PUBLIC

Detailed Design

Market Renewal Program: Energy

Pre-Dispatch Calculation Engine

Detailed Design

Issue 2.0

This document provides a detailed overview of the processes related to the Pre-Dispatch Calculation Engine that will be implemented for the Energy work stream of the Market Renewal Program, including related market rules and procedural requirements.

DES-24

Disclaimer

This document provides an overview of the proposed detailed design for the Ontario Market Renewal Program (MRP) and must be read in the context of the related MRP detailed design documents. As such, the narratives included in this document are subject to on-going revision. The posting of this design document is made exclusively for the convenience of *market participants* and other interested parties.

The information contained in this design document and related detailed design documents shall not be relied upon as a basis for any commitment, expectation, interpretation and/or design decision made by any *market participant* or other interested party.

The *market rules*, *market manuals*, applicable laws, and other related documents will govern the future market.

Document Change History

Issue	Reason for Issue	Date
1.0	First publication for external stakeholder review.	September 30, 2020
2.0	Second publication after consideration of external stakeholder feedback.	January 28, 2021

Related Documents

Document ID	Document Title
DES-13	MRP High-level Design: Single Schedule Market
DES-14	MRP High-level Design: Day-Ahead Market
DES-15	MRP High-level Design: Enhanced Real-Time Unit Commitment
DES-16	MRP Detailed Design: Overview
DES-17	MRP Detailed Design: Authorization and Participation
DES-18	MRP Detailed Design: Prudential Security
DES-19	MRP Detailed Design: Facility Registration
DES-20	MRP Detailed Design: Revenue Meter Registration
DES-21	MRP Detailed Design: Offers, Bids and Data Inputs
DES-22	MRP Detailed Design: Grid and Market Operations Integration
DES-23	MRP Detailed Design: Day-Ahead Market Calculation Engine
DES-24	MRP Detailed Design: Pre-Dispatch Calculation Engine
DES-25	MRP Detailed Design: Real-Time Calculation Engine
DES-26	MRP Detailed Design: Market Power Mitigation
DES-27	MRP Detailed Design: Publishing and Reporting Market Information
DES-28	MRP Detailed Design: Market Settlement
DES-29	MRP Detailed Design: Market Billing and Funds Administration

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Table of Changes

This detailed design document has been updated since version 1. For more detailed information about these changes, refer to the “MRP Energy Detailed Design - Version 2.0 Updates” document.

1. Introduction

1.1. Purpose

This document is a section of the Market Renewal Program (MRP) detailed design document series specific to the Energy work stream. This document provides the details of the business design and the requirements for *market rules,* market-facing and internal procedures and the data flow required to support the Pre-Dispatch (PD) Calculation Engine processes as related to the introduction of the future day-ahead market and the *real-time market*. This design document will aid in the coordinated development of business processes, *market rules* and supporting systems.

As illustrated in Figure 1-1, this document is an integral part of the MRP detailed design document series and will provide the design basis for the development of the governing documents and design documents.

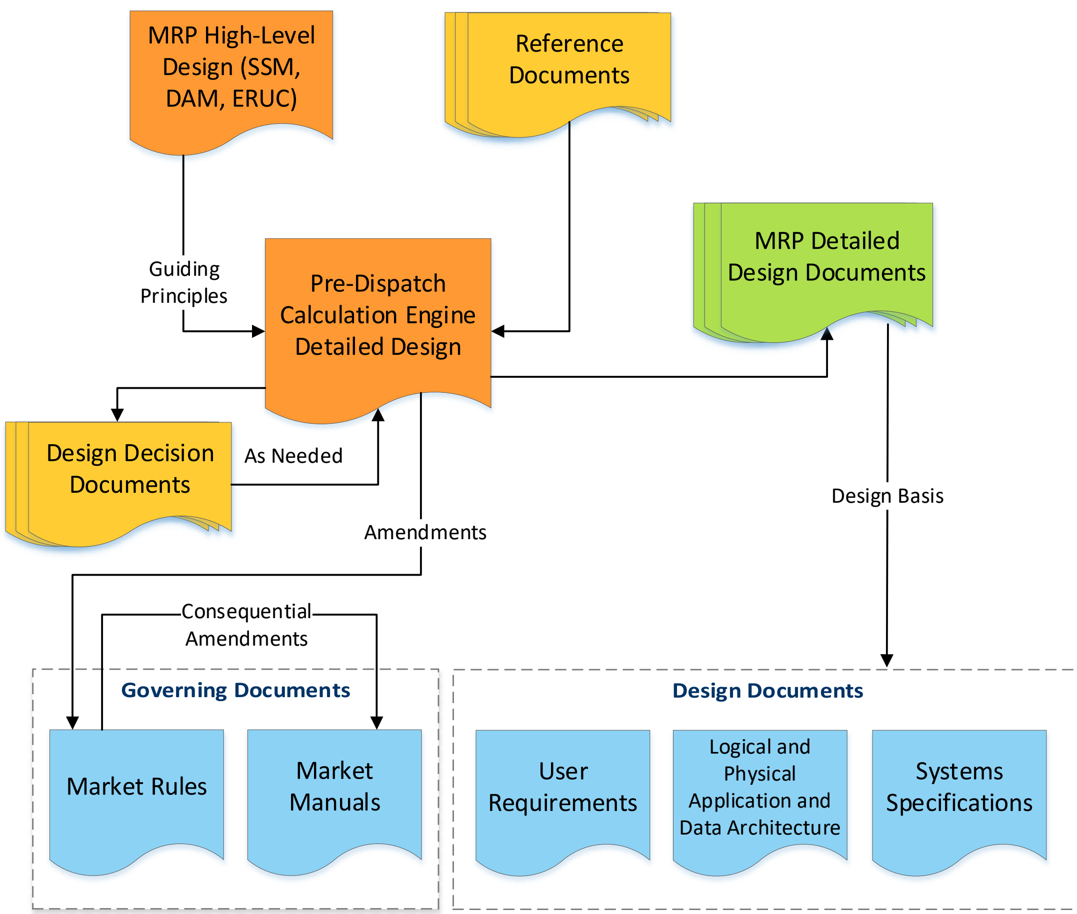

Figure 1-1: Detailed Design Document Relationships

1.2. Scope

This document describes the PD Calculation Engine process requirements in terms of:

- detailed functional design;
- supporting *market rule* requirements;
- supporting procedure requirements, and
- business process and information flow requirements.

Various portions of this document make reference to current business practices, rules, procedures and processes of the PD Calculation engine. However, this document is not meant as a restatement of the existing design of the *Independent Electricity System Operator (IESO)* process. Rather this document focuses on existing components only to the extent that they might be used in the current or amended form in support of the future day-ahead market and *real-time market*.

1.3. Who Should Use This Document

This document is a public document for use by the MRP project team, pertinent *IESO* departments and external stakeholders. Portions of this document that are only pertinent to *IESO* internal processes and procedures may not be incorporated into the public version.

1.4. Assumptions and Limitations

Assumptions:

While this document makes references to specific parameters that might be used in the PD Calculation Engine processes, this document does not impart any assumptions as to what the value of those parameters might ultimately be. The setting of such parameters will be a matter of *IESO* policy to be determined at a later date under the amended authority of the *market rules*.

Limitations:

The business process design presented in Sections 2 and Section 6 of this document provides a logical breakdown of the various sub-processes described in the detailed business design presented in Section 3. However, factors such as existing and future system boundaries and system capabilities may alter the ultimate design of these sub-processes.

1.5. Conventions

The standard conventions followed for this document are as follows:

- Title case is used to highlight process or component names; and
- Italics are used to highlight *market rule* terms that are defined in Chapter 11 of the *market rules*.

1.6. Roles and Responsibilities

This document does not set any specific roles or responsibilities. This document is intended to provide the design basis for development of the documentation associated with the *IESO* Project Lifecycle that will be produced in conjunction with the MRP.

1.7. How This Document Is Organized

This document is organized as follows:

- Section 2 of this document briefly describes the current *IESO's* pre-dispatch Dispatch Scheduler and Optimizer (DSO) and the difference between that engine and the future PD calculation engine.
- Section 3 of this document provides a detailed description of the functional design inferred from sections relevant to the PD Calculation Engine in the high-level designs for Single Schedule Market (SSM), Day-Ahead Market (DAM) and Enhanced Real-time Unit Commitment (ERUC).
- Section 4 of this document describes how the PD Calculation Engine processes will be enabled under the authority of the *market rules* in terms of existing rule provisions, amended rule provisions and additional rule provisions that will need to be developed.
- Section 5 of this document describes the requirements of the PD Calculation Engine processes for a system of internal and market-facing procedures in terms of existing procedures, amended procedures and additional procedures that will need to be developed.
- Section 6 of this document provides an overview of the arrangement of *IESO* processes supporting the overall PD Calculation Engine processes described in Section 3. This section also outlines the logical boundaries and interfaces of the various sub-processes related to the PD Calculation Engine in terms of existing processes, amended processes and additional processes that will need to be developed.

– End of Section –

2. Summary of the Current and Future State

2.1. The Calculation Engine in Today's Pre-Dispatch Scheduling Process

The core component of the current *IESO-administered markets* is a calculation engine referred to as the Dispatch Scheduler and Optimizer (DSO). The DSO implements the *dispatch algorithm* as defined in the *market rules* to formulate schedules for *generation facilities*, *dispatchable loads* and *intertie* transactions, and to calculate *market prices* for *energy* and *operating reserve*.

The DSO operates in both the pre-dispatch timeframe and the real-time timeframe and supports both *pre-dispatch scheduling* and real-time *dispatch*. The *pre-dispatch scheduling* process uses an iterative run of the DSO looking at future *dispatch hours.* Each iterative pre-dispatch DSO run uses updated *market participant* and *IESO* inputs to find an optimal outcome by integrating market and *reliability* priorities.

The *pre-dispatch scheduling* process is a means to transition from day-ahead scheduling to real-time operations. While the day-ahead commitment process (DACP) can commit resources to meet the following day's expected *demand*, conditions may change after the DACP is complete. Changes in Ontario supply and *demand* can occur due to various factors related to the weather forecast, supply from *variable generators* or system conditions. *Bids* and *offers* from all resources are evaluated in the pre-dispatch timeframe between the completion of the DACP and the real-time *dispatch*. This evaluation is undertaken to reliably meet real-time *demand* at the lowest possible cost.

Pre-dispatch scheduling determines advisory prices and schedules over a number of future hours. It also determines schedules for imports and exports for the next *dispatch hour. Pre-dispatch scheduling* combines with the *real-time dispatch process* to form the *IESO's real-time market.*

The DSO *pre-dispatch scheduling* process is run hourly in the pre-dispatch timeframe. It conducts two independent and simultaneous passes to produce two schedules for the pre-dispatch advisory hours. These schedules are referred to as the constrained *pre-dispatch schedule* and the unconstrained *pre-dispatch schedule*.

2.1.1. The Constrained Pre-Dispatch Schedule

To maintain the *reliability* of the *IESO-controlled grid*, a constrained *pre-dispatch schedule* that takes into account the resource and system constraints is required. DSO constrained *pre-dispatch* scheduling considers the detailed network model of the *IESO-controlled grid*, allowing it to account for losses associated with moving electricity through the system, resource constraints and *security* constraints.

DSO constrained *pre-dispatch scheduling* produces advisory *pre-dispatch* schedules for each pre-dispatch advisory hour, providing a forward looking view of future operation for *market participants* and the *IESO*.

2.1.2. The Unconstrained Pre-Dispatch Schedule

The DSO unconstrained *pre-dispatch schedule* is used to determine a uniform hourly advisory price across the province and at each *intertie zone* every hour. These prices ignore most resource and system constraints. Therefore, the uniform price does not reflect the real cost of generating or consuming electricity at different locations within Ontario.

The pre-dispatch hourly price is advisory in nature and is not used for market *settlement* with one exception. The *intertie congestion price (ICP)* reflects differences between the *intertie zone* price and the uniform hourly advisory price determined in the unconstrained *pre-dispatch schedule*. It is added to the five-minute real-time prices to determine the real-time *intertie* zonal prices used for *settlement* of *intertie* transactions.

2.1.3. Single Hour Optimization Look-Ahead Period, Timing and Frequency

The pre-dispatch DSO provides advisory schedules by performing optimization over a single hour look-ahead period at specific timings and with a pre-defined frequency.

2.1.3.1 Single Hour Optimization

The pre-dispatch DSO provides advisory schedules for all hours in the pre-dispatch time horizon using a one-hour look-ahead period. This means that costs are evaluated separately for each hour and physical limitations that span multiple hours such as *minimum generation block run time* are not modelled.

2.1.3.2 Timing and Frequency

The timing of the *pre-dispatch scheduling* process for each *dispatch day* starts after the DACP completes at 15:00 Eastern Standard Time (EST) of the *pre-dispatch day* and encompasses all hours up to and including the last hour of the next *dispatch day*. As such, the pre-dispatch DSO produces rolling hourly advisory schedules for a time horizon of 9 to 32 hours in advance of a *dispatch hour.* Both the pre-dispatch DSO and the real-time DSO runs and the resulting schedules are produced on Eastern Standard Time (EST) throughout the calendar year.

The pre-dispatch DSO runs hourly and provides advisory prices and schedules, including binding *intertie* schedules for the next *dispatch hour* by 15 minutes past the hour. The hourly run frequency and notification time facilitate the coordination of *intertie* transaction schedules between the *IESO* and neighbouring jurisdictions.

The timing also provides an opportunity for *market participants* to review advisory schedules and prices and respond by revising *bids* or *offers* before the next pre-dispatch DSO run, if desired. For most resources, the *pre-dispatch scheduling* process does not produce any form of financial guarantee. Instead, it provides information on how resources are likely to be *dispatched*, so that *market participants* can prepare for real-time operation.

Finally, the timely provision of advisory schedules and prices inform *registered market participants* for non-quick start (NQS) *generation facilities* of their eligibility to self-commit under the existing Real-Time Generation Cost Guarantee (RT-GCG) program.

Figure 2-1 illustrates the timing and the hours evaluated by each pre-dispatch DSO run. The hour ending (HE) convention is used to number each hour in a day, from HE1 to HE24. For example, HE2 runs from 01:01 to 02:00 EST. The pre-dispatch DSO run that starts after 01:00 runs during HE2.

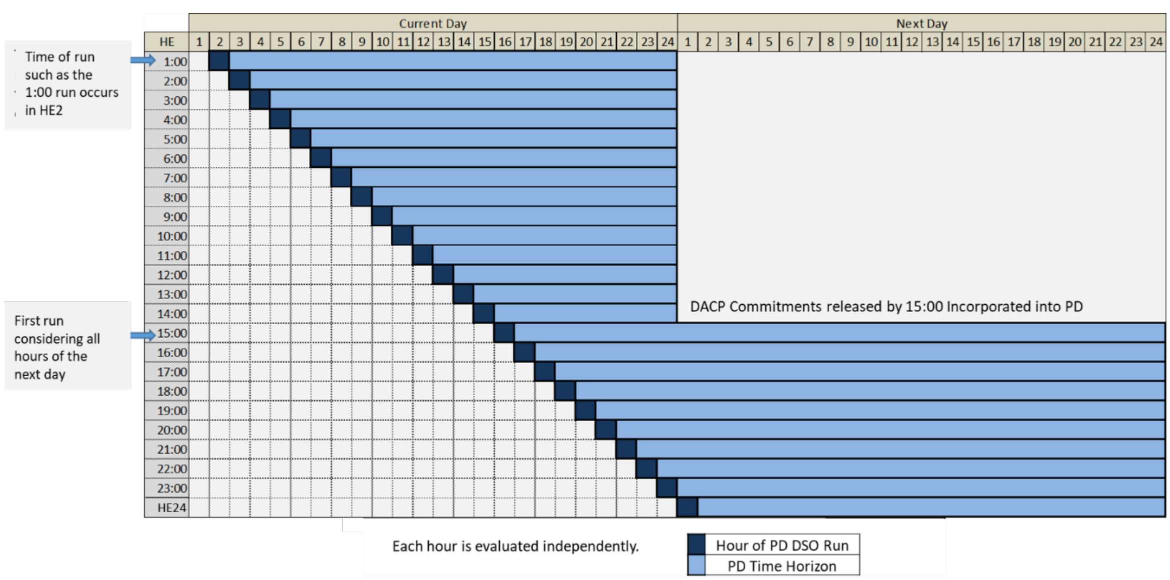

Figure 2-1: Current PD Calculation Engine Run Timing and Single Hour Look-Ahead Period

2.1.4. Inputs to the Pre-Dispatch DSO

The pre-dispatch DSO requires data inputs from both *market participants* and the *IESO* to calculate the constrained *pre-dispatch schedules* and unconstrained *pre-dispatch schedules*.

2.1.4.1 Market Participant Inputs

Market participant inputs used by the pre-dispatch DSO include:

- *Offers* to supply *energy* and/or *operating reserve* from dispatchable resources;
- *Intertie bids* and *offers* for *energy* and *operating reserve*;
- *Bids* for the withdrawal of *energy* by *dispatchable loads*;
- *Bids* to reduce *energy* withdrawals by *hourly demand response* resources;
- Ramp rates;
- *Self-schedules* from non-dispatchable generation resources provided as an *offer* for *energy* with a single *price-quantity pair*. This *price-quantity pair* indicates both the schedule and the price below which the resource is expected to reduce its output to zero;
- Daily *energy* limits for *energy*-limited resources; and
- *Outage* information from all resources.

2.1.4.2 IESO Inputs

The *IESO* provides data inputs to the pre-dispatch DSO that include:

- *Demand* forecasts;
- *Operating reserve* requirements;
- *Variable generation* forecasts;
- DACP and RT-GCG operational commitments;
- *Hourly demand response* resource schedules for the next two hours; and
- Network information such as transmission line data and constraints.

The *IESO* currently produces a single, province-wide *demand* forecast that is used to support scheduling decisions in the *pre-dispatch scheduling* processes. Hourly forecasts are used in the DSO to calculate *pre-dispatch schedules* for the remaining hours of the *pre-dispatch day* and *dispatch day*. The province-wide forecast is generated using historical *demand* data and expectations of future load consumption that are based on several factors, including weather forecasts.

For each *registered facility* supplying *variable generation,* the *IESO* provides production forecasts for all remaining hours of the *pre-dispatch day* and *dispatch day*.

NQS operational commitments from the DACP and the RT-GCG program are provided to both schedules of the pre-dispatch DSO. All other dispatchable *generation facilities* and *dispatchable loads* are available for hourly scheduling in the constrained *pre-dispatch* schedule without constraints imposed by the DACP or previous runs of the *pre-dispatch scheduling* process.

2.1.5. Pre-Dispatch DSO Integration with the DACE and Real-Time DSO

The pre-dispatch DSO runs independently from the day-ahead calculation engine (DACE) with two exceptions.

- *Offers* and *bids* for *energy* and *operating reserve* submitted into the DACP are carried over as inputs to the *pre-dispatch scheduling* process unless updated by the *market participant*.
    - *Offers* from combined cycle *facilities* choosing to be represented as a *pseudo-unit* are only used in the DACE and *offers* must be submitted on a physical unit basis in the pre-dispatch timeframe.
- NQS *generation facility* operational commitments from the DACP are carried over to the pre-dispatch DSO. These operational commitments provide minimum operational constraints for the *minimum loading point* (MLP) and for all hours in which the *generation unit* was scheduled by the DACE to at least the unit's MLP.

The pre-dispatch DSO also runs independently from the real-time DSO except for NQS *generation facility* operational commitments and *intertie* schedules. The NQS *generation facility* operational commitments considered by the pre-dispatch DSO are provided to the real-time DSO. The constrained and unconstrained *intertie* schedules calculated by the pre-dispatch DSO are provided to the real-time DSO, subject to the *intertie* check-out procedure and curtailment in real time.

2.1.6. The Dispatch Algorithm

The constrained *pre-dispatch* schedule and unconstrained *pre-dispatch schedule* are both calculated by a joint optimization in which the *bids* and *offers* in the *energy market* and *offers* in the *operating reserve market* are evaluated at the same time. Each hour in the *pre-dispatch scheduling* process for the remaining hours of the *pre-dispatch day* and *dispatch day* is evaluated and optimized independently of all other hours with the objective to maximize the gains from trade within the hour.

The constrained *pre-dispatch* schedule considers key system operational constraints in order to optimize and maintain system *security*. These constraints include *operating reserve* requirements, transmission *security* constraints, *intertie* limits and generation limitations.

The unconstrained *pre-dispatch* schedule does not consider all operational constraints, but respects *operating reserve* requirements, *intertie* limits and ramp rates.

2.1.6.1 Unit Commitment Process for NQS Generation Facilities

The *pre-dispatch scheduling* process provides information on how generation resources are likely to be *dispatched.* It does not perform unit commitment of NQS resources. This is because it does not recognize operational restrictions such as *minimum loading point* (MLP) or *minimum generation block run-time* (MGBRT) and does not take into account *start-up costs* and *speed no-load costs*. It schedules NQS resources in the same manner as it does for other resources; hourly advisory schedules are provided based on incremental *energy offers*.

Today's unit commitment decisions in the *pre-dispatch scheduling* process are voluntarily invoked by *market participants* through the RT-GCG program. *Market participants* can invoke a unit commitment if their NQS resource has a pre-dispatch advisory schedule at MLP or greater for at least half of its MGBRT hours. Once a unit commitment has been invoked the pre-dispatch DSO respects operational restrictions such as MLP and MGBRT.

2.1.7. Outputs from the Pre-Dispatch DSO

The pre-dispatch DSO receives inputs from *market participants* and the *IESO* and produces a set of results in the form of schedules and prices. Only *intertie* schedules for the next *dispatch hour* are binding; internal resource schedules in the next *dispatch hour* and schedules for all remaining hours of the *pre-dispatch day* and *dispatch day* are advisory.

Figure 2-2 provides a high-level overview of the current calculation engine for the *pre-dispatch scheduling* processes.

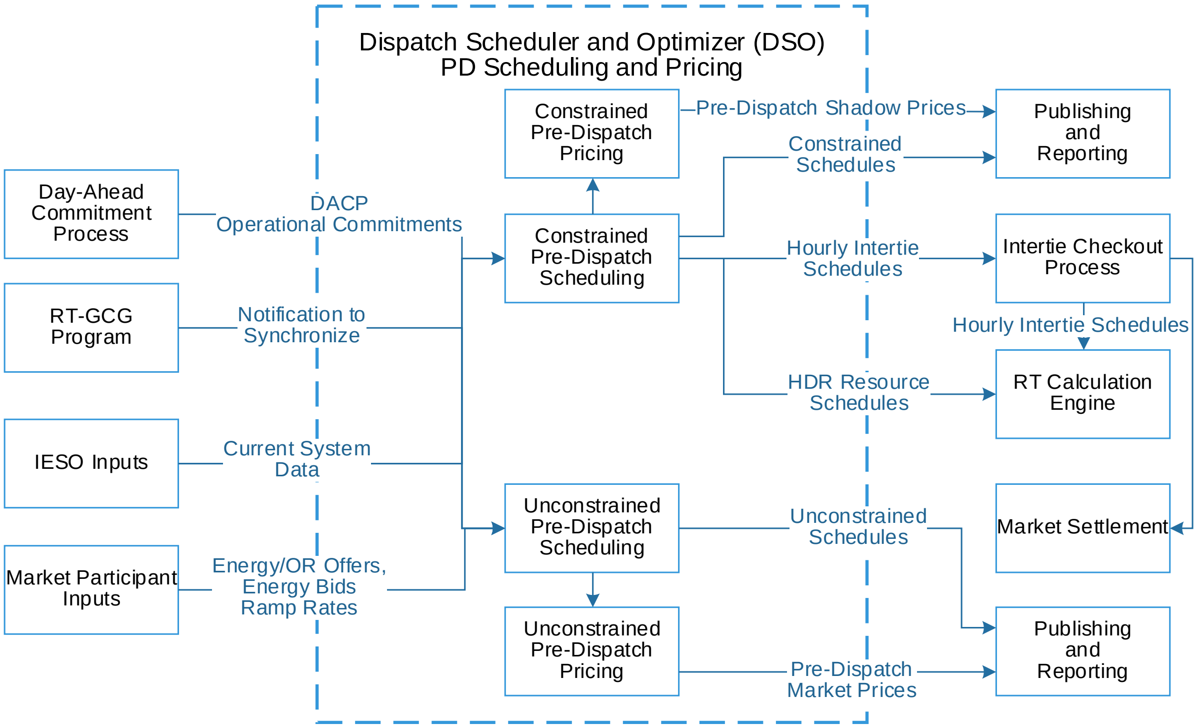

Figure 2-2: Current PD Calculation Engine Processes

2.2. The Calculation Engine in the Future Pre-Dispatch Scheduling Process

In the future market, the pre-dispatch DSO will be replaced by a redesigned PD calculation engine that will incorporate several changes. The PD calculation engine will:

- be composed of one pass, Pre-Dispatch Scheduling Process. This pass will take into account resource and system constraints to determine advisory schedules, locational marginal prices (LMPs) and zonal prices;
- schedule additional unit commitments as needed by assessing the *energy offers*, start-up *offers* and speed-no-load *offers* from NQS *generation facilities*;
- optimize over a longer look-ahead period that always includes the remaining hours of the day, and may include the next *dispatch* day; and
- include an ex-ante Market Power Mitigation process.

The PD calculation engine will use some outputs from the DAM calculation engine along with revised *market participant* and *IESO* data inputs to determine pre-dispatch LMPs and schedules. These LMPs and schedules will be advisory only[1] and will not be used for *settlement*. The PD calculation engine will continue to set binding schedules for *intertie* transactions in the last run before a given *dispatch hour*.

2.2.1. Multi-Hour Optimization

The PD calculation engine will use multi-hour optimization that optimizes all *bids, offers* and resource costs over a longer look-ahead period. This multi-hour optimization will also consider resource operating restrictions for all applicable resources. In addition, DAM financially binding schedules for NQS resources will be provided with an initial commitment for their MGBRT and MLP operational restrictions in all runs of the PD calculation engine.

2.2.2. Timing and Frequency

The PD calculation engine runs will continue to occur hourly to provide advisory prices and schedules. It will occur within the period between clearing of the day-ahead market and the real-time *dispatch*.

While the DAM financially binding schedules for the next *dispatch* day will be provided daily on the current *dispatch day* at 13:30 EPT, the initial PD calculation engine run for the next *dispatch* day will start with the 20:00 EST run in the current *dispatch day*.

The 20:00 EST PD calculation engine run will have the longest look-ahead period, optimizing over 27 hours, from HE22 of the current *dispatch day* until HE24 of the next *dispatch day*, inclusive. The 19:00 EST evaluation has the shortest look ahead period with four hours of optimization for HE21 to HE24 (inclusive) of that day.

By 15 minutes past the hour, schedules for all hours in the PD look-ahead period will be provided to all dispatchable and non-dispatchable suppliers, loads that are considered dispatchable in the pre-dispatch timeframe and *intertie* transactions. These results will include notification of new NQS resource PD operational commitments such as binding start-up instructions and extensions.

By 30 minutes past the hour, advisory LMPs and zonal prices will be provided. The schedule information provided at 30 minutes past the hour will not change information already provided at 15 minutes past the hour.

Figure 2-3 illustrates the timing and the hours evaluated by the future PD calculation engine runs. All hours considered by the optimization are included in the look-ahead period.

[1]One exception is that *intertie* congestion determined in the last run before a given *dispatch hour* will continue to affect real-time *settlement* of *intertie* transactions.

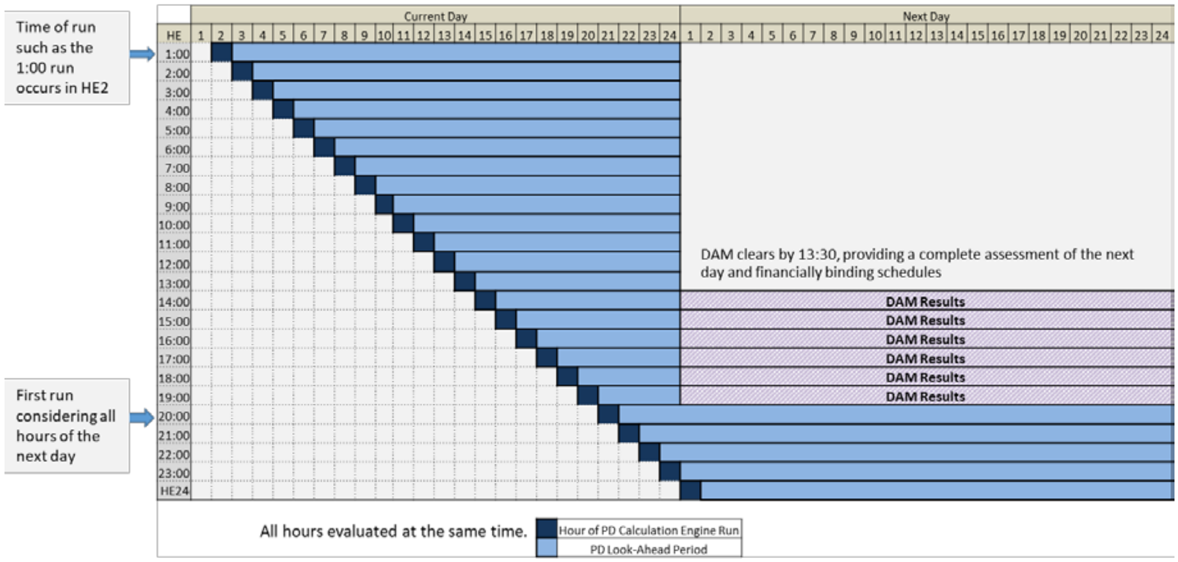

Figure 2-3: Future PD Calculation Engine Run Timing and Multi-Hour Look-Ahead Period

2.2.3. Inputs to the Future Pre-Dispatch Calculation Engine

As with the DAM calculation engine, the PD calculation engine will use inputs from *market participants* and the *IESO*.

2.2.3.1 Market Participant Inputs

Similar to the current process, the PD calculation engine will require *market participants* to submit *dispatch data*. The existing data submission constructs of daily generator data (DGD) will be retired and replaced by the submission of hourly and daily *dispatch data* parameters.

Market participants with NQS resources will be required to submit financial *dispatch data* parameters in pre-dispatch that will include hourly *energy offers*, speed-no-load *offers*, and start-up *offers*.

Market participants will continue to register applicable operational restrictions for their resources. They will also be authorized to submit non-financial *dispatch data* parameters into the market as daily *dispatch data*.

In addition to the common set of *dispatch data* parameters, NQS and hydroelectric resources will have additional *dispatch data* parameters specific to the operational characteristics of these generation resources. For a detailed description of the changes to *market participant* inputs, refer to the Offers, Bids and Data Inputs detailed design document.

2.2.3.2 IESO Inputs

In addition to the *IESO* inputs that the pre-dispatch DSO uses, the PD calculation engine will utilize new *IESO* data inputs.

Examples of these new data inputs include those associated with the enhanced network model providing pricing locations for all *delivery points* associated with dispatchable *generation facilities*, *dispatchable loads*, non-dispatchable *generation facilities*, *non-dispatchable loads* and price responsive loads. *Demand* forecasts will be produced as the sum of four separate area *demand* forecasts to better reflect localized weather conditions and consumption patterns for each area. Similar to today's market, the PD calculation engine will use a *demand* forecast of the forecast hourly peak *demand* for any hour where there is a significant difference between forecast peak *demand* and forecast average *demand* quantity.

For a detailed description of the changes to *IESO* inputs, refer to the Offers, Bids and Data Inputs detailed design document.

2.2.4. PD Calculation Engine Integration with the DAM and RT Calculation Engines

The PD calculation engine will run independently from the DAM calculation engine with the following exceptions:

- *Offers* and *bids* for *energy* and *operating reserve* submitted into the DAM, including *offers* from *pseudo-units,* are carried over as inputs to the *pre-dispatch scheduling* process unless updated by the *market participant.* Updates are subject to restrictions as described in the Grid and Market Operations detailed design document;
- NQS *generation facility* operational commitments are carried over as minimum operational constraints to the PD calculation engine. DAM operational commitments are carried over to the PD calculation engine as minimum operational constraints to the resource's MLP for a length of the resource's MGBRT*.* DAM schedules for other dispatchable generation resources are not input into the *pre-dispatch scheduling* process; and
- The DAM scheduled quantities for import and export transactions will limit import and export schedules. Beyond the first two forecast hours of the pre-disaptch look-ahead period, the PD engine will not consider import *offer* and export *bid* laminations that are higher than a transaction's day-ahead *market schedule*. Capacity imports/exports and imports to meet *reliability* needs are not limited by their DAM scheduled quantities in all forecast hours of the look-ahead period.

The PD calculation engine also runs independently from the RT calculation engine with the following exceptions:

- Hydroelectric *generation facility* minimum daily *energy* limits when binding and hourly must-run amounts are carried over from the PD calculation engine to the RT calculation engine as minimum operational constraints;
- NQS *generation facility* DAM and PD operational commitments are carried over from the PD calculation engine to the RT calculation engine as minimum operational constraints; and
- The *intertie* schedules calculated by the PD calculation engine are provided to the RT calculation engine, subject to the *intertie* check-out procedure and curtailment in real time.

2.2.5. The Dispatch Algorithm

Consistent with the current market, *security*-constrained advisory schedules will be produced by the PD calculation engine for *market participants* that *offer* and *bid* into the market. A *security*-constrained optimization engine will consider key system operational constraints in order to optimize and maintain system *security*. These constraints will include *operating reserve* requirements, transmission *security* constraints and generation limitations.

The future PD calculation engine will be composed of one pass, Pass 1: Pre-Dispatch Scheduling Process, which calculates both constrained pre-dispatch schedules and LMPs. Pass 1 will first calculate advisory schedules and prices by determining the optimal unit commitment and economic *dispatch* over the pre-dispatch look-ahead period for *energy* and *operating reserves.* Pass 1 will then perform the ex-ante Market Power Mitigation processes, the results of which will be applied to scheduling and pricing in subsequent PD calculation engine runs.

The following provides a description of the steps included in the PD calculation engine pass:

- Pre-Dispatch Scheduling: Determines commitments for NQS resources and schedules for all resources, including self-scheduling suppliers. It uses as-offered *dispatch data* from *market participants* except for *dispatch data* that was mitigated in ex-ante Market Power Mitigation in a previous run of pre-dispatch. Pre-Dispatch Scheduling will perform a *security*-constrained unit commitment and economic *dispatch* that maximize the gains from trade and considers resource and system constraints. The commitments calculated will serve as inputs into Pre-Dispatch Pricing. The schedules will be binding for *intertie* transactions and NQS operational commitment extensions in the upcoming *dispatch hour*, and will be used to issue binding start-up instructions as required.
- Pre-Dispatch Pricing: Determines LMPs that account for resource and system constraints. It uses the same *dispatch data* and the set of *IESO* inputs as used in Pre-Dispatch Scheduling with one exception. Instead of the

constraint violation penalty curves for *reliability*, this step uses the constraint violation penalty curves that are relevant for pricing. The LMPs produced are advisory and not used for *settlement*. The prices determined will be used in ex-ante Market Power Mitigation.

- Market Power Mitigation: After Pre-Dispatch Scheduling and Pre-Dispatch Pricing are complete, the PD calculation engine will run the ex-ante Market Power Mitigation process. For all forecast hours of the look-ahead period, it will identify areas of restricted competition and the *dispatch data* parameters submitted for resources in these areas that fail the conduct and price impact tests. For hours beyond the first forecast hour, such *dispatch data* will be replaced by their reference levels for all future PD calculation engine runs containing such hours in their look-ahead period. The ex-ante Market Power Mitigation process comprises the following steps:
- Constrained Area Conditions Test: The initiation of the ex-ante Market Power Mitigation process is based on specific conditions corresponding to the constrained area to which a resource belongs. When an area is constrained from being supplied by additional resources, competition is reduced and this creates the potential for the exercise of market power. The constrained area conditions test will use the results of Pre-Dispatch Pricing to determine if the conduct test of the ex-ante Market Power Mitigation process needs to be initiated. For more information regarding the different types of constrained areas, refer to the Market Power Mitigation detailed design document.
- Conduct Test (if necessary): If conditions related to the restriction of competition are met, the conduct test will determine if financial *dispatch data* parameter values submitted by a *market participant* for a resource differ from their reference levels by more than the relevant conduct threshold. If one or more *dispatch data* parameter values for any resource fail the conduct test, then Reference Level Scheduling and Reference Level Pricing will occur to facilitate the price impact test. If no financial *dispatch data* parameter value fails the conduct test, then no further steps in the ex-ante Market Power Mitigation process are necessary.
- Reference Level Scheduling (if necessary): Uses nearly all of the same inputs and produces the same outputs as Pre-Dispatch Scheduling. The exception is that any *dispatch data* parameter value that failed the conduct test will be replaced by the reference level value for that *dispatch data* parameter.
- Reference Level Pricing (if necessary): Uses nearly all of the same inputs and produces the same outputs as Pre-Dispatch Pricing with the following two differences:

  - The *dispatch data* parameter values that failed the conduct test will be replaced by the reference level value for that *dispatch data* parameter; and
  - The commitments and resource schedules that are inputs to this step will be obtained from Reference Level Scheduling.
- Price Impact Test (if necessary): Compares the prices from Pre-Dispatch Pricing to those from Reference Level Pricing. The price impact test is failed if one or more prices in Pre-Dispatch Pricing is greater than the corresponding price from Reference Level Pricing by a specified impact threshold. If the Price Impact test is failed by a resource, then reference levels will be used to replace the *dispatch data* parameters that failed the conduct test for that resource and these mitigated parameters will be used in future PD calculation engine runs.

An updated *dispatch data* set to be used in the next PD calculation engine run will be determined, adding to the mitigation decisions from the previous PD calculation engine runs. This updated dataset will also be passed to the RT calculation engine for the following *dispatch hour*.

2.2.5.1 Enhanced Real-Time Unit Commitment for NQS Generation Facilities

The *dispatch algorithm* described above is an enhanced unit commitment process that takes into account many of the operating characteristics of NQS *generation facilities* and uses a multi-hour optimization to make NQS commitment decisions. This improved modelling will recognize and respect NQS operational restrictions such as MLP, MGBRT and MGBDT that limit the resource's ability to generate. The enhanced unit commitment will also evaluate start-up *offers* and speed-no load *offers*.

The PD calculation engine will commit NQS *generation facilities* and schedule them to come online and reach MLP at a certain time based on their submitted *dispatch data*. At the time of commitment, the PD calculation engine will provide a binding start-up instruction that is based on *energy offers*, start-up *offers* and speed-no-load *offers* and takes into account operational restrictions over multiple hours.

The PD calculation engine will not change a MLP and MGBRT operational constraint set in respect of a DAM schedule. However, NQS *generation facilities* may receive a PD operational commitment that is an advancement or extension to an existing DAM commitment.

2.2.6. Outputs from the PD Calculation Engine

Pre-Dispatch Scheduling Process will produce a set of results in the form of hourly schedules for all dispatchable and non-dispatchable *generation facilities*, *intertie* transactions, *dispatchable loads* and *hourly demand response* resources. It will also produce hourly advisory LMPs and hourly zonal prices.

Intertie schedules for the next *dispatch hour* will continue to be binding. The NQS operational commitment extensions will also be binding in the upcoming *dispatch hour*, along with the NQS commitments in future hours that meet the criteria to receive a binding start-up instruction.

Internal resource schedules in the next *dispatch hour* and schedules for all other PD look-ahead period hours will continue to be advisory.

The output of the PD calculation engine includes private and public reporting to the *market participants* and the *IESO* including private notifications of information relating to binding start-up instructions and operational constraints, specifically:

- Notification: the process and timing for notifying *market participants* of a binding start-up instruction and operational constraints; and
- Confirmation: the process and timing of the confirmation the *IESO* will need to receive from *market participants* in response to any notification of commitment, in order to ensure operational certainty.

Refer to the Publishing and Reporting Market Information detailed design document for details of these outputs.

Figure 2-4 provides a high-level overview of the future PD calculation engine processes. The notation “pdr (pre-dispatch run) n+1” indicates the approach to applying the results from the market power mitigation tests to subsequent PD calculation engine runs.

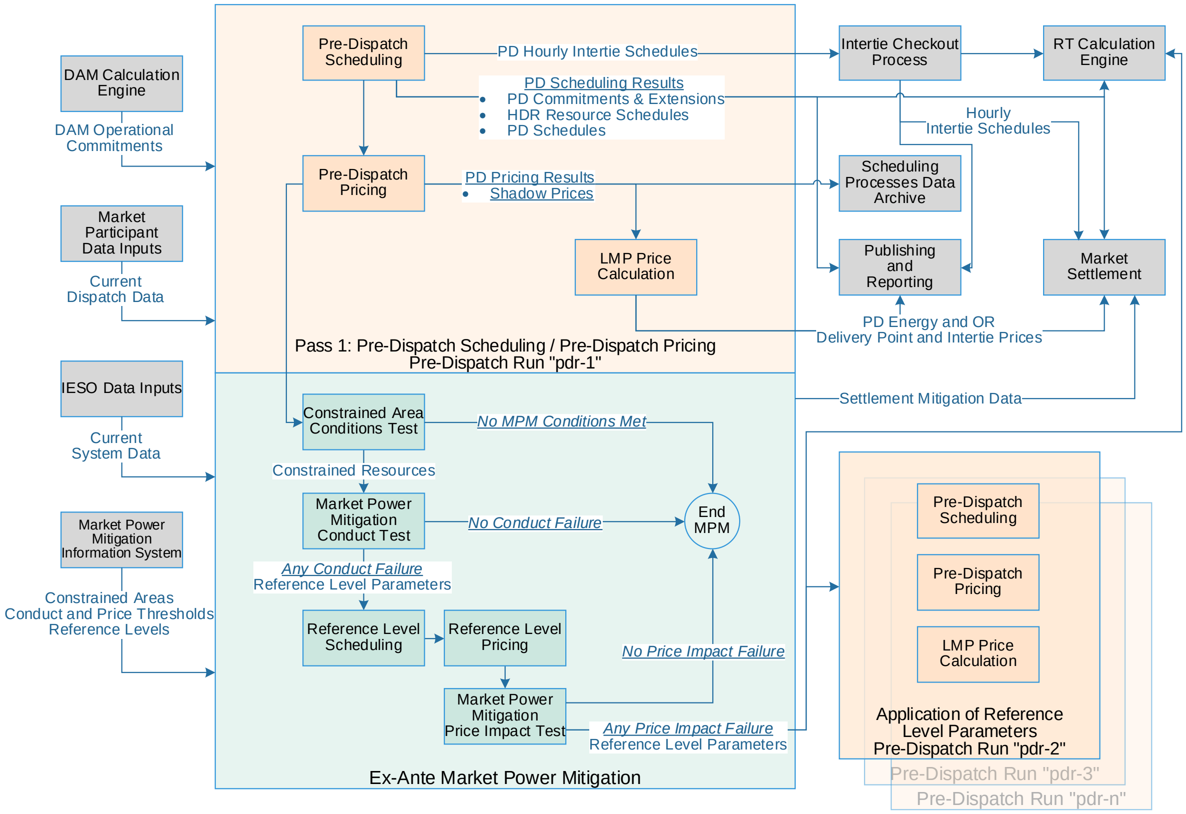

Figure 2-4: Future PD Calculation Engine Processes

– End of Section –

3. Detailed Functional Design

3.1. Structure of this Section

For the purposes of this document, schedules and prices for a 'resource' refer to schedules and prices for a resource within a *generation facility* or *dispatchable load facility* for a *registered market participant*.

The design of the Pre-Dispatch (PD) calculation engine will be described in terms of:

- Objectives
- PD Calculation Engine Functions
- Inputs into the PD Calculation Engine
- Initialization
- Pass 1: Pre-Dispatch Scheduling Process
    - Pre-Dispatch Scheduling
    - Pre-Dispatch Pricing
    - Market Power Mitigation
        - Constrained Area Conditions Test
        - Conduct Test
        - Reference Level Scheduling
        - Reference Level Pricing
        - Price Impact Test
- Security Assessment Function
- Pricing Formulas
- Data Generation for Settlement Mitigation
- The Pseudo-Unit Model
- Determination of the Non-Dispatchable Load Forecast

3.2. Objectives

The objective of this detailed functional design is to define the PD calculation engine functions in terms of the scheduling and pricing algorithms used to maximize gains from trade for *energy* and *operating reserve* while providing for the necessary *reliability* and *security* of the *IESO-controlled grid*. This design also defines the PD calculation engine functions that are required for the ex-ante Market Power Mitigation process.

The high-level designs for MRP identify several objectives for the Ontario *real-time market* for *energy* and *operating reserve*. These objectives, when achieved, will provide the following improvements to the overall *IESO-administered markets*:

- Ensuring the most cost-effective set of resources will be available to meet *demand* in real-time when changes in system needs arise in the pre-dispatch timeframe;
- Enhancing the real-time unit commitment process so that it considers all *offered* costs and resource constraints to arrive at the most cost-effective NQS resources available in real time by issuing operational commitments as required; and
- Providing information to resources on how they are likely to be *dispatched* so they can prepare for real-time operation.

3.3. PD Calculation Engine Functions

Pre-dispatch scheduling and pricing will be driven by a PD calculation engine composed of a single pass–Pre-Dispatch Scheduling Process–that calculates both schedules and LMPs.

The PD calculation engine will perform a multi-hour optimization to calculate advisory schedules and prices by determining the optimal unit commitment and economic *dispatch* over the pre-dispatch look-ahead period*.* These schedules will be binding for *intertie* transactions. NQS operational commitment extensions will be binding in the upcoming *dispatch hour*, along with NQS commitments in future hours that meet the criteria to receive a binding start-up instruction. The PD calculation engine will then perform the Market Power Mitigation processes, the results of which will be applied to Pre-Dispatch Scheduling and Pre-Dispatch Pricing in subsequent PD calculation engine runs.

A scheduling algorithm will calculate hourly commitment statuses and resource schedules to meet *demand*. It will perform a *security*-constrained unit commitment and economic *dispatch* of available resources*.* This will be achieved by performing multiple iterations between an optimization function and a *security* assessment function.

The multiple iterations will be carried out as follows:

1. The optimization function will determine commitment status decisions and the optimal economic scheduling of committed resources. To do this, the optimization function will consider inputs from *market participants* and the *IESO*, and also take into account resource and system constraints.
2. Each time the optimization function determines resource schedules, the *security* assessment function will assess the *security* of the resulting constrained *dispatch* by considering transmission and operating limits. If the *security* assessment function identifies limit violations, an updated *security* constraint set will be provided to the optimization function, and another iteration will be performed.
3. The scheduling algorithm will conclude when the *security* assessment function does not identify any additional *security* limits for the optimization function to enforce.

The commitment statuses determine the eligibility of a resource for economic scheduling within the scheduling algorithm and the corresponding pricing algorithm. For each hour of the pre-dispatch timeframe, the commitment status of a resource will either be “committed” or “not committed”, and the following will apply:

- If a resource is committed, then it will be scheduled to at least its MLP and will be eligible for economic scheduling above its MLP; or

- If a resource is not committed, it will not be eligible for economic scheduling. It will receive a zero schedule, unless it is an hour where ramp *energy* to MLP is scheduled.

A non-dispatchable resource or a quick-start resource will always be committed in each hour when it has been *offered* because such resources do not have commitment costs and have an MLP of zero. The commitment status of an eligible NQS resource for any given hour will be determined by the scheduling algorithm. The commitment statuses determined in Pre-Dispatch Scheduling will be used to derive operational commitments.

A pricing algorithm will calculate LMPs. The pricing algorithm will primarily use the same set of *market participant* inputs, *IESO* inputs and resource and system constraints as the scheduling algorithm. It will use the commitment statuses and certain resource schedules from the scheduling algorithm to determine LMPs by performing a *security*-constrained economic *dispatch.* Similar to the scheduling algorithm, the pricing algorithm will perform multiple iterations between an optimization function and a *security* assessment function. The pricing algorithm will use the same *security* assessment function that is used in the scheduling algorithm. However, the optimization function will be modified to:

- enforce the unit commitment statuses determined in the scheduling algorithm;
- use the constraint violation penalty curves for determining *market prices*;
- not schedule *intertie* transactions for *emergency* purchases that do not support a sale; and
- allow an *offer* or *bid* lamination to set price in accordance with the price-setting eligibility principle, which will be applied after taking the scheduling algorithm results into account.

The PD calculation engine will use the *security* assessment function in the scheduling and pricing algorithms to perform the following calculations and analyses, and provide inputs to the subsequent optimization function iteration.

1. Base case power flow: A base case (also known as pre-contingency) power flow will be prepared and solved for each hour. The base case solution will use the resource schedules produced by the optimization function along with planned transmission *outages*, load distribution factors and settings and parameters such as normal breaker/switch statuses, transformer tap positions, and desired voltages associated with the network model.
2. Pre-contingency *security* assessment: Continuous thermal limits for all monitored equipment and OSLs will be assessed using the base case solution for pre-contingency limit violations. Violated limits will be linearized and

incorporated as constraints for use by the subsequent iteration of the optimization function.

3. Loss calculation: The base case solution will be used to calculate the marginal loss factors and loss adjustment that will be used in the *energy* balance constraint of the optimization function.
4. Contingency analysis: A linear power flow will be used to simulate all valid contingencies, calculate post-contingency flows and check for limited-time (i.e. *emergency*) thermal limit violations. Violated limits will be linearized and incorporated as constraints for use by the subsequent iteration of the optimization function.

The inputs to the PD calculation engine are described in Section 3.4. Section 3.5 describes the initialization processes that the PD calculation engine will perform before the execution of its pass. Section 3.6 provides mathematical formulations of the optimization function for the scheduling algorithm and pricing algorithm. A description of the *security* assessment function common to the scheduling and pricing algorithms is provided in Section 3.7.

3.4. Inputs into the PD Calculation Engine

The PD calculation engine requires various inputs for its optimization function, the ex-ante Market Power Mitigation process and the *security* assessment function. The inputs for each function and their notations are described in the following sections.

For more information on the nomenclature used for the variables and the mathematical symbols used in the notations, refer to Appendix D.

3.4.1. Inputs into the Optimization Function

The optimization function requires:

- *market participant* inputs: This set will include *bids* and *offers*, in addition to reference levels that were applied as a result of a failure of the market power mitigation Price Impact test in a prior PD calculation engine run;
- inputs provided by the *IESO*; and
- the *security* constraint sets, marginal loss factors and loss adjustment provided by the *security* assessment function.

The optimization function for the pricing algorithm may also require the results of the preceding scheduling algorithm execution as inputs. Such inputs will be specified at the outset of the specific optimization function formulation.

3.4.1.1 Look-Ahead Period

The PD calculation engine will calculate resource schedules for the remaining hours of the current *dispatch day*. Starting with the 20:00 EST run, the PD calculation engine will also calculate schedules for all hours of the next *dispatch day*. Each hour for which the PD calculation engine calculates schedules will be referred to as a time-step. Time-steps are indexed by integers beginning at 1. Time-step 1 schedules are set based on the value determined by the *IESO's energy* management system. Therefore, time-step 1 schedules are not part of the PD calculation engine optimization.

For example, the 5:00 EST PD calculation engine run will have 19 hours in the look-ahead period. Time-step 1 corresponds to the HE6 PD schedules, which are already set, and time-step 2 corresponds to the HE7 PD schedules, which is the first forecast hour to be scheduled.

As another example, the 22:00 EST PD calculation engine run will have 26 hours in the look-ahead period. Time-step 1 corresponds to the HE23 PD schedules, which are already set. Time-step 2 corresponds to the HE24 PD schedules, which is the first forecast hour to be scheduled. HE6 of the next day is time-step 8. For more details on time-step 1 schedules, see Section 3.4.1.6.

The following notation will be used for indexing the days of the look-ahead period:

- $DAYS$ shall designate the set of days in the look-ahead period. If the look-ahead period spans one day, then $DAYS = \{tod\}$. If the look-ahead period spans two days, then $DAYS = \{tod, tom\}$.

The following notation will be used for indexing time-steps:

- n_{LAP} shall designate the number of time-steps in the look-ahead period;
- $TS = \{2,..,n_{LAP}\}$ shall designate the set of all time-steps in the look-ahead period that are included in the PD calculation engine optimization; and
- $TS_{tod} \subseteq TS$ shall designate the time-steps in the look-ahead period that are part of the current *dispatch day*.

If the look-ahead period spans two days, the following additional notation will be used:

- $TS_{tom} \subseteq TS$ shall designate the time-steps in the look-ahead period that are part of the next *dispatch day*; and
- $t_{tom} \in TS_{tom}$ shall designate the first time-step of the next *dispatch day*.

3.4.1.2 Fundamental Sets and Location Identifiers

For the purpose of describing the PD calculation engine processes and the constraints used by these processes, each internal resource whose *bids* and *offers* are considered by the optimization function will be identified by a unique bus, where:

- B shall designate the set of buses within Ontario, corresponding to *bids* and *offers* at locations on the *IESO-controlled grid*.

If more than one internal resource is connected to the *IESO-controlled grid* at the same electrical location, they will be considered to be at separate buses for the purposes of the optimization function.

Imports scheduled from and exports scheduled to each of the *intertie zones* will be modelled in the PD calculation engine as though they are occurring at a proxy location. Imports shall be modelled as though they are generation emanating from sources at the proxy location, and *exports* shall be modelled as though they are load occurring at sinks at the proxy location. The *IESO* shall define a number of source and sink buses in the *intertie zones* to be used by imports and exports. The electrical location of these source and sink buses will be identical for all *intertie* transactions at the same proxy location. However, transactions at the same proxy location but specified as occurring at different *intertie zones*, subject to phase shifter operation, will be modelled as flowing across independent paths.

Each import *offer* will be identified by a unique *intertie zone* source bus and each export *bid* will be identified by a unique *intertie zone* sink bus, where:

- A shall designate the set of all *intertie zones*;
- D shall designate the set of buses outside Ontario, corresponding to *bids, offers* and off-market transactions at *intertie zones*;
- $DX \subseteq D$ shall designate the subset of buses outside Ontario that correspond to exports;
- $DI \subseteq D$ shall designate the subset of buses outside Ontario that correspond to imports;
- $D_a \subseteq D$ shall designate the set of all buses outside Ontario in *intertie zone* $a \in A$;
- $DX_a \subseteq D_a$ shall designate the subset of buses outside Ontario that correspond to exports in *intertie zone* $a \in A$; and
- $DI_a \subseteq D_a$ shall designate the subset of buses outside Ontario that correspond to imports in *intertie zone* $a \in A$.

Assume B and D are disjoint (i.e. have no elements in common). The optimization function evaluates *bids* and *offers* for $b \in B \cup D$.

3.4.1.3 Load Inputs

Load inputs can belong to one of the following categories:

- *Demand* forecasts prepared by the *IESO*;
- *Dispatch data* for *dispatchable loads*;
- *Dispatch data* for *hourly demand response* resources. This includes both physical *hourly demand response* resources for which a *registered wholesale meter* and *delivery point* have been defined and virtual *hourly demand response* resources aggregated within various zones in the *distribution system*; and
- *Bids* to export *energy*.

Internal load buses of a specific resource type will be denoted as follows:

- $B^{DL} \subseteq B$ shall designate the set of buses identifying *dispatchable loads*; and
- $B^{HDR} \subseteq B$ shall designate the set of buses identifying *hourly demand response* resources.

Bid for *energy* laminations and *offer* for *operating reserve* laminations at a load bus will be denoted as follows:

- $J_{t,b}^{E}$ shall designate the set of *bid* for *energy* laminations for $b \in B \cup DX$ for time-step $t \in TS$;
- $J_{t,b}^{10S}$ shall designate the set of synchronized *ten-minute operating reserve offer* laminations at bus $b \in B$ for time-step $t \in TS$;
- $J_{t,b}^{10N}$ shall designate the set of non-synchronized *ten-minute operating reserve offer* laminations at bus $b \in B \cup DX$ for time-step $t \in TS$; and
- $J_{t,b}^{30R}$ shall designate the set of *thirty-minute operating reserve offer* laminations at bus $b \in B \cup DX$ for time-step $t \in TS$.

Demand Forecasts

The *IESO* shall prepare hourly *demand* forecasts that are representative of transmission losses and forecast consumption of all *load facilities* and *hourly demand response* resources. These *demand* forecasts will be produced for each of the *IESO's demand* forecast areas[2] and for each time-step of the look-ahead period. Before the optimization function uses these forecasts, they will be adjusted as described in Section 3.11 to arrive at a quantity that is representative of load that is considered non-dispatchable and is inclusive of losses, where:

- FL_t shall designate the hourly province-wide non-dispatchable *demand* forecast for time-step $t \in TS$.

The distribution of forecasted load to load locations within each forecast area is performed within the *security* assessment function. See Section 3.7.1.3 for more detail.

Dispatch Data for Dispatchable Loads

Registered market participants representing *dispatchable loads* may submit a *bid* to consume *energy*, *offers* to provide *operating reserve* and affiliated ramp rates. At most 20 *price-quantity pairs* corresponding to 19 laminations may be submitted in the *bid* to consume *energy*. At most five *price-quantity pairs* corresponding to four laminations may be submitted for each class of *operating reserve* the *dispatchable load* is qualified to provide. The non-dispatchable portion of a *dispatchable load*, i.e. the quantity of *energy* that is *bid* at $MMCP$, must always be scheduled. Table 3-1 lists the parameters for *dispatch data* submitted for a *dispatchable load* identified by bus $b \in B^{DL}$.

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[2] In the future market, the *IESO* will produce the existing province-wide *demand* forecast as the sum of separate *demand* forecasts for four *demand* forecast areas. For more information on *demand* forecasts, refer to the Offers, Bids and Data Inputs detailed design document.

Table 3-1: Parameters for Dispatch Data Submitted for Dispatchable Loads

Parameter	Description
$QDL_{t,b,j}$	shall designate an incremental quantity of *energy* consumption that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$.
$PDL_{t,b,j}$	shall designate the *bid* price to consume an incremental quantity of *energy* in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$. The *bid* price indicates the lowest *energy* price at which the *dispatchable load* prefers to forgo *energy* consumption.
$Q10SDL_{t,b,j}$	shall designate the synchronized *ten-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10S}_{t,b}$.
$P10SDL_{t,b,j}$	shall designate the price of being scheduled to provide synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10S}_{t,b}$.
$Q10NDL_{t,b,j}$	shall designate the non-synchronized *ten-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10N}_{t,b}$.
$P10NDL_{t,b,j}$	shall designate the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10N}_{t,b}$.
$Q30RDL_{t,b,j}$	shall designate the *thirty-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{30R}_{t,b}$.
$P30RDL_{t,b,j}$	shall designate the price of being scheduled to provide *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{30R}_{t,b}$.
$ORRDL_{b}$	shall designate the *operating reserve* ramp rate in MW per minute for reductions in load consumption.
$URRDL_{b}$	shall designate the maximum rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption.
$DRRDL_{b}$	shall designate the maximum rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption.

Parameter	Description
$QDLFIRM_{t,b}$	shall designate the quantity of *energy* that is *bid* at *MMCP* in time-step $t \in TS$.

As detailed in the Offers, Bids and Data Inputs detailed design document, *registered market participants* representing *dispatchable loads* may submit up to five ramp rates[3] for *energy* for each *dispatch hour*. The PD calculation engine will evaluate the same *energy* ramp rates for each time-step in the look-ahead period. The *energy* ramp rates used will correspond to the submitted *energy* ramp rates for the first time-step in which the *registered market participant* has submitted an *energy bid*. Similarly, the PD calculation engine will evaluate the same *operating reserve* ramp rate for each time-step in the look-ahead period.

The PD calculation engine will respect the *energy* ramping constraints determined by the submitted MW quantity (up to five), ramp up rate and ramp down rate value sets. The optimization function formulations provided in this document assume one ramp up rate and one ramp down rate apply across the entire operating range of a *dispatchable load*. For more information, see the *energy* ramping constraints in Section 3.6.1.5.

Dispatch Data for Hourly Demand Response Resources

An *hourly demand response* resource may submit an *energy bid* and affiliated ramp rates. If the resource is an aggregator, its *bid* will be identified with a proxy bus. The electrical location of this proxy bus depends only on the zone in which the *hourly demand response* resource has submitted a *bid*. Table 3-2 lists the parameters for *dispatch data* submitted for a physical or virtual *hourly demand response* resource identified by bus $b \in B^{HDR}$.

Table 3-2: Parameters for Dispatch Data Submitted for Hourly Demand Response Resources

Parameter	Description
$QHDR_{t,b,j}$	shall designate an incremental quantity of reduction in *energy* consumption that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J^E_{t,b}$.
$PHDR_{t,b,j}$	shall designate the *bid* price to incrementally reduce *energy* consumption in time-step $t \in TS$ in association with *bid* lamination $j \in J^E_{t,b}$. The *bid* price indicates the lowest *energy*

[3] The ramp rates include MW quantity, ramp up rate and ramp down rate values.

Parameter	Description
	price at which the resource prefers to forgo *energy* consumption.
$URRHDR_b$	shall designate the maximum rate in MW per minute at which the *hourly demand response* resource can decrease its amount of *energy* consumption.
$DRRHDR_b$	shall designate the maximum rate in MW per minute at which the *hourly demand response* resource can increase its amount of *energy* consumption.

If an *hourly demand response* resource has been activated, the resource will be scheduled to meet the corresponding obligation as per the Resource Minimum and Maximum Constraints sub-section in Section 3.4.1.5.

Bids to Export Energy

Each *bid* to export designates the amount of *energy* that the *registered market participant* wishes to schedule for export at a given price to an *intertie zone* and *boundary entity* proxy location. Except for Quebec, exports to other jurisdictions cannot be scheduled over individual *interties*. Several *intertie zones* are defined for Quebec so that exports may be scheduled over individual *interties* between Quebec and Ontario.

Market participants may submit *bids* to export *energy* along with *offers* to provide *operating reserve*. A maximum of 20 *price-quantity pairs* corresponding to 19 laminations may be submitted in a *bid* to export *energy*. A maximum of five *price-quantity pairs* corresponding to four laminations may be submitted for each class of *operating reserve* the exporter is qualified to provide.

Table 3-3 lists the parameters for *dispatch data* submitted for a *bid* to export at an *intertie zone* sink bus $d \in DX$.

Table 3-3: Parameters for Dispatch Data Submitted for Export Bids

Parameter	Description
$QXL_{t,d,j}$	shall designate the maximum quantity of *energy* for which the export to bus d in time-step $t \in TS$ may be scheduled in association with *bid* lamination $j \in J^E_{t,d}$.
$PXL_{t,d,j}$	shall designate the *bid* price of the exporter at bus d for an incremental quantity of *energy* in time-step $t \in TS$ in association with *bid* lamination $j \in J^E_{t,d}$. The *bid* price indicates the highest price at which the exporter is willing to be scheduled.

Parameter	Description
$Q10NXL_{t,d,j}$	shall designate the non-synchronized *ten-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{10N}$.
$P10NXL_{t,d,j}$	shall designate the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{10N}$.
$Q30RXL_{t,d,j}$	shall designate the *thirty-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$.
$P30RXL_{t,d,j}$	shall designate the price of being scheduled to provide *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$

If an export *bid* lamination's price is equal to the *maximum market clearing price* ($MMCP$), a price of $8 \cdot MMCP$ will be used in the optimization function for the scheduling algorithm and a price of $MMCP$ will be used in the optimization function for the pricing algorithm.

The PD calculation engine will economically schedule DAM scheduled *intertie* transactions and *bids* for export for non-DAM scheduled *intertie* transactions for the first two forecast hours of the look-ahead period. The DAM scheduled quantities for export transactions will limit export schedules beyond the first two forecast hours of the look-ahead period to only DAM scheduled *intertie* transactions. For *intertie zone* sink bus $d \in DX$:

- $SXLT_{t,d}^{DAM}$ shall designate the DAM scheduled quantity of *energy* for export to bus d in time-step $t \in \{4,..,n_{LAP}\}$;
- $S10NXLT_{t,d}^{DAM}$ shall designate the DAM scheduled quantity of non-synchronized *ten-minute operating reserve* in time-step $t \in \{4,..,n_{LAP}\}$; and
- $S30RXLT_{t,d}^{DAM}$ shall designate the DAM scheduled quantity of thirty-minute *operating reserve* in time-step $t \in \{4,..,n_{LAP}\}$.

Export *bids* that are flagged as *capacity exports* are eligible for economic scheduling beyond the first two forecast hours of the look-ahead period regardless of their DAM schedules. For each time-step $t \in \{4,..,n_{LAP}\}$:

- $DX_t^{CAPEX} \subseteq DX$ shall designate the *intertie zone* sink buses identifying export *bids* flagged as *capacity exports* in time-step t.

