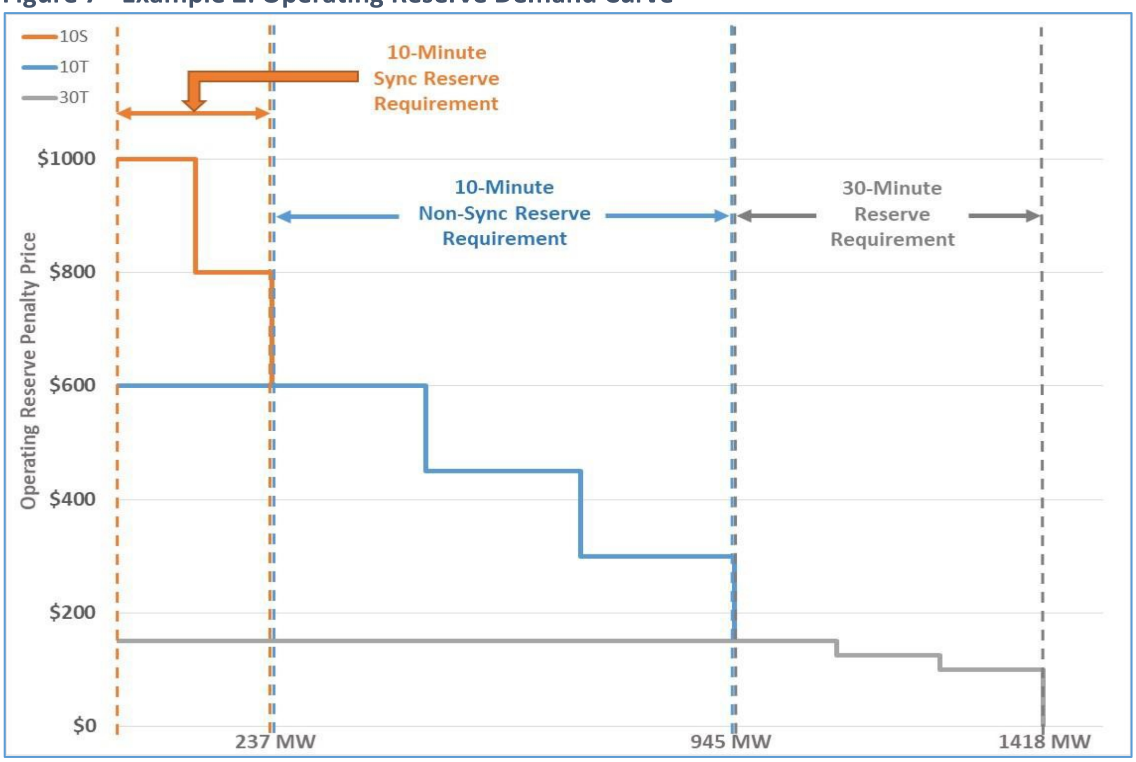
Requirement (MW)	Individual OR Class Prices ($/MW)	Cumulative Price ($/MW)
0 – 473	$450	$600
474 – 709	$300	$450
710 – 945	$150	$300

Table 6.3 – OR Class 30T (10S +10N + 30R)

Requirement (MW)	Individual OR Class Prices ($/MW)	Cumulative Price ($/MW)
0 – 1,102	$150	$150
1,103 – 1,260	$125	$125
1,261 – 1,418	$100	$100

Figure 7 provides an illustration of the different ORDC curves. It demonstrates how they combine to set the cumulative penalty price for each type of reserve.

Figure 7 - Example 2: Operating Reserve Demand Curve



Area Operating Reserve

Constraints for area operating reserve are tightly related to those for transmission line limits. Given this relationship, the maximum area ORDC will be set equal to the penalty price ($8,000) of a significant transmission violation when determining market prices. Note that while the area reserve penalty price below is $8,000, the settlement cap of $2,000 still applies. The methodology for establishing transmission limit penalty prices is described in section 3.3 below.

The minimum area ORDC will be set equal to the lowest price step used in the pricing run for the system-wide 10T operating reserve requirement (i.e. $150). This is because minimum area reserve requirements only ever specify the minimum amount of 10-minute reserve to be scheduled within an area. **Table** 7 lists the penalty prices for OR area constraints.

