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MRP PD & RT Engine Review

Independent Electricity System Operator

As of February 29, 2024

Disclaimer

Our Services were performed and this Report was developed in accordance with our engagement letter dated September 6, 2023 and are subject to the terms and conditions included therein.

Our role is advisory only the Independent Electricity System Operator (IESO) is responsible for all management functions and decisions relating to this engagement, including establishing and maintaining internal controls, evaluating and accepting the adequacy of the scope of the Services in addressing IESO needs and making decisions regarding whether to proceed with recommendations. IESO is also responsible for the results achieved from using the Services or deliverables.

Our work was limited to the specific procedures and analysis described herein and was based only on the information made available through February 29, 2024. Accordingly, changes in circumstances after this date could affect the findings outlined in this Report. We are providing no opinion, attestation or other form of assurance with respect to our work and we did not verify or audit any information provided to us.

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Glossary of Terms

Table 1: Glossary of Terms

Term	Definition
Test data	This is the sample data that IESO provided for the Dispatch Scheduling and Optimization (DSO) calculation engines. This is not production data; however, the data was curated from the current DSO inputs and augmented with synthetic inputs to provide coverage for the inputs and testing of the new MRP calculation engines inputs.
Base case	The original run that the IESO had executed on the DSO system, which also serves as the reference point for conducting scenario tests.
Save case	This is a saved data input, intermediate, and final outputs from a calculation engine run.
Screening test	An analysis of outputs from the calculation engine to assess their compliance with the applicable market rules.
Automated test	A screening test designed to compute the difference between outputs of specific market rules and calculation engines based on relevant data inputs.
Scenario test	A test designed and run on the calculation engine systems by changing specific data inputs in the base case to trigger an expected outcome.
Limitation of a test	Factors that limit the testing scope, despite such tests being in the original scope of the pre-implementation review.
Exceptions	This refers to violations or deviations identified in the tests between PwC computed values and outputs from IESO's calculation engines.
Defects	Exceptions confirmed by the IESO as an error in the implementation of the calculation engine algorithms.

1. Executive Summary

This document provides details on PwC's independent pre-implementation review of the Pre-Dispatch (PD) and the Real-Time (RT) Calculation Engine for the IESO Market Renewal Program (MRP). The Pre-Dispatch calculation engine will enable integration between DAM and RT calculation engines producing security-constrained commitment schedules and prices to maximize the gains from trade while considering resource and system constraints. The Real-Time calculation engine performs a constrained multi-interval optimization of energy and operating reserve schedules for the next eleven five-minute intervals by minimizing the "total costs" from scheduled resources.

The review of the PD and RT engine was conducted from September 2023 to February 2024 using the market rules described in Chapter 7 - Appendix 7.2A (MR-00459-R00) and Appendix 7.3A (MR-00460-R00) respectively. This review focused on assessing the compliance of the scheduling and pricing algorithms that maximize trade gains for energy and operating reserves and ensures grid reliability against the market rules. All tests were conducted using test data provided by the IESO from October 18, 2023, and November 18, 2023, respective runs of the PD and RT engine in IESO's test environment. The purpose of the review was to assess the compliance of the PD and RT calculation engines against the new market rules. Testing was performed using test data provided by the IESO on each engine separately.

A suite of automated and scenario tests was developed and executed against the market rules. Automated tests were used to screen resource schedules to detect economically sub-optimal dispatches and violations of unit limits or operational limits for both energy and operating reserves for all resources and dispatch hours in 27-hour intervals for PD and 288 five-minute interval periods for RT. While automated tests focused on screening the outputs of the algorithms based on the data provided by the IESO, scenario tests covered conditions that were not observed and tested in the automated tests, focusing on how the market rules are respected within the calculation engines.

The findings from the pre-implementation review are noted below.

Summary Findings

The following observations were made during the review of the PD and RT engines:

- The engines respected the operational limits described in the market rules, passing all automated and scenario tests not impacted by the Market Power Mitigation (MPM) process.
- All resource cost calculations for both quick-start and non-quick-start resources were computed correctly.
- Based on the results of scenario tests performed, the co-optimization of energy and operating reserves, cascading hydroelectric generation, tie-breaking mechanism, penalty factor violations, and intertie limit tests all passed.

Two (2) exceptions that were observed in the review for the conditions necessary for triggering MPM in the PD engine as highlighted below.

1. **MPM Exceptions – Conduct Test**

   A subset of resources was incorrectly flagged to have passed or failed the **conduct test** for energy resources in a Narrowly Constrained Area (NCA). The IESO indicated that this exception impacted resources with price curves that sum up to zero. The IESO informed PwC that a patch for these exceptions has been applied and tested, but testing was not re-performed by PwC.

2. **MPM Exceptions – Price Impact Test**

   A subset of resources was incorrectly flagged to have failed or passed the **price impact test** for energy for resources in an NCA. The IESO indicated that this exception was caused by an incorrectly applied mathematical sign in the implementation. We also identified a subset of resources that were flagged to have failed or passed the price impact test when their LMPs are negative. The IESO indicated that this exception was related to an incorrect mathematical formulation. The IESO informed PwC that a patch for these exceptions has been applied and tested, but testing was not re-performed by PwC.

The MPM exceptions noted had the potential to impact unit commitments, locational marginal prices, and the overall optimality of the PD solution, as well as the overall optimality of the Real-Time (RT) solutions given that they leverage outputs from PD.

Note: A separate report provides the results of the independent review for the Day-Ahead Market calculation engine.

2. Introduction

Background

The Independent Electricity System Operator is responsible for managing the efficient operation of the Ontario wholesale electricity market and maintaining the reliability of the Ontario electricity grid. This mandate necessitates that the IESO balances the requirements for secure grid operation with the Market Rules to drive towards optimizing the market efficiency at least cost. The Market Renewal Program (MRP) will enhance Ontario's electricity market design by improving how electricity is supplied, scheduled, and priced, leading to system efficiencies, and supporting the grid of the future.

While Ontario has benefitted from a wholesale electricity market that has enabled reliable and cost-effective operation of the electricity system over the past 20 years, efforts are underway through the MRP to modernize Ontario's electricity markets to address inefficiencies and embrace the continued transition to new and diverse resources. The MRP will improve the current market design in Ontario and lead to system efficiencies that support the grid of the future.

To deliver on its mission to enhance the efficiency of the electricity market in Ontario, the MRP will:

- Replace the two-schedule market with a **single schedule market (SSM)** that will address current misalignments between price and dispatch, eliminating the need for unnecessary out-of-market payments.
- Introduce a **day-ahead market (DAM)** that will provide greater operational certainty to the IESO and greater financial certainty to market participants, which lowers the cost of producing electricity and ensures we commit only the resources required to meet system needs.
- Introduce an **enhanced real-time unit commitment (ERUC) process** to reduce the cost of scheduling and dispatching resources to meet demand as it changes from the day-ahead to real-time.

To support these objectives, the MRP is introducing three new calculation engines:

- The day-ahead market calculation engine (DAM-CE)
- The pre-dispatch calculation engine (PD-CE)
- The real-time calculation engine (RT-CE)

This pre-implementation review for the PD-CE and the RT-CE was conducted between September 2023 and February 2024.

Overview of the PD and RT Calculation Engines

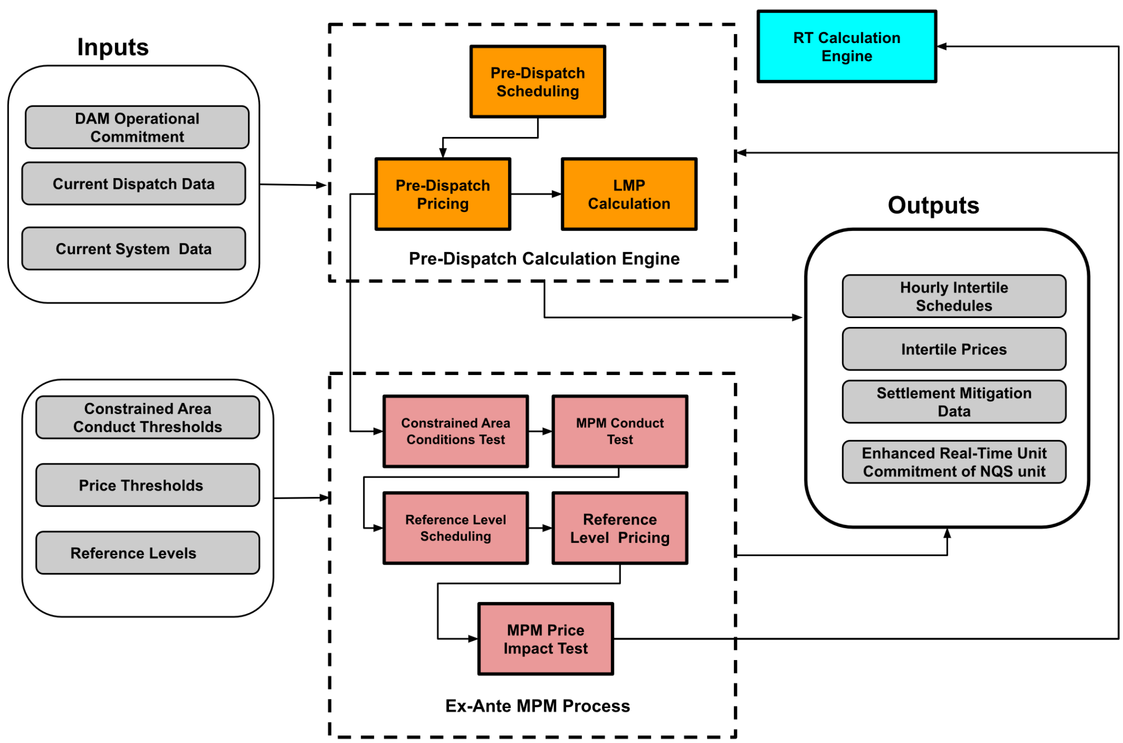
Pre-Dispatch Calculation Engine

The PD calculation engine is a dedicated software program that optimizes energy and operating reserves of resources and provides advisory schedules and prices based on hourly runs that occur before the real-time dispatch. The PD engine extends DAM commitments for NQS generation facilities if deemed necessary, though the DAM commitments are maintained as minimum operational requirements to the PD calculation engine.

The PD engine operates over a single pass to determine the least-cost security-constrained advisory schedule and locational marginal prices (LMPs) based on market participants' bids and offers submitted while enforcing operational constraints. The pass commences by determining the optimal unit commitment and economic dispatch over the optimization horizon, this can also include an extension of the prior commitments established by the DAM engine, before performing an ex-ante MPM process used in all subsequent PD engine runs.

Figure 1 provides a simple overview of the overall process for Pre-Dispatch scheduling and pricing. The inputs, processes and outputs of the PD calculation engine are described below. Further details on the inputs and outputs of PD detail can be found in *Figure 3.*

Figure 1: Pre-Dispatch Market Scheduling and Pricing Overview Diagram



Inputs to the PD calculation Engine

The optimization functions, ex-ante Market Power Mitigation (MPM) process and security assessment functions that make up the PD calculation engine require different inputs to ensure proper functionality.

- **Optimization Functions:** These algorithms require inputs from Market Participants, such as bids, offers, operational characteristics of facilities, and from the IESO, such as Energy Management System (EMS), Outage Scheduler (OS), Demand Forecast System (DFS), Resource Dispatch (RD), Dispatch Data Management System (DDMS), Centralized Forecasting System Database (CFSDB) and Tie-Breaking Modifier Database (TBMD), and the security constraint sets, marginal loss factors and loss adjustments provided as outputs from the security assessment function.
- **Ex-Ante MPM process:** This applies to areas of restricted competition on the IESO-controlled grid for which conduct tests are performed using constrained area specific thresholds to enforce certain conditions. Inputs for the process include constrained area designations, reference level, conduct and price impact thresholds.
- **Security Assessment Function:** The function uses outputs from the optimization functions such as schedules for load and supply resources, IESO operating security limits that ensure power flows remain within reliability criteria, and the network model, as inputs to perform security analysis of the grid.

Operations of the PD Calculation Engine

The PD engine operates over a single pass to determine the least-cost security-constrained advisory schedule and locational marginal prices (LMPs) based on market participants' bids and offers submitted while enforcing operational constraints. The pass commences by determining the optimal unit commitment and economic dispatch over the optimization horizon, this can also include an extension of the prior commitments established by the DAM engine, before performing an ex-ante MPM process used in all subsequent PD engine runs.

The PD dispatch algorithm utilizes an enhanced unit commitment process, considering the operational properties of NQS generation facilities, and respecting the limitations when performing multi-hour optimization to make commitment decisions while respecting enforcing DAM commitments as the minimum commitments.

Outputs of the PD Calculation Engine

The results of each PD calculation engine include hourly dispatch schedules for committed resources, advisory LMPs and zonal prices, as well as binding intertie schedules for immediate next dispatch hour, and NQS operational commitment extensions. Resource schedules for other hours in the look-ahead period will also be produced though such schedules will be advisory.

Real-Time Calculation Engine

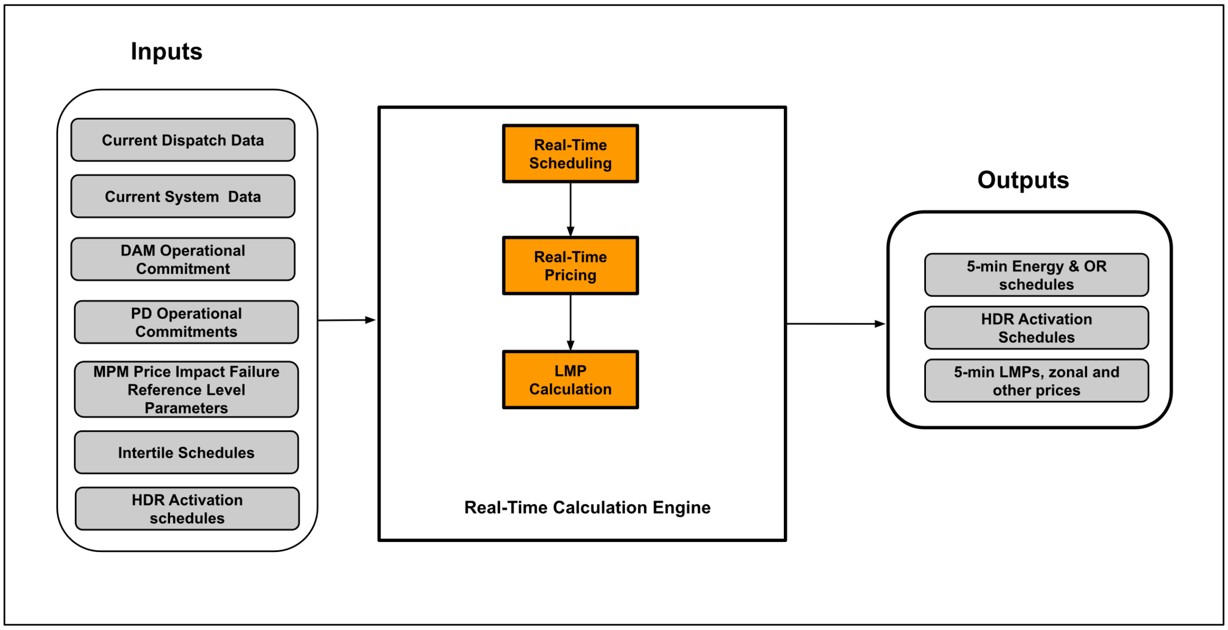
The Real-time market calculation engine is a software program that performs a constrained multi-interval optimization of energy and operating reserve schedules for the next eleven five-minute intervals by minimizing the "total costs" from scheduled resources. The first interval represents the actual dispatch interval with the remaining ten serving as advisory dispatch instructions. The multi-interval approach ensures resources are scheduled in advance of actual requirements across the grid by providing participants with an indication of operational expectations across the next hour.

The RT engine operates over a single pass multi-interval optimization process that performs scheduling and pricing using resource and system constraints to determine real-time dispatch instructions, advisory dispatch instructions for subsequent MIO look-ahead period, locational marginal prices (LMPs) and zonal prices. Unlike the two-pass approach of the legacy Dispatch Scheduler and Optimizer (DSO), the new RT engine will not require the congestion management settlement credits (CMSC) due to divergence of dispatch schedules and prices produced from the unconstrained-constrained optimization system.

The RT engine combines the RT dispatch scheduling algorithm with a RT pricing algorithm which determines LMPs following the principle for price-setting eligibility. It will use initial resource schedules from the Real-Time scheduling algorithm to compute settlement-ready prices.

Figure 2 provides a simple overview of the overall process for Real-Time scheduling and pricing. The inputs, processes and outputs of the RT calculation engine are described below. Further details on the inputs and outputs of RT detail can be found in *Figure 4*.

Figure 2: Real-Time Scheduling and Pricing Overview Diagram



Inputs to the RT calculation Engine

The optimization and security assessment functions that make up the RT calculation engine require different inputs to ensure proper functionality.

- **Optimization Function**: It requires market participant inputs (bids, offers, operational characteristics of facilities, reference levels due to failed Pre-dispatch MPM process), IESO inputs (sources include Energy Management System (EMS), Outage Scheduler (OS), Demand Forecast System (DFS), Resource Dispatch (RD), Dispatch Data Management System (DDMS), Centralized Forecasting System Database (CFSDB) and Tie-Breaking Modifier Database (TBMD)), and the security constraint sets, marginal loss factors and loss adjustments provided as outputs from the security assessment function.
- **Security Assessment functions**: The function uses outputs from the optimization function such as schedules for load and supply resources, IESO operating security limits that ensure power flows remain within reliability criteria, and the network model as inputs to perform security analysis of the grid.

Operations of the RT Calculation Engine

The Real-Time Market operates over a resource and system constrained single pass to determine resource schedules and LMPs that meet the market forecasted energy demand using market participants and IESO inputs.

The Real-time scheduling performs security-constrained economic dispatch of available resources to fulfil the IESO's non-dispatchable demand forecast and established operating reserve requirements. It also takes the pre-dispatch scheduling process pre-determined intertie and hourly demand response resource schedules as well as operational commitments of NQS resources. Dispatch data from the previous hour's pre-dispatch to maximize gains based on the difference between the total price of bids and offers scheduled in real-time scheduling algorithm.

The Real-Time pricing algorithm will perform similar processes to the RT scheduling algorithm but also determine LMPs following the principle for price-setting eligibility. It will use initial resource schedules from the Real-Time scheduling algorithm to compute settlement-ready prices.

Outputs of the RT Calculation Engine

The result of the RT calculation engine is a set of financially binding resource schedules, and market-settlement ready prices for all resources for the next five-minute interval and advisory schedules for the subsequent ten five-minute intervals to ensure reliability.

3. Objective and scope of review

Objective

The IESO commissioned the independent pre-implementation review of the PD Calculation Engine and RT Calculation Engine, to assess if they are operating in compliance with the draft Market Rules for the Ontario electricity market as defined in the Market Renewal Program (Chapter 7 - Appendix 7.2A (MR-00459-R00) for PD) (Chapter 7 - Appendix 7.3A (MR-00460-R00) for RT), and as amended in *Appendix B* of this document.

Scope of review

The tests for the PD and RT Calculation Engine were conducted using test data extracted by the IESO from an engine run on October 18, 2023, and November 18, 2023, respectively.