Export Bids in Wheeling Through Transactions

A wheeling through transaction consists of an individual *bid* to export *energy* to an *intertie zone* and an individual *offer* to import *energy* from another *intertie zone* in the same hour. Both the export *bid* and the import *offer* will be linked using the same North American Energy Standards Board (NAESB) e-Tag identifiers. The PD calculation engine will ensure that the export *bid* and import *offer* of the wheeling through transaction receive equal schedules. Wheeling through transactions will not be eligible to provide *operating reserve*.

For each time-step $t \in TS$:

- $L_t \subseteq DX \times DI$ shall designate the set of linked *intertie zone* sink and source buses corresponding to wheeling through transactions. Here, L_t is a set with elements of the form (dx, di) where $dx \in DX$ and $di \in DI$.

3.4.1.4 Supply Inputs

Supply inputs can belong to one of the following categories:

- *Dispatch data* for *self-scheduling generation facilities*, *transitional scheduling generators* and *intermittent generators*, known as non-dispatchable *generation facilities*;
- *Dispatch data* for dispatchable *generation facilities*; and
- Offers to import *energy* and provide *operating reserve*.

Internal supply buses of a specific resource type will be denoted as follows:

- $B^{NDG} \subseteq B$ shall designate the set of buses identifying non-dispatchable generation resources; and
- $B^{DG} \subseteq B$ shall designate the set of buses identifying dispatchable generation resources. Dispatchable generation resources can be further categorized by resource type as described in the Dispatch Data for Dispatchable Generation Facilities sub-section below.

Offer for *energy* laminations and *offer* for *operating reserve* laminations at a supply bus will be denoted as follows:

- $K^{E}_{t,b}$ shall designate the set of *offer* for *energy* laminations for $b \in B \cup DI$ for time-step $t \in TS$;
- $K^{10S}_{t,b}$ shall designate the set of synchronized *ten-minute operating reserve offer* laminations at bus $b \in B$ for time-step $t \in TS$;
- $K^{10N}_{t,b}$ shall designate the set of non-synchronized *ten-minute operating reserve offer* laminations at bus $b \in B \cup DI$ for time-step $t \in TS$; and

- $K_{t,b}^{30R}$ shall designate the set of *thirty minute operating reserve* offer laminations at bus $b \in B \cup DI$ for time-step $t \in TS$.

Dispatch Data for Non-Dispatchable Generation Facilities

The PD calculation engine takes into account the forecast output from non-dispatchable generation resources. The *registered market participants* of *self-scheduling generation facilities*, *transitional scheduling generators* and *intermittent generators* will provide *dispatch data* on forecast production and the lowest price at which they wish to be scheduled. The forecast production and price will be treated as an *offer* for *energy* with a single lamination. Table 3-4 lists the parameters for *dispatch data* submitted for a non-dispatchable generation resource identified by bus $b \in B^{NDG}$.

Table 3-4: Parameters for Dispatch Data Submitted for Non-Dispatchable Generation

Parameter	Description
$QNDG_{t,b,k}$	shall designate the incremental quantity of *energy* generation that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{E}$.
$PNDG_{t,b,k}$	shall designate the *offered energy* price for incremental generation in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{E}$. The *offered* price indicates the lowest price at which the non-dispatchable generation resource is willing to be scheduled.

Dispatch Data for Dispatchable Generation Facilities

Registered market participants representing dispatchable *generation facilities* may submit *offers* to supply *energy*, *offers* to provide *operating reserve*, and other affiliated *dispatch data*. A maximum of 20 *price-quantity pairs* corresponding to 19 laminations may be submitted in the *offer* to produce *energy*. A maximum of five *price-quantity pairs* corresponding to four laminations may be submitted for each class of *operating reserve* a resource is qualified to provide. The other *dispatch data* that may be submitted depend on the *facility* type. For example, NQS *generation facilities* may provide an *offered* value of starting a resource, operating that resource at its *minimum loading point,* and increasing output above the *minimum loading point*.

The following inputs are common to all dispatchable *generation facilities*. Table 3-5 lists the parameters for *dispatch data* submitted for a dispatchable generation resource identified by bus $b \in B^{DG}$.

Table 3-5: Parameters for Dispatch Data Submitted for Dispatchable Generation

Parameter	Description
$MinQDG_{q,b}$	shall designate the *minimum loading point* for day $q \in DAYS$. The *minimum loading point* is the minimum MW output that a resource must maintain to remain stable without the support of ignition and therefore, the minimum amount of *energy* the resource must be scheduled to produce in any time-step it is committed by the PD calculation engine.
$QDG_{t,b,k}$	shall designate an incremental quantity of *energy* (above and beyond the *minimum loading point*) that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K^{E}_{t,b}$.
$PDG_{t,b,k}$	shall designate the *offered energy* price for incremental generation in time-step $t \in TS$ in association with *offer* lamination $k \in K^{E}_{t,b}$. The *offered* price indicates the lowest *energy* price at which the resource is willing to be scheduled.
$Q10SDG_{t,b,k}$	shall designate the *offered* quantity of synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10S}_{t,b}$.
$P10SDG_{t,b,k}$	shall designate the *offered* price of being scheduled to provide synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10S}_{t,b}$.
$Q10NDG_{t,b,k}$	shall designate the *offered* quantity of non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10N}_{t,b}$.
$P10NDG_{t,b,k}$	shall designate the *offered* price of being scheduled to provide non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10N}_{t,b}$.
$Q30RDG_{t,b,k}$	shall designate the *offered* quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{30R}_{t,b}$
$P30RDG_{t,b,k}$	shall designate the *offered* price of being scheduled to provide *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{30R}_{t,b}$.
$ORRDG_{b}$	shall designate the maximum *operating reserve* ramp rate in MW per minute.

Parameter	Description
$URRDG_b$	shall designate the maximum rate in MW per minute at which the resource can increase the amount of *energy* it supplies (ramp rate up).
$DRRDG_b$	shall designate the maximum rate in MW per minute at which the resource can decrease the amount of *energy* it supplies (ramp rate down).
$RLP30R_{t,b}$	shall designate the reserve loading point for *thirty-minute operating reserve* in time-step $t \in TS$ indicating the minimum output level at which the resource can provide its full *thirty-minute operating reserve* amount.
$RLP10S_{t,b}$	shall designate the reserve loading point for synchronized *ten-minute operating reserve* in time-step $t \in TS$ indicating the minimum output level at which the resource can provide its full synchronized *ten-minute operating reserve* amount.

As detailed in the Offers, Bids and Data Inputs detailed design document, *registered market participants* representing dispatchable *generation facilities* may submit up to five ramp rates for *energy* for each *dispatch hour*. The PD calculation engine will evaluate the same *energy* ramp rates for each time-step in the look-ahead period. The *energy* ramp rates used will correspond to the *offered energy* ramp rates for the first time-step in which the *registered market participant* has submitted an *energy offer*. Similarly, the PD calculation engine will evaluate the same *operating reserve* ramp rate for each time-step in the look-ahead period.

The PD calculation engine will respect the *energy* ramping constraints determined by the *offered* MW quantity (up to five), ramp up rate and ramp down rate value sets. The optimization function formulations provided in this document assume one ramp up rate and one ramp down rate apply across the entire dispatchable range of a dispatchable generation resource. For more information, see the *energy* ramping constraints in Section 3.6.1.5.

Committed resources, which are scheduled to operate at or above their *minimum loading point*, may be scheduled for all types of *operating reserve*. Uncommitted resources will not be scheduled for any type of *operating reserve*. Quick start resources will have a *minimum loading point* ($MinQDG_{q,b}$) of zero. These resources will be considered committed for all time-steps of the look-ahead period. See Section 3.3 for more information.

In addition to the above inputs that are common to all dispatchable generation resources, the PD calculation engine will evaluate additional inputs for the following generation resource types to further enable representation of their operating characteristics:

- NQS resources: start-up *offer*, minimum generation costs, *minimum generation block run time*, minimum generation block down time (MGBDT), maximum number of starts per day and ramp up *energy* to MLP profile;
- PSU resources: steam turbine share of MLP region, steam turbine share of dispatchable region, ramp up *energy* to MLP profile for the combustion turbine and steam turbine, indication of whether the PSU can provide *ten-minute operating reserve* while scheduled in its duct firing region;
- *Variable generation* resources: *IESO's* centralized *variable generation* forecast;
- *Energy*-limited resources: maximum daily *energy* limit; and
- Hydroelectric resources: *forbidden regions*, minimum daily *energy* limit, minimum hourly output, hourly must run, *maximum number of starts per day*, linked resources, time lag and MWh ratio.

Buses identifying resources of these types will be denoted as follows:

- $B^{NQS} \subseteq B^{DG}$ shall designate the subset of buses identifying NQS resources;
- $B^{PSU} \subseteq B^{NQS}$ shall designate the subset of buses identifying PSU resources;
- $B^{VG} \subseteq B^{DG}$ shall designate the subset of buses identifying *variable generation* resources;
- $B^{ELR} \subseteq B^{DG}$ shall designate the subset of buses identifying *energy*-limited resources; and
- $B^{HE} \subseteq B^{DG}$ shall designate the subset of buses identifying hydroelectric resources.

A resource may belong to more than one of the above sets. For example, a hydroelectric resource may be *energy*-limited.

The following sections provide further detail on the notations that will be used to represent the operational characteristics that are specific to a generation resource type.

NQS Resources

As described in the Offers, Bids and Data Inputs detailed design document, *registered market participants* representing NQS *generation facilities* may *offer* some operational and cost parameters as a function of their thermal state (either hot, warm or cold), where:

- $THERM = \{COLD, WARM, HOT\}$ shall designate the set of thermal states for NQS resources.

The parameters that depend on the thermal state are *minimum generation block down-time* (used to determine the thermal state of a resource), lead time, *start-up cost* and ramp up *energy* to MLP. The PD calculation engine will assess lead-time, *start-up cost* and ramp up *energy* to MLP values based on the thermal state inferred from the scheduled resource down time.

Minimum generation cost, *minimum generation block run time* and maximum number of starts do not depend on thermal state.

Table 3-6 lists the parameters for *dispatch data* submitted for an NQS resource identified by bus $b \in B^{NQS}$.

Table 3-6: Parameters for Dispatch Data Submitted for NQS Resources

Parameter	Description
$MGODG_{t,b}$	shall designate the *offered* minimum generation cost to operate at *minimum loading point* in time-step $t \in TS$. This parameter is calculated based on the speed no-load *offer* and *energy* laminations up to the resource's *minimum loading point* submitted by the *market participant*.
$MGBRTDG_{q,b}$	shall designate the *minimum generation block run-time* – the shortest period (in hours) the resource must be scheduled to operate to at least its *minimum loading point* if its *offer* to generate is accepted and the resource reaches its *minimum loading point* within *dispatch day* $q \in DAYS$.
$MaxStartsDG_{q,b}$	shall designate the maximum number of times an NQS resource can be scheduled to start within *dispatch day* $q \in DAYS$.
$MGBDTDG_{q,b}^{HOT}$	shall designate the *minimum generation block down-time* for a hot thermal state. This parameter indicates the shortest period (in hours) between the end of the last hour the resource is scheduled to operate at or above its *minimum loading point* within *dispatch day* $q \in DAYS$ and the beginning of the next hour the resource is scheduled to operate at or above its *minimum loading point*.
$MGBDTDG_{q,b}^{WARM}$	shall designate the *minimum generation block down-time* for a warm thermal state. If the period of time between the hour the resource is scheduled to operate at or above its *minimum loading point* in *dispatch day* $q \in DAYS$ and the beginning of the next hour the resource is scheduled to operate at or above its

Parameter	Description
	minimum loading point exceeds $MGBDTDG_{q,b}^{WARM}$ but does not exceed $MGBDTDG_{q,b}^{COLD}$, then the resource's thermal state is considered to be warm.
$MGBDTDG_{q,b}^{COLD}$	shall designate the *minimum generation block down-time* for a cold thermal state. If the period of time between the hour the resource is scheduled to operate at or above its *minimum loading point* in *dispatch day* $q \in DAYS$ and the beginning of the next hour the resource is scheduled to operate at or above its *minimum loading point* exceeds $\mathrm{MGBDTDG}_{q,b}^{COLD}$, then the resource's thermal state is considered to be cold.
$SUDG_{t,b}^{m}$	shall designate the start-up offer to start, synchronize and reach *minimum loading point* in time-step $t \in TS$ for thermal state $m \in THERM$.
$LT_{q,b}^{m}$	shall designate the lead time indicating the number of hours it takes the resource to start, synchronize and reach *minimum loading point* from an offline state in *dispatch day* $q \in DAYS$ for thermal state $m \in THERM$.
$RampHrs_{q,b}^{m}$	shall designate the number of hours it takes the resource to ramp from 0 to its *minimum loading point* in *dispatch day* $q \in DAYS$ for thermal state $m \in THERM$.
$RampE_{q,b,w}^{m}$	shall designate the quantity of *energy* injected w hours before the resource reaches its *minimum loading point* in *dispatch day* $q \in DAYS$ for $w \in \{1,..,RampHrs_{q,b}^{m}\}$ and thermal state $m \in THERM$.
$SNL_{t,b}$	shall designate the speed no-load offer, which is the cost required to operate in a synchronized status while injecting no *energy* to the *IESO-controlled grid* in time-step $t \in TS$.
$K_{t,b}^{LTMLP}$	shall designate the set of *energy offer* laminations for quantities up to the *minimum loading point* in time-step $t \in TS$.
$QLTMLP_{t,b,k}$	shall designate an incremental quantity of *energy* generation (up to the *minimum loading point*) that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$.
$PLTMLP_{t,b,k}$	shall designate the *offered energy* price for incremental generation in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$.

Certain daily *dispatch data* parameters will be fixed to one value across the look-ahead period when the PD look-ahead period spans multiple *dispatch days*. This is because the engine would likely be unable to produce a solution if inconsistent *dispatch data* across two *dispatch days* leads to conflicts within the optimization or increases runtime outside of the required solution time. This will be discussed further in Section 3.5.5, which also provides the affiliated notation.

The minimum generation cost for an NQS resource indicates the cost of operating the resource at its *minimum loading point* in a specific hour. Although this cost is not submitted directly by the *registered market participant*, it can be calculated from the speed no-load *offer* and *energy* laminations up to the resource's *minimum loading point*. For an NQS resource identified by bus $b \in B^{NQS}$, the minimum generation cost in time-step $t \in TS$ can be calculated as follows:

$$MGODG_{t,b} = SNL_{t,b} + \sum_{k \in K_{t,b}^{LTMLP}} PLTMLP_{t,b,k} \cdot QLTMLP_{t,b,k}.$$

For the purposes of market power mitigation, the component speed no-load and *energy* laminations up to the resource's *minimum loading point* will be compared against their respective reference levels separately. Within the optimization function of the PD calculation engine, the minimum generation cost as derived from these *offered* parameters will be evaluated as a whole in determining a commitment decision.

PSU Resources

For combined cycle *facilities* that have elected and are eligible to be represented as a *pseudo-unit* resource, additional inputs are required to reflect the physical unit loading as a function of the *pseudo-unit* schedules. For more information about how the PSU model is derived from registration parameters and submitted *dispatch data* parameters, see Section 3.10.

Table 3-7 lists the parameters for *dispatch data* submitted for a PSU resource identified by bus $b \in B^{PSU}$.

Table 3-7: Parameters for Dispatch Data Submitted for PSU Resources

Parameter	Description
$K_{t,b}^{DR} \subseteq K_{t,b}^{E}$	shall designate the *energy offer* laminations corresponding to the dispatchable region of the *pseudo-unit* in time-step $t \in TS$.
$K_{t,b}^{DF} \subseteq K_{t,b}^{E}$	shall designate the *energy offer* laminations corresponding to the duct firing region of the *pseudo-unit* in time-step $t \in TS$.
$STShareMLP_b$	shall designate the steam turbine share of the MLP region.
$STShareDR_b$	shall designate the steam turbine share of the dispatchable region.

Parameter	Description
$RampCT_{q,b,w}^{m}$	shall designate the quantity of *energy* injected w hours before the resource reaches its *minimum loading point* in *dispatch day* $q \in DAYS$ and thermal state $m \in THERM$ that is attributed to the combustion turbine for $w \in \{1,..,RampHrs_{q,b}^{m}\}$.
$RampST_{q,b,w}^{m}$	shall designate the quantity of *energy* injected w hours before the resource reaches its *minimum loading point* in *dispatch day* $q \in DAYS$ for thermal state $m \in THERM$ that is attributed to the steam turbine for $w \in \{1,..,RampHrs_{q,b}^{m}\}$.

To calculate the loading on a specific steam turbine, the combined cycle *facility* must identify the PSU resources sharing a steam turbine, where:

- PST shall designate the set of steam turbines being *offered* as part of a PSU; and
- $B_p^{ST} \subseteq B^{PSU}$ shall designate the subset of buses identifying PSU resources with a share of steam turbine $p \in PST$.

At the time of registration, a combined cycle *facility* will indicate using a flag that a PSU resource may not provide *ten-minute operating reserve* from its duct firing region, where:

- $B^{NO10DF} \subseteq B^{PSU}$ shall designate the subset of buses identifying a PSU resource that cannot provide *ten-minute operating reserve* from its duct firing region.

The formulation provided in the optimization function assumes the PSU model parameters are constant across the look-ahead period. However, logic will applied be to handle changes in the single-cycle mode flag between *dispatch days* if:

- the look-ahead period spans multiple *dispatch days*;
- the single-cycle mode flag submitted by the *market participant* differs in these days; and
- the PSU is currently in-service operating in the mode for the current *dispatch day*.

This treatment is also applicable if the single-cycle mode flag submitted by the *market participant* differs between two *dispatch days* and the PSU remained in-service across midnight between these days to satisfy a commitment or *reliability* constraint. See Section 3.10.5 for more information.

Variable Generation Resources

For each *registered facility* supplying *variable generation*, the *IESO* will continue to provide an hourly production forecast for all time-steps of the look-ahead period which will serve to limit the amount of *energy* that the *variable generation* resource may be scheduled to generate in each respective hour. This forecast is provided by a *forecasting entity* and is based on meteorological and technical data provided from *variable generation* resources. For the *variable generation* resource identified by bus $b \in B^{VG}$ and time-step $t \in TS$:

$FG_{t,b}$ shall designate the *IESO* forecast for time-step t.

Energy-Limited Resources

Energy-limited resources constitute a subset of generation resources that may be limited in the amount of *energy* they can provide during each *dispatch day*.

For the *energy*-limited resource identified by bus $b \in B^{ELR}$:

- $MaxDEL_{q,b}$ shall designate the daily limit on the amount of *energy* that the resource may be scheduled to generate over the course of *dispatch day* $q \in DAYS$. This limit does not apply to a shared hydroelectric resource.
- To improve the ability of the PD calculation engine to find a feasible solution, it will be allowed to violate the *MaxDEL* constraints at a cost. See Section 3.4.1.5 for details.

Hydroelectric Resources

Hydroelectric resources may optionally submit additional *dispatch data* reflecting their operating characteristics. For resources choosing not to submit some or all of these *dispatch data*, the corresponding constraints will not need to be enforced by the PD calculation engine. Table 3-8 lists the parameters for *dispatch data* submitted for a hydroelectric resource identified by bus $b \in B^{HE}$.

Table 3-8: Parameters for Dispatch Data Submitted for Hydroelectric Resources

Parameter	Description
$MinHMR_{t,b}$	shall designate the hourly must-run value, which is the minimum amount of *energy* that the resource is required to produce in time-step $t \in TS$ to prevent the resource from operating in a manner that, as a *dispatch instruction*, reasonably could be expected to endanger the safety of any person, damage equipment, or violate any *applicable law.* This minimum amount will be scheduled regardless of whether the resource would be scheduled to operate based on its *offer* price.

Parameter	Description
	Hourly must-run is a new hourly *dispatch data* parameter. For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.
$MinHO_{t,b}$	shall designate the minimum hourly output, which is the amount of *energy* that the resource is required to produce in time-step $t \in TS$, if scheduled to operate, to prevent the resource from operating in a manner that, as a *dispatch instruction*, reasonably could be expected to endanger the safety of any person, damage equipment, or violate any *applicable law*. Minimum hourly output is a new hourly *dispatch data* parameter. For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.
$MinDEL_{q,b}$	shall designate the minimum amount of *energy* that the resource that is not a shared hydroelectric resource must be scheduled to generate within *dispatch day* $q \in DAYS$ to prevent the resource from operating in a manner that, as a *dispatch instruction*, reasonably could be expected to endanger the safety of any person, damage equipment, or violate any *applicable law.* Minimum daily *energy* limit is a new daily *dispatch data* parameter. For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.
$MaxStartsHE_{q,b}$	shall designate the maximum number of times the hydroelectric resource can be scheduled to start within *dispatch day* $q \in DAYS$.
$StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$	shall designate the MW quantities for measuring unit starts; one unit start is counted between time-step t and $(t+1)$ if the schedule increases from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$. Start indication value is a new optional registration parameter that represents the minimum quantity of *energy* a resource must be scheduled to determine whether the *generation units* associated with resource have used up one or more of their *maximum number of starts per day*. For more details on this parameter, refer to the Facility Registration detailed design document.

Parameter	Description
$(ForL_{q,b,i}, ForU_{q,b,i})$ for $i \in \{1,..,NFor_{q,b}\}$	shall designate the lower and upper limits of the resource's *forbidden regions* indicating that the resource cannot be scheduled strictly between $ForL_{q,b,i}$ and $ForU_{q,b,i}$ for all $i \in \{1,..,NFor_{q,b}\}$ within *dispatch day* $q \in DAYS$. *Forbidden regions* is a new daily *dispatch data* parameter used to represent one or more operating ranges, in MW, within which a hydroelectric *generation unit* cannot maintain steady state operation without causing equipment damage. For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.

Market participants may register two or more hydroelectric resources as having a shared daily *energy* limit when these resources are collectively limited in the amount of *energy* they can or must provide during each day. Table 3-9 lists the parameters for *dispatch data* submitted for hydroelectric resources with a shared *energy* limit.

Table 3-9: Parameters for Dispatch Data Submitted for Hydroelectric Resources – Shared Energy Limit

Parameter	Description
SHE	shall designate the set indexing the sets of hydroelectric resources with a shared daily *energy* limit. Shared daily *energy* limit will be a new registration parameter that will indicate whether one or more resources registered by the same *market participant* draw water from the same forebay. For more details on this parameter, refer to the Facility Registration detailed design document.
$B_s^{HE} \subseteq B^{HE}$	shall designate the subset of buses identifying hydroelectric resources in set $s \in SHE$.
$MaxSDEL_{q,s}$	shall designate the maximum daily *energy* limit shared by all hydroelectric resources in set $s \in SHE$ for *dispatch day* $q \in DAYS$. Maximum daily *energy* limit is an existing *dispatch data* parameter that has been enhanced so that *registered market participants* will also be able to submit a single Max DEL value for two or more dispatchable hydroelectric *generation unit* resource types that are registered as sharing the same forebay. For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.

Parameter	Description
$MinSDEL_{q,s}$	shall designate the minimum amount of *energy* that all hydroelectric resources in set $s \in SHE$ must be collectively scheduled to generate within *dispatch day* $q \in DAYS$ to prevent the resources from operating in a manner that, as a dispatch instruction, reasonably could be expected to endanger the safety of any person, damage equipment, or violate any *applicable law.* Minimum daily *energy* limit is a new *dispatch data* parameter that represents the minimum amount of *energy*, in MWh, that a set of *generation units* must be scheduled to supply within a *dispatch day.* For more details on this parameter, refer to the Offers, Bids and Data Inputs detailed design document.

Multiple hydroelectric resources owned by the same *registered market participant* and located on a cascade river system may provide linkage inputs. These inputs are used to represent physical operating characteristics where *energy* produced by one or more upstream resources requires a proportional amount of *energy* to be produced by one or more downstream resources after a period of time to prevent the downstream resource from operating in a manner that, as a *dispatch instruction*, reasonably could be expected to endanger the safety of any person, damage equipment or violate any *applicable law*.

To calculate the *energy* produced by linked hydroelectric resources, the upstream and downstream resources located on cascade river systems must be identified, where:

- $\wp(B^{HE})$ shall designate the power set (the set of all subsets) of the set B^{HE}.
- $B_{up}^{HE} \subseteq \wp(B^{HE})$ shall designate the set of buses identifying all hydroelectric resources on the upstream of cascade river systems.
- $B_{dn}^{HE} \subseteq \wp(B^{HE})$ shall designate the set of buses identifying all hydroelectric resources on the downstream of cascade river systems.

Linked resources, time lag and MWh ratio will be three new daily *dispatch data* parameters used to represent the *energy* production and time lag relationship between generation resources on a hydroelectric cascade river system. For more information on this parameter, refer to the Offer, Bids and Data Inputs detailed design document. Table 3-10 lists the parameters for *dispatch data* submitted for linked hydroelectric resources.

Table 3-10: Parameters for Dispatch Data Submitted for Linked Hydroelectric Resources

Parameter	Description
$LNK_q \subseteq B_{up}^{HE} \times B_{dn}^{HE}$	shall designate the set of linked hydroelectric resources for *dispatch day* $q \in DAYS$. Here LNK_q is a set with elements of the form (b_1, b_2) where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$.
$Lag_{q,b_1,b_2} \in \{0,..,23\}$	shall designate the time lag in hours between upstream hydroelectric resources $b_1 \in B_{up}^{HE}$ and downstream hydroelectric resources $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNK_q$ and *dispatch day* $q \in DAYS$.
$MWhRatio_{q,b_1,b_2}$	shall designate the MWh ratio between upstream hydroelectric resources $b_1 \in B_{up}^{HE}$ and downstream hydroelectric resources $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNK_q$ and *dispatch day* $q \in DAYS$. For every MWh scheduled at buses b_1 in a given hour, $MWhRatio_{q,b_1,b_2}$ must be scheduled at buses b_2 exactly Lag_{b_1,b_2} hours later.

To improve the ability of the PD calculation engine to find a feasible solution, it will be allowed to violate certain hydroelectric constraints at a cost. See Section 3.4.1.5 for details.

Offers to Import Energy

Each *offer* to import designates the amount of *energy* that the *registered market participant* is willing to schedule at a given price for an *intertie zone* and *boundary entity* proxy location. Except for Quebec, imports to other jurisdictions cannot be scheduled over individual *interties*. Several *intertie zones* are defined for Quebec so that imports may be scheduled over individual *interties* between Quebec and Ontario.

Market participants may submit *offers* to import *energy* along with *offers* to provide *operating reserve*. A maximum of 20 *price-quantity pairs* corresponding to 19 laminations may be submitted in the *offer* to import *energy*. A maximum of five *price-quantity pairs* corresponding to four laminations may be submitted for each class of *operating reserve* the importer is qualified to provide.

Table 3-11 lists the parameters for *dispatch data* submitted for an *intertie zone* source bus $d \in DI$.

Table 3-11: Parameters for Dispatch Data Submitted for Import Offers

Parameter	Description
$QIG_{t,d,k}$	shall designate the maximum quantity of *energy* for which an import from bus d in time-step $t \in TS$ may be scheduled in association with *offer* lamination $k \in K^{E}_{t,d}$.
$PIG_{t,d,k}$	shall designate the *offered* price of the importer at bus d for an incremental quantity of *energy* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{E}_{t,d}$. The *offered* price indicates the lowest price at which the importer is willing to be scheduled.
$Q10NIG_{t,d,k}$	shall designate the non-synchronized *ten-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10N}_{t,d}$.
$P10NIG_{t,d,k}$	shall designate the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{10N}_{t,d}$.
$Q30RIG_{t,d,k}$	shall designate the *thirty-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K^{30R}_{t,d}$.
$P30RIG_{t,d,k}$	shall designate the price of being scheduled to provide *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{30R}_{t,d}$.

The PD calculation engine will economically schedule DAM scheduled *intertie* transactions and *offers* for import for non-DAM scheduled *intertie* transactions for the first two forecast hours of the look-ahead period. The DAM scheduled quantities for import transactions will limit import schedules beyond the first two forecast hours of the look-ahead period to only DAM scheduled *intertie* transactions. For *intertie zone* source bus $d \in DI$:

- $SIGT^{DAM}_{t,d}$ shall designate the DAM scheduled quantity of *energy* for import from bus d in time-step $t \in \{4,..,n_{LAP}\}$;
- $S10NIGT^{DAM}_{t,d}$ shall designate the DAM scheduled quantity of non-synchronized *ten-minute operating reserve* in time-step $t \in \{4,..,n_{LAP}\}$; and
- $S30RIGT^{DAM}_{t,d}$ shall designate the DAM scheduled quantity of *thirty-minute operating reserve* in time-step $t \in \{4,..,n_{LAP}\}$.

For the purposes of *reliability*, import *offers* at certain *intertie zones* in certain time-steps with no DAM schedule may be evaluated beyond the first two forecast hours of the look-ahead period. See the Grid and Market Operations Integration detailed design for more information. For *intertie zone* source bus $d \in DI$:

- $SIGT^{EXTRA}_{t,d}$ shall designate the extra quantity of *energy* for import from bus d in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for *reliability* purposes;
- $S10NIGT^{EXTRA}_{t,d}$ shall designate the extra quantity of non-synchronized *ten-minute operating reserve* for import from bus d in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for *reliability* purposes; and
- $S30RIGT^{EXTRA}_{t,d}$ shall designate the extra quantity of *thirty-minute operating reserve* for import from bus d in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for *reliability* purposes.

Additionally, import *offers* that are flagged as capacity imports are eligible for economic scheduling beyond the first two forecast hours of the look-ahead period regardless of their DAM schedules. For each time-step $t \in \{4,..,n_{LAP}\}$:

- $DI^{CAPEX}_{t} \subseteq DI$ shall designate the *intertie zone* source buses identifying import *offers* flagged as capacity imports in time-step $t \in \{4,..,n_{LAP}\}$.

Import Offers in Wheeling Through Transactions

As mentioned in Section 3.4.1.3, wheeling through transactions consist of an individual *bid* to export *energy* to an *intertie zone* and an individual *offer* to import *energy* into another *intertie zone* in the same hour. Both the export *bid* and the import *offer* will be linked using the same e-Tag identifiers. The PD calculation engine will ensure that the export *bid* and the import *offer* of the wheeling through transaction receive equal schedules. Wheeling through transactions are not eligible to provide *operating reserve*. For each time-step $t \in TS$:

- $L_t \subseteq DX \times DI$ shall designate the set of linked *intertie zone* sink and source buses corresponding to wheeling through transactions. Here L_t is a set with elements of the form (dx, di) where $dx \in DX$ and $di \in DI$.

3.4.1.5 Additional IESO Data Inputs

This section describes the additional inputs that the *IESO* will provide to the PD calculation engine to enable system *reliability* when a solution is determined.

Operating Reserve Requirements

The *IESO* will input minimum *operating reserve* requirements for each time-step. *Operating reserve* requirements will include minimum requirements for the total amount of synchronized *ten-minute operating reserve*, the total amount of *ten-minute operating reserve* and the total amount of *thirty-minute operating reserve*. For each time-step $t \in TS$:

- $TOT10S_t$ shall designate the synchronized *ten-minute operating reserve* requirement;
- $TOT10R_t$ shall designate the *ten-minute operating reserve* requirement; and

- $TOT30R_t$ shall designate the *thirty-minute operating reserve* requirement, which may also include an increase to account for the flexibility *operating reserve* requirement.

In addition, the *IESO* will define a number of regions within Ontario that will have their own regional *operating reserve* minimum requirements and maximum restrictions. Each region shall consist of a set of buses at which *operating reserve* scheduled may be used to satisfy the minimum requirement for that region and is limited by the maximum restriction for that region, where:

- $ORREG$ shall designate the set of regions for which regional *operating reserve* limits have been defined;
- $B_r^{REG} \subseteq B$ shall designate the set of internal buses in *operating reserve* region $r \in ORREG$;
- $D_r^{REG} \subseteq D$ shall designate the set of *intertie zone* buses in *operating reserve* region $r \in ORREG$;
- $REGMin10R_{t,r}$ shall designate the minimum requirement[4] for total *ten-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;
- $REGMin30R_{t,r}$ shall designate the minimum requirement[5] for *thirty-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;
- $REGMax10R_{t,r}$ shall designate the maximum amount of total *ten-minute operating reserve* that may be provided in region $r \in ORREG$ in time-step $t \in TS$; and
- $REGMax30R_{t,r}$ shall designate the maximum amount of *thirty-minute operating reserve* that may be provided in region $r \in ORREG$ in time-step $t \in TS$.

Intertie Limits

The *IESO* will establish *intertie* limits based on its assessment of the amount of *energy* and *operating reserve* that can be imported into Ontario, or the amount of *energy* that can be exported from Ontario during the look-ahead period. These limits will belong to one of the following two categories:

1. Flow limits:
    - Import limit: Limits on the sum of the total net scheduled inflow of *energy* (imports minus exports) into Ontario from one or more *intertie zones* and scheduled *operating reserve* from one or more *intertie zones* in each time-step.

[4] These minimum limits could be set at zero.

[5] These minimum limits could be set at zero.

  - o Export limit: Limits on the total net scheduled outflow of *energy* (exports minus imports) from Ontario into one or more *intertie zones* in each time-step.

2. Net interchange scheduling limit (NISL): Limit on the change in total scheduled *energy* flows over all the *interties* between Ontario and the *intertie* zones from time-step to time-step.

Flow Limits

The *IESO* will define flow limit constraints by specifying the flow limit, the *intertie* zones contributing to the constraint and the contribution of each *intertie* zone to the constraint. Let Z_{Sch} contain all the import and export flow constraints that the *IESO* has defined.

For each such constraint $z \in Z_{Sch}$:

- $EnCoeff_{a,z}$ shall designate the coefficient for calculating the contribution of scheduled *energy* flows and *operating reserve* inflows for *intertie* zone $a \in A$. A coefficient of $+1$ will describe flows into Ontario while a coefficient of -1 will describe flows out of Ontario; and
- $MaxExtSch_{t,z}$ shall designate the maximum flow limit in time-step $t \in TS$.

Net Interchange Scheduling Limits

The net interchange scheduling limit constraint limits time-step to time-step changes in net interchange. For time-step $t \in TS$:

- $ExtDSC_t$ shall designate the maximum decrease in net flows over all *interties* from time-step $(t-1)$ to time-step t; and
- $ExtUSC_t$ shall designate the maximum increase in net flows over all *interties* from time-step $(t-1)$ to time-step t.

Time-step to time-step increases in net interchange from all the *intertie zones* should not exceed $ExtUSC_t$, and time-step to time-step decreases in net interchange from all *intertie zones* should not exceed $ExtDSC_t$.

Resource Minimum and Maximum Constraints

Dispatchable Load

The minimum and maximum consumption of a *dispatchable load* may be limited for the following reasons:

- *Reliability* constraints: a constraint imposed as a result of a control action may limit the minimum or maximum consumption of a *dispatchable load*.

The PD calculation engine will accordingly enforce the minimum and maximum constraints on the consumption of a *dispatchable load*. For time-step $t \in TS$:

- $MinDL_{t,b}$ shall designate the most restrictive of the above minimum consumption limits for the *dispatchable load* at bus $b \in B^{DL}$; and
- $MaxDL_{t,b}$ shall designate the most restrictive of the above maximum consumption limits for the *dispatchable load* at bus $b \in B^{DL}$.

Non-Dispatchable and Dispatchable Generation Resources

The minimum and maximum output of an internal generation resource may be limited for the following reasons:

- *Reliability* constraints: The *IESO* will identify resources that must operate for *reliability* purposes. The *IESO* may, as required, place minimum or maximum constraints on these resources to support *reliability must-run contracts*, *reactive support service* contracts or other *reliability* needs, to enable the reliable operation of the system.
- *Regulation*: The *IESO* will continue to enter into contracts with *market participants* for certain dispatchable generation resources to provide *regulation*. Resources providing *automatic generation control (AGC)* will be flagged as must-commit in all hours in which they are designated as *AGC* providers and such *generation facilities* must submit *energy offers* in these hours. A resource providing *AGC* will be scheduled to at least the more restrictive of its minimum *AGC* limit and its *minimum loading point* plus the designated *AGC* range. It will be scheduled to at most the more restrictive of its maximum *AGC* limit and its maximum *offered energy* quantity minus the designated *AGC* range. Generation resources nominated to provide *AGC* are not allowed to supply *operating reserve* into the *real-time market*.
- DAM and Prior PD commitments: Operational commitments for NQS resources will lead to a minimum constraint forcing the resource to its *minimum loading point* in the time-steps of the commitment.
- Outages and De-rates: *Outages* or de-rates from the *IESO's* Outage Coordination and Scheduling System (OCSS) limit a generation resource's maximum output.

The PD calculation engine will accordingly enforce minimum and maximum constraints on the output of an internal generation resource. For time-step $t \in TS$:

- $MinNDG_{t,b}$ shall designate the most restrictive of the above minimum output limits for the non-dispatchable generation resource at bus $b \in B^{NDG}$;
- $MaxNDG_{t,b}$ shall designate the most restrictive of the above maximum output limits for the non-dispatchable generation resource at bus $b \in B^{NDG}$;

- $MinDG_{t,b}$ shall designate the most restrictive of the above minimum output limits for the dispatchable generation resource at bus $b \in B^{DG}$; and
- $MaxDG_{t,b}$ shall designate the most restrictive of the above maximum output limits for the dispatchable generation resource at bus $b \in B^{DG}$.

PSU Resources

Within the optimization function of the PD calculation engine, most minimum and maximum limits on the output of a PSU resource will be enforced in the same way minimum and maximum limits on the output of other dispatchable generation resources are enforced. However, the minimum and maximum limits may be input to the PD calculation engine on a physical-unit basis and then converted to a constraint on the corresponding PSU resources before the execution of the PD calculation engine pass. Such minimum and maximum limits for the PSU resource at bus $b \in B^{PSU}$ for time-step $t \in TS$ will be represented by $MinDG_{t,b}$ and $MaxDG_{t,b}$ as described above. The logic to perform the conversion of physical-unit limitations to PSU limitations is described in Section 3.10.3.

Special logic will apply when a de-rate is submitted on the combustion turbine. To model this logic, the dispatchable and duct firing capacity of the PSU resource will be calculated as described in Section 3.10.2. For time-step $t \in TS$ and for the PSU resource at bus $b \in B^{PSU}$:

- $MaxMLP_{t,b}$ shall designate the maximum output limit in time-step t for the MLP region;
- $MaxDR_{t,b}$ shall designate the maximum output limit in time-step t for the dispatchable region; and
- $MaxDF_{t,b}$ shall designate the maximum output limit in time-step t for the duct firing region.

HDR Activation and Non-Activation

Activated *hourly demand response* resources will be scheduled to provide a specific level of load reduction in a given hour. *Hourly demand response* resources deemed not activated in a given hour cannot be scheduled to provide load reduction. Activation and non-activation decisions for a given *dispatch hour* are made in the *pre-dispatch scheduling* process three hours prior to that hour. The PD calculation engine will receive this information in the form of minimum and maximum limits for an *hourly demand response* resource schedule. For each time-step $t \in TS$ and each bus $b \in B^{HDR}$:

- $MinHDR_{t,b}$ shall designate the minimum load reduction level that may be scheduled in time-step $t \in TS$; and

- $MaxHDR_{t,b}$ shall designate the maximum load reduction level that may be scheduled in time-step $t \in TS$.

The minimum and maximum values will coincide in time-steps for which the *hourly demand response* resource will be fixed to a specific schedule as determined by activation/non-activation decisions. In time-steps for which a decision is not yet made, no corresponding limit will be imposed on the resource schedule.

Off-Market Transactions

The following off-market transactions will be modelled at their respective buses within the optimization function and *security* assessment function. These transactions are fixed and therefore have an affiliated quantity as for *bids* to export and *offers* to import but no affiliated *bid/offer* price considered in the objective function.

Inadvertent Payback

The *intertie* transactions that correspond to inadvertent payback transactions will be identified and such transactions must receive a schedule equal to the specified quantity. For time-step $t \in TS$:

- $DX_t^{INP} \subseteq DX$ shall designate the *intertie zone* sink buses corresponding to inadvertent payback transactions for time-step $t \in TS$; and
- $DI_t^{INP} \subseteq DI$ shall designate the *intertie zone* source buses corresponding to inadvertent payback transactions for time-step $t \in TS$.

Emergency Energy

The *intertie* transactions that correspond to *emergency energy* transactions will be identified and such transactions must receive a schedule equal to the specified quantity. For time-step $t \in TS$:

- $DX_t^{EM} \subseteq DX$ shall designate the *intertie zone* sink buses corresponding to *emergency* sale transactions for time-step $t \in TS$; and
- $DI_t^{EM} \subseteq DI$ shall designate the *intertie zone* source buses corresponding to *emergency* purchase transactions for time-step $t \in TS$.

In the case of an *emergency energy* purchase that does not support a sale, the corresponding transaction must be fully scheduled in the scheduling algorithm and not considered in the pricing algorithm, where:

- $DI_t^{EMNS} \subseteq DI_t^{EM}$ shall designate the *intertie zone* source buses flagged as *emergency* purchases that do not support sales in time-step $t \in TS$

Intertie Curtailments

Intertie curtailments limit the schedules of specific *intertie* transactions when restrictions on *intertie* schedules are not recognized by the *IESO* market tools.

For *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$:

- $ICMaxXL_{t,d}$ shall designate any maximum limit on the quantity of *energy* scheduled for export to bus d in time-step t as the result of an *intertie* curtailment; and
- $ICMinXL_{t,d}$ shall designate any minimum limit on the quantity of *energy* scheduled for export to bus d in time-step t as the result of an *intertie* curtailment.
- For *intertie zone* source bus $d \in DI$ and time-step $t \in TS$:
- $ICMaxIG_{t,d}$ shall designate any maximum limit on the quantity of *energy* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment;
- $ICMax10NIG_{t,d}$ shall designate any maximum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment;
- $ICMax30RIG_{t,d}$ shall designate any maximum limit on the quantity of *thirty-minute operating reserve* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment;
- $ICMinIG_{t,d}$ shall designate any minimum limit on the quantity of *energy* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment;
- $ICMin10NIG_{t,d}$ shall designate any minimum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment; and
- $ICMin30RIG_{t,d}$ shall designate any minimum limit on the quantity of *thirty-minute operating reserve* scheduled for import from bus d in time-step t as the result of an *intertie* curtailment.

Constraint Violation Penalties

In some situations, the PD calculation engine might be unable to resolve all system constraints. For example, the PD calculation engine would fail to produce a solution when insufficient generation is *offered* to meet the forecast *demand* unless the engine is permitted to serve only a portion of the forecast *demand*. To ensure the PD calculation engine can always find a feasible solution, it will be allowed to violate certain system constraints at a cost.[6] This will be achieved via constraint violation penalty curves that establish the value placed on satisfying a constraint and indicate the relative priority of satisfying a certain constraint compared to other constraints. The constraint violation penalty curves used by the scheduling algorithm to produce constrained schedules may differ from the constraint violation penalty curves used by the pricing algorithm to calculate *market prices* in order to produce *settlement*-ready prices.

The constraints described in this section include constraint violation variables with affiliated penalty price terms appearing in the objective function. The number of violation variables required for the scheduling algorithm and pricing algorithm may differ depending on the number of segments in the applicable constraint violation penalty curve. For notational purposes, the scheduling and pricing penalty curves for each constraint will be assumed to have the same number of segments and any segments that are not required will be assigned a quantity of zero. The notation for the affiliated prices and quantities is described below.

The *energy* balance constraint may be violated for both reasons of under generation and over generation. For time-step $t \in TS$:

- $(PLdViolSch_{t,i}, QLdViolSch_{t,i})$ for $i \in \{1,..,N_{LdViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under generation used for scheduling to meet the *IESO's reliability* requirements;
- $(PLdViolPrc_{t,i}, QLdViolPrc_{t,i})$ for $i \in \{1,..,N_{LdViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under generation used for calculating *market prices*;
- $(PGenViolSch_{t,i}, QGenViolSch_{t,i})$ for $i \in \{1,..,N_{GenViol_t}\}$ shall designate the price-quantity segments of the penalty curve for over generation used for scheduling to meet the *IESO*'s *reliability* requirements; and
- $(PGenViolPrc_{t,i}, QGenViolPrc_{t,i})$ for $i \in \{1,..,N_{GenViol_t}\}$ shall designate the price-quantity segments of the penalty curve for over generation used for calculating *market prices*.

The synchronized *ten-minute operating reserve* constraint may be violated to allow a shortfall. For time-step $t \in TS$:

- $(P10SViolSch_{t,i}, Q10SViolSch_{t,i})$ for $i \in \{1,..,N_{10SViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used for scheduling to meet the *IESO*'s *reliability* requirements; and

[6] Under such conditions, system *reliability* will be maintained by *IESO* control actions.

- $(P10SViolPrc_{t,i}, Q10SViolPrc_{t,i})$ for $i \in \{1,..,N_{10SViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used for calculating *market prices*.

The total *ten-minute operating reserve* constraint may be violated to allow a shortfall. For time-step $t \in TS$:

- $(P10RViolSch_{t,i}, Q10RViolSch_{t,i})$ for $i \in \{1,..,N_{10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used for scheduling to meet the *IESO's reliability* requirements; and
- $(P10RViolPrc_{t,i}, Q10RViolPrc_{t,i})$ for $i \in \{1,..,N_{10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used for calculating *market prices*.

The *thirty-minute operating reserve* constraint may be violated to allow a shortfall. For time-step $t \in TS$:

- $(P30RViolSch_{t,i}, Q30RViolSch_{t,i})$ for $i \in \{1,..,N_{30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used for scheduling to meet the *IESO's reliability* requirements; and
- $(P30RViolPrc_{t,i}, Q30RViolPrc_{t,i})$ for $i \in \{1,..,N_{30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used for calculating *market prices*.

Area minimum and maximum *operating reserve* requirements may be violated. For time-step $t \in TS$:

- $(PREG10RViolSch_{t,i}, QREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{REG10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used for scheduling to meet the *IESO's* reliability requirements;
- $(PREG10RViolPrc_{t,i}, QREG10RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used for calculating *market prices*;
- $(PREG30RViolSch_{t,i}, QREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{REG30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used for scheduling to meet the *IESO's reliability* requirements;

- $(PREG30RViolPrc_{t,i}, QREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used for calculating *market prices*;
- $(PXREG10RViolSch_{t,i}, QXREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used for scheduling to meet the *IESO's reliability* requirements;
- $(PXREG10RViolPrc_{t,i}, QXREG10RViolPrc_{t,i})$ for $i \in \{1,..,N_{XREG10RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used for calculating *market prices*;
- $(PXREG30RViolSch_{t,i}, QXREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used for scheduling to meet the *IESO*'s *reliability* requirements; and
- $(PXREG30RViolPrc_{t,i}, QXREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{XREG30RViol_t}\}$ shall designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used for calculating *market prices*.

Pre-contingency and post-contingency internal transmission limits may be violated. As described in Section 3.4.1.7, transmission constraints may be identified for any *facility* (or group of *facilities*) within Ontario. The set of *facilities* (or groups of *facilities*) for which transmission constraints may be identified shall be designated by F. For time-step $t \in TS$:

- $(PPreITLViolSch_{f,t,i}, QPreITLViolSch_{f,t,i})$ for $i \in \{1,..,N_{PreITLViol_{f,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used for scheduling to meet the *IESO*'s *reliability* requirements;
- $(PPreITLViolPrc_{f,t,i}, QPreITLViolPrc_{f,t,i})$ for $i \in \{1,..,N_{PreITLViol_{f,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used for calculating *market prices*. As described in the Offers, Bids and Data Inputs detailed design document, the quantity will be based on a percentage of the applicable transmission *security limit*. As the percentage and limit do not depend on the optimization function decisions, the quantity can be precomputed and treated as fixed within the PD calculation engine optimization function;
- $(PITLViolSch_{c,f,t,i}, QITLViolSch_{c,f,t,i})$ for $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used for scheduling to meet the *IESO*'s *reliability* requirements; and

- $(PITLViolPrc_{c,f,t,i}, QITLViolPrc_{c,f,t,i})$ for $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used for calculating *market prices*. Similar to pre-contingency limits, the penalty curve quantities are based on a percentage of the applicable transmission *security limit* and are fixed within the PD calculation engine optimization function.

Intertie scheduling limits may be violated. For time-step $t \in TS$:

- $(PPreXTLViolSch_{z,t,i}, QPreXTLViolSch_{z,t,i})$ for $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used for scheduling to meet the *IESO's reliability* requirements;
- $(PPreXTLViolPrc_{z,t,i}, QPreXTLViolPrc_{z,t,i})$ for $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used for calculating *market prices*;
- $(PNIUViolSch_{t,i}, QNIUViolSch_{t,i})$ for $i \in \{1,..,N_{NIUViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the time-step t net interchange increase constraint between time-steps $(t\text{-}1)$ and t used for scheduling to meet the *IESO's reliability* requirements;
- $(PNIUViolPrc_{t,i}, QNIUViolPrc_{t,i})$ for $i \in \{1,..,N_{NIUViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the time-step t net interchange increase constraint between time-steps $(t\text{-}1)$ and t used for calculating *market prices*;
- $(PNIDViolSch_{t,i}, QNIDViolSch_{t,i})$ for $i \in \{1,..,N_{NIDViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the time-step t net interchange decrease constraint between time-steps $(t\text{-}1)$ and t used for scheduling to meet the *IESO's reliability* requirements; and
- $(PNIDViolPrc_{t,i}, QNIDViolPrc_{t,i})$ for $i \in \{1,..,N_{NIDViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding the time-step t net interchange decrease constraint between time-steps $(t\text{-}1)$ and t used for calculating *market prices*.

Maximum and minimum daily *energy* limits for individual resources and shared maximum and minimum daily *energy* limits may be violated. For time-step $t \in TS$:

- $(PMaxDelViolSch_{t,i}, QMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding a resource's maximum daily *energy* limit used for scheduling to meet the *IESO*'s *reliability* requirements;

- $(PMaxDelViolPrc_{t,i}, QMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding a resource's maximum daily *energy* limit used for calculating *market prices*;
- $(PMinDelViolSch_{t,i}, QMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{MinDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under-scheduling a resource's minimum daily *energy* limit used for scheduling to meet the *IESO*'s *reliability* requirements;
- $(PMinDelViolPrc_{t,i}, QMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MinDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under-scheduling a resource's minimum daily *energy* limit used for calculating *market prices*;
- $(PSMaxDelViolSch_{t,i}, QSMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMaxDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding a shared maximum daily *energy* limit used for scheduling to meet the *IESO*'s *reliability* requirements;
- $(PSMaxDelViolPrc_{t,i}, QSMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for exceeding a shared maximum daily *energy* limit used for calculating *market prices*;
- $(PSMinDelViolSch_{t,i}, QSMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMinDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under-scheduling a shared minimum daily *energy* limit used for scheduling to meet the *IESO's reliability* requirements; and
- $(PSMinDelViolPrc_{t,i}, QSMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{SMinDelViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under-scheduling a shared minimum daily *energy* limit used for calculating *market prices*.

The downstream resource of a hydroelectric linkage may be violated for both reasons of under generation and over generation. For time-step $t \in TS$:

- $(POGenLnkViolSch_{t,i}, QOGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{OGenLnkViol_t}\}$ shall designate the price-quantity segments of the penalty curve for over generation on a downstream resource used for scheduling to meet the *IESO*'s *reliability* requirements; and
- $(PUGenLnkViolSch_{t,i}, QUGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{UGenLnkViol_t}\}$ shall designate the price-quantity segments of the penalty curve for under generation on a downstream resource used for scheduling to meet the *IESO*'s *reliability* requirements.

Tie-Breaking

When there exist two or more equivalent *bids* or *offers* for *energy* or *offers* for *operating reserve* that do not create differences in the optimization, tie-breaking rules will be used by the PD calculation engine. Two tie-breaking methods will be used.

The first tie-breaking method pertains to only *variable generation* resources and its application is facilitated by pre-processing *variable generation offers* within the initialization processes of the PD calculation engine. The intent of this method is to break ties when two or more *energy offers* from *variable generation* resources are such that there is no difference in the cost to the market of using either *offer*. In such instances, the schedules for these *offers* shall be determined using the daily *dispatch* order for *variable generation*, where:

- $\mathrm{NumVG_t}$ shall designate the number of *variable generation* resources in the daily *dispatch* order for time-step $t \in TS$; and
- $TBM_{t,b} \in \{1,..,NumVG_t\}$ shall designate the tie-breaking modifier for the *variable generation* resource at bus $b \in B^{VG}$ for time-step $t \in TS$.

The second tie-breaking method pertains to all *bids* and *offers* for *energy* and *offers* for *operating reserve* and is applied using a quadratic penalty within the optimization function of the PD calculation engine. The intent of this method is to break ties when two or more *bids* or *offers* are such that there is no difference in the cost to the market of using either *bid/offer*. In such instances, the schedules for these *bids* or *offers* shall be pro-rated based on the amount of *energy offered* and available at the corresponding price. No additional input to the PD calculation engine is required to perform this pro-rata tie-breaking.

3.4.1.6 Initial Scheduling Assumptions

The PD calculation engine will use data specifying the initial schedules and commitment of resources for the first time-step of the look-ahead period, which is not scheduled by the optimization function. This data is described in the following sections.

Initial Schedules

By default, initial schedules (i.e. schedules for time-step 1 of the look-ahead period) will be based on the value determined by the *IESO's energy* management system. The initial schedules for NQS resources may be determined differently to align with the commitment status logic described below. NQS resources that are not committed in time-step 1 will receive an initial schedule of zero. NQS resources that are committed in time-step 1 will receive an initial schedule consistent with the advisory schedule calculated by the RT calculation engine.

For notational convenience, the initial resource schedules will be denoted using the scheduling variables in Section 3.6.1.2 with the time-step set to 1. For example, $SDG_{1,b,k}$ shall denote the initial schedule of the dispatchable generation resource at bus $b \in B^{DG}$ affiliated with *offer* lamination $k \in K^E_{1,b}$.

Initial Commitment Status, Number of Hours in Operation and Number of Hours Down

The NQS commitment status for time-step 1 will be determined from the previous PD calculation engine run commitment status for its time-step 2. An exception to this is if the RT calculation engine has kept the resource at or above its MLP to respect a *reliability* constraint. In cases of a *reliability* constraint, the RT calculation engine advisory schedule will determine the commitment status.

Thus, for bus $b \in B^{NQS}$:

- $ODG_{1,b}$ shall designate the commitment status for the resource at bus b as determined by the logic described above.

Additionally, the remaining *minimum generation block run-time* and *minimum generation block down-time* based on the resource's time up or time down at the end of time-step 1 must be respected. *Energy* management system data determined based on telemetry, along with the anticipated schedule for time-step 1 of the look-ahead period, will be used to determine this data. For bus $b \in B^{NQS}$:

- $InitOperHrs_b$ shall designate the number of consecutive hours at the end of time-step 1 for which the resource at bus $b \in B$ has been, and is anticipated to be, operating at or above its MLP. It shall be set to zero for resources with $ODG_{1,b} = 0$; and
- $InitDownHrs_b$ shall designate the number of consecutive hours at the end of time-step 1 for which the resource at bus $b \in B$ has not been, and is not anticipated to be, operating at or above its MLP. It shall be set to zero for resources with $ODG_{1,b} = 1$

Initial Net Interchange Schedule

The PD calculation engine requires the initial net *interchange schedule*. This value is the difference between all imports to Ontario and all exports from Ontario, for the first hour of the look-ahead period (time-step 1). By default, this value will be based on fixed schedules for imports and exports from the RT calculation engine. For notational convenience, this value will be inferred from the initial resources schedules for imports and exports using the scheduling variables in Section 3.6.1.2 with the time-step set to 1.

Number of Starts for NQS Resources

The number of starts scheduled for NQS resources must respect the number of starts already incurred in the current *dispatch day* as determined by the actual operation of the resource, plus any anticipated starts indicated by time-step 1 initial conditions, where:

- $NumStarts_b$ shall designate the number of starts the resource at bus $b \in B^{NQS}$ has incurred in the current *dispatch* day, plus any anticipated starts indicated by time-step 1 initial conditions.

When the look-ahead period spans two *dispatch days*, only starts that have occurred in the current *dispatch day* will have been observed and therefore this parameter is only required for one day.

Number of Starts for Hydroelectric Resources

Similarly, the number of starts for hydroelectric resources must respect the number of starts already incurred as determined by the actual operation of the resource, plus any anticipated starts in time-step 1 of the look-ahead period, where:

- $NumStartsHE_b$ shall designate the number of starts the resource at bus $b \in B^{HE}$ has incurred in the current *dispatch day*, plus any anticipated starts in time-step 1 of the look-ahead period.

Cumulative Energy Production for Energy-Limited and Hydroelectric Resources

The actual *energy* produced up to the current hour in the current *dispatch day*, plus the *energy* scheduled in time-step 1 of the look-ahead period, will limit the schedule of an *energy*-limited resource for the remainder of the current *dispatch day*. This quantity will also offset the amount of *energy* that must be scheduled to satisfy a hydroelectric resource's minimum daily *energy* limit. For the resource at bus $b \in B^{ELR} \cup B^{HE}$:

- $EngyUsed_b$ shall designate the MWh of generation already provided in the current *dispatch day*, plus the MWh of generation scheduled in time-step 1 of the look-ahead period.

Similarly, the actual *energy* produced up to the current hour in the current *dispatch day*, plus the *energy* scheduled in time-step 1 of the look-ahead period, will limit the schedule of resources with a shared maximum daily *energy* limit. This quantity will also offset the amount of *energy* that must be scheduled to satisfy the shared minimum daily *energy* limit. For the set of hydroelectric resources sharing a daily *energy* limit $s \in SHE$:

- $EngyUsedSHE_s$ shall designate the MWh of generation already provided in the current *dispatch day* by resources sharing the daily *energy* limit plus the MWh of generation scheduled in time-step 1 of the look-ahead period.

Past Hourly Production for Linked Hydroelectric Resources

For linked hydroelectric resources, the past hourly *energy* production of upstream resources will be used to schedule downstream resources for time-steps in the look-ahead period within the time lag. These past hourly production schedules will be equal to the output determined by the *IESO's energy* management system based on real-time telemetry less any production scheduled as part of an *operating reserve* activation. For all linked hydroelectric resources $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t \leq LagC_{b_1,b_2}$[7]:

- $PastMWh_{t,b_1}$ shall designate the total MWh of generation provided by resource b_1 exactly $LagC_{b_1,b_2}$ hours prior to time-step t.

As time-step 1 is not scheduled within the PD calculation engine optimization, the schedules of downstream resources linked to time-step 1 upstream resource schedules will be pre-determined. For this purpose, an upstream resource schedule in time-step 1 will be the average value of its advisory schedules from the last RT calculation engine run that successfully completed before the PD calculation engine run commenced. If the advisory schedule reflects an *operating reserve* activation for an upstream resource, then the schedule determined by the RT calculation run prior to the *operating reserve* activation will be used. For all linked hydroelectric resources $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t = LagC_{b_1,b_2} + 1$:

- $PastMWh_{t,b_1}$ shall designate the total MWh of generation determined for resource b_1 for time-step 1 to be used for scheduling downstream resources in time-step t.

3.4.1.7 Inputs Provided by the Security Assessment Function

Transmission inputs to the optimization function are calculated by the *security* assessment function based on information prepared by the *IESO* to enable the PD calculation engine to evaluate the *security* of the *IESO-controlled grid.*

Transmission Constraints

A set of linearized transmission constraints will be provided by the *security* assessment function. Operating *security limits* and thermal limits for both pre-contingency and post-contingency conditions will be considered, where:

- F shall designate the set of *facilities* (or groups of *facilities*) in Ontario for which transmission constraints may be identified; and

[7] As described in Section 3.5.5, the PD calculation engine will use one set of hydroelectric linkage parameters across the look-ahead period where $LNKC$ denotes the linkages and $\mathrm{LagC}_{b_1,b}$ denotes the time lag for $(b_1,b_2) \in LNKC$.

- C shall designate the set of contingency conditions that are considered in the *security* assessment function.

For each time-step $t \in TS$, if the pre-contingency limit on *facility* $f \in F$ is violated, the *security* assessment function will calculate a linearization of the constraint in the optimization function scheduling variables and provide the affiliated coefficients and limit. Let $\mathrm{F_t} \subseteq \mathrm{F}$ designate the set of *facilities* whose pre-contingency limit was violated in time-step t of a preceding *security* assessment function iteration. For a *facility* $f \in F_t$:

- $\mathrm{PreConSF_{t,f,b}}$ shall designate the pre-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during time-step t under pre-contingency conditions; and
- $AdjNormMaxFlow_{t,f}$ shall designate the corresponding limit indicating the maximum flow allowed on *facility* f in time-step t under pre-contingency conditions.

For each time-step $t \in TS$ and contingency $c \in C$, if the post-contingency limit on *facility* $f \in F$ is violated, the *security* assessment function will calculate a linearization of the constraint in the optimization function scheduling variables and provide the affiliated coefficients and limit. Let $F_{t,c} \subseteq F$ designate the set of *facilities* whose post-contingency limit for contingency c was violated in time-step t of a preceding *security* assessment function iteration. For a *facility* $f \in F_{t,c}$:

- $SF_{t,c,f,b}$ shall designate the post-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during time-step t under post-contingency conditions for contingency c; and
- $AdjEmMaxFlow_{t,c,f}$ shall designate the corresponding limit indicating the maximum flow allowed on *facility* f in time-step t under post-contingency conditions for contingency c.

Transmission Losses

Losses will be modelled in the PD calculation engine using marginal loss factors and a loss adjustment. As described in Section 3.7.2.3, the marginal loss factors for each time-step will be calculated using a base case power flow from the *security* assessment function based on the schedules determined for that time-step by the optimization function.

Therefore, the marginal loss factors will be calculated dynamically and can be different in distinct time-steps, where:

- $MglLoss_{t,b}$ shall designate a marginal loss factor and shall reflect the marginal impact on transmission losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at resource bus $b \in B \cup D$ in time-step $t \in TS$. When determining marginal loss factors, the impact of local branches (e.g. load step-down transformers) between the resource bus and the resource *connection point* to the *IESO-controlled grid* will be excluded; and

- $LossAdj_t$ shall designate any adjustment needed for time-step $t \in TS$ to correct for any discrepancy between Ontario total system losses calculated using a base case power flow from the *security* assessment function and linearized losses that would be calculated using the marginal loss factors.

A discrepancy may arise because a linear equation based on marginal loss factors is used to represent losses, but losses are not a linear function of load. The adjustment required may be positive or negative and will depend on the location of the *reference bus.* For the purposes of the optimization function formulation, the convention will be that a positive value for the loss adjustment term reflects the need for less generation to cover losses.

3.4.1.8 Inputs Provided by the Ex-Ante Market Power Mitigation Process in Prior PD Calculation Engine Runs

The following *offers* may be subject to the ex-ante Market Power Mitigation process when a resource is located in an area of restricted competition:

- *Offers* for *energy* from a dispatchable generation resource;
- *Offers* for *operating reserve* from a *dispatchable load* or a dispatchable generation resource; and
- NQS commitment costs, including start-up *offer*, speed no-load *offer* and *energy offer* for the *energy* to MLP.

If such *offers* are mitigated to their respective reference levels within a prior PD calculation engine run, these reference levels will be used as inputs to the current PD calculation engine run. In cases where a resource provides updated *offers* that are priced lower than the respective reference levels, the updated *offers* will be used for the current PD calculation engine run.

3.4.2. Inputs into the Ex-Ante Market Power Mitigation Process

Inputs to the ex-ante Market Power Mitigation process will include inputs to the constrained area conditions test, conduct test and price impact test.

3.4.2.1 Condition Testing Inputs

The ex-ante Market Power Mitigation process in the PD calculation engine will apply to areas of restricted competition within the *IESO-controlled grid*. The constrained area to which a resource belongs is a reflection of the extent to which competition is restricted for that resource. The *IESO* will apply conduct tests using conduct thresholds specific to the constrained area that meets the conditions.