Table 7 - Area Operating Reserve Penalty Prices (Pricing)

OR Area Constraint	ORDC Price ($/MW)
Maximum Requirement	$8,000*
Minimum Requirement	$150

*The maximum market clearing price of $2,000 will continue to apply.

3.2. Net Intertie Scheduling Limit

3.2.1. Description

The net intertie schedule is the sum of all changes in imports (positive) and exports (negative) from the previous hour's schedule. For example, if imports increased by 100 MW and exports decreased by 100 MW from one hour to the next, the net intertie schedule would be zero. Responding to large changes in the net intertie schedule can have an adverse impact on the reliability of the IESO-controlled grid. Internal generation may not be able to ramp up or down fast enough to satisfy a large net change in intertie flows from hour to hour. To prevent these problems, the IESO limits the change in the net hourly intertie schedule via the Net Intertie Scheduling Limit (NISL).

NISL is the only constraint violation that is not directly tied to a reliability standard obligation. The IESO limits the net change from hour-to-hour to 700 MW unless respecting this limit would negatively impact reliability, such as during a supply shortfall.

3.2.2. Methodology

Different NISL penalty prices will be applied for scheduling resources and determining market pricing. The penalty price for scheduling will be adjusted from today's current value and a new value for determining market price during NISL violations will be utilized. Using the same penalty price for both scheduling and pricing was explored. However, it was determined that multi-hour optimization in the pre-dispatch timeframe would increase the magnitude and frequency of NISL events. For this reason, that option was not chosen.

3.2.3. Penalty Prices

Scheduling

Today's NISL penalty price is equal to the import and export limit penalty price, set at $40,000. This equal standing does not appropriately reflect the operational priority of these constraints. Given that NISL is not tied directly to a reliability standard, it should not compete in violation priority with import/export limits. To avoid this, the NISL constraint violation penalty price will be set below the import and export limit violation price.

The NISL constraint violation penalty price will be set to $35,000, which will be equidistant with the under- or over-generation violation ($30,000), and import/export limit violation ($40,000) used in scheduling. The optimization will therefore violate the NISL constraint before the import/export limit constraint.

Market Pricing

To determine market prices, the penalty price for the NISL constraint will be set based on the 99th percentile of the historic NISL shadow price. The NISL shadow price in the constrained pre-dispatch sequence has historically corresponded to approximately $500.

Choosing the 99th percentile of the historic NISL shadow price achieves the following:

- Provides an appropriate market reference without exposing the market to undue costs as a result of extreme market clearing results (inclusive of violations);
- Limits the frequency of make-whole payments that would be required to address more expensive scheduling decisions that address the NISL constraint; and
- Limits the frequency of occurrences where scheduled imports/exports would be prevented from setting the NISL congestion cost.

3.3. Transmission Limits

3.3.1. Description

Transmission limits are Operating Security Limits (OSLs) and thermal ratings that are be used by the calculation engines to schedule resources within the maximum transfer capabilities of the IESO-controlled grid. These constraints are intended to safeguard the set of schedules produced from violating any security limits.

3.3.2. Methodology

The existing penalty price for transmission limits will be used in scheduling and a new penalty price curve will be established to determine market prices during transmission violations.

The transmission violation penalty price curve will use graduated pricing and be divided into two segments. The break point between the two segments will be a MW quantity equal to 2% of the given transmission limit. The first step signifies a transmission violation of minor magnitude, which is priced correspondingly with a lower value. This small step aims to provide an early indicator of a violation that is generally temporary and of a manageable scale. This segment of the curve will be priced based on a calculated cost which is intended to reflect the average market outcome across a wide sample of transmission violation and binding transmission constraint scenarios.

The second segment of the curve will cover all transmission violations that exceed 2%. This segment will be priced to reflect all actions the IESO is required to take to alleviate a transmission constraint violation, including the possibility of shedding load.

3.3.3. Penalty Prices

Scheduling

Market scheduling will continue to treat all transmission constraints as non-discretionary limits, with a transmission violation penalty price of $60,000 for all violations.

Market Pricing

Minor Violation

The price for the first step of the transmission violation penalty price curve will be developed though analysis of historical occurrences of binding and violated transmission constraints. The price lamination will be the average market price at which transmission violations of less than 2% are resolved via participant offers.