Scope inclusions.

- Results of the PD and RT Calculation Engine for all passes, including how it sets or respects the operational limits for resources such as:
  - Scheduling variable bounds
  - Ramp rate limits
  - Maximum generation capacity
  - Hydro cascading parameters
  - Pseudo unit energy contributions
  - Energy bids
  - Resource dispatches
- The determination of resource costs, LMPs, and other settlement-ready prices were also considered as part of the review.
- The determination of Resource Cost, Locational Marginal Prices and other Settlement-Ready Prices were also considered as part of the review.
- Economic efficiency of schedules produced by the engines, the co-optimization of energy and operating reserve dispatch schedules, intertie scheduling, tie-breaking methods of variable generators, and violation testing based on penalty cost factors.
- The effect of changes to participant offer data based on provided reference level dispatch data on the PD inputs were considered to assess the impact of the Market Power Mitigation process on resulting outputs.

Scope exclusions

The scope does not include:

- Performing any validation of the completeness and accuracy of the input data and whether they were submitted into the PD and RT Calculation Engine accurately and completely.
- Any review or assessment over the design and operating effectiveness of controls relating to the PD and RT processes, including issuing any external review opinion.
- An assessment on how test data integrates across the engines.

- Other than the PD and RT Calculation Engine, other components within the solution:
  - User interface, engine application and any reporting outputs
  - Internal processes of the solution such as the validation of completeness and accuracy market participant and IESO data inputs before it reaches the calculation engine. This includes all validation of bid quantities, prices, ramp rates, break quantities, users, and timestamps.
  - Estimation of Non-Dispatchable Load (NDL), dynamically created system losses, dynamically created MPM parameters and the Network Security Assessment (NSA) were outside the scope of our review as they are dependent on the network design model that represents the IESO grid.
- The following outputs of the engines were also out of scope:
  - Obligation Indicator Index (OII)
  - Flow-limited transmission circuits
  - Dynamic loss calculations
  - Thresholds determined by the MPM module

Limitations of review

We performed our pre-implementation review using automated and scenario testing of data provided by the IESO from the calculation engines with the purpose of validating the outputs of the calculation engine against the market rules. In the case of the PD and RT review, our test scenarios were based on Chapter 7 - Appendix 7.2A (MR-00459-R00) and Chapter 7 - Appendix 7.3A (MR-00460-R00) of the IESO Market Rules respectively. Any exceptions identified as part of testing were reviewed with the IESO. The following denotes the limitations of our automated and scenario tests:

Test Data:

The IESO provided test data for testing and PwC did not modify any of the provided data. PwC's pre-implementation review is not intended to replace technical or user testing that the IT system vendor or IESO shall conduct. The efficacy of tests conducted is contingent upon the predetermined quality of the test data, operating under the assumption of both completeness and accuracy.

Additionally, PwC did not observe the following conditions in data and thus were not able to test them:

- Off-market transactions, reserve activation and mid-hour import/export schedule changes due to external reliability constraints. Typically, these are tested in a production environment based on actions taken by the control room, but there is no expectation that it can be triggered within the engine itself in the test environment.
- For MPM Dynamic Constrained Areas (DCA), Broad Constrained Areas (BCA), and Global Market Power (GMP) conditions were not present in the data. However, the conduct and price impact tests for DCA and BCA use the same formulations as NCA, which was observed in the data.

Available Information/Knowledge:

Our work was limited to the specific procedures and analysis described herein and was based only on the information made available up to February 29, 2024. Therefore, any alterations in circumstances beyond this date may influence the conclusions drawn in this report.

We did not verify or audit any input data provided to us for this review. We performed procedures to assess the sufficiency and reliability of the data as appropriate for our work.

Figure 3: Overall Pre-Dispatch Calculation Engine Test Scope

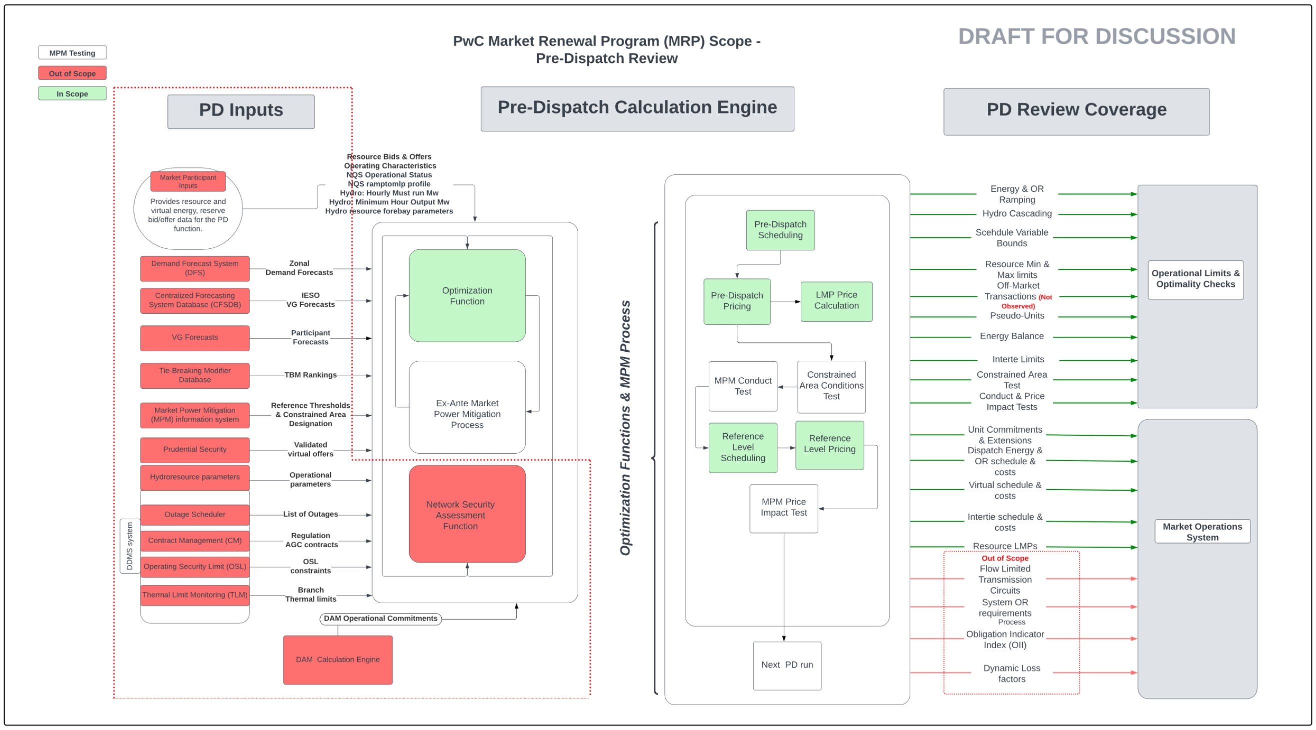
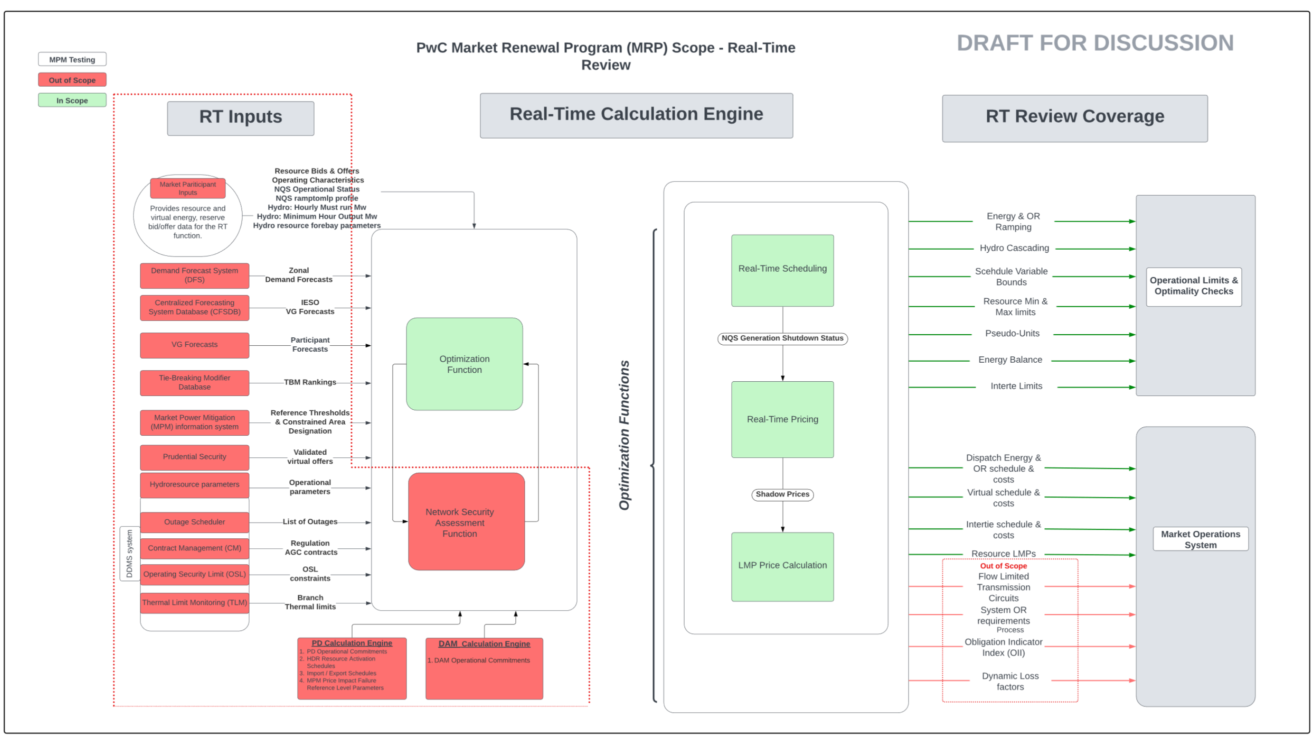


Figure 4: Overall Real-Time Calculation Engine Test Scope



4. PwC's pre-implementation review approach

Review of the PD Calculation Engine

Our approach to the review was to assess the outputs of the PD and RT calculation engine for violations of the in-scope Market Rules as drafted in the Market Renewal Program (MRP) Chapter 7 - Appendix 7.2A and Appendix 7.3A. These violations, also referred to as exceptions, were identified by comparing the calculation engine outputs with the PwC calculated values (i.e., computed in accordance with the applicable market rules). This approach allowed us to review all resources in the IESO-controlled grid for all 27-hour intervals (PD) and all 288 five-minute intervals (RT) of the base case provided by the IESO. We developed and executed Automated Screening Tests to assess the PD and RT produced schedules for compliance with market rules related to limit violations and economic optimality. Using these tests, we reviewed each hour (PD) and five-minute interval (RT) of the test day and all resources within the IESO-controlled grid (~400) scheduled therein.

For conditions that were not observed in the data provided or not covered by automated screening tests, we developed and performed a series of scenario tests by making changes to the PD and RT inputs for the save case of the original data and observing the effects on the PD and RT outputs. Save cases are saved data inputs, intermediate, and final outputs from a PD and RT calculation engine run. These data extracts allowed us to screen the data that was being outputted from the calculation engines to validate their compliance with the market rules.

Any potential exceptions which would indicate a limit violation or sub-optimal dispatch identified through the above noted tests were reviewed with the IESO. We worked with the IESO to identify the root cause of these issues and obtained detailed explanations to confirm exceptions.

Market rule review

We gained an understanding of the applicable Market Rules, and related processes and procedures by:

- Reviewing applicable IESO Market Rules and Materials (i.e., Detailed Design documents, Market Rule Amendment Proposal Form, Videos).
- Reviewing the PD and RT procedural and high-level design documentation; and
- Interviewing IESO personnel responsible for the implementation of the PD and RT calculation engine.

Automated testing

We developed and executed Automated Screening Tests to assess the PD and RT calculation engine produced outputs (i.e., schedules, resource costs, commitments, and prices) for compliance with Market Rules related to operational limit violations and economic optimality. Some of the limits tested include energy limits, ramp limits, resource minimums and maximums, and energy bid and offer prices. The key activities undertaken include:

- Developing and executing automated tests to assess compliance of the calculation engine output with the mathematical limits and representations in Appendix 7.2A and 7.3A of the Market Rules as drafted for the MRP.
- Analysis each of the PD and RT schedules (i.e., energy and operating reserve) to identify individual dispatches that may be economically sub-optimal (i.e., assessing marginal units and the prices of the resources scheduled, as well as the total costs) or in violation of the unit's limits or the security constraints.

This was done for each of the 27-hour (PD) and 288 five-minute (RT) intervals in the dispatch day as provided in the base case.

- Review of the resource-level cost calculation by recomputing the total resource cost per interval which consists of the resource commitment costs (start-up, speed-no-load) energy and operating reserve costs and comparing it to the calculation engine output.

See *Table 2* for a list of automated tests performed and its objectives.

Table 2: Overview of PwC's Automated Tests

Automated Test	Test Objectives	PD	RT
Schedule Variable Bounds	To check if the resources scheduled are within their expected bounds or limits.	Yes	Yes
Resource Schedule Maximum & Minimum	To check if resource schedules respect the operational minimum and maximum limits.	Yes	Yes
OR Scheduling & Ramping	To check if the resource operating reserve schedules respect their schedule requirements and operational limits.	Yes	Yes
Pseudo-Unit Translation & Constraints	To check that a resource's pseudo units are modelled correctly based on the underlying combustion and steam energy components.	Yes	Yes
Wheeling Through Transactions	To check that the amount of scheduled export energy equals the amount of scheduled import energy.	Yes	NA
Energy Ramping - MIO	To check that the dispatch energy schedules respect a resource's ramp capacity throughout its ramp-up and ramp-down periods.	Yes	Yes
OR Ramping - MIO	To check that the dispatch operating reserve schedules respect a resource's ramp capacity throughout its ramp-up and ramp-down periods.	Yes	Yes
Max Number of Starts, MGBRT, MGBDT - NQS	To check that NQS resource parameters and statuses are respected in the solution.	Yes	Yes
Total Energy balance - Reliability	To check that the total energy schedules across all hourly resources balance out to ensure dispatch reliability. For example, matching the total generation, imports, exports, and interties.	Yes	Yes
Total OR balance - Reliability	To check that total resource operating reserve contributions meet the total operating reserve requirements for all the hours.	Yes	Yes
LMP calculation for Energy and OR	To check that LMPs are being computed consistently in accordance with the market rules.	Yes	Yes
Resource Cost Calculation	To check that resource costs accurately account for appropriate commitment and dispatch costs in accordance with the applicable market rules.	Yes	Yes
MPM Conduct Test	To check if the appropriate conditions were met for resources identified to have passed or failed the PD conduct test.	Yes	NA
MPM Price Impact Test	To check if the appropriate conditions were met for resources identified to have passed or failed the PD price impact test.	Yes	NA

Scenario testing

For the market conditions that were neither observed in the data (i.e., some conditions in the data were not present to conduct the test) nor covered by automated testing, we developed and performed scenario tests using the base case. All the scenario tests were conducted remotely in conjunction with IESO staff using the Dispatch Scheduling and Optimization (DSO) system. This was done as follows:

1. In the IESO testing environment, specific inputs were changed to trigger certain processes and achieve results as defined by applicable market rules.
2. The relevant calculation engine was run.
3. The outputs at the end of the engine run were reviewed to assess compliance with the expected results as outlined in the applicable market rules.

Some examples of scenarios initiated by adjusting the input data include:

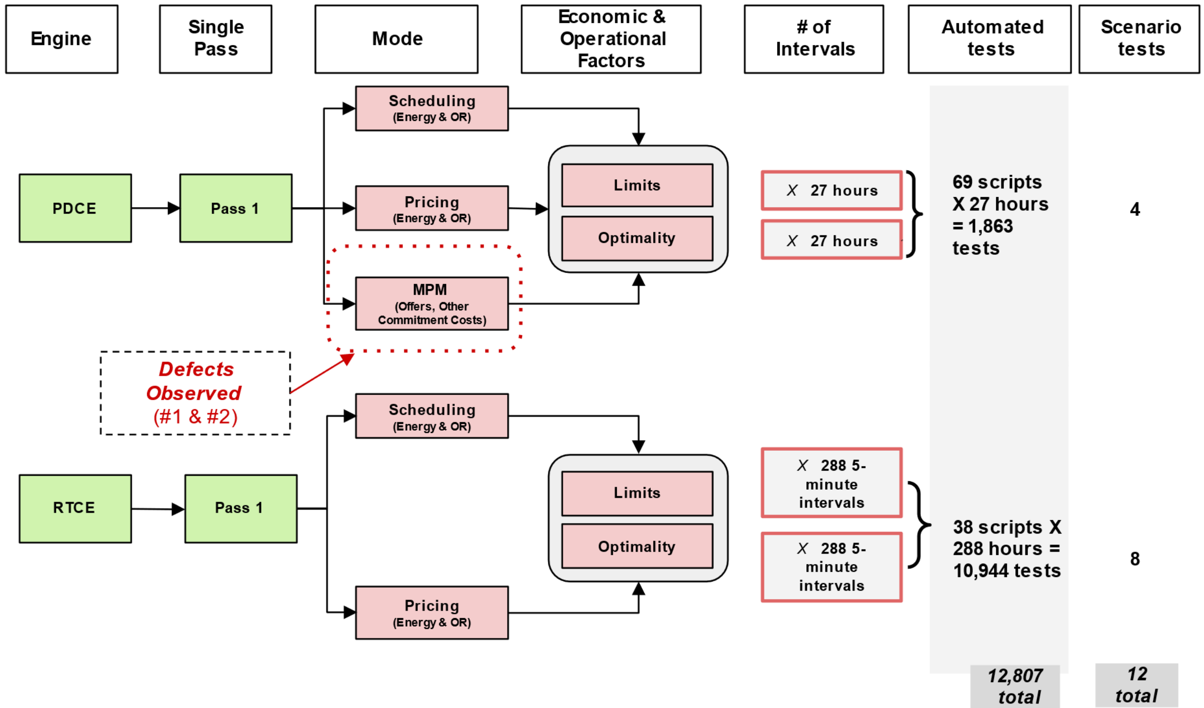
- Triggering changes in penalty factor violations and LMPs.
- Verifying that the scheduled Energy and OR dispatches respect the optimal cost solution.
- Observing potential changes in cost solution.
- Observing the presence of high-cost solutions if NQS resources are not committed.
- Observing energy dispatches across hydro-generators.

See *Table 3* for a list of scenario tests performed and its objectives.

Table 3: Overview of PwC's Scenario Tests

Scenario Test	Test Objectives	PD	RT
Import & Export Commitments - Intertie Testing	To Observe the resource commitments for import and exports.	Yes	NA
Violation Testing for Penalty Cost Factors and Intertie Limits	To observe violation variables and how they impact LMPs when conditions are not met.	Yes	Yes
Energy and OR Co-Optimization	To observe if the scheduled energy and operational reserve dispatches respect the optimal cost solution.	Yes	Yes
Base Case Optimization Testing - (Non-quick start Units)	To observe if the solution cost will be higher when NQS resources are not committed or if NQS resources with identical offers and break points have different speed no load and start-up costs such that only one of the units are scheduled.	Yes	NA
Tie-Breaking Mechanism	To observe the tie breaking mechanism for variable generation resources with equivalent LMPs dispatched for energy and OR.	NA	Yes
Objective Function	To re-compute objective functions to incorporate potential costs or resource scenarios not observed during automated testing.	NA	Yes

Figure 5: Overview of PwC's Pre-Dispatch and Real-Time Calculation Engine Tests



5. Results of the pre-implementation review

A summary of results and findings observed are detailed below. Where applicable, mitigative actions undertaken by the IESO regarding exceptions are also documented. Tables 3 and 4 show a report of the automated and scenario test results.