Constrained Area Designations

Depending on how frequently the transmission constraints bind in an area, that area will be classified as one of the following: narrow constrained area (NCA), dynamic constrained area (DCA) or broad constrained area (BCA). A list of NCAs and DCAs, along with *facilities* leading to the formation of and resources located in an NCA or a DCA, will be provided as inputs to the PD calculation engine, where:

- NCA shall designate the set of narrow constrained areas;
- DCA shall designate the set of dynamic constrained areas;
- $F_n^{NCA} \subseteq F$ shall designate the set of *facilities* whose pre-contingency transmission limit is expected to be binding, resulting in an NCA n;
- $F_d^{DCA} \subseteq F$ shall designate the set of *facilities* whose pre-contingency transmission limit is expected to be binding, resulting in a DCA d;
- $B_n^{NCA} \subseteq B$ shall designate the set of all resources in NCA, n, that could potentially meet the conditions for Market Power Mitigation testing; and
- $B_d^{DCA} \subseteq B$ shall designate the set of all resources in DCA, *d*, that could potentially meet the conditions for Market Power Mitigation testing.
- BCAs will be determined for time-step in the look-ahead period according to the evaluated grid configuration, where:
- $BCACondThresh$ shall designate the threshold for the congestion component of a resource’s LMP, above which the resource will meet the BCA condition.

Conditions to test for global market power in the *energy* and *operating reserve* markets will be determined for each time-step within the PD calculation engine look-ahead period and will consider the following inputs:

- $IBPThresh$ shall designate the *intertie* border price (IBP) threshold;
- $D^{GMPRef} \subseteq D$ shall designate the set of Global Market Power Reference Interties, and proxy locations associated with those *interties*; and
- $ORGCondThresh$ shall designate the threshold for a resource’s *operating reserve* LMP, above which the resource will meet the Global Market Power (*operating reserve*) condition.

3.4.2.2 Conduct Test Inputs

If the conditions for ex-ante market power mitigation are met, the identified set of resources will be subject to a conduct test. The *IESO* will use reference levels and conduct thresholds to test for the potential for the exercise of market power.

Reference Levels

Reference levels will be the *IESO*'s estimate of the competitive *offer* of a resource. For the purposes of the PD calculation engine, there will be reference levels for the following *offered* values:

- $PDGRef_{t,b,k}$ shall designate the *energy offer* reference level for lamination $k \in K^{E}_{t,b}$ of the *offer* from the resource at bus $b \in B^{DG}$ in time-step $t \in TS$;
- $P10SDGRef_{t,b,k}$ shall designate the synchronized *ten-minute operating reserve offer* reference level for lamination $k \in K^{10S}_{t,b}$ of the *offer* from the resource at bus $b \in B^{DG}$ in time-step $t \in TS$;
- $P10NDGRef_{t,b,k}$ shall designate the non-synchronized *ten-minute operating reserve offer* reference level for lamination $k \in K^{10N}_{t,b}$ of the *offer* from the resource at bus $b \in B^{DG}$ in time-step $t \in TS$;
- $P30RDGRef_{t,b,k}$ shall designate the thirty-minute *operating reserve offer* reference level for lamination $k \in K^{30R}_{t,b}$ of the *offer* from the resource at bus $b \in B^{DG}$ in time-step $t \in TS$;
- $SUDGRef_{t,b}$ shall designate the start-up *offer* reference level for the resource at bus $b \in B^{NQS}$ in time-step $t \in TS$;
- $SNLRef_{t,b}$ shall designate the speed no-load *offer* reference level for the resource at bus $b \in B^{NQS}$ in time-step $t \in TS$; and
- $PLTMLPRef_{t,b,k}$ shall designate the *energy offer* for the *energy* to MLP reference level for lamination $k \in K^{LTMLP}_{t,b}$ of the *offer* from the resource at bus $b \in B^{DG}$ in time-step $t \in TS$.

Conduct Thresholds

Conduct thresholds will be used in conjunction with reference levels to determine if resources that are tested for economic withholding have failed the conduct test. Conduct thresholds will be provided for every *dispatch data* parameter for which there exists a reference level, and will vary by constrained zone designation. For the purposes of the PD calculation engine, the following conduct thresholds will be provided:

- $CTEnThresh1^{NCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test;
- $CTEnThresh2^{NCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the NCA conduct test;

- $CTSUThresh^{NCA}$ shall designate the start-up offer conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test;
- $CTSNLThresh^{NCA}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test;
- $CTEnThresh1^{DCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test;
- $CTEnThresh2^{DCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the DCA conduct test;
- $CTSUThresh^{DCA}$ shall designate the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test;
- $CTSNLThresh^{DCA}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test;
- $CTEnThresh1^{BCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test;
- $CTEnThresh2^{BCA}$ shall designate the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the BCA conduct test;
- $CTSUThresh^{BCA}$ shall designate the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test;
- $CTSNLThresh^{BCA}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test;
- $CTEnThresh1^{GMP}$ shall designate the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*energy*) conduct test;
- $CTEnThresh2^{GMP}$ shall designate the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the Global Market Power (*energy*) conduct test;

- $CTSUThresh^{GMP}$ shall designate the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*energy*) conduct test;
- $CTSNLThresh^{GMP}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*energy*) conduct test;
- $CTORThresh1^{ORL}$ shall designate the *operating reserve offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTORThresh2^{ORL}$ shall designate the *operating reserve offer* conduct threshold, pertaining to allowable \$/MW increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTEnThresh1^{ORL}$ shall designate the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTEnThresh2^{ORL}$ shall designate the *energy offer* for the *energy* to MLP conduct threshold, pertaining to allowable \$/MWh increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTSUThresh^{ORL}$ shall designate the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTSNLThresh^{ORL}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (*operating reserve*) conduct test;
- $CTORThresh1^{ORG}$ shall designate the *operating reserve offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test;
- $CTORThresh2^{ORG}$ shall designate the *operating reserve offer* conduct threshold, pertaining to allowable \$/MW increase above the reference level,

to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test;

- $CTEnThresh1^{ORG}$ shall designate the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test;
- $CTEnThresh2^{ORG}$ shall designate the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test;
- $CTSUThresh^{ORG}$ shall designate the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test; and
- $CTSNLThresh^{ORG}$ shall designate the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (*operating reserve*) conduct test.

For more details on the conduct thresholds that the *IESO* will use, refer to Appendix E in this document.

Other Inputs

Other inputs required for the PD calculation engine to perform the conduct test include:

- $CTEnMinOffer$ shall designate the minimum *energy offer* value for the *offer* lamination to be included in the conduct test. *Energy offer* laminations below this value are excluded from the conduct test; and
- $CTORMinOffer$ shall designate the minimum *operating reserve offer* value for the *offer* lamination to be included in the conduct test. *Operating reserve offer* laminations below this value are excluded from the conduct test.

3.4.2.3 Price Impact Test Inputs

Resources with *dispatch data* parameters that fail the conduct test will be tested ex-ante for potential price impact.

Price Impact Thresholds

Impact thresholds will be used to determine whether *market participant offers* have a significant enough effect on *energy* or *operating reserve* prices to warrant intervention. Impact thresholds will be provided to the PD calculation engine for *energy* and *operating reserve* LMPs, and will vary for each constrained zone designation.

For the purposes of the PD calculation engine, the following price impact thresholds will be provided:

- $ITThresh1^{NCA}$ shall designate the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the NCA price impact test;
- $ITThresh2^{NCA}$ shall designate the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the NCA price impact test;
- $ITThresh1^{DCA}$ shall designate the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the DCA price impact test;
- $ITThresh2^{DCA}$ shall designate the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the DCA price impact test;
- $ITThresh1^{BCA}$ shall designate the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the BCA price impact test;
- $ITThresh2^{BCA}$ shall designate the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the BCA price impact test;
- $ITThresh1^{GMP}$ shall designate the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the Global Market Power (*energy*) price impact test;
- $ITThresh2^{GMP}$ shall designate the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that were subject to the Global Market Power (*energy*) price impact test;
- $ITThresh1^{ORG}$ shall designate the price impact threshold, pertaining to allowable percent increase in the *operating reserve* LMP from Pre-Dispatch

Pricing above the *operating reserve* LMP from Reference Level Pricing, to be used for resources that were subject to the Global Market Power (*operating reserve*) price impact test; and

- $ITThresh2^{ORG}$ shall designate the price impact threshold, pertaining to allowable $/MW increase in the *operating reserve* LMP from Pre-Dispatch Pricing above the *operating reserve* LMP from Reference Level Pricing, to be used for resources that were subject to the Global Market Power (*operating reserve*) price impact test.

For more details on the conduct thresholds that the *IESO* will use, refer to Appendix E in this document.

3.4.3. Inputs into the Security Assessment Function

The PD calculation engine *security* assessment function will use the outputs of the optimization function, *security limits* and the network model to perform *security* analysis of the *IESO-controlled grid*. Section 3.7.1 provides further details on how these inputs are used by the *security* assessment function in the PD calculation engine.

3.4.3.1 Inputs Provided by the Optimization Function

The optimization function will provide the *security* assessment function with schedules for load and supply resources (withdrawals and injections), which will be represented at their corresponding electrical buses in the network model.

3.4.3.2 Security Limits

The *security* assessment function will continue to apply a set of equations, known as operating *security* limits (OSLs). OSLs help ensure that power flows remain within North American Electric Reliability Corporation (*NERC*) and Northeast Power Coordinating Council (NPCC) *reliability* criteria both pre-contingency and following *contingency events*. The *security* assessment function will also continue to use pre-contingency and post-contingency thermal ratings to help ensure that schedules result in transmission flows that respect the thermal limits.

3.4.3.3 Network Model

The *security* assessment function will continue to use data related to the power system model, load distribution factors, contingencies and monitored equipment.

3.5. Initialization

Before commencing its pass, the PD calculation engine will perform any necessary initialization processes. These processes produce required engine inputs that are not provided by *market participants* or the *IESO* directly. Initialization is required prior to the first optimization function iteration to:

- assess network inputs to select a *reference bus* and determine islanding conditions;
- enforce any assumptions on the evaluation of *dispatch data* when the look-ahead period spans two *dispatch days*; and
- pre-process data that must be adjusted before evaluation by the optimization function, including data pertaining to:
    - *variable generation* resource tie-breaking logic;
    - minimum and maximum generation constraints that apply to *pseudo-units;* and
    - *start-up costs* and first hour available to start for NQS resources.

3.5.1. Reference Bus

The optimization function will use a fixed *reference bus* as a starting point to determine all LMPs. By default, this *reference bus* will be the Richview Transformer Station. If the *reference bus* is out of service, then an alternative station will be determined as per the prevailing system conditions.

3.5.2. Islanding

In the case of a network split, only the island with the largest number of *IESO-controlled grid* buses will be considered, and the following will apply:

- Resources, imports and exports that are not in the largest island will be assumed to neither inject nor withdraw and, therefore, will be disregarded by the optimization function;
- The load forecasts used by the optimization function will only include *demand* forecast areas in the largest island; and
- If necessary, the *reference bus* will be updated to a bus within the largest island.

For any nodes outside the largest island, prices will be determined as per the methodology detailed in Section 3.8.3.

3.5.3. Variable Generation Resource Tie-Breaking

As described in the Tie-Breaking sub-section in Section 3.4.1.5, *variable generation* resource *energy offer* prices will be modified prior to the PD calculation engine pass for the purposes of tie-breaking. For each time-step $t \in TS$, each *variable generation* resource bus $b \in B^{VG}$ and each *offer* lamination $k \in K^{E}_{t,b}$, the *offer* price $PDG_{t,b,k}$ shall be updated to $PDG_{t,b,k} - \left(\frac{TBM_{t,b}}{NumVG_t}\right)\rho$ where ρ is a small nominal value of order 10^{-4}.

3.5.4. PSU Constraints

For a combined cycle *facility* that has elected to be represented as a *pseudo-unit*, any minimum or maximum generation constraint applied to a corresponding physical unit will be pre-processed to determine an appropriate constraint for the PSU resources. The logic for determining the appropriate constraints is described in Section 3.10.

3.5.5. Evaluation of Daily Dispatch Data Across Two Dispatch Days

When the pre-dispatch look-ahead period spans two *dispatch days* (i.e. the 20:00 EST to 23:00 EST PD calculation engine runs of the current *dispatch day*) certain daily *dispatch data* parameters will be evaluated across the entire look-ahead period using the daily *dispatch data* submitted for the second day. The daily *dispatch data* parameters that will be evaluated in this manner include:

- Linked resources (LNK_q for $q \in DAYS$), time lag (Lag_{q,b_1,b_2} for $q \in DAYS$ and $(b_1,b_2) \in LNK_q$) and MWh ratio ($MWhRatio_{q,b_1,b_2}$ for $q \in DAYS$ and $(b_1,b_2) \in LNK_q$);
- Minimum loading point ($MinQDG_{q,b}$ for $b \in B^{DG}$ and $q \in DAYS$);
- Minimum generation block run-time ($MGBRTDG_{q,b}$ for $b \in B^{NQS}$ and $q \in DAYS$);
- Minimum generation block down time ($MGBDTDG^{m}_{q,b}$ for $b \in B^{NQS}, m \in THERM$ and $q \in DAYS$);
- Lead time ($LT^{m}_{q,b}$ *for* $b \in B^{NQS}, m \in THERM$ *and* $q \in DAYS$);
- Ramp up *energy* to MLP ($RampE^{m}_{q,b,w}$ for $b \in B^{NQS}, m \in THERM$, $q \in DAYS$ and $w \in \{1,..,RampHrs^{m}_{q,b}\}$) and Ramp up hours to MLP ($RampHrs^{m}_{q,b}$ for $b \in B^{NQS}, m \in THERM$, and $q \in DAYS$); and
- Ramp up *energy* to MLP for CT ($RampCT^{m}_{q,b,w}$ for $b \in B^{PSU}, m \in THERM$, $q \in DAYS$ and $w \in \{1,..,RampHrs^{m}_{q,b}\}$) and ST portion ($RampST^{m}_{q,b,w}$ for $b \in B^{PSU}, m \in THERM$, $q \in DAYS$ and $w \in \{1,..,RampHrs^{m}_{q,b}\}$).

Parameters will be introduced within the formulation of the optimization function that represent the fixed values for this daily *dispatch data*. When the look-ahead period spans two *dispatch days*, these will be equal to the second day value. When the look-ahead periods spans one *dispatch day*, these parameters will equal to the value for that day, where[8]:

- $LNKC$ shall designate the linked resources and is defined by

$$LNKC = \begin{cases} LNK_{tod} & if\ DAYS\ = \{tod\} \\ LNK_{tom} & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $LagC_{b_1,b_2}$ shall designate the time lag between resources $(b_1,b_2) \in LNKC$ and is defined by

$$LagC_{b_1,b_2} = \begin{cases} Lag_{tod,b_1,b_2} & if\ DAYS\ = \{tod\} \\ Lag_{tom,b_1,b_2} & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $MWhRatioC_{b_1,b_2}$ shall designate the MWh ratio for resources $(b_1,b_2) \in LNKC$ and is defined by

$$MWhRatioC_{b_1,b_2} = \begin{cases} MWhRatio_{tod,b_1,b_2} & if\ DAYS\ = \{tod\} \\ MWhRatio_{tom,b_1,b_2} & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $MinQDGC_b$ shall designate the *minimum loading point* for dispatchable generation resource $b \in B^{DG}$ and is defined by

$$MinQDGC_b = \begin{cases} MinQDG_{tod,b} & if\ DAYS\ = \{tod\} \\ MinQDG_{tom,b} & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $MGBRTDGC_b$ shall designate the *minimum generation block run time* for NQS resource $b \in B^{NQS}$ and is defined by

$$MGBRTDGC_b = \begin{cases} MGBRTDG_{tod,b} & if\ DAYS\ = \{tod\} \\ MGBRTDG_{tom,b} & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $MGBDTDGC_b^m$ shall designate the *minimum generation block down time* for NQS resource $b \in B^{NQS}$ for thermal state $m \in THERM$ and is defined by

$$MGBDTDGC_b^m = \begin{cases} MGBDTDG_{tod,b}^m & if\ DAYS\ = \{tod\} \\ MGBDTDG_{tom,b}^m & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- LTC_b^m shall designate the lead time for NQS resource $b \in B^{NQS}$ for thermal state $m \in THERM$ and is defined by

$$LTC_b^m = \begin{cases} LT_{tod,b}^m & if\ DAYS\ = \{tod\} \\ LT_{tom,b}^m & if\ DAYS\ =\ \{tod, tom\} \end{cases}.$$

- $RampHrsC_b^m$ shall designate the ramp up hours to MLP for NQS resource $b \in B^{NQS}$ for thermal state $m \in THERM$ and is defined by

[8] "C" will be added to parameter notations to indicate a parameter which takes the same value across the entire look-ahead period.

$$RampHrsC_b^m = \begin{cases} RampHrs_{tod,b}^m & if\ DAYS\ = \{tod\} \\ RampHrs_{tom,b}^m & if\ DAYS\ = \{tod, tom\} \end{cases}.$$

- $RampEC_{b,w}^m$ for $w \in \{1,..,RampHrsC_b^m\}$ shall designate the ramp up *energy* to MLP for NQS resource $b \in B^{NQS}$ for thermal state $m \in THERM$ and is defined by

$$RampEC_{b,w}^m = \begin{cases} RampE_{tod,b,w}^m & if\ DAYS\ = \{tod\} \\ RampE_{tom,b,w}^m & if\ DAYS\ = \{tod, tom\} \end{cases}.$$

- $RampCTC_{b,w}^m$ for $w \in \{1,..,RampHrsC_b^m\}$ shall designate the ramp up *energy* to MLP for the CT of the PSU resource at bus $b \in B^{PSU}$ for thermal state $m \in THERM$ and is defined by

$$RampCTC_{b,w}^m = \begin{cases} RampCT_{tod,b,w}^m & if\ DAYS\ = \{tod\} \\ RampCT_{tom,b,w}^m & if\ DAYS\ = \{tod, tom\} \end{cases}.$$

- $RampSTC_{b,w}^m$ for $w \in \{1,..,RampHrsC_b^m\}$ shall designate the ramp up *energy* to MLP for the ST portion of the PSU resource at bus $b \in B^{PSU}$ for thermal state $m \in THERM$ and is defined by

$$RampSTC_{b,w}^m = \begin{cases} RampST_{tod,b,w}^m & if\ DAYS\ = \{tod\} \\ RampST_{tom,b,w}^m & if\ DAYS\ = \{tod, tom\} \end{cases}.$$

An exception to the assignment of values described above is made when an NQS resource receives a commitment prior to the 20:00 EST PD calculation engine run but that commitment is not yet complete. In this case, $MinQDG_{tod,b}$ and $MGBRTDG_{tod,b}$ will continue to be applied until the commitment is complete, even if this commitment extends into the next *dispatch day*. Any new commitments made in the 20:00 EST PD calculation engine run or later will use $MinQDG_{tom,b}$ and $MGBRTDG_{tom,b}$.

Other than the single-cycle mode flag, all other daily *dispatch data* will be evaluated using the current day value for all *dispatch hours* in the current *dispatch day* and the next day value for all *dispatch hours* in the next *dispatch day*.

3.5.6. Evaluation of Start-up Cost for NQS Advancements

Some NQS resources may have secured operational commitments in the day-ahead market that fall within the PD look-ahead period. As described in the Grid and Market Operations Integration detailed design document, the *pre-dispatch scheduling* process may issue an advancement of such DAM operational commitments. Any advancement is advisory until such time a binding start-up instruction is issued.

The PD calculation engine will evaluate *start-up costs* for the advancement of NQS resource commitments to align with the *settlement* outcomes described in the Market Settlement detailed design document. These *settlement* outcomes depend on whether the operational commitment is extended inside or outside of the so-called advancement period. The advancement period is the set of hours before the

DAM commitment equaling the sum of the resource's *minimum generation block run time* and hot *minimum generation block down time*. It is defined so that if the NQS resource is scheduled to start in the advancement period, then the resource must be scheduled at or above its *minimum loading point* to the conclusion of its DAM operational commitment to respect the resource's operational parameters and existing commitment. Each PD calculation engine run will evaluate advancements according to the *start-up cost* used in *settlement* as follows.

1. When considering advancing a DAM operational commitment to an hour within the advancement period:
    a. If the *start-up cost* in the hour is greater than the DAM *start-up cost*, then the increase in *start-up costs* will be considered.
    b. If the *start-up cost* in the hour is less than the DAM *start-up cost*, then the decrease in *start-up costs* will not be considered. This is because the start will be settled against the DAM *start-up cost*.
2. When considering advancing a DAM operational commitment to an hour outside the advancement period: the *start-up cost* in the hour will replace the DAM *start-up cost*.

For each commitment scheduled in the DAM, the *start-up cost* evaluated by the DAM calculation engine will be used to determine the appropriate *start-up cost* for an advancement of the commitment. For NQS resource bus $b \in B^{NQS}$:

- $TSC_b \subseteq TS$ shall designate the set of time-steps representing the first hour of a DAM operational commitment for the resource. A resource can have multiple operational commitments from the DAM within the look-ahead period. A time-step will be included in this set for each such commitment; and
- $SUDG_{t,b}^{DAM}$ shall designate the *start-up cost* used to evaluate the DAM commitment starting in time-step $t \in TSC_b$.

For each time-step $t_{DAM} \in TSC_b$ such that t_{DAM} falls in *dispatch day* $q \in DAYS$, the resource must be committed in time-steps $\{t_{DAM},..,min(t_{DAM} + MGBRTDG_{q,b}\text{-}1, n_{LAP})\}$. The PD calculation engine will enforce this commitment constraint as described in the Resource Minimum and Maximum constraints section of Section 3.4.1.5.

To evaluate the *start-up costs* for NQS resources, the *start-up costs* used in the objective function of the PD optimization will be determined in respect of fixed DAM operational commitments. For the NQS resource at bus $b \in B^{NQS}$:

- $SUAdjDG_{t,b}^{m}$ shall designate the *start-up cost* that the optimization function will evaluate in time-step $t \in TS$ under thermal state m.

The value for $SUAdjDG_{t,b}^{m}$ for the NQS resource at bus $b \in B^{NQS}$ under thermal state $m \in THERM$ is determined for time-step $t \in TS$ as follows.

1. If the time-step falls in the advancement period of a DAM operational commitment, then the *start-up cost* for the DAM operational commitment will be considered whenever it is higher than the *offered start-up cost*. That is, if there exists $t_{DAM} \in TSC_b$ in day $q \in DAYS$ such that $t \in \{max(t_{DAM}$- $(MGBRTDG_{q,b} + MGBDTDG_{q,b}^{HOT}), 2),...,t_{DAM}\}$ then:
   a. If $SUDG_{t,b}^{m} \geq SUDG_{t,b}^{DAM}$, set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{m}$.
   b. Otherwise, $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{DAM}$.
2. Otherwise, the *offered start-up cost* will be used:
   a. Set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{m}$.

3.5.7. Evaluation of NQS First Time-Step Available to Start

Based on when an NQS resource was last at its MLP before desynchronization, the PD calculation engine will determine the first time-step the resource can next reach MLP. This time-step must respect the resource's hot *minimum generation block down time* and must also respect the lead time associated with the resource's anticipated thermal state for the hour it reaches MLP. It will be assumed that the resource can be started in all future time-steps beyond this time-step.

For the NQS resource at bus $b \in B^{NQS}$ that has been offline $InitDownHrs_b$ hours:

- If $0 \leq InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{HOT}$ then the unit cannot be scheduled to reach MLP in time-step $t \in TS$ since hot *minimum generation block down time* cannot be respected. The following steps will apply to time-steps not excluded for this reason.
- If $InitDownHrs_b + LTC_b^{HOT} + 1 \leq MGBDTDGC_b^{WARM}$, then a lead time of LTC_b^{HOT} will be applied to the next start and the resource can be scheduled to reach MLP in time-step $t \in TS$ if and only if $t \geq LTC_b^{HOT} + 2$.
- Else if $InitDownHrs_b + LTC_b^{WARM} + 1 \leq MGBDTDGC_b^{COLD}$, then a lead time of LTC_b^{WARM} will be applied to the next start and the resource can be scheduled to reach MLP in time-step $t \in TS$ if and only if $t \geq LTC_b^{WARM} + 2$.
- Else a lead time of LTC_b^{COLD} will be applied to the next start and the resource can be scheduled to reach MLP in time-step $t \in TS$ if and only if $t \geq LTC_b^{COLD} + 2$.

If a resource is currently online, a decision to shut down the resource in a specific time-step dictates the anticipated thermal state in future time-steps for which a decision to restart the resource may be made. These decisions are made simultaneously. The lead time parameter can be ignored for the later start since any schedule satisfying the resource's hot MGBDT will necessarily satisfy lead time.

3.6. Pass 1: Pre-Dispatch Scheduling Process

Pass 1 will use *market participant* and *IESO* inputs along with resource and system constraints to determine a set of resource schedules and commitments. These schedules and commitments are calculated to meet the *IESO's* hourly non-dispatchable forecast *demand* and the *demand* from *dispatchable loads*, *hourly demand response* resources and exports. Pass 1 will also determine LMPs consistent with these scheduling and commitment decisions.

Pass 1 will assess whether certain conditions related to transmission congestion have been met, and if the steps related to ex-ante Market Power Mitigation need to be performed. If Pass 1 performs ex-ante Market Power Mitigation and the Price Impact test is failed for a resource, then the specific *dispatch data* inputs for that resource that failed the conduct test are identified. As discussed in Section 3.4.1.8, reference levels for the *dispatch data* that failed the conduct and price impact tests will be used in the subsequent runs of Pre-Dispatch Scheduling and Pre-Dispatch Pricing through to the real-time timeframe.

3.6.1. Pre-Dispatch Scheduling

Pre-Dispatch Scheduling will perform a *security*-constrained unit commitment and economic *dispatch* to meet the *IESO*'s hourly non-dispatchable *demand* forecast and *IESO*-specified *operating reserve* requirements. Pre-Dispatch Scheduling will also evaluate *demand* from *dispatchable loads*, *hourly demand response* resources and *bids* to export *energy*.

Pre-Dispatch Scheduling will use *bids* and *offers* submitted by *market participants* to maximize the gains from trade. The gains from trade is the difference between the total price of *bids* that are scheduled and the total price of *offers* that are scheduled. The optimization is subject to the constraints accompanying those *bids* and *offers*, and constraints imposed by the *IESO* to maintain *reliability*.

Pre-Dispatch Scheduling will determine commitment statuses and schedules based on the inputs described in Section 3.4. These commitments will serve as inputs into Pre-Dispatch Pricing.

The following sections describe the formulation of the optimization function for Pre-Dispatch Scheduling.

3.6.1.1 Inputs

All applicable inputs identified in Section 3.4.1 will be evaluated.

3.6.1.2 Variables and Objective Function

The PD calculation engine will solve for the following variables:

- $SDL_{t,b,j}$ shall represent the amount of *dispatchable load* scheduled at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,b}$;
- $S10SDL_{t,b,j}$ shall represent the amount of synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{10S}_{t,b}$;
- $S10NDL_{t,b,j}$ shall represent the amount of non-synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{10N}_{t,b}$;
- $S30RDL_{t,b,j}$ shall represent the amount of *thirty-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{30R}_{t,b}$;
- $SHDR_{t,b,j}$ shall represent the amount of *hourly demand response* reduction scheduled at bus $b \in B^{HDR}$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,b}$;
- $SXL_{t,d,j}$ shall represent the amount of exports scheduled to *intertie zone* sink bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,d}$;
- $S10NXL_{t,d,j}$ shall represent the amount of non-synchronized *ten-minute operating reserve* scheduled from *intertie zone* sink bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{10N}_{t,d}$;
- $S30RXL_{t,d,j}$ shall represent the amount of *thirty-minute operating reserve* scheduled from *intertie zone* sink bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{30R}_{t,d}$;
- $SNDG_{t,b,k}$ shall represent the amount of non-dispatchable generation scheduled at bus $b \in B^{NDG}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$;
- $SDG_{t,b,k}$ shall represent the amount of dispatchable generation scheduled at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$. This is in addition to any $MinQDGC_b$, the *minimum loading point*, which must be committed before any such generation is scheduled;
- $ODG_{t,b}$ shall represent whether the dispatchable generation resource at bus $b \in B^{DG}$ has been scheduled at or above its *minimum loading point* in time-step $t \in TS$;
- $IDG_{t,b}$ shall represent whether the dispatchable generation resource at bus $b \in B^{DG}$ has been scheduled to start (reach its *minimum loading point*) in time-step $t \in TS$;
- $S10SDG_{t,b,k}$ shall represent the amount of synchronized *ten-minute operating reserve* that a qualified dispatchable generation resource is scheduled to

provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10S}$;

- $S10NDG_{t,b,k}$ shall represent the amount of non-synchronized *ten-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$;
- $\mathrm{S30RDG_{t,b,k}}$ shall represent the amount of *thirty-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{30R}$;
- $SCT_{t,b}$ shall represent the schedule of the combustion turbine associated with the PSU resource at bus $b \in B^{PSU}$ in time-step $t \in TS$;
- $SST_{t,p}$ shall represent the schedule of steam turbine $p \in PST$ in time-step $t \in TS$;
- $O10R_{t,b}$ shall represent whether the PSU resource at bus $b \in B^{NO10DF}$ has been scheduled for *ten-minute operating reserve* in time-step $t \in TS$;
- $OHO_{t,b}$ shall represent whether the hydroelectric resource at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$;
- $OFR_{t,b,i}$ for $i \in \{1,..,NFor_{q,b}\}$ shall represent whether the hydroelectric resource at bus $b \in B^{HE}$ has been scheduled at or below $ForL_{q,b,i}$, or, at or above $ForU_{q,b,i}$ in time-step $t \in TS$;
- $IHE_{t,b,i}$ shall represent whether the hydroelectric resource at bus $b \in B^{HE}$ registered a start between time-step $(t-1)$ and t as result of its schedule increasing from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$;
- $SIG_{t,d,k}$ shall represent the amount of imports from *intertie zone* source bus $d \in DI$ scheduled in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{E}$;
- $S10NIG_{t,d,k}$ shall represent the amount of non-synchronized *ten-minute operating reserve* scheduled from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{10N}$;
- $S30RIG_{t,d,k}$ shall represent the amount of *thirty-minute operating reserve* scheduled from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{30R}$;
- TB_t shall represent any adjustment to the objective function to facilitate pro-rata tie-breaking in time-step $t \in TS$, as described in Section 3.4.1.5 and this section; and

- $ViolCost_t$ shall represent the cost incurred in order to avoid having the schedules for time-step $t \in TS$ violate certain constraints, as described in Section 3.4.1.5 and this section.

Within the optimization function formulation provided in the document, $T_{t,b} \in THERM$ shall represent the thermal state used to evaluate the *start-up cost* and ramp *energy* to MLP profile for the resource at bus $b \in B^{NQS}$ in time-step $t \in TS$. This thermal state will be evaluated dynamically within the optimization function as it relates to the variables $ODG_{ts,b}$ for $ts \in TS$. For more information, see the NQS Resource constraints in Section 3.6.1.5.

To maximize the gains from trade, the objective function in Pre-Dispatch Scheduling will maximize the value of the following expression:

$$\sum_{t \in TS} \begin{pmatrix} ObjDL_t - ObjHDR_t + ObjXL_t - ObjNDG_t \\ - ObjDG_t - ObjIG_t - TB_t - ViolCost_t \end{pmatrix}$$

where:

$$ObjDL_t = \sum_{b \in B^{DL}} \begin{pmatrix} \sum_{j \in J_{t,b}^{E}} SDL_{t,b,j} \cdot PDL_{t,b,j} - \sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \cdot P10SDL_{t,b,j} - \\ \sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \cdot P10NDL_{t,b,j} - \sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \cdot P30RDL_{t,b,j} \end{pmatrix};$$

$$ObjHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J_{t,b}^{E}} SHDR_{t,b,j} \cdot PHDR_{t,b,j} \right);$$

$$ObjXL_t = \sum_{d \in DX} \begin{pmatrix} \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j} \cdot PXL_{t,d,j} - \sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \cdot P10NXL_{t,d,j} \\ - \sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \cdot P30RXL_{t,d,j} \end{pmatrix};$$

$$ObjNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{t,b}^{E}} SNDG_{t,b,k} \cdot PNDG_{t,b,k} \right);$$

$$ObjDG_t = \sum_{b \in B^{DG}} \begin{pmatrix} \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \cdot PDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \cdot P10SDG_{t,b,k} + \\ \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \cdot P10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \cdot P30RDG_{t,b,k} \end{pmatrix} + \sum_{b \in B^{NQS}} \left(ODG_{t,b} \cdot MGODG_{t,b} + IDG_{t,b} \cdot SUAdjDG_{t,b}^{T_{t,b}} \right);$$

and

$$ObjIG_t = \sum_{d \in DI} \left(\sum_{k \in K^E_{t,d}} SIG_{t,d,k} \cdot PIG_{t,d,k} + \sum_{k \in K^{10N}_{t,d}} S10NIG_{t,d,k} \cdot P10NIG_{t,d,k} + \sum_{k \in K^{30R}_{t,d}} S30RIG_{t,d,k} \cdot P30RIG_{t,d,k} \right).$$

The tie-breaking term - TB_t - is obtained by adding a term for each *bid* or *offer* lamination. For each lamination, this term is the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost is calculated by multiplying a base penalty cost of $TBPen$ by the amount of the lamination scheduled and then dividing by the maximum amount that could have been scheduled. When this penalty cost is multiplied by the amount scheduled from that lamination, a quadratic function that increases as the amount scheduled increases is obtained. This effectively increases the *bid* or *offer* price by zero if nothing is scheduled from the lamination, but by $TBPen$ if the maximum amount that could have been scheduled is scheduled. This slight price gradient, which is smaller than the minimum step size of *bid* or *offer* prices, will ensure that two otherwise tied laminations will be scheduled to the point where their modified costs are identical, effectively achieving a pro-rated result.

$ViolCost_t$ calculates the total constraint violation cost and depends on the constraint violation variables. The constraint violation variables for time-step $t \in TS$ are:

- $SLdViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{LdViol_t}\}$ of the penalty curve for the *energy* balance constraint (allowing under-generation);
- $SGenViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{GenViol_t}\}$ of the penalty curve for the *energy* balance constraint (allowing over-generation);
- $S10SViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{10SViol_t}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;
- $S10RViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{10RViol_t}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;
- $S30RViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{30RViol_t}\}$ of the penalty curve for the *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;
- $SREG10RViol_{r,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{REG10RViol_t}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;
- $SREG30RViol_{r,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{REG30RViol_t}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

- $SXREG10RViol_{r,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{XREG10RViol_t}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;
- $SXREG30RViol_{r,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{XREG30RViol_t}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;
- $SPreITLViol_{f,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{PreITLViol_{f,t}}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$;
- $SITLViol_{c,f,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$;
- $SPreXTLViol_{z,t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ of the penalty curve for violating the import/export limit affiliated with *intertie* limit constraint $z \in Z_{Sch}$;
- $SNIUViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{NIUViol_t}\}$ of the penalty curve for exceeding the net interchange increase limit between time-steps $(t\text{-}1)$ and t; and
- $SNIDViol_{t,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{NIDViol_t}\}$ of the penalty curve for exceeding the net interchange decrease limit between time-steps $(t\text{-}1)$ and t.
- $SMaxDelViol_{t,b,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{MaxDelViol_t}\}$ of the penalty curve for exceeding the maximum daily *energy* limit constraint for a resource at bus $b \in B^{ELR}$.
- $SMinDelViol_{t,b,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{MinDelViol_t}\}$ of the penalty curve for violating the minimum daily *energy* limit constraint for a resource at bus $b \in B^{HE}$.
- $SSMaxDelViol_{t,s,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{SMaxDelViol_t}\}$ of the penalty curve for exceeding the shared maximum daily *energy* limit constraint for hydroelectric resources in set $s \in SHE$.
- $SSMinDelViol_{t,s,i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{SMinDelViol_t}\}$ of the penalty curve for violating the shared minimum daily *energy* limit constraint for hydroelectric resources in set $s \in SHE$.
- $SOGenLnkViol_{t,(b_1,b_2),i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{OGenLnkViol_t}\}$ of the penalty curve for violating the linked hydroelectric resources constraint by over-generating the downstream resource, for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$.

- $SUGenLnkViol_{t,(b_1,b_2),i}$ is the violation variable affiliated with segment $i \in \{1,..,N_{UGenLnkViol_t}\}$ of the penalty curve for violating the linked hydroelectric resources constraint by under-generating the downstream resource, for $(b_1,b_2) \in LNK$ such that $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$.

From these variables, the violation cost is computed as follows:

$$
\begin{aligned}
ViolCost_t = & \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} \cdot PLdViolSch_{t,i} \\
& - \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} \cdot PGenViolSch_{t,i} \\
& + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \cdot P10SViolSch_{t,i} \\
& + \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \cdot P10RViolSch_{t,i} \\
& + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \cdot P30RViolSch_{t,i} \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \cdot PREG10RViolSch_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \cdot PREG30RViolSch_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \cdot PXREG10RViolSch_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i} \cdot PXREG30RViolSch_{t,i} \right) \\
& + \sum_{f \in F_t} \left(\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \cdot PPreITLViolSch_{f,t,i} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{t,c}} \left(\sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i} \cdot PITLViolSch_{c,f,t,i} \right) \\
& + \sum_{z \in Z_{Sch}} \left(\sum_{i=1..N_{PreXTLViol_{z,t}}} SPreXTLViol_{z,t,i} \cdot PPreXTLViolSch_{z,t,i} \right) \\
& + \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i} \cdot PNIUViolSch_{t,i} \\
& + \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i} \cdot PNIDViolSch_{t,i}
\end{aligned}
$$

$$+ \sum_{b \in B^{ELR}} \left(\sum_{i=1..N_{MaxDelViol_t}} SMaxDelViol_{t,b,i} \cdot PMaxDelViolSch_{t,b,i} \right)$$

$$+ \sum_{b \in B^{HE}} \left(\sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \cdot PMinDelViolSch_{t,b,i} \right)$$

$$+ \sum_{s \in \mathrm{SHE}} \left(\sum_{i=1..N_{SMaxDelViol_t}} SSMaxDelViol_{t,s,i} \cdot PSMaxDelViolSch_{t,s,i} \right)$$

$$+ \sum_{s \in \mathrm{SHE}} \left(\sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \cdot PSMinDelViolSch_{t,s,i} \right)$$

$$+ \sum_{(b_1,b_2) \in LNK} \left(\sum_{i=1..N_t} SOGenLnkViol_{\mathrm{t},(b_1,b_2),i} \cdot PSOGenLnkViolSch_{t,(b_1,b_2),i} \right)$$

$$+ \sum_{(b_1,b_2) \in LNK} \left(\sum_{i=1..N_t} SUGenLnkViol_{t,b_1,b_2,i} \cdot PSUGenLnkViolSch_{\mathrm{t},(b_1,b_2),i} \right).$$

This maximization will be subject to the constraints described in the next sections.

3.6.1.3 Constraints Overview

The constraints that apply to the optimization can be divided into three categories:

1. Single hour constraints to ensure that the schedules determined in the optimization do not violate the parameters specified in the *dispatch data* submitted by *registered market participants*;
2. Inter-hour and multi-hour constraints to ensure that the schedules determined in the optimization do not violate the parameters specified in the *dispatch data* submitted by *registered market participants*, and
3. Constraints to ensure that those schedules do not violate the *reliability* inputs established by the *IESO*.

3.6.1.4 Bid/Offer Constraints Applying to Single Hours

Scheduling Variable Bounds and Commitment Status Variables

As described in Section 3.3, a dispatchable generation resource is said to be committed in a specific time-step if it is scheduled at or above its *minimum loading point* in that time-step. A Boolean variable $ODG_{t,b}$ indicates whether the resource at bus $b \in B^{DG}$ is committed in time-step $t \in TS$. A value of zero indicates that a resource is not committed, while a value of one indicates that it is committed. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$ODG_{t,b} \in \{0,1\}.$$

Reliability must-run resources will be considered committed for all must-run hours. Regulating units will be considered committed for all the hours that they are regulating. As described in Section 3.3, a dispatchable generation resource with zero commitment cost (i.e., its *minimum loading point*, start-up *offer,* speed no-load *offer*, *minimum generation block run-time* and *minimum generation block down time* are zero) will be considered committed for all hours. If the dispatchable generation resource at bus $b \in B^{DG}$ is considered committed according to these rules in time-step $t \in TS$ then:

$$ODG_{t,b} = 1.$$

No schedule can be negative, nor can any schedule exceed the quantity *offered* for the respective market (*energy* and *operating reserve*). Therefore, for all time-steps $t \in TS$:

$0 \leq SDL_{t,b,j} \leq QDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{E}_{t,b}$;

$0 \leq S10SDL_{t,b,j} \leq Q10SDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{10S}_{t,b}$;

$0 \leq S10NDL_{t,b,j} \leq Q10NDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{10N}_{t,b}$;

$0 \leq S30RDL_{t,b,j} \leq Q30RDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{30R}_{t,b}$;

$0 \leq SHDR_{t,b,j} \leq QHDR_{t,b,j}$ for all $b \in B^{HDR}$, $j \in J^{E}_{t,b}$;

$0 \leq SXL_{t,d,j} \leq QXL_{t,d,j}$ for all $d \in DX$, $j \in J^{E}_{t,d}$;

$0 \leq S10NXL_{t,d,j} \leq Q10NXL_{t,d,j}$ for all $d \in DX$, $j \in J^{10N}_{t,d}$;

$0 \leq S30RXL_{t,d,j} \leq Q30RXL_{t,d,j}$ for all $d \in DX$, $j \in J^{30R}_{t,d}$;

$0 \leq SNDG_{t,b,k} \leq QNDG_{t,b,k}$ for all $b \in B^{NDG}$, $k \in K^{E}_{t,b}$;

$0 \leq SIG_{t,d,k} \leq QIG_{t,d,k}$ for all $d \in DI$, $k \in K^{E}_{t,d}$;

$0 \leq S10NIG_{t,d,k} \leq Q10NIG_{t,d,k}$ for all $d \in DI$, $k \in K^{10N}_{t,d}$; and

$0 \leq S30RIG_{t,d,k} \leq Q30RIG_{t,d,k}$ for all $d \in DI$, $k \in K^{30R}_{t,d}$.

In addition to restrictions on their schedules similar to those above, the schedules for dispatchable generation resources must be consistent with their commitment status. Dispatchable *generation* resources can be scheduled to produce *energy* and *operating reserve* only if their commitment status variable is equal to 1. Therefore, for all time-steps $t \in TS$:

$0 \leq SDG_{t,b,k} \leq ODG_{t,b} \cdot QDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{E}_{t,b}$;

$0 \leq S10SDG_{t,b,k} \leq ODG_{t,b} \cdot Q10SDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{10S}_{t,b}$;

$0 \leq S10NDG_{t,b,k} \leq ODG_{t,b} \cdot Q10NDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{10N}_{t,b}$; and

$0 \leq S30RDG_{t,b,k} \leq ODG_{t,b} \cdot Q30RDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{30R}_{t,b}$.

Resource Minimums and Maximums

The schedule of an internal resource may be limited depending on the impact of the constraints detailed in Resource Minimum and Maximum constraints within Section 3.4.1.5.

Dispatchable Load

A constraint is required to limit *dispatchable loads* within their minimum and maximum consumption for a time-step. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$MinDL_{t,b} \leq \sum_{j \in J^E_{t,b}} SDL_{t,b,j} \leq MaxDL_{t,b}.$$

The non-dispatchable portion of a *dispatchable load* must always be scheduled. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J^E_{t,b}} SDL_{t,b,j} \geq QDLFIRM_{t,b}.$$

Non-Dispatchable Generation Resources

A constraint is required to limit non-dispatchable generation resources within their minimum and maximum output for a time-step. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{NDG}$:

$$MinNDG_{t,b} \leq \sum_{k \in K^E_{t,b}} SNDG_{t,b,k} \leq MaxNDG_{t,b}.$$

Dispatchable Generation Resources

A constraint is required to limit dispatchable generation resources within their minimum and maximum output for a time-step. The maximum output of a dispatchable *variable generation* resource will additionally be limited by its forecast. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$, let

$$AdjMaxDG_{t,b} = \begin{cases} Min(MaxDG_{t,b}, FG_{t,b}) & if\ b \in B^{VG} \\ MaxDG_{t,b} & otherwise \end{cases}$$

and

$$AdjMinDG_{t,b} = Min(MinDG_{t,b}, AdjMaxDG_{t,b}).$$

Then, for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$AdjMinDG_{t,b} \leq MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq AdjMaxDG_{t,b}.$$

If the commitment status of the resource is fixed to 1 (i.e. $ODG_{t,b} = 1$) and if this is inconsistent with the adjusted minimum and maximum constraints (i.e. $MinQDGC_b > AdjMaxDG_{t,b}$), then the commitment status will be relaxed. If the total *offered* quantity does not exceed the minimum

$$(\mathrm{MinQDGC_b} + \textstyle\sum_{k \in K_{t,b}^E} \mathrm{QDG_{t,b,k}} < \mathrm{AdjMinDG_{t,b}})$$

then the resource will receive a schedule of zero.

Maximum constraints are also respected in hours where an NQS resource is ramping to its *minimum loading point*. In the case where an operational commitment has not yet been issued, a resource will not be scheduled to reach *minimum loading point* for a number of hours immediately following outages that make the resource grid-incapable. The number of hours will correspond to the number of ramp-to-MLP hours associated with the resource's warm state. In the case where an operational commitment has already been issued, the PD calculation engine will schedule ramp *energy* in respect of the maximum constraint.

HDR Activation and Non-Activation

Any minimum and maximum limits placed on *hourly demand response* resource schedules for the purposes of reflecting activation/non-activation decisions must be respected. For all time-steps $t \in TS$ and all buses $b \in B^{HDR}$:

$$MinHDR_{t,b} \leq \sum_{j \in J_{t,b}^E} SHDR_{t,b,j} \leq MaxHDR_{t,b}.$$

Off-Market Transactions

Intertie schedules will account for off-market transactions as detailed in Off-Market Transactions within Section 3.4.1.5.

Inadvertent Payback

A constraint is required to schedule inadvertent payback transactions. For all time-steps $t \in TS$ and all *intertie zone* sink buses corresponding to an inadvertent payback transaction $d \in DX_t^{INP}$:

$$\sum_{j \in J_{t,d}^E} SXL_{t,d,j} = \sum_{j \in J_{t,d}^E} QXL_{t,d,j}.$$

For all time-steps $t \in TS$ and all *intertie zone* source buses corresponding to an inadvertent payback transaction $d \in DI_t^{INP}$:

$$\sum_{k\in K_{t,d}^{E}} SIG_{t,d,k} = \sum_{k\in K_{t,d}^{E}} QIG_{t,d,k}.$$

Emergency Energy

A constraint is required to schedule *emergency energy*. For all time-steps $t \in TS$ and all *intertie zone* sink buses corresponding to an *emergency energy* sale $d \in DX_t^{EM}$:

$$\sum_{j\in J_{t,d}^{E}} SXL_{t,d,j} = \sum_{j\in J_{t,d}^{E}} QXL_{t,d,j}.$$

For all time-steps $t \in TS$ and all *intertie zone* source buses corresponding to *emergency energy* purchase $d \in DI_t^{EM}$:

$$\sum_{k\in K_{t,d}^{E}} SIG_{t,d,k} = \sum_{k\in K_{t,d}^{E}} QIG_{t,d,k}.$$

Intertie Minimum and Maximum Constraints

Intertie schedules may be limited by DAM schedules beyond the first two forecast hours of the look-ahead period, or by *intertie* curtailments as detailed within Section 3.4.1.5.

Import and Export Limits Beyond the First Two Forecast Hours

$$\sum_{j\in J_{t,d}^{E}} SXL_{t,d,j} \le SXLT_{t,d}^{DAM};$$

$$\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j} \le S10NXLT_{t,d}^{DAM};$$

and

$$\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j} \le S30RXLT_{t,d}^{DAM}.$$

Except for transactions flagged as capacity imports or off-market transactions, the DAM scheduled quantities for import transactions plus any additional *offered* quantities permitted for *reliability* reasons will limit import schedules beyond the first two forecast hours of the look-ahead period. For time-step $t \in \{4,..,n_{LAP}\}$ and *intertie zone* source bus $d \in DI$ such that $d \notin DI_t^{CAPEX} \cup DI_t^{EM} \cup DI_t^{INP}$:

$$\sum_{k\in K_{t,d}^{E}} SIG_{t,d,k} \le SIGT_{t,d}^{DAM} + SIGT_{t,d}^{EXTRA};$$

$$\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \leq S10NIGT_{t,d}^{DAM} + S10NIGT_{t,d}^{EXTRA};$$

and

$$\sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \leq S30RIGT_{t,d}^{DAM} + S30RIGT_{t,d}^{EXTRA}.$$

Intertie Curtailments

Intertie schedules must respect any limits placed on transactions as the result of *intertie* curtailments.

For *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$:

$$ICMinXL_{t,d} \leq \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j} \leq ICMaxXL_{t,d}.$$

For *intertie zone* source bus $d \in DI$ and time-step $t \in TS$:

$$ICMinIG_{t,d} \leq \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} \leq ICMaxIG_{t,d};$$

$$ICMin10NIG_{t,d} \leq \sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \leq ICMax10NIG_{t,d};$$

and

$$ICMin30RIG_{t,d} \leq \sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \leq ICMax30RIG_{t,d}.$$

Operating Reserve Scheduling

Dispatchable Load

The total *operating reserve* (10-minute synchronized, 10-minute non-synchronized and 30-minute) from a *dispatchable load* cannot exceed its ramp capability over 30 minutes. It cannot exceed the total scheduled load less the non-dispatchable portion. Lastly, it cannot exceed the remaining portion of its capacity that is dispatchable after considering minimum load consumption constraints. These conditions can be enforced by the following constraints for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} + \sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} + \sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \leq 30 \cdot ORRDL_{b};$$

$$\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} + \sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} + \sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \leq \sum_{j \in J_{t,b}^{E}} SDL_{t,b,j} - QDLFIRM_{t,b};$$

and

$$\sum_{j\in J_{t,b}^{10S}} \mathrm{S10SDL}_{t,b,j} + \sum_{j\in J_{t,b}^{10N}} \mathrm{S10NDL}_{t,b,j} + \sum_{j\in J_{t,b}^{30R}} \mathrm{S30RDL}_{t,b,j} \leq \sum_{j\in J_{t,b}^{E}} \mathrm{SDL}_{t,b,j} \text{ -} \mathrm{MinDL}_{t,b}.$$

The amount of synchronized *ten-minute operating reserve* plus the non-synchronized *ten-minute reserve* that a *dispatchable load* is scheduled to provide cannot exceed the amount by which it can decrease its load over 10 minutes, as limited by its *operating reserve* ramp rate. This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j} + \sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j} \leq 10 \cdot ORRDL_b.$$

Exports

The total *operating reserve* (10-minute non-synchronized and 30-minute) from an hourly export cannot exceed the total scheduled export.

This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all *intertie zone* sink buses $d \in DX$:

$$\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j} + \sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j} \ \leq \sum_{j\in J_{t,d}^{E}} SXL_{t,d,j}.$$

Dispatchable Generation Resources

The total *operating reserve* (10-minute synchronized, 10-minute non-synchronized and 30-minute) from a committed dispatchable generation resource cannot exceed its ramp capability over 30 minutes. It cannot exceed the remaining capacity (maximum *offered* generation minus the *energy* schedule). Lastly, it cannot exceed its unscheduled capacity. These conditions can be enforced by the following constraints for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq 30 \cdot ORRDG_b;$$

$$\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \sum_{k\in K_{t,b}^{E}} (QDG_{t,b,k} - SDG_{t,b,k});$$

and

$$\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}$$
$$\leq AdjMaxDG_{t,b} - \sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} \ - \ MinQDGC_b.$$

The amount of *ten-minute operating reserve,* both synchronized and non-synchronized, that a dispatchable generation resource is scheduled to provide cannot exceed the amount by which it can increase its output over 10 minutes, as limited by its *operating reserve* ramp rate. This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \leq 10 \cdot ORRDG_b.$$

The amount of synchronized *ten-minute operating reserve* that a dispatchable generation resource is scheduled to provide is limited by its synchronized *ten-minute operating reserve* loading point. This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DG}$ with $RLP10S_{t,b} > 0$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \leq \left(MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) \cdot \left(\frac{1}{RLP10S_{t,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_b, \sum_{k \in K_{t,b}^{10S}} Q10SDG_{t,b,k} \right\} \right).$$

The amount of *thirty-minute operating reserve* that a dispatchable generation resource is scheduled to provide is limited by its *thirty-minute operating reserve* loading point.

This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DG}$ with $RLP30R_{t,b} > 0$:

$$\sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \left(MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) \cdot \left(\frac{1}{RLP30R_{t,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_b, \sum_{k \in K_{t,b}^{30R}} Q30RDG_{t,b,k} \right\} \right).$$

Imports

The total *operating reserve* (10-minute non-synchronized and 30-minute) from an hourly import cannot exceed the remaining capacity (maximum import *offer* minus scheduled *energy* import). This condition can be enforced by the following constraint for all time-steps $t \in TS$ and all *intertie zone* source buses $d \in DI$:

$$\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k} + \sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k} \le \sum_{k\in K_{t,d}^{E}} (QIG_{t,d,k} - SIG_{t,d,k}).$$

PSU Resources

De-rates

De-rates are enforced on the operating region to which they apply as described in Section 3.10.2. These constraints apply to both *energy* and *operating reserve* schedules. For all time-steps $t \in TS$ and PSU resource buses $b \in B^{PSU}$:

$$MinQDGC_b \cdot ODG_{t,b} \le MaxMLP_{t,b},$$

$$\sum_{k\in K_{t,b}^{DR}} SDG_{t,b,k} \le MaxDR_{t,b},$$

$$\sum_{k\in K_{t,b}^{DF}} SDG_{t,b,k} \le MaxDF_{t,b},$$

and

$$\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k} \le MaxDR_{t,b} + MaxDF_{t,b}.$$

Translation Between PU and PSU Schedules

Physical unit schedules can be calculated from the *pseudo-unit* schedules using the PSU model and sharing percentages.

For all time-steps $t \in TS$ and PSU resource buses $b \in B^{PSU}$:

$$SCT_{t,b} = (1 - STShareMLP_b) \cdot MinQDGC_b \cdot ODG_{t,b} + (1 - STShareDR_b) \cdot \left(\sum_{k\in K_{t,b}^{DR}} SDG_{t,b,k} \right),$$

and for all time-steps $t \in TS$ and steam turbines $p \in PST$:

$$SST_{t,p} = \sum_{b\in B_p^{ST}} \left(\begin{array}{c} STShareMLP_b \cdot MinQDGC_b \cdot ODG_{t,b} + \\ STShareDR_b \cdot \left(\sum_{k\in K_{t,b}^{DR}} SDG_{t,b,k} \right) + \sum_{k\in K_{t,b}^{DF}} SDG_{t,b,k} \end{array} \right).$$

Transmission constraint sensitivity factors and loss factors are provided on a physical unit basis. Accordingly, the combustion turbine and steam turbine schedules will be used in the *energy* balance constraint and the transmission constraints described in Section 3.6.1.6.

For the purposes of such constraints, the combustion turbine schedule for the PSU resource at bus $b \in B^{PSU}$ in time-step $t \in TS$ will be equal to:

- $SCT_{t,b}$ if the PSU resource is scheduled at or above MLP;
- $RampCTC^{m}_{b,w}$ if the resource is schedule to reach MLP in thermal state $m \in THERM$ in time-step $t+w$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$; or
- 0 otherwise.

For the purposes of such constraints, the steam turbine schedule for $p \in PST$ will be equal to $SST_{t,p}$ plus any contribution from PSU resources $b \in B^{ST}_{p}$ ramping to MLP as given by $RampSTC^{m}_{b,w}$ for a resource scheduled to reach MLP in thermal state $m \in THERM$ in time-step $(t+w)$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$.

The PD calculation engine will evaluate effective sensitivity and loss factors as a function of the unit loading as determined above. For the purposes of the formulations, the *energy* balance and transmission constraints expressed in this document assume that a PSU's effective sensitivity and loss factors are constant across its operating range.

Duct Firing Operating Reserve Limitations

For a PSU resource that cannot provide *ten-minute operating reserve* from its duct firing region, constraints are required to limit the resource from being scheduled in its duct firing region whenever the resource is scheduled for *ten-minute operating reserve.* For all time-steps $t \in TS$ and PSU resource buses $b \in B^{NO10DF}$:

$$O10R_{t,b} \in \{0,1\},$$

and

$$\sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} + \sum_{k \in K^{10S}_{t,b}} S10SDG_{t,b,k} + \sum_{k \in K^{10N}_{t,b}} S10NDG_{t,b,k} \leq MaxDR_{t,b} + (1 - O10R_{t,b}) \cdot MaxDF_{t,b}$$

For all time-steps $t \in TS$, PSU resource buses $b \in B^{NO10DF}$, and laminations $k \in K^{10S}_{t,b}$:

$$S10SDG_{t,b,k} \leq O10R_{t,b} \cdot Q10SDG_{t,b,k}.$$

For all time-steps $t \in TS$, PSU resource buses $b \in B^{NO10DF}$, and laminations $k \in K^{10N}_{t,b}$:

$$S10NDG_{t,b,k} \leq O10R_{t,b} \cdot Q10NDG_{t,b,k}.$$

Hydroelectric Resources

A hydroelectric resource must be scheduled for its hourly must-run amount. For all time-steps $t \in TS$ and hydroelectric resource buses $b \in B^{HE}$:

$$ODG_{t,b} \cdot MinQDGC_{b} + \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \geq MinHMR_{t,b}.$$

Either a hydroelectric resource must be scheduled to 0 or its minimum hourly output must be respected. For all time-steps $t \in TS$ and all hydroelectric resources buses $b \in B^{HE}$:

$$OHO_{t,b} \in \{0,1\} ;$$

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \geq MinHO_{t,b} \cdot OHO_{t,b} ;$$

and for all $k \in K^E_{t,b}$:

$$0 \leq SDG_{t,b,k} \leq OHO_{t,b} \cdot QDG_{t,b,k}.$$

A hydroelectric resource cannot be scheduled within its *forbidden regions*. For all *dispatch days* $q \in DAYS$, all time-steps $t \in TS$ in *dispatch day* q, all hydroelectric resource buses $b \in B^{HE}$ and all $i \in \{1,..,NFor_{q,b}\}$:

$$OFR_{t,b,i} \in \{0,1\};$$

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq OFR_{t,b,i} \cdot ForL_{q,b,i} + (1 - OFR_{t,b,i}) \cdot \left(MinQDGC_b + \sum_{k \in K^E_{t,b}} QDG_{t,b,k} \right);$$

and

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \geq (1 - OFR_{t,b,i}) \cdot ForU_{q,b,i}.$$

Wheeling Through Transactions

In the case of wheeling through transactions, the amount of scheduled export *energy* must be equal to the amount of scheduled import *energy*. Therefore, for all time-steps $t \in TS$ and all linked *intertie zone* sink and source buses $(dx,di) \in L_t$:

$$\sum_{j \in J^E_{t,dx}} SXL_{t,dx,j} = \sum_{k \in K^E_{t,di}} SIG_{t,di,k}.$$

3.6.1.5 Bid/Offer Inter-Hour/Multi-Hour Constraints

Energy Ramping

In the following ramping constraints, a single ramp up rate and a single ramp down rate ($URRDG_b$ and $DRRDG_b$ for dispatchable generation resources, $URRDL_b$ and $DRRDL_b$ for *dispatchable loads*) are used. That is, the ramp rates are considered to be constant over the full operating range of the dispatchable generation resource or *dispatchable load*. However, the PD calculation engine will respect the ramping restrictions determined by the (up to five) *offered* MW quantity, ramp up rate and ramp down rate value sets.

In all ramping constraints, the schedules for time-step 1 are obtained from the initial scheduling assumptions. For all time-steps $t \in TS$ the ramping rates in all ramping constraints must be adjusted to allow the resource to:

- Ramp down from its lower limit in time-step $(t - 1)$ to its upper limit in time-step t; and
- Ramp up from its upper limit in time-step $(t - 1)$ to its lower limit in time-step t.

This will allow a solution to be obtained when changes to the upper and lower limits between time-step are beyond the ramping capability of the resources.

Dispatchable Load

Energy schedules for a *dispatchable load* cannot vary by more than an hour's ramping capability for that resource. This is enforced by the following constraint for all time-steps $t \in TS$ and buses $b \in B^{DL}$:

$$\sum_{j \in J^E_{t-1,b}} SDL_{t-1,b,j} - 60 \cdot DRRDL_b \le \sum_{j \in J^E_{t,b}} SDL_{t,b,j} \le \sum_{j \in J^E_{t-1,b}} SDL_{t-1,b,j} + 60 \cdot URRDL_b.$$

Hourly Demand Response Resources

Energy schedules for an *hourly demand response* resource cannot vary by more than an hour's ramping capability for that resource. This is enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{HDR}$:

$$\sum_{j \in J^E_{t-1,b}} (QHDR_{t-1,b,j} - SHDR_{t-1,b,j}) - 60 \cdot URRHDR_b \le \sum_{j \in J^E_{t,b}} (QHDR_{t,b,j} - SHDR_{t,b,j})$$
$$\le \sum_{j \in J^E_{t-1,b}} (QHDR_{t-1,b,j} - SHDR_{t-1,b,j}) + 60 \cdot DRRHDR_b.$$

Dispatchable Generation Resources

Energy schedules for each dispatchable generation resource cannot vary by more than an hour's ramping capability for that resource. The following three-part constraint handles ramping for a resource when it is committed. The constraint covers incremental change above the resource's *minimum loading point* (MLP) in the hours where:

- the resource first reaches MLP (Start Up);
- the resource stays on at or above MLP (Continued On); and

- the last hour the resource is scheduled at or above MLP before being scheduled off (Shut Down).

Only the “Continued On” constraint applies to quick-start resources because they are always committed.

For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

1. Start Up Scenario ($ODG_{t,b}=1, ODG_{t-1,b}=0$):

$$0 \leq \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \leq 30 \cdot URRDG_{b}$$

2. Continued On Scenario ($ODG_{t,b}=1, ODG_{t-1,b}=1$):

$$\sum_{k \in K^{E}_{t-1,b}} SDG_{t-1,b,k} - 60 \cdot DRRDG_{b} \leq \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \leq \sum_{k \in K^{E}_{t-1,b}} SDG_{t-1,b,k} + 60 \cdot URRDG_{b}$$

3. Shut Down Scenario ($ODG_{t,b} = 1, ODG_{t+1,b} = 0$):

$$0 \leq \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \leq 30 \cdot DRRDG_{b}$$

In time-steps where NQS resources are ramping up to MLP, *energy* will be scheduled using the submitted ramp up *energy* to MLP profile. This is described in the equation for injections at a dispatchable generation resource bus in Section 3.6.1.6. In time-steps where NQS resources are ramping down from MLP, no *energy* will be scheduled.

Operating Reserve Ramping

Dispatchable Loads

In addition to *energy* ramping limitations, the total reserve (10-minute synchronized, 10-minute non-synchronized and 30-minute) from a *dispatchable load* cannot exceed the *dispatchable load's* ramp capability to decrease load consumption.

For all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} + \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} + \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \leq \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} - \sum_{j \in J^{E}_{t-1,b}} SDL_{t-1,b,j} + 60 \cdot DRRDL_{b}.$$

Dispatchable Generation Resources

In addition to *energy* ramping limitations, the total reserve (10-minute synchronized, 10-minute non-synchronized and 30-minute) from a committed dispatchable generation resource cannot exceed its ramp capability to increase generation. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \sum_{k \in K_{t-1,b}^{E}} SDG_{t-1,b,k} - \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + 60 \cdot URRDG_b;$$

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq [(t-n) \cdot 60 + 30] \cdot URRDG_b \cdot ODG_{t,b}$$

where n is the time-step of the last start before or in time-step t; and

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{h,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq [(m-t) \cdot 60 + 30] \cdot DRRDG_b \cdot ODG_{t,b}$$

where m is the time-step of the last shutdown in or after time-step t.

NQS Resources

Schedules for NQS resources must observe *minimum generation block run-times*, *minimum generation block down times* and *maximum number of starts per day*.