The steps behind the process of price setting are as follows:

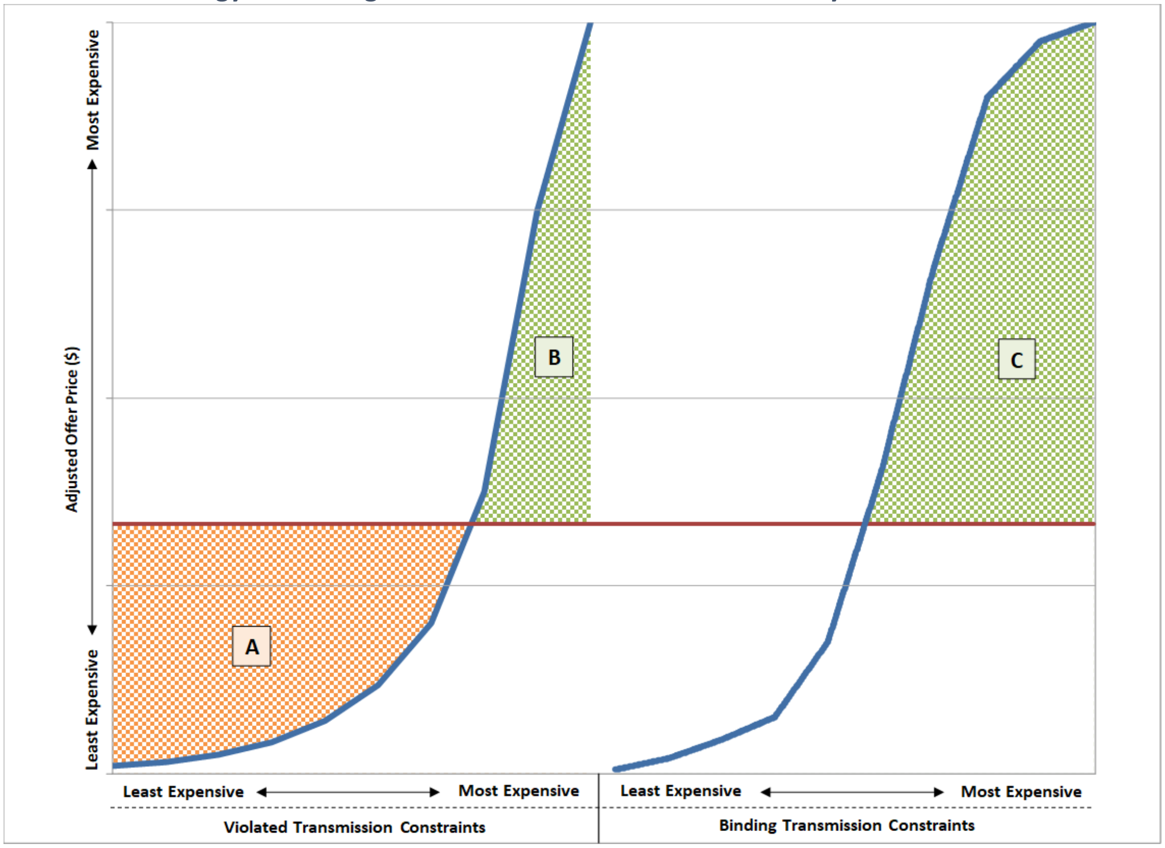
1. Collect occurrences of transmission violations and calculate the cost, adjusted for losses and shift factors, of the last megawatt dispatched in order to reduce flows by 1 MW in order to derive the marginal shadow price set by bids and offers.
2. Collect occurrences of binding transmission constraints and their respective shadow prices.
3. Sort the shadow prices in ascending order for violated transmission constraints.
4. Sort the shadow prices in ascending order for binding transmission constraints.
5. Set the violation price where the magnitude of overstating the marginal cost of a violation is equal to the magnitude of understating the marginal cost of a violation plus the magnitude of understating the marginal cost of a binding constraint.

Illustratively, these steps are represented in **Figure 8**. Where the effects of the violation price (as described by the red horizontal line) are measured across the occurrences of violated transmission constraints (Areas A and B) and again across occurrences of binding transmission constraints (Area C).