Summary of Results

The PD and RT calculation engine pre-implementation review results can be summarized as follows:

1. For automated screening tests executed, all operational limits of resources (such as energy and operating reserve ramping, hydro-cascading, unit commitments, minimum and maximum limits, etc.) that were tested as part of the automated screening of resources passed as described in the appropriate market rules. See *Table 4* for the results on the operational limits that were tested.
2. For scenario tests executed, the co-optimization of energy and operating reserves, cascading hydroelectric generation, tie-breaking mechanism, penalty factor violations, and intertie limit tests all passed. See *Table 5*, for the results of the scenario tests conducted.
3. For the Ex-ante MPM in the PD engine, automated tests were conducted across all resources dispatched for energy or operating reserves. The following exceptions were identified:
    a. For the MPM Conduct Test for energy, some resources in Narrowly Constrained Areas (NCA) were incorrectly flagged to have failed or passed.
    b. For the MPM Price Impact Test for energy, some resources in Narrowly Constrained Areas (NCA) were incorrectly flagged to have failed or passed.

The MPM related exceptions impact the overall integrity of the MPM process because incorrectly flagged resources may lead to incorrect pricing being used for energy offers, start-up cost, and speed-no-load cost, resulting in wrong unit commitments and locational marginal prices of market participant resources. PwC did not perform any retesting of the patches that IESO applied to the engine.

Table 4: Result Overview of PwC's Automated Tests

	PD		RT	
Automated Test	**Test Results**	**Comments**	**Test Results**	**Comments**
Schedule Variable Bounds	No exceptions	NA	No exceptions	NA
Resource Schedule Maximum & Minimum	No exceptions	NA	No exceptions	NA
OR Scheduling & Ramping	No exceptions	NA	No exceptions	NA
Pseudo-Unit Translation & Constraints	No exceptions	NA	No exceptions	NA
Wheeling Through Transactions	No exceptions	NA	NA	NA
Energy Ramping - MIO	No exceptions	NA	No exceptions	NA
OR Ramping - MIO	No exceptions	NA	No exceptions	NA
Max Number of Starts, MGBRT, MGBDT - NQS	No exceptions	NA	No exceptions	NA
Total Energy balance - Reliability	No exceptions	NA	No exceptions	NA

Automated Test	PD		RT	
	Test Results	Comments	Test Results	Comments
Total OR balance - Reliability	No exceptions	NA	No exceptions	NA
LMP calculation for Energy and OR	No exceptions	NA	No exceptions	NA
Resource Cost Calculation	No exceptions	NA	No exceptions	NA
MPM Conduct Test	Exceptions noted	IESO informed PwC that a patch has been applied and tested, but PwC did not retest.	NA	NA
MPM Price Impact Test	Exceptions noted	IESO informed PwC that a patch has been applied and tested, but PwC did not retest.	NA	NA

Table 5: Result Overview of PwC's Scenario Test

Scenario Test	PD		RT	
	Test Status	Comments	Test Status	Comments
Import & Export Commitments - Intertie Testing	No exceptions	NA	NA	NA
Violation Testing for Penalty Cost Factors and Intertie Limits	No exceptions	NA	No exceptions	NA
Energy and OR Co-Optimization	No exceptions	NA	No exceptions	NA
Base Case Optimization Testing - (Non-quick start Units)	No exceptions	NA	NA	NA
Tie-Breaking Mechanism	NA	NA	No exceptions	NA
Objective Function	NA	NA	No exceptions	NA

Appendices

Appendix A – Chapter 7 - Appendix 7.2 (The Pre-Dispatch Calculation Engine)

The Market Rules subject of the review is provided below, extracted from Market Rule Amendment Proposal Form (Identification No. MR-00459-R00) draft published as of July 8, 2022.

1 Appendix 7.2 – The Pre-Dispatch Calculation Engine Process

1.1 Purpose

1.1.1 This appendix describes the process used by the *pre-dispatch calculation engine* to determine commitments, schedules, and prices for the pre-dispatch look-ahead period.

2 Pre-Dispatch Calculation Engine

2.1 Pre-Dispatch Look-Ahead Period

2.1.1 The pre-dispatch look-ahead period is the time horizon considered in the multi-hour optimization. The pre-dispatch look-ahead period changes depending on when the *pre-dispatch calculation engine* runs:

2.1.1.1 for the *pre-dispatch calculation engine* runs from 00:00 EST to 19:00 EST in the current *dispatch day*, the pre-dispatch look-ahead period consists of the remaining hours of the current *dispatch day*; and

2.1.1.2 for the *pre-dispatch calculation engine* runs from 20:00 EST to 23:00 EST in the current *dispatch day*, the pre-dispatch look-ahead period consists of the remaining hours of the current *dispatch day* in addition to all hours in the next *dispatch day*.

2.2 Pre-Dispatch Calculation Engine Pass

2.2.1 The *pre-dispatch calculation engine* shall execute one pass, Pass 1, the Pre-Dispatch Scheduling Process Pass, in accordance with section 7, to produce *pre-dispatch schedules*, commitments and *locational marginal prices*:

3 Information Used by the Pre-Dispatch Calculation Engine

3.1.1 The *pre-dispatch calculation engine* shall use the information in section 3A.1 of Chapter 7.

4 Sets, Indices and Paramaters Used in the Pre-Dispatch Calculation Engine

4.1 Fundamental Sets and Indices

4.1.1 A designates the set of all *intertie zones*;

4.1.2 B designates the set of buses identifying all *dispatchable* and non-*dispatchable resources* within Ontario;

4.1.3 $B^{DG} \subseteq B$ designates the set of buses identifying *dispatchable generation resources*;

4.1.4 $B^{DL} \subseteq B$ designates the set of buses identifying *dispatchable loads*;

4.1.5 $B^{ELR} \subseteq B^{DG}$ designates the subset of buses identifying *energy limited resources*;

4.1.6 $B^{HDR} \subseteq B$ designates the set of buses identifying *hourly demand response resources*;

4.1.7 $B^{HE} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources*;

4.1.8 $\wp(B^{HE})$ designates the set of all subsets of the set B^{HE};

4.1.9 $B_{up}{}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all upstream *dispatchable* hydroelectric *generation resources* with a registered *forebay* that are linked via *time lag* and *MWh ratio dispatch data* with downstream *dispatchable* hydroelectric *generation resources* with a registered *forebay*;

4.1.10 $B_{dn}{}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all downstream *dispatchable* hydroelectric *generation resources* with a registered *forebay* that are linked via *time lag* and *MWh ratio dispatch data* with upstream *dispatchable* hydroelectric *generation resources* with a registered *forebay*;

4.1.11 $B_s^{HE} \subseteq B^{HE}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

4.1.12 $B^{NDG} \subseteq B$ designates the set of buses identifying *non-dispatchable generation resources*;

4.1.13 $B^{NO10DF} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* that cannot provide *ten-minute operating reserve* from the duct firing region;

4.1.14 $B^{NQS} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable nonquick start resources*;

4.1.15 $B^{PSU} \subseteq B^{NQS}$ designates the subset of buses identifying *pseudo-units*;

4.1.16 $B_r^{REG} \subseteq B$ designates the set of internal buses in *operating reserve* region $r \in ORREG$;

4.1.17 $B_p^{ST} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* with a share of steam turbine $p \in PST$;

4.1.18 $B^{VG} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable variable generation resources*;

4.1.19 C designates the set of contingencies that shall be considered in the *security* assessment function;

4.1.20 D designates the set of buses outside Ontario corresponding to imports and exports at *intertie zones*;

4.1.21 $DAYS$ designates the set of days in the look-ahead period. If the lookahead period spans one day, then $DAYS = \{tod\}$. If the look-ahead period spans two days, then $DAYS = \{tod, tom\}$;

4.1.22 $D_r^{REG} \subseteq D$ designates the set of *intertie zone* buses identifying *boundary entity resources* in *operating reserve* region $r \in ORREG$;

4.1.23 $DX \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids*;

4.1.24 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

4.1.25 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone* $a \in A$;

4.1.26 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone* $a \in A$;

4.1.27 $DI_t^{CAPEX} \subseteq DI$ designates the *intertie zone* source buses identifying import *offers* flagged as capacity imports in time-step $t \in \{4,..,n_{LAP}\}$;

4.1.28 $DI_t^{EM} \subseteq DI$ designates the *intertie zone* buses corresponding to *emergency energy* import transactions for time-step $t \in TS$;

4.1.29 $DI_t^{EMNS} \subseteq DI_t^{EM}$ designates the *intertie zone* buses corresponding to *emergency energy* import transactions that do not support *emergency energy* export transactions in time-step $t \in TS$;

4.1.30 $DI_t^{INP} \subseteq DI$ designates the *intertie zone* buses corresponding to inadvertent *energy* payback import transactions for time-step $t \in TS$;

4.1.31 $DX_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone* $a \in A$;

4.1.32 $DX_t^{CAPEX} \subseteq DX$ designates the *intertie zone* sink buses identifying export *bids* flagged as *capacity exports* in time-step t;

4.1.33 $DX_t^{INP} \subseteq DX$ designates the *intertie zone* buses corresponding to inadvertent *energy* payback export transactions for time-step $t \in TS$;

4.1.34 $DX_t^{EM} \subseteq DX$ designates the *intertie zone* buses corresponding to *emergency energy* export transactions for time-step $t \in TS$;

4.1.35 F designates the set of *facilities* and groups of *facilities* for which transmission constraints may be identified;

4.1.36 $F_t \subseteq F$ designates the set of *facilities* whose pre-contingency limit was violated in time step t as determined by a preceding *security* assessment function iteration;

4.1.37 $F_{t,c} \subseteq F$ designates the set of *facilities* whose post-contingency limit for contingency c is violated in time step tt as determined by a preceding *security* assessment function iteration;

4.1.38 $J_{t,b}^{E}$ designates the set of *bid* laminations for energy at bus $b \in B \cup DX$ for time-step $t \in TS$;

4.1.39 $J_{t,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.40 $J'_{t,b}^{10S}$ designates the set of *reference level value* laminations for synchronized *ten*-minute *operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.41 $J_{t,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten minute operating reserve* at bus $b \in B \cup DX$ for time-step $t \in TS$;

4.1.42 $J'_{t,b}{}^{10N}$ designates the set of *reference level value* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$

4.1.43 $J_{t,b}{}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve offer* at bus b $B \cup DX$ for time-step t TS;

4.1.44 $J'_{t,b}{}^{30R}$ designates the set of *reference level value* laminations for *thirty minute operating reserve* at bus for time-step t TS;

4.1.45 $K_{t,b}{}^{DF} \subseteq K_{t,b}{}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the duct firing region of a *pseudo-unit* at bus b B^{PSU} for time-step t TS;

4.1.46 $K_{t,b}{}^{DR}$ $K_{t,b}{}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$ for time-step t TS;

4.1.47 $K_{t,b}{}^{E}$ designates the set of *offer* laminations for *energy* at bus $b \in B \cup DI$ for time-step $t \in TS$;

4.1.48 $K'_{t,b}{}^{E}$ designates the set of *reference level value* laminations for *energy* at bus $b \in B$ for time-step $t \in TS$;

4.1.49 $K_{t,b}{}^{LTMLP}$ designates the set of *offer* laminations for *energy* quantities up to the *minimum loading point* for a *non-quick start resource* at bus $b \in B^{NQS}$ for time-step $t \in TS$;

4.1.50 $K'_{t,b}{}^{LTMLP}$ designates the set of *reference level value* laminations for *energy* quantities up to the *minimum loading point reference level* for a *non-quick start resource* at bus $b \in B^{NQS}$ for time-step $t \in TS$;

4.1.51 $K_{t,b}{}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.52 $K'_{t,b}{}^{10S}$ designates the set of *reference level value* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.53 $K_{t,b}{}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B \cup DI$ for time-step $t \in TS$;

4.1.54 $K'_{t,b}{}^{10N}$ designates the set of *reference level value* laminations for nonsynchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.55 $K_{t,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus $b \in B \cup DI$ for time-step $t \in TS$;

4.1.56 $K'_{t,b}^{30R}$ designates the set of *reference level value* laminations for *thirty-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

4.1.57 L designates the set of buses where the *locational marginal prices* represent prices for *delivery points* associated with *non-dispatchable* and *dispatchable generation resources*, *dispatchable loads*, *hourly demand response resources*, *price responsive loads* and *non-dispatchable loads*;

4.1.58 $L_y^{NDL} \subseteq L$, designates the buses contributing to the zonal price for *nondispatchable load* zone $y \in Y$;

4.1.59 $L_m^{VIRT} \subseteq L$, designates the buses contributing to the *virtual zonal price* for *virtual transaction zone* $m \in M$;

4.1.60 M designates the set of *virtual transaction zones*;

4.1.61 NCA designates the set of *narrow constrained areas*;

4.1.62 DCA designates the set of *dynamic constrained areas*;

4.1.63 BCA designates the set of broad constrained areas;

4.1.64 PST designates the set of steam turbines *offered* as part of a *pseudo-unit*;

4.1.65 SHE designates the set indexing the sets of *dispatchable* hydroelectric *generation resources* with a *maximum daily energy limit* or a *minimum daily energy limit* or both for a registered *forebay*;

4.1.66 $THERM = \{COLD, WARM, HOT\}$ designates the set of *thermal states* for *non-quick start resources*;

4.1.67 $TS = \{2,..,n_{LAP}\}$ designates the set of all time-steps in the look-ahead period that are included in the *pre-dispatch calculation engine* optimization, where n_{LAP} designates the number of time-steps in the look-ahead period;

4.1.68 $TS_{tod} \subseteq TS$ designates the time-steps in the look-ahead period that are part of the current *dispatch day;*

4.1.69 $TS_{tom} \subseteq TS$ designates the time-steps in the look-ahead period that are part of the next *dispatch day*;

4.1.70 $TSC_b \subseteq TS$ designates the set of time-steps representing the first hour of a day ahead operational commitment for the *resource* at bus $b \in B$;

4.1.71 $t_{tom} \in TS_{tom}$ designates the first time-step of the next *dispatch day*;

4.1.72 Y designates the *non-dispatchable load* zones in Ontario; and

4.1.73 Z_{Sch} designates the set of all *intertie* limit constraints.

4.2 Market Participant Data Parameters

4.2.1 With respect to a *non-dispatchable generation resource* identified by bus $b \in B^{NDG}$:

4.2.1.1 $QNDG_{t,b,k}$ designates the maximum incremental quantity of *energy* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{E}$; and

4.2.1.2 $PNDG_{t,b,k}$ designates the price for the maximum incremental quantity of *energy* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,bE}$.

4.2.2 With respect to a *dispatchable generation resource* identified by bus $b \in B^{DG}$:

4.2.2.1 $MinQDG_{q,b}$ designates the *minimum loading point* for day $q \in DAYS$;

4.2.2.2 $QDG_{t,b,k}$ designates the maximum incremental quantity of *energy* above the *minimum loading point* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{E}$;

4.2.2.3 $PDG_{t,b,k}$ designates the price for the maximum incremental quantity of *energy* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{E}$;

4.2.2.4 $Q10SDG_{t,b,k}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{10S}$;

4.2.2.5 $P10SDG_{t,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{10S}$;

4.2.2.6 $Q10NDG_{t,b,k}$ designates the maximum incremental quantity of nonsynchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{10N}$;

4.2.2.7 $P10NDG_{t,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in timestep $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{10N}$;

4.2.2.8 $Q30RDG_{t,b,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{30R}$;

4.2.2.9 $P30RDG_{t,b,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{30R}$;

4.2.2.10 $ORRDG_b$ designates the maximum *operating reserve* ramp rate in MW per minute;

4.2.2.11 $NumRRDG_{t,b}$ designates the number of ramp rates provided in timestep $t \in TS$;

4.2.2.12 $RmpRngMaxDG_{t,b,w}$ for $w \in \{1..,NumRRDG_{t,b}\}$ designates the w[th] ramp rate break point in time-step $t \in TS$;

4.2.2.13 $URRDG_{t,b,w}$ for $w \in \{1,..,NumRRDG_{t,b}\}$ designates the ramp rate in MW per minute at which the *resource* can increase the amount of *energy* it supplies in time-step $t \in TS$ while operating in the range between $RmpRngMaxDG_{t,b,w-1}$ and $RmpRngMaxDG_{t,b,w}$, where $RmpRngMaxDG_{t,b,0}0$ shall be equal to zero;

4.2.2.14 $DRRDG_{t,b,w}$ for $w \in \{1,..,NumRRDG_{t,b}\}$ designates the ramp rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies in time-step $t \in TS$ while operating in the range between $RmpRngMaxDG_{t,b,w-1}$ and $RmpRngMaxDG_{tt,b,w}$, where $RmpRngMaxDG_{t,b,0}$ shall be equal to zero;

4.2.2.15 $RLP30R_{t,b}$ designates the *reserve loading point* for *thirty-minute operating reserve* in time-step $t \in TS$; and

4.2.2.16 $RLP10S_{t,b}$ designates the *reserve loading point* for synchronized *ten-minute operating reserve* in time-step $t \in TS$.

4.2.3 With respect to a *dispatchable non-quick start resource* identified by bus $b \in B^{NQS}$:

4.2.3.1 $LT_{q,b}^{m}$ designates the *lead time* in *dispatch day* $q \in DAYS$ for *thermal state* $m \in THERM$;

4.2.3.2 $MGODG_{t,b}$ designates the minimum generation cost to operate at *minimum loading point* in time-step $t \in TS$. This parameter is calculated as follows:

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

4.2.3.3 $MGBRTDG_{q,b}$ designates the *minimum generation block run-time* within *dispatch day* $q \in DAYS$;

4.2.3.4 $MaxStartsDG_{q,b}$ designates the *maximum number of starts per day* within *dispatch day* $q \in DAYS$;

4.2.3.5 $MGBDTDG_{q,b}^{HOT}$ designates the *minimum generation block down-time* for a hot *thermal state* within *dispatch day* $q \in DAYS$;

4.2.3.6 $MGBDTDG_{q,b}^{WARM}$ designates the *minimum generation block down-time* for a warm *thermal state* in *dispatch day* $q \in DAYS$;

4.2.3.7 $MGBDTDG_{q,b}^{COLD}$ designates the *minimum generation block down-time* for a cold *thermal state* in *dispatch day q* ∈*DAYS*;

4.2.3.8 $PLTMLP_{t,b,k}$ designates the price for the maximum incremental quantity of *energy* up to the *minimum loading point* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$;

4.2.3.9 $QLTMLP_{t,b,k}$ designates the maximum incremental quantity of *energy* up to the *minimum loading point* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$;

4.2.3.10 $RampE_{q,b,w}^{m}$ designates the *ramp up energy to minimum loading point* in *dispatch day q* ∈*DAYS* for $w \in \{1,\ldots,RampHrs_{q,b}^{m}\}$ and *thermal state m* ∈*THERM*;

4.2.3.11 $RampHrs_{q,b}^{m}$ designates the *ramp hours to minimum loading point* in *dispatch day q* ∈*DAYS* for *thermal state m* ∈*THERM*;

4.2.3.12 $SNL_{t,b}$ designates the *speed no-load offer* in time-step $t \in TS$;

4.2.3.13 $SUDG_{t,b}^{m}$ designates the *start-up offer* in time-step $t \in TS$ for *thermal state* $m \in THERM$;

4.2.3.14 $SUDG_{t,b}^{DAM}$ designates the *start-up offer* used to evaluate the *day-ahead market* commitment starting in time-step $t \in TSC_b$;

4.2.3.15 $SUAdjDG^{m}_{t,b}$ designates the *start-up offer* that the optimization function will evaluate in time-step $t \in TS$ under *thermal state m*.