In the first forecast hour of the look-ahead period (time-step 2), a resource's current hours on determines any remaining *minimum generation block run-time* to enforce. If $0 < InitOperHrs_b < MGBRTDG_{tod,b}$, then the resource at bus $b \in B^{NQS}$ has yet to complete its *minimum generation block run-time*, and:

$$ODG_{2,b}, ODG_{3,b}, \ldots, ODG_{\min\left(n_{LAP}, MGBRTDG_{tod,b} - InitOperHrs_b + 1\right), b} = 1.$$

During the look-ahead period, if $ODG_{t-1,b} = 0$ and $ODG_{t,b} = 1$ for time-step $t \in TS$, then the resource at bus $b \in B^{NQS}$ has been scheduled to start up during time-step t. It must be scheduled to remain in operation until it has completed its *minimum generation block run-time* or to the end of the look-ahead period. Therefore:

$$ODG_{t+1,b}, ODG_{t+2,b}, \ldots, ODG_{\min(n_{LAP}, t + MGBRTDGC_b - 1), b} = 1.$$

In the first forecast hour of the look-ahead period (time-step 2), the number of hours a resource has been down for determines any remaining *minimum generation block down time* to enforce. The MGBDT for a hot thermal state must always be respected. If $0 < InitDownHrs_b < MGBDTDG_{tod,b}^{HOT}$, then the resource at bus $b \in B^{NQS}$ has yet to complete its *minimum generation block down time*, and:

$$ODG_{2,b}, ODG_{3,b}, \ldots, ODG_{\min\left(n_{LAP}, MGBDTDG_{tod,b}^{HOT} - InitDownHrs_b + 1\right), b} = 0.$$

During the look-ahead period, if $ODG_{t-1,b} = 1$ and $ODG_{t,b} = 0$ for time-step $t \in TS$, then the resource at bus $b \in B^{NQS}$ has been scheduled to shut down during time-step t. It must be scheduled to remain off until it has completed its hot *minimum generation block down time* or to the end of the look-ahead period. Therefore:

$$ODG_{t+1,b}, ODG_{t+2,b}, \ldots, ODG_{min(n_{LAP}, t+MGBDTDGC_b^{HOT}-1),b} = 0.$$

A Boolean variable $IDG_{t,b}$ indicates that the NQS resource at bus $b \in B^{NQS}$ is scheduled to reach its *minimum loading point* in time-step $t \in TS$ after being scheduled below its *minimum loading point* in the preceding time-step. A value of zero indicates that a resource is not scheduled to reach its *minimum loading point*, while a value of one indicates that it is scheduled to reach its *minimum loading point*. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{NQS}$:

$$IDG_{t,b} = \begin{cases} 1 & \text{if } ODG_{t-1,b} = 0 \text{ and } ODG_{t,b} = 1 \\ 0 & \text{otherwise.} \end{cases}$$

To ensure that NQS resources are not scheduled to be cycled on and off more than their specified maximum number in a day, the following constraint is defined for all buses $b \in B^{NQS}$:

$$\sum_{t \in TS_{tod}} IDG_{t,b} \leq MaxStartsDG_{tod,b} - NumStarts_{tod,b}.$$

and if the look-ahead period spans two *dispatch days* then:

$$\sum_{t \in TS_{tom}} IDG_{t,b} \leq MaxStartsDG_{tom,b}.$$

Modelling of NQS Resource Thermal State

If a resource is currently offline, each future time-step can be assigned a thermal state (hot/warm/cold) based on the number of hours the resource has been offline (i.e. below MLP) and the resource's submitted hot, warm and cold *minimum generation block down time* parameters. The *start-up cost* to bring the resource online again from its current offline status is determined by the assigned thermal state.

As detailed in the Offers, Bids and Data Inputs detailed design document:

- MGBDT(hot) represents the minimum number of hours a resource must remain offline before it may be scheduled to generate at or above its MLP when the resource is considered to be in a hot operating state. The resource can no longer be scheduled in the hot operating state after it has been offline greater than or equal to the number of hours submitted for MGBDT(warm);
- MGBDT(warm) represents the minimum number of hours a resource must remain offline before it may be scheduled to generate at or above its MLP

when the resource is considered to be in a warm operating state. The resource can no longer be scheduled in the warm operating state after it has been offline greater than or equal to the number of hours submitted for MGBDT(cold); and

- MGBDT(cold) represents the minimum number of hours a resource must remain offline before it may be scheduled to generate at or above its MLP when the resource is considered to be in a cold operating state.

Based on the example in Figure 3-1 the resource must remain offline for four hours to satisfy the *minimum generation block down time* hot operational constraint. After the resource has been offline for four hours, the PD calculation engine will evaluate the resource using all of the associated hot *dispatch data* values as submitted by the *registered market participant*. The PD calculation engine will use all corresponding hot *dispatch data* submitted for the resource until the warm MGBDT has been reached. At that time, the corresponding warm *dispatch data* will be used to determine a schedule or operational commitment for the resource.

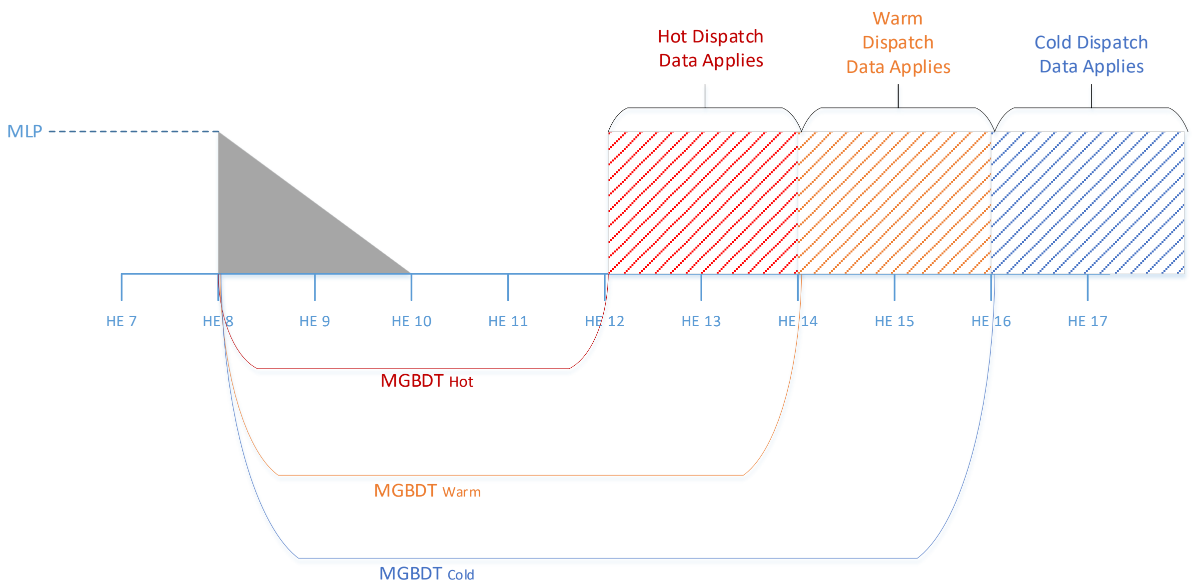

Figure 3-1: MGBDT and Thermal State Dispatch Data Relationship

In the PD calculation engine, the following formulation is used to assign a *start-up cost* and ramp *energy* to MLP profile for NQS resources based on thermal state.

For the NQS resource at bus $b \in B^{NQS}$ that has been offline $InitDownHrs_b$ hours, and for future MLP time-step $t \in \{2,....,n_{LAP}\}$:

- If $0 \leq InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{HOT}$, then the unit cannot be scheduled in time-step t because hot *minimum generation block down time* cannot be respected;
- If $MGBDTDGC_b^{HOT} < InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{WARM}$, then the unit will be assigned a “HOT” thermal state for time-step t and the *start-up cost*

$SUDG^{HOT}_{t,b}$ will apply. The ramp *energy* to MLP profile will be $RampEC^{HOT}_{b,w}$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$;

- If $MGBDTDGC^{WARM}_{b} < InitDownHrs_b + t - 1 \leq MGBDTDGC^{COLD}_{b}$, then the unit will be assigned a "WARM" thermal state for time-step t and the *start-up cost* $SUDG^{WARM}_{t,b}$ will apply. The ramp *energy* to MLP profile will be $RampEC^{WARM}_{b,w}$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$; and
- If $MGBDTDGC^{COLD}_{b} < InitDownHrs_b + t - 1$ then the unit will be assigned a "COLD" thermal state for time-step t and the start-up cost $SUDG^{COLD}_{t,b}$ will apply. The ramp *energy* to MLP profile will be $RampEC^{COLD}_{b,w}$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$.

If a resource is currently online, a decision to shut down the unit in a specific hour dictates the anticipated thermal state in future hours in which a decision to restart the unit may be made. These decisions are made simultaneously. Ramp *energy* to MLP and *start-up cost* will be associated with the future thermal state and must respect the rules laid out above.

Energy-Limited Resources

Energy-limited resources cannot be scheduled to provide more *energy* than they have indicated they are capable of providing. The submitted *energy* limit both limits the total amount of *energy* scheduled over the course of a *dispatch day* and prevents *operating reserve* schedules which, when activated, would result in an exceedance of the submitted daily *energy* limit. If the look-ahead period spans two *dispatch days*, constraints are required for both days. The constraints for the current *dispatch day* must consider the amount of *energy* already provided by the resource. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution.

Given these factors, for all buses $b \in B^{ELR}$ where an *energy*-limited resource is located and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T}\left(ODG_{t,b}\cdot MinQDGC_b + \sum_{k\in K^{E}_{t,b}} SDG_{t,b,k}\right) + 10ORConv\left(\sum_{k\in K^{10S}_{T,b}} S10SDG_{T,b,k} + \sum_{k\in K^{10N}_{T,b}} S10NDG_{T,b,k}\right) + 30ORConv\left(\sum_{k\in K^{30R}_{T,b}} S30RDG_{T,b,k}\right) - \sum_{i=1..N_{MaxDelViol_T}} SMaxDelViol_{T,b,i} \leq MaxDEL_{tod,b} - EngyUsed_b.$$

If the look-ahead period spans two *dispatch days*, for all buses $b \in B^{ELR}$ where an *energy*-limited resource is located and all time-steps $T \in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)$$
$$+10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)$$
$$+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)-\sum_{i=1..N_{MaxDelViol_T}}SMaxDelViol_{T,b,i}$$
$$\leq MaxDEL_{tom,b}.$$

The factors $10ORConv$ and $30ORConv$ are applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy*-limited resources to convert MW into MWh.

As implicitly indicated by the constraints formulated above, ramp *energy* to MLP will not be counted against the daily *energy* limit by the PD calculation engine.

Hydroelectric Resources

A hydroelectric resource must be scheduled for at least its minimum daily *energy*. If the look-ahead period spans two *dispatch days*, a constraint is required for both days. The constraint for today must consider the amount of *energy* already provided by the resource. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution.

For all hydroelectric resource buses $b\in B^{HE}$:

$$\sum_{t\in TS_{tod}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right.$$
$$\left.+\sum_{i=1..N_{MinDelViol_t}}SMinDelViol_{t,b,i}\right)\geq MinDEL_{tod,b}-EngyUsed_b.$$

If the look-ahead period spans two *dispatch days*, for all hydroelectric resource buses $b\in B^{HE}$:

$$\sum_{t\in TS_{tom}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right.$$
$$\left.+\sum_{i=1..N_{MinDelViol_t}}SMinDelViol_{t,b,i}\right)\geq MinDEL_{tom,b}.$$

A Boolean variable $IHE_{t,b,i}$ indicates that a start for the hydroelectric resource at bus $b\in B^{HE}$ was counted in time-step $t\in TS$ as a result of the resource schedule increasing from below its i-th start indication value to at or above its i-th start indication for $i \in \{1,..,NStartMW_b\}$. A value of zero indicates that a start was not counted, while a value of one indicates that a start was counted. Therefore, for all time-steps $t \in TS$, buses $b \in B^{HE}$ and start indication values $i \in \{1,..,NStartMW_b\}$:

$$IHE_{t,b,i} = \begin{cases} 1 \quad if \left(ODG_{t-1,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t-1,b}} SDG_{t-1,b,k} < StartMW_{b,i} \right) \\ \quad and \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \geq StartMW_{b,i} \right) \\ 0 \quad otherwise. \end{cases}$$

Hydroelectric resources cannot be scheduled to be started more times than permitted by their *maximum number of starts per day* value. If the look-ahead period spans two *dispatch days*, a constraint is required for both days. The constraint for today must consider the number of starts already incurred by the resource. For all hydroelectric resource buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tod}} \left(\sum_{i=1..NStartMW_b} IHE_{t,b,i} \right) \leq MaxStartsHE_{tod,b} - NumStartsHE_b.$$

If the look-ahead period spans two *dispatch days*, for all hydroelectric resource buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tom}} \left(\sum_{i=1..NStartMW_b} IHE_{t,b,i} \right) \leq MaxStartsHE_{tom,b}.$$

The schedules for hydroelectric resources must respect shared maximum daily *energy* limits. If the look-ahead period spans two *dispatch days*, constraints are required for both days. The constraints for today must consider the amount of *energy* already provided by resources with the shared daily *energy* limit. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution.

For all sets $s \in SHE$ and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)$$
$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}$$
$$\leq MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

If the look-ahead period spans two *dispatch days*, then for all sets $s\in SHE$ and all time-steps $T\in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)$$
$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}\leq MaxSDEL_{tom,s}.$$

The factors $10ORConv$ and $30ORConv$ are applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy*-limited resources to convert MW into MWh.

The schedules for hydroelectric resources must respect shared minimum daily *energy* limits. If the look-ahead period spans two *dispatch days*, a constraint is required for both days. The constraint for today must consider the amount of *energy* already provided by resources with the shared daily *energy* limit. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution.

For all sets $s\in SHE$:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tod,s} - EngyUsedSHE_s.$$

If the look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tom,s}.$$

For linked hydroelectric resources, *energy* scheduled at the upstream resources in one time-step will result in a proportional amount of *energy* being scheduled at the linked downstream resources in the time-step determined by the time lag. In time-steps for which the upstream resources schedule is not determined in the PD calculation engine optimization, the constraint will link either the historical or time-step 1 anticipated production for the upstream resources to the schedule for the downstream resources. Violation variables for both over and under generation at the downstream resource are provided for these constraints to improve the ability of the PD calculation engine to find a solution. For all linked hydroelectric resources between upstream resources $b_1 \in B_{up}^{HE}$ and downstream resources $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t \leq LagC_{b_1,b_2}+1$:

$$\sum_{b_2 \in B_{dn}^{HE}} \left(ODG_{t,b_2} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^E} SDG_{t,b_2,k} \right) - \sum_{i=1..N_{OGenLnkViol_{t+Lag_{b_1,b_2}}}} SOGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i} + \sum_{i=1..N_{UGenLnkViol_{t+Lag_{b_1,b_2}}}} SUGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i} = MWhRatioC_{b_1,b_2} \cdot PastMWh_{t,b_1}.$$

$=$ In time-steps for which both the upstream and downstream resource schedules are determined in the PD calculation engine optimization, the constraint will link the scheduling variables for both the upstream and downstream resources.

For all linked hydroelectric resources between upstream resources $b_1 \in B_{up}^{HE}$ and downstream resources $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNKC$ and time-steps $t \in TS$ such that $t + LagC_{b_1,b_2} \leq n_{LAP}$:

$$\sum_{b_2 \in B_{dn}^{HE}} \left(ODG_{t+LagC_{b_1,b_2},b_2} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t+LagC_{b_1,b_2},b_2}^{E}} SDG_{t+LagC_{b_1,b_2},b_2,k} \right)$$
$$- \sum_{i=1..N_{OGenLnkViol_{t+Lag_{b_1,b_2}}}} SOGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i}$$
$$+ \sum_{i=1..N_{UGenLnkViol_{t+Lag_{b_1,b_2}}}} SUGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i}$$
$$= MWhRatioC_{b_1,b_2} \cdot \sum_{b_1 \in B_{up}^{HE}} \left(ODG_{t,b_1} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k} \right)$$

3.6.1.6 Constraints to Ensure Schedules Do Not Violate Reliability Requirements

Energy Balance

For each time-step of the look-ahead period, the total amount of *energy* scheduled on supply resources, including scheduled imports, must be equal to the forecast *demand* and *energy* scheduled on load resources, including scheduled exports. This constraint will also account for transmission losses and is described further in terms of its constituent parts.

Define the total amount of withdrawals scheduled at load bus $b \in B$ in time-step $t \in TS$, $With_{t,b}$, as either:

- all *dispatchable load* scheduled at bus b if $b \in B^{DL}$; or
- the *hourly demand response* quantity *bid* at bus b, net the amount of reduction scheduled if $b \in B^{HDR}$

so that

$$With_{t,b} = \begin{cases} \sum_{j \in J_{t,b}^{E}} SDL_{t,b,j} & if\ b \in B^{DL} \\ \sum_{j \in J_{t,b}^{E}} (QHDR_{t,b,j} - SHDR_{t,b,j}) & if\ b \in B^{HDR} \end{cases}.$$

Define the total amount of withdrawals scheduled at *intertie zone* sink bus $d \in DX$ in time-step $t \in TS$, $With_{t,d}$, as the exports from Ontario to the *intertie zone* sink bus.

Thus,

$$With_{t,d} = \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j}.$$

Define the total amount of injections scheduled at internal generation resource bus $b \in B$ in time-steps $t \in TS$, $Inj_{t,b}$, as the sum of:

either:

- non-dispatchable generation scheduled at that bus if $b \in B^{NDG}$; or
- dispatchable generation scheduled at that bus if $b \in B^{DG}$; and
- ramp up *energy* to *minimum loading point* if $b \in B^{NQS}$.

Let

$$OfferInj_{t,b} = \begin{cases} \sum_{k \in K_{t,b}^{E}} SNDG_{t,b,k} & if\ b \in B^{NDG} \\ ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} & if\ b \in B^{DG} \end{cases}$$

and

$$RampInj_{t,b} = \begin{cases} \sum_{w=1..min(RampHrsC_b^m, n_{LAP}-t)} RampEC_{b,w}^m \cdot IDG_{t+w,b} & if\ b \in B^{NQS} \\ 0 & otherwise \end{cases}$$

so that

$$Inj_{t,b} = OfferInj_{t,b} + RampInj_{t,b}.$$

Define the total amount of injections scheduled at *intertie zone* source bus $d \in DI$ in time-step $t \in TS$, $Inj_{t,d}$, as the imports into Ontario from that *intertie zone* source bus. Thus

$$Inj_{t,d} = \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k}.$$

Injections and withdrawals at each bus must be multiplied by one plus the marginal loss factor to reflect the losses or reduction in losses that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other, after taking into account the adjustment for any discrepancy between total and marginal losses. Load or generation reduction associated with the *demand* constraint violation will be subtracted from the total load or generation to ensure that the PD calculation engine will always produce a solution. The resulting *energy* balance constraint for time-step $t \in TS$ is

$$FL_t + \sum_{b \in B^{DL} \cup B^{HDR}} (1 + MglLoss_{t,b}) \cdot With_{t,b} + \sum_{d \in DX} (1 + MglLoss_{t,d}) \cdot With_{t,d} - \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} = \sum_{b \in B^{NDG} \cup B^{DG}} (1 + MglLoss_{t,b}) \cdot Inj_{t,b} + \sum_{d \in DI} (1 + MglLoss_{t,d}) \cdot Inj_{t,d} - \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} + LossAdj_t.$$

Operating Reserve Requirements

Sufficient *operating reserve* must be scheduled to meet system-wide requirements for synchronized *ten-minute operating reserve*, total *ten-minute operating reserve,* and *thirty-minute operating reserve* plus, when applicable, flexibility *operating reserve*. All applicable regional minimum requirements and maximum restrictions for *operating reserve* must also be respected. Constraint violation penalty curves will be used to impose a penalty cost for not meeting the *IESO*'s system-wide *operating reserve* requirements, not meeting a regional minimum requirement, or not adhering to a regional maximum restriction. The *IESO* will therefore meet its full *operating reserve* requirements unless the cost of doing so would be higher than the applicable penalty cost.

Therefore, the following constraints are required for each time-step $t \in TS$:

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \geq TOT10S_t;$$

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) + \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \geq TOT10R_t;$$

and

$$\sum_{b\in B^{DL}}\left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right)+\sum_{b\in B^{DL}}\left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right)$$
$$+\sum_{d\in DX}\left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right)$$
$$+\sum_{d\in DI}\left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right)+\sum_{b\in B^{DL}}\left(\sum_{j\in J_{t,b}^{30R}} S30RDL_{t,b,j}\right)$$
$$+\sum_{d\in DX}\left(\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right)$$
$$+\sum_{d\in DI}\left(\sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k}\right)+\sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \ \geq\ TOT30R_t.$$

The following constraints are required for each time-step $t\in TS$ and each region $r\in ORREG$:

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right)+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right)+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right)$$
$$+\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \ \geq\ REGMin10R_{t,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right)+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right)+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right)$$
$$-\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \leq\ REGMax10R_{t,r};$$

$$
\begin{aligned}
\sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right) &+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right) + \sum_{d\in D_r^{REG}\cap DX} \left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right) + \sum_{d\in D_r^{REG}\cap DI} \left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{30R}} S30RDL_{t,b,j}\right) + \sum_{d\in D_r^{REG}\cap DX} \left(\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right) + \sum_{d\in D_r^{REG}\cap DI} \left(\sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k}\right) \\
&+ \sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \;\geq\; REGMin30R_{t,r};
\end{aligned}
$$

and

$$
\begin{aligned}
\sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right) &+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right) + \sum_{d\in D_r^{REG}\cap DX} \left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right) + \sum_{d\in D_r^{REG}\cap DI} \left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DL}} \left(\sum_{j\in J_{t,b}^{30R}} S30RDL_{t,b,k}\right) + \sum_{d\in D_r^{REG}\cap DX} \left(\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j}\right) \\
&+ \sum_{b\in B_r^{REG}\cap B^{DG}} \left(\sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right) + \sum_{d\in D_r^{REG}\cap DI} \left(\sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k}\right) \\
&- \sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i} \;\leq\; REGMax30R_{t,r}.
\end{aligned}
$$

IESO Internal Transmission Limits

The *IESO* must ensure that the set of PD schedules produced would not violate any *security limits* in either the pre-contingency state or after any contingency. To develop the constraints to ensure that this occurs, the total amount of *energy* scheduled to be injected at each bus and the total amount of *energy* scheduled to be withdrawn at each bus as developed for the *energy* balance constraint will be used.

The *security* assessment function of the PD calculation engine will linearize violated pre-contingency transmission limits on *facilities* within Ontario. For all time-steps $t \in TS$ and *facilities* $f \in F_t$, the linearized constraints will take the form:

$$\sum_{b \in B^{NDG} \cup B^{DG}} PreConSF_{t,f,b} \cdot Inj_{t,b} - \sum_{b \in B^{DL} \cup B^{HDR}} PreConSF_{t,f,b} \cdot With_{t,b} + \sum_{d \in DI} PreConSF_{t,f,d} \cdot Inj_{t,d} - \sum_{d \in DX} PreConSF_{t,f,d} \cdot With_{t,d} - \sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \leq AdjNormMaxFlow_{t,f}.$$

Similarly, for all time-steps $t \in TS$, contingencies $c \in C$, and *facilities* $f \in F_{t,c}$, the linearized constraints will take the form:

$$\sum_{b \in B^{NDG} \cup B^{DG}} SF_{t,c,f,b} \cdot Inj_{t,b} - \sum_{b \in B^{DL} \cup B^{HDR}} SF_{t,c,f,b} \cdot With_{t,b} + \sum_{d \in DI} SF_{t,c,f,d} \cdot Inj_{t,d} - \sum_{d \in DX} SF_{t,c,f,d} \cdot With_{t,d} - \sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{t,c,f,i} \leq AdjEmMaxFlow_{t,c,f.}$$

Intertie Limits

The *IESO* must make sure that the set of PD schedules produced will not violate any *security limits* associated with *interties* between Ontario and *intertie zones*. In each time-step, the net amount of *energy* scheduled to flow over each *intertie* and the amount of scheduled *operating reserve* that would be delivered across the *intertie* must be calculated. For each flow limit constraint, these *energy* and *operating reserve* quantities (if applicable) will be summed over all affected *interties* and the result will be compared to the limit associated with that constraint. Therefore, for all time-steps $t \in TS$ and all constraints $z \in Z_{Sch}$:

$$\sum_{a \in A:\, EnCoeff_{a,z} \neq 0} \left[EnCoeff_{a,z} \left(\sum_{d \in DI_a} \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} - \sum_{d \in DX_a} \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j} \right) + 0.5 \cdot (EnCoeff_{a,z} + 1) \left(\sum_{d \in DI_a} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} + \sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \right) + \sum_{d \in DX_a} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} + \sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \right) \right) \right] - \sum_{i=1..N_{PreConXTLViol_{z,t}}} SPreXTLViol_{z,t,i} \leq MaxExtSch_{t,z}.$$

To model an *intertie* as out-of-service, the *intertie* transmission limits will be set to zero and all import *offers*, export *bids* and *operating reserve offers* will receive a zero schedule.

Changes in the net *energy* schedule over all *interties* cannot exceed the limits set forth by the *IESO* for hour-to-hour changes in those schedules. The net import schedule is summed over all *interties* for a given time-step to obtain the net *interchange schedule* for the time-step, and:

- It cannot exceed the net *interchange schedule* for the previous time-step plus the maximum permitted hourly increase.
- It cannot be less than the net *interchange schedule* for the previous time-step minus the maximum permitted hourly decrease.

Violation variables are provided for both the up and down ramp limits to ensure that the PD calculation engine will always find a solution. Therefore, for all time-steps $t \in TS$:

$$\begin{aligned}
&\sum_{d\in DI}\sum_{k\in K_{t-1,d}^{E}} SIG_{t-1,d,k} - \sum_{d\in DX}\sum_{j\in J_{t-1,d}^{E}} SXL_{t-1,d,j} - ExtDSC_t - \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i} \\
&\quad \le \sum_{d\in DI}\sum_{k\in K_{t,d}^{E}} SIG_{t,d,k} - \sum_{d\in DX}\sum_{j\in J_{t,d}^{E}} SXL_{t,d,j} \\
&\quad \le \sum_{d\in DI}\sum_{k\in K_{t-1,d}^{E}} SIG_{t-1,d,k} - \sum_{d\in DX}\sum_{j\in J_{t-1,d}^{E}} SXL_{t-1,d,j} + ExtUSC_t \\
&\quad + \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i}.
\end{aligned}$$

Penalty Price Variable Bounds

The following constraints restrict the penalty price variables to the ranges determined by the penalty price curves. For all time-steps $t \in TS$:

$0 \le SLdViol_{t,i} \le QLdViolSch_{t,i}$ for all $i \in \{1,..,N_{LdViol_t}\}$;

$0 \le SGenViol_{t,i} \le QGenViolSch_{t,i}$ for all $i \in \{1,..,N_{GenViol_t}\}$;

$0 \le S10SViol_{t,i} \le Q10SViolSch_{t,i}$ for all $i \in \{1,..,N_{10SViol_t}\}$;

$0 \le S10RViol_{t,i} \le Q10RViolSch_{t,i}$ for all $i \in \{1,..,N_{10RViol_t}\}$;

$0 \le S30RViol_{t,i} \le Q30RViolSch_{t,i}$ for all $i \in \{1,..,N_{30RViol_t}\}$;

$0 \le SREG10RViol_{r,t,i} \le QREG10RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG10RViol_t}\}$;

$0 \le SREG30RViol_{r,t,i} \le QREG30RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG30RViol_t}\}$;

$0 \le SXREG10RViol_{r,t,i} \le QXREG10RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG10RViol_t}\}$;

$0 \le SXREG30RViol_{r,t,i} \le QXREG30RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG30RViol_t}\}$;

$0 \leq SPreITLViol_{f,t,i} \leq QPreITLViolSch_{f,t,i}$ for all $f \in F_t$, $i \in \{1,..,N_{PreITLViol_{f,t}}\}$;

$0 \leq SITLViol_{c,f,t,i} \leq QITLViolSch_{c,f,t,i}$ for all $c \in C$, $f \in F_{t,c}$, $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$;

$0 \leq SPreXTLViol_{z,t,i} \leq QPreXTLViolSch_{z,t,i}$ for all $z \in Z_{Sch}$, $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$;

$0 \leq SNIUViol_{t,i} \leq QNIUViolSch_{t,i}$ for all $i \in \{1,..,N_{NIUViol_t}\}$;

$0 \leq SNIDViol_{t,i} \leq QNIDViolSch_{t,i}$ for all $i \in \{1,..,N_{NIDViol_t}\}\}$;

$0 \leq SMaxDelViol_{t,b,i} \leq QMaxDelViolSch_{t,b,i}$ for all $b \in B^{ELR}$, $i \in \{1,..,N_{MaxDelViol_t}\}$;

$0 \leq SMinDelViol_{t,b,i} \leq QMinDelViolSch_{t,b,i}$ for all $b \in B^{HE}$, $i \in \{1,..,N_{MinDelViol_t}\}$;

$0 \leq SSMaxDelViol_{t,s,i} \leq QSMaxDelViolSch_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMaxDelViol_t}\}$;

$0 \leq SSMinDelViol_{t,s,i} \leq QSMinDelViolSch_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMinDelViol_t}\}$;

$0 \leq SOGenLnkViol_{t,(b_1,b_2),i} \leq QOGenLnkViol_{t,(b_1,b_2),i}$ for all $(b_1,b_2) \in LNK$, $i \in \{1,..,N_{OGenLnkViol}\}$; and

$0 \leq SUGenLnkViol_{t,(b_1,b_2),i} \leq QUGenLnkViol_{t,(b_1,b_2),i}$ for all $(b_1,b_2) \in LNK$, $i \in \{1,..,N_{UGenLnkViol_t}\}$.

3.6.1.7 Outputs

Pre-Dispatch Scheduling will produce schedules and unit commitment statuses for all resources. For each variable SXX, SXX^{PDS} shall designate the value determined in Pre-Dispatch Scheduling.

For example:

- $SDL^{PDS}_{t,b,j}$ shall designate the schedule computed for lamination j of the *dispatchable load bid* at bus $b \in B^{DL}$ in time-step $t \in TS$; or
- $OHO^{PDS}_{t,b}$ shall designate whether the hydroelectric resource at bus $b \in B^{HE}$ was scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

In particular, the unit commitment statuses and affiliated start-up decision determined in Pre-Dispatch Scheduling will be denoted as follows:

- $ODG^{PDS}_{t,b} \in \{0,1\}$ shall designate whether the dispatchable generation resource at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$; and
- $IDG^{PDS}_{t,b} \in \{0,1\}$ shall designate whether the dispatchable generation resource at bus $b \in B^{DG}$ was scheduled to start (reach its *minimum loading point*) in time-steps $t \in TS$.

The PD calculation engine will record all such values for informational purposes. Internal resource schedules are provided to *market participants* at a 0.1 MW granularity. *Intertie* schedules are provided at a 1 MW granularity.

Advisory Schedules, Intertie Schedules and Operational Commitments

The schedules determined by Pass 1, Pre-Dispatch Scheduling, as described above, will be the pre-dispatch advisory schedules for the *pre-dispatch scheduling* process. For each scheduling variable, SXX^1 shall designate the Pass 1 scheduling results. These schedules will be *published* by 15 minutes past the hour. These schedules will determine binding *intertie* schedules for the next hour, extensions of NQS operational commitments and binding start-up instructions for NQS resources.

3.6.2. Pre-Dispatch Pricing

Pre-Dispatch Pricing will perform a *security*-constrained economic *dispatch* to meet the non-dispatchable forecast *demand* and *IESO*-specified *operating reserve* requirements. Pre-Dispatch Pricing will also evaluate *demand* from *dispatchable loads*, *hourly demand response* resources and *bids* to export *energy*. Pre-Dispatch Pricing will use the commitment statuses and resource schedules determined in Pre-Dispatch Scheduling to calculate prices in accordance with the principle for price-setting eligibility.[9]

Pre-Dispatch Pricing will use *bids* and *offers* submitted by *market participants* to maximize the gains from trade. Like Pre-Dispatch Scheduling, the optimization is subject to the resource constraints accompanying those *bids* and *offers*, and system constraints enforced by the *IESO* to maintain *reliability*. However, the objective function and constraints will reflect the set of constraint violation penalty curves for market pricing.

Pre-Dispatch Pricing will determine a set of prices based upon the inputs described in Section 3.4 and applicable outputs provided by Pre-Dispatch Scheduling. The LMPs and related shadow prices will be used in ex-ante Market Power Mitigation. The prices produced will not be financially binding.

The following sections describe the formulation of the optimization function for Pre-Dispatch Pricing.

3.6.2.1 Inputs

All applicable inputs identified in Section 3.4.1 will be evaluated. Table 3-12 lists the outputs of Pre-Dispatch Scheduling that will also be used in Pre-Dispatch Pricing.

[9] The marginal price at each location is set by the *offer* or *bid* that is able to supply the next increment of demand at that locale. Resources are able to meet that demand when they can be scheduled without restriction due to a system constraint or an operational constraint of a resource.

Table 3-12: Outputs of Pre-Dispatch Scheduling as Input to Pre-Dispatch Pricing

Input	Description
$SDG_{t,b,k}^{PDS}$	The amount of dispatchable generation scheduled at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{E}$. This is in addition to any $MinQDGC_b$, the *minimum loading point*, which must be committed before any such generation is scheduled.
$ODG_{t,b}^{PDS}$	Designates whether dispatchable generation at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$.
$S10SDG_{t,b,k}^{PDS}$	The amount of synchronized *ten-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10S}$
$S10NDG_{t,b,k}^{PDS}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$.
$S30RDG_{t,b,k}^{PDS}$	The amount of *thirty-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{30R}$.
$OHO_{t,b}^{PDS}$	Designates whether the hydroelectric resource at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

3.6.2.2 Variables and Objective Function

The variables used are mostly the same as those used in Pre-Dispatch Scheduling. However, the variables representing unit commitment decisions and hydroelectric minimum hourly output and start decisions are not needed as these decisions are fixed. Violation variables for the linked hydroelectric resource constraints are not needed in Pre-Dispatch Pricing. This is because the schedules of linked hydroelectric resources will largely be fixed from Pre-Dispatch Scheduling. That is, the same variables will be used except:

- $IDG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ will no longer appear in the formulation;
- $ODG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ will be fixed to a constant value as described in Section 3.6.2.3;

- $OHO_{t,b}$ for bus $b \in B^{HE}$ and time-step $t \in TS$ will be fixed to a constant value as described in Section 3.6.2.3; and
- $IHE_{t,b,i}$ for $b \in B^{HE}$, time-step $t \in TS$ and start indication value $i \in \{1,..,NStartMW_b\}$ will no longer appear in the formulation because hydroelectric resources with a limited number of starts will be scheduled in respect of their eligibility to set prices as described in Section 3.6.2.3.
- $SOGenLnkViol_{t,(b_1,b_2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, time-step $t \in TS$ and $i \in \{1,..,N_{OGenLnkViol_t}\}$ will no longer appear in the formulation.
- $SUGenLnkViol_{h,(b_1,b_2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, time-step $t \in TS$ and $i \in \{1,..,N_{UGenLnkViol_t}\}$ will no longer appear in the formulation.

Similar to Pre-Dispatch Scheduling, the objective function will be to maximize the gains from trade. However, any *start-up costs* and costs to operate at *minimum loading point* are not evaluated since the corresponding unit commitment decisions are fixed within Pre-Dispatch Pricing. The objective function is the same as in Pre-Dispatch Scheduling except:

- the start-up and minimum generation costs are constants and thus are dropped from the objective; and
- the violation cost is calculated using the set of constraint violation penalty curves for determining *market prices*.

Thus, Pre-Dispatch Pricing will maximize the value of the following expression:

$$\sum_{t \in TS} \begin{pmatrix} ObjDL_t - ObjHDR_t + ObjXL_t - ObjNDG_t \\ - ObjDG_t - ObjIG_t - TB_t - ViolCost_t \end{pmatrix}$$

where:

$$ObjDL_t = \sum_{b \in B^{DL}} \begin{pmatrix} \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} \cdot PDL_{t,b,j} - \sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} \cdot P10SDL_{t,b,j} - \\ \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} \cdot P10NDL_{t,b,j} - \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \cdot P30RDL_{t,b,j} \end{pmatrix};$$

$$ObjHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J^{E}_{t,b}} SHDR_{t,b,j} \cdot PHDR_{t,b,j} \right);$$

$$ObjXL_t = \sum_{d \in DX} \begin{pmatrix} \sum_{j \in J^{E}_{t,d}} SXL_{t,d,j} \cdot PXL_{t,d,j} - \sum_{j \in J^{10N}_{t,d}} S10NXL_{t,d,j} \cdot P10NXL_{t,d,j} \\ - \sum_{j \in J^{30R}_{t,d}} S30RXL_{t,d,j} \cdot P30RXL_{t,d,j} \end{pmatrix};$$

$$ObjNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{t,b}^{E}} SNDG_{t,b,k} \cdot PNDG_{t,b,k} \right);$$

$$ObjDG_t = \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \cdot PDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \cdot P10SDG_{t,b,k} + \\ \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \cdot P10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \cdot P30RDG_{t,b,k} \end{array} \right);$$

$$ObjIG_t = \sum_{d \in DI} \left(\begin{array}{c} \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} \cdot PIG_{t,d,k} + \sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \cdot P10NIG_{t,d,k} \\ + \sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \cdot P30RIG_{t,d,k} \end{array} \right) ;$$

and

$$
\begin{aligned}
ViolCost_t = & \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} \cdot PLdViolPrc_{t,i} \\
& - \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} \cdot PGenViolPrc_{t,i} \\
& + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \cdot P10SViolPrc_{t,i} \\
& + \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \cdot P10RViolPrc_{t,i} \\
& + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \cdot P30RViolPrc_{t,i} \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \cdot PREG10RViolPrc_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \cdot PREG30RViolPrc_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \cdot PXREG10RViolPrc_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i} \cdot PXREG30RViolPrc_{t,i} \right) \\
& + \sum_{f \in F_t} \left(\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \cdot PPreITLViolPrc_{f,t,i} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{t,c}} \left(\sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i} \cdot PITLViolPrc_{c,f,t,i} \right) \\
& + \sum_{z \in Z_{Sch}} \left(\sum_{i=1..N_{PreXTLViol_t}} SPreXTLViol_{z,t,i} \cdot PPreXTLViolPrc_{z,t,i} \right) \\
& + \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i} \cdot PNIUViolPrc_{t,i} \\
& + \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i} \cdot PNIDViolPrc_{t,i} \\
& + \sum_{b \in B^{ELR}} \left(\sum_{i=1..N_{MaxDelViol_t}} SMaxDelViol_{t,b,i} \cdot PMaxDelViolPrc_{t,b,i} \right) \\
& + \sum_{b \in B^{HE}} \left(\sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \cdot PMinDelViolPrc_{t,b,i} \right)
\end{aligned}
$$

$$+\sum_{s\in \mathrm{SHE}}\left(\sum_{i=1..N_{SMaxDelViol_t}} SSMaxDelViol_{t,s,i}\cdot PSMaxDelViolPrc_{t,s,i}\right)$$

$$+\sum_{s\in \mathrm{SHE}}\left(\sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i}\cdot PSMinDelViolPrc_{t,s,i}\right)$$

The tie-breaking term TB_t is defined as in Pre-Dispatch Scheduling. The maximization will be subject to the constraints described in the next sections.

3.6.2.3 Constraints Overview

The prices determined by Pre-Dispatch Pricing are intended to be a reflection of the marginal value of the *dispatch* and commitment decisions made in Pre-Dispatch Scheduling. Therefore, many of the constraints enforced in Pre-Dispatch Pricing are analogous to the constraints enforced in Pre-Dispatch Scheduling. However, additional constraints are required to ensure the eligibility of an *offer* or *bid* lamination to set price is appropriately reflected. The following list describes the additional constraints required.

Commitment Status Variables

Commitment decisions are fixed to the commitment statuses of resources calculated in Pre-Dispatch Scheduling. Therefore, for all time-steps $t\in TS$ and all buses $b\in B^{DG}$:

$$ODG_{t,b} = ODG_{t,b}^{PDS}.$$

Energy-Limited Resources

For *energy*-limited resources with a maximum daily *energy* limit that was binding in Pre-Dispatch Scheduling, the schedules calculated in Pre-Dispatch Scheduling will determine the price-setting eligibility of the resource’s *energy* and *operating reserve offer* laminations. In each time-step, *energy* or *operating reserve* laminations up to the total amount of *energy* and *operating reserve* scheduled in Pre-Dispatch Scheduling will be eligible to set prices.

For bus $b\in B^{ELR}$, if there exists a time-step $T\in TS_{tod}$ such that

$$\sum_{t=2..T}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}^{PDS}\right)$$
$$+10ORConv\left(\sum_{k\in K_{T,b}^{10S}} S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}} S10NDG_{T,b,k}^{PDS}\right)$$
$$+30ORConv\left(\sum_{k\in K_{T,b}^{30R}} S30RDG_{T,b,k}^{PDS}\right)=MaxDEL_{tod,b}-EngyUsed_b,$$

then the maximum daily *energy* limit constraint is considered to be binding for the current *dispatch day* in Pre-Dispatch Scheduling. In such circumstances, the following constraint must hold for bus $b \in B^{ELR}$ for all time-steps $t \in TS_{tod}$:

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \le \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k}^{PDS}.$$

If the look-ahead period spans two *dispatch days*, then for bus $b \in B^{ELR}$, if there exists a time-step $T \in TS_{tom}$ such that

$$\sum_{t=t_{tom}..T} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} \right) + 10ORConv \left(\sum_{k \in K_{T,b}^{10S}} S10SDG_{T,b,k}^{PDS} + \sum_{k \in K_{T,b}^{10N}} S10NDG_{T,b,k}^{PDS} \right) + 30ORConv \left(\sum_{k \in K_{T,b}^{30R}} S30RDG_{T,b,k}^{PDS} \right) = MaxDEL_{tom,b},$$

then the maximum daily *energy* limit constraint is considered to be binding for the next *dispatch day* in Pre-Dispatch Scheduling. In such circumstances, the following constraint must hold for bus $b \in B^{ELR}$ for all time-steps $t \in TS_{tom}$:

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \le \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k}^{PDS}.$$

Hydroelectric Resources

For hydroelectric resources, the following constraints will be used to reflect the eligibility of *offer* laminations to set prices in the *energy* and *operating reserve* markets. For certain operational constraints, a resource will only be limited in its ability to set prices in the *energy* market because the resource is still eligible to be scheduled for *operating reserve* when its *energy* schedule is limited by such a constraint.

Minimum Hourly Output

When a hydroelectric resource is scheduled for *energy* at or above its minimum hourly output in Pre-Dispatch Scheduling, the hydroelectric resource will also be scheduled at or above its minimum hourly output in Pre-Dispatch Pricing. The *energy offer* laminations corresponding to the minimum hourly output amount will be ineligible to set prices. When a hydroelectric resource with a minimum hourly output amount receives a zero schedule in Pre-Dispatch Scheduling, the hydroelectric resource will also receive a zero schedule in Pre-Dispatch Pricing and will be ineligible to set prices in the *energy* market. Thus, for all time-steps $t \in TS$ and hydroelectric buses $b \in B^{HE}$:

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq MinHO_{t,b} \cdot OHO_{t,b}^{PDS}$$

and for all $k \in K_{t,b}^E$:

$$0 \leq SDG_{t,b,k} \leq OHO_{t,b}^{PDS} \cdot QDG_{t,b,k}.$$

That is, the variable $OHO_{t,b}$ used in Pre-Dispatch Scheduling will be set equal to the constant $OHO_{t,b}^{PDS}$.

Limited Number of Starts

Hydroelectric resources with a limited number of starts will be scheduled so that the resource is limited to set prices within an operating range consistent with the number of starts utilized by the resource's schedule determined by Pre-Dispatch Scheduling. To achieve this, the resource's schedule will be restricted to fall between the same start indication values as it fell between in Pre-Dispatch Scheduling. Thus, for all hydroelectric buses $b \in B^{HE}$ and all time-steps $t \in TS$:

If $0 \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} < StartMW_{b,1}$, then

$$0 \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq StartMW_{b,1} - 0.1$$

If $StartMW_{b,i} \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} < StartMW_{b,i+1}$ for $i \in \{1,..,(NStartMW_b - 1)\}$, then

$$StartMW_{b,i} \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq StartMW_{b,i+1} - 0.1$$

If $ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \geq StartMW_{b,NStartMW_b}$, then

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq StartMW_{b,NStartMW_b}.$$

Minimum Daily Energy Limit

For hydroelectric resources with a minimum daily *energy* limit that was binding in Pre-Dispatch Scheduling, the *energy* schedules calculated in Pre-Dispatch Scheduling will be treated as fixed blocks and will be ineligible to set prices. Thus, for all hydroelectric buses $b \in B^{HE}$ such that $MinDEL_{tod,b} > 0$ and

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tod,b} - EngyUsed_b,$$

the following constraints must hold for all time-steps $t \in TS_{tod}$ and *offer* laminations $k \in K_{t,b}^E$:

$$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}.$$

If the look-ahead period spans two *dispatch days*, for all hydroelectric resource buses $b \in B^{HE}$ such that $MinDEL_{tom,b} > 0$ and

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tom,b},$$

the following constraints must hold for all time-steps $t \in TS_{tom}$ and *offer* laminations $k \in K_{t,b}^E$:

$$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}.$$

Shared Minimum Daily Energy Limit

A similar constraint holds for all sets of hydroelectric resources with a shared minimum daily *energy* limit that was binding in Pre-Dispatch Scheduling. In each hour, the sum of *energy* schedules calculated in Pre-Dispatch Scheduling for all resources in each set will be ineligible to set prices. *Energy* schedules for individual resources in each set may be changed compared to schedules in Pre-Dispatch Scheduling, but the sum of *energy* scheduled in each set will be at least equal to the sum of *energy* scheduled in Pre-Dispatch Scheduling.

Thus, for all sets $s \in SHE$ such that:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tod,s} - EngyUsedSHE_s,$$

the following constraints must hold for all time-steps $t \in TS_{tod} \in$:

$$\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) \geq \sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) .$$

If the look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$ such that:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tom,s}$$

the following constraints must hold for all time-steps $t \in TS_{tom}$:

$$\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) \geq \sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right).$$

Shared Maximum Daily Energy Limit

Hydroelectric resources with a binding maximum daily *energy* limit are constrained as per the *energy*-limited resource constraints described above. Similar constraints hold for all sets of hydroelectric resources with a shared maximum daily *energy* limit that was binding in Pre-Dispatch Scheduling. In each hour, the sum of *energy* schedules calculated in Pre-Dispatch Scheduling for all resources in each set will be eligible to set prices. *Energy* schedules for individual resources in each set may be changed compared to schedules in Pre-Dispatch Scheduling, but the sum of *energy* scheduled in each set will be less than or equal to the sum of *energy* scheduled in Pre-Dispatch Scheduling.

For all sets $s \in SHE$, if there exists $T \in TS_{tod}$ such that

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}^{PDS}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}^{PDS}\right)\right)$$
$$=MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

then the maximum daily *energy* limit constraint is considered to be binding for the current *dispatch day* in Pre-Dispatch Scheduling.

In such circumstances, the following constraint must hold for all time-steps $t\in TS_{tod}$:

$$\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}+\sum_{k\in K_{t,b}^{10S}}S10SDG_{t,b,k}+\sum_{k\in K_{t,b}^{10N}}S10NDG_{t,b,k}+\sum_{k\in K_{t,b}^{30R}}S30RDG_{t,b,k}\right)$$
$$\leq\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}+\sum_{k\in K_{t,b}^{10S}}S10SDG_{t,b,k}^{PDS}+\sum_{k\in K_{t,b}^{10N}}S10NDG_{t,b,k}^{PDS}\right.$$
$$\left.+\sum_{k\in K_{t,b}^{30R}}S30RDG_{t,b,k}^{PDS}\right).$$

If the look-ahead period spans two *dispatch days*, if there exists a time-step $T\in TS_{tom}$ such that

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}^{PDS}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}^{PDS}\right)\right)=MaxSDEL_{tom,s},$$

then the maximum daily *energy* limit constraint is considered to be binding for the next *dispatch day* in Pre-Dispatch Scheduling.

In such circumstances, the following constraint must hold for all and time-steps $t \in TS_{tom}$:

$$\sum_{b \in B_s^{HE}} \left(\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \right) \leq \sum_{b \in B_s^{HE}} \left(\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k}^{PDS} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k}^{PDS} \right).$$

Linked Hydroelectric Resources

Energy offer laminations for linked hydroelectric resources on a cascade river system will be eligible to set prices consistently with the schedules calculated in Pre-Dispatch Scheduling. For all downstream resources for which a MWh ratio was respected in Pre-Dispatch Scheduling, the resource will be scheduled between its schedule from Pre-Dispatch Scheduling plus or minus Δ for some small tolerance Δ. For all upstream resources for which a MWh ratio was respected in Pre-Dispatch Scheduling, the resource will be scheduled between its schedule from Pre-Dispatch Scheduling plus or minus Δ for some small tolerance Δ. Each resource schedule will continue to be limited by its *offer* quantity bounds and any applicable resource minimum or maximum constraints.

For all linked downstream hydroelectric resources b_2 such that $(b_1, b_2) \in LNKC$ where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$ and all time-steps $t \in TS$:

$$ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k}^{PDS} - \Delta \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k} \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k}^{PDS} + \Delta.$$

For all linked upstream hydroelectric resources b_1 such that $(b_1, b_2) \in LNKC$ where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$ and all time-steps $t \in TS$ such that $t + LagC_{b_1,b_2} \leq n_{LAP}$:

$$ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k}^{PDS} - \Delta \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k} \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k}^{PDS} + \Delta.$$

3.6.2.4 Bid/Offer Constraints Applying to Single Hours

Scheduling Variable Bounds and Commitment Status Variables

No schedule can be negative, nor can any schedule exceed the quantity *offered* for the respective market (*energy* and *operating reserve*). Therefore, for all time-steps $t \in TS$:

$0 \leq SDL_{t,b,j} \leq QDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{E}_{t,b}$;

$0 \leq S10SDL_{t,b,j} \leq Q10SDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in J^{10S}_{t,b}$;

$0 \leq S10NDL_{t,b,j} \leq Q10NDL_{t,b,j}$ for all $b \in B^{DL}$, $j \in$

$0 \leq S30RDL_{t,b,j} \leq Q30RDL_{t,b,j}$ $J^{10N}_{t,b}$; for all $b \in B^{DL}$, $j \in J^{30R}_{t,b}$;

$0 \leq SHDR_{t,b,j} \leq QHDR_{t,b,j}$ for all $b \in B^{HDR}$, $j \in J^{E}_{t,b}$;

$0 \leq SXL_{t,d,j} \leq QXL_{t,d,j}$ for all $d \in DX$, $j \in J^{E}_{t,d}$;

$0 \leq S10NXL_{t,d,j} \leq Q10NXL_{t,d,j}$ for all $d \in DX$, $j \in J^{10N}_{t,d}$;

$0 \leq S30RXL_{t,d,j} \leq Q30RXL_{t,d,j}$ for all $d \in DX$, $j \in J^{30R}_{t,d}$;

$0 \leq SNDG_{t,b,k} \leq QNDG_{t,b,k}$ for all $b \in B^{NDG}$, $k \in K^{E}_{t,b}$;

$0 \leq SIG_{t,d,k} \leq QIG_{t,d,k}$ for all $d \in DI$, $k \in K^{E}_{t,d}$;

$0 \leq S10NIG_{t,d,k} \leq Q10NIG_{t,d,k}$ for all $d \in DI$, $k \in K^{10N}_{t,d}$; and

$0 \leq S30RIG_{t,d,k} \leq Q30RIG_{t,d,k}$ for all $d \in DI$, $k \in K^{30R}_{t,d}$.

The schedules for dispatchable generation resources must also be consistent with their commitment status. Dispatchable generation resources can be scheduled to produce *energy* and *operating reserve* only if the generation resources are committed. Therefore, for all time-steps $t \in TS$:

$0 \leq SDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot QDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{E}_{t,b}$;

$0 \leq S10SDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q10SDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{10S}_{t,b}$;

$0 \leq S10NDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q10NDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{10N}_{t,b}$; and

$0 \leq S30RDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q30RDG_{t,b,k}$ for all $b \in B^{DG}$, $k \in K^{30R}_{t,b}$.

Resource Minimums and Maximums

The constraints are the same as in Pre-Dispatch Scheduling. Resource minimum and maximum constraints limit a resource's ability to set prices to within the operating region defined by such constraints.

Off-Market Transactions

The constraints are the same as in Pre-Dispatch Scheduling, with the exception of *emergency energy*.

Emergency Energy

A constraint is required to schedule *emergency energy*. These transactions are fixed and therefore have no *offer* price considered in the objective function.

For all time-steps $t \in TS$ and all *intertie zone* sink buses corresponding to an *emergency* sale transaction $d \in DX_t^{EM}$:

$$\sum_{j \in J_{t,d}^E} SXL_{t,d,j} = \sum_{j \in J_{t,d}^E} QXL_{t,d,j}.$$

For all time-steps $t \in TS$ and all *intertie zone* source buses corresponding to an *emergency energy* purchase that supports a sale $d \in DI_t^{EM}$ such that $d \notin DI_t^{EMNS}$:

$$\sum_{k \in K_{t,d}^E} SIG_{t,d,k} = \sum_{k \in K_{t,d}^E} QIG_{t,d,k}.$$

Given that *emergency energy* purchases that do not support a sale should not be scheduled in the pricing algorithm, the following constraint will be respected in Pre-Dispatch Pricing. For all time-steps $t \in TS$ and all *intertie zone* source buses corresponding to an *emergency energy* purchase that does not support a sale $d \in DI_t^{EMNS}$:

$$\sum_{k \in K_{t,d}^E} SIG_{t,d,k} = 0.$$

Intertie Minimum and Maximum Constraints

The constraints are the same as in Pre-Dispatch Scheduling.

Operating Reserve Scheduling

The constraints are the same as in Pre-Dispatch Scheduling.

PSU Resources

The constraints are the same as in Pre-Dispatch Scheduling. A PSU resource that cannot provide *ten-minute operating reserve* from its duct firing region will be eligible to set prices within an operating range consistent with the schedules calculated. If the resource is scheduled for *energy* within the duct firing region, it will eligible to set prices in the *energy* and *thirty-minute operating reserve* markets. If the resource is not scheduled for *energy* within its duct firing region, it will be eligible to set prices in the *energy* and all *operating reserve* markets.

Hydroelectric Resources

A hydroelectric resource must be scheduled for its hourly must-run amount. For all time-steps $t \in TS$ and hydroelectric resource buses $b \in B^{HE}$:

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq MinHMR_{t,b}.$$

The *energy offer* laminations corresponding to the hourly must-run amount will be ineligible to set prices.

The minimum hourly output constraints as described in Pre-Dispatch Scheduling are not required as they are replaced by the corresponding constraints in Section 3.6.2.3.

A hydroelectric resource cannot be scheduled within its *forbidden regions*. For all *dispatch days* $q \in DAYS$, all time-steps $t \in TS$ in *dispatch day* q, all hydroelectric resource buses $b \in B^{HE}$ and all $i \in \{1,..,NFor_{q,b}\}$:

$$OFR_{t,b,i} \in \{0,1\};$$

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq OFR_{t,b,i} \cdot ForL_{q,b,i} + (1 - OFR_{t,b,i}) \cdot \left(MinQDGC_b + \sum_{k \in K_{t,b}^E} QDG_{t,b,k} \right);$$

and

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq (1 - OFR_{t,b,i}) \cdot ForU_{q,b,i}.$$

A hydroelectric resource will be scheduled in respect of its *forbidden regions*, and therefore the resource is limited to set prices within the operating range determined by the adjacent *forbidden regions* between which the resource was scheduled.

Wheeling Through Transactions

These constraints are the same as in Pre-Dispatch Scheduling.

3.6.2.5 Bid/Offer Inter-Hour/Multi-Hour Constraints

Energy Ramping

These constraints are the same as in Pre-Dispatch Scheduling.

Operating Reserve Ramping

These constraints are the same as in Pre-Dispatch Scheduling.

NQS Resources

The variables associated with commitment of NQS resources are held fixed and therefore these constraints are no longer required.

Energy-Limited Resources

These constraints are the same as in Pre-Dispatch Scheduling. Schedules of *energy*-limited resources with a maximum daily *energy* limit that was binding in Pre-Dispatch Scheduling are additionally constrained as per Section 3.6.2.3.

Hydroelectric Resources

A hydroelectric resource must be scheduled for at least its minimum daily *energy*. If the look-ahead period spans two *dispatch days*, a constraint is required for both days. The constraint for today must consider the amount of *energy* already provided by the resource. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution. For all hydroelectric resource buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tod,b} - EngyUsed_b.$$

If the look-ahead period spans two *dispatch days*, for all hydroelectric resource buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tom,b}.$$

For hydroelectric resources with a binding minimum daily *energy* limit in Pre-Dispatch Scheduling, the constraints in Section 3.6.2.3 imply the above constraint.

The maximum number of starts constraints are no longer required as they are replaced by the corresponding constraints in Section 3.6.2.3.

The schedules for hydroelectric resources must respect shared maximum daily *energy* limits. If the look-ahead period spans two *dispatch days*, constraints are required for both days. The constraints for today must consider the amount of *energy* already provided by resources with the shared daily *energy* limit. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution. For all sets $s \in SHE$ and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)$$
$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}$$
$$\leq MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

If the look-ahead period spans two *dispatch days*, then for all sets $s\in SHE$ and all time-steps $T\in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$
$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)$$
$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}\leq MaxSDEL_{tom,s}$$

The factors $10ORConv$ and $30ORConv$ are applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy*-limited resources to convert MW into MWh.

The schedules for hydroelectric resources must respect shared minimum daily *energy* limits. If the look-ahead period spans two *dispatch days*, a constraint is required for both days. The constraint for today must consider the amount of *energy* already provided by resources with the shared daily *energy* limit. A violation variable is provided for these constraints to improve the ability of the PD calculation engine to find a solution.

For all sets $s \in SHE_{tod}$ and all time-steps $t \in TS_{tod}$:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tod,s} - EngyUsedSHE_s.$$

If the look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tom,s}.$$

Analogous to maximum daily *energy* limits and minimum daily *energy* limits for a single resource, additional constraints will be applied when shared daily *energy* limits are binding as described in Section 3.6.2.3.

3.6.2.6 Constraints to Ensure Schedules Do Not Violate Reliability Requirements

Energy Balance

The constraint is the same as in Pre-Dispatch Scheduling. The marginal loss factors used in the *energy* balance constraint in Pre-Dispatch Pricing will be fixed to the marginal loss factors used in the last optimization function iteration of Pre-Dispatch Scheduling.

Operating Reserve Requirements

The constraints are the same as in Pre-Dispatch Scheduling.

IESO Internal Transmission Limits

The constraints are the same as in Pre-Dispatch Scheduling. The sensitivities and limits considered are those provided by the most recent *security* assessment function iteration.

Intertie Limits

The constraints are the same as in Pre-Dispatch Scheduling.

Penalty Price Variable Bounds

The following constraints restrict the penalty price variables to the ranges determined by the penalty price curves. For all time-steps $t \in TS$:

$0 \leq SLdViol_{t,i} \leq QLdViolPrc_{t,i}$ for all $i \in \{1,..,N_{LdViol_t}\}$;

$0 \leq SGenViol_{t,i} \leq QGenViolPrc_{t,i}$ for all $i \in \{1,..,N_{GenViol_t}\}$;

$0 \leq S10SViol_{t,i} \leq Q10SViolPrc_{t,i}$ for all $i \in \{1,..,N_{10SViol_t}\}$;

$0 \leq S10RViol_{t,i} \leq Q10RViolPrc_{t,i}$ for all $i \in \{1,..,N_{10RPrc_t}\}$;

$0 \leq S30RViol_{t,i} \leq Q30RViolPrc_{t,i}$ for all $i \in \{1,..,N_{30RPrc_t}\}$;

$0 \leq SREG10RViol_{r,t,i} \leq QREG10RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG10RPrc_t}\}$;

$0 \leq SREG30RViol_{r,t,i} \leq QREG30RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG30RPrc_t}\}$;

$0 \leq SXREG10RViol_{r,t,i} \leq QXREG10RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG10RPrc_t}\}$;

$0 \leq SXREG30RViol_{r,t,i} \leq QXREG30RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG30RPrc_t}\}$;

$0 \leq SPreITLViol_{f,t,i} \leq QPreITLViolPrc_{f,t,i}$ for all $f \in F_t$, $i \in \{1,..,N_{PreITLPrc_{f,t}}\}$;

$0 \leq SITLViol_{f,c,t,i} \leq QITLViolPrc_{f,c,t,i}$ for all $c \in C$, $f \in F_{c,t}$, $i \in \{1,..,N_{PITLPrc_{c,f,t}}\}$;

$0 \leq SPreXTLViol_{z,t,i} \leq QPreXTLViolPrc_{z,t,i}$ for all $z \in Z_{Sch}$, $i \in \{1,..,N_{PreXTLPrc_{z,t}}\}$;

$0 \leq SNIUViol_{t,i} \leq QNIUViolPrc_{t,i}$ for all $i \in \{1,..,N_{NIUPrc_t}\}$;

$0 \leq SNIDViol_{t,i} \leq QNIDViolPrc_{t,i}$ for all $i \in \{1,..,N_{NIDPrc_t}\}$;

$0 \leq SMaxDelViol_{t,b,i} \leq QMaxDelViolPrc_{t,b,i}$ for all $b \in B^{ELR}$, $i \in \{1,..,N_{MaxDelViol_t}\}$;

$0 \leq SMinDelViol_{t,b,i} \leq QMinDelViolPrc_{t,b,i}$ for all $b \in B^{HE}$, $i \in \{1,..,N_{MinDelViol_t}\}$;

$0 \leq SSMaxDelViol_{t,s,i} \leq QSMaxDelViolPrc_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMaxDelViol_t}\}$; and

$0 \leq SSMinDelViol_{t,s,i} \leq QSMinDelViolPrc_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMinDelViol_t}\}$.

3.6.2.7 Outputs

Pre-Dispatch Pricing will produce shadow prices for all constraints contributing to locational prices. A shadow price for a constraint reflects the cost savings achieved by relaxing that constraint a small amount and measuring the marginal response. LMPs will be calculated using the pricing formulas provided in Section 3.8, which specify how constraint shadow prices, marginal loss factors and constraint sensitivities are used to determine an LMP and its components.

Table 3-13 lists the shadow prices outputs of Pre-Dispatch Pricing constraints that will be produced for each time-step $t \in TS$:

Table 3-13: Shadow Pricing Outputs of Pre-Dispatch Pricing

Output	Description
SPL_t^{PDP}	shall designate the shadow price for the *energy* balance constraint.
$SPNormT_{t,f}^{PDP}$	shall designate the shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in time-step t.
$SPEmT_{t,c,f}^{PDP}$	shall designate the shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step t.
$SPExtT_{t,z}^{PDP}$	shall designate the shadow price for the import or export limit constraint $z \in Z_{Sch}$ in time-step t.
$SPNIUExtBwdT_t^{PDP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step $(t - 1)$ and time-step t.
$SPNIDExtBwdT_t^{PDP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step $(t - 1)$ and time-step t.
$SPNIUExtFwdT_t^{PDP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step t and time-step $(t + 1)$.
$SPNIDExtFwdT_t^{PDP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step t and time-step $(t + 1)$.
$SP10S_t^{PDP}$	shall designate the shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in time-step t.
$SP10R_t^{PDP}$	shall designate the shadow price for the total *ten-minute operating reserve* requirement constraint in time-step t.
$SP30R_t^{PDP}$	shall designate the shadow price for the total *thirty-minute operating reserve* requirement constraint in time-step t.
$SPREGMin10R_{t,r}^{PDP}$	shall designate the shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.
$SPREGMin30R_{t,r}^{PDP}$	shall designate the shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.

Output	Description
$SPREGMax10R_{t,r}^{PDP}$	shall designate the shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.
$SPREGMax30R_{t,r}^{PDP}$	shall designate the shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.

Table 3-14 lists the LMPs and components for each time-step $t \in TS$ calculated using the pricing formulas in Section 3.8.

Table 3-14: LMP Outputs of Pre-Dispatch Pricing

Output	Description
$PRef_{t}^{PDP}$	shall designate the time-step t *energy* reference price.
$LMP_{t,b}^{PDP}$	shall designate the time-step t LMP for bus $b \in B$.
$PLoss_{t,b}^{PDP}$	shall designate the time-step t loss component for bus $b \in B$.
$PCong_{t,b}^{PDP}$	shall designate the time-step t congestion component for bus $b \in B$.
$ExtLMP_{t,d}^{PDP}$	shall designate the time-step t LMP for *intertie zone* bus $d \in D$.
$IntLMP_{t,d}^{PDP}$	shall designate the time-step t *intertie* border price (IBP) for *intertie zone* bus $d \in D$.
$PLoss_{t,d}^{PDP}$	shall designate the time-step t loss component for *intertie zone* bus $d \in D$.
$PIntCong_{t,d}^{PDP}$	shall designate the time-step t internal congestion component for *intertie zone* bus $d \in D$.
$PExtCong_{t,d}^{PDP}$	shall designate the time-step t *intertie* congestion component for *intertie zone* bus $d \in D$.
$PNISL_{t,d}^{PDP}$	shall designate the time-step t net interchange scheduling limit congestion component for *intertie zone* bus $d \in D$.
$L30RP_{t,b}^{PDP}$	shall designate the time-step t *thirty-minute operating reserve* price for bus $b \in B$.
$L10NP_{t,b}^{PDP}$	shall designate the time-step t non-synchronized *ten-minute operating reserve* price for bus $b \in B$.