Area A – magnitude where the violation price is higher than the marginal market cost of a violation
Area B – magnitude where the violation price is lower than the marginal market cost of a violation
Area C – magnitude where the violation price is lower than the marginal market cost of a binding constraint

The violation price will be set at the point where Area A equals Area B plus Area C. This is the point where the violation price is equal to the average market outcome for resolving minor transmission violations. This means that the penalty price will reflect the marginal cost, on average, of the resources that the market is on balance willing to pay in order to resolve the minor transmission violation. Setting the penalty price to the average marginal cost will provide an efficient pricing outcome and transparently signal the cost of the minor transmission violation to the market.

Figure 8 – Methodology for Setting Minor Transmission Violation Penalty Price



Significant Violation

The second step of the transmission violation penalty price curve will correspond to a significant impact to the reliability of the grid. At this level of violation, the IESO will take all actions necessary to alleviate the transmission constraint violation including the possibility of shedding load. This step should be priced above all other violation types, and should be priced at a level where all nodes local to the violated constraint should result in a settlement price of the MMCP. Therefore, the formula below will be used to calculate the violation price:

$$Significant\ Violation\ Price = \frac{MMCP}{Material\ Shift\ Factor}$$

A shift factor is a measure of the relative electrical proximity and directness of a pricing node to a constraint. The proposed material shift factor in the above formula, is representative of historically re-dispatched resources used to alleviate transmission congestion, and will need to be determined for the purposes of pricing this step.

The process for calculating the material shift factor will be to identify historical transmission congestion events and record the shift factors of the resources used to alleviate the congestion. In the case of a transmission constraint violation, all shift factors will be recorded. Materiality will determine the minimum proximity and directness that a node needs to have in order for a significant violation to set the settlement price at MMCP.

While there is no decision at this time related to the value of the material shift factor it is envisioned that at a minimum it would be no less than 25%. A supplier with a generation shift factor of 25% with respect to a given constraint is considered to be significantly impactful.

If a supplier has a generation shift factor of 25% - meaning that 25% of its power will impact the constraint - it would be necessary to have a penalty price of $8,000 to result in a $2,000 congestion component (25% * $8,000 = $2,000) at that supplier's location. An LMP of $2,000 is appropriate for suppliers who are able to resolve significant transmission constraints. It should be noted that even if a supplier had a generation shift factor of 100% with respect to the constraint in question, the maximum market clearing price of $2,000 would still be applicable.

3.4. Under-/Over-Generation

3.4.1. Description

Under-generation refers to a generation scarcity condition when market demand exceeds available supply. These events can occur as a result of excess system demand or when the system has limited ramp-up capability to match rapidly increasing demand.

Over-generation is the case when there is surplus generation in the system which exceeds market demand. These events can occur as a result of excess surplus baseload generation in the system or when the system has limited ramp-down capability to match rapidly decreasing demand.

3.4.2. Methodology

Both the scheduling and pricing components of the optimization will use a single penalty price for under-generation and over-generation. Scheduling will use the existing penalty prices and market pricing will use a new value.

3.4.3. Penalty Prices

Scheduling

Scheduling will continue to use a penalty price of $30,000 for under-generation and -$30,000 for over-generation.

In Ontario current and future markets energy and OR are jointly optimized. From an operational perspective, energy is a higher priority than OR. As energy shortfalls emerge, OR should be converted into energy before violating the under-generation constraint. For determining schedules, the IESO will use a $30,000 penalty price for under-generation and $6,000 to $12,000 for system-wide OR penalty prices. The higher price on energy under-generation ensures that OR is depleted prior to running short of energy.

Market Pricing

Under-Generation

In order to achieve efficient market schedules, the under-generation penalty price used for market pricing should be greater than the maximum offer price. This is necessary to make sure all energy offers are considered when determining market pricing.

Market pricing should place a higher value on energy shortages than on OR shortages. This hierarchy will direct the calculation engine to convert OR to energy as shortage conditions emerge, and will allow the

OR price to increase as the OR supply is used up. Based on the proposed ORDC methodology, maximum market clearing price and the potential impact of losses, the under-generation penalty price would be approximately $4,000.

This value is the result of the summation of the maximum offer price of $2,000 for energy, plus the maximum ORDC price of $1,000. This $3,000 value then needs to the reflect the potential impact of transmission losses.[5] Loss factors on the IESO-controlled grid can be as high as 1.35.