4.2.4 With respect to an *energy limited resource* identified by bus $b \in B^{ELR}$:

4.2.4.1 $MaxDEL_{q,b}$ designates the *maximum daily energy limit* for a single *resource* with or without a registered *forebay* within *dispatch day* $q \in DAYS$..

4.2.5 With respect to a *dispatchable* hydroelectric *generation resource* identified by bus $b \in B^{HE}$:

4.2.5.1 $MinHMR_{t,b}$ designates the *hourly must-run* value in time-step $t \in TS$;

4.2.5.2 $MinHO_{t,b}$ designates the *minimum hourly output* in time-step $t \in TS$;

4.2.5.3 $MinDEL_{q,b}$ designates the *minimum daily energy limit* for a single *resource* with of without a registered *forebay* within *dispatch day* $q \in DAYS$.;

4.2.5.4 $MaxStartsHE_{q,b}$ designates the *maximum number of starts per day* within *dispatch day* $q \in DAYS$;

4.2.5.5 $StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$ designates the *start indication value* for measuring *maximum number of starts per day*; a start is counted between time-step t and $(t+1)$ if the schedule increases from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$; and

4.2.5.6 $(ForL_{q,b,i}, ForU_{q,b,i})$ for $i \in \{1,..,NFor_{q,b}\}$ designates the lower and upper limits of the *forbidden regions* and indicate that the *resource* cannot be scheduled between $ForL_{q,b,i}$ and $ForU_{q,b,i}$ for all $i \in \{1,..,NFor_{q,b}\}$ within *dispatch day* $q \in DAYS$.

4.2.6 With respect to multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay*:

4.2.6.1 $MaxSDEL_{q,s}$ designates the *maximum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$ for *dispatch day* $q \in DAYS$; and

4.2.6.2 $MinSDEL_{q,s}$ designates the *minimum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$ within *dispatch day* $q \in DAYS$.

4.2.7 With respect to a *dispatchable* hydroelectric *generation resource* for which a *MWh ratio* was respected:

4.2.7.1 $LNK_q \subseteq B_{up}^{HE} \times B_{dn}^{HE}$ designates the set of linked *dispatchable* hydroelectric *generation resources* for *dispatch day* $q \in DAYS$, where LNK_q designates a set with elements of the form (b_1, b_2) where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$;

4.2.7.2 $Lag_{q,b1,b2} \in \{0,...23\}$ designates the *time lag* in hours between upstream *dispatchable* hydroelectric *generation resources* $b1 \in B_{up}^{HE}$ and downstream *dispatchable* hydroelectric *generation resources* $b2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNK_q$ for *dispatch day* $q \in DAYS$; and

4.2.7.3 $MWhRatio_{q,b1,b2}$ designates the *MWh ratio* between upstream *dispatchable* hydroelectric *generation resources* $b1 \in B_{up}^{HE}$ and downstream *dispatchable* hydroelectric *generation resources* $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNK_q$ for *dispatch day* $q \in DAYS$.

4.2.8 With respect to a *pseudo-unit* identified by bus $b \in B^{PSU}$:

4.2.8.1 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region;

4.2.8.2 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region;

4.2.8.3 $RampCT_{q,b,w}^m$ designates the quantity of *energy* injected w hours before the *pseudo-unit* 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 $w \in \{1,..,RampHrs_{q,b}^m\}$; and

4.2.8.4 $RampST_{q,b,w}^{m}$ designates the quantity of *energy* injected w hours before the *pseudo-unit* 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 $w \in \{1,..,RampHrs_{q,b}^{m}\}$.

4.2.9 With respect to a *dispatchable load* identified by bus $b \in B^{DL}$:

4.2.9.1 $QDL_{t,b,j}$ designates the maximum incremental quantity of *energy* that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J_{t,b}^{E}$;

4.2.9.2 $PDL_{t,b,j}$ designates the price for the maximum incremental quantity of *energy* in time-step $t \in TS$ in association with *bid* lamination $j \in J_{t,b}^{E}$;

4.2.9.3 $Q10SDL_{t,b,j}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,b}^{10S}$;

4.2.9.4 $P10SDL_{t,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,b}^{10S}$;

4.2.9.5 $Q10NDL_{t,b,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,b}^{10N}$;

4.2.9.6 $P10NDL_{t,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in timestep $t \in TS$ in association with *offer* lamination $j \; J_{t,b}^{10N}$;

4.2.9.7 $Q30RDL_{t,b,j}$ designates the maximum incremental quantity of *thirty minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,b}^{30R}$;

4.2.9.8 $P30RDL_{t,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{30R}$;

4.2.9.9 $ORRDL_{b}$ designates the *operating reserve* ramp rate in MW per minute for reductions in load consumption;

4.2.9.10 $NumRRDL_{t,b}$ designates the number of ramp rates provided in timestep $t \in TS$;

4.2.9.11 $RmpRngMaxDL_{t,b,w}$ for $w \in \{1,..,NumRRDL_{t,b}\}$ designates the w^th^ ramp rate break point in time-step $t \in TS$;

4.2.9.12 $URRDL_{t,b,w}$ for $w \in \{1,..,NumRRDL_{t,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption in time-step $t \in TS$ while operating in the range between $RmpRngMaxDL_{t,b,w-1}$ and $RmgRngMaxDL_{t,b,w}$, where $RmpRngMaxDL_{t,b,0}$ shall be equal to zero;

4.2.9.13 $DRRDL_{t,b,w}$ for $w \in \{1..,NumRRDL_{t,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption in time-step $t \in TS$ while operating in the range between $RmpRngMaxDL_{t,b,w-1}$ and $RmpRngMaxDL_{t,b,w}$, where $RmpRngMaxDL_{t,b,0}$ shall be equal to zero; and

4.2.9.14 $QDLFIRM_{t,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in time-step $t \in TS$.

4.2.10 With respect to an *hourly demand response resource* identified by bus $b \in B^{HDR}$:

4.2.10.1 $QHDR_{t,b,j}$ designates an maximum incremental quantity of reduction in *energy* consumption that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J_{t,b}^{E}$;

4.2.10.2 $PHDR_{t,b,j}$ designates the price for the maximum incremental quantity of reduction in *energy* consumption for time-step $t \in TS$ in association with *bid* lamination $j \in J_{t,b}^{E}$;

4.2.10.3 $URRHDR_{b}$ designates the maximum rate in MW per minute at which the *hourly demand response resource* can decrease its amount of *energy* consumption; and

4.2.10.4 $DRRHDR_{b}$ designates the maximum rate in MW per minute at which the *hourly demand response resource* can increase its amount of *energy* consumption.

4.2.11 With respect to a *boundary entity resource* import from *intertie zone* bus $d \in DI$, where the *locational marginal price* represents the price for the *intertie metering point*:

4.2.11.1 $QIG_{t,d,k}$ designates the maximum incremental quantity of *energy* that may be scheduled to import in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{E}$;

$PIG_{t,d,k}$ designates the price for the maximum incremental quantity of *energy* may be scheduled to import in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{E}$;

4.2.11.3 $Q10NIG_{t,d,k}$ designates the maximum incremental quantity of nonsynchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{10N}$;

4.2.11.4 $P10NIG_{t,d,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in timestep $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{10N}$;

4.2.11.5 $Q30RIG_{t,\mathrm{d,k}}$ designates the maximum incremental quantity of *thirty-minute operating reserve* quantity that may be scheduled in time-step $\mathrm{t} \in \mathrm{TS}$ in association with *offer* lamination $\mathrm{k} \in \mathrm{K_{t,d}}^{30\mathrm{R}}$; and

4.2.11.6 $P30RIG_{t,\mathrm{d,k}}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $\mathrm{t} \in \mathrm{TS}$ in association with *offer* lamination $\mathrm{k} \in \mathrm{K_{t,d}}^{30\mathrm{R}}$.

4.2.12 With respect to a *boundary entity resource* export to *intertie zone* sink bus $\in \mathrm{DX}$, where the *locational marginal price* represents the price for the *intertie metering point*:

4.2.12.1 $QXL_{t,\mathrm{d,j}}$ designates the maximum incremental quantity of *energy* that may be scheduled to export in time-step $\mathrm{t} \in TS$ in association with *bid* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{\mathrm{E}}$;

4.2.12.2 $PXL_{t,\mathrm{d,j}}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to export in time-step $\mathrm{t} \in TS$ in association with *bid* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{\mathrm{E}}$;

4.2.12.3 $Q10NXL_{t,\mathrm{d,j}}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled to provide in time-step $\mathrm{t} \in \mathrm{TS}$ in association with *offer* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{10\mathrm{N}}$;

4.2.12.4 $P10NXL_{t,\mathrm{d,j}}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in timestep $\mathrm{t} \in TS$ in association with *offer* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{10\mathrm{N}}$;

4.2.12.5 $Q30RXL_{t,\mathrm{d,j}}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled to provide in timestep $\mathrm{t} \in TS$ in association with *offer* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{30\mathrm{R}}$; and

$P30RXL_{t,\mathrm{d,j}}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $\mathrm{t} \in \mathrm{TS}$ in association with *offer* lamination $\mathrm{j} \in \mathrm{J_{t,d}}^{30\mathrm{R}}$

With respect to a wheeling through transaction:

$L_t \subseteq DX \times DI$ designates the set of linked *boundary entity resource* import and export buses corresponding to *wheeling through transactions*, where $\mathrm{L_t}$ is a set with elements of the form (dx, di) where $dx \in DX$ and $di \in DI$.

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

4.3.1.1 $FG_{t,\mathrm{b}}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus $\mathrm{b} \in B^{VG}$ in timestep $\in TS$.

4.3.2 Variable Generation Tie-Breaking

4.3.2.1 $NumVG_t$ designates the number of *variable generation resources* in the daily *dispatch* order for time-step $t \in TS$; and

4.3.2.2 $TBM_{t,b} \in \{1,..,NumVG_t\}$ designates the tie-breaking modifier for the *variable generation resource* at bus $b \in B^{VG}$ for time-step t TS.

4.3.3 Intertie Curtailments

4.3.3.1 $ICMaxXL_{t,d}$ designates the maximum limit on the quantity of *energy* scheduled for export to *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.2 $ICMinXL_{t,d}$ designates the minimum limit on the quantity of *energy* scheduled for export to *intertie zone* sink bus $d \in DX$ and time step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.3 $ICMaxIG_{t,d}$ designates the maximum limit on the quantity of *energy* scheduled for import from *intertie zone* source bus $d \in DI$ and timestep $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.4 $ICMax10NIG_{t,d}$ designates the maximum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.5 $ICMax30RIG_{t,d}$ designates the maximum limit on the quantity of *thirty-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.6 $ICMinIG_{t,d}$ designates the minimum limit on the quantity of *energy* scheduled for import from *intertie zone* source bus $d \in DI$ and timestep $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.7 $ICMin10NIG_{t,d}$ designates the minimum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment; and

4.3.3.8 $ICMin30RIG_{t,d}$ designates the minimum limit on the quantity of *thirtyminute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment.

4.3.4 Operating Reserve Requirements

4.3.4.1 $TOT10S_t$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.4.2 $TOT10R_t$ designates the total *ten-minute operating reserve* requirement;

4.3.4.3 $TOT30R_t$ designates the *thirty-minute operating reserve* requirement;

4.3.4.4 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.4.5 $REGMin10R_{t,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;

4.3.4.6 $REGMin30R_{t,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;

4.3.4.7 $REGMax10R_{t,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in timestep $t \in TS$; and

4.3.4.8 $REGMax30R_{t,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in timestep $t \in TS$.

4.3.5 Intertie Limits

4.3.5.1 $EnCoeff_{a,z}$ designates the coefficient for calculating the contribution of scheduled *energy* flows and *operating reserve* inflows for *intertie* zone $a \in A$ which is part of *intertie* limit constraint $z \in Z_{Sch}$. A coefficient of $+1$ shall describe flows into Ontario while a coefficient of -1 shall describe flows out of Ontario;

4.3.5.2 $MaxExtSch_{t,z}$ designates the maximum flow limit for *intertie* flow constraint $z \in Z_{Sch}$ in time-step $t \in TS$;

4.3.5.3 $ExtDSC_t$ designates the net interchange scheduling limit for when the net flows over all *interties* from time-step $(t-1)$ to time-step t decrease; and

4.3.5.4 $ExtUSC_t$ designates the net interchange scheduling limit for when the net flows over all *interties* from time-step $(t-1)$ to time-step t increase.

4.3.6 Resource Minimum and Maximum Constraints

4.3.6.1 Where applicable the minimum or maximum output of a *dispatchable generation resource* or a *non-dispatchable generation resource*, minimum or maximum consumption of a *dispatchable load*, and minimum and maximum reduction of an *hourly demand response resource* may be limited due to *reliability* constraints, applicable *contracted ancillary services*, day-ahead operational commitments, previous pre-dispatch operational commitments, *outages*, derates, activation/non-activation of *hourly demand response resources* and other constraints, such that:

4.3.6.1.1 $MinDL_{t,b}$ designates the most restrictive minimum consumption limit for the *dispatchable load* at bus $b \in B^{DL}$;

4.3.6.1.2 $MaxDL_{t,b}$ designates the most restrictive maximum consumption limit for the *dispatchable load* at bus $b \in B^{DL}$;

4.3.6.1.3 $MinNDG_{t,b}$ designates the most restrictive minimum output limit for the *non-dispatchable generation resource* at bus $b \in B^{NDG}$;

4.3.6.1.4 $MaxNDG_{t,b}$ designates the most restrictive maximum output limit for the *non-dispatchable generation resource* at bus $b \in B^{NDG}$;

4.3.6.1.5 $MinDG_{t,b}$ designates the most restrictive minimum output limit for the *dispatchable generation resource* at bus $b \in B^{DG}$;

4.3.6.1.6 $MaxDG_{t,b}$ designates the most restrictive maximum output limit for the *dispatchable generation resource* at bus $b \in B^{DG}$;

4.3.6.1.7 $MaxMLP_{t,b}$ designates the maximum output limit in time-step t for the *minimum loading point* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.8 $MaxDR_{t,b}$ designates the maximum output limit in time-step t for the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.9 $MaxDF_{t,b}$ designates the maximum output limit in time-step t for the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.10 $MinHDR_{t,b}$ designates the minimum load reduction level that may be scheduled for the *hourly demand response resource* at bus $b \in B^{HDR}$; and

4.3.6.1.11 $MaxHDR_{t,b}$ designates the maximum load reduction level that may be scheduled for the *hourly demand response resource* at bus $b \in B^{HDR}$.

4.3.7 Constraint violation penalties for time step $t \in TS$:

4.3.7.1 $(PLdViolSch_{t,i}, QLdViolSch_{t,i})$ for $i \in \{1,..,N_{LdViolt}\}$ designates the price-quantity segments of the penalty curve for under generation used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.2 $(PLdViolPrc_{t,i}, QLdViolPrc_{t,i})$ for $i \in \{1,..,N_{LdViolt}\}$ designates the pricequantity segments of the penalty curve for under generation used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.3 $(PGenViolSch_{t,i}, QGenViolSch_{t,i})$ for $i \in \{1,..,N_{GenViolt}\}$ designates the price-quantity segments of the penalty curve for over generation used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.4 $(PGenViolPrc_{t,i}, QGenViolPrc_{t,i})$ for $i \in \{1,..,N_{GenViolt}\}$ designates the price-quantity segments of the penalty curve for over generation used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.5 $(P10SViolSch_{t,i}, Q10SViolSch_{t,i})$ for $i \in \{1,..,N_{10SViolt}\}$ designates the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.6 $(P10SViolPrc_{t,i}, Q10SViolPrc_{t,i})$ for $i \in \{1,..,N_{10SViolt}\}$ designates the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.7 $(P10RViolSch_{t,i}, Q10RViolSch_{t,i})$ for $i \in \{1,..,N_{10RViolt}\}$ designates the price-quantity segments of the penalty curve for the total *ten-minute* *operating reserve* requirement used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.8 $(P10RViolPrc_{t,i}, Q10RViolPrc_{t,i})$ for $i \in \{1,..,N_{10RViolt}\}$ designates the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.9 $(P30RViolSch_{t,i}, Q30RViolSch_{t,i})$ for $i \in \{1,..,N_{30RViolt}\}$ designates 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 by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.10 $(P30RViolPrc_{t,i}, Q30RViolPrc_{t,i})$ for $i \in \{1,..,N_{30RViolt}\}$ designates 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 by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.11 $(PREG10RViolSch_{t,i}, QREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{REG10RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.12 $(PREG10RViolPrc_{t,i}, QREG10RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG10RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.13 $(PREG30RViolSch_{t,i}, QREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{REG30RViolt}\}$ designates the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.14 $(PREG30RViolPrc_{t,i}, QREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG30RViolt}\}$ designates the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.15 $(PXREG10RViolSch_{t,i}, QXREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG10RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.16 $(PXREG10RViolPrc_{t,i}, QXREG10RViolPrc_{t,i})$ for $I \in \{1,..,N_{XREG10RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.17 $(PXREG30RViolSch_{t,i}, QXREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG30RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.18 $(PXREG30RViolPrc_{t,i}, QXREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{XREG30RViolt}\}$ designates the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.19 $(PPreITLViolSchf_{t,i}, QPreITLViolSchf_{t,i})$ for $i \in \{1,..,N_{preITLViolf,t}\}$ designates the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.20 $(PPreITLViolPrcf_{t,i}, QPreITLViolPrcf_{t,i})$ for $i \in \{1,..,N_{PreITLViolf,t}\}$ designates the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.21 $(PITLViolSchc_{,f,t,i}, QITLViolSchc_{,f,t,i})$ for $i \in \{1,..,N_{ITLViolc,f,t}\}$ designates 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 by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.22 $(PITLViolPrcc_{,f,t,i}, QITLViolPrcc_{,f,t,i})$ for $i \in \{1,..,N_{ITLViolc,f,t}\}$ designates 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 by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.23 $(PPreXTLViolSchz_{,t,i}, QPreXTLViolSchz_{,t,i})$ for $I \in \{1,..,N_{PreXTLViolz,t}\}$ designates the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used by the PreDispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.24 $(PPreXTLViolPrc_{z,t,i}, QPreXTLViolPrc_{z,t,i})$ for $i \in \{1,..,N_{PreXTLViolz,t}\}$ designates the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used by the PreDispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.25 $(PNIUViolSch_{t,i}, QNIUViolSch_{t,i})$ for $i \in \{1,..,N_{NIUViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding the timestep t net interchange increase constraint between time-steps $(t\text{-}1)$ and t used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.26 $(PNIUViolPrc_{t,i}, QNIUViolPrc_{t,i})$ for $i \in \{1,..,N_{NIUViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding the timestep t net interchange increase constraint between time-steps $(t\text{-}1)$ and t used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.27 $(PNIDViolSch_{t,i}, QNIDViolSch_{t,i})$ for $i \in \{1,..,N_{NIDViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding the timestep t net interchange decrease constraint between time-steps $(t\text{-}1)$ and t used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.28 $(PNIDViolPrc_{t,i}, QNIDViolPrc_{t,i})$ for $i \in \{1,..,N_{NIDViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding the timestep t net interchange decrease constraint between time-steps $(t\text{-}1)$ and t used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.29 $(PMaxDelViolSch_{t,i}, QMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{MaxDelViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by the PreDispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.30 $(PMaxDelViolPrc_{t,i}, QMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViolt}\}$ designates the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by the PreDispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.31 $(PMinDelViolSch_{t,i}, QMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{MinDelViolt}\}$ designates the price-quantity segments of the penalty curve for underscheduling a *resource's minimum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.32 $(PMinDelViolPrc_{t,i}, QMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MinDelViolt}\}$ designates the price-quantity segments of the penalty curve for underscheduling a *resource's minimum daily energy limit* used by the PreDispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.33 $(PSMaxDelViolSch_{t,i}, QSMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMaxDelViolt}\}$ designate the price-quantity segments of the penalty curve for exceeding a shared *maximum daily energy limit* used by the PreDispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.34 $(PSMaxDelViolPrc_{t,i}, QSMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViolt}\}$ designate the price-quantity segments of the penalty curve for exceeding a shared *maximum daily energy limit* used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.35 $(PSMinDelViolSch_{t,i}, QSMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMinDelViolt}\}$ designate the price-quantity segments of the penalty curve for under-scheduling a shared *minimum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.36 $(PSMinDelViolPrc_{t,i}, QSMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{SMinDelViolt}\}$ designate the price-quantity segments of the penalty curve for underscheduling a shared *minimum daily energy limit* used by the PreDispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.37 $(POGenLnkViolSch_{t,i}, QOGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{OGenLnkViolt}\}$ designate the price-quantity segments of the penalty curve for over generation on a downstream *resource* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.38 $(PUGenLnkViolSch_{t,i}, QUGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{UGenLnkViolt}\}$ designate the price-quantity segments of the penalty curve for under generation on a downstream *resource* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12; and

4.3.7.39 $NISLPen$ designates the net interchange scheduling limit constraint violation penalty price for *locational marginal pricing*.