Output	Description
$L10SP_{t,b}^{PDP}$	shall designate the time-step t synchronized *ten-minute operating reserve* price for bus $b \in B$.
$ExtL30RP_{t,d}^{PDP}$	shall designate the time-step t *thirty-minute operating reserve* price for *intertie zone* bus $d \in D$.
$ExtL10NP_{t,d}^{PDP}$	shall designate the time-step t non-synchronized *ten-minute operating reserve* price for *intertie zone* bus $d \in D$.

The PD calculation engine will record all such values for informational purposes.

Advisory Prices and Intertie Congestion Prices

The LMPs and shadow prices determined by Pre-Dispatch Pricing, as described above, will be the pre-dispatch advisory prices for the *pre-dispatch scheduling* process. For each pricing output, a superscript of 1, e.g. $SPXX^1$, shall designate the Pass 1 pricing results. These prices will be *published* by 30 minutes past the hour.

3.6.3. Market Power Mitigation

The *IESO* will assess resources for market power following Pre-Dispatch Pricing. Market Power Mitigation will use outputs from Pre-Dispatch Pricing to assess whether certain conditions related to transmission congestion have been met. The constrained area conditions test will determine the set of resources (if any) that need to be tested for Market Power Mitigation. The conduct test will then check if those resources *offered* within the conduct thresholds. *Market participant offers* that failed the conduct test will be replaced by their reference level for Reference Level Scheduling and Pricing. The price impact test will compare the LMPs from Pre-Dispatch Pricing with those from Reference Level Pricing. If a resource fails the price impact test, reference levels for the *dispatch data* parameters that failed the conduct test will be used in the subsequent runs of Pre-Dispatch Scheduling and Pre-Dispatch Pricing for that hour through to the real-time timeframe.

3.6.3.1 Constrained Area Conditions Test

The *IESO* will implement a conduct and impact testing methodology that will identify exercises of market power only when competition is restricted. The *IESO* will use a specific set of conditions to determine if competition is restricted. These conditions are categorized into local market power conditions and global market power conditions. If no conditions are met than the conduct test is not applied.

The following list identifies the *IESO*-defined conditions that would meet mitigation testing for *energy* and *operating reserve*. Refer to the Market Power Mitigation detailed design document for more details. Each of these conditions will be tested for separately, as detailed below.

- Local Market Power (*Energy*), including:
    - Narrow Constrained Area (NCA)
    - Dynamic Constrained Area (DCA)
    - Broad Constrained Area (BCA)
- Global Market Power (*Energy*)
- Global Market Power (*Operating Reserve*)
- Local Market Power (*Operating Reserve*)

The outputs of the conditions test are the set of resources that will be subject to the conduct test. A different set of resources will be identified for each market power condition as the conduct test depends on the condition triggered. The resource sets identified will be denoted as follows:

- $BCond_t^{NCA}$ shall designate the resources in an NCA that must be checked for Local Market Power for *energy* in time-step $t \in TS$.
- $\mathrm{BCond}_t^{\mathrm{DCA}}$ shall designate the resources in a DCA that must be checked for Local Market Power for *energy* in time-step $t \in TS$.
- $BCond_t^{BCA}$ shall designate the resources in a BCA that must be checked for Local Market Power for *energy* in time-step $t \in TS$.
- $BCond_t^{GMP}$ shall designate the resources that must be checked for Global Market Power for *energy* in time-step $t \in TS$.
- $BCond_t^{10S}$ shall designate that resources that must be checked for Local Market Power for synchronized *ten-minute operating reserve* in time-step $t \in TS$.
- $\mathrm{BCond}_t^{\mathrm{10N}}$ shall designate that resources that must be checked for Local Market Power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$.
- $BCond_t^{30R}$ shall designate that resources that must be checked for Local Market Power for *thirty-minute operating reserve* in time-step $t \in TS$.
- $BCond_t^{GMP10S}$ shall designate that resources that must be checked for Global Market Power for synchronized *ten-minute operating reserve* in time-step $t \in TS$.
- $BCond_t^{GMP10N}$ shall designate that resources that must be checked for Global Market Power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$.
- $BCond_t^{GMP30R}$ shall designate that resources that must be checked for Global Market Power for *thirty-minute operating reserve* in time-step $t \in TS$.

Inputs into the Constrained Area Conditions Test

The constrained area conditions test will use the applicable inputs identified in Section 3.4.2. Table 3-15 lists the Pre-Dispatch Pricing outputs that will be also be used by the constrained area conditions test.

Table 3-15: Outputs of Pre-Dispatch Pricing as Input to the Constrained Area Conditions Test

Input	Description
$LMP_{t,b}^{PDP}$	The LMP for bus $b \in B$ in time-step $t \in TS$.
$PCong_{t,b}^{PDP}$	The congestion component of the LMP for bus $b \in B$ in time-step $t \in TS$.
$ExtLMP_{t,d}^{PDP}$	The LMP for *intertie* bus $d \in D$ in time-step $t \in TS$.
$PExtCong_{t,d}^{PDP}$	The *intertie* congestion component of the LMP for *intertie* bus $d \in D$ in time-step $t \in TS$.
$PIntCong_{t,d}^{PDP}$	The internal congestion component of the LMP for *intertie* bus $d \in D$ in time-step $t \in TS$.
$IntLMP_{t,d}^{PDP}$	The *intertie* border price (IBP) for *intertie* bus $d \in D$ in time-step $t \in TS$.
$SPNormT_{t,f}^{PDP}$	The shadow price associated with the rate of change of the objective function for a change in the limit, $AdjNormMaxFlow_{t,f}$ on flows over transmission *facilities* in normal conditions for *facility* $f \in F$ in time-step $t \in TS$.
$SPEmT_{h,c,f}^{AOP}$	shall designate the shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in hour h.
$SPNIUExtBwdT_{t}^{PDP}$	The shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step $(t-1)$ and time-step t.
$L30RP_{t,b}^{PDP}$	The *thirty-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$.
$L10NP_{t,b}^{PDP}$	The non-synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$.
$L10SP_{t,b}^{PDP}$	The synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$.

Conditions Test for Local Market Power (Energy) Constrained Areas

The following sections describe the conditions that must be met for resources located within an NCA, DCA or BCA to qualify for Local Market Power (*energy*) mitigation testing.

NCA and DCA

If at least one transmission constraint for the NCA or DCA is binding in Pre-Dispatch Pricing, all resources identified as within that constrained area will qualify to undergo the conduct test.

NCAs or DCAs that meet this criterion will be assigned to the following subsets:

- NCA_t' shall designate the NCAs that qualify for MPM in time-step $t \in TS$; and
- DCA_t' shall designate the DCAs that qualify for MPM in time-step $t \in TS$.

The process for identifying resources in NCAs and DCAs that qualify for MPM is as follows:

For each $n \in NCA$ and time-step $t \in TS$:

- For each transmission *facility* that transmits flow into n, $f \in F_n^{NCA}$, check if $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit. If true, place n in the set NCA_t' and assign the resources in n to the set $BCond_t^{NCA}$.

For each $d \in DCA$ and time-step $t \in TS$:

- For each transmission *facility* that transmits flow into d, $f \in F_d^{DCA}$, check if $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit. If true, place d in the set DCA_t' and assign the resources in n to the set $BCond_t^{DCA}$.

BCA

A BCA will be identified where the congestion component of the resource's LMP is greater than $BCACondThresh$, and the resource is not part of an NCA or DCA that has a binding transmission constraint.

The process for identifying BCAs that qualify for MPM is as follows:

For each time-step $t \in TS$:

- For each bus $b \in B^{DG}$ such that $b \notin BCond_t^{NCA} \cup BCond_t^{DCA}$, check if $PCong_{t,b}^{AOP} > BCACondThresh$. If true, then place resource b in the set $BCond_t^{BCA}$.

Conditions Test for Global Market Power (Energy) Constrained Areas

There are two conditions that must both be present to test *energy* resources for global market power. The PD calculation engine will check for these conditions, and if met, perform the conduct test on applicable resources. Conditions and applicable resources are discussed below.

Condition 1: Unable to schedule incremental imports

The first two forecast hours in the look-ahead period will be assessed for this condition, while the remainder of the time-steps in the look-ahead period will not. Therefore, for time-steps $t=\{2,3\}$, the condition will be assessed and is indicated by one of the following:

- Import congestion, represented by a negative *intertie* congestion component, is present on all of the Global Market Power Reference Interties. This condition is indicated by:

  $PExtCong_{t,d}^{PDP} < 0$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the reference *interties* proxy location

- Net Intertie Scheduling Limit (NISL) is binding for imports, represented by a non-zero NISL shadow price for incremental imports. This condition is indicated by:

  $SPNIUExtBwdT_{t}^{PDP} \neq 0$

Condition 2: Pricing

If the *intertie* border price (IBP) at the reference *interties* is greater than the specified threshold value, then condition 2 will be met. This condition is indicated in time-step $t \in TS$ by:

$IntLMP_{t,d}^{PDP} > IBPThresh$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the reference *interties* proxy location.

Resources Tested

If both conditions 1 and 2 are met, the PD calculation engine will test financial *dispatch data* from resources that can meet incremental load within Ontario for global market power. Resources with a congestion component at least $1/MWh below the internal congestion component at all of the Global Market Power Reference Interties will be exempted from testing for global market power. The process for identifying resources that qualify for the conduct test for global market power in the *energy* market is as follows:

For each time-step $t \in TS$, if condition 1 and 2 to trigger global market power for *energy* testing are met:

1. Place all $b \in B^{DG}$ in the set $BCond_{t}^{GMP}$.
2. Next, for each transmission *facility*, check if $SPNormT_{h,f}^{AOP} \neq 0$ *or* $SPEmT_{h,c,f}^{AOP} \neq 0$. If true, then remove all resources that have positive sensitivity factor on that transnsmission *facility* from the set $BCond_{h}^{GMP}$.

{And, for all resources $b \in B^{DG}$ in all zones, if $\mathrm{PCong}_{\mathrm{t,b}}^{\mathrm{PDP}} < \mathrm{PIntCong}_{\mathrm{t,d}}^{\mathrm{PDP}} - \frac{\$1}{\mathrm{MWh}}$ where $d \in D^{GMPRef}$ (must be true for all Global Market Power Reference *interties*), then remove resource from the set $BCond_t^{GMP}$.

Conditions Test for Local Market Power (Operating Reserve) Constrained Areas

Conditions to test for local market power in the *operating reserve market* occur when there are reserve areas with a minimum requirement greater than zero. Resources *offering operating reserve* in these areas will be subject to the conduct test unless the resource is also located in a reserve area with a binding maximum restriction constraint. In that case, the resource would be exempt from mitigation testing for local market power in the *operating reserve* market.

The process for identifying the resources that qualify for mitigation testing for local market power for *operating reserve* is as follows.

For each $b \in B^{DG} \cup B^{DL}$ and time-step $t \in TS$:

- If b is in a region with a binding area reserve maximum restriction constraint, then b is exempt from the conduct test.
- Otherwise, if b is in a region with a non-zero area reserve minimum requirement, then b is subject to the conduct test and is placed in the set $BCond_t^{10S}$, $BCond_t^{10N}$,or $BCond_t^{30R}$.

Conditions Test for Global Market Power (Operating Reserve) Constrained Areas

Conditions to test for global market power in the *operating reserve* market occur when there is an *operating reserve* LMP greater than $ORGCondThresh$. All resources *offering* in that class of *operating reserve* will be tested, except resources in a reserve area with a binding maximum restriction constraint.

The process for identifying the resources that qualify for mitigation testing for global market power in *operating reserve* is as follows:

For each $b \in B^{DG} \cup B^{DL}$ and time-step $t \in TS$:

- If b is in a region with a binding max constraint, then b is exempt from the conduct test;

Otherwise:

- Check if $L10SP_{t,b}^{PDP} > ORGCondThresh$. If true, then add resource b to $BCond_t^{GMP10S}$;
- Check if $L10NP_{t,b}^{PDP} > ORGCondThresh$. If true, then add resource b to $BCond_t^{GMP10N}$; and
- Check if $L30RP_{t,b}^{PDP} > ORGCondThresh$. If true, then add resource b to $BCond_t^{GMP30R}$.

3.6.3.2 Conduct Test

All resources that meet the constrained area conditions test criteria will undergo a conduct test. If no such resources are identified, the Market Power Mitigation process is complete and the conduct test will not occur.

In the conduct test, the *dispatch data* parameters submitted by *market participants* for their resources will be evaluated against reference levels. The conduct test checks whether financial *dispatch data* parameter values are within a set threshold level of the reference level. If a resource qualifies for more than one conduct test in either *energy* or *operating reserve*, the test with the most stringent threshold levels will be performed.

If all resource financial *dispatch data* parameters pass the conduct test, the Market Power Mitigation process is complete and no mitigation is required. If one or more financial *dispatch data* parameter fail the conduct test, the PD calculation engine will perform Reference Level Scheduling, Reference Level Pricing and the Price Impact Test.

Inputs into the Market Power Mitigation Conduct Test

The conduct test will use the applicable inputs identified in Section 3.4.2.

Variables

A set of resources that failed the conduct test for at least one financial *dispatch data* parameter will be identified for each condition, where:

- BCT_t^{NCA} shall designate the resources in an NCA that failed the conduct test for at least one *dispatch data* parameter in time-step $t \in TS$;
- BCT_t^{DCA} shall designate the resources in a DCA that failed the conduct test for at least one *dispatch data* parameter in time-step $t \in TS$;
- BCT_t^{BCA} shall designate the resources in a BCA that failed the conduct test for at least one *dispatch data* parameter in time-step $t \in TS$;
- BCT_t^{GMP} shall designate the resources that failed the Global Market Power (*energy*) conduct test for at least one *dispatch data* parameter in time-step $t \in TS$;
- BCT_t^{ORL} shall designate the resources that failed the Local Market Power (*operating reserve*) conduct test for at least one *dispatch data* parameter in time-step $t \in TS$; and
- BCT_t^{ORG} shall designate the resources that failed the Global Market Power conduct test for *operating reserve* for at least one *dispatch data* parameter in time-step $t \in TS$.

The conduct test will also identify the following sets of *dispatch data* parameters for all time-steps $t \in TS$:

- $PARAME_{t,b}$ shall designate the set of *dispatch data* parameters that failed the *energy* conduct test for bus $b \in \{BCT_t^{NCA} \cup BCT_t^{DCA} \cup BCT_t^{BCA} \cup BCT_t^{GMP}\}$ in time-step *t*; and
- $PARAMOR_{t,b}$ shall designate the set of *dispatch data* parameters that failed the *operating reserve* conduct test for bus $b \in \{BCT_t^{ORL} \cup BCT_t^{ORG}\}$ in time-step t.

For any resource at bus $b \in B^{DG}$, the following *dispatch data* parameters may be identified in $PARAME_{t,b}$:

- $EnergyOffer_k$ indicating a non-zero quantity of the *energy offer* above MLP lamination $k \in K_{t,b}^{E}$ failed the conduct test;
- $EnergyToMLP_k$ indicating a non-zero quantity of the *energy offer* for *energy* to MLP lamination $k \in K_{t,b}^{LTMLP}$ failed the conduct test;
- $SUOffer$ indicating the start-up *offer* failed the conduct test; and
- $SNLOffer$ indicating the speed no-load *offer* failed the conduct test.

For any resource at bus $b \in B^{DG} \cup B^{DL}$, the following *dispatch data* parameters may be identified in $PARAMOR_{t,b}$.

- $OR10SOffer_k$ indicating a non-zero quantity of the ten-minute synchronized *operating reserve offer* lamination $k \in K_{t,b}^{10S}$ failed the conduct test;
- $OR10NOffer_k$ indicating a non-zero quantity of the ten-minute non-synchronized *operating reserve offer* lamination $k \in K_{t,b}^{10N}$ failed the conduct test;
- $OR30ROffer_k$ indicating a non-zero quantity of the *thirty-minute operating reserve offer* lamination $k \in K_{t,b}^{30R}$ failed the conduct test;
- $SUOffer$ indicating the start-up *offer* failed the conduct test;
- $SNLOffer$ indicating the speed no-load *offer* failed the conduct test; and
- $EnergyToMLP_k$ indicating a non-zero quantity of the *energy offer* for the *energy* to MLP lamination $k \in K_{t,b}^{E}$ failed the conduct test.

Commitment cost *dispatch data* parameters will be tested for all hours prior to and including the last hour where conditions are met for both the *energy* and *operating reserve* conduct test.

Conduct Test for Energy

Resources that qualify for testing for market power mitigation in the *energy* market will have the following *dispatch data* parameters evaluated:

- *Energy offer*, including *offers* up to and above MLP (only applicable if *energy offer* is greater than $CTEnMinOffer$),
- Start-up *offer*, and
- Speed no-load *offer*.

The *IESO* will perform the conduct test for resources that were selected in the constrained area conditions test for NCAs as follows.

For each time-step $t \in TS$ and $b \in BCond_t^{NCA}$:

- Evaluate *energy offer* above MLP: For all $k \in K_{t,b}^{E}$, if $PDG_{t,b,k} > CTEnMinOffer$ and $PDG_{t,b,k} > min\,(PDGRef_{t,b,k} * (1 + CTEnThresh1^{NCA}), PDGRef_{t,b,k} + CTEnThresh2^{NCA})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{NCA} and add $EnergyOffer_k$ to $PARAME_{t,b}$.
- Evaluate *energy offer* for the range of production up to MLP: For all time-steps prior to and including the time-step that meets the conditions test, for all $k \in K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > min\,(PLTMLPRef_{t,b,k} * (1 + CTEnThresh1^{NCA}), PLTMLPRef_{t,b,k} + CTEnThresh2^{NCA})$ then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{NCA} and add $EnergyToMLP_k$ to $PARAME_{t,b}$.
- Evaluate start-up *offer*: For all time-steps prior to and including the time-step that meets the conditions test, if $SUDG_{t,b} > SUDGRef_{t,b} * (1 + CTSUThresh^{NCA})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{NCA} and add $SUOffer$ to $PARAME_{t,b}$.
- Evaluate speed no-load *offer*: For all time-steps prior to and including the time-step that meets the conditions test, if $SNL_{t,b} > SNLRef_{t,b} * (1 + CTSNLThresh^{NCA})$, then conduct test failed for resource at bus b. Assign resource to subset BCT_t^{NCA} and add $SNLOffer$ to $PARAME_{t,b}$.

The conduct test for DCA, BCA, and Global Market Power (*energy*) would take the same form, while referencing resources in $BCond_t^{DCA}$, $BCond_t^{BCA}$, and $BCond_t^{GMP}$ and using the appropriate conduct test thresholds. Additionally, resources will be assigned to the subsets BCT_t^{DCA}, BCT_t^{BCA}, and BCT_t^{GMP}.

Conduct Test for Operating Reserve

Resources that qualify for *operating reserve* market power mitigation will have the following parameters evaluated:

- *Operating reserve offer* (only applicable if *operating reserve offer* is greater than $CTORMinOffer$),
- Start-up *offer*,
- Speed no-load *offer*; and

- *Energy offers* for the range of production up to MLP.

As noted above, if a resource qualifies for more than one *operating reserve* conduct test, the test with the most stringent threshold levels will be performed.

The *IESO* will perform the conduct test for resources that were selected in the Local Market Power *operating reserve* constrained area conditions test as follows.

For each time-step $t \in TS$ and $b \in BCond_t^{10S} \cup BCond_t^{10N} \cup BCond_t^{30R}$:

- Evaluate *operating reserve offer*:
    - For all $k \in K_{t,b}^{10S}$ such that $P10SDG_{t,b,k} > CTORMinOffer$ and $P10SDG_{t,b,k} > min(P10SDGRef_{t,b,k} * (1 + CTORThresh1^{ORL}), P10SDGRef_{t,b,k} + CTORThresh2^{ORL})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{t,b}$.
    - For all $k \in K_{t,b}^{10N}$ such that $P10NDG_{t,b,k} > CTORMinOffer$ and $P10NDG_{t,b,k} > min(P10NDGRef_{t,b,k} * (1 + CTORThresh1^{ORL}), P10NDGRef_{t,b,k} + CTORThresh2^{ORL})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{t,b}$.
    - For all $k \in K_{t,b}^{30R}$ such that $P30RDG_{t,b,k} > CTORMinOffer$ and $P30RDG_{t,b,k} > min(P30RDGRef_{t,b,k} * (1 + CTORThresh1^{ORL}), P30RDGRef_{t,b,k} + CTORThresh2^{ORL})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{t,b}$.
- Evaluate start-up *offer*: For all time-steps prior to and including the time-step that meets the conditions test, if $SUDG_{t,b} > SUDGRef_{t,b} * (1 + CTSUThresh^{ORL})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $SUOffer$ to $PARAMOR_{t,b}$.
- Evaluate speed no-load *offer*: For all time-steps prior to and including the time-step that meets the conditions test, if $SNL_{t,b} > SNLRef_{t,b} * (1 + CTSNLThresh^{ORL})$, then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $SNLOffer$ to $PARAMOR_{t,b}$.
- Evaluate *energy offers* for the range of production up to MLP: For all time-steps prior to and including the time-step that meets the conditions test, for all $k \in K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > min(PLTMLPRef_{t,b,k} * (1 + CTEnThresh1^{ORL}), PLTMLPRef_{t,b,k} + CTEnThresh2^{ORL})$ then conduct test failed for resource at bus *b*. Assign resource to subset BCT_t^{ORL} and add $EnergyToMLP_k$ to $PARAMOR_{t,b}$.

The conduct test for global market power *operating reserve* would take the same form, while referencing resources in $BCond_t^{GMP10S}$, $BCond_t^{GMP10N}$, and $BCond_t^{GMP30R}$ and using the appropriate conduct test thresholds. Additionally, resources will be assigned to the subset BCT_t^{ORG}.

Outputs

The outputs of the conduct test will include the following for each time-step $t \in TS$:

- The set of resources that failed the conduct test for at least one parameter by condition type (i.e. resources included in the sets BCT_t^{NCA}, BCT_t^{DCA}, BCT_t^{BCA}, BCT_t^{GMP}, BCT_t^{ORL}, BCT_t^{ORG}).
- The *dispatch data* parameters that failed the conduct test for the resource at bus b (i.e. *dispatch data* parameters included in the sets $PARAME_{t,b}$ and $PARAMOR_{t,b}$), and
- A revised set of financial *dispatch data* parameters for resources that failed a conduct test with *dispatch data* parameters that failed the conduct test replaced reference levels. This set is referred to as the reference level *dispatch data.* For *energy* and *operating reserve offers* with multiple laminations:
  - If one or more lamination in the *energy offer* for the range of production up to MLP fails the conduct test, the PD calculation engine will replace all laminations in the *energy offer* for the range of production up to MLP.
  - If one or more lamination in the *energy offer* for the range of production above MLP fails the conduct test, the PD calculation engine will replace all laminations in *energy offers* for the entire range of production (up to and above MLP).
  - If one or more lamination in the *operating reserve offer* fails the conduct test, the PD calculation engine will replace all laminations in the *operating reserve offer*.

3.6.3.3 Reference Level Scheduling

Reference Level Scheduling will perform a *security*-constrained unit commitment and economic *dispatch* similar to that performed by Pre-Dispatch Scheduling. Reference Level Scheduling only differs from Pre-Dispatch Scheduling in that it will use reference level *dispatch data* for any financial *dispatch data* from *registered market participants* that failed the conduct test.

Reference Level Scheduling will determine commitment statuses and schedules. These commitments will serve as inputs into Reference Level Pricing. The schedules produced will not be financially binding and will only be used within ex-ante Market Power Mitigation.

The following sections describe the formulation of the optimization function for Reference Level Scheduling.

Inputs

All applicable inputs identified in Section 3.4.1 will be used. Reference level *dispatch data* will be used for any financial *dispatch data* parameters from *registered market participants* that failed the conduct test in the current PD calculation engine run.

Additionally, if an NQS resource start-up *offer* failed the conduct test, the evaluation of the *start-up cost* for an NQS resource advancement (described in Section 3.5.6) must be performed, with the appropriate start-up *offer* considered by the optimization function in each time-step.

Variables, Objective Function, and Constraints

The variables, objective function and set of constraints are the same as those used in Pre-Dispatch Scheduling.

Outputs

Reference Level Scheduling will produce schedules and unit commitment statuses for all resources.

For each scheduling variable SXX, SXX^{RLS} shall designate the value determined in Reference Level Scheduling.

In particular, the unit commitment statuses and affiliated start-up decision determined in Reference Level Scheduling will be denoted as follows:

- $ODG_{t,b}^{RLS} \in \{0,1\}$ shall designate whether the dispatchable generation resource at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$; and
- $IDG_{t,b}^{RLS} \in \{0,1\}$ shall designate whether the dispatchable generation resource at bus $b \in B^{DG}$ was scheduled to start (reach its *minimum loading point*) in time-step $t \in TS$.

The PD calculation engine will record all such values for informational purposes.

3.6.3.4 Reference Level Pricing

Reference Level Pricing will perform a *security*-constrained economic *dispatch* similar to that performed by Pre-Dispatch Pricing. Reference Level Pricing differs from Pre-Dispatch Pricing in that it will use reference level *dispatch data* for any inputs from *registered market participants* that failed the conduct test in the current PD calculation engine run. Reference Level Pricing also differs from Pre-Dispatch Pricing in that the principle for price-setting eligibility will be applied by taking into account the Reference Level Scheduling results.

Reference Level Pricing will determine an initial set of LMPs. The LMPs will be used in the price impact test. The prices produced will not be financially binding.

The following sections describe the formulation of the optimization function for Reference Level Pricing.

Inputs

All applicable inputs identified in Section 3.4.1 will be evaluated. Reference level *dispatch data* will be used for any inputs from *registered market participants* that failed the conduct test in the current PD calculation engine run.

Table 3-16 lists the outputs of Reference Level Scheduling that will also be used for Reference Level Pricing.

Table 3-16: Output of Reference Level Scheduling as Input to Reference Level Pricing

Input	Description
$SDG_{t,b,k}^{RLS}$	The amount of dispatchable generation scheduled at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{E}$. This is in addition to any $MinQDG_b$, the *minimum loading point*, which must be committed before any such generation is scheduled.
$ODG_{t,b}^{RLS}$	Designates whether dispatchable generation at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$.
$S10SDG_{t,b,k}^{RLS}$	The amount of ten-minute synchronized *operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10S}$.
$S10NDG_{t,b,k}^{RLS}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$.
$S30RDG_{t,b,k}^{RLS}$	The amount of *thirty-minute operating reserve* that a qualified dispatchable generation resource is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{30R}$.
$OHO_{t,b}^{RLS}$	Designates whether the hydroelectric resource at but $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

Variables, Objective Function, and Constraints

The variables and objective function are the same as those used in Pre-Dispatch Pricing. Many of the constraints enforced in Reference Level Pricing are the same as those enforced in Pre-Dispatch Pricing. However, the constraints used to determine prices must be modified to take into account the Reference Level Scheduling results. That is, for the additional constraint listed in Section 3.6.2.3, the Pre-Dispatch Scheduling results are replaced by the Reference Level Scheduling results as follows:

- $SDG_{t,b,k}^{PDS}$ is replaced by $SDG_{t,b,k}^{RLS}$ for all $t \in TS, b \in B^{ELR} \cup B^{HE}, k \in K_{t,d}^{E}$;
- $ODG_{t,b}^{PDS}$ is replaced by $ODG_{t,b}^{RLS}$ for all $t \in TS, b \in B^{DG}$;
- $IDG_{t,b}^{PDS}$ is replaced by $IDG_{t,b}^{RLS}$ for all $t \in TS, b \in B^{DG}$;
- $S10SDG_{t,b,k}^{PDS}$ is replaced by $S10SDG_{t,b,k}^{RLS}$ for all $t \in TS, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10S}$;
- $S10NDG_{t,b,k}^{PDS}$ is replaced by $S10NDG_{t,b,k}^{RLS}$ for all $t \in TS, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10N}$;
- $S30RDG_{t,b,k}^{PDS}$ is replaced by $S30RDG_{t,b,k}^{RLS}$ for all $t \in TS, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{30R}$; and
- $OHO_{t,b}^{PDS}$ is replaced by $OHO_{t,b}^{RLS}$ for all $t \in TS, b \in B^{HE}$.

Additionally, the marginal loss factors used in the *energy* balance constraint in Reference Level Pricing will be fixed to the marginal loss factors used in the last optimization function iteration of Reference Level Scheduling.

Outputs

Table 3-17 lists the shadow prices for Reference Level Pricing constraints that will be produced for each time-step $t \in TS$.

Table 3-17: Shadow Price Outputs of Reference Level Pricing

Output	Description
SPL_{t}^{RLP}	shall designate the shadow price for the *energy* balance constraint.
$SPNormT_{t,f}^{RLP}$	shall designate the shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in time-step t.
$SPEmT_{t,c,f}^{RLP}$	shall designate the shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step t.
$SPExtT_{t,z}^{RLP}$	shall designate the shadow price for the import or export limit constraint $z \in Z_{Sch}$ in time-step t.

Output	Description
$SPNIUExtBwdT_t^{RLP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step (t–1) and time-step t.
$SPNIDExtBwdT_t^{RLP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step ($t-1$) and time-step t.
$SPNIUExtFwdT_t^{RLP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step t and time-step ($t+1$).
$SPNIDExtFwdT_t^{RLP}$	shall designate the shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step t and time-step ($t+1$).
$SP10S_t^{RLP}$	shall designate the shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in time-step t.
$SP10R_t^{RLP}$	shall designate the shadow price for the total *ten-minute operating reserve* requirement constraint in time-step t.
$SP30R_t^{RLP}$	shall designate the shadow price for the total *thirty-minute operating reserve* requirement constraint in time-step t.
$SPREGMin10R_{t,r}^{RLP}$	shall designate the shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.
$SPREGMin30R_{t,r}^{RLP}$	shall designate the shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.
$SPREGMax10R_{t,r}^{RLP}$	shall designate the shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.
$SPREGMax30R_{t,r}^{RLP}$	shall designate the shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step t.

Table 3-18 lists the LMPs and components for each time-step $t \in TS$ calculated using the pricing formulas in Section 3.6.2.

Table 3-18: LMP Outputs of Reference Level Pricing

Output	Description
$PRef_t^{RLP}$	shall designate the time-step t *energy* reference price.
$LMP_{t,b}^{RLP}$	shall designate the time-step t LMP for bus $b \in B$.

Output	Description
$PLoss_{t,b}^{RLP}$	shall designate the time-step t loss component for bus $b \in B$.
$PCong_{t,b}^{RLP}$	shall designate the time-step t congestion component for bus $b \in B$.
$ExtLMP_{t,d}^{RLP}$	shall designate the time-step t LMP for *intertie zone* bus $d \in D$.
$IntLMP_{t,d}^{RLP}$	shall designate the time-step t *intertie* border price (IBP) for *intertie zone* bus $d \in D$.
$PLoss_{t,d}^{RLP}$	shall designate the time-step t loss component for *intertie zone* bus $d \in D$.
$PIntCong_{t,d}^{RLP}$	shall designate the time-step t internal congestion component for *intertie zone* bus $d \in D$.
$PExtCong_{t,d}^{RLP}$	shall designate the time-step t *intertie* congestion component for *intertie zone* bus $d \in D$.
$PNISL_{t,d}^{RLP}$	shall designate the time-step t net interchange scheduling limit congestion component for *intertie zone* bus $d \in D$.
$L30RP_{t,b}^{RLP}$	shall designate the time-step t *thirty-minute operating reserve* price for bus $b \in B$.
$L10NP_{t,b}^{RLP}$	shall designate the time-step t non-synchronized *ten-minute operating reserve* price for bus $b \in B$.
$L10SP_{t,b}^{RLP}$	shall designate the time-step t synchronized *ten-minute operating reserve* price for bus $b \in B$.
$ExtL30RP_{t,d}^{RLP}$	shall designate the time-step t *thirty-minute operating reserve* price for *intertie zone* bus $d \in D$.
$ExtL10NP_{t,d}^{RLP}$	shall designate the time-step t non-synchronized *ten-minute operating reserve* price for *intertie zone* bus $d \in D$.

3.6.3.5 Price Impact Test

If one or more *dispatch data* parameters fail a conduct test for economic withholding, then the ex-ante price impact test will be run.

The ex-ante price impact test will compare the Pre-Dispatch Pricing LMPs for *energy* or *operating reserve* prices with the Reference Level Pricing LMPs for *energy* or *operating reserve* prices, respectively. If prices in the Pre-Dispatch Pricing results are greater than the prices from the Reference Level Pricing results by more than the relevant impact threshold, the resource will be considered to have failed the price impact test.

The resources which fail the price impact test in a given hour will be added to the accumulated set of resources from previous PD calculation engine runs with failed the price impact test in the same future hour. All the parameters that failed the conduct test for those resources in that hour will be replaced by their reference levels.

Inputs into the Market Power Mitigation Price Impact Test

The price impact test will use the applicable inputs identified in Section 3.4.2. Table 3-19 lists the Pre-Dispatch Pricing and Reference Level Pricing outputs that will be also be used by the price impact test.

Table 3-19: Outputs of Pre-Dispatch Pricing and Reference Level Pricing as Input to the Price Impact Test

Input	Description
$LMP_{t,b}^{PDP}$	The LMP for bus $b \in B$ in time-step $t \in TS$ from Pre-Dispatch Pricing.
$L30RP_{t,b}^{PDP}$	The *thirty-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Pre-Dispatch Pricing.
$L10NP_{t,b}^{PDP}$	The non-synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Pre-Dispatch Pricing.
$L10SP_{t,b}^{PDP}$	The synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Pre-Dispatch Pricing.
$LMP_{t,b}^{RLP}$	The LMP for bus $b \in B$ in time-step $t \in TS$ from Reference Level Pricing.
$L30RP_{t,b}^{RLP}$	The *thirty-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Reference Level Pricing.
$L10NP_{t,b}^{RLP}$	The non-synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Reference Level Pricing.
$L10SP_{t,b}^{RLP}$	The synchronized *ten-minute operating reserve* price at bus $b \in B$ in time-step $t \in TS$ from Reference Level Pricing.

Variables

A set of resources that failed the impact test will be identified for each condition for all time-steps $t \in TS$, where:

- BIT_t^{NCA} shall designate the resources in an NCA that failed the price impact test for *energy* LMP.

- BIT_t^{DCA} shall designate the resources in a DCA that failed the price impact test for *energy* LMP.
- BIT_t^{BCA} shall designate the resources in a BCA that failed price impact test for *energy* LMP.
- BIT_t^{GMP} shall designate the resources that failed the Global Market Power (*energy*) price impact test for *energy* LMP.
- BIT_t^{ORL} shall designate the resources that failed the Local Market Power (*operating reserve*) price impact test for at least one type of *operating reserve* LMP.
- BIT_t^{ORG} shall designate the resources that failed the Global Market Power (*operating reserve*) price impact test for at least one type of *operating reserve* LMP.
- $LMPIT_{t,b}$ shall designate the LMP that failed the price impact test for bus $b \in BIT_t^{NCA} \cup BIT_t^{DCA} \cup BIT_t^{BCA} \cup BIT_t^{GMP} \cup BIT_t^{ORL} \cup BIT_t^{ORGMP}$ in time-step $t \in TS$.

For any resource at bus $b \in B^{DG} \cup B^{DL}$, the following LMPs may be identified in $LMPIT_{t,b}$:

- $EnergyLMP$ indicating that the *energy* LMP failed the price impact test.
- $OR10SLMP$ indicating that the synchronized *ten-minute operating reserve* LMP failed the price impact test.
- $OR10NLMP$ indicating that the non-synchronized *ten-minute operating reserve* LMP failed the price impact test.
- $OR30RLMP$ indicating that the *thirty-minute operating reserve* LMP failed the price impact test.

Price Impact Test for Energy

The *IESO* will perform the price impact test for resources that were selected in the corresponding conduct test for *energy* as follows.

Local Market Power (Energy):

- Check NCA: For each time-step $t \in TS$ and $b \in BCT_t^{NCA}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{NCA}), LMP_{t,b}^{RLP} + ITThresh2^{NCA})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{NCA} and add $EnergyLMP$ to $LMPIT_{t,b}$.
- Check DCA: For each time-step $t \in TS$ and $b \in BCT_t^{DCA}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{DCA}), LMP_{h,b}^{RLP} + ITThresh2^{DCA})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{DCA} and add $EnergyLMP$ to $LMPIT_{t,b}$.

- Check BCA: For each time-step $t \in TS$ and $b \in BCT_t^{BCA}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{BCA}), LMP_{t,b}^{RLP} + ITThresh2^{BCA})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{BCA} and add $EnergyLMP$ to $LMPIT_{t,b}$.

Global Market Power (Energy):

For each time-step $t \in TS$ and $b \in BCT_t^{GMP}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{GMP}), LMP_{t,b}^{RLP} + ITThresh2^{GMP})$, price impact test failed for resource at bus b. Assign resource to subset BIT_t^{GMP} and add $EnergyLMP$ to $LMPIT_{t,b}$.

Price Impact Test for Operating Reserve

The *IESO* will perform the price impact test for resources that were selected in the corresponding conduct test for *operating reserve* as follows.

Local Market Power (Operating Reserve)

For each time-step $t \in TS$ and $b \in BCT_t^{ORL}$:

- If $L30RP_{t,b}^{PDP} > L30RP_{t,b}^{RLP}$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORL} and add $OR30RLMP$ to $LMPIT_{t,b}$.
- If $L10NP_{t,b}^{PDP} > L10NP_{t,b}^{RLP}$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORL} and add $OR10NLMP$ to $LMPIT_{t,b}$.
- If $L10SP_{t,b}^{PDP} > L10SP_{t,b}^{RLP}$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORL} and add $OR10SLMP$ to $LMPIT_{t,b}$.

Global Market Power (Operating Reserve)

For each time-step $t \in TS$ and $b \in BCT_t^{ORG}$:

- If $L30RP_{t,b}^{PDP} > min(L30RP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L30RP_{t,b}^{RLP} + ITThresh2^{ORG})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORG} and add $OR30RLMP$ to $LMPIT_{t,b}$.
- If $L10NP_{t,b}^{PDP} > min(L10NP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L10NP_{t,b}^{RLP} + ITThresh2^{ORG})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORG} and add $OR10NLMP$ to $LMPIT_{t,b}$.
- If $L10SP_{t,b}^{PDP} > min(L10SP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L10SP_{t,b}^{RLP} + ITThresh2^{ORG})$, price impact test failed for resource at bus *b*. Assign resource to subset BIT_t^{ORG} and add $OR10SLMP$ to $LMPIT_{t,b}$.

Outputs

The outputs of the price impact test will include:

1. The set of resources that failed the price impact test in each time-step $t \in TS$ by condition type (i.e. resources included in the sets BIT_t^{NCA}, BIT_t^{DCA}, BIT_t^{BCA}, BIT_t^{GMP}, BIT_t^{ORL}, $\mathrm{BIT_t^{ORG}}$);
    - These resources will be included in the set of resources that have failed the impact test for a given future hour;
2. The LMPs (*energy* and *operating reserve*) that failed the price impact test in each time-step $t \in TS$ for each resource at bus b (i.e. parameters included in the set $LMPIT_{t,b}$); and
3. The *dispatch data* for future PD calculation engine runs, which consists of a revised set of *offer* data for resources that failed the price impact test and is derived as follows:
    - For such resources, the *dispatch data* parameters that failed the conduct test will be replaced with their reference levels; and
    - These *dispatch data* parameters will remain mitigated in the failed hour throughout subsequent PD calculation engine runs.

More detail on the revised set of *offer* data that must be output by the price impact test is provided below:

- If a resource has failed a price impact test for *energy* and falls in one of the sets BIT_t^{NCA}, BIT_t^{DCA}, BIT_t^{BCA}, or BIT_t^{GMP}, the *dispatch data* parameters in $PARAME_{t,b}$ will be used to determine which *dispatch data* parameters should be replaced.
- If a resource has failed a price impact test for *operating reserve* and is included in one of the sets BIT_t^{ORL} or BIT_t^{ORG}, the *dispatch data* parameters in $PARAMOR_{t,b}$ will be used to determine which *dispatch data offer* parameters should be replaced.
- If an NQS resource has failed a price impact test in any hour, commitment cost parameters that failed the conduct test in that hour and any hour prior will have their values replaced with the reference level for those hours. This is expressed as:
    - For each time-step t∈TS and all $b \in B^{NQS} \cap (BIT_t^{NCA} \cup BIT_t^{DCA} \cup BIT_t^{BCA} \cup BIT_t^{GMP})$, for hours prior to and including the hour that failed the price impact test, $T \in \{1,..,t\}$, if $b \in BCT_T^{NCA} \cup BCT_T^{DCA} \cup BCT_T^{BCA} \cup BCT_T^{GMP}$ and $PARAME_{T,b}$ contains any of the commitment cost parameters $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with reference levels.

- The same formulation is true for Local Market Power and global market power in the *operating reserve* market, except $PARAMOR_{T,b}$ must be checked.

- When a resource in an NCA or a DCA fails the price impact test, all other resources in that constrained area that failed the conduct test in that hour for at least one parameter will also be subject to market power mitigation (regardless of whether or not the resource failed the price impact test). For NQS resources, commitment cost parameters that failed the conduct test in any hour prior will also have their values replaced with reference levels for those hours. This can be expressed as:
  - For each time-step $t \in TS$, if BIT_t^{NCA} includes one or more resource in NCA, n, all resources $b \in BCT_t^{NCA}$ for NCA, n, will have the parameters in $PARAME_{t,b}$ replaced with reference levels. Additionally, for all hours up to the hour in which a resource failed the price impact test for n, for all $b \in BCT_t^{NCA}$, if $PARAME_{t,b}$ contains any of the commitment cost parameters $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with reference levels.
  - For each time-step $t \in TS$, if BIT_t^{DCA} includes one or more resource in DCA, d, all resources, $b \in BCT_t^{DCA}$ for DCA, d, will have the parameters in $PARAME_{t,b}$ replaced with reference levels. Additionally, for all hours up to the hour in which a resource failed the price impact test for d, for all $b \in BCT_t^{DCA}$, if $PARAME_{t,b}$ contains any of the commitment cost parameters $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with reference levels.

- When a resource fails the *operating reserve* local market power price impact test, all other resources in the same reserve area with a non-zero reserve minimum requirement that failed the conduct test for at least one parameter will also be subject to market power mitigation (regardless of whether or not the resource failed the price impact test). NQS resources, commitment cost parameters that failed the conduct test in any hour prior will also have their values replaced with reference levels for those hours. This can be expressed as:
  - For each time-step $t \in TS$, if BIT_t^{ORL} includes one or more resource in reserve area, r, all resources, $b \in BIT_t^{ORL}$ for reserve area, r, will have the parameters in $PARAMOR_{t,b}$ replaced with reference levels. Additionally, for all hours up to the hour in which a resource failed the price impact test for r, for all $b \in BCT_t^{ORL}$, if $PARAME_{t,b}$ contains any of the commitment cost parameters $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with reference levels.

3.6.4. Outputs for Energy and Operating Reserve Settlement

Table 3-20 lists the constrained schedules and prices calculated by the PD calculation engine that will be used to determine the NQS Generator Failure charge.

Table 3-20: PD Output used to Determine NQS Generator Failure Charge

Output	Description
$SDG^{1}_{t,b,k}$	The amount of dispatchable generation scheduled at bus $b \in B^{NQS}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$. This is in addition to any $MinQDG_b$, the *minimum loading point*, which must be committed before any such generation is scheduled.
$LMP^{1}_{t,b}$	The time-step t LMP for node $b \in B^{NQS}$.

The first hour of the commitment for which a binding-start up instruction must be issued as well as the evaluated *offers* are also required to settle the NQS Generator Failure charge. For more information, see the Market Settlement detailed design document.

Table 3-21 and Table 3-22 list the PD calculation engine outputs that will be used to determine the binding *intertie* schedules and Intertie Failure Charge, respectively.

Table 3-21: PD Output used to Produce Binding Intertie Schedules

Output	Description
$SXL^{1}_{t,d,j}$	The amount of exports scheduled to *intertie zone* sink bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,d}$.
$SIG^{1}_{t,d,k}$	The amount of imports from *intertie zone* source bus $d \in DI$ scheduled in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,d}$.

Table 3-22: PD Output used to Determine Intertie Failure Charge

Output	Description
$ExtLMP^{1}_{t,d}$	The time-step t LMP for *intertie zone* bus $d \in D$.
$ICP^{1}_{t,d}$	The time-step t *intertie* congestion price for *intertie zone* bus $d \in D$.

3.7. Security Assessment Function

The *security* assessment function assesses power system *security* using the schedules produced by the optimization function. As indicated in Section 3.3, the scheduling and pricing algorithms of the PD calculation engine will include multiple iterations between the optimization function and the *security* assessment function described here. Information about the *IESO-controlled grid* such as operating *security limits* (OSLs), thermal ratings, the network model, loop flow and the status of power system equipment will be used by the *security* assessment function to evaluate the *security* of the schedules provided by the optimization function against the expected transmission system capability. As part of its evaluation, the *security* assessment function will create the following information to provide to the next optimization function iteration:

- A *security* constraint set corresponding to violated thermal and/or operating *security limits*;
- Marginal loss factors; and
- A loss adjustment.

For each identified *security* constraint, the *security* assessment function will provide the coefficients and limits of a linear constraint in the optimization function variables to be enforced by the optimization function.

The following sections describe the inputs, the process and the outputs of the *security* assessment function.

3.7.1. Inputs

3.7.1.1 Inputs Provided by the Optimization Function

The optimization function will continue to provide the *security* assessment function with schedules for load and supply resources. With the exception of PSU resources, such schedules will be represented at their corresponding electrical buses in the network model. The *security* assessment function will use the physical unit representation of combined cycle *facilities* that have elected to be represented as a PSU.

The following outputs of the optimization function are used by the *security* assessment function:

- The schedules for *dispatchable loads* and *hourly demand response* resources;
- The schedules for non-dispatchable and dispatchable generation; and
- The schedules for *boundary entity* resource sources and sinks at each *intertie zone.*

3.7.1.2 Security Limits

Security limits are OSLs and thermal limits. OSLs are associated with transient stability limits, voltage stability limits, dynamic stability limits and voltage decline limits. They also include limits based on equipment ratings such as thermal ratings and short-circuit capabilities. The PD calculation engine will use OSLs and thermal limits to perform a *security* analysis of the *IESO-controlled grid*.

The *IESO* defines OSLs as a set of equations along with their activation plans. Each OSL equation is applicable for a specific area of the *IESO-controlled grid* under all elements in-service and/or specific *outage* conditions. An activation plan specifies which OSLs are applicable for a time period.

The *security* assessment function of the PD calculation engine will create a linearized constraint when it determines that an OSL is violated. The linearized constraints are passed to the optimization function and are included as new constraints in the next iteration of optimization function.

An OSL equation will continue to be a function of any of the following network variables:

- Any transformer, line, branch group, or phase shifter MW flow;
- Any generation resource MW outputs;
- Any load MW; and
- The primary *demand*.

The line, transformer, branch group and phase shifter MW flows in the OSL equations will be replaced with the sum of the pre-contingency sensitivity factors multiplied by scheduling variables.

If it is determined that an OSL is violated, the linearized constraint passed to the optimization function will include the schedules of load and generation resources as scheduling variables with their corresponding sensitivity factors.

The PD calculation engine will use pre-contingency and post-contingency thermal ratings so that PD schedules result in transmission flows that respect the thermal limits. The ratings used by the PD calculation engine will be based on lookup table limits provided by *transmitters* and forecasted weather data. The *security* assessment function will create a linearized constraint when it determines that a thermal limit is violated.

3.7.1.3 Network Model

The *security* assessment function will use the following data from the network model:

- Power system model data;

- Load distribution factors;
- A list of contingencies; and
- A list of monitored elements.

Power System Model Data

The power system model is a topology representation of the *IESO-controlled grid* and a simplified representation of power systems in neighbouring jurisdictions. The power system model data will continue to include attributes and parameters for the following power system equipment and their controls:

- Buses, breakers, switches, mid-span openers and line jumpers;
- High-voltage AC and DC transmission lines;
- Switchable and fixed shunt devices including:
  - Capacitors;
  - Reactors;
  - SVCs; and
  - STATCOMs
- Series capacitors and reactors;
- Transformers, including:
  - Two-winding, three-windings and autotransformers;
  - Voltage and VAr regulators and phase shifters with impedance correction tables as a function of angle or voltage tap positions; and
  - Tap changers: Fixed, manual, automatic, off-load and on-load
- Synchronous condensers, generation resources, and load resources;
- *Regulation* modes, VAr capability curves, target voltages, target MWs/percentages, voltage/MW ranges, tap ratio ranges, and angle ranges as applicable to controlling devices;
- Attributes such as voltage levels and assignment to zones and areas;
- Branch groups and the power system equipment that make up each branch group; and
- *Boundary Entity* Resources (BERs) (i.e. sources/sinks) used for interchange scheduling purposes.

The normal tap positions for angle and voltage taps, the *regulation* modes of voltage taps, reactors, capacitors, phase shifters and the desired low limit/high limit voltages at buses, and normal breaker and disconnect switch statuses will continue to be obtained from the power system model data.

For each hour, based on outage information, breaker and switch statuses will be modified from normal status to reflect power system equipment *outage* conditions.

Loop flows resulting from the *dispatch* within other *control areas* or transactions between other *control areas* that are not recorded as imports or exports within Ontario (or both) will affect the loading on transmission within Ontario. The *IESO* will continue to model loop flows into or out of Ontario at various *intertie zones* as though they were generation or load that exist at given buses or combinations of buses in the *control areas* containing those *intertie zones*.

Load Distribution Factors

Load distribution factors define the load pattern that will be used to distribute the *IESO demand* forecast for each *demand* forecast area. The *security* assessment function will use load distribution factors to determine forecasted MW quantities at *non-dispatchable load* locations, price responsive load locations, and no *bid dispatchable loads* based on the *IESO demand* forecast.

List of Contingencies

The list of contingencies will continue to include contingency name, description of contingencies and configuration settings/flags such as priority setting and flags to indicate whether 115 kV equipment should be monitored when a contingency is simulated.

List of Monitored Equipment

The list of monitored equipment indicates the equipment to be monitored for violation of thermal limits and/or voltage limits. It will continue to include the following information:

- The power system equipment name;
- The equipment type; and
- The monitoring type, i.e. thermal, voltage or no monitoring.

3.7.2. Security Assessment Function Processing

The *security* assessment function will perform the following calculations and analysis:

- Prepare a base case power flow solution for each time-step of the look-ahead period;

- Perform a pre-contingency *security* assessment on the base case power flow solution using pre-contingency thermal limits and operating *security limits;*
- Prepare linearized constraints using sensitivity factors for any violated pre-contingency thermal limits and operating *security limits*;
- Calculate total losses, marginal loss factors, and the loss adjustment. The loss adjustment is required to account for the difference between the total losses and the linearized losses calculated using the marginal loss factors;
- Simulate the specified contingencies to perform a post-contingency *security* assessment on the post-contingency state of the base case power flow solution using post-contingency thermal limits; and
- Prepare linearized constraints using sensitivity factors for any violated post-contingency thermal limits.

3.7.2.1 Base Case Power Flow

An AC power flow solution will continue to be prepared for each time-step. If the AC power flow solution fails to converge for any time-step, a non-linear DC power flow will continue to be used for that time-step. If the non-linear DC power flow solution fails to converge for any time-step, a linear DC power flow will be used for that time-step.

The power flow solution will have features to model adjustments of phase shifters, voltage regulating transformers, reactors and capacitors, and MVAr output of generating units and synchronous condensers. In case of a network split, only the island with the largest number of *IESO-controlled grid* buses will continue to be considered.

3.7.2.2 Pre-contingency Security Assessment

When the AC or non-linear DC power flow solution is used, the pre-contingency *security* assessment will continue to check all monitored equipment for violation of their pre-contingency thermal limits. It will also check for violation of any applicable OSL equations. For every violated limit, a linearized constraint will be generated.

When the linear DC power flow solution is used, the pre-contingency *security* assessment may develop linear constraints to help the AC or non-linear DC power flow solution converge in the subsequent iterations.

These linearized constraints will be expressed in terms of scheduling variables and sensitivity factors so they can be provided to the optimization function to be used in the next optimization function iteration.

The sensitivity factors will continue to be derived based on the power flow Jacobian matrix. The sensitivity factor for a resource with respect to a line flow for example, indicates the fraction of *energy* injected at the resource bus which flows on the line.

The pre-contingency *security* assessment will continue to use the following inputs:

- OSL equations;
- Pre-contingency thermal limits;
- List of monitored equipment; and
- Base case power flow solution which also includes calculated MW flows on lines, transformers, phase shifters, and branch groups.

The line, transformer, branch group and phase shifter MW flows in the OSL equations will continue to be replaced with the sum of the pre-contingency sensitivity factors multiplied by scheduling variables. The minimum and maximum limits of OSL equations will be adjusted to reflect the difference between the calculated MW flows and the linearized MW flows using the sensitivity factors.

For an *intertie zone* connected to Ontario through regulating phase shifters that receive shares of the *intertie* schedule, the effective sensitivity factor of *boundary entities* in the *intertie zone* will continue to be calculated using the Jacobian matrix, shares of phase shifters in the *intertie* schedule and phase shifter sensitivities.

3.7.2.3 Loss Calculation

The *security* assessment function will calculate total losses, marginal loss factors and a loss adjustment for each time-step using the base case power flow solution. All of these loss related quantities can continue to vary from time-step to time-step.

In the future, the static marginal loss factors used today will no longer be used. In the scheduling algorithm, the *security* assessment function will pass the marginal loss factors it calculates for each time-step to the optimization function. In the pricing algorithm, the optimization function will use the marginal loss factors used in the last optimization function iteration of the corresponding scheduling algorithm.

Total losses will exclude losses in Ontario's neighboring jurisdictions. When determining marginal loss factors, the impact of losses on local branches (e.g. load step-down transformers) between the resource bus and the resource *connection point* to the *IESO-controlled grid* and losses on branches in Ontario's neighboring jurisdictions will be excluded.

3.7.2.4 Contingency Analysis

The contingency analysis function will continue to use a linear power flow analysis and consists of the following sub-functions:

- Post-contingency connectivity analysis;
- Post-contingency MW flow calculation; and
- Checking of post-contingency thermal limit violations and building of linearized constraints for violated limits.

The contingency analysis will continue to use a linear power flow analysis based on the base case power flow solution, the list of contingencies to be simulated, the list of monitored equipment and the post-contingency thermal limits. The contingencies will continue to be defined as *outages* to branches (lines, transformers and phase shifters), *outages* to injections, or *outages* to withdrawals.

The contingency analysis function will be able to model post-contingency control actions such as automatic angle tap adjustments.

The calculated post-contingency MW flows will continue to be compared to the post-contingency branch thermal limits for all the monitored equipment. For each monitored equipment, up to a pre-defined configurable number of the most severe violations will be linearized and passed to the optimization function as a linear constraint.

The calculation of the post-contingency sensitivity factors will be similar to that of the pre-contingency sensitivity factors. The updated power flow Jacobian matrix and post-contingency system states will continue to be used in the calculation of the sensitivity factors.

3.7.3. Outputs

The following outputs of the *security* assessment function will be provided to the optimization function:

- Marginal loss factors of resources, which represent the marginal impact on *IESO-controlled grid* losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at a resource in a specific time-step.
- Loss adjustment quantity for each time-step which is needed to correct for any discrepancy between total losses in the *IESO-controlled grid* obtained from the base case power flow and the linearized losses calculated using the marginal loss factors. Total losses will exclude losses in Ontario’s neighboring jurisdictions.

- The linearized constraints for all violated pre-contingency limits for each time-step.
- The linearized constraints for all violated post-contingency thermal limits for each time-step.

The following outputs of the *security* assessment function are required to calculate LMPs as described in Section 3.8:

- Marginal loss factors;
- Pre-contingency sensitivity factors; and
- Post-contingency sensitivity factors.

3.8. Pricing Formulas

The PD calculation engine will calculate LMPs for all pricing nodes using shadow prices, constraint sensitivities and marginal loss factors.

LMPs for *energy* will be calculated for the following pricing nodes:

- Dispatchable and non-dispatchable generation resource buses;
- *Dispatchable load* and *hourly demand response* resource buses;
- *Non-dispatchable load* and price responsive load buses; and
- *Intertie zone* source and sink buses.

LMPs for *operating reserve* will be calculated for the following pricing nodes:

- Dispatchable generation resource buses;
- *Dispatchable load* buses; and
- *Intertie zone* source and sink buses.

The set of internal pricing nodes will be designated by L and will include:

- Resources scheduled by the PD calculation engine optimization function (designated B as per Section 3.4.1.2), and
- *Non-dispatchable load* locations and other internal locations without an active *bid* or *offer*.

The set of external pricing nodes will be designated by D as in Section 3.4.1.2.

Prices will be calculated using the shadow prices determined by the pricing algorithm. If a price is not within the maximum clearing price and the *settlement* floor price (the *settlement* bounds), the price and its components will be modified. The following parameters will be used when performing price modification:

- $EngyPrcCeil$ shall designate the maximum *energy* price and be set equal to the *maximum market clearing price* of $2,000/MWh;
- $EngyPrcFlr$ shall designate the *settlement* floor price and be set equal to -$100/MWh;
- $ORPrcCeil$ shall designate the *maximum operating reserve price* for any class of *operating reserve* and be set equal to the *maximum market clearing price* of $2,000/MW;
- $ORPrcFlr$ shall designate the minimum *operating reserve price* for any class of *operating reserve* and be set equal to $0/MW; and
- $NISLPen$ shall designate the net interchange scheduling limit constraint violation penalty price for *market pricing*.

A weighted average of the above prices will be used to determine informational zonal prices for the following pricing locations:

- Virtual transaction zonal trading entities; and
- *Non-dispatchable load* zones, including the Ontario Zone. Other *non-dispatchable load* zones are sub-zones of the Ontario Zone.

Non-dispatchable load zones will only contain *non-dispatchable load* buses, whereas virtual transaction zonal trading entities will be assigned buses for all load types. The PD calculation engine will receive virtual transaction trading zone and *non-dispatchable load* zone definitions specifying the buses whose LMPs will contribute to the zonal prices.

The weight assigned to each bus in contributing to the zonal price for a virtual transaction zonal trading entity will be equal to the weighting factors used to calculate the virtual zonal price in the day-ahead market for the applicable hour, where:

- M shall designate the set of virtual transaction zonal trading entities within Ontario;
- $L_m^{VIRT} \subseteq L$ shall designate the buses contributing to the virtual transaction zonal trading entity price for virtual transaction zonal trading entity $m \in M$; and
- $WF_{t,m,b}^{VIRT}$ shall designate the weighting factor for bus $b \in L_m^{VIRT}$ used to calculate the price for virtual transaction zonal trading entity $m \in M$ for time-step $t \in TS$.

The load distribution pattern as provided to the *security* assessment function will be used to determine the weight assigned to each bus in contributing to the zonal price for a *non-dispatchable load* zone. The weighting factors will be obtained by renormalizing the load distribution factors so that the sum of weighting factors for an individual zone is one, where:

- Y shall designate the *non-dispatchable load* zones in Ontario;
- $L_y^{NDL} \subseteq L$ shall designate the buses contributing to the zonal price for *non-dispatchable load* zone $y \in Y$; and
- $WF_{h,y,b}^{NDL}$ shall designate the weighting factor for bus $b \in L_y^{NDL}$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for time-step $t \in TS$.

If there is insufficient information to calculate an accurate price, or if the process fails to produce a price for any other reason, this will be flagged for further review by the *IESO*.

3.8.1. Locational Marginal Prices for Energy

The LMP at a bus in a time-step measures the *offered* cost of meeting an infinitesimal change in the amount of load at that bus in that time-step, or equivalently, measures the value of an incremental amount of generation at that bus in that time-step.

3.8.1.1 Energy LMPs for Internal Pricing Nodes

For each time-step $t \in TS$, *energy* LMPs and components will be calculated for every node $b \in L$ where a non-dispatchable or dispatchable generation resource, a *dispatchable load*, an *hourly demand response* resource, or a *non-dispatchable load* is sited, where:

- $LMP^1_{t,b}$ shall designate the Pass 1 time-step t LMP;
- $PRef^1_t$ shall designate the Pass 1 time-step t *energy* reference price;
- $PLoss^1_{t,b}$ shall designate the Pass 1 time-step t loss component; and
- $PCong^1_{t,b}$ shall designate the Pass 1 time-step t congestion component.

The Pass 1 LMP at bus $b \in L$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitLMP^1_{t,b} = InitPRef^1_t + InitPLoss^1_{t,b} + InitPCong^1_{t,b}$$

where

$$InitPRef^1_t = SPL^1_t\,;$$

$$InitPLoss^1_{t,b} = MglLoss^1_{t,b} \cdot SPL^1_t\,;$$

and

$$InitPCong^1_{t,b} = \sum_{f \in F_t} PreConSF_{t,f,b} \cdot SPNormT^1_{t,f} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,b} \cdot SPEmT^1_{t,c,f}.$$

The reference price and loss component together reflect the marginal cost of meeting load at bus b, exclusive of congestion, the effect of marginal losses and reflect the quantity of *energy* that must be injected at the *reference bus* to meet additional load at bus b. The congestion component reflects the cost of transmission congestion between the *reference bus* and bus b and is calculated by adding the individual incremental congestion costs for the binding transmission constraints on all electrical paths between the *reference bus* and bus b. Each congestion cost is obtained by multiplying the shadow price for the binding transmission constraint by the corresponding sensitivity factor for bus b.

An *energy* LMP can fall outside the *settlement* bounds provided by $EngyPrcFlr$ and $EngyPrcCeil$ as a result of joint optimization or constraint violation pricing. When this occurs, the LMP and its components (reference, loss and congestion) will be modified so that the LMP is within the *settlement* bounds.

The reference price will be modified if it is not within the *settlement* bounds. For time-step $t \in TS$:

a. If $InitPRef_t^1 > EngyPrcCeil$, set $PRef_t^1 = EngyPrcCeil$.

b. If $InitPRef_t^1 < EngyPrcFlr$, set $PRef_t^1 = EngyPrcFlr$.

c. Otherwise, set $PRef_t^1 = InitPRef_t^1$.

The LMP and components at internal bus $b \in L$ in time-step $t \in TS$ will be modified as follows:

1. Modify the LMP to be within *settlement* bounds.

   a. If $InitLMP_{t,b}^1 > EngyPrcCeil$, set $LMP_{t,b}^1 = EngyPrcCeil$.

   b. If $InitLMP_{t,b}^1 < EngyPrcFlr$, set $LMP_{t,b}^1 = EngyPrcFlr$.

   c. Otherwise, set $LMP_{t,b}^1 = InitLMP_{t,b}^1$.

2. If the reference price has been modified (i.e. $PRef_t^1 \neq InitPRef_t^1$), recalculate the loss component.

   a. If $PRef_t^1 \neq InitPRef_t^1$, set $PLoss_{t,b}^1 = MglLoss_{t,b}^1 \cdot PRef_t^1$.

   b. Otherwise, set $PLoss_{t,b}^1 = InitPLoss_{t,b}^1$.

3. Modify the congestion component so the relationship between LMP, reference price, loss component and congestion component holds, provided the congestion component does not change mathematical signs as a result. If the congestion component changes its mathematical sign, set it to 0 and modify the loss component to maintain the relationship.

   a. If $LMP_{t,b}^1 - PRef_t^1 - PLoss_{t,b}^1$ and $InitPCong_{t,b}^1$ have the same mathematical sign, then set $PCong_{t,b}^1 = LMP_{t,b}^1 - PRef_t^1 - PLoss_{t,b}^1$.

   b. Otherwise, set $PCong_{t,b}^1 = 0$ and set $PLoss_{t,b}^1 = LMP_{t,b}^1 - PRef_t^1$.

If $PRef_t^1 = InitPRef_t^1$, then the LMP and components for nodes with prices within the *settlement* bounds will not be modified. If $PRef_t^1 \neq InitPRef_t^1$, then the LMP for nodes with prices within the *settlement* bounds will not be modified, but the components will be modified.