Multiplying $3,000 by 1.35 yields the approximate value of $4,000 for the under-generation penalty price.

Over-Generation

Similar to under-generation, the over-generation penalty price must be less than the minimum offer price (-$2,000). There are many resources in the supply stack with low- or negatively-priced offers. Consequently, the over-generation violation price should be no greater than the lowest offer price allowed. However, unlike under-generation, co-optimization with OR is not a concern as there is a abundance of operating reserve and energy offers.

Transmission losses must also be considered for over-generation penalty prices because the same transmission losses apply as they do for under-generation. Multiplying -$2,000 by 1.35 yields the approximate value of -$3,000 for the under-generation penalty price.

This value will allow an energy offer at the minimum price, with high transmission loss factors, to be scheduled prior to an over-generation constraint violation.

3.5. Import/Export Scheduling Limit

3.5.1. Description

Each of Ontario's interties has a maximum allowable import and export transmission capability that relates to its power flow limit, which is the amount of electricity it can carry. These limits are used to ensure system stability and acceptable thermal loading levels.

3.5.2. Methodology

A single penalty price will be used for both scheduling and pricing of import and export limits. Scheduling will use the existing penalty price and pricing will use a new value.

The purpose of using penalty price curves is to transparently signal to the market the increasing severity of a constraint, either in magnitude or reliability to the grid. Due to the nature of interties, which interconnect separate reliability coordinated areas, reliability standards are implemented to minimize the risk of widespread impacts. Hence intertie schedule adherence is not discretionary and, as a result, warrants a single (high) penalty price in both scheduling and pricing to signal a significant violation.

[5] Transmission losses from energy at a distant generator can make a $2,000 offer appear uneconomic at the reference location. If these transmission losses aren't accounted for in the penalty price, the calculation engine could determine that the penalty price is more economic than the energy offer.

3.5.3. Penalty Prices

Scheduling

Since the import and export constraint violations are reliability-based constraints, the violation cost will be $40,000 for all magnitudes of violations. This high violation cost ensures that dispatch results achieve the operational priority of avoiding import and export violations where possible.

Market Pricing

In scheduling, the constraint hierarchy is set such that the IESO will minimize all import or export constraint violations unless the intertie can alleviate an internal transmission limit, and must be among the last available options prior to a transmission violation. The penalty price for market pricing will reflect the same hierarchy.

The internal transmission constraint violation price used to determine pricing will have the highest penalty price; subject to further study, this value will be in the range of $8,000. Thus, so long as the import and export constraint violation price is lower it will maintain the constraint violation hierarchy used in scheduling.

The import and export constraint violation price is the second most expensive penalty price currently implemented by the IESO. Thus, so long as the import/export penalty price for market pricing is higher than the penalty price used for under- or over-generation (currently the third highest price) it will maintain the constraint violation hierarchy used for scheduling.

The penalty price for under-generation is $4,000. Therefore, the proposed penalty price for import and export violations is $6,000.

In the event that any intertie price, whether for energy or operating reserve, clear in excess of +/- MMCP, the IESO for the purpose of settlements shall replace the price with the appropriate +/- MMCP.

4. Conclusion

In preparation for the engagement session, stakeholders are encouraged to submit any questions or requests for clarification in advance of the interactive session.

For questions or feedback, please email engagement@ieso.ca.

5. Appendix A

Table A1 - Summary Table of Penalty Prices

Constraint	Penalty Price	
	Scheduling	Pricing*
Operating Reserve	Total Reserve: $6,000/MW 10-Minute Total: $10,000/MW 10-Minute Spinning: $12,000/MW	Operating Reserve Demand Curve (see Table 7 on page 13)
Net Intertie Scheduling Limit	$35,000/MWh	$500/MW
Transmission Limit	$60,000/MWh	Penalty Price Curve (Lamination 1 < 2% violation) (Lamination 2 > 2% violation)
Under and Over Generation	Under-Generation: $30,000/MWh Over-Generation: -$30,000/MWh	Under-Generation: $4,000/MW Over-Generation: -$3,000/MW
Import/Export Scheduling Limit	$40,000/MWh	$6,000/MW

*The maximum market clearing price of $2,000 will continue to apply.