4.3.8 Price Bounds

4.3.8.1 $EngyPrcCeil$ designates and is equal to the *maximum market clearing price* for *energy*;

4.3.8.2 $EngyPrcFlr$ designates and is equal to the *settlement floor price* for *energy*;

4.3.8.3 $ORPrcCeil$ designates and is equal to the *maximum operating reserve price* for all classes of *operating reserve*; and

4.3.8.4 $ORPrcFlr$ designates the minimum price for all classes of *operating reserve* and is equal to $0.

4.3.9 Ex-Ante Market Power Mitigation

4.3.9.1 $BCACondThresh$ designates the threshold for the congestion component of a *resource's locational marginal price* for *energy*, above which the *resource* will meet the broad constrained area condition, and is equal to $25/MWh;

4.3.9.2 $IBPThresh$ designates the *intertie border price* threshold for *energy* and is equal to $100/MWh;

4.3.9.3 $ORGCondThresh$ designates the global market power condition threshold for a *resource's locational marginal price* for *operating reserve* and is equal to $15/MW*;*

4.3.9.4 $PDGRef_{t,b,k'}$ designates the *reference level value* for *energy* lamination $k' \in K'_{t,b}{}^{E}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.5 $P10SDGRef_{t,b,k'}$ designates the *reference level value* for synchronized *ten-minute operating reserve* lamination $k' \in K'_{t,b}{}^{10S}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.6 $P10NDGRef_{t,b,k'}$ designates the *reference level value* for nonsynchronized *ten-minute operating reserve* lamination $k' \in K'_{t,b}{}^{10N}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.7 $P30RDGRef_{t,b,k'}$ designates the *reference level value* for *thirty-minute operating reserve* lamination $k' \in K'_{t,b}{}^{30R}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.8 $P10SDLRef_{t,b,j'}$ designates the *reference level value* for synchronized *ten-minute operating reserve* lamination $j' \in J'_{t,b}{}^{10S}$ for the *resource* at bus $b \in B^{DL}$ in time-step $t \in TS$;

4.3.9.9 $P10NDLRef_{t,b,j'}$ designates the *reference level value* for non-synchronized *ten-minute operating reserve* lamination $j' \in J'_{t,b}{}^{10N}$ for the *resource* at bus $b \in B^{DL}$ in time-step $t \in TS$;

4.3.9.10 $P30RDLRef_{t,b,j'}$ designates the *reference level value* for *thirty-minute operating reserve* lamination $j' \in J'_{t,b}{}^{30R}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$

4.3.9.11 $SUDGRef_{t,b}$ designates the *reference level value* for the *start-up offer* for the *resource* at bus $b \in B^{NQS}$ in time-step $t \in TS$;

- $SNLRef_{t,b}$ designates the *reference level value* for the *speed no-load offer* for the *resource* at bus $b \in B^{NQS}$ in time-step $t \in TS$;

4.3.9.13 $PLTMLPRef_{t,b,k'}$ designates the *reference level value* for the *energy* up to the *minimum loading point reference level* lamination $k' \in K'_{h,b}{}^{LTMLP}$ of the *offer* for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.14 $CTEnThresh1^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 50%;

4.3.9.15 $CTEnThresh2^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.9.16 $CTSUThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.17 $CTSNLThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.18 $CTEnThresh1^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 50%;

4.3.9.19 $CTEnThresh2^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.9.20 $CTSUThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.21 $CTSNLThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.22 $CTEnThresh1^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

- $CTEnThresh2^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $100/MWh;

4.3.9.24 $CTSUThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 100%;

4.3.9.25 $CTSNLThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 100%;

4.3.9.26 $CTEnThresh1^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

4.3.9.27 $CTEnThresh2^{GMP}$ designates the global market power conduct threshold for a *resource* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $100 MW/h;

4.3.9.28 $CTSUThresh^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 100%;

4.3.9.29 $CTSNLThresh^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 100%;

4.3.9.30 $CTORThresh1^{ORL}$ designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to 10%;

4.3.9.31 $CTORThresh2^{ORL}$ designates the local market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.9.32 $CTEnThresh1^{ORL}$ designates the local marker power conduct threshold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 10%;

4.3.9.33 $CTEnThresh2^{ORL}$ designates the local market power conduct threshold for *energy* to *minimum loading point* conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *energy* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

4.3.9.34 $CTSUThresh^{ORL}$ designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 10%;

4.3.9.35 $CTSNLThresh^{ORL}$ designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 10%;

4.3.9.36 $CTORThresh1^{ORG}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to 50%;

4.3.9.37 $CTORThresh2^{ORG}$ designates the global market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.9.38 $CTEnThresh1^{ORG}$ designates the global market power conduct threshold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 50%;

4.3.9.39 $CTEnThresh2^{ORG}$ designates the global market power conduct threshold for *energy* to *minimum loading point* for a *resource* as a $/MW increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

4.3.9.40 $CTSUThresh^{ORG}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.41 $CTSNLThresh^{ORG}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.42 $CTEnMinOffer$ designates the minimum price for the *offer* lamination for *energy* to be included in the Conduct Test. *Offer* laminations for *energy* below this value are excluded from the Conduct Test and is equal to $25/MWh;

4.3.9.43 $CTORMinOffer$ designates the minimum price for the *offer* lamination for *operating reserve* to be included in the Conduct Test. *Offer* laminations for *operating reserve* below this value are excluded from the Conduct Test and is equal to \$5/MW;

4.3.9.44 $ITThresh1^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.9.45 $ITThresh2^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a \$/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to \$25/MWh;

4.3.9.46 $ITThresh1^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.9.47 $ITThresh2^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a \$/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to \$25/MWh;

4.3.9.48 $ITThresh1^{BCA}$ designates the price impact threshold for a *resource* in a broad constrained area as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.9.49 $ITThresh2^{BCA}$ designates the price impact threshold for a *resource* in a broad *constrained* area as a \$/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to\$50/MWh;

4.3.9.50 $ITThresh1^{GMP}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.9.51 $ITThresh2^{GMP}$ designates the global market power price impact threshold for a *resource* as a \$/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to \$50/MWh;

4.3.9.52 $ITThresh1^{ORG}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *operating reserve locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to 50%; and

4.3.9.53 $ITThresh2^{ORG}$ designates the global market power price impact threshold for a *resource* as a \$/MW increase in the *operating reserve locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to \$25/MW.

4.3.10 Weighting Factors for Zonal Prices

4.3.10.1 $WF_{t,m,b}^{VIRT}$ designates the weighting factor for bus $b \in L_m^{VIRT}$ used to calculate the price for *virtual transaction zone* $m \in M$ for time-step $t \in TS$ and is equal to the weighting factor used in the *day-ahead market* for the applicable hour;

4.3.10.2 $WF_{h,y,b}^{NDL}$ designates the weighting factor for bus $b \in L^{NDL}_y$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for time-step $t \in TS$. The weighting factors shall be obtained by renormalizing the load distribution factors so that for a given time-step the sum of weighting factors for a *non-dispatchable load* zone is equal to one.

4.3.11 Day-Ahead Market Scheduled Intertie Transactions

4.3.11.1 $SIGT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of import *energy* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.2 $S10NIGT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of non-synchronized *ten-minute operating reserve* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.3 $S30RIGT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of *thirty-minute operating reserve* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.4 $SXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of export *energy* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.5 $S10NXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of non-synchronized *ten-minute operating reserve* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$; and

4.3.11.6 $S30RXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of *thirty-minute operating reserve* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$.

4.3.12 Import Offers Without a Day-Ahead Market Schedule

4.3.12.1 $SIGT_{t,d}^{EXTRA}$ designates the extra quantity of *energy* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*;

4.3.12.2 $S10NIGT_{t,d}^{EXTRA}$ designates the extra quantity of non-synchronized *ten-minute operating reserve* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*; and

4.3.12.3 $S30RIGT_{t,d}^{EXTRA}$ designates the extra quantity of *thirty-minute operating reserve* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*.

4.4 Other Data Parameters

4.4.1 Non-Dispatchable Demand Forecast

4.4.1.1 FL_t designates the total province-wide non-*dispatchable demand* forecast for time-step $t \in TS$ calculated by the *security* assessment function.

4.4.2 Internal Transmission Constraints

4.4.2.1 $PreConSF_{t,f,b}$ designates 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;

4.4.2.2 $AdjNormMaxFlow_{t,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in time-step t under pre-contingency conditions;

4.4.2.3 $SF_{t,c,f,b}$ designates 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

4.4.2.4 $AdjEmMaxFlow_{t,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in time-step t under post-contingency conditions for contingency c.

4.4.3 Transmission Losses

4.4.3.1 $MglLoss_{t,b}$ designates the marginal loss factor and represents 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 $t \in TS$; and

4.4.3.2 $LossAdj_t$ designates 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.

5 Initialization

5.1 Purpose

5.1.1 The initialization processes set out in this section 5 shall occur prior to the execution of the *pre-dispatch calculation engine* described in section 2.2.1 above.

5.2 Reference Bus

5.2.1 The *IESO* shall use Richview Transformer Station as the *pre-dispatch calculation engine's* default *reference bus* for the calculation of *locational marginal prices.*

5.2.2 If the default *reference bus* is out of service, another in-service bus shall be selected.

5.3 Islanding Conditions

- In the event of a network split, the *pre-dispatch calculation engine* shall:

5.3.1.1 only evaluate *resources* that are within the *main island*;

5.3.1.2 use only forecasts of *demand* forecast areas in the *main island*; and

5.3.1.3 use a bus within the *main island* in place of the *reference bus* if the *reference bus* does not fall within the *main island*.

5.4 Variable Generation Tie-Breaking

5.4.1 For each time-step $t \in TS$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K_{t,b}^{E}$, the *offer* price $PDG_{t,b,k}$ shall be modified to $PDG_{t,b,k} - (TBM^{t,b} / NumVGt)\rho$, where ρ is a small nominal value of order 10^{-4}.

5.5 Pseudo-Unit Constraints

5.5.1 Constraints for *pseudo-units* corresponding to minimum and maximum constraints on physical *resources* shall be determined in accordance with section 15.

5.6 Dispatch Data Across Two Dispatch Days

5.6.1 If the pre-dispatch look-ahead period spans two *dispatch days*, then the *pre-dispatch calculation engine* shall set the parameters below as follows:

5.6.1.1 $LNKC$, which designates the linked *dispatchable* hydroelectric *generation resources* and is defined by:

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

5.6.1.2 $LagC_{b1,b2}$, which designates the *time lag* between *dispatchable* hydroelectric *generation resources* (b_1, b_2) $\in LNKC$ and is defined by:

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

5.6.1.3 $MWhRatioC_{b1,b2}$, which designates the *MWh ratio* for *dispatchable* hydroelectric *generation resources* (b_1, b_2) ∈ *LNKC* and is defined by:

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

5.6.1.4 $MinQDGC_b$, which designates the *minimum loading point* for *dispatchable generation resource* b ∈ B^{DG} and, subject to section 5.6.2, is defined by:

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

5.6.1.5 $MGBRTDGC_b$, which designates the *minimum generation block run time* for *non-quick start resource* b ∈ B^{NQS} and, subject to section 5.6.2, is defined by:

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

5.6.1.6 $MGBDTDGC_b{}^m$, which designates the *minimum generation block down time* for *non-quick start resource* b ∈ B^{NQS} for *thermal state* m ∈ *THERM* and is defined by:

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

5.6.1.7 $LTC_b{}^m$, which designates the *lead time* for *non-quick start resource* b ∈ B^{NQS} for *thermal state* m ∈ *THERM* and is defined by

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

5.6.1.8 $RampHrsC_b{}^m$, which designates the *ramp hours to minimum loading point* for a *non-quick start resource* b ∈ B^{NQS} for *thermal state* m ∈ *THERM* and is defined by:

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

5.6.1.9 $RampEC_{b,w}{}^m$ for w ∈ {1,..,$RampHrsC_b{}^m$}, which designates the *ramp up energy to minimum loading point* for a *non-quick start resource* b ∈ B^{NQS} for *thermal state* m ∈ *THERM* and is defined by:

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

5.6.1.10 $RampCTC_{b,w}{}^m$ for w ∈ {1,..,$RampHrsC_b{}^m$}, which designates the *ramp up energy to minimum loading point* for the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ for *thermal state* $m \in THERM$ and is defined by:

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

5.6.1.11 $RampSTC_{b,w}^{m}$ for $w \in \{1,..,RampHrsC_b^m\}$, which designates the *ramp up energy to minimum loading point* for the steam turbine portion of the *pseudo-unit* at bus $b \in B^{PSU}$ for *thermal state* $m \in THERM$ and is defined by:

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

5.6.2 If a *non-quick start resource* receives a commitment prior to the 20:00 EST *pre-dispatch calculation engine* run but that commitment is not yet complete, then:

5.6.2.1 $MinQDG_{tod,b}$ and $MGBRTDG_{tod,b}$ shall continue to be applied until the commitment is complete; and

5.6.2.2 $MinQDG_{tom,b}$ and $MGBRTDG_{tom,b}$ shall be applied for any new commitments made in the 20:00 EST *pre-dispatch calculation engine run* or later.

5.6.3 For all other daily *dispatch data*, except the single-cycle mode flag determined in section 15.5, the current day value shall be used for all *dispatch hours* in the current *dispatch day* and the next day value shall be used for all *dispatch hours* in the next *dispatch day*.

5.7 Start-Up Offers for Non-Quick Start Resource Advancements

5.7.1 The *pre-dispatch calculation engine* shall use *start-up offers* for *non-quick start resources* with a day-ahead operational commitment as follows:

5.7.1.1 If the time-step t in the set of hours preceding the start-up time $t_{DAM} \in TSC_b$ of a day-ahead operational commitment in day $q \in DAYS$ are such that $t \in \{max(t_{DAM}-(MGBRTDG_{q,b} + MGBDTDG_{q,b}^{HOT}),2),\ldots,t_{DAM}\}$, then:

If $SUDG_{t,b}^{m} \geq SUDG_{t,b}^{DAM}$, then set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{m}$

If $SUDG_{t,b}^{m} < SUDG_{t,b}^{DAM}$, then set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{DAM}$

5.7.1.2 If the time-step t in the set of hours preceding the start-up time $t_{DAM} \in TSC_b$ of a day-ahead operational commitment in day $q \in DAYS$ are *offer*such that $t \notin \{max(t_{DAM}-(MGBRTDG_{q,b} + MGBDTDG_{q,b}^{HOT}), 2),\ldots,t_{DAM}\}$, then:

$$SUAdjDGt_{,bm} = SUDGt_{,bm}$$

5.8 Non-Quick Start Resource First Time-Step Available to Start

5.8.1 The *pre-dispatch calculation engine* shall determine the first time-step a *non-quick start resource* can be scheduled to its *minimum loading point* as follows:

5.8.1.1 For a *non-quick start resource* at bus $b \in B^{NQS}$ that has not been scheduled at or above its *minimum loading point* for $InitDownHrs_b$ hours:

5.8.1.1.1 If $0 \leq InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{HOT}$, then the *resource* cannot be scheduled to reach *minimum loading point* in time-step $t \in TS$;

5.8.1.1.2 If $InitDownHrs_b + LTC_b^{HOT} + 1 \leq MGBDTDGC_b^{WARM}$, then a *lead time* of LTC_b^{HOT} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_b^{HOT} + 2$;

5.8.1.1.3 If $InitDownHrs_b + LTC_b^{WARM} + 1 \leq MGBDTDGC_b^{COLD}$, then a *lead time* of LTC_b^{WARM} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_b^{WARM} + 2$; and

5.8.1.1.4 If a *lead time* of LTC_b^{COLD} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_{bCOLD} + 2$.

5.9 Initial Scheduling Assumptions

5.9.1 Initial Schedules

5.9.1.1 The following parameters designate the initial *energy* schedules used for time-step 1 of the pre-dispatch look-ahead period and shall be based on the values determined by the *IESO's energy* management system for internal *resources* and the most recent *interchange schedules* for time-step 1 for *boundary entity resources*:

5.9.1.1.1 $SDL_{1,b,j}$ designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$;

5.9.1.1.2 $SHDR_{1,b,j}$ designates the amount of *energy* an *hourly demand response resource* is scheduled to reduce consumption at bus $b \in B^{HDR}$;

5.9.1.1.3 $SXL_{1,d,j}$ designates the amount of *energy* a *bounday entity resource* is scheduled to export at bus $d \in DX$;

5.9.1.1.4 $SDG_{1,b,k}$ designates the amount of *energy* that a *dispatchable* *generation resource* is scheduled to provide at bus $b \in B^{DG}$;

5.9.1.1.5 $SCT_{1,b}$ designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$;

5.9.1.1.6 $SST_{1,p}$ designates the schedule of steam turbine $p \in PST$;

5.9.1.1.7 $SIG_{1,d,k}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* source bus $d \in DI$;

5.9.1.2 The initial schedules for *non-quick start resources* shall be determined to align with the commitment status logic described in section 5.9.2.