3.8.1.2 Energy LMPs for Intertie Zone Source and Sink Buses

For each time-step $t \in TS$, *energy* LMPs and components will be calculated for *intertie zone* bus $d \in D$, where:

- $ExtLMP_{t,d}^1$ shall designate the Pass 1 time-step t LMP;
- $IntLMP_{t,d}^1$ shall designate the Pass 1 time-step t *intertie* border price (IBP);
- $ICP_{t,d}^1$ shall designate the Pass 1 time-step t *intertie congestion price* (ICP);

- $PRef_t^1$ shall designate the Pass 1 time-step t *energy* reference price;
- $PLoss_{t,d}^1$ shall designate the Pass 1 time-step t loss component;
- $PIntCong_{t,d}^1$ shall designate the Pass 1 time-step t internal congestion component;
- $PExtCong_{t,d}^1$ shall designate the Pass 1 time-step t *intertie* congestion component; and
- $PNISL_{t,d}^1$ shall designate the Pass 1 time-step t net interchange scheduling limit congestion component.

The LMP will be the same for all buses at the same proxy location and *intertie zone*. *Intertie* transactions associated with the same proxy location, but specified as occurring at different *intertie zones*, subject to phase shifter operation, will be modelled as flowing across independent paths. Pricing of these transactions will utilize shadow prices associated with the internal transmission constraints, interchange scheduling limits and transmission losses applicable to the path associated to the relevant *intertie zone*. The Pass 1 LMP at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in time-step t will be initially calculated as follows:

$$InitExtLMP_{t,d}^1 = InitIntLMP_{t,d}^1 + InitICP_{t,d}^1$$

where

$$InitPRef_t^1 = SPL_t^1;$$

$$InitPLoss_{t,d}^1 = MglLoss_{t,d}^1 \cdot SPL_t^1;$$

$$InitPIntCong_{t,d}^1 = \sum_{f \in F_t} PreConSF_{t,f,d} \cdot SPNormT_{t,f}^1 + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,d} \cdot SPEmT_{t,c,f}^1;$$

$$InitIntLMP_{t,d}^1 = InitPRef_t^1 + InitPLoss_{t,d}^1 + InitPIntCong_{t,d}^1;$$

$$InitICP_{t,d}^1 = InitPExtCong_{t,d}^1 + InitPNISL_{t,d}^1;$$

$$InitPExtCong_{t,d}^1 = \sum_{z \in Z_{sch}} EnCoeff_{a,z} \cdot SPExtT_{t,z}^1;$$

and

$$InitPNISL_{t,d}^1 = SPNIUExtBwdT_t^1 - SPNIUExtFwdT_t^1 - SPNIDExtBwdT_t^1 + SPNIDExtFwdT_t^1.$$

The components comprising the *intertie* border price for a proxy location in an *intertie zone* are analogous to the components of the *energy* LMP for an internal pricing node. The marginal loss factor used to calculate the loss component will not account for losses in Ontario's neighbouring jurisdictions. The *intertie* congestion component reflects the cost of congestion at the *intertie* and is calculated by adding the individual congestion costs for the binding import and export transmission limits that affect transactions scheduled at the *intertie zone*. The NISL congestion component reflects the cost of congestion due to hour-to-hour limitations on changes in net flows over all *interties*. The *intertie* and NISL congestion components may be zero outside the first two forecast hours of the look-ahead period. This is because *bids* and *offers* from *intertie* transactions without a corresponding DAM scheduled quantity are not considered, subject to the exemptions described previously, and therefore are ineligible to set price.

To model an *intertie* as out-of-service, the *intertie* transmission limits will be set to zero and all import *offers* and export *bids* will receive a zero schedule. In this case, the LMP will be set to the *intertie* border price.

An *energy* LMP can fall outside the *settlement* bounds provided by $EngyPrcFlr$ and $EngyPrcCeil$ as a result of joint optimization or constraint violation pricing. When this occurs, the LMP at the *intertie zone* bus and its components (reference loss, internal congestion, *intertie* congestion, and NISL congestion) will be modified so that the LMP to within the *settlement* bounds.

The modification of the IBP, reference price, loss component and internal congestion component to obtain $IntLMP^{1}_{t,d}$, $PRef^{1}_{t}$, $PLoss^{1}_{t,d}$ and $PIntCong^{1}_{t,d}$ will follow the procedure for price modification for internal nodes as specified in Section 3.8.1.1. The LMP, *ICP*, external congestion component and NISL congestion component at *intertie zone* bus $d \in D$ in time-step $t \in TS$ will then be modified as follows:

1. Revise the LMP to within *settlement* bounds.
    a. If $InitExtLMP^{1}_{t,d} > EngyPrcCeil$, set $ExtLMP^{1}_{t,d} = EngyPrcCeil$.
    b. If $InitExtLMP^{1}_{t,d} < EngyPrcFlr$, set $ExtLMP^{1}_{t,d} = EngyPrcFlr$.
    c. Otherwise, set $ExtLMP^{1}_{t,d} = InitExtLMP^{1}_{t,d}$.
2. If the modified LMP and IBP coincide, set the external and NISL congestion components to zero.
    a. If $ExtLMP^{1}_{t,d} = IntLMP^{1}_{t,d}$, set $PExtCong^{1}_{t,d} = 0$ and $PNISL^{1}_{t,d} = 0$.
3. Otherwise, modify the *intertie* congestion and NISL congestion components pro-rata to maintain the relationship between LMP and price components, capping the NISL congestion component at the NISL penalty price.
    a. If $ExtLMP^{1}_{t,d} \neq IntLMP^{1}_{t,d}$, set
    $PNISL^{1}_{t,d} = (ExtLMP^{1}_{t,d} - IntLMP^{1}_{t,d}) \cdot \left(\frac{InitPNISL^{1}_{h,d}}{InitPNISL^{1}_{t,d} + InitPExtCong^{1}_{t,d}}\right)$.
        i. If $PNISL^{1}_{t,d} > NISLPen$, set $PNISL^{1}_{t,d} = NISLPen$.
        ii. If $PNISL^{1}_{t,d} < (-1) \cdot NISLPen$, set $PNISL^{1}_{t,d} = (-1) \cdot NISLPen$
    b. Then set $PExtCong^{1}_{t,d} = ExtLMP^{1}_{t,d} - IntLMP^{1}_{t,d} - PNISL^{1}_{t,d}$.

4. Calculate the ICP as the sum of the modified *intertie* congestion and NISL congestion components.

   a. $ICP^{1}_{t,d} = PExtCong^{1}_{t,d} + PNISL^{1}_{t,d}$

3.8.1.3 Zonal Energy Prices

For each pricing zone (including zones for *non-dispatchable load* and virtual transactions), the affiliated zonal *energy* price for an hour will be calculated as the sum of the hourly reference price, the load distribution-weighted loss component within the zone, and the load distribution-weighted congestion component within the zone.

For each time-step t, the Pass 1 *energy* price for virtual transaction zonal trading entity $m \in M$ will be calculated as follows:

$$VZonalP^{1}_{t,m} = PRef^{1}_{t} + VZonalPLoss^{1}_{t,m} + VZonalPCong^{1}_{t,m}$$

where

$$VZonalPLoss^{1}_{t,m} = \sum_{b \in L^{VIRT}_{m}} WF^{VIRT}_{t,m,b} \cdot PLoss^{1}_{t,b}$$

and

$$VZonalPCong^{1}_{t,m} = \sum_{b \in L^{VIRT}_{m}} WF^{VIRT}_{t,m,b} \cdot PCong^{1}_{t,b}.$$

For each time-step t, the Pass 1 *energy* price for *non-dispatchable load* zone $y \in Y$ is calculated as follows:

$$ZonalP^{1}_{t,y} = PRef^{1}_{t} + ZonalPLoss^{1}_{t,y} + ZonalPCong^{1}_{t,y}$$

where

$$ZonalPLoss^{1}_{t,y} = \sum_{b \in L^{NDL}_{y}} WF^{NDL}_{t,y,b} \cdot PLoss^{1}_{t,b}$$

and

$$ZonalPCong^{1}_{t,y} = \sum_{b \in L^{NDL}_{y}} WF^{NDL}_{t,y,b} \cdot PCong^{1}_{t,b}.$$

3.8.2. Locational Marginal Prices for Operating Reserve

The LMP for a category of *operating reserve* at a bus in a time-step measures the *offered* cost of meeting an infinitesimal change in the reserve requirement for that category of *operating reserve* in that time-step. This is determined while also accounting for binding constraints associated with the reserve areas to which the bus belongs. *Operating reserve* prices will continue to be calculated by cooptimizing *energy* and the three categories of *operating reserve*, as implied by the formulation of the optimization function.

3.8.2.1 Operating Reserve LMPs for Internal Pricing Nodes

For each time-step *t*, *operating reserve* LMPs and components will be calculated for every bus $b \in B$ where a dispatchable generation resource or *dispatchable load* is sited, where:

- $L30RP^1_{t,b}$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* price;
- $P30RRef^1_t$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* reference price;
- $P30RCong^1_{t,b}$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* congestion component;
- $L10NP^1_{t,b}$ shall designate the Pass 1 time-step *t* non-synchronized *ten-minute operating reserve* price;
- $P10NRef^1_t$ shall designate the Pass 1 time-step *t* non-synchronized *ten-minute operating reserve* reference price;
- $P10NCong^1_{t,b}$ shall designate the Pass 1 time-step *t* non-synchronized *ten-minute operating reserve* congestion component;
- $L10SP^1_{t,b}$ shall designate the Pass 1 time-step *t* synchronized *ten-minute operating reserve* price;
- $P10SRef^1_t$ shall designate the Pass 1 time-step *t* synchronized *ten-minute operating reserve* reference price; and
- $P10SCong^1_{t,b}$ shall designate the Pass 1 time-step *t* synchronized *ten-minute operating reserve* congestion component.

For each bus $b \in B$, define $ORREG_b \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus b.

The Pass 1 *thirty-minute operating reserve* LMP at bus $b \in B$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitL30RP^1_{t,b} = InitP30RRef^1_t + InitP30RCong^1_{t,b}$$

where

$$InitP30RRef^1_t = SP30R^1_t$$

and

$$InitP30RCong^1_{t,b} = \sum_{r \in ORREG_b} SPREGMin30R^1_{t,r} - \sum_{r \in ORREG_b} SPREGMax30R^1_{t,r}.$$

The reference price reflects the cost of meeting an infinitesimal change in the *thirty-minute operating reserve* requirement at the *reference bus*. The congestion component reflects the cost of binding constraints associated with *reserve* areas to which the bus belongs. Such constraints in turn reflect transmission limits that prevent the delivery of activated *operating reserve* into or out of a reserve area.

The Pass 1 non-synchronized *ten-minute operating reserve* LMP at bus $b \in B$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitL10NP^1_{t,b} = InitP10NRef^1_t + InitP10NCong^1_{t,b}$$

where

$$InitP10NRef^1_t = SP10R^1_t + SP30R^1_t$$

and

$$InitP10NCong^1_{t,b} = \sum_{r \in ORREG_b} \left(SPREGMin10R^1_{r,t} + SPREGMin30R^1_{r,t}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R^1_{r,t} + SPREGMax30R^1_{r,t}\right).$$

The reference price reflects the cost of meeting an infinitesimal change in the non-synchronized *ten-minute operating reserve* requirement. The congestion component reflects the cost of binding constraints associated with reserve areas to which the bus belongs. Such constraints in turn reflect transmission limits that prevent the delivery of activated *operating reserve* into or out of a reserve area.

The Pass 1 synchronized *ten-minute operating reserve* LMP at bus $b \in B$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitL10SP^1_{t,b} = InitP10SRef^1_t + InitP10SCong^1_{t,b}$$

where

$$InitP10SRef^1_t = SP10S^1_t + SP10R^1_t + SP30R^1_t$$

and

$$InitP10SCong^1_{t,b} = \sum_{r \in ORREG_b} \left(SPREGMin10R^1_{r,t} + SPREGMin30R^1_{r,t}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R^1_{r,t} + SPREGMax30R^1_{r,t}\right).$$

The reference price reflects the cost of meeting an infinitesimal change in the synchronized *ten-minute operating reserve* requirement. The congestion component reflects the cost of binding constraints associated with reserve areas to which the bus belongs. Such constraints in turn reflect transmission limits that prevent the delivery of activated *operating reserve* into or out of a reserve area.

An *operating reserve* LMP can fall outside the *settlement* bounds of $ORPrcFlr$ and $ORPrcCeil$ as a result of joint optimization or constraint violation pricing. When this occurs, the *operating reserve* LMP and its components (reference and congestion) will be modified so that the LMP is within the *settlement* bounds.

For each class of *operating* reserve, the reference price will be modified when it does not fall within the *settlement* bounds. For time-step $t \in TS$:

1. Set $P30RRef_t^1 = Min(Max(InitP30RRef_t^1, ORPrcFlr), ORPrcCeil)$.
2. Set $P10NRef_t^1 = Min(Max(InitP10NRef_t^1, ORPrcFlr), ORPrcCeil)$.
3. Set $10SRef_t^1 = Min(Max(InitP10SRef_t^1, ORPrcFlr), ORPrcCeil)$.

For each class of *operating reserve*, the LMP and components at internal bus $b \in B$ in time-step $t \in TS$ will be modified as follows:

1. Set $L30RP_{t,b}^1 = Min(Max(InitL30RP_{t,b}^1, ORPrcFlr), ORPrcCeil)$ and set $P30RCong_{t,b}^1 = L30RP_{t,b}^1 - P30RRef_t^1$.
2. Set $L10NP_{t,b}^1 = Min(Max(InitL10NP_{t,b}^1, ORPrcFlr), ORPrcCeil)$ and set $P10NCong_{t,b}^1 = L10NP_{t,b}^1 - P10NRef_t^1$.
3. Set $L10SP_{t,b}^1 = Min(Max(InitL10SP_{t,b}^1, ORPrcFlr), ORPrcCeil)$ and set $P10SCong_{t,b}^1 = L10SP_{t,b}^1 - P10SRef_t^1$.

3.8.2.2 Operating Reserve LMPs for Intertie Zone Source and Sink Buses

The calculation of *operating reserve* LMPs for *intertie zone* buses is similar to internal buses except for additionally accounting for binding net import constraints. Such constraints can limit the amount of *operating reserve* that can be imported into Ontario.

For each time-step $t \in TS$, the following *operating reserve* LMPs and components are calculated for *intertie zone* bus $d \in D$, where:

- $ExtL30RP_{t,d}^1$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* price;
- $P30RRef_t^1$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* reference price;
- $P30RIntCong_{t,d}^1$ shall designate the Pass 1 time-step *t thirty-minute operating reserve* internal congestion component;
- $P30RExtCong_{t,d}^1$ shall designate the Pass 1 time-step *t thirty-minute operating reserve intertie* congestion component;

- $ExtL10NP^{1}_{t,d}$ shall designate the Pass 1 time-step t non-synchronized *ten-minute operating reserve* price;
- $P10NRef^{1}_{t}$ shall designate the Pass 1 time-step t non-synchronized *ten-minute operating reserve* reference price;
- $P10NIntCong^{1}_{t,d}$ shall designate the Pass 1 time-step t non-synchronized *ten-minute operating reserve* internal congestion component; and
- $P10NExtCong^{1}_{t,d}$ shall designate the Pass 1 time-step t non-synchronized *ten-minute operating reserve intertie* congestion component.

The LMP will be the same for all buses at the same proxy location and *intertie zone*. Reserve imports associated with the same proxy location, but specified as occurring at a different *intertie zone*, subject to phase shifter operation, will be modelled as flowing across independent paths. Pricing of these reserve imports will utilize shadow prices associated with interchange scheduling limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

For each *intertie zone* bus $d \in D$, define $ORREG_d \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus d.

The Pass 1 *thirty-minute operating reserve* LMP at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitExtL30RP^{1}_{t,d} = InitP30RRef^{1}_{t} + InitP30RIntCong^{1}_{t,d} + InitP30RExtCong^{1}_{t,d}$$

where

$$InitP30RRef^{1}_{t} = SP30R^{1}_{t};$$

$$InitP30RIntCong^{1}_{t,d} = \sum_{r \in ORREG_d} SPREGMin30R^{1}_{t,r} - \sum_{r \in ORREG_d} SPREGMax30R^{1}_{t,r};$$

and

$$InitP30RExtCong^{1}_{t,d} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT^{1}_{t,z}.$$

The reference and internal congestion components are analogous to the components of the *thirty-minute operative reserve* LMP for an internal pricing node. The *intertie* congestion component reflects the cost of congestion at the *intertie* and is calculated by adding the individual congestion costs for the binding import limits that affect *operating reserve* transactions scheduled at the *intertie zone*.

The Pass 1 *ten-minute operating reserve* LMP at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in time-step $t \in TS$ will be initially calculated as follows:

$$InitExtL10NP^{1}_{t,d} = InitP10NRef^{1}_{t} + InitP10NIntCong^{1}_{t,d} + InitP10NExtCong^{1}_{t,d}$$

where

$$InitP10NRef^{1}_{t} = SP10R^{1}_{t} + SP30R^{1}_{t};$$

$$InitP10NIntCong^{1}_{t,d} = \sum_{r \in ORREG_d} \left(SPREGMin10R^{1}_{r,t} + SPREGMin30R^{1}_{r,t}\right) - \sum_{r \in ORREG_d} \left(SPREGMax10R^{1}_{r,t} + SPREGMax30R^{1}_{r,t}\right);$$

and

$$InitP10NExtCong^{1}_{t,d} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT^{1}_{t,z}.$$

The reference and internal congestion components are analogous to the components of the *ten-minute operative reserve* LMP for an internal pricing node. The *intertie* congestion component reflects the cost of congestion at the *intertie* and is calculated by adding the individual congestion costs for the binding import limits that affect *operating reserve* transactions scheduled at the *intertie zone*.

There is no need to calculate a price for synchronized *ten-minute operating reserve* at *intertie zone* buses because synchronized *ten-minute operating reserve* cannot be imported.

To model an *intertie* as out-of-service, the *intertie* transmission limits will be set to zero and all *operating reserve offers* will receive a zero schedule. In this case, the *intertie operating reserve* prices will be set to be equal to the reference price for that class of *operating reserve* plus the applicable internal congestion component as described above.

An *operating reserve* LMP can fall outside the *settlement* bounds of $ORPrcFlr$ and $ORPrcCeil$ as a result of joint optimization or constraint violation pricing. When this occurs, the *operating reserve* LMP at an *intertie zone* bus and its components (reference, internal congestion and *intertie* congestion) will be modified so that the LMP is within the *settlement* bounds.

For *thirty-minute operating reserve*, the LMP and components at *intertie zone* bus $d \in D$ in time-step $t \in TS$ will be modified as follows:

1. Calculate $IntL30R = InitP30RRef^{1}_{t} + InitP30RIntCong^{1}_{t,d}$ and modify its components using the procedure for price modification for internal nodes as specified in Section 3.8.2.1 to obtain $P30RRef^{1}_{t}$ and $P30RIntCong^{1}_{t,d}$.
2. Set $ExtL30RP^{1}_{t,b} = Min(Max(InitExtL30RP^{1}_{t,b}, ORPrcFlr), ORPrcCeil)$.
3. Set $P30RExtCong^{1}_{t,d} = ExtL30RP^{1}_{t,b} - P30RRef^{1}_{t} - P30RIntCong^{1}_{t,d}$.

For *ten-minute operating reserve*, the LMP and components at *intertie zone* bus $d \in D$ in time-step $t \in TS$ will be modified as follows:

1. Calculate $IntL10N = InitP10NRef_t^1 + InitP10NIntCong_{t,d}^1$ and modify its components using the procedure for price modification for internal nodes as specified in Section 3.8.2.1 to obtain $P10NRef_t^1$ and $P10NIntCong_{t,d}^1$.
2. Set $ExtL10NP_{t,b}^1 = Min(Max(InitExtL10NP_{t,b}^1, ORPrcFlr), ORPrcCeil)$.
3. Set $P10NExtCong_{t,d}^1 = ExtL10NP_{t,b}^1 - P10NRef_t^1 - P10NIntCong_{t,d}^1$.

3.8.3. Pricing for Islanded Nodes

NQS resources that are not connected to the main (i.e. largest) island of the system will be reconnected as inactive units (zero MW and zero MVAr) within the *security* assessment function so as to produce a price. Steps one to three of the pricing for islanded nodes logic will be used to produce a price for NQS resources:

1. Find connection paths over open switches that connect the NQS resource to the main island.
2. Determine the priority rating for each connection path identified based on a weighted sum of the base voltage over all open switches used by the reconnection path and the MW ratings of the newly connected branches.
3. Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

The substitution rules outlined in steps four to eight will be used to produce a price for all other pricing nodes that are not connected to the main island of the system due to a transmission *outage*, disconnection, a resource being out of service or a resource operating in *segregated mode of operation*. These substitutions rules will also apply to NQS resources for which steps one to three was unable to determine a price. The PD calculation engine will be provided a node-level and *facility*-level substitution list for each pricing node to be used in applying the substitution rules. Steps four to eight of the pricing for islanded nodes logic will be as follows:

1. Use the LMP at a node in the node-level substitution list, provided such node is connected to the main island.
2. If no such nodes are identified, use the average LMP of all nodes at the same voltage level within the same *facility* that are connected to the main island.
3. If no such nodes are identified, use the average LMP of all nodes within the same *facility* that are connected to the main island.

4. If no such nodes are identified, use the average LMP of all nodes from another *facility* that is connected to the main island, as determined by the *facility*-level substitution list.
5. If a price is yet to be determined, use the LMP for the *reference bus*.

3.9. Data Generation for Settlement Mitigation

This section describes the enhanced mitigated for conduct *dispatch data* required for the *settlement* mitigation of RT make-whole payments. This section should be read in conjunction with Section 3.9 of the Real-Time Calculation Engine detailed design document.

Any resource that meets the conditions for the testing of RT make-whole payments will be subject to the make-whole payment impact test as described in the Market Settlement detailed design document. To execute the make-whole payment impact test, the *settlement process* will require additional *dispatch data* called enhanced mitigated for conduct *dispatch data*. This data will be generated by the Pre-Settlement Mitigation process after the PD and RT calculation engines have completed all scheduling, pricing, and Market Power Mitigation processes.

3.9.1. Calculation Engine Inputs Provided to the Pre-Settlement Mitigation Process

The Pre-Settlement Mitigation process uses information from the PD and RT calculation engines. Information required from the RT calculation engine is described in Section 3.9.1 of the Real-Time Calculation Engine detailed design document. The following information from the PD calculation engine will be required by the pre-settlement mitigation process:

- A list of resources that were mitigated by the PD calculation engine and were *dispatched* by the RT calculation engine. For each resource, the following data is required for the *dispatch hour* from the last PD calculation engine run prior to the *dispatch hour*:
    - the constrained area conditions that the resources met;
    - the reference levels used in the conduct test; and
- A list of NQS resources that received PD operational commitments - including new commitments, advancements and extensions - outside the hours of any DAM financially binding schedule the resource received. For each NQS resource, the following data is required:
    - the hour(s) of the PD operational commitment;
    - the constrained area conditions met in each hour of the operational commitment from each of the following PD calculation engine runs from:
        - when the binding start-up instruction was issued. This is needed to test commitment costs for conduct; and

        - the last PD calculation engine run prior to the *dispatch hour.* This is needed to test incremental *energy* and *operating reserve* for conduct; and
    - if the resource was committed for *reliability* purposes.

3.9.2. Outputs of the Pre-Settlement Mitigation Process

The output of the Pre-Settlement Mitigation process will be the enhanced mitigated for conduct *dispatch data* set, which includes the additional data that is necessary for the make whole payment impact testing in the *settlement process*.

For NQS resources with PD operational commitments, the enhanced mitigated for conduct *dispatch data* set includes the following for each commitment period that is comprised of a consecutive set of hours:

- The set of hours in the commitment period that did not receive a DAM financially binding schedule, and the most restrictive constrained area condition met in this set of hours; and
- A revised set of *dispatch data* for resources subject to the conduct test, using the constrained area condition described above. For resources that did not meet a constrained area condition, the global market power thresholds should be used as applicable. In this data set:
    - the *dispatch data* parameter values that fail the conduct test are replaced with their reference levels; and
    - the *dispatch data* parameter values that pass the conduct test are kept as as-offered.

For resources that met a constrained area condition in pre-dispatch, as per Section 3.6.3.1, and received a real-time *dispatch*, the enhanced mitigated for conduct *dispatch data* set includes the following for the *dispatch hour*:

- The constrained area condition met in the last PD calculation engine run prior to the *dispatch hour*; and
- A revised set of *dispatch data* for resources subject to the conduct test, using the constrained area condition described above. In this data set:
    - the *dispatch data* parameter values that fail the conduct test are replaced with their reference levels; and
    - the *dispatch data* parameter values that pass the conduct test are kept as as-offered.

For resources with control action *reliability* constraints applied to any hour in pre-dispatch or any five-minute interval in real time, the enhanced mitigated for conduct *dispatch data* set includes:

- The set of hours in which:
  - o *reliability* constraint applied to the resource in pre-dispatch; and
  - o *reliability* constraint applied to the resource in at least one five-minute interval in real time.
- A revised set of *dispatch data* subject to conduct test using the *reliability* threshold. In this data set:
  - o the *dispatch data* parameter values that fail the conduct test are replaced with their reference levels; and
  - o the *dispatch data* parameter values that pass the conduct test are kept as as-offered.

For resources that submitted new *dispatch data* within the real-time mandatory window that were entered as inputs to the RT calculation engine, the enhanced mitigated for conduct *dispatch data* set includes:

- A revised set of *dispatch data* subject to the conduct test using the appropriate thresholds (see Table 3-23). In this data set:
  - o the *dispatch data* parameter values that fail the conduct test are replaced with their reference levels; and
  - o the *dispatch data* parameter values that pass the conduct test are kept as as-offered values.

For any resource described above having dual-fuel status, the enhanced mitigated for conduct *dispatch data* set includes two sets of revised *dispatch data* with parameters tested for conduct for applicable condition, against each reference level:

- the lower cost reference levels; and
- the higher cost reference levels.

Table 3-23 lists the conduct test thresholds that must be used to perform the conduct test depending on when the resource was committed.

Table 3-23: Resources for which an Enhanced Mitigated for Conduct Dispatch Data Set Must Be Provided

Resource	Conduct Threshold Used
All resources supplying *energy* that qualified for ex-ante market power mitigation testing. This includes resources identified for NCA,	The most stringent market power mitigation thresholds for which the resource qualifies.

Resource	Conduct Threshold Used
DCA, BCA, and Global Market Power (*energy*) mitigation testing.	
All NQS resources that were committed and scheduled for *energy* that did not qualify for ex-ante mitigation testing and: • had a positive congestion component greater than $0/MWh on any binding constraint; or • had a sensitivity factor greater than 0.02 on a non-binding constraint. Additionally, this constraint would have been binding or would have been violated but for the commitment of the resource.	The threshold that corresponds with the non-binding constraint that would have been binding or violated without the commitment (NCA, DCA, or BCA)
All other NQS resources that were committed and scheduled for *energy*.	Global Market Power (*energy*) thresholds
All resources that were scheduled for *reliability* (i.e., minimum constraint applied).	*Reliability* constraints thresholds
All resources supplying *operating reserve* that qualified for ex-ante market power mitigation testing both for Local Market Power (*operating reserve*) and Global Market Power (*operating reserve*), and are scheduled to provide *operating reserve.*	The most stringent market power mitigation thresholds for which the resource qualifies.
All NQS resources that were committed and scheduled for *operating reserve*, and were not qualified for ex-ante mitigation testing.	Global Market Power (*operating reserve*) thresholds
Resources that submitted new *dispatch data* within the real-time mandatory window.	The most stringent market power mitigation thresholds for which the resource qualified, if applicable. Otherwise, the Global Market Power (*energy*) and Global Market Power (*operating reserve*) thresholds.

3.10. The Pseudo-Unit Model

Combined cycle *facilities offering* in the day-ahead market as *pseudo-units* (PSUs) will also *offer* into the *pre-dispatch scheduling* processes and *real-time market* as one or more PSUs each comprised of a single combustion turbine (CT) together with its share of the steam turbine (ST) capacity. The CTs and ST are referred to as the physical units (PUs). The PSU model defines the boundaries for PSU schedules and the proportional relationship between the CT and ST.

The PD calculation engine optimization function will evaluate a combined cycle *facility* electing PSU modelling as a set of PSU resources that capture the joint economics of operating the CT and the affiliated portion of the ST together. Each PSU resource is scheduled independently, with each PSU modelling a CT and a portion of the ST. Each PSU resource is scheduled proportionally according to a fixed ratio of *energy* output between the CT and ST within specific operating regions.

The PD calculation engine *security* assessment function models the physical power system and therefore must model the combined cycle *facilities* electing PSU modelling as PUs. Injections into the power system must be simulated at their physical buses. Therefore, PU sensitivity factors will be provided in the transmission limits passed from the *security* assessment function to the optimization function.

Although the optimization function will evaluate resource economics on a PSU basis, it must handle operational information that is provided on a PU basis, either within the optimization or via pre-processing. The following operational information is provided on a PU basis:

- Both transmission constraint sensitivity factors and marginal loss factors for the CT and ST will be provided to the optimization function and translated within the optimization using the PSU model; and
- Any minimum or maximum generation constraint applied to a CT or ST will be pre-processed before the execution of the PD calculation engine pass to provide limits on the affiliated PSU resources for the optimization function to enforce. *Outages* and de-rates will also be pre-processed before the execution of the PD calculation engine pass.

Because the optimization function will calculate resource schedules on a PSU basis, post-processing logic will be used to allocate PSU schedules to the corresponding PUs.

3.10.1. Model Parameters

For a combined cycle *facility* with K combustion turbines and one steam turbine, the following registration parameters and daily *dispatch data* parameters determine the underlying relationship between the PSUs and PUs:

- $CMCR_k$ indicating the registered maximum continuous rating of CT $k \in \{1,..,K\}$ in MW;
- $CMLP_k$ indicating the *minimum loading point* of CT $k \in \{1,..,K\}$ in MW;
- $SMCR$ indicating the registered maximum continuous rating of the ST in MW;
- $SMLP$ indicating the *minimum loading point* of the ST in MW for a 1x1 configuration;
- SDF indicating the amount of duct firing capacity available on the ST in MW;
- $STPortion_k$ indicating the percentage of the ST capacity attributed to PSU $k \in \{1,..,K\}$; and
- $CSCM_k \in \{0,1\}$ indicating whether PSU $k \in \{1,..,K\}$ is flagged to operate in single-cycle mode.

From this data, the following model parameters can be calculated for each PSU $k \in \{1,..,K\}$:

- $MMCR_k$ designates the maximum continuous rating of PSU k and is given by $CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$.
- $MMLP_k$ designates the *minimum loading point* of PSU k and is given by $CMLP_k + SMLP \cdot (1 - CSCM_k)$.
- MDF_k designates the duct firing capacity of PSU k and is given by $SDF \cdot STPortion_k \cdot (1 - CSCM_k)$.
- MDR_k designates the dispatchable capacity of PSU k and is given by $MMCR_k - MMLP_k - MDF_k$.

The PSU model has three distinct operating regions: MLP, dispatchable and duct firing. The model parameters above determine the three operating regions of PSU $k \in \{1,..,K\}$, each with an affiliated ST and CT share.

- The MLP region refers to capacity between 0 and $MMLP_k$:
    - o The ST share in this region is

$$STShareMLP_k = \frac{SMLP \cdot (1\text{-}CSCM_k)}{MMLP_k}.$$

    - o The CT share in this region is

$$CTShareMLP_k = \frac{CMLP_k}{MMLP_k}.$$

- The dispatchable region refers to capacity between $MMLP_k$ and $MMLP_k + MDR_k$:
    - o The ST share in this region is

$$STShareDR_k = \frac{(1\text{-}CSCM_k)(SMCR{\cdot}STPortion_k\text{-}SMLP\text{-}SDF{\cdot}STPortion_k)}{MDR_k}.$$

- o The CT share in this region is

$$CTShareDR_k = \frac{CMCR_k\text{-}CMLP_k}{MDR_k}.$$

- The duct firing region refers to capacity between $MMLP_k + MDR_k$ and $MMCR_k$:
  - o The ST share in this region is 1.
  - o The CT share in this region is 0.

Although the single-cycle mode flag is daily *dispatch data*, the logic described in Section 3.10.5 will apply if the look-ahead period spans two *dispatch days* and the *market participant* submits a different flag for each *dispatch day*.

3.10.2. Application of PU De-rates to the PSU Model

Market participants will continue to be able to submit de-rates on the CTs and ST corresponding to a combined cycle *facility* that has elected PSU modelling. When a de-rate is submitted on a physical unit, the PSU model parameters defining the dispatchable capacity and duct firing capacity will be updated in the PD calculation engine to respect the de-rate.

To enable the PD calculation engine to respect these PU de-rates, the *energy offers* submitted on a PSU basis will be scheduled based on the following logic:

1. A pre-processing step will determine the available parts of the operating regions above based on the CT and ST sharing relationships and the application of the PU de-rates.
2. If part of an operating region is determined to be unavailable, the corresponding *offer* laminations will not be scheduled for *energy* and *operating reserve*.

De-rates will be applied respecting the proportional relationship defined by the PSU model. The pre-processing step will not impact the CT and ST shares within the modelled operating regions and will ensure that both *energy* and *operating reserve* schedules respect the proportional relationship between the CT and the ST.

3.10.2.1 Pre-processing of De-rates

In the pre-processing step, the following operating region parameters for time-step $t \in TS$ will be calculated for each PSU $k \in \{1,..,K\}$:

- $MLP_{t,k}$ indicating the *minimum loading point* of PSU k in time-step t;
- $DR_{t,k}$ indicating the dispatchable capacity of PSU k in time-step t; and

- $DF_{t,k}$ indicating the duct firing capacity of PSU k in time-step t.

For each time-step $t \in TS$, the following data is required for the pre-processing step:

- $CTCap_{t,k}$ indicating the capacity of CT $k \in \{1,..,K\}$ in time-step t as determined by submitted de-rates;
- $STCap_t$ indicating the capacity of the ST in time-step t as determined by submitted de-rates; and
- $TotalQ_{t,k}$ indicating the total quantity of *energy offered* for PSU $k \in \{1,..,K\}$ in time-step t.

The first task is to calculate the amount of *energy offered* attributed to each CT ($CTAmt_{t,k}$) and ST portion ($STAmt_{t,k}$). To do so, the *energy offered* on a PSU is divided between the CT and ST according to the share percentages. For PSU $k \in \{1,..,K\}$ and time-step $t \in TS$:

1. If $TotalQ_{t,k} < MMLP_k$ then:
   a. Calculate $CTAmt_{t,k} = 0$.
   b. Calculate $STAmt_{t,k} = 0$.
2. Otherwise:
   a. Calculate $CTAmtMLP = MMLP_k \cdot CTShareMLP_k$.
   b. Calculate $STAmtMLP = MMLP_k \cdot STShareMLP_k$.
   c. If $TotalQ_{t,k} > MMLP_k + MDR_k$, then:
      i. Calculate $CTAmtDR = MDR_k \cdot CTShareDR_k$.
      ii. Calculate $STAmtDR = MDR_k \cdot STShareDR_k$.
      iii. Calculate $STAmtDF = (1\text{-}CSCM_k) \cdot (TotalQ_{t,k}\text{-}MMLP_k\text{-}MDR_k)$.
   d. Otherwise:
      i. Calculate $CTAmtDR = (TotalQ_{t,k}\text{-}MMLP_k) \cdot CTShareDR_k$.
      ii. Calculate $STAmtDR = (TotalQ_{t,k}\text{-}MMLP_k) \cdot STShareDR_k$.
      iii. Calculate $STAmtDF = 0$.
   e. Calculate $CTAmt_{t,k} = CTAmtMLP + CTAmtDR$.
   f. Calculate $STAmt_{t,k} = STAmtMLP + STAmtDR + STAmtDF$.

The next task is to allocate the ST capacity to each PSU pro-rata according to the amount of *energy offered* attributed to each ST portion. For PSU $k \in \{1,..,K\}$ and time-step $t \in TS$:

3. Calculate $PRSTCap_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}} \right) \cdot STCap_t$.

The last task is to recalculate the operating regions based on the application of the PU de-rates and the available parts of the CT and ST. For PSU $k \in \{1,..,K\}$ and time-step $t \in TS$:

4. Determine if the PSU is unavailable.
    a. If $CTAmt_{t,k} < CMLP_k$, then the PSU is unavailable.
    b. If $STAmt_{t,k} < SMLP \cdot (1 - CSCM_k)$, then the PSU is unavailable.
    c. If $CTCap_{t,k} < CMLP_k$, then the PSU is unavailable.
    d. If $PRSTCap_{t,k} < SMLP \cdot (1 - CSCM_k)$, then the PSU is unavailable.
5. Initialize the operating region parameters for time-step $t \in TS$ to the model parameter values.
    a. Set $MLP_{t,k} = MMLP_k$.
    b. Set $DR_{t,k} = MDR_k$.
    c. Set $DF_{t,k} = MDF_k$.
6. Apply the de-rate on the CT to the dispatchable region.
    a. Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k = CTCap_{t,k}$.
    b. Update $DR_{t,k} = min(DR_{t,k}, P \cdot MDR_k)$.
7. If the PSU is not operating in single-cycle mode, then incrementally restrict the capacity by considering the de-rate of the ST, applying the limit first to the duct firing region and then to the dispatchable region. If the PSU is operating in single-cycle mode, then the de-rate of the ST does not apply. If $CSCM_k = 0$:
    a. Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{t,k}$.
    b. If $R \leq 1$, update $DF_{t,k} = 0$, and $DR_{t,k} = min(DR_{t,k}, R \cdot MDR_k)$.
    c. If $R > 1$, update $DF_{t,k} = min(DF_{t,k}, PRSTCap_{t,k} - SMLP - STShareDR_k \cdot MDR_k)$.

3.10.2.2 Identifying Available Energy Laminations

Once the de-rated operating regions have been established, scheduling limitations will be applied so that the corresponding unavailable *offer* laminations will not be scheduled for *energy* and *operating reserve*.

The *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for time-step $t \in TS$ will be calculated for each PSU $k \in \{1,..,K\}$, where:

- $QMLP_{t,k}$ indicates the total quantity that may be scheduled in the MLP region;

- $QDR_{t,k}$ indicates the total quantity that may be scheduled in the dispatchable region; and
- $QDF_{t,k}$ indicates the total quantity that may be scheduled in the duct firing region.

The available *offered* quantity laminations will be determined as follows:

- The first *offered* quantity laminations up to $MLP_{t,k}$ will comprise the MLP region *offer* laminations. The available laminations will have an offered quantity less than $QMLP_{t,k}$;
- The *offered* quantity laminations between $MLP_{t,k}$ and $MDR_{t,k}$ will comprise the dispatchable region *offer* laminations. The available laminations will have an offered quantity between $MLP_{t,k}$ and $QDR_{t,k}$; and
- The *offered* quantity laminations between $MDR_{t,k}$ and $DF_{t,k}$ will comprise the duct firing region *offer* laminations. The available laminations will have an *offered* quantity between $MDR_{t,k}$ and $QDF_{t,k}$.

Necessarily, the following conditions will hold:

- $0 \leq QMLP_{t,k} \leq MLP_{t,k}$;
- $0 \leq QDR_{t,k} \leq DR_{t,k}$;
- $0 \leq QDF_{t,k} \leq DF_{t,k}$;
- if $QMLP_{t,k} < MLP_{t,k}$, then the PSU is unavailable and $QDR_{t,k} = QDF_{t,k} = 0$; and
- if $QDR_{t,k} < DR_{t,k}$, then $QDF_{t,k} = 0$.

3.10.3. Applying Minimum and Maximum Constraints to PSUs

As described earlier, *market participant* and *IESO* inputs into the PD calculation engine may limit the minimum or maximum output of a resource. The minimum and maximum constraints pertaining to a combined cycle *facility* electing PSU modelling may be provided to the PD calculation engine as either: a constraint on a given CT or ST, or a constraint on a given PSU resource, where:

- Commitment constraints will be provided on a physical unit basis, simultaneously identifying the physical unit as “committed” and indicating the corresponding minimum output of the unit;
- *Outages* and/or de-rates will be provided on a physical unit basis;
- *Reliability* constraints and manual constraints will typically be provided on a physical unit basis; and
- Certain manual actions such as *operating reserve* activations will be provided as a PSU constraint.

For all constraints provided on a physical unit basis, the constraints will be translated to a PSU constraint before the execution of the PD calculation engine pass. Only the most limiting PSU constraints will be enforced within the optimization function.

For a combined cycle *facility* with K CTs and one ST, the following data will be required to translate PSU and PU constraints to the limits enforced by the PD calculation engine optimization function:

- The model parameters $MMLP_k$, MDR_k, MDF_k, $STShareMLP_k$, $CTShareMLP_k$, $STShareDR_k$ and $CTShareDR_k$ for PSU $k \in \{1,..,K\}$;
- The effective operation regions $MLP_{t,k}$,$DR_{t,k}$ and $DF_{t,k}$ for time-step $t \in TS$ and PSU $k \in \{1,..,K\}$;
- The *offer* quantities $QMLP_{t,k}$,$QDR_{t,k}$ and $QDF_{t,k}$ that may be scheduled for *energy* and *operating reserve* in each operating region for time-step $t \in TS$ and PSU $k \in \{1,..,K\}$;
- The amount of *energy offered* attributed to the ST portion, $STAmt_{t,k}$ for time-step $t \in TS$ and PSU $k \in \{1,..,K\}$;
- The single-cycle flag $CSCM_k \in \{0,1\}$ indicating whether PSU $k \in \{1,..,K\}$ is flagged to operate in single-cycle mode, accounting for consideration of ST *forced outages* as described in Section 3.10.4; and
- $CTCmtd_{t,k} \in \{0,1\}$ indicating whether CT $k \in \{1,..K\}$ is considered committed in time-step $t \in TS$.

The subsequent sub-sections describe how each category of constraint can be translated into either:

- PSU maximum limitations, denoted $PSUMax_{t,k}$ for PSU $k \in \{1,..,K\}$ and time-step $t \in TS$; or
- PSU minimum limitations, denoted $PSUMin_{t,k}$ for PSU $k \in \{1,..,K\}$ and time-step $t \in TS$.
- Suppose Q constraints impacting the combined cycle *facility* have been provided to the PD calculation engine. For time-step $t \in TS$ and for constraint $q \in \{1,..,Q\}$, the following limitations will be calculated:
- $PSUMin^q_{t,k}$ indicating the minimum limitation on PSU k determined by translating constraint q. When constraint q does not provide a minimum limitation on PSU k, then $PSUMin^q_{t,k}$ shall be set equal to 0; and
- $PSUMax^q_{t,k}$ indicating the maximum limitation on PSU k determined by translating constraint q. When constraint q does not provide a maximum limitation on PSU k, then $PSUMax^q_{t,k}$ shall be set equal to $MLP_{t,k} + DR_{t,k} + DF_{t,k}$.

The minimum and maximum limitations applied within the optimization function will be calculated as follows:

$$MinDG_{t,k} = max_{q \in \{1,..Q\}} PSUMin^{q}_{t,k}$$

and

$$MaxDG_{t,k} = min_{q \in \{1,..Q\}} PSUMax^{q}_{t,k}$$

where the necessary mapping from PSU $k \in \{1,..,K\}$ to bus $b \in B^{PSU}$ identifying a PSU resource applies.

3.10.3.1 PSU Minimum Constraints

PSU minimum constraints can modify the minimum operating limit for a given PSU resource to maintain output at or above a specific value. Unlike other PSU constraints that are provided on the physical CT or ST, PSU minimum constraints do not require any pre-processing translations and can be applied directly to the PSU resource. The minimum constraint will revise the resource's lower operating limit so that the apportioned PU schedules produced by the PD calculation engine will collectively respect the minimum constraint value.

Suppose a minimum constraint of $PMin$ is provided on PSU $k \in \{1,..,K\}$ for time-step $t \in TS$. The PSU constraint is mapped directly to a PSU minimum constraint for the same amount, and so

$$PSUMin_{t,k} = PMin.$$

3.10.3.2 PSU Maximum Constraints

PSU maximum constraints can modify the high operating limit for a given PSU resource to maintain output at or below a specific value. Like PSU minimum constraints, PSU maximum constraints will also be applied directly to the PSU resource without additional pre-processing. These maximum constraints will be respected so that the collective apportioned PU schedules produced by the PD calculation engine do not exceed the maximum constraint value.

Suppose a maximum constraint of $PMax$ is provided on PSU $k \in \{1,..,K\}$ for time-step $t \in TS$. The PSU constraint is mapped directly to a PSU maximum constraint for the same amount, and so

$$PSUMax_{t,k} = PMax.$$

3.10.3.3 CT Minimum Constraints

At times, it may be necessary to apply minimum physical unit constraints directly to the CT of an associated PSU resource to maintain an output at or above a specified value. The minimum constraint on the physical unit will be translated to an equivalent minimum constraint on the PSU. For a PSU resource in combined cycle mode, the CT minimum constraint will place an implied minimum restriction on the associated ST due to the PSU model relationship. The PD calculation engine will schedule the PSU resource to respect the PSU equivalent constraint, resulting in apportioned PU schedules that respect the CT minimum limitation and implied ST limitation.

Suppose a minimum constraint of $CTMin$ is provided on CT $k \in \{1,..,K\}$ for time-step $t \in TS$. The constraint will be translated to PSU k as follows:

1. If the PSU is not flagged to operate in single-cycle mode (i.e. if $CSCM_k = 0$), then map the CT constraint directly to a PSU constraint using the PSU model. A restriction on the ST will be implicitly applied according to the sharing percentages.
   a. First calculate the effect of the constraint on the ST within the MLP and dispatchable regions.
      i. If $CTMin < MLP_{t,k} \cdot CTShareMLP_k$, then set
      $$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right),$$
      $$STMinDR = 0.$$
      ii. Otherwise, if $CTMin \geq MLP_{t,k} \cdot CTShareMLP_k$, then set
      $$STMinMLP = MLP_{t,k} \cdot STShareMLP_k,$$
      $$STMinDR = \left(CTMin - MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$
   b. Calculate $PSUMin_{t,k} = CTMin + STMinMLP + STMinDR$.
2. Otherwise, if the PSU is flagged to operate in single-cycle mode (i.e. if $CSCM_k = 1$), then map the CT constraint directly to the PSU. A restriction on the ST will not be implicitly applied according to the PSU model, and so
$$PSUMin_{t,k} = CTMin.$$

3.10.3.4 CT Maximum Constraints

It may also be necessary to apply maximum physical unit limitations on the CT of an associated PSU resource to limit the CT's maximum output at or below a specific value. The maximum constraint on the physical unit will be translated to an equivalent maximum constraint on the PSU. For a PSU resource in combined cycle mode, the CT maximum constraint will place an implied maximum restriction on the associated ST due to the PSU model relationship. The PD calculation engine will schedule the PSU resource to respect the PSU equivalent constraint, resulting in apportioned PU schedules that respect the CT maximum output and implied ST limitation.

Suppose a maximum constraint of $CTMax$ is provided on CT $k \in \{1,..,K\}$ for time-step $t \in TS$. The constraint will be translated to PSU k as follows:

1. If the PSU is not flagged to operate in single-cycle mode (i.e. if $CSCM_k = 0$), then map the CT constraint directly to a PSU constraint using the PSU model. A restriction on the ST will be implicitly applied according to the sharing percentages. A CT maximum constraint will always prevent the PSU from being scheduled in its duct firing region.
    a. If $CTMax < MLP_{t,k} \cdot CTShareMLP_k$, then the PSU is unavailable (i.e. $PSUMax_{t,k} = 0$).
    b. Otherwise, calculate the effect of the constraint on the ST within the MLP and dispatchable regions.
        i. Set

        $$STMaxMLP = MLP_{t,k} \cdot STShareMLP_k,$$
        $$STMaxDR = \left(CTMax\text{-}MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

        ii. Calculate $PSUMax_{t,k} = CTMax + STMaxMLP + STMaxDR$.
2. Otherwise, if the PSU is flagged to operate in single-cycle mode (i.e. if $CSCM_k = 1$), then map the CT constraint directly to the PSU. A restriction on the ST will not be implicitly applied according to the PSU model, and so

$$PSUMax_{t,k} = CTMax.$$

3.10.3.5 ST Minimum Constraints

ST minimum constraints are required to limit the minimum output of a physical ST unit such that the output of the ST is maintained at or above a specific value. An ST minimum constraint can be mapped to one or more PSU resources. It will be assigned equally to committed PSUs and translated to one or more equivalent PSU minimum constraints. The ST minimum constraint will place an implied minimum constraint on associated CT resources due to the PSU model relationship. The PD calculation engine will schedule impacted PSU resources to respect the PSU equivalent constraint(s), resulting in apportioned PU schedules that respect the ST minimum output and the associated CT implied limitations.

Suppose a minimum constraint of $STMin$ is provided on the ST for time-step $t \in TS$. The constraint will be translated to PSUs that are committed and not operating in single-cycle mode as follows:

1. Identify $A \subseteq \{1,..,K\}$ indicating the set of PSUs to which the constraint may be allocated. PSU $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k = 0$ and $CTCmtd_{t,k} = 1$. If the set A is empty (i.e. there are no PSUs on which to

allocate the constraint), then no further steps are required and the ST minimum constraint will not be translated to any PSU constraints.

2. Determine the ST portion of the capacity of PSU $k \in A$. $STCap_k$ designates this portion and is given by

$$STCap_k = QMLP_{t,k} \cdot STShareMLP_k + QDR_{t,k} \cdot STShareDR_k + QDF_{t,k}.$$

3. Allocate the $STMin$ constraint equally to each PSU $k \in A$. $STPMin_k$ designates the amount allocated to the ST portion of PSU $k \in A$ and is determined by allocating $STMin$ equally to each PSU $k \in A$, while limiting the amount allocated to the ST portion of PSU k by $STCap_k$.

4. Map the ST portion minimum constraint to a PSU constraint using the PSU model. A restriction on the CT will be implicitly applied according to the sharing percentages. For each PSU $k \in A$:

   a. First calculate the effect of the constraint on the CT within the MLP and dispatchable regions.

      i. If $STPMin_k < MLP_{t,k} \cdot STShareMLP_k$, then set

      $$CTMinMLP_k = STPMin_k \cdot \left(\frac{CTShareMLP_k}{STShareMLP_k}\right),$$
      $$CTMinDR_k = 0.$$

      ii. Otherwise, if $STPMin_k \geq MLP_{t,k} \cdot STShareMLP_k$, then set

      $$CTMinMLP_k = MLP_{t,k} \cdot CTShareMLP_k,$$
      $$CTMinDR_k = \left(STPMin_k - MLP_{t,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right).$$

   b. Calculate $PSUMin_{t,k} = STPMin_k + CTMinMLP_k + CTMinDR_k$.

If enough PSUs with sufficient ST capacity are not committed to allocate the constraint amount fully, this process may not translate the entire quantity of the ST minimum constraint to PSU constraints.

3.10.3.6 ST Maximum Constraints

ST maximum constraints are required to limit the output of a physical ST at or below a specific value. An ST maximum constraint will be prorated across the available capacity of associated in service PSU resources and translated to one or more equivalent PSU maximum constraints. The ST maximum constraint may place an implied maximum constraint on associated CT resources due to the PSU model relationship. The PD calculation engine will schedule impacted PSU resources to respect the PSU equivalent constraint(s), resulting in apportioned PU dispatches that respect the ST maximum output and any associated CT implied limitations.

Suppose a maximum constraint of $STMax$ is provided on the ST for time-step $t \in TS$. The constraint will be translated to all PSUs in the same way in which a ST de-rate is translated to all PSUs as follows:

1. Allocate the ST maximum constraint to each PSU pro-rata according to the amount of *energy offered* attributed to each ST portion. For PSU $k \in \{1,..,K\}$ and time-step $t \in TS$, calculate:

$$PRSTMax_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}}\right) \cdot STMax.$$

2. Map the ST portion maximum constraint to a PSU constraint using the PSU model. A restriction on the CT will be implicitly applied according to the sharing percentages. For each PSU $k \in \{1,..,K\}$ such that $CSCM_k = 0$:
   a. If the prorated ST maximum constraint limits the ST portion to below its MLP (i.e. $PRSTMax_{t,k} < SMLP \cdot (1 - CSCM_k)$), then the PSU is unavailable (i.e. $PSUMax_{t,k} = 0$).
   b. Otherwise, calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTMax_{t,k}$.
      i. If $R \leq 1$, set
      $$PSUMax_{t,k} = MLP_{t,k} + min(DR_{t,k}, R \cdot MDR_k).$$
      ii. If $R > 1$, set
      $$PSUMax_{t,k} = MLP_{t,k} + DR_{t,k} + PRSTMax_{t,k} - SMLP - STShareDR_k \cdot MDR_k.$$

3.10.3.7 Equal ST Minimum and Maximum Constraints

ST minimum constraints and maximum constraints of equal amounts may not result in PSU resource minimum and maximum constraints of equal amounts. This may occur because ST minimum constraints are only allocated to committed PSUs and are allocated equally to committed PSUs as opposed to pro-rated across available capacity. Equal minimum and maximum ST constraints may be applied to fix the steam turbine to a given output for safety, equipment or *reliability* reasons. In these circumstances, the ST minimum constraint allocation logic will be used to determine equal minimum and maximum constraints to be applied to the PSUs because the constraint represents an operational concern and is best allocated to committed PSUs.

3.10.4. Steam Turbine Forced Outages

When the steam turbine of a combined cycle *facility* electing PSU modelling experiences a *forced outage*, the PD calculation engine will automatically evaluate the corresponding PSUs as if the resources were being *offered* in single-cycle mode. This treatment will prevent the PD calculation engine from scheduling the PSUs to zero in cases where the ST *outage* slip is submitted before the single-cycle mode flag has been updated. For more information, see the Grid and Market Operations Integration detailed design document.

3.10.5. Single-Cycle Flag Across Two Dispatch Days

When the pre-dispatch look-ahead period spans two *dispatch days*, the single-cycle mode flag for the second day will be used for the entire look-ahead period, with two exceptions related to whether there is a *reliability* constraint on the PSU.

The first exception is if the flag submitted by the *market participant* differs between the two *dispatch days,* the PSU is currently in-service and the PSU is not currently subject to a *reliability* or commitment constraint. In this circumstance, the PSU will receive a 0 MW schedule in HE1 of the second *dispatch day* to respect the *market participant* submitted change in operating mode.

The second exception is if the flag submitted by the *market participant* differs between the two *dispatch days*, the PSU is currently in-service and the PSU is currently subject to either a *reliability* or a commitment constraint. In this circumstance, the PSU will receive a 0 MW schedule in the first time-step of the next *dispatch day* for which no commitment or *reliability* constraint applies. This treatment is also applicable when a PSU remains in-service across midnight to satisfy a commitment or *reliability* constraint. The pre-dispatch look-ahead period no longer spans two *dispatch days* but the PD calculation engine will continue to schedule the PSU using the single-cycle mode flag submitted for the previous *dispatch day* before forcing the resource to a 0 MW schedule once the constraint no longer applies.

3.10.6. Translation of PSU Schedules to PU Schedules

The PSU model determines the logic for translating *energy* and *operating reserve* schedules for the PSUs representing a combined cycle *facility* to *energy* and *operating reserve* schedules for the corresponding physical units.

For a combined cycle *facility* with K combustion turbines and one steam turbine, the following *energy* and *operating reserve* schedules for the physical units will be computed from the PSU schedules for time-step $t \in TS$:

- $CTE_{t,k}$ indicating the *energy* schedule for CT $k \in \{1,..,K\}$;
- $STPE_{t,k}$ indicating the *energy* schedule for the ST portion of PSU $k \in \{1,..,K\}$;
- STE_t indicating the *energy* schedule for the ST;
- $CT10S_{t,k}$ indicating the synchronized *ten-minute operating reserve* schedule for CT $k \in \{1,..,K\}$;

- $STP10S_{t,k}$ indicating the synchronized *ten-minute operating reserve* schedule for the ST portion of PSU $k \in \{1,..,K\}$;
- $ST10S_t$ indicating the synchronized *ten-minute operating reserve* schedule for the ST;
- $CT10N_{t,k}$ indicating the non-synchronized *ten-minute operating reserve* schedule for CT $k \in \{1,..,K\}$;
- $STP10N_{t,k}$ indicating the non-synchronized *ten-minute operating reserve* schedule for the ST portion of PSU $k \in \{1,..,K\}$;
- $ST10N_t$ indicating the non-synchronized *ten-minute operating reserve* schedule for the ST;
- $CT30R_{t,k}$ indicating the *thirty-minute operating reserve* schedule for CT $k \in \{1,..,K\}$;
- $STP30R_{t,k}$ indicating the *thirty-minute operating reserve* schedule for the ST portion of PSU $k \in \{1,..,K\}$; and
- $ST30R_t$ indicating the *thirty-minute operating reserve* schedule for the ST.

Suppose the PD calculation engine has determined the following *energy* and *operating reserve* schedules for PSU $k \in \{1,..,K\}$ in time-step $t \in TS$:

- $SE_{t,k}$ indicating the total amount of *energy* scheduled. This schedule can be broken into three components so that $SE_{t,k} = SEMLP_{t,k} + SEDR_{t,k} + SEDF_{t,k}$ where:
  - $SEMLP_{t,k}$ indicates the portion of the schedule corresponding to the MLP region. Necessarily $0 \leq SEMLP_{t,k} \leq QMLP_{t,k}$;
  - $SEDR_{t,k}$ indicates the portion of the schedule corresponding to the dispatchable region. Necessarily $0 \leq SEDR_{t,k} \leq QDR_{t,k}$ and $SEDR_{t,k} > 0$ only if $SEMLP_{t,k} = QMLP_{t,k}$;
  - $SEDF_{t,k}$ indicates the portion of the schedule corresponding to the duct firing region. Necessarily $0 \leq SEDF_{t,k} \leq QDF_{t,k}$ and $SEDF_{t,k} > 0$ only if $SEDR_{t,k} = QDR_{t,k}$;
- $S10S_{t,k}$ indicating the total amount of synchronized *ten-minute operating reserve* scheduled;
- $S10N_{t,k}$ indicating the total amount of non-synchronized *ten-minute operating reserve* scheduled. If the PSU cannot provide *operating reserve* from its duct firing region then necessarily $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} \leq QMLP_{t,k} + QDR_{t,k}$; and
- $S30R_{t,k}$ indicating the total amount of *thirty-minute operating reserve* scheduled. Necessarily $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} + S30R_{t,k} \leq QMLP_{t,k} + QDR_{t,k} + QDF_{t,k}$.

The following additional data is required to translate these PSU schedules to PU schedules:

- The *offer* quantities $QMLP_{t,k}$,$QDR_{t,k}$ and $QDF_{t,k}$ that may be scheduled for *energy* and *operating reserve* in each operating region for time-step $t \in TS$ and PSU $k \in \{1,..K\}$; and
- The ST and CT shares of the MLP and dispatchable regions for PSU $k \in K$ given by $STShareMLP_k$, $CTShareMLP_k$, $STShareDR_k$, and $CTShareDR_k$.

The logic to calculate the *energy* and *operating reserve* schedules for the CT and ST portion for PSU $k \in \{1,..,K\}$ in time-step $t \in TS$ depends on whether the PSU is scheduled at or above its *minimum loading point*. The procedure is as follows:

1. If $SE_{h,k} \geq MLP_{h,k}$, then the PSU model applies and the following logic used:
   a. The *energy* schedules from the MLP, dispatchable and duct firing regions are assigned to the CT and ST according to the sharing percentages as follows:

$$CTE_{t,k} = SEMLP_{t,k} \cdot CTShareMLP_k + SEDR_{h,k} \cdot CTShareDR_k,$$
$$STPE_{t,k} = SEMLP_{t,k} \cdot STShareMLP_k + SEDR_{t,k} \cdot STShareDR_k + SEDF_{t,k}.$$

   b. The *operating reserve* schedules are then assigned to the dispatchable and duct firing regions based on remaining capacity, assigning the spinning reserve first and then non-spinning as follows:

$$RoomDR_{t,k} = QDR_{t,k} \text{-} SEDR_{t,k},$$
$$10SDR_{t,k} = min(RoomDR_{t,k}, S10S_{t,k}),$$
$$10NDR_{t,k} = min(RoomDR_{t,k} \text{-} 10SDR_{t,k}, S10N_{t,k}),$$
$$30RDR_{t,k} = min(RoomDR_{t,k} \text{-} 10SDR_{t,k} \text{-} 10NDR_{t,k}, S30R_{t,k}),$$
$$CT10S_{t,k} = 10SDR_{t,k} \cdot CTShareDR_k,$$
$$STP10S_{t,k} = 10SDR_{t,k} \cdot STShareDR_k + (S10S_{t,k} \text{-} 10SDR_{t,k}),$$
$$CT10N_{t,k} = 10NDR_{t,k} \cdot CTShareDR_k,$$
$$STP10N_{t,k} = 10NDR_{t,k} \cdot STShareDR_k + (S10N_{t,k} \text{-} 10NDR_{t,k}),$$
$$CT30R_{t,k} = 30RDR_{t,k} \cdot CTShareDR_k,$$
$$STP30R_{t,k} = 30RDR_{t,k} \cdot STShareDR_k + (S30R_{t,k} \text{-} 30RDR_{t,k}).$$

2. If $SE_{t,k} < MLP_{t,k}$ and is ramping to MLP, the translation will be determined by the ramp up *energy* to MLP profile.

After the PSU schedules are allocated to the CT and ST portion, the ST portion schedules are summed to obtain the ST schedule as follows:

$$STE_t = \sum_{k=1,..,K} STPE_{t,k},$$

$$ST10S_t = \sum_{k=1,..,K} STP10S_{t,k},$$

$$ST10N_t = \sum_{k=1,..,K} STP10N_{t,k},$$

and

$$ST30R_t = \sum_{k=1,..,K} STP30R_{t,k}.$$

3.10.7. Pricing for PSUs

The PD calculation engine will produce prices for PSUs by calculating weighted average marginal loss factors and weighted average sensitivities based on the PSU model parameters and scheduling results.

3.11. Determination of the Non-Dispatchable Demand Forecast

The *IESO* will produce hourly average and hourly peak *demand* forecasts for each *demand* forecast area. These *demand* forecasts are representative of transmission losses and average or peak forecast consumption of all *load facilities* and *hourly demand response* resources in their respective *demand* forecast area.

The PD calculation engine optimization function uses an hourly province-wide non-dispatchable *demand* forecast quantity for each time-step t, denoted by FL_t. This quantity will be derived from either the average or peak *demand* forecasts through the selection process described in the Grid and Market Operations Integration detailed design document. Regardless of which set of forecasts is used, FL_t will be determined by identifying the portion of the *demand* forecasts for each *demand* forecast area attributed to loads that are considered non-dispatchable and losses, as described in the following steps:

1. The *IESO demand* forecasts for each *demand* forecast area minus the total of the *bid* quantities submitted for virtual *hourly demand response* resources will be distributed to all *load facilities* with *delivery points* in the areas using the load distribution factors described in Section 3.7.1.3. The distributed forecast MW quantities will then be adjusted to account for the *bid* quantities for physical *hourly demand response* resources by subtracting the *bid* quantities for physical *hourly demand response* resources from their respective associated non-dispatchable or price responsive *load facility*.
2. The forecast quantity for time-step t, FL_t, will be obtained by adding:
    - the forecast MW quantities reflecting losses;
    - the forecast MW quantities distributed to *delivery points* for *non-dispatchable loads;*
    - the forecast MW quantities distributed to *delivery points* for price responsive loads; and
    - the forecast MW quantities distributed to *delivery points* for *dispatchable loads* when no *bid* is submitted for a *dispatchable load.*

– End of Section –

4. Market Rule Requirements

The *market rules* govern the *IESO-controlled grid* and establish and govern the *IESO-administered markets*. The *market rules* codify obligations, rights and authorities for both the *IESO* and *market participants*, and the conditions under which those rights and authorities may be exercised and those obligations met.

This section is intended to provide an inventory of the changes to *market rul*e provisions required to support the PD Calculation Engine detailed design, and is intended to guide the development of m*arket rule* amendments.

This inventory is not meant to be an exhaustive list of required rule changes, but is a “snapshot” in time based on the current state of design development of this specific design document. Resulting *market rule amendments* will incorporate the integration of the individual design documents.

New and amended Chapter 11 defined terms: These terms will be consolidated in a single document at a later time as part of the *market rule amendment* process, and will support multiple design documents.

The inventory is developed in the following tables, which describe the impacts to the *market rules* and classify them into the following three types:

- Existing – no change: Identifies those provisions of the existing *market rules* that are not impacted by the design requirements.
- Existing – requires amendment: Identifies those provisions of the existing *market rules* that will need to be amended to support the design requirements.
- New: Identifies new *market rules* that will likely need to be added to support the design requirements.