5.9.2 The following parameters designate initial commitment status, number of hours in operation and number of hours down for time-step 1 of the pre-dispatch look-ahead period:

5.9.2.1 $ODG_{1,b}$ designates whether the *dispatchable generation resource* at bus $b \in B^{NQS}$ has been scheduled at or above its *minimum loading point* in time-step 1, where $ODG_{1,b}$ shall be set to $ODG_{2,b}$ from the previous *pre-dispatch calculation engine run* unless the *real-time calculation engine* has kept such *resource* at or above its *minimum loading point* to respect a *reliability* constraint. In such cases, $ODG_{1,b}$ shall be determined by the *real-time calculation engine* advisory schedule;

5.9.2.2 $InitOperHrs_b$ designates the number of consecutive hours at the end of time-step 1 for which the *resource* at bus $b \in B^{NQS}$ has been, and is anticipated to be, operating at or above its *minimum loading point*. For *resources* with $ODG_{1,b} = 0$, $InitOperHrs_b$ shall be set to zero; and

5.9.2.3 $InitDownHrs_b$ designates the number of consecutive hours at the end of time-step 1 for which the *resource* at bus $b \in B^{NQS}$ has not been, and is not anticipated to be, operating at or above its *minimum loading point*. For *resources* with $ODG_{1,b} = 1$, $InitDownHrs_b$ shall be set to zero.

5.9.3 Initial Net Interchange Schedule

5.9.3.1 The initial net *interchange schedule* value shall be the difference between all imports to Ontario and all exports from Ontario for timestep 1. By default, this value will be based on fixed schedules for imports and exports from the *real-time calculation engine*.

5.9.4 Number of Starts for Non-Quick Start Resources

5.9.4.1 $NumStarts_b$ designates the number of starts the *resource* at bus $b \in B^{NQS}$ has incurred in the current *dispatch* day, plus any anticipated starts in time-step 1.

5.9.5 Number of Starts for Hydroelectric Resources

5.9.5.1 $NumStartsHE_b$ designates 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.

5.9.6 Cumulative Energy Production for Energy Limited Resources and Dispatchable Hydroelectric Resources

5.9.6.1 $EngyUsed_b$ designates the *energy* already provided by the *resource* at bus $b \in B^{ELR} \cup B^{HE}$ in the current *dispatch day*, plus the *energy* scheduled in time-step 1; and

5.9.6.2 $EngyUsedSHE_s$ designates the *energy* already provided in the current *dispatch day* by all *resources* sharing a *maximum daily energy limit* or *minimum daily energy limit* in set $s \in SHE$ plus the *energy* scheduled in time-step 1.

5.9.7 Past Hourly Production for Linked Hydroelectric Resources

5.9.7.1 For linked hydroelectric *resources*, the past hourly *energy* production of upstream *resources* shall be used to schedule downstream *resources* for time-steps in the pre-dispatch look-ahead period within the *time lag*. These past hourly production schedules shall 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 $t \leq LagC_{b1,b2}$, $PastMWh_{t,b1}$ designates the total *energy* produced by *resource* bb_1 exactly $LagC_{b1,b2}$ hours prior to time-step t.

5.9.7.2 The schedules of downstream *resources* linked to time-step 1 upstream *resource* schedules shall be pre-determined based on the average value of the upstream *resource* advisory schedules from the last *real-time calculation engine* run that successfully completed before the *pre-dispatch calculation engine* run commenced. If the advisory schedule reflects an *operating reserve* activation for an upstream *resource*, then the schedule determined by the *real-time calculation engine* run prior to the *operating reserve* activation shall be used. For all linked hydroelectric *resources* $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t = LagC_{b1,b2}$, $PastMWh_{t,b1}$ designates the total *energy* determined for *resource* b_1 for time-step 1 to be used for scheduling downstream *resources* in time-step t.

6 Security Assessment Function in the Pre-Dispatch Calculation Engine

6.1 Interaction between the Security Assessment Function and Optimization Functions

6.1.1 The scheduling and pricing algorithms of the *pre-dispatch calculation engine* shall perform multiple iterations of the optimization functions and the *security* assessment function to check for violations of monitored thermal limits and operating *security limits* using the schedules produced by the optimization functions.

6.1.2 As multiple iterations are performed, the transmission constraints produced by the *security* assessment function shall be used by the optimization functions.

6.1.3 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudounits*.

6.2 Inputs into the Security Assessment Function

6.2.1 The *security* assessment function shall use the following inputs: 6.2.1.1 the *IESO demand* forecasts; and

6.2.1.2 applicable *IESO-controlled grid* information pursuant to section 3A.1 of Chapter 7.

6.2.2 The *security* assessment function shall also use the following outputs of the optimization functions:

6.2.2.1 the schedules for *dispatchable loads* and *hourly demand response resources*;

6.2.2.2 the schedules for *non-dispatchable generation resources* and *dispatchable generation resources*; and

6.2.2.3 the schedules for *boundary entity resources* at each *intertie zone*.

6.3 Security Assessment Function Processing

6.3.1 The *security* assessment function shall determine the province-wide non-*dispatchable demand* forecast for time-step t, FL_t, as follows:

6.3.1.1 determine forecast MW quantities for all *load resources* and losses using the *IESO demand* forecasts for *demand* forecast areas, load distribution factors, and the total of the *bid* quantities submitted for virtual *hourly demand response resources* and physical *hourly demand response resources*; and

6.3.1.2 determine FL_{tt} by adding the forecast MW quantities determined for each *non-dispatchable load*, each *price responsive load*, and each *dispatchable load* with no *bid*, including forecast MW losses in the *demand* forecast areas.

6.3.2 The *security* assessment function shall perform the following calculations and analyses:

6.3.2.1 A base case solution function shall prepare a power flow solution for each time-step. The base case solution function shall select the power system model state applicable to the forecast of conditions for the time-step and input schedules.

6.3.2.2 The base case solution function shall use an AC power flow analysis. If the AC power flow analysis fails to converge, the base case solution function shall use a non-linear DC power flow analysis. If the nonlinear DC power flow analysis fails to converge, the base case solution function shall use a linear DC power flow analysis.

6.3.2.3 If the AC or non-linear DC power flow analysis converges, continuous thermal limits for all monitored equipment and operating *security limits* shall be monitored to check for pre-contingency limit violations.

6.3.2.4 Violated pre-contingency limits shall be linearized using precontingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.5 If the linear DC power flow analysis is used, the pre-contingency *security* assessment may develop linear constraints to facilitate the convergence of the AC or non-linear DC power flow analysis in the subsequent iterations.

6.3.2.6 A linear power flow analysis shall be used to simulate contingencies, calculate post-contingency flows and check all monitored equipment for limited-time thermal limit violations.

6.3.2.7 Violated post-contingency limits shall be linearized using postcontingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.8 The base case solution shall be used to calculate Ontario *transmission system* losses, marginal loss factors and loss adjustment for each timestep. The impact of losses on branches between the *resource* bus and the *resource connection point* to the *IESO-controlled grid* and losses on branches outside Ontario shall be excluded when determining marginal loss factors.

6.3.2.9 The Pre-Dispatch Scheduling and the Reference Level Scheduling algorithms described in sections 8 and 12, respectively, shall use the marginal loss factors for each time step calculated by the *security* assessment function.

6.3.2.10 The Pre-Dispatch Pricing and Reference Level Pricing algoritms described in sections 9 and 13, respectively, shall use the marginal loss factors used in the last iteration of the optimization function in the corresponding scheduling algorithm.

6.4 Outputs from the Security Assessment Function

6.4.1 The outputs of the *security* assessment function used in the optimization functions include the following:

6.4.1.1 a set of linearized constraints for all violated pre-contingency and post-contingency limits for each time-step. The sensitivities and limits associated with the constraints shall be those provided by the most recent *security* assessment function iteration;

6.4.1.2 pre-contingency and post-contingency sensitivity factors for each time step;

6.4.1.3 the marginal loss factors as described in sections 6.3.2.8 - 6.3.2.10; and

6.4.1.4 loss adjustment quantity for each time-step.

7 Pass 1: Pre-Dispatch Scheduling Process

7.1.1 Pass 1 shall use *market participant* and *IESO* inputs and *resource* and system constraints to determine a set of *resource* schedules, commitments and *locational marginal prices*. Pass 1 shall consist of the following algorithms and tests:

- the Pre-Dispatch Scheduling algorithm described in section 8;
- the Pre-Dispatch Pricing algorithm described in section 9;
- the Constrained Area Conditions Test described in section 10;
- the Conduct Test described in section 11;
- the Reference Level Scheduling algorithm described in section 12;
- the Reference Level Pricing algorithm described in section 13; and
- the Price Impact Test described in section 14.

8 Pre-Dispatch Scheduling

8.1 Purpose

8.1.1 The Pre-Dispatch Scheduling algorithm shall perform a *security* constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants,* subject to section 14.7.1.3, to meet the *IESO's* provincewide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

8.2 Information, Sets, Indices and Parameters

8.2.1 Information, sets, indices and parameters used by the Pre-Dispatch Scheduling algorithm are described in sections 3 and 4.

8.3 Variables and Objective Function

8.3.1 The Pre-Dispatch Scheduling algorithm shall solve for the following variables:

8.3.1.1 $SDL_{t,b,j}$, which designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J_{t,b}^{E}$;

8.3.1.2 $S10SDL_{t,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J_{t,b}^{10S}$;

8.3.1.3 $S10NDL_{t,b,j}$, which designates the amount of non-synchronized *ten minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J_{t,b}^{10N}$;

8.3.1.4 $S30RDL_{t,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J_{t,b}^{30R}$;

8.3.1.5 $SHDR_{t,b,j}$, which designates the amount of *energy* reduction scheduled for an *hourly demand response resource* at bus $b \in B^{HDR}$ in time-step $t \in TS$ in association with lamination $j \in J_{t,b}^{E}$;

8.3.1.6 $SXL_{t,d,j}$, which designates the amount of *energy* a *boundary entity resource* is scheduled to export at bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J_{t,d}^{E}$;

8.3.1.7 $S10NXL_{t,d,j}$, which designates the amount of non-synchronized *ten minute operating reserve* that a *boundary entity resource* is scheduled to provide at bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J_{t,d}^{30R}$;

8.3.1.8 $S30RXL_{t,d,j}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J_{t,d}^{30R}$;

8.3.1.9 $SNDG_{t,b,k}$, which designates the amount of *energy* that a *non dispatchable generation resource* is scheduled to provide at bus $b \in B^{NDG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{E}$;

8.3.1.10 $SDG_{t,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{E}$;

8.3.1.11 $ODG_{t,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled at or above its *minimum loading point* in time-step $t \in TS$;

8.3.1.12 $IDG_{t,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled to reach its *minimum loading point* in time-step $t \in TS$;

8.3.1.13 $S10SDG_{t,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10S}$;

8.3.1.14 $S10NDG_{t,b,k}$, which designates the amount of non-synchronized *tenminute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$

8.3.1.15 $S30RDG_{t,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{30R}$;

8.3.1.16 $SCT_{t,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ in time-step $t \in TS$;

8.3.1.17 $SST_{t,p}$, which designates the schedule of steam turbine $p \in PST$ in time-step $t \in TS$;

8.3.1.18 $O10R_{t,b}$, which designates whether the *pseudo-unit* at bus $b \in B^{NO10DF}$ has been scheduled for *ten-minute operating reserve* in timestep $t \in TS$;

8.3.1.19 $OHO_{t,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$;

8.3.1.20 $OFR_{t,b,i}$ for $i \in \{1,..,NFor_{q,b}\}$, which designates whether the *dispatchable* hydroelectric *generation 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 timestep $t \in TS$;

8.3.1.21 $IHE_{t,b,i}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ registered a start between timestep $(t-1)$ and t as a result of its schedule increasing from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$;

8.3.1.22 $SIG_{t,d,k}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{E}$;

8.3.1.23 $S10NIG_{t,d,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{10N}$;

8.3.1.24 $S30RIG_{t,d,k}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{30R}$;

8.3.1.25 TB_t , which designates any adjustment to the objective function to facilitate pro-rata tie-breaking in time-step $t \in TS$, as described in section 8.3.2.1; and

8.3.1.26 $ViolCost_t$, which designates the cost incurred in order to avoid having the schedules violate constraints in time-step $t \in TS$, as described in section 8.3.2.3.

8.3.2 The objective function for the Pre-Dispatch Scheduling algorithm shall maximize gains from trade by maximizing 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:

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

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

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

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

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

and

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

8.3.2.1 The tie-breaking term TB_t shall sum a term for each *bid* or *offer* lamination. For each lamination, this term shall be the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost shall be 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. That is:

$$TB_t = TBDL_t + TBHDR_t + TBXL_t + TBNDG_t + TBDG_t + TBIG_t$$

Where

$$TBDL_t = \sum_{b \in B^{DL}} \left(\begin{array}{c} \sum_{j \in J_{t,b}^{E}} \left(\frac{(SDL_{t,b,j})^2 \cdot TBPen}{QDL_{t,b,j}} \right) + \sum_{j \in J_{t,b}^{10S}} \left(\frac{(S10SDL_{t,b,j})^2 \cdot TBPen}{Q10SDL_{t,b,j}} \right) + \\ \sum_{j \in J_{t,b}^{10N}} \left(\frac{(S10NDL_{t,b,j})^2 \cdot TBPen}{Q10NDL_{t,b,j}} \right) + \sum_{j \in J_{t,b}^{30R}} \left(\frac{(S30RDL_{t,b,j})^2 \cdot TBPen}{Q30RDL_{t,b,j}} \right) \end{array} \right);$$

$$TBHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J_{t,b}^{E}} \frac{(SHDR_{t,b,j})^2 \cdot TBPen}{QHDR_{t,b,j}} \right); /$$

$$TBXL_t = \sum_{d \in DX} \left(\begin{array}{c} \sum_{j \in J_{t,d}^{E}} \left(\frac{(SXL_{t,d,j})^2 \cdot TBPen}{QXL_{t,d,j}} \right) + \sum_{j \in J_{t,d}^{10N}} \left(\frac{(S10NXL_{t,d,j})^2 \cdot TBPen}{Q10NXL_{t,d,j}} \right) \\ + \sum_{j \in J_{t,d}^{30R}} \left(\frac{(S30RXL_{t,d,j})^2 \cdot TBPen}{Q30RXL_{t,d,j}} \right) \end{array} \right);$$

$$TBNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{t,b}^{E}} \left(\frac{(SNDG_{t,b,k})^2 \cdot TBPen}{QNDG_{t,b,k}} \right) \right);$$

$$TBDG_t = \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K_{t,b}^{E}} \left(\frac{(SDG_{t,b,k})^2 \cdot TBPen}{QDG_{t,b,k}} \right) + \sum_{k \in K_{t,b}^{10S}} \left(\frac{(S10SDG_{t,b,k})^2 \cdot TBPen}{Q10SDG_{t,b,k}} \right) + \\ \sum_{k \in K_{t,b}^{10N}} \left(\frac{(S10NDG_{t,b,k})^2 \cdot TBPen}{Q10NDG_{t,b,k}} \right) + \sum_{k \in K_{t,b}^{30R}} \left(\frac{(S30RDG_{t,b,k})^2 \cdot TBPen}{Q30RDG_{t,b,k}} \right) \end{array} \right);$$

and

$$TBIG_t = \sum_{d \in DI} \left(\begin{array}{c} \sum_{k \in K_{t,d}^{E}} \left(\frac{(SIG_{t,d,k})^2 \cdot TBPen}{QIG_{t,d,k}} \right) + \sum_{k \in K_{t,d}^{10N}} \left(\frac{(S10NIG_{t,d,k})^2 \cdot TBPen}{Q10NIG_{t,d,k}} \right) \\ + \sum_{k \in K_{t,d}^{30R}} \left(\frac{(S30RIG_{t,d,k})^2 \cdot TBPen}{Q30RIG_{t,d,k}} \right) \end{array} \right).$$

8.3.2.2 $ViolCost_t$ shall be calculated for time-step $t \in TS$ using the following variables:

8.3.2.2.1 $SLdViol_{t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{LdViolt}\}$ of the penalty curve for the *energy* balance constraint allowing under-generation;

8.3.2.2.2 $SGenViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{GenViolt}\}$ of the penalty curve for the *energy* balance constraint allowing over-generation;

8.3.2.2.3 $S10SViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,...,N_{10SViolt}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;

8.3.2.2.4 $S10RViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,...,N_{10RViolt}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;

8.3.2.2.5 $S30RViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,...,N_{30RViolt}\}$ of the penalty curve for the *thirty minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;

8.3.2.2.6 $SREG10RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{REG10RViolt}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.7 $SREG30RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{REG30RViolt}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{XREG10RViolt}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.9 $SXREG30RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{XREG30RViolt}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.10 $SPreITLViol_{f,t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{PreITLViolf,t}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$;

8.3.2.2.11 $SITLViol_{c,f,t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{ITLViolc,f,t}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$;

8.3.2.2.12 $SPreXTLViol_{z,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{PreXTLViolz,t}\}$ of the penalty curve for violating the import/export limit affiliated with *intertie* limit constraint $z \in Z_{Sch}$;

8.3.2.2.13 $SNIUViol_{t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{NIUViolt}\}$ of the penalty curve for exceeding the net interchange increase limit between time-steps $(t-1)$ and t;

8.3.2.2.14 $SNIDViol_{t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{NIDViolt}\}$ of the penalty curve for exceeding the net interchange decrease limit between time-steps $(t-1)$ and t;

8.3.2.2.15 $SMaxDelViol_{t,b,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{MaxDelViolt}\}$ of the penalty curve for exceeding the *maximum daily energy limit* constraint for a *resource* at bus $b \in B^{ELR}$;

8.3.2.2.16 $SMinDelViol_{t,b,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{MinDelViolt}\}$ of the penalty curve for violating the *minimum daily energy limit* constraint for a *resource* at bus $b \in B^{HE}$;

8.3.2.2.17 $SSMaxDelViol_{t,s,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{SMaxDelViolt}\}$ of the penalty curve for exceeding the shared *maximum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

8.3.2.2.18 $SSMinDelViol_{t,s,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{SMinDelViolt}\}$ of the penalty curve for violating the shared *minimum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

8.3.2.2.19 $SOGenLnkViol_{t,(b1,b2),i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{OGenLnkViolt}\}$ of the penalty curve for violating the linked *dispatchable* hydroelectric *generation resources* constraint by over-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b1 \in B_{up}^{HE}$ and $b2 \in B_{dn}^{HE}$; and

8.3.2.2.20 $SUGenLnkViol_{t,(b1,b2),i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{UGenLnkViolt}\}$ of the penalty curve for violating the linked *dispatchable* hydroelectric *generation resources* constraint by under-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b1 \in B_{up}^{HE}$ and $b2 \in B_{dn}^{HE}$.

8.3.2.3 $ViolCost_t$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_t = & \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} \cdot PLdViolSch_{t,i} \ - \\
& \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} \cdot PGenViolSch_{t,i} + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \cdot P10SViolSch_{t,i} + \\
& \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \cdot P10RViolSch_{t,i} + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \cdot P30RViolSch_{t,i} + \\
& \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \cdot PREG10RViolSch_{t,i} \right) + \\
& \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \cdot PREG30RViolSch_{t,i} \right) + \\
& \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \cdot PXREG10RViolSch_{t,i} \right) + \\
& \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i} \cdot PXREG30RViolSch_{t,i} \right) \\
& \ldots
\end{aligned}
$$

$$
\begin{aligned}
& + \sum_{f \in F_t} \left(\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \cdot PPreITLViolSch_{f,t,i} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{t,c}} \left(\sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i} \cdot PITLViolSch_{c,f,t,i} \right) \\
& + \sum_{z \in Z_{Sch}} \left(\sum_{i=1..N_{PreXTLViol_{z,t}}} SPreXTLViol_{z,t,i} \cdot PPreXTLViolSch_{z,t,i} \right) \\
& + \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i} \cdot PNIUViolSch_{t,i} + \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i} \cdot PNIDViolSch_{t,i}
\end{aligned}
$$

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

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

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

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

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

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

8.4 Constraints

8.4.1 The constraints described in sections 8.5 – 8.7 apply to the optimization function in the Pre-Dispatch Scheduling algorithm.

8.5 Dispatch Data Constraints Applying to Individual Hours

8.5.1 Scheduling Variable Bounds

8.5.1.1 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:

$ODG_{t,b} \in \{0,1\}$ for all time-steps $t \in TS$ and all buses $b \in B^{DG}$.

8.5.1.2 *Reliability must-run resources* are considered committed for all must run hours.

8.5.1.3 *Resources* providing *regulation* are considered committed for all the hours that they are regulating.

8.5.1.4 *Dispatchable generation resources* that have *minimum loading points*, *start-up offers, speed no-load offers*, *minimum generation block runtimes* and *minimum generation block down times* equal to zero shall be considered committed for all hours.

8.5.1.5 If the *dispatchable generation resource* at bus $b \in B^{DG}$ is considered committed according to the requirements in sections 8.5.1.2, 8.5.1.3, and 8.5.1.4 in time-step $t \in TS$ then:

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

8.5.1.6 No schedule shall be negative, nor shall any schedule exceed the quantity *offered* for the respective *energy* and *operating reserve* market. Therefore:

$0 \leq SDL_{t,b,j} \leq QDL_{t,b,j}$ 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 $d \in DI, k \in K^{30R}_{t,d}$

for all time-steps $t \in TS$.

8.5.1.7 *Generation resources* may be scheduled for *energy* and/or *operating reserve* only if their commitment status 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 $b \in B^{DG}, k \in K^{30R}_{t,b}$.

8.5.2 Resource Minimums and Maximums for Energy

8.5.2.1 A constraint shall limit schedules for *dispatchable loads* within their minimum and maximum consumption for a time-step. For all timesteps $t \in TS$ and all buses $b \in B^{DL}$:

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

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

$$\sum_{j \in J_{t,b}^{E}} SDL_{t,b,j} \geq QDLFIRM_{t,b}.$$

8.5.2.3 A constraint shall limit schedules for *non-dispatchable generation resources* within their minimum and maximum output for a time-step. For all time-steps $t \in TS$ and all buses $b \in B^{NDG}$:

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

8.5.2.4 A constraint shall limit schedules for *dispatchable generation resources* within their minimum and maximum output for a timestep. For a *dispatchable variable generation resource*, the maximum schedule shall be limited by its forecast. That is:

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

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

and

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

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

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

8.5.2.5 If the commitment status, $ODG_{t,b}$, of a *dispatchable generation resource* is equal to 1 and if this status is inconsistent with the adjusted minimum and maximum constraints, $MinQDGC_b > AdjMaxDG_{t,b}$, then the commitment status value, $ODG_{t,b}$, shall be changed to a value between 0 and 1.

8.5.2.6 If the total *offered* quantity does not exceed the minimum, $MinQDGC_b + \sum_{k \in K_{t,b}^E} QDG_{t,b,k} < AdjMinDG_{t,b}$, then the *resource* shall receive a schedule of zero.

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

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

8.5.3 Off-Market Transactions

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

$$\sum_{j \in J^E_{t,d}} SXL_{t,d,j} = \sum_{j \in J^E_{t,d}} QXL_{t,d,j}.$$

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

$$\sum_{k \in K^E_{t,d}} SIG_{t,d,k} = \sum_{k \in K^E_{t,d}} QIG_{t,d,k}.$$

8.5.3.3 For all time-steps $t \in TS$ and all *intertie zone* buses corresponding to an *emergency energy* export $d \in DX_t^{EM}$:

$$\sum_{j \in J^E_{t,d}} SXL_{t,d,j} = \sum_{j \in J^E_{t,d}} QXL_{t,d,j}.$$

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

$$\sum_{k \in K^E_{t,d}} SIG_{t,d,k} = \sum_{k \in K^E_{t,d}} QIG_{t,d,k}.$$

8.5.4 Intertie Minimum and Maximum Constraints

8.5.4.1 A constraint shall limit export schedules beyond the first two forecast hours of the pre-dispatch look-ahead period to the corresponding *day ahead market* schedules for export transactions, subject to Chapter 7, section 5.2.2. For time-step $t \in \{1,..,n_{LAP}\}$ and *intertie zone* sink bus $d \in DX$ such that $d \notin DX_t^{CAPEX} \cup DX_t^{EM} \cup DX_t^{INP}$:

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

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

and

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

8.5.4.2 Import *offers* with no *day-ahead market* schedule may be evaluated beyond the first two forecast hours of the look-ahead period for the purpose of *reliability*.

8.5.4.3 A constraint shall limit import schedules beyond the first two forecast hours of the pre-dispatch look-ahead period to the corresponding *day ahead market* schedules for import transactions plus any additional *offered* quantities permitted for *reliability* reasons, with the exception of transactions flagged as capacity imports or off-market transactions, subject to Chapter 7, section 5.2.2. For time-step $t \in \{4,..,n_{LAP}\}$ and *intertie zone* source bus $d \in DI$ such that $d \notin DI_t^{CAPEX} \cup DI_t^{EM} \cup DI_t^{INP}$:

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

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

and

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

8.5.4.4 A constraint shall limit *intertie* schedules as a result of *intertie* curtailments. For *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$:

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

8.5.4.4.1 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

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

8.5.5 Operating Reserve Requirements

8.5.5.1 The total synchronized *ten-minute operating reserve*, nonsynchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled from a *dispatchable load* shall not exceed:

8.5.5.1.1 the *dispatchable* load's ramp capability over 30 minutes;

8.5.5.1.2 the total scheduled load less the non-*dispatchable* portion; and

8.5.5.1.3 the remaining portion of its capacity that is *dispatchable* after considering minimum load consumption constraints.

8.5.5.1.4 These restrictions shall 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

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

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

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

8.5.5.3 The total non-synchronized *ten-minute operating reserve* and *thirty minute operating reserve* scheduled for an hour shall not exceed total scheduled exports. This restriction shall be enforced by the following constraint for all all time-steps $t \in TS$ and all *intertie zone* sink buses $d \in DX$:

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

8.5.5.4 The total *operating reserve* scheduled from a committed *dispatchable generation resource* shall not exceed that *resource*'s: (i) ramp capability over 30 minutes; (ii) remaining capacity; and (iii) unscheduled capacity. These restrictions shall 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

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

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

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

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

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

8.5.5.7 The amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for *thirty-minute operating reserve*. This restriction shall be enforced by the following constraint for all time-steps t ∈ TS and all buses b ∈ B^{DG} with $RLP30R_{t,b} > 0$:

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

8.5.5.8 The total non-synchronized *ten-minute operating reserve* and *thirty minute operating reserve* scheduled for an hour shall not exceed the remaining maximum import *offers* minus scheduled *energy* imports. This restriction shall be enforced by the following constraint for all time-steps $t \in TS$ and all *intertie zone* source buses $d \in DI$:

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

8.5.6 Pseudo-Units

8.5.6.1 A constraint shall be required to calculate physical *generation resource* schedules from *pseudo-unit* schedules using the steam turbine shares in the operating regions of the *pseudo-unit* determined in section 15. For all time-steps $t \in TS$ and *pseudo-unit* 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 $p \in PST$:

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

8.5.6.2 Maximum constraints shall be enforced on the operating region to which they apply for both *energy* and *operating reserve* schedules. For all time-steps $t \in TS$ and *pseudo-unit* buses $b \in B^{PSU}$:

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

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

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

and

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

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

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

and

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

8.5.6.3.1 For all time-steps $t \in TS$, *pseudo-unit* buses $b \in B^{NO10DF}$, and laminations $k \in K_{t,d}^{10S}$:

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

8.5.6.3.2 For all time-steps $t \in TS$, *pseudo-unit* buses $b \in B^{NO10DF}$, and laminations $k \in K_{t,b}^{10N}$:

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

8.5.6.4 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the combustion turbine schedule for the *pseudo-unit* at bus $b \in B^{PSU}$ in in time-step $t \in TS$ will be equal to:

8.5.6.4.1 $SCT_{t,b}$ if the *pseudo-unit* is scheduled at or above *minimum loading point*;

8.5.6.4.2 $RampCTC_{b,w}^{m}$ if the *pseudo-unit* is scheduled to reach *minimum loading point* in *thermal state* $m \in THERM$ in time-step $t + w$ for $w \in \{1,..,RampHrsC_b^m\}$; or

8.5.6.4.3 0 otherwise.

8.5.6.5 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the steam turbine schedule for $p \in PST$ shall be equal to $SST_{h,p}$ plus any contribution from *pseudo-unit* $b \in B_p^{ST}$ ramping to *minimum loading point* as given by $RampSTC_{b,w}^{m}$ for a *pseudo-unit* scheduled to reach *minimum loading point* in *thermal state* $m \in THERM$ in time-step $(t + w)$ for $w \in \{1,..,RampHrsC_b^m\}$.

8.5.7 Dispatchable Hydroelectric Generation Resources

8.5.7.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled to at least its *hourly must-run* quantity. For all time-steps $t \in TS$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq MinHMR_{t,b}.$$

8.5.7.2 A *dispatchable* hydroelectric *generation resource* shall either be scheduled to 0 or to at least its *minimum hourly output*. For all timesteps $t \in TS$ and all hydroelectric *generation resource* buses $b \in B^{HE}$:

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

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

and for all $k \in K_{t,b}^E$:

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

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

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

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

and

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

8.5.8 Wheeling Through Transactions

8.5.8.1 The amount of scheduled export *energy* must be equal to the amount of scheduled import *energy* for *wheeling through transactions*. For all time-steps $t \in TS$ and all linked *boundary entity resource* buses $(dx, di) \in L_t$:

$$\sum_{j \in J_{t,dx}^E} SXL_{t,dx,j} = \sum_{k \in K_{t,di}^E} SIG_{t,di,k}.$$

8.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

8.6.1 Energy Ramping

8.6.1.1 For *disptachable loads*, the constraints in section 8.6.1.5 and section 8.6.2.1 use $URRDL_b$ to represent a ramp up rate selected from $URRDL_{t,b,w}$ and uses $DRRDL_b$ to represent a ramp down rate selected from $DRRDL_{t,b,w}$.

8.6.1.2 For *disptachable generation resources*, the constraints in section 8.6.1.7 and section 8.6.2.2 use $URRDG_b$ to represent a ramp up rate selected from $URRDG_{t,b,w}$ and uses $DRRDG_b$ to represent a ramp down rate selected from $DRRDG_{t,b,w}$.

8.6.1.3 The *pre-dispatch calculation engine* shall respect the ramping restrictions determined by the up to five *offered* MW quantity, ramp up rate and ramp down rate value sets.

8.6.1.4 In all ramping constraints, the schedules for time-step 1 are obtained from the initial scheduling assumptions in section 5.9. For all timesteps $t \in TS$ the ramping rates in all ramping constraints shall be adjusted to allow the applicable *resource* to:

8.6.1.3.1 ramp down from its lower limit in time-step $(t - 1)$ to its upper limit in time-step t; and

8.6.1.3.2 ramp up from its upper limit in time-step $(t-1)$ to its lower limit in time-step t.

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

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

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

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

8.6.1.7 *Energy* schedules for a *dispatchable generation resource* that is committed cannot vary by more than an hour's ramping capability for the applicable *resource*. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

8.6.1.7.1 For the first hour a *resource* reaches its *minimum loading point*, where $ODG_{t,b} = 1, ODG_{t-1,b} = 0$, the following constraint shall be applied:

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

8.6.1.7.2 If the *resource* stays on at or above *minimum loading point* and $ODG_{t,b}= 1, ODG_{t-1,b}= 1$, the following constraint shall be applied:

$$\sum_{k \in K_{t-1,b}^{E}} SDG_{t-1,b,k} - 60 \cdot DRRDG_b \leq \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{k \in K_{t-1,b}^{E}} SDG_{t-1,b,k} + 60 \cdot URRDG_b$$

8.6.1.7.3 For the last hour the *resource* is scheduled at or above *minimum loading point* before being scheduled off, where $ODG_{t,b}=1, ODG_{tt+1,bb} = 0$, the following constraint shall be applied:

$$0 \leq \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq 30 \cdot DRRDG_b$$

8.6.1.8 The first and third constraint in section 8.6.1.6 do not apply to a *quick start resource*.

8.6.1.9 For time-steps where *non-quick start resources* are ramping up to *minimum loading point*, *energy* shall be scheduled for these *resources* using the submitted *ramp up energy to minimum loading point*.

8.6.2 Operating Reserve Ramping

8.6.2.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from *dispatchable loads* shall not exceed their ramp capability to decrease load consumption and for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

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

8.6.2.2 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from a committed *dispatchable generation resource* shall not exceed its ramp capability to increase generation and for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

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

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

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

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

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

8.6.3 Non-Quick Start Resources

8.6.3.1 Schedules for a *non-quick start resource* shall not violate such *resource's minimum generation block run-times*, *minimum generation block down times* and *maximum number of starts per day*.

8.6.3.2 In the first forecast hour of the pre-dispatch look-ahead period, a *resource*'s current hours on shall determine 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:

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

8.6.3.3 In the first forecast hour of the pre-dispatch look-ahead period (i.e. time-step 2), the number of hours a *resource* has been down shall determine any remaining *minimum generation block down time* to enforce and shall respect the *minimum generation block down time* for a hot *thermal state*. 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:

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

8.6.3.4 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 and shall be scheduled to remain in operation until it has completed its *minimum generation block run-time* or to the end of the pre-dispatch look-ahead period. Therefore:

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

8.6.3.5 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 and shall be scheduled to remain off until it has completed its hot *minimum generation block down time* or to the end of the pre-dispatch look-ahead period. Therefore:

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

8.6.3.6 A Boolean variable $IDG_{t,b}$ indicates that the *non-quick start 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 $b \in B^{NQS}$:

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

8.6.3.7 A *non-quick start resource* shall not be scheduled more than its *maximum number of starts per day*. For all buses $b \in B^{NQS}$:

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

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

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

8.6.3.8 For a *non-quick start resource* at bus $b \in B^{NQS}$ that has been offline $InitDownHrs_b$ hours, and for future *minimum loading point* time-step $t \in \{1,\ldots,n_{LAP}\}$, the *pre-dispatch calcluation* engine shall assign a *start-up offer* and ramp *energy* to *minimum loading point* profile as follows:

8.6.3.8.1 If $0 \leq InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{HOT}$, then the *resource* cannot be scheduled in time-step t;

8.6.3.8.2 If $MGBDTDGC_b^{HOT} < InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{WARM}$, then the *resource* will be assigned a "HOT" *thermal state* for timestep tt and the *start-up offer* $SUDG_{t,b}^{HOT}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $RampEC_{b,w}^{HOT}$ for $w \in \{1,\ldots,RampHrsC_b^m\}$;

8.6.3.8.3 If $MGBDTDGC_b^{WARM} < InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{COLD}$, then the *resource* will be assigned a "WARM" *thermal state* for time-step t and the *start-up offer* $SUDG_{t,b}^{WARM}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $RampEC_{b,w}^{WARM}$ for $w \in \{1,..,RampHrsC_b^m\}$; and

8.6.3.8.4 If $MGBDTDGC_b^{COLD} < InitDownHrs_b + t - 1$ then the *resource* will be assigned a "COLD" *thermal state* for time-step t and the *start-up offer* $SUDG_{t,b}^{COLD}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $RampEC_{b,w}^{COLD}$ for $w \in \{1,..,RampHrsC_b^m\}$.

8.6.3.9 For a *non-quick start resource* at bus $b \in B^{NQS}$ that is in-service as determined by its initial condition, the *pre-dispatch calculation engine* shall assign a *start-up offer* and *ramp up energy to minimum loading point* profile associated with the future *thermal state* as specified in section 8.6.3.8.

8.6.4 Energy Limited Resources

8.6.4.1 An *energy limited resource* shall not be scheduled to provide:

8.6.4.1.1 more *energy* than the *maximum daily energy limit* specified for such *resource*; or

8.6.4.1.2 *energy* in amounts that would preclude such *resource* from providing *operating reserve* when activated;

8.6.4.1.3 for all buses $b \in B^{ELR}$ where an *energy limited resource* is located and all time-steps $T \in TS_{tod}$.

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

8.6.4.2 If the pre-dispatch look-ahead period spans two *dispatch days*, the constraints in section 8.6.4.1 shall apply to an *energy limited resource* for each *dispatch day*, and shall consider the amount of *energy* already provided by the *resource* for the current *dispatch day*. Therefore, for all buses $b\in B^{ELR}$ where an *energy limited resource* is located and all time-steps $T\in TS_{tom}$:

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

where the factors $10\ ORConv$ and $30\ ORConv$ are applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy limited resources* to convert MW into MWh. Violation variables for over-scheduling a *resource's maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution.

8.6.5 Dispatchable Hydroelectric Generation Resources

Dispatchable hydroelectric *generation resources* shall be scheduled for at least their *minimum daily energy limit*. If the pre-dispatch lookahead period spans two *dispatch days*, the constraint shall be applied for both days. Violation variables for under-scheduling a *resource's minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses b :

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

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

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

8.6.5.2 A Boolean variable $IHE_{t,b,I}$ indicates that a start for the hydroelectric *dispatchable generation resource* at bus $b \in B^{HE}$ was counted in timestep $t \in TS$ 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* $i \in \{1,..,NStartMW_b\}$:

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

8.6.5.3 *Dispatchable* hydroelectric *generation resources* shall not be scheduled to be started more times than permitted by their *maximum number of starts per day.* If the pre-dispatch look-ahead period spans two *dispatch days*, this constraint shall be applied for both days. The following constraint shall apply for all buses $b \in B^{HE}$:

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

8.6.5.3.1 and if the pre-dispatch look-ahead period spans two *dispatch days*, for buses $b \in B^{HE}$:

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

8.6.5.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not exceed shared *maximum daily energy limits*. If the pre-dispatch look-ahead period spans two *dispatch days*, the constraint shall be applied for both days, where the constraint for today shall consider the amount of *energy* already provided by *resources* with a registered *forebay*. Violation variables for over-scheduling the *maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s \in SHE$ and all time-steps $T \in TS_{tod}$:

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

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

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

where the factors $10\ ORConv$ and $30\ ORConv$ shall be applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* to convert MW into MWh.