Table 4-1: Market Rule Appendix 7.5 Impacts

Market Rule Section	Type	Topic	Requirement
Appendix 7.5 – The Market Clearing and Pricing Process			
Appendix 7.5 All Sections	Existing - requires amendment	All topics	• This appendix describes the process to be used to determine *pre-dispatch schedules*, *real-time schedules*, *market schedules* and *market prices*. • This appendix will be retired and replaced with new appendices to describe the *dispatch* scheduling and pricing process, the PD calculation engine process and the RT calculation engine process. Note: The inventory for the new appendix to describe the RT calculation engine process is included in the Real-Time Calculation Engine detailed design document.

Table 4-2: Market Rule Appendix 7.X Impacts

Market Rule Section	Type	Topic	Requirement
Appendix 7.X – The Dispatch Scheduling and Pricing Process			
Appendix 7.X.1	New	Interpretation	This new section includes a description of the appendix and what information will be included in the appendix. • Section 1.1 will clarify the purpose of the appendix. The appendix describes the process to be used to determine *pre-dispatch schedules*, *real-time schedules*, and prices. The appendix will detail the following: o Modes of operation; o The inputs to the *dispatch* scheduling and pricing process; and o The outputs from the *dispatch* scheduling and pricing process.
Appendix 7.X.2	New	Modes of Operation	This new section sets out the *market rules* around the operation of the *dispatch* scheduling and pricing process.

Market Rule Section	Type	Topic	Requirement
			• Section 1.1 will clarify the two modes of operation used by the PD calculation engine process and the RT calculation engine process. The *dispatch* scheduling and pricing software may be operated to determine either a *pre-dispatch schedule* or a *real-time schedule* and any associated prices as required by these *market rules*. • Section 1.2 will include details around the *pre-dispatch schedules* from the PD calculation engine process. The *pre-dispatch schedule* shall represent individual periods, each of one-hour duration, for the look-ahead period (i.e. the remaining hours of the current *dispatch day* and for runs starting at 20:00 EST, the look-ahead period includes all hours in the next *dispatch day*). It represents the *energy* forecast to be injected into or withdrawn from the *IESO-controlled grid*, and the *operating reserve* to be maintained, by each *market participant* in each *dispatch hour*. • Section 1.3 will include the details around the *real-time schedules* and the resulting *dispatch instructions* from the RT calculation engine process. The *real-time schedule* shall be issued for individual *dispatch intervals*. It represents the *energy* to be injected into or withdrawn from the *IESO-controlled grid*, and the *operating reserve* to be maintained, by dispatchable resources supplying *energy* or *operating reserve*, or consuming *energy*, in each *dispatch interval*. • Section 1.4 will include the details around schedules corresponding to *offers* and *bids* located in *intertie zones* adjoining the *IESO control area*. The schedules shall be fixed for all *dispatch intervals* within a *dispatch hour* in the *real-time schedule* to equal the *interchange schedules* determined for that same *dispatch*

Market Rule Section	Type	Topic	Requirement
			hour based on the last *pre-dispatch schedule* determined prior to solving the *real-time schedule*. Overlap: RT Calculation Engine detailed design document.
Appendix 7.X.3	New	Inputs	This new section sets out the *market rules* around the inputs to the *dispatch scheduling* and pricing process. • Section 1.1 will include the inputs to the *dispatch scheduling* and pricing process. Note: The inputs to the *dispatch* scheduling and pricing process that are common to both the PD calculation engine and the RT calculation engine processes will be identified in this section. For the purposes of this inventory, all inputs to the PD calculation engine process are identified in Appendix 7.XA. All inputs to the RT calculation engine are identified in Appendix 7.XB. Overlap: RT Calculation Engine detailed design document.
Appendix 7.X.4	New	Outputs	This new section sets out the *market rules* around the outputs in the *dispatch* scheduling and pricing process. • Section 1.1 will include the outputs to the *dispatch* scheduling and pricing process. • Section 1.2 – Dispatch Instructions: The section will include a reference to the *market rules* section in Chapter 7. Note: Some outputs from the PD calculation engine process may be included in this section. For the purposes of this inventory, all outputs from the PD calculation engine process are identified in Appendix 7.XA. Overlap: RT Calculation Engine detailed design document.

Table 4-3: Market Rule Appendix 7.X Impacts

Market Rule Section	Type	Topic	Requirement
Appendix 7.XA – The Pre-Dispatch Calculation Engine Process			
Section 1	New	Interpretation	This new section includes a description of the appendix and what information will be included in the appendix. • Section 1.1 will clarify the purpose of the appendix. The appendix describes the PD calculation engine process used to determine *pre-dispatch schedules* and prices. The appendix will detail the following: • The inputs to the PD calculation engine; • The outputs from the PD calculation engine; and • The mathematical description of the algorithms/tests for the single pass in the PD calculation engine. Similar to the existing Appendix 7.5 – The Market Clearing and Pricing Process, the *market rules* will state that the PD calculation engine output data described in Appendix 7.XA will not require the *IESO* to *publish* the output data except where expressly required by the *market rules*.
Section 2	New	The Pre-Dispatch Calculation Engine - Overview	This new section provides an overview of the PD calculation engine. • Section 2.1 will set out the purpose of the PD calculation engine and will describe the single pass. • Pass 1, the Pre-Dispatch Scheduling Pass, determines a set of resource schedules and commitments to meet the *IESO*'s hourly forecast *demand* and the *demand* from *dispatchable loads*, *hourly demand response* resources and exports. Pass 1 also determines locational marginal prices consistent with the scheduling and commitment decisions made in the pass.

Market Rule Section	Type	Topic	Requirement
Section 3	New	Inputs into the Pre-Dispatch Calculation Engine	This new section sets out the *market rules* around the inputs into the PD calculation engine. • Section 3.1 – Overview: The inputs will be categorized by the PD calculation engine's three functions: o Optimization function; o *Security* assessment function; and o Ex-ante market power mitigation process. • Section 3.2 – Inputs into the Optimization Function o Section 3.2.1 – Demand Forecasts: The section will include details of the hourly *demand* forecast prepared by the *IESO* for each of the *IESO demand* forecast areas. The *demand* forecasts will be modified to a quantity that is representative of load that is considered non-dispatchable and is inclusive of losses. The forecasts will be produced for each time-step of the look-ahead period (i.e. the remaining hours of the current *dispatch day* and for runs starting at 20:00 EST, the look-ahead period includes all hours in the next *dispatch day*). o Section 3.2.2 – Forecasts from Non-Dispatchable Generation Resources: The section will include details on the forecast output from *self-scheduling generation facilities, transitional scheduling generators* and *intermittent generators* submitted by *registered market participants* in accordance with Chapter 7. o Section 3.2.3 – Forecasts from Variable Generation Resources: The section will include details on the hourly forecast for *variable generation* produced by the *IESO* for all time-steps of the look-ahead

Market Rule Section	Type	Topic	Requirement
			period (i.e. the remaining hours of the current *dispatch day* and for runs starting at 20:00 EST, the look-ahead period includes all hours in the next *dispatch day*). o Section 3.2.4 – Energy Bids and Offers: The section will include *energy offers* and *energy bids* and other associated *dispatch data* parameters submitted by *registered market participants* submitted in accordance with Chapter 7. o Section 3.2.5 – Operating Reserve Offers: The section will include *operating reserve offers* and other associated *dispatch data* parameters submitted in accordance with Chapter 7. o Section 3.2.6 – Energy Limited Resources: This section will include details on *energy* limited resources and the daily limit on the amount of *energy* that they can generate over the course of the *dispatch day*. o Section 3.2.7 – Non-Quick Start Resources: The section will list the inputs for non-quick-start *generation facilities* including the minimum generation cost calculated from the speed-no-load offer and *energy offer* laminations up to the resource's *minimum loading point*. Additional inputs include start-up *offer*, speed no-load *offer*, *minimum generation block run time*, *minimum generation block down time*, *maximum number of starts per day*, and ramp up *energy* to *minimum loading point* profile. o Section 3.2.8 – Pseudo-Units: The section will list the inputs for *pseudo-units* including the steam turbine share of the *minimum loading point* region, steam

Market Rule Section	Type	Topic	Requirement
			turbine share of the dispatchable region, ramp up *energy* to *minimum loading point* profile for the combustion turbine and steam turbine, and whether the *pseudo-unit* cannot provide *ten-minute operating reserve* while scheduled in its duct firing region. o Section 3.2.9 – Hydroelectric Resources: The section will list the input for hydroelectric resources, which include *forbidden regions*, minimum and maximum daily *energy* limits, minimum hourly output, hourly must run, *maximum number of starts per day*, linked resources, time lag and MWh ratio *dispatch data* parameters. o Section 3.2.10 – Imports and Exports: The section will include details on the inputs for imports and exports, specifically those outside the normal market *bids* and *offers* including, but not limited to, *emergency energy* and inadvertent *intertie* flows. o Section 3.2.11 – Inputs Provided by the Security Assessment Function: The section will include details on the inputs provided by the *security* assessment function, which include: ▪ Transmission constraints (including marginal loss factors and loss adjustments); and ▪ Transmission losses. o Section 3.2.12– Inputs to subsequent PD calculation engine runs provided by the Ex-Ante Market Power Mitigation Process. The section will include details on the inputs provided by the Ex-Ante Market Power Mitigation Process, which include *dispatch data* replaced by reference level

Market Rule Section	Type	Topic	Requirement
			values resulting from the failure of conduct and price impact tests executed by the PD calculation engine for *dispatchable loads* and dispatchable generation resources. o Section 3.2.13 – Initial Scheduling Assumptions: The section will include details on the initial schedules and commitment of resources for the first time-step of the look-ahead period (i.e. the remaining hours of the current *dispatch day* and for runs starting at 20:00 EST, the look-ahead period includes all hours in the next *dispatch day*), which is not scheduled by the optimization function. o Section 3.2.14 – Other Inputs: The *IESO* shall also provide other inputs into the PD calculation engine for the optimization function. These include: ▪ *Operating reserve* requirements; ▪ Resource minimum and maximum constraints; ▪ *Intertie* limits; ▪ *Intertie* curtailments; and ▪ Constraint violation penalties. • Section 3.3 – Inputs into the Ex-Ante Market Power Mitigation Process o Section 3.3.1 – Condition Testing Inputs ▪ Section 3.3.1.2 – Constrained Area Designations: The designation of constrained areas is based on frequency and duration of congestion in the area, and whether the constraints result in supply resources being dispatched up, in accordance with the new

Market Rule Section	Type	Topic	Requirement
			Appendix 7.8 – Market Power Mitigation. o Section 3.3.2 – Conduct Test Inputs o Section 3.3.2.1 – Reference Levels: Reference levels will be the *IESO*'s estimate of the competitive *offer* of a resource in accordance with the new Appendix 7.8 – Market Power Mitigation. o Section 3.3.2.2 – Conduct Thresholds: Conduct thresholds will be used with reference levels to determine whether the *dispatch data* values *offered* by a resource deviate significantly from what the values would have been in a competitive market in accordance with the new Appendix 7.8 – Market Power Mitigation. o Section 3.3.2.3 – Other Inputs: ▪ Minimum Energy Offer: The minimum *energy offer* value for the *offer* lamination to be included in the Conduct Test. *Energy offer* laminations below this value are excluded from the Conduct Test. ▪ Minimum Operating Reserve Offer: The minimum *operating reserve offer* value for the *offer* lamination to be included in the Conduct Test. *Operating reserve offer* laminations below this value are excluded from the Conduct Test. o Section 3.3.3 – Price Impact Test Inputs o Section 3.3.3.1 – Price Impact Thresholds: Price impact thresholds will be used to test for economic withholding in accordance with the new Appendix 7.8 – Market Power Mitigation.

Market Rule Section	**Type**	**Topic**	**Requirement**
			• Section 3.4 – Inputs into the Security Assessment Function o Section 3.4.1 – Inputs Provided by the Optimization Function: The Optimization Function will provide schedules for load and supply resources (withdrawals and injections). o Section 3.4.2 – Other inputs: ▪ *Security limits*; ▪ Power system model data; ▪ List of contingencies; ▪ List of monitored equipment; and ▪ Load distribution factors. Overlap: Market Power Mitigation detailed design document, Offers, Bids and Data Input detailed design document, and DAM Calculation Engine detailed design document.
Section 4	New	Initialization	This new section sets out the *market rules* around the initialization processes. • Section 4.1 – Overview: The section will include an overview of the initialization processes. Prior to the execution of its single pass, the PD calculation engine will perform the initialization processes, which include Sections 4.1.1 through 4.1.7. o Section 4.1.1 – References Bus: The section will include details on the selection of a *reference bus*. o Section 4.1.2 – Islanding: The section will include details determining islanding conditions. o Section 4.1.3 – Variable Generation Resource Tie-Breaking: The section will include details on the application of the *variable generator* tie-breaking logic. o Section 4.1.4 – Pseudo-Unit Minimum and Maximum Constraints: The section will

Market Rule Section	Type	Topic	Requirement
			include details on the pre-processing of minimum and maximum generation constraints that apply to *pseudo-units*. o Section 4.1.5 – Evaluation of Start-Up Cost for Non-Quick Start Resource Advancements: The section will include details on the evaluation of *start-up costs* for the advancement of non-quicks start resource DAM operational commitments. o Section 4.1.6 – Evaluation of Non-Quick Start First Time-Step Available to Start: The section will include details on the evaluation of the first time-step the non-quick start resource can reach *minimum loading point*. o Section 4.1.7 – Evaluation of Dispatch Data Across Two Dispatch Days: The section will include details on the evaluation of *dispatch data* where the look-ahead period (i.e. the 20:00 EST to 23:00 EST runs of the PD calculation engine) spans two *dispatch days*.
Section 5	New	Security Assessment	This new section will set out the *market rules* around the *security* assessment function. • Section 5.1 – Overview: The section will provide an overview of the *security* assessment function. The *security* assessment function assesses power system *security* using the schedules produced by the optimization function. For resource schedules and prices, the PD calculation engine iterates between the optimization function and the *security* assessment function. • Section 5.2 – Inputs: The section will include the inputs into the *security* assessment function by referencing the inputs identified in Section 3 of Appendix 7.XA. • Section 5.3 – Security Assessment Function Processing: The *security* assessment function

Market Rule Section	Type	Topic	Requirement
			performs the following calculations and analyses (the details for these will be included in the *market rules*): o Base case power flow; o Pre-contingency *security* assessment; o Prepare linearized constraints for pre-contingency limits; o Loss calculation; o Contingency analysis; and o Prepare linearized constraints for post-contingency limits. • Section 5.4 – Outputs: The section will list the outputs from the *security* assessment function. The outputs include, but are not limited to: o Marginal loss factors for resources; o *Security* constraint set corresponding to violated pre-contingency limits and post-contingency thermal limits; o Loss adjustment; and o Sensitivity factors required to calculate locational marginal prices (pre-contingency and post-contingency).
Section 6	New	Pass 1: Pre-Dispatch Scheduling Pass	This new section sets out the *market rules* around the single pass of the PD calculation engine, including the inputs, mathematical formulations, and outputs. • Section 6.1 – Overview: The section will contain an overview of Pass 1. Pass 1 determines a set of resource schedules and commitments to meet the *IESO*'s forecast non-dispatchable *demand* and the *demand* from *dispatchable loads*, *hourly demand response* resources and exports. Pass 1 also determines locational marginal prices consistent with these scheduling and commitment decisions. • Sections 6.2 to 6.8 will detail the algorithms/tests within Pass 1. For the

Market Rule Section	Type	Topic	Requirement
			purposes of this inventory, these sections are broken out by algorithm/test as follows: o Pre-Dispatch Scheduling; o Pre-Dispatch Pricing; o Constrained Area Conditions Test; o Conduct Test; o Reference Level Scheduling; o Reference Level Pricing; and o Price Impact Test. • Section 6.9 – Locational Marginal Prices: The section will outline the locational marginal prices for Pass 1, determined in accordance with Section 8 of Appendix 7.XA. • Section 6.10 – Outputs: The section will list the outputs from Pass 1, which include but are not limited to: o Schedules; o Unit commitment statuses; o Shadow prices; and o Locational marginal prices.
Section 6.2	New	Pre-Dispatch Scheduling	This new section sets out the *market rules* around the Pre-Dispatch Scheduling algorithm. • Section 6.2.1 – Overview: The section includes an overview of the Pre-Dispatch Scheduling algorithm. Pre-Dispatch Scheduling will perform a *security*-constrained unit commitment and economic *dispatch* to meet the *IESO's* non-dispatchable *demand* forecast and *IESO*-specified *operating reserve* requirements, as well as *demand* from *dispatchable loads*, *hourly demand response* resources and *bids* to export *energy*. • Section 6.2.2 – Inputs: The section lists the inputs to the Pre-Dispatch Scheduling algorithm by referencing the inputs identified in Section 3 of Appendix 7.XA.

Market Rule Section	Type	Topic	Requirement
			• Section 6.2.3 – Optimization Function for Pre-Dispatch Scheduling: The section includes details on the optimization function including: o Optimization Objective: The section will include the objective (to maximize the gains from trade). o Variables – The section will list the variables for which the calculation engine will solve for. o Objective Function: The section will include the optimization of the objective function in Pre-Dispatch Scheduling, which is to maximize the expression (Note: the expression will be included in the *market rules*). • Section 6.2.4 – Optimization Constraints: The section outlines the three constraint categories that apply to the schedules determined in the optimization: o Single hour constraints that ensure no violation of parameters specified in the *dispatch data* submitted by *registered market participants*; • Inter-hour and multi-hour constraints that ensure no violation of parameters specified in the *dispatch data* submitted by *registered market participants*; and • Constraints that ensure no violations of *IESO* established *reliability* criteria. • Section 6.2.5 – Bid/Offer Constraints Applying to Single Hours: The section will include details on the single hour constraints including: o Scheduling variable bounds and commitment status variables; o Resource minimums and maximums; o *Intertie* minimum and maximum constraints;

Market Rule Section	Type	Topic	Requirement
			o Off-market transactions (*emergency energy* and inadvertent *intertie* flows); o *Operating reserve* scheduling; o *Pseudo-units*; o Hydroelectric resources; and o Imports/exports (linked wheel transactions). • Section 6.2.6 – Bid/Offer Inter-Hour/Multi-Hour Constraints: The section will include details on the inter-hour/multi-hour constraints including: o *Energy* ramping; o *Operating reserve* ramping; o Non-quick-start resources; o *Energy*-limited resources; and o Hydroelectric resources. • Section 6.2.7 – Constraints to Ensure Schedules Do Not Violate Reliability Requirements: The section will include details on the constraints that ensure no *IESO* established *reliability* criteria are violated including: o *Energy* balance; o *Operating reserve* requirements; o *IESO* internal transmission limits; o *Intertie* limits; and o Penalty price variable bounds. • Section 6.2.8 – Outputs: The section will list the outputs from the Pre-Dispatch Scheduling algorithm. Pre-Dispatch Scheduling will produce schedules and unit commitment statuses.
Section 6.3	New	Pre-Dispatch Pricing	This new section sets out the *market rules* around the Pre-Dispatch Pricing algorithm. • Section 6.3.1 – Overview: The section includes an overview of the Pre-Dispatch Pricing algorithm. Pre-Dispatch Pricing will perform a *security*-constrained economic *dispatch* to meet the *IESO's* non-dispatchable *demand* forecast and *IESO*-specified *operating reserve*

Market Rule Section	Type	Topic	Requirement
			requirements, as well as *demand* from *dispatchable loads*, *hourly demand response* resources and *bids* to export *energy*. • Section 6.3.2 – Inputs: The section includes the inputs to the Pre-Dispatch Pricing algorithm by referencing the inputs identified in Section 3 of Appendix 7.XA. The section will also include a list of outputs from Pre-Dispatch Scheduling that are used as inputs to the Pre-Dispatch Pricing algorithm. • Section 6.3.3 – Optimization Function for Pre-Dispatch Pricing: The section includes details on the optimization function including: o Optimization Objective: The section will include the objective (to maximize the gains from trade). o Variables: The section will list the variables for which the PD calculation engine will solve for. o Objective Function: The optimization of the objective function in Pre-Dispatch Pricing is to maximize the expression (the expression will be included in the *market rules*). The objective function for the Pre-Dispatch Pricing is similar to Pre-Dispatch Scheduling, with the following exceptions: ▪ The start-up and minimum generation costs are constants and thus are dropped from the objective; and ▪ The violation cost is calculated using the set of constraint violation penalty curves for determining *market prices*. • Section 6.3.4 – Optimization Constraints: The section outlines the four constraint categories that apply to the schedules and prices determined in the optimization:

Market Rule Section	Type	Topic	Requirement
			o Single hour constraints that ensure no violation of parameters specified in the *dispatch data* submitted by *registered market participants*; o Inter-hour and multi-hour constraints that ensure no violation of parameters specified in the *dispatch data* submitted by *registered market participants*; and o Constraints that ensure no violations of *IESO* established *reliability* inputs; and o Constraints that ensure the eligibility of an *offer* or *bid* lamination to set price is appropriately reflected. • Section 6.3.5 – Bid/Offer Constraints Applying to Single Hours: The section will include details on the single hour constraints including: o Scheduling variable bounds and unit commitment statuses; o Resource minimum and maximums; o *Intertie* minimum and maximum constraints; o Off-market transactions (*emergency energy* and inadvertent *intertie* flows); o *Operating reserve* scheduling; o *Pseudo-units*; o Hydroelectric resources; and o Imports/exports (linked wheel transactions). • Section 6.3.6 – Bid/Offer Inter-Hour/Multi-Hour Constraints: The section will include details on the inter-hour/multi-hour constraints including: o *Energy* ramping; o *Operating reserve* ramping; o Non-quick-start resources; o *Energy*-limited resources; and o Hydroelectric resources.

Market Rule Section	Type	Topic	Requirement
			• Section 6.3.7 – Constraints to Ensure Schedules Do Not Violate Reliability Requirements: The section will include details on the constraints that ensure no *IESO* established *reliability* criteria is violated including: o *Energy* balance; o *Operating reserve* requirements; o *IESO* internal transmission limits; o *Intertie* limits; and o Penalty price variable bounds. • Section 6.3.8 - Constraints to Ensure Price-Setting Eligibility Reflect Offer/B*id* Laminations. The section will include details on the constraints that ensure the eligibility of an *offer* or *bid* lamination to set price is appropriately reflected for: o *Energy* limited resources; and o Hydroelectric resources; • Section 6.3.9 – Outputs: The section will list the outputs from the Pre-Dispatch Pricing algorithm. Pre-Dispatch Pricing will produce shadow prices for all constraints contributing to locational prices. Pre-Dispatch Pricing will also produce locational marginal prices in accordance with Section 8 of Appendix 7.XA. Note: The locational marginal prices calculated will not be used for the *settlement* purposes and will be calculated for advisory only, with the following exception: o The *intertie congestion price* determined in the last run before a given *dispatch hour* will affect real-time *settlement* of *intertie* transactions.
Section 6.4	New	Constrained Area Conditions Test	This new section sets out the *market rules* around the Constrained Area Conditions Test. • Section 6.4.1 – Overview: The section includes an overview of the Constrained Area Conditions Test. The purpose of the test is to:

Market Rule Section	Type	Topic	Requirement
			o Identify when and where competition is restricted; and o Determine which resources will undergo the Conduct Test, Section 6.5, for financial *dispatch data* parameters. • Section 6.4.2 – Conditions Test Categories: The section outlines the four test categories that identify the *IESO*-defined conditions that would meet mitigation testing for *energy* and *operating reserve*: o Local market power (*energy*), including: ▪ Narrow constrained area (NCA); ▪ Dynamic constrained area (DCA); and ▪ Broad constrained area (BCA); ▪ Local market power (*operating reserve*); ▪ Global market power (*energy*); and ▪ Global market power (*operating reserve*). • Section 6.4.3 – Inputs: The section includes the inputs to the Constrained Area Conditions Test by referencing the inputs identified in Section 3.3. The section will also include a list of outputs from Pre-Dispatch Pricing that are used as inputs to Constrained Area Conditions Test. • Section 6.4.4 – Local Market Power (*Energy*) Constrained Area Conditions Test: The section will include details on the conditions that must be met to qualify for local market power (*energy*) mitigation testing for resources located within the following areas: o NCA and DCA; or o BCA. • Section 6.4.5 – Local Market Power (Operating Reserve) Constrained Area Condition Test: The section will include details on identifying

Market Rule Section	Type	Topic	Requirement
			resources *offering operating reserve* for reserve areas with a minimum requirement greater than zero. If the resource is located in a reserve area with a binding maximum restriction constraint, then the resource will be exempted from the Conduct Test. • Section 6.4.6 – Global Market Power (*Energy*) Constrained Area Conditions Test: The section will include details on the two conditions, that must be both met, to identify resources for the test. The two conditions include: o Condition 1: Unable to schedule incremental imports; and o Condition 2: The Intertie Border Price at the reference *interties* is greater than the specified threshold value. • Exemptions: Resources with a congestion component at least $1/MWh below the internal congestion component at all of the Global Market Power Reference Interties will be exempted from testing for global market power. Section 6.4.7 – Global Market Power (Operating Reserve) Constrained Area Conditions Test: The section will include details on identifying resources in the class of *operating reserve* where the locational marginal price is greater than the threshold for a resource's *operating reserve* locational marginal price. If the resource is located in a reserve area with a binding maximum restriction constraint, then the resource will be exempted from the Conduct Test. • Section 6.4.8 – Outputs: The section will list the outputs from the Constrained Area Conditions Test. The output of the Constrained Area Condition Test is a set of resources that will be subject to the Conduct Test, Section 6.5. Overlap: Market Power Mitigation Chapter

Market Rule Section	Type	Topic	Requirement
Section 6.5	New	Conduct Test	This new section sets out the *market rules* around the Conduct Test. • Section 6.5.1 – Overview: The section includes an overview of the Conduct Test. The resources that were identified in the Constrained Area Conditions Test, Section 6.4, will be required to undergo the Conduct Test. If no resources were identified, the Conduct Test will not be required. For a resource that is eligible for more than one Conduct Test for either *energy* or *operating reserve*, the test with the most stringent threshold levels will be performed. • Section 6.5.2 – Inputs: The section includes the inputs to the Conduct Test by referencing the inputs identified in Section 3.3. The inputs will also include the resources identified in Section 6.4 – Constrained Area Conditions Test. • Section 6.5.3 – Conduct Test for Energy: The section will include details on the evaluation of the following *dispatch data* parameters: o *Energy offer*, including *offers* up to and above *minimum loading point* (only applicable if *energy offer* is greater than the minimum *energy offer* value for the *offer* lamination to be included in the Conduct Test); ▪ Start-up *offer*; and ▪ Speed-no-load *offer*. • Section 6.5.4 – Conduct Test for Operating Reserve: The section will include details on the evaluation of the following *dispatch data* parameters: o Operating *reserve offer* (only applicable if *operating reserve offer* is greater than the minimum *operating reserve offer* value for the *offer* lamination to be included in the Conduct Test); ▪ Start-up *offer*;

Market Rule Section	Type	Topic	Requirement
			▪ Speed-no-load *offer*; and ▪ *Energy offers* for the range of production up to *minimum loading point*. • Section 6.5.5 – Outputs: The section will list the outputs from the Conduct Test. The outputs from the Conduct Test include: o The set of resources that failed the Conduct Test; o The *dispatch data* parameters that failed the Conduct Test; and o Reference level *dispatch data* (revised set of financial *dispatch data* parameters for resources that failed a Conduct Test with *dispatch data* parameters that failed the Conduct Test replaced with reference levels). Overlap: Market Power Mitigation Chapter
Section 6.6	New	Reference Level Scheduling	This new section sets out the *market rules* around the Reference Level Scheduling algorithm. • Section 6.6.1 – Overview: The section includes an overview of the Reference Level Scheduling algorithm. Reference Level Scheduling will perform a *security*-constrained unit commitment and economic *dispatch*, similar to Pre-Dispatch Scheduling with the following exception: o Reference Level Scheduling uses reference level *dispatch data* for any financial *dispatch data* from *registered market participants* that failed the Conduct Test. • Section 6.6.2 – Inputs: The section lists the inputs to the Reference Level Scheduling algorithm by referencing the inputs identified in Section 3 of Appendix 7.XA. The inputs will also include the outputs from the Conduct Test, Section 6.5.5.

Market Rule Section	Type	Topic	Requirement
			Note: If a non-quick start resource start-up *offer* failed the Conduct Test, the evaluation of *start-up cost* for a non-quick start resource advancement, Section 4.1.5, will be performed with the appropriate start-up *offer*. • Section 6.6.3 – Optimization Function for Reference Level Scheduling: The optimization function for Reference Level Scheduling is the same as the optimization function for Pre-Dispatch Scheduling. The section will include a reference to the Pre-Dispatch Scheduling optimization function, Section 6.2.3. • Section 6.6.4 – Optimization Constraints: The optimization constraints for Reference Level Scheduling are the same as the optimization constraints for Pre-Dispatch Scheduling. The section will include a reference to the Pre-Dispatch Scheduling optimization constraints, Sections 6.2.4 through 6.2.7. • Section 6.6.5 – Outputs: The section will list the outputs from the Reference Level Scheduling algorithm. Reference Level Scheduling will produce resource schedules and unit commitments.
Section 6.7	New	Reference Level Pricing	This new section sets out the *market rules* around the Reference Level Pricing algorithm. • Section 6.7.1 – Overview: The section includes an overview of the Reference Level Pricing algorithm. Reference Level Pricing will perform a *security*-constrained economic *dispatch* similar to that performed by Pre-Dispatch Pricing with the following exception: o Reference Level Pricing uses reference level *dispatch data* for any inputs from *registered market participants* that failed the Conduct Test in the current PD calculation engine run. • Section 6.7.2 – Inputs: The section lists the inputs to the Reference Level Pricing algorithm

Market Rule Section	Type	Topic	Requirement
			by referencing the inputs identified in Section 3 of Appendix 7.XA. The inputs will also include the outputs from the Conduct Test, Section 6.5.5, and from Reference Level Scheduling, Section 6.6.5. • Section 6.7.3 – Optimization Function: The optimization function for Reference Level Pricing is the same as the optimization function for Pre-Dispatch Pricing. The section will include a reference to the Pre-Dispatch Pricing optimization function, Section 6.3.3. • Section 6.7.4 – Optimization Constraints: The optimization constraints for Reference Level Pricing are the same as the optimization constraints for Pre-Dispatch Pricing with the following exceptions: o The constraints used to apply the principle for price setting eligibility must be modified to take into account the Reference Level Scheduling results; and o The marginal loss factor used in the *energy* balance constraint will be fixed to the marginal loss factors used in the last optimization function iteration of Reference Level Scheduling. The section will include a reference to the Pre-Dispatch Pricing optimization constraints, Sections 6.3.4 through 6.3.8. • Section 6.7.5 – Outputs: The section will list the outputs from the Reference Level Pricing algorithm. Reference Level Pricing will produce shadow prices for Reference Level Pricing constraints, as well as locational marginal prices.
Section 6.8	New	Price Impact Test	This new section sets out the *market rules* around the Price Impact Test. • Section 6.8.1 – Overview: The section includes an overview of the Price Impact Test. The Price

Market Rule Section	Type	Topic	Requirement
			Impact Test is required when one or more *dispatch data* parameters fail the Conduct Test. The Price Impact Test compares the Pre-Dispatch Pricing *energy* (or *operating reserve*) locational marginal prices with the Reference Level Pricing *energy* (or *operating reserve*) locational marginal prices. • Section 6.8.2 – Inputs: The section includes the inputs to the Price Impact Test by referencing the inputs identified in Section 3.3. The resources that failed the Conduct Test, the outputs identified in Section 6.5.5, will be listed in the inputs section. The inputs will also include the *energy* and *operating reserve* prices identified in Section 6.3 – Pre-Dispatch Pricing and Section 6.7 – Reference Level Pricing. • Section 6.8.3 – Price Impact Test for Energy: The section will include details on the Price Impact Test for the following two condition categories: o Local market power (*energy*); and o Global market power (*energy*). • Section 6.8.4 – Price Impact Test for Operating Reserve: The section will include details on the Price Impact Test for the following two condition categories: o Local market power (*operating reserve*); and o Global market power (*operating reserve*). • Section 6.8.5 – Outputs: The section will list the outputs from the Price Impact Test. The outputs from the Price Impact Test include: o The set of resources that failed the Price Impact Test in each time-step by condition type; o The locational marginal prices (*energy* and *operating reserve*) that failed the Price Impact Test in each time-step; and

Market Rule Section	Type	Topic	Requirement
			o Pre-dispatch *dispatch data* for future PD calculation engine runs (revised set of *dispatch data* for resources that failed the Price Impact Test with *dispatch data* parameters that failed the Conduct Test replaced with corresponding reference level values). Overlap: Market Power Mitigation Chapter
Section 7	New	Combined Cycle Modelling	This new section sets out the *market rules* around combined cycle modelling. • Section 7.1 – Overview: The section will provide an overview of combined cycle modelling. *Registered market participants* with combined cycle plants of one or more combustion turbines and one steam turbine may choose to have the associated *generation units* modelled as one or more *pseudo-units*. • Section 7.2 – Modelling by the Pre-Dispatch Calculation Engine: The section will include details on the modelling of *pseudo-units* and the pricing for *pseudo-units* in the PD calculation engine. o Section 7.2.1 – The section will include details on the modelling of *pseudo-units* in the optimization function and in the *security* assessment function. The PD calculation engine will evaluate combined cycle facilities electing to be modelled as a *pseudo-unit*(*s*) in (1) the optimization function as a *pseudo-unit*(*s*) and (2) in the *security* assessment function as physical units. o Section 7.2.1.1 – Model Parameters: The section will include the parameters used for modelling, including *facility* registration and daily *dispatch data*. o Section 7.2.1.2 – Physical Unit De-rates and Pseudo-Units: The section will include details on the impact of the

Market Rule Section	Type	Topic	Requirement
			application of the physical unit de-rates to the operating regions and associated *energy offers* for *pseudo-units*. o Section 7.2.1.3 – Minimum and Maximum Constraints: The section will include details on the application of minimum and maximum constraints to *pseudo-units* for the following constraints: ▪ *Pseudo-unit* minimum and maximum constraints; ▪ Combustion turbine minimum and maximum constraints; ▪ Steam turbine minimum and maximum constraints; and ▪ Equal steam turbine minimum and maximum constraints. o Section 7.2.1.4 – Treatment of Steam Turbine Forced Outages: The section will include details on the treatment of a *forced outage* for steam turbines associated to a *pseudo-unit*. The PD calculation engine will model the corresponding *pseudo-units* as if the resources were in single-cycle mode. o Section 7.2.1.5 – Single-Cycle Flag Across Two Dispatch Days: The section will include details on the single-cycle mode flag for look-ahead periods that span two *dispatch days* (i.e. for runs starting at 20:00 EST). o Section 7.2.1.6 – Translation of Pseudo-Unit Schedules to Physical Unit Schedules: The section will include details on the translation of *pseudo-unit* schedules to physical unit schedules. The section will detail the translation for (1) when a *pseudo-unit* is scheduled above or at its *minimum loading point* and (2)

Market Rule Section	Type	Topic	Requirement
			when a *pseudo-unit* is scheduled below its *minimum loading point*. • Section 7.2.2 – Pricing for Pseudo-Units: The section will include details on the prices for *pseudo-units* produced by the PD calculation engine.
Section 8	New	Pricing Formulation	This new section sets out the *market rules* around the calculation of locational marginal prices. • Section 8.1 – Overview: The section will provide an overview of the pricing formulation for calculating locational marginal prices including: o Locational marginal prices for *energy*; o Locational marginal prices for *operating reserve*; and o Prices for islanded nodes. • The prices will be determined as follows: o Prices will be calculated using the shadow prices determined by the pricing algorithm, accounting for constraint sensitivities and marginal loss factors. If the prices are not within the maximum clearing price and the *settlement* floor price, the price and its components will be modified by the PD calculation engine. A weighted average of the above locational marginal prices will be used to determine zonal prices for virtual transaction zonal trading entities and for *non-dispatchable load* zones, including the Ontario Zone. Note: If locational marginal prices are unable to be produced due to insufficient information, or if the process fails, it will be flagged for further review by the *IESO*. • Section 8.2 – Locational Marginal Prices for Energy: The section will include details on the

Market Rule Section	Type	Topic	Requirement
			price formulation for *energy* locational marginal prices for: o Internal pricing nodes; o *Intertie zone* source and sink buses; and o Zones. • Section 8.3 – Locational Marginal Prices for Operating Reserve: The section will include details on the price formulation for *operating reserve* locational marginal prices for: o Internal pricing nodes; and o *Intertie zone* source and sink buses. • Section 8.4 – Prices for Islanded Nodes: The section will include details for: o The reconnection methodology for non-quick-start resources that are not connected to the main island of the system; and o The substitution methodology used to produce a price for all other pricing nodes that are not connected to the main island of the system due to one of the following reasons: ▪ Transmission *outage*; ▪ Disconnection; ▪ A resource being out of service; or ▪ Operation in *segregated mode of operation*.
Section 9	New	Tie-Breaking	This new section sets out the *market rules* around the tie-breaking methodology. • Section 9.1 – Overview: The section will provide an overview of the tie-breaking methodology used in the optimization function. Two tie-breaking methods will be used as follows: o Section 9.1.1 - Except as otherwise noted in section 9.1.2, if two or more *bids/offers* for *energy* or *offers* for

Market Rule Section	Type	Topic	Requirement
			operating reserve have the same *bid/offer* price that does not cause differences in the cost to the market of utilising each *bid/offer*, the schedules from these *bids/offers* shall be prorated based on an amount of *energy bid/offered* at that *bid/offer price* (or based on an amount *operating reserved offered* at the *offer price*). o Section 9.1.2 - For *variable generators* that are *registered market participants*, if two or more *energy offers* have the same *offer* price resulting in no differences in the cost to the *IESO-administered markets* of utilising any of the *offers*. The schedules for these *offers* shall be determined using the daily *dispatch* order for *variable generation* using a tie-breaking modifier.

Table 4-4: Market Rule Appendix 7.XB Impacts

Market Rule Section	Type	Topic	Requirement
Appendix 7.XB – The Real-Time Calculation Engine Process			
Appendix 7.XB All Sections	New	All Topics	This appendix describes the RT calculation engine process and is included in the RT Calculation Engine detailed design document.

– End of Section –

5. Procedural Requirements

5.1. Market-Facing Procedural Impacts

Existing *market manuals* and training materials related to the PD Calculation Engine processes will be retained to the extent possible. The majority of changes result from the redesigned optimization engine. More specifically, the PD Calculation Engine will optimize over a longer look-ahead period. Updates will be made to all applicable *market manuals* that reflect changes to the PD calculation engine processes.

The documents most directly related to the Pre-Dispatch Calculation Engine detailed design are the following:

Market Manuals:

- Market Manual 4: Market Operations, Part 4.2 - Submission of Dispatch Data in the RT Energy and Operating Reserve Markets;
- Market Manual 4: Market Operations, Part 4.3 - Real Time Scheduling of the Physical Markets;
- Market Manual 4: Market Operations, Part 4.4 - Transmission Rights Auction;
- Market Manual 4: Market Operations, Part 4.5 - Market Suspension and Resumption;
- Market Manual 4: Market Operations, Part 4.6 - RT Generation Cost Guarantee Program
- Market Manual 7: System Operations, Part 7.1 - IESO-Controlled Grid Operating Procedures;
- Market Manual 7: System Operations, Part 7.2 - Near-Term Assessments and Reports;
- Market Manual 7: System Operations, Part 7.4 - IESO-Controlled Grid Operating Policies
- Market Manual 9: Day-Ahead Commitment, Part 9.0 - DACP Overview;
- Market Manual 9: Day-Ahead Commitment, Part 9.2 - Submitting Operational and Market Data for the DACP;
- Market Manual 9: Day-Ahead Commitment, Part 9.3 - Operation of the DACP;
- Market Manual 9: Day-Ahead Commitment, Part 9.4 - Real-Time Integration of the DACP; and

- Market Manual 9: Day-Ahead Commitment, Part - 9.5 Settlement for the DACP; and
- Market Manual 13: Capacity Exports.

Training Material:

- Introduction to Ontario's Physical Markets

The following tables identify sections within *market manuals* and training materials that will not require changes, will require modification and new sections that will need to be added to support the PD Calculation Engine processes in the future market.

Table 5-1: Impacts to Market Manual 4: Market Operations

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.2 – Submission of Dispatch data in the Real-Time Energy and Operating Reserve Markets	No change	All Sections	This detailed design document does not impact this section.
	No change	2.0 Real-Time Energy and Operating Reserve Markets	This detailed design document does not impact this section.
	No change	2.1 Offers and Bids for Energy and Offers for Operating Reserve in the Real-Time Energy Markets	This detailed design document does not impact this section.
	No change	2.2 Energy Schedules and Forecasts	This detailed design document does not impact this section.
	Modification	2.3 Timing of the Real-Time Energy and Operating Reserve Markets	Refer to Grid and Market Operations Integration detailed design document for the list of modifications to this market manual section.

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.2 – Submission of Dispatch data in the Real-Time Energy and Operating Reserve Markets	Modification	2.3.1 Generation Units with Start-Up Delays	Procedure to address *generation units* with start-up delays in PD to be updated to reflect the new lead time and ramp up to MLP *dispatch data* parameters to account for start-up delays in scheduling. Refer to Grid and Market Operations Integration detailed design document for the list of modifications to this market manual section.
	No change	2.3.2 Replacement Energy Offers Program 2.3.3 Procedural Steps for Submitting Dispatch Data and Revisions Until Two Hours Prior to the Dispatch Hour 2.3.4 Procedural Steps for Submitting Dispatch Data and Revisions Within Two Hours of the Dispatch Hour	This detailed design document does not impact this section.
	Modification	2.4 The Structure of Dispatch Data: 2.4.1 Energy Offers and Bids 2.4.2 OR Offers 2.4.3 Energy Schedules and Forecasts	Refer to the Offers, Bids and Data Inputs detailed design document for the list of modifications to this market manual section.
	No change	2.4.4. Standing Dispatch Data	This detailed design document does not impact this section.

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.2 – Submission of Dispatch data in the Real-Time Energy and Operating Reserve Markets	Modification	2.5 Dispatch Data for Importing and Exporting Energy and Importing Operating Reserve	Refer to the Offers, Bids and Data Inputs detailed design document for a list of modifications to this market manual section.
	Modification	2.5.1 Boundary Entity Resources	Refer to the Offers, Bids and Data Inputs detailed design document for a list of modifications to this market manual section.
	No change	2.5.2 Ramp Rates	This detailed design document does not impact this section.
	Modification	2.5.3 e-Tagging	Reference to CMSC and PD short report to be removed. The PD schedules will be *published* in a report.
	Modification	2.5.4 Wheeling Through Interchange Schedules	Refer to the DAM Calculation Engine detailed design document for a list of modifications to this market manual section.
	No change	2.5.5 Validation	This detailed design document does not impact this section.
	No change	2.6 Capacity Exports	This detailed design document does not impact this section.
	Modification	2.6.1 Dispatch Data Requirements for Scheduling a Called Capacity Export	Refer to the Offers, Bids and Data Inputs detailed design document for a list of modifications to this market manual section.
	No change	2.6.2 Changes/Updates to Called Capacity Exports or Capacity Resources	This detailed design document does not impact this section.

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.2 – Submission of Dispatch data in the Real-Time Energy and Operating Reserve Markets	No change	2.7 Requests for Segregated Mode of Operation	This detailed design document does not impact this section.
	Modification	2.8 Publication of Pre-dispatch Schedules	Reference to prices to be replaced by location marginal pricing. Refer to Grid and Market Operations Integration detailed design document for the list of additional modifications to this market manual section.
	Modification	Appendix A: Content of Dispatch Data	Refer to the Offers, Bids and Data Inputs detailed design document for the list of modifications to this market manual section.
	No change	Appendix B: Short Notice Change Criteria	This detailed design document does not impact this section.
	No change	Appendix C: Contingency Plan	This detailed design document does not impact this section.

Procedure	**Type of Change (no change, modification, new)**	**Section**	**Description**
Part 4.2 – Submission of Dispatch data in the Real-Time Energy and Operating Reserve Markets	Modification	Appendix D: Pre-dispatch Schedule Production and Publication	Section D.1 will be updated to reflect that DAM resource commitments will be used as an input into the PD process. Section D.2 will be updated to reflect the evaluation of *intertie* transactions in PD beyond T+3, and remove reference to the re-calculation of *pre-dispatch schedules*. Reference to *market schedules* and prices in section D.4 will be updated to reflect schedule and locational marginal prices. Additional changes to this appendix are described in the Offers, Bids and Data Inputs, and the Grid and Market Operations Integration detailed design documents.
	No change	Appendix E: Boundary Entity Resources Appendix F: Ontario Specific E-Tag Requirements	This detailed design document does not impact this section.
Part 4.3 - Real Time Scheduling of the Physical Markets	No change	1.3 Roles and Responsibilities	This detailed design document does not impact this section.
	No change	2.0 Participant Workstation and Dispatch Workstation	This detailed design document does not impact this section.

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.3 - Real Time Scheduling of the Physical Markets	Modification	3.0 Determining Real-Time Schedules	Footnote to be updated to reflect that the *pre-dispatch scheduling* process will include all the remaining hours of the current *dispatch day*, and from 20:00 EST onward, it will also include all the hours of next *dispatch day*.
	No change	4.0 Determining Market Information	This detailed design document does not impact this section.
	No change	5.0 Releasing Real-Time and Market Information 5.1 Publication of Real-Time Schedule Information 5.1.1 Registered Facilities (other than boundary entities and HDR resources) 5.1.3 Boundary Entities 5.1.4 All Market Participants 5.2 Publication of Real-Time Dispatch Information	This detailed design document does not impact this section.
	No change	5.1.2 Hourly Demand Response (HDR) Resources	This detailed design document does not impact this section.
	No change	6.0 Determining Dispatch Instructions 6.1 Registered Facilities (other than HDR resources and boundary entities)	This detailed design document does not impact this section.

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.3 - Real Time Scheduling of the Physical Markets	No change	6.2 Hourly Demand Response (HDR) Resources 6.3 Boundary Entities	This detailed design document does not impact this section.
	Modification	6.4 Intertie Scheduling Protocols 6.4.1 IESO/NYISO Protocol: NY90 6.4.2 Curtailed and Failed Interchange Schedules 6.4.3 IESO/MISO Protocol: MISO Protocol 6.4.4 IESO/Hydro-Quebec: Bilateral Capacity Agreements	References to *intertie pre-dispatch schedules* will be updated to reflect that *intertie* transaction *offers* and *bids* that are not scheduled in DAM or are received after DAM will not be considered in *pre-dispatch scheduling* for forecast hours beyond T+2, except transactions identified as capacity transactions or to address a system adequacy shortfall. Section will need to be updated to reflect that the curtailment code impact on the scheduling algorithm and the pricing algorithm is equal. Refer to the Grid and Market Operations Integration detailed design document for details of the updates required to this section.
Part 4.3 - Real Time Scheduling of the Physical Markets	Modification	6.5 Pre-Emptive Curtailments	Reference to constrained schedule will be updated to reflect scheduling algorithm, and reference to pre-dispatch constrained and unconstrained sequence to be replaced by the *pre-dispatch scheduling* process, which consists of scheduling, pricing, and market power mitigation.

Procedure	Type of Change (no change, modification, new)	Section	Description
			Refer to the Grid and Market Operations Integration detailed design document for details of the updates required to this section.
Part 4.3 - Real Time Scheduling of the Physical Markets	Modification	6.6 Transaction Coding 6.6.1 Principles of Coding 6.6.2 Methodology for Failure Code Application	References to unconstrained, unconstrained sequence, and *market schedule* will be updated to reflect the pricing algorithm. Section 6.6.2 will be updated to reflect the impact of adequacy curtailments on *intertie* transaction scheduling. Refer to the Grid and Market Operations Integration detailed design document for details of the updates required to this section.
	Modification	6.7 Capacity Export Scheduling and Curtailment 6.7.1 Capacity Export Delivery 6.7.2 Curtailment Provisions	Refer to the Grid and Market Operations Integration detailed design document for details of the updates required to this section.
	No change	7. Issuing Dispatch Instructions 7.1 Registered Facilities (other than HDR resources and boundary entities)	This detailed design document does not impact this section.

Procedure	**Type of Change (no change, modification, new)**	**Section**	**Description**
	Modification	7.2 Hourly Demand Response Resources 7.2.1 Dispatch Instructions for CMPs with HDR Resources	Table 7-2: Procedural Steps for Dispatch Instructions for HDR Resources to be updated to reflect the use of area *demand* forecast and dynamic losses in *pre-dispatch scheduling*, and reference to shadow price will be replaced by locational marginal price.
Part 4.3 - Real Time Scheduling of the Physical Markets	Modification	7.3 Boundary Entities 7.3.1 Dispatch Instructions for Boundary Entities	Reference to *market schedule* to be removed. Table 7-3: Procedural Steps for Boundary Entity Dispatch Instructions to be updated to reflect the use of area *demand* forecast and dynamic losses in *pre-dispatch scheduling*, and *offer* and *bid* price requirement for linked wheel transactions to be removed.
	No change	7.4 Dispatch of Operating Reserve (OR) 7.5 Manual Procurement of Operating Reserve during forced or planned tools outages 7.6 Compliance with Dispatch Instructions	This detailed design document does not impact this section.

Procedure	Type of Change (no change, modification, new)	Section	Description
	Modification	7.7 Generation Units Turnaround Time	Procedure to address *generation unit* turnaround time to be updated to reflect that the *minimum generation block down time* (MGBDT) submitted for different thermal states is respected in *pre-dispatch scheduling*. Refer to the Grid and Market Operations Integration detailed design document for details of the updates required to this section.
Part 4.3 - Real Time Scheduling of the Physical Markets	No change	8. Issuing Dispatch Advisories 8.1 Registered Facilities (other than HDR resources and boundary entities) 8.2 Boundary Entities and HDR Resources 8.2.1 Compliance with Dispatch Advisories	This detailed design document does not impact this section.
	No change	9. Administrative Pricing Appendix A: Administrative Guidelines	This detailed design document does not impact this section.
	No change	10. Compliance Aggregation	This detailed design document does not impact this section.
Part 4.4 - Transmission Rights Auction	No change	All Sections except Appendix B, Appendix C, and Appendix G	No changes required to sections other than Appendix B: Pre-auction Publication, Appendix C: TR Monthly Financial Report, and Appendix G: Summary of Transmission Rights

Procedure	Type of Change (no change, modification, new)	Section	Description
Part 4.4 - Transmission Rights Auction	No change	Appendix B: Pre-auction Publication Appendix C: TR Monthly Financial Report Appendix G: Summary of Transmission Rights	This detailed design document does not impact this section.
Part 4.5 - Market Suspension and Resumption	No change	All Sections	This detailed design document does not impact this section.
Part 4.6 - RT Generation Cost Guarantee Program	Modification	Entire document	Refer to the Grid and Market Operations Integration and Market Settlement detailed design documents for details of the updates required to this section.

Table 5-2: Impacts to Market Manual 7: System Operations

Procedure	Type of change (no change, modification, new)	Section	Description
Part 7.1 - IESO-Controlled Grid Operating Procedures	No change	Entire document	This detailed design document does not impact this section.

Procedure	**Type of change (no change, modification, new)**	**Section**	**Description**
Part 7.2: Near-Term Assessments and Reports	No change	All Sections except Section 2.0, Section 2.4, Section 4.4, and Appendix D.2	No changes required to sections other than Section 2. Adequacy and Transmission Limits Reports, Section 2.4 Producing and Publishing the Ontario Zonal Demand Forecast Report, Section 4.4 IESO Control Actions (Nuclear Manoeuvres Forecasted or Occurring), and Appendix D.2 Forecast Demand
	Modification	2. Adequacy and Transmission Limits Reports 2.4 Producing and Publishing the Ontario Zonal Demand Forecast Report Appendix D.2 Forecast Demand	Section will be updated to reflect that the Ontario total *demand* forecast will be the sum of the *demand* forecast areas.
	Modification	4.4 IESO Control Actions (Nuclear Manoeuvres Forecasted or Occurring)	Reference to constrained-off nuclear unit to be replaced by nuclear reduction to reflect that there is only a single schedule
	No change	5.0 Control Action Operating Reserve	This detailed design document does not impact this section.

Procedure	Type of change (no change, modification, new)	Section	Description
Part 7.3: Outage Management	No change	All Sections except Section 4.1	No changes required to sections other than Section 4.1 Generation Facilities.
	Modification	4.1 Generation Facilities	Section 4.1.1: De-ratings reference to *generation units* with start-up delays in PD to be removed to reflect the new lead time and ramp up to MLP *dispatch data* parameters to account for start-up delays in scheduling. Refer to Grid and Market Operations Integration detailed design document for the list of modifications to this market manual section.
	No change	5.0 Replacement Energy to Support Planned Outages	This detailed design document does not impact this section.
Part 7.4: IESO-Controlled Grid Operating Policies	No change	Entire document	This detailed design document does not impact this section.

Table 5-3: Impacts to Market Manual 9: Day-Ahead Commitment

Procedure	Type of change (no change, modification, new)	Section	Description
Part 9.0: Day-Ahead Commitment Process Overview	Modification	Entire document	Market Manual 9 will be replaced. DACP will be replaced with a financially-binding DAM. Sections will be updated to reflect that the initial PD calculation engine run will occur at 20:00 EST and PD forecast hours.

Procedure	**Type of change (no change, modification, new)**	**Section**	**Description**
Part 9.2: Submitting Operational and Market Data for the DACP	Modification	Entire document	Sections will be updated to reflect the initial PD calculation engine run will occur at 20:00 EST, and the PD calculation engine will evaluate the same *dispatch data* parameters that are submitted for DAM. Update required to reflect that PSU resources will be evaluated by the *pre-dispatch scheduling* process. Additional changes are described in the Offers, Bids and Data Inputs, and the Grid and Market Operations Integration detailed design documents.
Part 9.3: Operation of the Day-Ahead Commitment Process	No change	All Sections except Section 4.2, Section 4.8.2, and Section 4.11.2	No changes required to sections other than Section 4.2 Use of Three-Part Offers in the DACE, 4.8.2 Pre-dispatch Reports, and 4.11.2 Standby Notices and Reports for Hourly Demand Response Resources.
Part 9.3: Operation of the Day-Ahead Commitment Process	Modification	4.2 Use of Three-Part Offers in the DACE	Reference to three-part *offers* to be updated to reflect that it will be evaluated by the pre-PD dispatch calculation engine. Refer to Grid and Market Operations Integration detailed design document for the list of additional modifications to this market manual section.

Procedure	**Type of change (no change, modification, new)**	**Section**	**Description**
Part 9.3: Operation of the Day-Ahead Commitment Process	Modification	4.8.2 Pre-dispatch Reports 4.11.2 Standby Notices and Reports for Hourly Demand Response Resources	Sections will be updated to reflect the initial PD calculation engine run will occur at 20:00 EST and PD forecast hours. Reference to shadow price will be updated to reflect locational marginal pricing.
Part 9.4: Real-Time Integration of the DACP	No change	All Sections except Section 4.1, Section 4.2, Section 4.4, and Section 4.6	No changes required to sections other than Section 4.1 Observing Day-Ahead Commitments in Real Time, 4.2 De-commitment and Withdrawal, 4.4 Real-Time Market Integration, and 4.6 Synchronize Units Committed in the Day-Ahead
	Modification	4.1 Observing Day-Ahead Commitments in Real Time 4.1.2 Passing DACP Commitments to Real Time	Reference to minimum constraint and initial PD calculation engine run time will be updated. Refer to Grid and Market Operations Integration detailed design document for the list of additional modifications to this market manual section.
	Modification	4.2 De-commitment and Withdrawal	Reference to Ontario *energy* price, Ontario market clearing price, and *real-time market* clearing price will be updated to reflect locational marginal pricing.

Procedure	Type of change (no change, modification, new)	Section	Description
Part 9.4: Real-Time Integration of the DACP	Modification	4.4 Real-Time Market Integration 4.4.1 Pseudo Unit Offer Submission — Real Time 4.4.2 Minimum Loading Point Price Cap	Section will be updated to reflect that the PD calculation engine will evaluate the same *dispatch data* parameters that are submitted for DAM. Update required to reflect that PSU resources will be evaluated by the PD calculation engine. Additional changes are described in the Offers, Bids and Data Inputs, and the Grid and Market Operations Integration detailed design documents.
	Modification	4.6 Synchronize Units Committed in the Day-Ahead	Section to be updated to reflect that the time required to start and synchronize the resource will be considered by the PD calculation engine, and the *IESO* will issue binding start-up instruction to committed resources. Refer to Grid and Market Operations Integration detailed design document for the list of additional modifications to this market manual section.
Part 9.5: Settlement for the Day-Ahead Commitment Process	Modification	Entire document	Refer to the Market Settlement detailed design document for details of the updates required to this section.

Table 5-4: Impacts to Market Manual 13: Capacity Exports

Procedure	Type of change (no change, modification, new)	Section	Description
Part 13.1: Capacity Export Requests	No change	Entire document	This detailed design document does not impact this section.

5.2. Internal Procedural Impacts

Some of the internal procedures identified in this section are related to other *IESO* processes that interact with the PD Calculation Engine processes. Changes to the PD Calculation Engine processes under the market renewal program will have an impact on other internal *manuals* related to the day-ahead, pre-dispatch and real-time dispatch and scheduling processes.

In addition, some areas of the current procedures heavily reference relevant *market rules* and supporting tools, most of which will be undergoing changes as a result of the new day-ahead market implementation and other solution enhancements. The existing procedures will be updated to account for the corresponding changes in the *market rules* and tools.

Changes or additions to internal *IESO* procedures are for internal *IESO* use as documented in Appendix B and are not included in the public version of this document. Appendix B details the impacts to internal procedures in terms of existing procedures that support the new market requirements, existing procedures that need to be updated, and new internal procedures that need to be created to support the future *real-time market* and day-ahead market.

– End of Section –

6. Business Process and Information Flow Overview

6.1. Market-Facing Process Impacts

This section provides an overview to the arrangement of processes required in order to support the overall PD Calculation Engine processes and the critical information flows between them.

The context diagrams presented in Section 2 of this document are considered as level 0 data flow diagrams and represent the major flows of information into and out of the Pre-Dispatch Calculation Engine process. This section now presents the Pre-Dispatch Calculation Engine process at the next level of detail (level 1). A further break-down of the processes presented in this section (i.e. levels 2,3,4…) falls into the realm of systems design and is beyond the scope of this document.

The data flow diagram does not illustrate:

- flow of time or sequence of events (as might be illustrated in a timeline diagram);
- decision rules (as might be illustrated in Flowchart); and
- logical architecture and systems architecture (as might be illustrated in a Logical Application and Data Architecture, and/or Physical Application and Data Architecture).

What it does illustrate however, is a logical breakdown of the sub-processes that constitute a large and complex system such as the Pre-Dispatch Calculation Engine process. Specifically, the data flow diagram presented below illustrates:

- the Pre-Dispatch Calculation Engine process as a grouping of several major and tightly coupled sub-processes;
- the key information flows between each of the processes;
- external sources of key information required by the Pre-Dispatch Calculation Engine process;
- external destinations of key information from the Pre-Dispatch Calculation Engine process; and
- the same logical boundary of the Pre-Dispatch Calculation Engine process as illustrated in the Level 0 context diagram presented in Section 2 of this document.

This section is not meant to impart information systems or technology architecture, but rather to capture the entire Pre-Dispatch Calculation Engine process as a series of interrelated sub-processes.

The functional design outlined in Section 3 of this document maps to the business process overview presented in this section. In any areas where there are inconsistencies between this section and the description of the business process provided in Section 3, the business process described in Section 3 will take precedence.

The data flow diagram illustrated in Figure 6-1 presents the Pre-Dispatch Calculation Engine processes. The following sections of this document will provide an overview to each of the main sub-processes of the Pre-Dispatch Calculation Engine process.

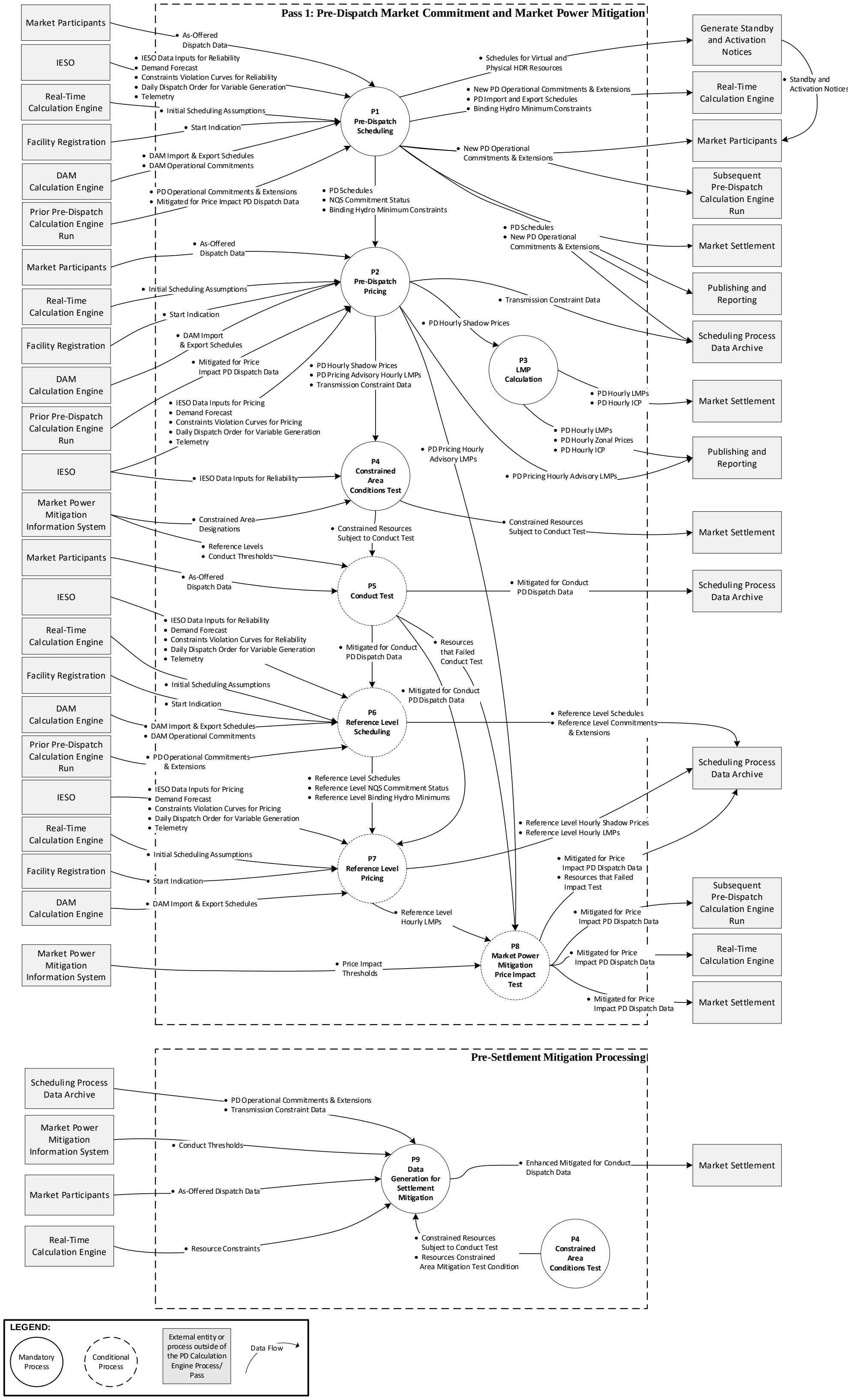

Figure 6-1: Level 1 Information Flow Diagram for the PD Calculation Engine

6.1.1. PD Processes for Scheduling and Price Formation

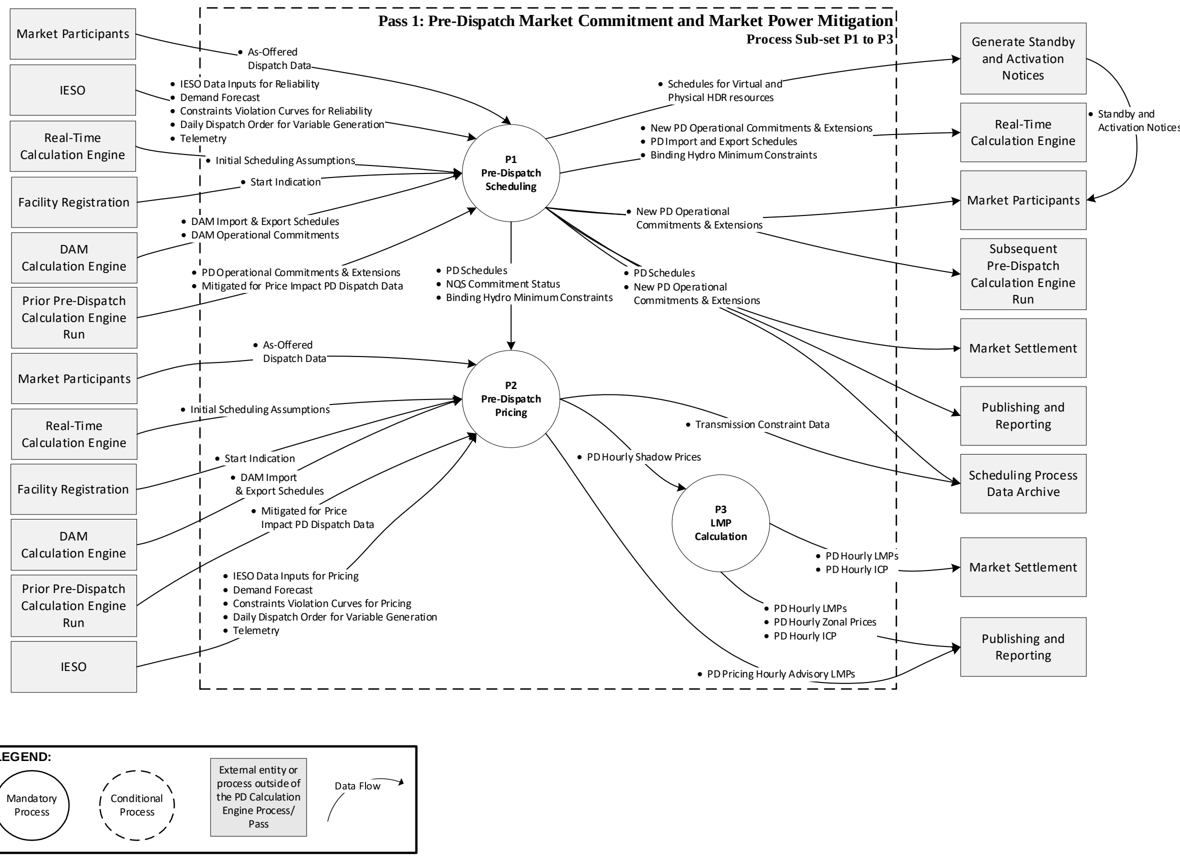

Figure 6-2: Level 1 Information Flow Diagram for Sub-Set of Pass 1 - P1 to P3

6.1.1.1 Process P1 – Pre-Dispatch Scheduling

Description

This process determines a set of advisory resource schedules for all dispatchable generation and load resources, non-dispatchable generation resources and *intertie* transactions. It also determines the PD operational commitments for eligible NQS resources. It maximizes the gains from trade using as-offered *dispatch data* from *market participants* except for the *dispatch data* that was mitigated in ex-ante Market Power Mitigation in a previous run of pre-dispatch. It also uses *IESO* data inputs including the constraint violation penalty curves for meeting the *IESO*'s *reliability* requirements.

Input and Output Data Flows

Table 6-1: Process P1 Input and Output Data Flows

Flow	Source	Target	Frequency
As-Offered Dispatch Data	Market Participants	P1	Hourly

Description:

- The as-offered *dispatch data* refers to the set of *dispatch data* for physical resources submitted by *market participants* for use in the PD scheduling process. As specified in the Grid and Market Operations Integration detailed design document, this data is initially submitted into the day-ahead market then updated based on any submitted revisions new additions to this data for the PD scheduling process. This data includes both hourly and daily *dispatch data* for *energy* and *operating reserve*.
- As-offered *dispatch data* must comply with the requirements for submission timing, revision, and restrictions specified in the Grid and Market Operations Integration detailed design document, and must have successfully passed the validation of non-financial *dispatch data* and financial *dispatch data* upon submission.

The *dispatch data* parameters listed below are submitted by *market participants* into the PD scheduling process of the *real-time market*:

- Hourly *energy bids* for:
  - Exports;
  - *Dispatchable loads*; and
  - *Hourly demand response* (HDR) resources.
- Financial *dispatch data* parameters are submitted by *market participants* for the specified resource type:
  - Hourly *energy offers* for:
    - Imports;

        - Dispatchable *generation facilities* including *variable generation*; and
        - Non-dispatchable *generation facilities*;
    - Hourly start-up *offers* for:
        - NQS generation facilities;
    - Hourly speed no-load *offers* for:
        - NQS generation facilities;
    - Hourly synchronized *ten-minute operating reserve offers* for:
        - *Dispatchable loads*; and
        - Dispatchable generation resources;
    - Hourly non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve offers* for:
        - Imports;
        - Exports;
        - *Dispatchable loads*; and
        - Dispatchable generation resources.

The non-financial *dispatch data* parameters listed below can be submitted by *market participants* for the specified resource type:

- For import *offers* and export *bids*:
    - e-Tag identifiers;
- For *hourly demand response* resources:
    - *Energy* ramp rates;
- For *dispatchable loads* and dispatchable *generation facilities*:
    - *Energy* ramp rates; and
    - *Operating reserve* ramp rate;
- For dispatchable generation facilities:
    - Minimum loading point (MLP);
    - reserve loading point for *thirty-minute operating reserve*; and
    - reserve loading point for synchronized *ten-minute operating reserve*;
- For *energy*-limited generation facilities:
    - Maximum daily *energy* limit;
- For dispatchable hydroelectric *generation facilities*:
    - Hourly must run;
    - Minimum hourly output;
    - Minimum daily *energy* limit;
    - Shared minimum daily *energy* limit, when applicable;
    - Shared maximum daily *energy* limit, when applicable;
    - Maximum number of starts per day;

- Forbidden regions; and
- Linked resources, time lag and MWh ratio.

- For NQS *generation facilities*, including physical unit and *pseudo-unit* resources*:*
  - Minimum loading point (MLP);
  - Minimum generation block run-time;
  - *Minimum generation block down-time* for thermal states of hot, warm and cold;
  - Maximum number of starts per day;
  - Ramp up *energy* to MLP (ramp hours to MLP; and *energy* per ramp hour) for thermal states of hot, warm and cold;
  - Single cycle mode flag, for PSU resources only;
  - Lead time for thermal states of hot, warm and cold.

For detailed descriptions, attributes and usage of the above *dispatch data* parameters, refer to Section 3.4.1 from Table 3-1 to Table 3-11.

Flow	Source	Target	Frequency
IESO Data Inputs for Reliability	IESO	P1	Hourly

Description:

The following *IESO* inputs will be used by Process P1 for the future *pre-dispatch scheduling* process:

- *Operating reserve* (OR) requirements for:
  - Synchronized and non-synchronized *ten-minute operating reserve*;
  - *Thirty-minute operating reserve*; and
  - Regional *operating reserve* minimum requirements and maximum restrictions.
- Refer to Section 3.4.1.5 for details of *operating reserve* requirements.

- Resource minimum and maximum constraints, including *reliability* constraints and *intertie* curtailments, for:
  - *Dispatchable loads*;
  - Dispatchable and non-dispatchable generation resources; and
  - *Intertie* transactions.
  - Refer to Section 3.4.1.5 for details of resource minimum and maximum constraints.
  - *Variable generation* resources.
  - Refer to Section 3.4.1.4 for details of *energy* schedule limits applied by use of the *IESO variable generation* forecast
- Network model: The network model contains a detailed topology representation of the *IESO-controlled grid* and a simplified representation of power systems in neighboring jurisdictions.

- For more information on the information required by the *security* assessment function of the P1 process, refer to Section 3.7.1.3.

Flow	Source	Target	Frequency
Demand Forecast	IESO	P1	Hourly

Description:

- The hourly *demand* forecast will be produced at the province-wide level as the sum of four separate area *demand* forecasts and for each time-step of the PD look-ahead period. Before the optimization function uses these forecasts, they will be adjusted as described in Section 3.11 to arrive at a quantity that is representative of load that is considered non-dispatchable and is inclusive of losses.
- The *IESO* specifies whether the PD calculation engine will use the average *demand* forecast or the peak *demand* forecast to determine the forecast quantity used within the optimization for a given PD time-step of the look-ahead period.
- Refer to Section 3.4.1.3, Section 3.7.1.3, and Section 3.11 for the use of the *demand* forecasts by the PD calculation engine.

Flow	Source	Target	Frequency
Constraint Violation Curves for Reliability	IESO	P1	Daily

Description:

- Constraint violation penalty curves will continue to be defined as the penalty functions for the violation of constraints in the scheduling algorithm. These penalty curves establish the value placed on satisfying a constraint and indicate the relative priority of satisfying a certain constraint compared to other constraints.
- The constraint violation penalty curves for *reliability* will be used by the scheduling algorithm to produce a solution when satisfying all constraints is not feasible and to evaluate if the cost of satisfying a constraint is too high relative to the applicable penalty cost.
- Refer to Section 3.4.1.5 for a detailed description of constraint violation penalties.

Flow	Source	Target	Frequency
Daily Dispatch Order for Variable Generation	IESO	P1	Daily

Description:

- The daily *dispatch* order is required for tie-breaking when scheduling *variable generation*. This data is used to break ties when two or more *energy offers* from *variable generation* resources are such that there is no difference in the cost to the market of using either *offer*.

Flow	Source	Target	Frequency
Initial Scheduling Assumptions	Real-Time Calculation Engine	P1	Hourly

Description:

- Initial scheduling assumptions are used by the PD calculation engine to represent the state of each resource at the start of each PD calculation engine run. Initial scheduling assumptions are based on the advisory schedules calculated by the RT calculation engine run.
- Refer to Section 3.4.1.6 for details of the data specifying the initial schedules and commitment of resources used by the PD calculation engine.

Flow	Source	Target	Frequency
Start Indication Value	Facility Registration	P1	Hourly

Description:

- Start indication value is a new optional registration parameter that represents the minimum quantity of *energy* a resource must be scheduled to determine whether the *generation units* associated with the resource have used up one or more of their *maximum number of starts per day*. For more details on this parameter, refer to the Facility Registration detailed design document.
- The PD engine will use the start indication value for hydroelectric generation resources to limit the cumulative number of starts that occur on a *dispatch day* to the number of starts indicated in the daily *dispatch data* submission.
- Refer to Section 3.6.1.5 for a detailed description on how the start indication value is used as a multi-hour constraint for hydroelectric generation resources.

Flow	Source	Target	Frequency
Telemetry	IESO	P1	Hourly

Description:

The P1 process uses the current *dispatch day* telemetry data to determine *energy* management system data that identifies the output of *generation facilities* within *the IESO-controlled grid* to inform the initial scheduling assumptions as follows:

- The cumulative output of linked hydroelectric generation resources will be used to determine the past hourly *energy* production of upstream resources, which will in turn be used to schedule downstream resources for time-steps in the look-ahead period within the time lag.
- The cumulative output of *energy* limited and hydroelectric generation resources will be used to determine the tracked *energy* used for a *dispatch day* for scheduling resource daily minimum and maximum *energy* limits.
- The historical output from the current *dispatch day* will be used to determine the number of starts performed by a hydroelectric generation resource so far in the *dispatch day*.
- The historical output from the current *dispatch day* will be used to determine the number of starts performed by an NQS generation resource so far in the dispatch day.
- Refer to Section 3.4.1.6 for a detailed description of telemetry data used for Initial Scheduling Assumptions.

Flow	**Source**	**Target**	**Frequency**
DAM Import and Export Schedules	DAM Calculation Engine	P1	Hourly

Description:

- The DAM export schedule quantities will create a maximum constraint for export schedules beyond the first two forecast hours of the PD look-ahead period; and the DAM import schedule quantities will create a maximum constraint for import schedules beyond the first two forecast hours of the PD look-ahead period.
- Refer to Section 3.6.1.4 for details of *energy* and *operating reserve* export and import transactions limited by DAM scheduled *intertie* transactions beyond the first two forecast hours of the PD look-ahead period, and the potential exemptions from this rule.

Flow	**Source**	**Target**	**Frequency**
DAM Operational Commitments	DAM Calculation Engine	P1	Hourly

Description:

- DAM operational commitments will be used to create a minimum constraint for an NQS resource so that it is scheduled to at least its *minimum loading point* for the time-steps of the DAM operational commitment.
- Refer to Sections 3.4.1.5 and 3.6.1.3 for details regarding minimum constraints applied to NQS generation resources arising from DAM operational commitments.

Flow	Source	Target	Frequency
PD Operational Commitments and Extensions	Prior Pre-Dispatch Calculation Engine Run	P1	Hourly

Description:

- PD operational commitments and extensions for NQS resources that were established in prior PD runs will be used to create a minimum constraint for an NQS *generation unit* so that it is scheduled to its *minimum loading point* for the time-steps of the PD operational commitment.
- Refer to Section 3.4.1.5 and Section 3.6.1.5 for details regarding minimum constraints applied to NQS generation resources arising from PD operational commitments.

Flow	Source	Target	Frequency
Mitigated for Price Impact PD Dispatch Data	Prior Pre-Dispatch Calculation Engine Run	P1, Subsequent Pre-Dispatch Calculation Engine Run	Hourly

Description:

- If an as-offered financial *dispatch data* parameter is mitigated to its reference level for a given hour based on a price impact test in a prior run of the PD calculation engine, the reference level will replace that as-offered financial *dispatch data* parameter for the given hour in every subsequent run of the PD calculation, unless:
    - o The as-offered financial *dispatch data* parameter is resubmitted with a price that is lower than the reference level.
- If an as-offered financial *dispatch data* parameter for a given hour is not mitigated in a prior PD calculation engine run, then the current as-offered financial *dispatch data* parameters will continue to be used by the PD calculation engine.

The above applies to the following financial *dispatch data*:

- *Offers* for *energy* for a dispatchable generation resource;
- *Offers* for *operating reserve* for a *dispatchable load* or a dispatchable generation resource; and
- For NQS resources, start-up *offers*, speed no-load *offers* and *energy offers* for the *energy* to MLP.

Flow	Source	Target	Frequency
Schedules for Virtual and Physical HDR Resources	P1	Generate Standby and Activation Notices	Hourly

Description:

Hourly demand response resource schedules will be calculated in each hour by the PD calculation engine. Hourly schedules will be produced for:

- Virtual *hourly demand response* resources;
- Physical HDR resources associated with *non-dispatchable loads*; and
- Physical HDR resources associated with price responsive loads.
- Based on these schedules, the *hourly demand response* resources may be placed on standby or activated to provide load reduction through the issuance of Standby and Activation Notices.

Flow	Source	Target	Frequency
New PD Operational Commitments and Extensions	P1	Subsequent Pre-Dispatch Calculation Engine Runs Real-Time Calculation Engine Market Settlement Market Participants Scheduling Process Data Archive	Hourly

Description:

- PD operational commitments and extensions for NQS resources that are established in the current PD run will be used to create a minimum constraint for an NQS resource so that it is scheduled by subsequent PD runs to at least its *minimum loading point* for the time-steps of the PD operational commitment.
- For more information, refer to Section 3.6.1.7.

Flow	Source	Target	Frequency
PD Import and Export Schedules	P1	Real-Time Calculation Engine	Hourly

Description:

- Pre-Dispatch Scheduling will produce schedules for *energy,* non-synchronized *ten-minute operating reserve, and thirty-minute operating reserve* for imports and exports;
- The PD import and export schedules for the first hour of the PD look-ahead period will be the *intertie* schedules for the RT calculation engine, subject to *intertie* check-out with neighbouring jurisdictions and *intertie* curtailments.
- For more information, refer to Section 3.6.1.7.

Flow	Source	Target	Frequency
Binding Hydro Minimum Constraints	P1	Real-Time Calculation Engine	Hourly

Description:

- For a given time step, the binding hydro minimum constraints will inform the RT calculation engine whether the hydroelectric resource must be scheduled to a minimum quantity required to respect the resource's daily minimum *energy* output in a given time step.

Flow	Source	Target	Frequency
PD Schedules	P1	Market Settlement Publishing and Reporting P2 Scheduling Process Data Archive	Hourly

Description:

- Pre-Dispatch Scheduling will produce schedules for the following resources and markets:
    - Energy, synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve*, and *thirty-minute operating reserve* schedules for dispatchable generation resources and *dispatchable load* resources;
    - E*nergy,* non-synchronized *ten-minute operating reserve, and thirty-minute operating reserve* for imports and exports;
    - *Energy,* synchronized *ten-minute operating reserve,* non-synchronized *ten-minute operating reserve, and thirty-minute operating reserve* schedules for the CT and ST physical units operating as a *pseudo-unit* (PSU) will be computed from the PSU schedules; and
    - *Energy* schedules for non-dispatchable generation resources.
- These schedules will be used as:
    - advisory information for *market participants*;
    - input into the Pre-Settlement Mitigation process;
    - input into Market Settlement for charge type eligibility and calculation; and
    - input into Pre-Dispatch Pricing to calculate prices in accordance with price-setting eligibility rules.

Flow	Source	Target	Frequency
NQS Commitment Status	P1	P2	Hourly

Description:

• The NQS commitment status will inform the PD Pricing Process P2 as to whether the NQS resource has a potential or actual operational commitment or extension in each time step result from Pre-Dispatch Scheduling Process P1.
  o Actual operational commitments and extensions may be DAM operational commitments, prior PD operational commitment and extensions, or new PD operational commitments and extensions.
  o Potential operational commitments are commitment decisions made in the most recent PD Scheduling Process P1 that will not create binding commitments for NQS resources.

6.1.1.2 Process P2 – Pre-Dispatch Pricing

Description

The Pre-Dispatch Pricing process will calculate shadow prices for all constraints contributing to locational prices. These shadow prices will be used in Process P3: LMP Price Calculation to calculate the LMPs that account for all resource and system constraints.

The Pre-Dispatch Pricing process uses the same set of *market participant* and *IESO* inputs used in Process P1: Pre-Dispatch Scheduling, with one main exception: the constraint violation penalty curves that are relevant for pricing.

Input and Output Data Flows

Table 6-2: Process P2 Input and Output Data Flows

Flow	**Source**	**Target**	**Frequency**
As-Offered Dispatch Data	Market Participants	P2	Hourly
Description: Process P2 uses the same as-offered *dispatch data* as used by Process P1. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
IESO Data Inputs for Pricing	IESO	P2	Hourly

Description: • The following *IESO* inputs will be used by Process P2: o Same inputs described as IESO Data Inputs for Reliability in Process P1; o *MMCP* - The *maximum market clearing price* (*MMCP*) will continue to define the maximum allowable price for *energy*, and the negative of which will continue to be the minimum allowable price for *energy* (negative *MMCP*); o *MORP* - The *maximum operating reserve price* (*MORP*) will continue to define the maximum allowable price for any class of *operating reserve*; and o *Settlement* floor prices.			
Flow	**Source**	**Target**	**Frequency**
Demand Forecast	IESO	P2	Hourly
Description: This process uses the same *demand* forecast data that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Constraint Violation Curves for Pricing	IESO	P2	Daily
Description: • Constraint violation penalty curves will continue to be defined as the penalty functions for the violation of constraints in the pricing algorithm. These penalty curves establish the value placed on satisfying a constraint and indicate the relative priority of satisfying a certain constraint compared to other constraints. • The constraint violation penalty curves for pricing will be used by the pricing algorithm to calculate *market prices* in order to produce PD prices. • Refer to Section 3.4.1.5 for a detailed description of violation penalties.			
Flow	**Source**	**Target**	**Frequency**
Daily Dispatch Order for Variable Generation	IESO	P2	Daily
Description: This process uses the same daily *dispatch* order for *variable generation* that Process P1 used. See description in Process P1 above.			

Flow	Source	Target	Frequency
Initial Scheduling Assumptions	Real-Time Calculation Engine	P2	Hourly
Description: This process uses the same initial scheduling assumptions that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Start Indication	Facility Registration	P2	Hourly
Description: This process uses the same Start Indication that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Telemetry	IESO	P2	Hourly
Description: This process uses the same Telemetry that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
DAM Import and Export Schedules	DAM Calculation Engine	P2	Hourly
Description: This process uses the same DAM import and export schedules that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Mitigated for Price Impact PD Dispatch Data	Prior Pre-Dispatch Calculation Engine Run	P2	Hourly
Description: This process uses the same mitigated for price impact PD *dispatch data* that Process P1 used. See description in Process P1 above.			

Flow	Source	Target	Frequency
NQS Commitment Status	P1	P2	Hourly

Description:

See description of output in Process P1 above.

Flow	Source	Target	Frequency
Binding Hydro Minimum Constraints	P1	P2	Hourly

Description:

See description of output in Process P1 above.

Flow	Source	Target	Frequency
PD Schedules	P1	P2	Hourly

Description:

See description of output in Process P1 above.

Flow	Source	Target	Frequency
PD Hourly Shadow Prices	P2	P3 P4	Hourly

Description:

- A shadow price reflects the cost savings achieved by relaxing a constraint by a small amount and measuring the marginal response on the objective function.
- Shadow prices will be used to calculate the PD Pricing hourly advisory LMPs and all of the PD hourly LMPs.
- Refer to Section 3.4, Table 3-13 for details of shadow price outputs from PD Pricing.

Flow	Source	Target	Frequency
PD Hourly LMPs	P2	Publishing and Reporting P4 P8	Hourly

Description:

- LMPs represent the cost to supply an incremental load (for *energy*) or reserve requirement (for *operating reserve*) at a specific location on the transmission grid.

- PD Pricing Advisory Hourly LMPs will be calculated using the pricing formulas provided in Section 3.8, which specify how constraint shadow prices marginal loss factors and constraint sensitivities are used to determine an LMP and its components.
- The PD Pricing Advisory Hourly LMPs and their components for *energy* and *operating reserve* are used as inputs into Process P4: Constraint Area Conditions Test and Process P8: Price Impact Test.
- Refer to Section 3.6.2.7, Table 3-14 for details of LMP Outputs from Pre-Dispatch Pricing.

Flow	Source	Target	Frequency
Transmission Constraint Data	P2	P4 Scheduling Process Data Archive	Hourly

Description:

- The transmission constraint data from the constrained area conditions test, and stored in the Scheduling Process Data Archive for use in the Process P9: Data Generation for Settlement Mitigation.
- This data includes:
    - The set of binding and non-binding transmission constraints; and
    - The sensitivity factors for each binding or non-binding transmission constraint.
- Process P4 will use only the binding constraint data, and Process P9 will use both binding and non-binding constraint data.

6.1.1.3 Process P3 – LMP Price Calculation

Description

The PD calculation engine will calculate LMPs for all pricing nodes using shadow prices, constraint sensitivities and marginal loss factors produced by Pre-Dispatch Pricing.

Input and Output Data Flows

Table 6-3: Process P3 Input and Output Data Flows

Flow	Source	Target	Frequency
PD Hourly Shadow Prices	P2	P3	Hourly

Description:

- See description of output in Process P2.

Flow	**Source**	**Target**	**Frequency**
PD Hourly LMPs	P3	Publishing and Reporting Market Settlement	Hourly

Description:

- LMPs represents the cost to supply an incremental load (for *energy*) or reserve requirement (for *operating reserve*) at a specific location on the transmission grid.
- PD Hourly LMPs are the PD Pricing Advisory Hourly LMPs that have been limited by the maximum clearing price and the *settlement* floor price.
- The following PD Hourly LMPs will be calculated:
    - LMPs for *energy* will be calculated for the following pricing nodes:
        - Dispatchable and non-dispatchable generation resource buses;
        - *Dispatchable load* and *hourly demand response* resource buses;
        - *Non-dispatchable load* and price responsive load buses; and
        - *Intertie zone* source and sink buses.
    - LMPs for *operating reserve* will be calculated for the following pricing nodes:
        - Dispatchable generation resource buses;
        - *Dispatchable load* buses; and
        - *Intertie zone* source and sink buses.
    - The *energy* and *operating reserve* LMPs for NQS generation resources and *intertie zones* sources and sinks are required for Market Settlement.
- Refer to Section 3.6.4 for details on the hourly LMPs required for Market Settlement.
- Refer to Section 3.8 for details on the calculation of hourly LMPs.

Flow	**Source**	**Target**	**Frequency**
PD Hourly Zonal Prices	P3	Publishing and Reporting	Daily

Description:

- The PD calculation engine will also produce several zonal prices that are aggregated based on the weighted average of PD Hourly LMPs at multiple load locations within the province. The following zonal prices will be produced:
  - The hourly Ontario zonal price is a single province-wide price.
  - Nine virtual transaction zonal trading entity prices.
- These prices are advisory and for information purposes only.
- Refer to Section 3.8 for details on the calculation of zonal prices.

Flow	Source	Target	Frequency
PD Hourly ICP	P3	Publishing and Reporting Market Settlement	Daily

Description:

- The PD calculation engine will also produce the hourly *intertie congestion price* (*ICP*).
- Refer to Section 3.8.1.2 and Section 3.6.2.3, Table 3-1 for details of the *ICP* calculation.

6.1.2. PD Processes for Market Power Mitigation

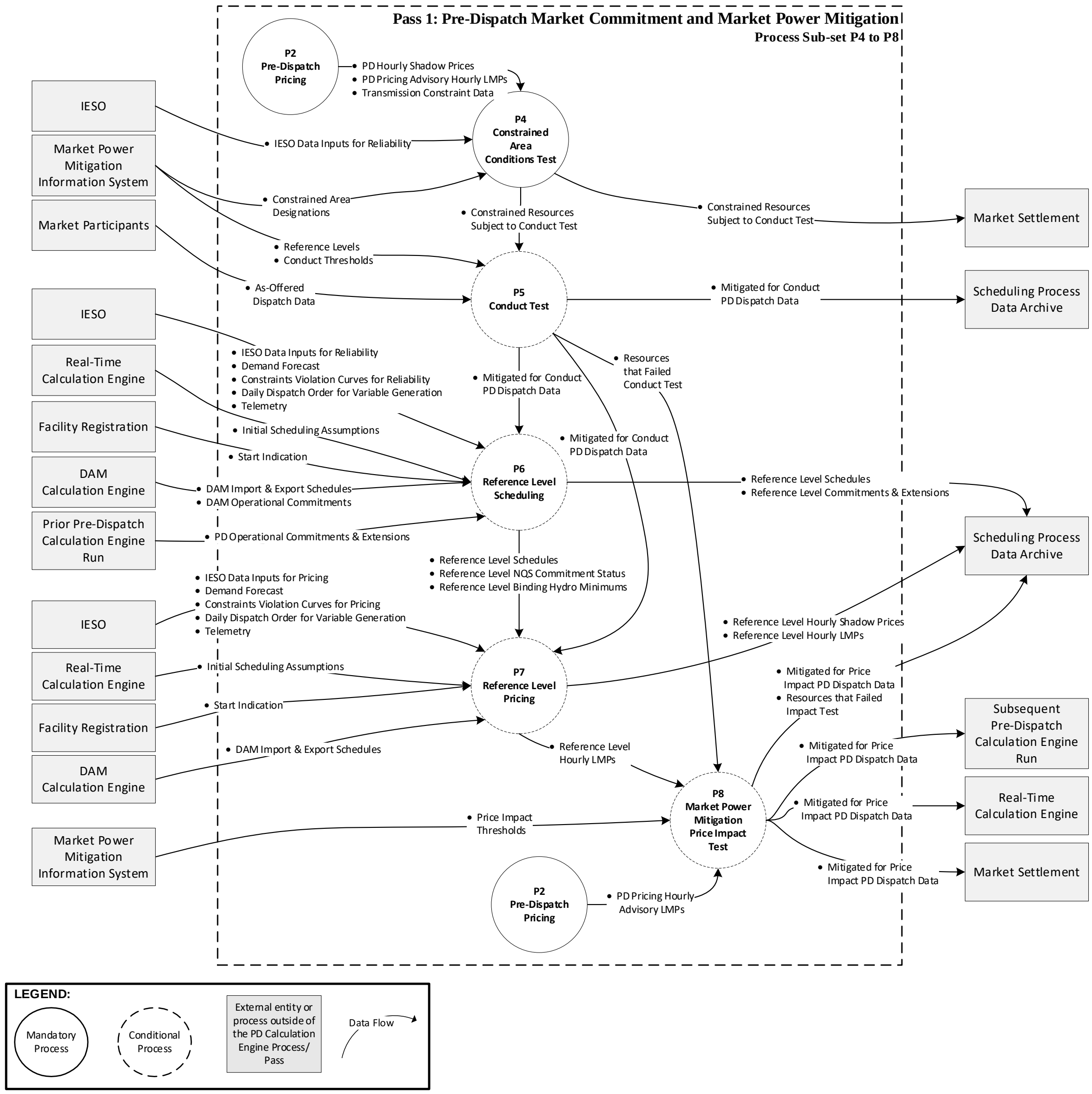

Figure 6-3: Level 1 Information Flow Diagram for Sub-Set of Pass 1 – P4 to P8

6.1.2.1 Process P4 – Constrained Area Conditions Test

Description

When an area is constrained from being supplied by additional resources, competition is reduced and this creates the potential for the exercise of market power. The Process P4: Constrained Area Conditions Test will check if resources meet the predefined conditions for a constrained area and use the results of the Process P2: Pre-Dispatch Pricing to determine if Process P5: Conduct Test needs to be initiated.

Each of the following conditions will be tested for separately:

- Local Market Power (*Energy*), including:
    - Narrow Constrained Area (NCA)
    - Dynamic Constrained Area (DCA)
    - Broad Constrained Area (BCA)
- Global Market Power (*Energy*)
- Global Market Power (*Operating Reserve*)
- Local Market Power (*Operating Reserve*)

Refer to the Market Power Mitigation detailed design document for more information on NCAs, DCAs and BCAs.

Input and Output Data Flows

Table 6-4: Process P4 Input and Output Data Flows

Flow	Source	Target	Frequency
IESO Data Inputs for Reliability	IESO	P4	Event-based
Description: • The *operating reserve* requirements from the *IESO* data inputs for *reliability* used by Process P1 are used by this process. See description in Process P1 above. • See Section 3.6.3 for further details.			
Flow	**Source**	**Target**	**Frequency**
PD Hourly Shadow Prices	P2	P4	Hourly
Description: See description of output in Process P2 above.			
Flow	**Source**	**Target**	**Frequency**
PD Hourly LMPs	P2	P4	Hourly
Description: See description of output in Process P2 above.			

Flow	Source	Target	Frequency
Transmission Constraint Data	P2	P4	Hourly

Description:

- See description of output in Process P2 above.
- This set of binding transmission constraints will be used in combination with the constrained area designations test to determine the set of resources identified as within a constrained area that may have local market power within an NCA or DCA for *energy* and *operating reserve*.
- Refer to Section 3.6.3 for further details.

Flow	Source	Target	Frequency
Constrained Area Designations	Market Power Mitigation Information System	P4	Hourly

Description:

- Constrained area designations input data defines three types of constrained areas: NCA, DCA, and BCA. The *IESO* will define these areas based on how frequently the transmission constraints bind in an area, as follows:
    - NCAs are areas where congestion is expected to be relatively frequent over a long duration. The *IESO* will assess NCA designations on an annual basis;
    - DCAs will be designated when congestion is expected to be relatively frequent but not for a long enough duration to warrant the designation of an NCA. An example of such a condition might be a transmission *outage* that results in, or is expected to result in, increased congestion leading into a load pocket for a period of days. In such cases, these load pockets will be designated as a DCA for the duration of these conditions.
    - BCA are areas where transmission constraints that are not NCA or DCA constraints, result in supply resources being dispatched up. Transmission constraints that create load pockets that bind relatively infrequently make up the BCA.
- The constrained area designations input data will include:
    - A list of OSLs applicable for each NCA and DCA;
    - the resources located within each NCA, DCA and BCA; and
    - the constrained area thresholds, against which the resource's LMP congestion component is compared.

Flow	Source	Target	Frequency
Constrained Resources Subject to Conduct Test	P4	P5 P9 Market Settlement	Hourly

Description:

- This is a list of all resources that met the criteria for each constrained area conditions test. A different set of resources will be identified for each market power condition.
- This list of resources will be required as inputs into:
  - Process P5 for the market power mitigation conduct test,
  - Process P9 to generate data for pre-settlement enhancement of mitigated *dispatch data*; and
  - The Resource Constrained Area Mitigation Test Conditions required for Process P9: Data Generation for Settlement Mitigation.

Flow	Source	Target	Frequency
Resource Constrained Area Mitigation Test Conditions	P4	P9	Daily

Description:

- The set of constrained area mitigation conditions that were met for each resource located within an NCA, DCA or BCA during each time-step of the PD look-ahead period to qualify for mitigation testing for:
  - Local Market Power (*energy*);
  - Global Market Power (*energy*);
  - Local Market Power (*operating reserve*); and
  - Global Market Power (*operating reserve*).
- The relevant impact threshold used in make-whole payment impact testing for each *market participant* will be applied depending on the constrained area condition under which the resource failed the conduct test.

6.1.2.2 Process P5 – Conduct Test

Description

This is a conditional test that will take place only if certain conditions related to the restriction of competition are met. The conduct test will determine if any financial *dispatch data* parameters for a resource that are unmitigated from the previous runs of PD differ from the *IESO*-determined registered reference levels by more than the relevant conduct threshold.

If one or more financial *dispatch data* parameter value for any resource fails the conduct test, then Process P6: Reference Level Scheduling and Process P7: Reference Level Pricing will occur to facilitate Process P8: Price Impact Test. If all financial *dispatch data* parameters specific to a resource pass the conduct test, no mitigation will be applied to that resource. If no financial *dispatch data* parameter values fail the conduct test, then no further steps in the ex-ante Market Power Mitigation process are necessary.

Input and Output Data Flows

Table 6-5: Process P5 Input and Output Data Flows

Flow	Source	Target	Frequency
Constrained Resources Subject to Conduct Test	P4	P5	Event-based
Description: See description of output in Process P4.			
Flow	**Source**	**Target**	**Frequency**
Reference Levels	Market Power Mitigation Information System	P5	Event-based
Description: • Reference levels are *IESO*-determined estimates of the financial and non-financial *dispatch data* parameters that a resource would have submitted if it were operating under competitive conditions. • The *IESO* will determine reference levels for financial *dispatch data* parameters that describe characteristics expressed in monetary terms. The financial *dispatch data* parameters are o *energy offers*, o *operating reserve offers*, o speed-no-load *offers*, and o start-up *offers*. • Reference levels for financial *dispatch data* parameters will be established in consultation with *market participants* using a cost-based methodology; and *market participants* will be able to view their applicable reference levels on a confidential basis.			

Flow	Source	Target	Frequency
Conduct Thresholds	Market Power Mitigation Information System	P5	Event-based

Description:

- Conduct thresholds are allowable tolerances above the established reference levels.
- The conduct threshold determines how much a financial *dispatch data* parameter can deviate from its reference level without failing the conduct test.
- A set of conduct thresholds will be determined for each constrained area condition and used as input for the conduct test.

Flow	Source	Target	Frequency
As-Offered Dispatch Data	Market Participant	P5	Event-based

Description:

This process uses the same as-offered *dispatch data* that Process P1 used. See description in Process P1.

Flow	Source	Target	Frequency
Mitigated for Conduct PD Dispatch Data	P5	P6 P7 Scheduling Process Data Archive	Event-based

Description:

- Mitigated for conduct *dispatch data* is the *dispatch data* for *energy* and *operating reserve* produced by the Process P5: Conduct Test. It includes:
  - Financial *dispatch data* parameters for resources that failed the conduct test and were mitigated to their reference level values. See the list of financial *dispatch data* parameters within the as-offered *dispatch data* in Process P1;
  - Financial *dispatch data* parameters for resources that passed the conduct test and were not mitigated; and
  - Financial *dispatch data* parameters for resources that did not qualify for conduct test.
- This data will be used in calculating the Reference Level schedules, commitments and LMPs through Process P6 and Process P7.

Flow	Source	Target	Frequency
Resources that Failed Conduct Test	P5	P8	Event-based
Description: This is a set of resources that failed the conduct test for at least one financial *dispatch data* parameter by condition type. This list of resources will be required as inputs to perform Process P8: Price Impact Test.			

6.1.2.3 Process P6 – Reference Level Scheduling

Description

This process is identical to Process P1: Pre-Dispatch Scheduling except that it will use mitigated financial *dispatch data* for resources that failed the conduct test.

The commitment decisions will serve as inputs into Reference Level Pricing.

Input and Output Data Flows

Table 6-6: Process P5 Input and Output Data Flows

Flow	Source	Target	Frequency
Mitigated for Conduct PD Dispatch Data	P5	P6	Event-based
Description: See description of output in Process P5.			
Flow	**Source**	**Target**	**Frequency**
IESO Data Inputs for Reliability	IESO	P6	Event-based
Description: This process uses the same *IESO* data inputs for *reliability* that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Demand Forecast	IESO	P6	Event-based

Description:

The same *demand* forecast data used by Process P1 is used by this process. See description in Process P1 above.

Flow	Source	Target	Frequency
Constraint Violation Curves for Reliability	IESO	P6	Event-based

Description:

This process uses the same constraint violation curves for *reliability* that Process P1 used. See description in Process P1 above.

Flow	Source	Target	Frequency
Daily Dispatch Order for Variable Generation	IESO	P6	Event-based

Description:

This process uses the same daily *dispatch* order for *variable generation* that Process P1 used. See description in Process P1 above.

Flow	Source	Target	Frequency
Initial Scheduling Assumptions	Real-Time Calculation Engine	P6	Event-based

Description:

This process uses the same initial scheduling assumptions that Process P1 used. See description in Process P1 above.

Flow	Source	Target	Frequency
Start Indication	Facility Registration	P6	Hourly

Description:

This process uses the same start indication that Process P1 used. See description in Process P1 above.

Flow	Source	Target	Frequency
Telemetry	IESO	P6	Hourly

Description:

This process uses the same telemetry that Process P1 used. See description in Process P1 above.

Flow	**Source**	**Target**	**Frequency**
DAM Import and Export Schedules	DAM Calculation Engine	P6	Event-based

Description:

This process uses the same DAM import and export schedules that Process P1 used. See description in Process P1 above.

Flow	**Source**	**Target**	**Frequency**
DAM Operational Commitments	DAM Calculation Engine	P6	Event-based

Description:

This process uses the same DAM operational commitments that Process P1 used. See description in Process P1 above.

Flow	**Source**	**Target**	**Frequency**
PD Operational Commitments and Extensions	Prior Pre-Dispatch Calculation Engine Run	P6	Event-based

Description:

This process uses the same PD operational commitments and extensions that Process P1 used. See description in Process P1 above.

Flow	**Source**	**Target**	**Frequency**
Reference Level Resource Schedules	P6	Scheduling Processes Data Archive P7	Event-based

Description:

- The reference level resource schedules for *energy* and *operating reserve* are the set of resource schedules generated during Process P6: Reference Level Scheduling. To produce the reference level resource schedules, any as-offered financial *dispatch data* value that failed the conduct test will be replaced by the reference level value for that financial *dispatch data* parameter. See the list of financial *dispatch data* parameters within the as-offered *dispatch data* in Process P1.

- These schedules will include the import and export schedules, which are the scheduled transactions between the *IESO-controlled grid* (ICG) and each *intertie zone*.

Flow	Source	Target	Frequency
Reference Level Commitments and Extensions	P6	Scheduling Processes Data Archive	Event-based

Description:

The reference level resource commitments are the set of commitments for eligible NQS resources generated from P6.

Flow	Source	Target	Frequency
Reference Level Binding Hydro Minimum Constraints	P6	P7	Hourly

Description:

The reference level binding hydro minimum constraints are the same output as the binding hydro minimum constraints described in Process P1, except created by Process P6: Reference Level Scheduling.

Flow	Source	Target	Frequency
Reference Level NQS Commitment Status	P6	P7	Hourly

Description:

- The NQS commitment status will inform the Process P7: Reference Level Pricing whether the NQS resource has a potential or actual operational commitment or extension in each time step result from Process P6: Reference Level Scheduling.
    - Actual operational commitments and extensions may be DAM operational commitments, prior PD operational commitment and extensions, or new PD operational commitments and extensions.
    - Potential operational commitments are commitment decisions made in this Process P6: Reference Level Scheduling that will not create binding commitments for NQS resources.
- No commitments made in Process P6: Reference Level Scheduling will become operational commitments. These results are for comparison with the Process P1: PD Scheduling results during the Process P8: Price Impact Test.

6.1.2.4 Process P7 – Reference Level Pricing

Description

This process will produce LMPs similar to the PD Pricing. Reference Level Pricing differs from PD Pricing in that it will use reference level *dispatch data* for any *dispatch data* parameter from *registered market participants* that failed the conduct test. Reference Level Pricing also differs from PD Pricing in that the principle for price-setting eligibility will be applied by taking into account the Reference Level Scheduling results.

Reference Level Pricing will determine a set of LMPs. The LMPs will be used in the Process P8: Price Impact Test. The prices produced will not be financially binding.

Input and Output Data Flows

Table 6-7: Process P7 Input and Output Data Flows

Flow	Source	Target	Frequency
Mitigated for Conduct PD Dispatch Data	P5	P7	Event-based
Description: See description of output in Process P5.			
Flow	**Source**	**Target**	**Frequency**
IESO Data Inputs for Pricing	IESO	P7	Event-based
Description: This process uses the same *IESO* data inputs for pricing that Process P2 used. See description in Process P2 above.			
Flow	**Source**	**Target**	**Frequency**
Demand Forecast	IESO	P7	Event-based
Description: This process uses the same *demand* forecast data that Process P1 used. See description in Process P1 above.			

Flow	Source	Target	Frequency
Constraint Violation Curves for Pricing	IESO	P7	Event-based
Description: This process uses the same constraint violation curves for pricing that Process P2 used. See description in Process P2 above.			
Flow	**Source**	**Target**	**Frequency**
Daily Dispatch Order for Variable Generation	IESO	P7	Event-based
Description: This process uses the same daily *dispatch* order for *variable generation* Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Initial Scheduling Assumptions	Real-Time Calculation Engine	P7	Event-based
Description: This process uses the same initial scheduling assumptions that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Start Indication	Facility Registration	P7	Hourly
Description: This process uses the same start indication that Process P1 used. See description in Process P1 above.			
Flow	**Source**	**Target**	**Frequency**
Telemetry	IESO	P7	Hourly
Description: This process uses the same telemetry that Process P1 used. See description in Process P1 above.			

Flow	Source	Target	Frequency
DAM Import and Export Schedules	DAM Calculation Engine	P7	Event-based

Description:

This process uses the same DAM import and export schedules that Process P1 used. See description in Process P1 above.

Flow	Source	Target	Frequency
Reference Level Binding Hydro Minimum Constraints	P6	P7	Hourly

Description:

See description of output in Process P6 above.

Flow	Source	Target	Frequency
Reference Level NQS Commitment Status	P6	P7	Hourly

Description:

See description of output in Process P6 above.

Flow	Source	Target	Frequency
Reference Level Hourly Shadow Prices	P7	Scheduling Processes Data Archive	Event-based

Description:

- See description of PD hourly shadow prices in Process P2.
- Reference level hourly shadow prices will be used to calculate the reference level hourly LMPs and not as a direct input into the Process P8: Price Impact Test.

Flow	Source	Target	Frequency
Reference Level Hourly LMPs	P7	P8 Scheduling Processes Data Archive	Event-based

Description:

- See the definition of PD Pricing Advisory Hourly LMPs in Process P2.

- Reference level hourly LMPs will be calculated using the results of Process P7 and the pricing formulas provided in Section 3.10, which specify how constraint shadow prices are used to determine an LMP and its components.
- The Reference level hourly LMPs for *energy* and *operating reserve* are used as inputs into the price impact test.

6.1.2.5 Process P8 – Price Impact Test

Description

The price impact test compares the LMPs from PD Pricing to the LMPs from the Reference Level Pricing for each resource that failed the conduct test. The price impact test is failed if one or more LMPs in PD Pricing is greater than the corresponding LMP from the Reference Level Pricing by a specified impact threshold. If the impact test is failed, then the resource's *dispatch data* that failed the price impact test is replaced by the reference level value for the failed *dispatch data* parameters and will be input as mitigated *dispatch data* for the resource in a subsequent run of Pre-Dispatch Scheduling and Pre-Dispatch Pricing.

Input and Output Data Flows

Table 6-8: Process P8 Input and Output Data Flows

Flow	Source	Target	Frequency
PD Hourly LMPs	P2	P8	Event-based
Description: See description of output in Process P2 above.			
Flow	**Source**	**Target**	**Frequency**
Resources that Failed Conduct Test	P5	P8	Event-based
Description: See description of output in Process P5 above.			
Flow	**Source**	**Target**	**Frequency**
Reference Level Hourly LMPs	P7	P8	Event-based

Description: See description of output in Process P7 above.			
Flow	**Source**	**Target**	**Frequency**
Price Impact Thresholds	Market Power Mitigation Information System	P8	Event-based
Description: • The price impact threshold is the allowance that is used to determine whether prices in the PD Pricing results are significantly higher than prices in the PD Reference Level Pricing results. • A set of price impact thresholds for each constrained area designation will be used as input for the price impact test.			
Flow	**Source**	**Target**	**Frequency**
Mitigated for Price Impact PD Dispatch Data	P8	Market Settlement Real-Time Calculation Engine Subsequent Pre-Dispatch Calculation Engine Runs Scheduling Process Data Archive	Event-based
Description: • See description in Process P1 above. • This data includes any updates to the mitigated for price impact PD *dispatch data* set from the most recent PD calculation engine run.			
Flow	**Source**	**Target**	**Frequency**
Resources that Failed the Price Impact Test	P8	Scheduling Process Data Archive	Event-based

Description:

- This is the list of resources that failed the price impact test in a given hour of the current or a prior PD calculation engine run.
- If prices in the Pre-Dispatch Pricing results are greater than the prices from the Reference Level Pricing results by more than the relevant impact threshold, the resource will be considered to have failed the price impact test.
- This list will be an accumulated set of resources and the hours in which failure occurred.

6.1.3. Pre-Settlement Mitigation Processing for Pre-dispatch and Real-time Data

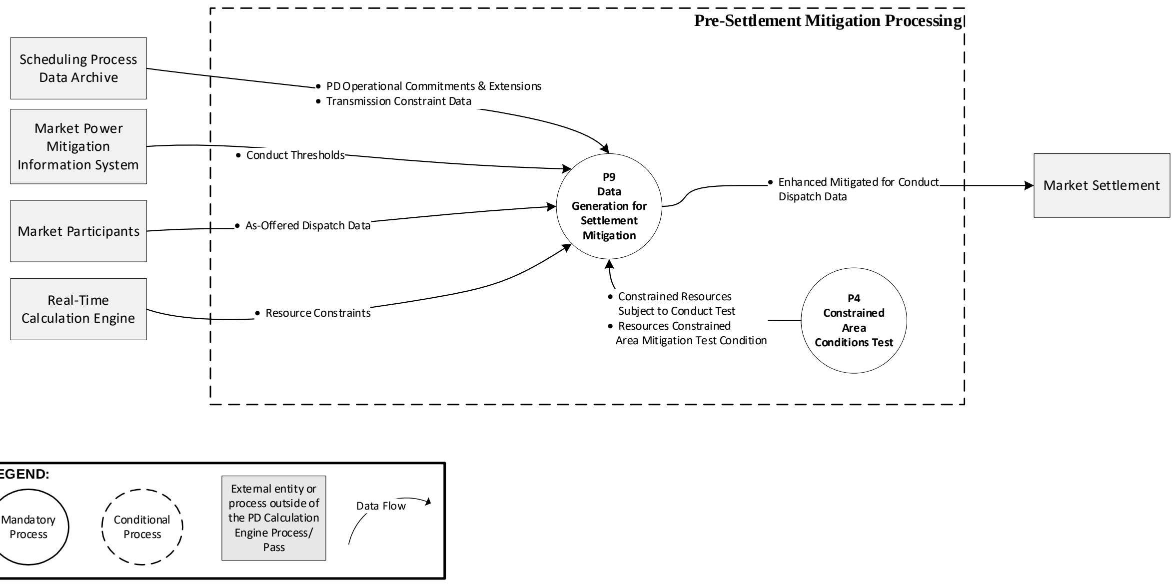

Figure 6-4: Level 1 Information Flow Diagram for Sub-Set of Pass 1 – P9

6.1.3.1 Process P9 – Data Generation for Settlement Mitigation

Description

This process will prepare *real-time market* enhanced mitigated for conduct *dispatch data* for the Settlement Mitigation make-whole payment tests within the *settlement process*. If conditions are met for more than one constrained area for the same resource in the same interval, hour or commitment period, then the as-offered *dispatch data* and make-whole payments impact will be tested using the most restrictive set of conduct thresholds.

Input and Output Data Flows

Table 6-9: Process P14 Input and Output Data Flows

Flow	Source	Target	Frequency
Conduct Thresholds	Market Power Mitigation Information System	P9	Daily
Description: The same conduct thresholds used by Process P5 is used by this process. See description in Process P5 above.			

Flow	Source	Target	Frequency
As-Offered Dispatch Data	Market Participants	P9	Daily

Description:

- This process uses the same as-offered *dispatch data* that Process P1 used. See description in Process P1 above.
- This data includes *dispatch data* submitted by *registered market participants* and approved by the *IESO* within the mandatory window.
- This data will be used for all resources that were qualified for ex-ante mitigation in the PD calculation engine, and all resources that are required for the Settlement Mitigation make-whole payment impact test.

Flow	Source	Target	Frequency
PD Operational Commitments and Extensions	Scheduling Process Data Archive	P9	Event-based

Description:

- See description of New PD Operational Commitments and Extensions in Process P1.
- The PD operational commitments and extensions from every run of Process P1: PD Scheduling within the *real-time market* for a given *dispatch day* will be stored in the Scheduling Process Data Archive for use in the Process P9: Data Generation for Settlement Mitigation.

Flow	Source	Target	Frequency
Transmission Constraint Data	Scheduling Process Data Archive	P9	Daily

Description:

- See description of Transmission Constraint Data in Process P2.
- The transmission constraint data from every run of Process P2: PD Pricing within the *real-time market* for a given *dispatch day* will be stored in the Scheduling Process Data Archive for use in Process P9: Data Generation for Settlement Mitigation.
- This data includes:
    - The set of binding and non-binding transmission constraints; and
    - The sensitivity factors for each binding or non-binding transmission constraint.

Flow	Source	Target	Frequency
Constrained Resources Subject to Conduct Test	P4	P9	Daily

Description:

See description of output in Process P4.

Flow	Source	Target	Frequency
Resource Constrained Area Mitigation Test Conditions	P4	P9	Daily

Description:

See description of output in Process P4.

Flow	Source	Target	Frequency
Resource Constraints	Real-Time Calculation Engine	P9	Daily

Description:

- This data includes the following information from the RT calculation engine:
    - List of resources with *reliability* constraints applied during the *dispatch hour*; and
    - Number of intervals over which the *reliability* constraints were applied for each resource.

Flow	Source	Target	Frequency
Enhanced Mitigated for Conduct Dispatch Data	P9	Market Settlement	Daily

Description:

- The enhanced mitigated for conduct *dispatch data* is the *real-time market dispatch data* set that must be generated for use in the Settlement Mitigation make-whole payment process.
- There will be one combined set of enhanced mitigated for conduct *dispatch data* from the PD calculation engine and RT calculation engine.

6.2. Internal Process Impacts

The internal processes currently used for the Pre-Dispatch calculation engine processes will continue to have relevance in the future day-ahead market and *real-time market*.

Internal *IESO* processes related to the Pre-Dispatch calculation engine processes include:

- Direct Short Term Operations

The above internal processes interact with various *IESO* processes as illustrated in Section 6.1. Some changes to the Pre-Dispatch calculation engine processes under the market renewal program will impact other internal *IESO* processes. This impact will be contingent upon the tools of the future day-ahead market and *real-time market* which will be developed during the next phases of the project.

Changes or additions to internal *IESO* processes are for internal *IESO* use as documented in Appendix C, and are not included in the public version of this document. Appendix C details the impacts to internal processes in terms of existing processes that support the new market requirements, existing activities that need to be updated, and process and information models that may need to be updated to support the future market.

– End of Section –

Appendix A: Market Participant Interfaces

There are no interfaces between *market participants* and the PD calculation engine. However, *market participant* interfaces with *IESO* PD processes are covered in the Offers, Bids and Data Inputs as well as the Grid and Market Operations Integration detailed design documents.

– End of Appendix –

Appendix B: Internal-Facing Procedural Requirements *[Internal only]*

This section is confidential to the IESO.

Appendix C: Business Process and Information Requirements *[Internal only]*

This section is confidential to the IESO.

Appendix D: Mathematical Notation and Conventions

Let A and B be sets. Let n be a positive integer. The following mathematical notation will be adopted.

Table D-1: Mathematical Notation and Conventions

Notation	Description	Sample Usage
$a \in A$	Denotes that item a is an element of set A.	If B is the set of all buses, then "$b \in B$" denotes that b identifies a specific bus.
$\{1,..,n\}$	Denotes the set of all positive integers between 1 and n, inclusive.	"For time-step $t \in \{2,..,n_{LAP}\}$" denotes that t identifies one of the time-steps 2,3, .., n_{LAP} of the look-ahead period.
$A \subseteq B$	Denotes that set A is a subset of set B. That is, if $a \in A$, then $a \in B$.	If B is the set of all buses and B^{DL} is the set of *dispatchable load* buses, then "$B^{DL} \subseteq B$" indicates that all *dispatchable load* buses are also elements of the set of buses.
$A \cap B$	Denotes the intersection of sets A and B. That is, if $c \in A$ and $c \in B$, then $c \in A \cap B$.	If B_r^{REG} is the set of buses in *operating reserve* region r and B^{DG} is the set of dispatchable generation buses, then "$B_r^{REG} \cap B^{DG}$" denotes the set of buses in *operating reserve* region r that are also dispatchable generation buses.
$A \cup B$	Denotes the union of sets A and B. That is, if $c \in A$ or $c \in B$, then $c \in A \cup B$.	If B^{DL} is the set of *dispatchable load* buses and B^{HDR} is the set of *hourly demand response* resource buses, then "$B^{DL} \cup B^{HDR}$" denotes the set containing all *dispatchable load* buses and all *hourly demand response* resource buses.
$A \times B$	Denotes the cross product of sets A and B. That is, $A \times B$ is the set of all pairs of elements (a,b) such that $a \in A$ and $b \in B$.	If DX is the set of sink buses and DI is the set of source buses, then $DX \times DI$ is the set of all possible pairs of source and sink buses.

Notation	Description	Sample Usage
$\wp(A)$	Denotes the power set of set A. That is the set of all subsets.	If B^{HE} is the set $\{x,y,z\}$ that represents the set of buses with hydroelectric resources, then the power set of B^{HE} are $\wp(B^{HE}) = \{\{\}, \{x\},\{y\},\{z\},\{x,y\},\{x,z\},\{y,z\},\{x,y,z\}\}$

Let n be a positive integer. Let a_1, a_2, ..., a_n be numbers. Then, standard notation for summation, minimum and maximum will be adopted as follows:

$\sum_{i=1..n} a_i$ denotes $a_1 + a_2 + ... + a_n$;

- $min(a_1,..,a_n)$ denotes the minimum (i.e. the smallest) of the values a_1, a_2, ..., a_n; and
- $max(a_1,..,a_n)$ denotes the maximum (i.e. the largest) of the values a_1, a_2, ..., a_n.

As far as feasible, the following conventions have been adopted for the purposes of naming parameters, variables and outputs:

- Parameters denoting *price-quantity pairs* will begin with the letters “P” and “Q” respectively while the remainder of the parameter name is identical;
- Variable names used within the optimization function will begin with the letter “O” or the letter “I” when such variables must be assigned integer values and will begin with the letter “S” otherwise;
- Variable and parameters pertaining to a particular resource or transaction type will contain an indication in the name. For example, many parameters and variables for dispatchable generation resources will contain “DG” in the name and many parameters for exports will contain “XL” in the name;
- Subsets of a given set will either be denoted by the same name with a superscript or be prefixed with that name; and
- Outputs from the scheduling or pricing algorithm for a specific process will be denoted by the corresponding variable with a superscript abbreviating the process name.

– End of Appendix–

Appendix E: Conduct and Impact Thresholds and Parameters

E.1. Market Power Mitigation Conduct Thresholds and Corresponding Parameters

Table E-1: Conduct Thresholds and Corresponding Parameters

Parameter	Description	Threshold	Reference to MPM tables
BCACondThresh	Designates the threshold for the congestion component of a resource's LMP, above which the resource will meet the BCA condition.	$25/MWh	Section 3.6.1.2
IBPThresh	Designates the Intertie Border Price (IBP) threshold.	$100/MWh	Section 3.6.1.3
ORGCondThresh	Designates the threshold for a resource's *operating reserve* LMP, above which the resource will meet the Global Market Power (Operating Reserve) condition.	$15/MW	Section 3.6.2.2
$CTEnThresh1^{NCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test	50%.	Table 3-5
$CTEnThresh2^{NCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the NCA conduct test.	$25/MWh	Table 3-5
$CTSUThresh^{NCA}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test.	25%	Table 3-5

Parameter	Description	Threshold	Reference to MPM tables
$CTSNLThresh^{NCA}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the NCA conduct test.	25%	Table 3-5
$CTEnThresh1^{DCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test.	50%	Table 3-5
$CTEnThresh2^{DCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the DCA conduct test.	$25/MWh	Table 3-5
$CTSUThresh^{DCA}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test.	25%	Table 3-5
$CTSNLThresh^{DCA}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the DCA conduct test.	25%	Table 3-5
$CTEnThresh1^{BCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test.	200%	Table 3-7
$CTEnThresh2^{BCA}$	Designates the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the BCA conduct test.	$100/MWh .	Table 3-7

Parameter	Description	Threshold	Reference to MPM tables
$CTSUThresh^{BCA}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test.	100%	Table 3-7
$CTSNLThresh^{BCA}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the BCA conduct test.	100%	Table 3-7
$CTEnThresh1^{GMP}$	Designates the *energy offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (Energy) conduct test.	200%	Table 3-9
$CTEnThresh2^{GMP}$	Designates the *energy offer* conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the Global Market Power (Energy) conduct test.	$100/MWh.	Table 3-9
$CTSUThresh^{GMP}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (Energy) conduct test.	100%	Table 3-9
$CTSNLThresh^{GMP}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (Energy) conduct test.	100%	Table 3-9

Parameter	Description	Threshold	Reference to MPM tables
$CTORThresh1^{ORL}$	Designates the *operating reserve offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	10%	Table 3-11
$CTORThresh2^{ORL}$	Designates the *operating reserve offer* conduct threshold, pertaining to allowable $/MW increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	$25/MW	Table 3-11
$CTEnThresh1^{ORL}$	Designates the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	10%	Table 3-11
$CTEnThresh2^{ORL}$	Designates the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	$25/MWh	Table 3-11
$CTSUThresh^{ORL}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	10%	Table 3-11
$CTSNLThresh^{ORL}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Local Market Power (OR) conduct test.	10%	Table 3-11

Parameter	Description	Threshold	Reference to MPM tables
$CTORThresh1^{ORG}$	Designates the *operating reserve offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	50%	Table 3-13
$CTORThresh2^{ORG}$	Designates the *operating reserve offer* conduct threshold, pertaining to allowable $/MW increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	$25/MW	Table 3-13
$CTEnThresh1^{ORG}$	Designates the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	50%	Table 3-13
$CTEnThresh2^{ORG}$	Designates the *energy offer* for *energy* to MLP conduct threshold, pertaining to allowable $/MWh increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	$25/MWh	Table 3-13
$CTSUThresh^{ORG}$	Designates the start-up *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	25%	Table 3-13
$CTSNLThresh^{ORG}$	Designates the speed no-load *offer* conduct threshold, pertaining to allowable percent increase above the reference level, to be used for resources that are subject to the Global Market Power (OR) conduct test.	25%	Table 3-13

Parameter	Description	Threshold	Reference to MPM tables
CTEnMinOffer	Designates the minimum *energy offer* value for the *offer* lamination to be included in the conduct test. *Energy offer* laminations below this value are excluded from the conduct test.	$25/MWh	Table 3-5, Table 3-7, Table 3-9
CTORMinOffer	Designates the minimum *operating reserve offer* value for the offer lamination to be included in the conduct test. *Operating reserve offer* laminations below this value are excluded from the conduct test.	$5/MW	Table 3-11, Table 3-13

E.2. Power Mitigation Price Impact Thresholds and Corresponding Parameters

Table E-2: Price Impact Thresholds and Corresponding Parameters

Parameter	Description	Threshold	Reference to MPM tables
$ITThresh1^{NCA}$	Designates the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the NCA price impact test.	50%	Table 3-6
$ITThresh2^{NCA}$	Designates the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the NCA price impact test.	$25/MWh	Table 3-6
$ITThresh1^{DCA}$	Designates the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from	50%	Table 3-6

Parameter	Description	Threshold	Reference to MPM tables
	Reference Level Pricing, to be used for resources that are subject to the DCA price impact test.		
$ITThresh2^{DCA}$	Designates the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the DCA price impact test.	$25/MWh	Table 3-6
$ITThresh1^{BCA}$	Designates the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the BCA price impact test.	100%	Table 3-8
$ITThresh2^{BCA}$	Designates the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the BCA price impact test.	$50/MWh	Table 3-8
$ITThresh1^{GMP}$	Designates the price impact threshold, pertaining to allowable percent increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the Global Market Power (Energy) price impact test.	100%	Table 3-10
$ITThresh2^{GMP}$	Designates the price impact threshold, pertaining to allowable $/MWh increase in the *energy* LMP from Pre-Dispatch Pricing above the *energy* LMP from Reference Level Pricing, to be used for resources that are subject to the Global	$50/MWh	Table 3-10

Parameter	Description	Threshold	Reference to MPM tables
	Market Power (Energy) price impact test.		
$ITThresh1^{ORG}$	Designates the price impact threshold, pertaining to allowable percent increase in the *operating reserve* LMP from Pre-Dispatch Pricing above the *operating reserve* LMP from Reference Level Pricing, to be used for resources that are subject to the Global Market Power (OR) price impact test.	50%	Table 3-14
$ITThresh2^{ORG}$	Designates the price impact threshold, pertaining to allowable $/MW increase in the *operating reserve* LMP from Pre-Dispatch Pricing above the *operating reserve* LMP from Reference Level Pricing, to be used for resources that are subject to the Global Market Power (OR) price impact test.	$25/MW	Table 3-14

– End of Appendix–

References

Document Name	Document ID
MRP Detailed Design: Overview	DES-16
MRP Detailed Design: Facility Registration	DES-19
MRP Detailed Design: Offers, Bids and Data Inputs	DES-21
MRP Detailed Design: Grid and Market Operations Integration	DES-22
MRP Detailed Design: Real-Time Calculation Engine	DES-25
MRP Detailed Design: Market Power Mitigation	DES-26
MRP Detailed Design: Publishing and Reporting Market Information	DES-27
MRP Detailed Design: Market Settlement	DES-28
Market Manual 4 Market Operations, Part 4.2 - Submission of Dispatch Data in the Real-Time Energy and Operating Reserve Markets	MDP_PRO_0027
Market Manual 4 Market Operations, Part 4.3 - Real Time Scheduling of the Physical Markets	MDP_PRO_0034
Market Manual 4: Market Operations, Part 4.4 - Transmission Rights Auction	MDP_PRO_0029
Market Manual 4 Market Operations, Part 4.5 - Market Suspension and Resumption	MDP_PRO_0030
Market Manual 4: Market Operations, Part 4.6 - RT Generation Cost Guarantee Program	PRO_324
Market Manual 7: System Operations, Part 7.1 - IESO-Controlled Grid Operating Procedures	MDP_PRO_0040
Market Manual 7: System Operations, Part 7.2 - Near-Term Assessments and Reports	IMP_PRO_0033
Market Manual 7: System Operations Part 7.4: IESO-Controlled Grid Operating Policies	IMP_POL_0002

Document Name	Document ID
Market Manual 9 Day-Ahead Commitment, Part 9.2 - Submitting Operational and Market Data for the DACP	IESO_MAN_0077
Market Manual 9 Day-Ahead Commitment, Part 9.3 - Operation of the DACP	IESO_MAN_0078
Market Manual 9 Day-Ahead Commitment, Part 9.4 - Real-Time Integration of the DACP	IESO_MAN_0079
Market Manual 9 Day-Ahead Commitment, Part 9.5 - Settlement for the DACP	IESO_MAN_0080
Manual 13 Capacity Exports, Part 13.1: Capacity Export Requests	PRO_357
Market Rules for the Ontario Electricity Market (Market Rules)	MDP_RUL_0002

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