8.6.5.5 Schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *minimum daily energy limits*. If the pre-dispatch look-ahead period spans two *dispatch days*, the constraint shall be applied for both days, where the constraint for today shall consider the amount of *energy* already provided by *resources* with a registered *forebay*. Violation variables for underscheduling the *minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s\in SHE$:

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

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

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

8.6.5.6 For linked *dispatchable* hydroelectric *generation resources* with a registered *forebay*, *energy* scheduled at the upstream *resource* in one time-step shall result in a proportional amount of *energy* being scheduled at the linked downstream *resource* in the time-step determined by the *time lag*.

8.6.5.7 For linked *dispatchable* hydroelectric *generation resources*, time-steps in which the upstream *resources* schedule is not determined in the *predispatch calculation engine* optimization, the constraint shall link either the historical or time-step 1 anticipated production for the upstream *resources* to the schedule for the downstream *resources*.

8.6.5.8 For all linked *dispatchable* hydroelectric *generation resources* between upstream *resources* $b1 \in B_{up}^{HE}$ and downstream *resources* $b2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t \leq LagC_{b1,b2}+1$:

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

8.6.5.9 For linked *dispatchable* hydroelectric *generation resources*, time-steps in which both the upstream and downstream *resource* schedules are determined in the *pre-dispatch calculation engine* optimization, the constraint will link the scheduling variables for both the upstream and downstream *resources*.

8.6.5.10 For all linked *dispatchable* hydroelectric *generation resources* between upstream *resources* $b1 \in B_{up}^{HE}$ and downstream *resources* $b2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNKC$ and time-steps $t \in TS$ such that $t + LagC_{b1,bs} \leq n_{LAP}$:

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

8.7 Constraints for Reliability Requirements

8.7.1 Energy Balance

8.7.1.1 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in time-step $t \in TS$, $With_{t,b}$ shall be represented by:

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

8.7.1.2 The total amount of export *energy* scheduled at *intertie zone* bus $d \in DX$ in time-step $t \in TS$, $With_{t,d}$, as the exports from Ontario to the *intertie zone* bus shall be represented by:

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

8.7.1.3 The total amount of injections scheduled at internal bus $b \in B$ in timestep $t \in TS$, $Inj_{t,b}$, shall be represented by:

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

where:

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

and

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

8.7.1.4 The total amount of import *energy* scheduled at *intertie zone* bus $d \in DI$ in time-step $t \in TS$, $Inj_{t,d}$, as the imports into Ontario from that *intertie zone* bus shall be represented by:

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

8.7.1.5 Injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor calculated by the *security* assessment function 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 shall be subtracted from the total load or generation for the *pre-dispatch calculation engine* to produce a solution. For time-step $t \in TS$, the *energy* balance shall be:

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

8.7.2 Operating Reserve Requirements

8.7.2.1 *Operating reserve* shall be scheduled to meet system-wide requirements for synchronized *ten-minute operating reserve*, total *ten-minute operating reserve,* and *thirty-minute operating reserve* while respecting all applicable regional minimum requirements and regional maximum restrictions for *operating reserve*.

8.7.2.2 Constraint violation penalty curves may 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. Full *operating reserve* requirements shall be scheduled unless the cost of doing so would be higher than the applicable penalty cost.

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

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

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

and

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

8.7.2.3 The following constraints shall be applied for each time-step $t \in$ _TS and each region $r \in$ _ORREG:

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

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

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

and

$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right)$$

$$+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right)\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right)$$

$$+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right)$$

$$+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right)+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{30R}} S30RDL_{t,b,k}\right)$$

$$+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right)$$

$$+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k}\right)-\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i}$$

$$\leq REGMax30R_{t,r}.$$

8.7.3 IESO Internal Transmission Limits

8.7.3.1 The Pre-Dispatch Scheduling algorithm shall produce a set of *energy* schedules that do not violate any *security limits* in the pre-contingency state and the post-contingency state subject to the remainder of this section 8.7.3. The total amount of *energy* scheduled to be injected and withdrawn at each bus used by the *energy* balance constraint in section 8.7.1.5, shall be used to produce these schedules.

8.7.3.2 Pre-contigency, $SPreITLViol_{f,t,i}$, and postcontingency, $SITLViol_{c,f,t,i}$, transmission limit violation variables shall allow the *pre-dispatch calculation engine* to find a solution.

8.7.3.3 For all time-steps $t \in TS$ and *facilities* $f \in F_t$, the linearized constraints for violated pre-contingency limits obtained from the *security* assessment function shall take the form:

$$\sum_{b\in B^{NDG}\cup B^{DG}} PreConSF_{t,f,b}\cdot Inj_{t,b}-\sum_{b\in B^{DL}\cup B^{HDR}} PreConSF_{t,f,b}\cdot With_{t,b}$$

$$+\sum_{d\in DI} PreConSF_{t,f,d}\cdot Inj_{t,d}-\sum_{d\in DX} PreConSF_{t,f,d}\cdot With_{t,d}$$

$$-\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i}\leq AdjNormMaxFlow_{t,f}.$$

8.7.3.4 For all time-steps $t \in TS$, contingencies $c \in C$, and *facilities* $f \in F_{t,c}$, the linearized constraints for violated post-contingency limits obtained from the *security* assessment function shall take the form:

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

8.7.4 Intertie Limits

8.7.4.1 The Pre-Dispatch Scheduling algorithm shall produce a set of *energy* and *operating reserve* schedules that respect any *security limits* associated with *interties* between Ontario and *intertie zones*. For all time-steps $t \in TS$ and all constraints $z \in Z_{Sch}$:

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

where for out-of-service *intertie zones*, the *intertie* limits shall be set to zero and all *boundary entity resources* shall receive a zero schedule for *energy* and *operating reserve*.

8.7.4.2 Changes in the hour-to-hour net *energy* schedule over all *interties* shall not exceed the net interchange scheduling limit. The net import schedule shall be summed over all *intertie zones* for a given time-step to obtain the net *interchange schedule* for the time-step, and shall not:

8.7.4.2.1 exceed the net *interchange schedule* for the previous time-step plus the net interchange scheduling limit; and

8.7.4.2.2 be less than the net *interchange schedule* for the previous time-step minus the net interchange scheduling limit.

8.7.4.3 Violation variables shall be provided for both the up and down ramp limits to allow the *pre-dispatch calculation engine* to find a solution and for all time-steps $t \in TS$:

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

8.7.5 Penalty Price Variable Bounds

8.7.5.1 Penalty price variables shall be restricted to the ranges determined by the constraint violation penalty curves for the Pre-Dispatch Scheduling algorithm and for time-steps $t \in TS$:

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

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

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

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

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

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

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

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

$0 \leq SXREG30RViol_{r,t,i} \leq QXREG30RViolSch_{t,i}$ 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 $(b_1,b_2) \in LNK$, $i \in \{1,..,N_{OGenLnkViol_t}\}$; and

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

8.8 Outputs

8.8.1 Outputs for the Pre-Dispatch Scheduling algorithm include *resource* schedules and commitments.

9 Pre-Dispatch Pricing

9.1 Purpose

9.1.1 The Pre-Dispatch Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, subject to section 14.7.1.3, and *resource* schedules and commitments produced by the Pre-Dispatch Scheduling algorithm to meet the *IESO's* province-wide non-dispatchable *demand* forecast and IESO-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

9.2 Information, Sets, Indices and Parameters

9.2.1 Information, sets, indices and parameters used by the Pre-Dispatch Pricing algorithm are described in section 3. In addition, the following *resource* schedules and commitments determined by the Pre-Dispatch Scheduling algorithm shall be used by the Pre-Dispatch Pricing algorithm:

9.2.1.1 $SDG_{t,b,k}^{PDS}$ designates the amount of *energy* that the *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in KE_{t,b}$;

9.2.1.2 $ODG_{t,b}^{PDS}$ designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$;

9.2.1.3 $S10SDG_{t,b,k}^{PDS}$ designates the amount of synchronized *ten-minute operating reserve* that the *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 $k \in K_{t,b}^{10S}$;

9.2.1.4 $S10NDG_{t,b,k}^{PDS}$ designates the amount of non-synchronized *ten-minute operating reserve* that the *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 $k \in K_{t,b}^{10N}$;

9.2.1.5 $S30RDG_{t,b,k}^{PDS}$ designates the amount of *thirty-minute operating reserve* that the *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 $k \in K_{t,b}^{30R}$; and

9.2.1.6 $OHO_{t,b}^{PDS}$ designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

9.3 Variables and Objective Function

9.3.1 The Pre-Dispatch Pricing algorithm shall solve for the same variables as in the Pre-Dispatch Scheduling algorithm, section 8.3.1, with the following exceptions:

9.3.1.1 $IDG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ shall not appear in the formulation;

9.3.1.2 $ODG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ will be fixed to a constant value, as determined by the Pre-Dispatch Scheduling algorithm;

9.3.1.3 $OHO_{t,b}$ for bus $b \in B^{HE}$ and time-step $t \in TS$ will be fixed to a constant value, as determined by the Pre-Dispatch Scheduling algorithm;

9.3.1.4 $IHE_{t,b,i}$ for $b \in B^{HE}$, time-step $t \in TS$ and *start indication value* $i \in \{1,..,NStartMW_b\}$ shall not appear in the formulation;

9.3.1.5 $SOGenLnkViol_{t,(b1,b2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$, time-step $t \in TS$ and $i \in \{1,..,N_{OGenLnkViolt}\}$ shall not appear in the formulation; and

9.3.1.6 $SUGenLnkViol_{t,(b1,b2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$, time-step $t \in TS$ and $i \in \{1,..,N_{UGenLnkViolt}\}$ shall not appear in the formulation.

9.3.2 The objective function for the Pre-Dispatch Pricing algorithm shall maximize gains from trade by maximizing 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:

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

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

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

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

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

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

9.3.2.1 The tie-breaking term, TB_t, shall be the same term described in section 8.3.2.1.

9.3.2.2 $ViolCost_t$ shall be calculated as follows:

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

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

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

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

9.3.2.3 The objective function of the Pre-Dispatch Pricing algorithm in section 9.3.2 shall be subject to the constraints described in sections 9.4 - 9.8.

9.4 Constraints

9.4.1 The constraints described in sections 9.5, 9.6, 9.7 and 9.8 apply to the optimization function in the Pre-Dispatch Pricing algorithm.

9.5 Dispatch Data Constraints Applying to Individual Hours

9.5.1 Scheduling Variable Bounds

9.5.1.1 *Energy* and *operating reserve* schedules shall not be negative and shall not exceed the quantity respectively offered for *energy* and *operating reserve*. For all time-steps $t \in TS$:

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

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

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

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

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

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

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

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

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

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

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

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

9.5.1.2

dispatchable generation resource may be scheduled for *energy* and *operating reserve* only if its commitment status variable, as determined by the Pre-Dispatch Scheduling algorithm, is equal to 1. For all timesteps $t \in TS$:

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

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

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

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

where $ODG_{t\text{b}}^{\text{PDS}}$ is a fixed constant in the above constraints, per section 9.8.1.1.

9.5.2 Resource Minimums and Maximums

9.5.2.1 The constraints in section 8.5.2 shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3 Off-Market Transactions

9.5.3.1 The constraints in sections 8.5.3.1 and 8.5.3.2 for inadvertent payback transactions shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3.2 In the case of *emergency energy* transactions, subject to section 9.5.3.3, the constraints in sections 8.5.3.3 and 8.5.3.4 shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3.3 For all time-steps $t \in TS$ and all *boundary entity resources* scheduled to import *emergency energy* that does not support an export $d \in DI_t^{EMNS}$:

$$\sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} = 0.$$

9.5.4 Intertie Minimum and Maximum Constraints

9.5.4.1 The constraints in section 8.5.4 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.5 Operating Reserve Scheduling

9.5.5.1 The constraints in section 8.5.5 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.6 Pseudo-Units

9.5.6.1 The constraints in section 8.5.6 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.7 Dispatchable Hydroelectric Generation Resources

9.5.7.1 The constraints in section 8.5.7 shall apply in the Pre-Dispatch Pricing algorithm as well, with the following exceptions:

9.5.7.1.1 *energy offer* laminations corresponding to the *hourly must-run* amount shall be ineligible to set prices;

9.5.7.1.2 *minimum hourly output* constraints shall be replaced by the constraints in section 9.8; and

9.5.7.1.3 a *dispatchable* hydroelectric *generation resource's* schedule shall respect its *forbidden regions* and may only set prices within the operating range determined by the adjacent *forbidden regions* between which the *resource* was scheduled.

9.5.8 Wheeling Through Transactions

9.5.8.1 The constraints in section 8.5.8 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

9.6.1 Energy Ramping

9.6.1.1 The constraints in section 8.6.1 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6.2 Operating Reserve Ramping

9.6.2.1 The constraints in section 8.6.2 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6.3 Energy Limited Resources

9.6.3.1 The constraints in section 8.6.4 shall apply to *energy limited resources*. If a *resource's maximum daily energy limit* is binding, then the constraints in section 9.8 shall also apply.

9.6.4 Dispatchable Hydroelectric Generation Resources

9.6.4.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled for *energy* to at least its *minimum daily energy limit*. Violation variables for under-scheduling a *resource's minimum daily energy limit* shall be provided to allow the *pre-dispatch calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

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

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

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

9.6.4.2 The constraints in section 9.8.3.3 shall apply to a *dispatchable* hydroelectric *generation resource* with a binding *minimum daily energy limit* in the Pre-Dispatch Scheduling algorithm.

9.6.4.3 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *maximum daily energy limits*. Violation variables for scheduling *resources* above the *maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s \in SHE$ and all timesteps $T \in TS_{tod}$:

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

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

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

where the factors $10ORConv$ and $30ORConv$ shall be applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* to convert MW into MWh.

9.6.4.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not violate shared *minimum daily energy limits*. Violation variables for scheduling *resources* below the *minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s\in SHE_{tod}$ and all time-steps $t\in TS_{tod}$.

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

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

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

9.7 Constraints for Reliability Requirements

9.7.1 Energy Balance

9.7.1.1 The constraint in section 8.7.1 shall also apply in the Pre-Dispatch Pricing algorithm, except the marginal loss factors used in the *energy* balance constraint in the Pre-Dispatch Pricing algorithm shall be fixed to the marginal loss factors used in the last optimization function iteration of the Pre-Dispatch Scheduling algorithm.

9.7.2 Operating Reserve Requirements

9.7.2.1 The constraints in section 8.7.2 shall also apply in the Pre-Dispatch Pricing algorithm.

9.7.3 IESO Internal Transmission Limits

9.7.3.1 The constraints in section 8.7.3 shall also apply in the Pre-Dispatch Pricing algorithm, except the sensitivities and limits considered shall be those provided by the most recent *security* assessment function iteration of the Pre-Dispatch Pricing algorithm.

9.7.4 Intertie Limits

9.7.4.1 The constraints in section 8.7.4 shall also apply in the Pre-Dispatch Pricing algorithm.

9.7.5 Penalty Price Variable Bounds

9.7.5.1 The following constraints shall restrict the penalty price variables to the ranges determined by the constraint violation penalty curves for the pricing algorithm. 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 $s \in SHE$, $i \in \{1,..,N_{SMinDelViol_t}\}$.

9.8 Constraints to Ensure the Price Setting Eligibility of Offer/Bid Laminations

9.8.1 Commitment Status Variables

9.8.1.1 Commitment decisions shall be fixed to the commitment statuses of *resources* calculated by the Pre-Dispatch Scheduling algorithm in section 8. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

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

9.8.2 Energy Limited Resources

9.8.2.1 For an *energy limited resource* with a *maximum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the schedules calculated by the Pre-Dispatch Scheduling algorithm shall 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 the Pre-Dispatch Scheduling algorithm shall be eligible to set prices. For bus $b \in B^{ELR}$, if there exists a time-step $T \in TS_{tod}$ such that:

$$\sum_{t=2..T}\left(ODG^{PDS}_{t,b}\cdot MinQDGC_b + \sum_{k\in K^E_{t,b}} SDG^{PDS}_{t,b,k}\right) + 10ORConv\left(\sum_{k\in K^{10S}_{T,b}} S10SDG^{PDS}_{T,b,k} + \sum_{k\in K^{10N}_{T,b}} S10NDG^{PDS}_{T,b,k}\right) + 30ORConv\left(\sum_{k\in K^{30R}_{T,b}} S30RDG^{PDS}_{T,b,k}\right) = MaxDEL_{tod,b} - EngyUsed_b$$

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

$$\sum_{k\in K^E_{t,b}} SDG_{t,b,k} \le \sum_{k\in K^E_{t,b}} SDG^{PDS}_{t,b,k} + \epsilon,$$

$$\sum_{k\in K^E_{t,b}} SDG_{t,b,k} + \sum_{k\in K^{10S}_{t,b}} S10SDG_{t,b,k} + \sum_{k\in K^{10N}_{t,b}} S10NDG_{t,b,k} + \sum_{k\in K^{30R}_{t,b}} S30RDG_{t,b,k} \le MaxDEL_{tod,b} - EngyUsed_b - \sum_{\tau=2}^{t-1}\sum_{k\in K^E_{t,b}} SDG^{PDS}_{\tau,b,k}.$$

where ϵ is a small positive constant.

9.8.2.2 If the pre-dispatch 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:

$$\sum_{t=t_{tom}..T}\left(ODG^{PDS}_{t,b}\cdot MinQDGC_b + \sum_{k\in K^E_{t,b}} SDG^{PDS}_{t,b,k}\right) + 10ORConv\left(\sum_{k\in K^{10S}_{T,b}} S10SDG^{PDS}_{T,b,k} + \sum_{k\in K^{10N}_{T,b}} S10NDG^{PDS}_{T,b,k}\right) + 30ORConv\left(\sum_{k\in K^{30R}_{T,b}} S30RDG^{PDS}_{T,b,k}\right) = MaxDEL_{tom,b}$$

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

$$\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq MaxDEL_{tom,b} - \sum_{\tau=tom}^{t-1} \sum_{k\in K_{t,b}^{E}} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3 Dispatchable Hydroelectric Generation Resources

9.8.3.1 If a *dispatchable* hydroelectric *generation resource* is scheduled to provide *energy* at or above its *minimum hourly output* in the Pre-Dispatch Scheduling algorithm, such *resource* shall also be scheduled at or above its *minimum hourly output* in the Pre-Dispatch Pricing algorithm. The *energy offer* laminations corresponding to the *minimum hourly output* amount shall be ineligible to set prices. If a *dispatchable* hydroelectric *generation resource* with a *minimum hourly output* amount receives a zero schedule in the Pre-Dispatch Scheduling algorithm, the *resource* shall also receive a zero schedule in the Pre-Dispatch Pricing algorithm and shall be ineligible to set prices in the *energy* market. For all time-steps $t \in TS$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} \geq MinHO_{t,b} \cdot OHO_{t,b}^{PDS}$$

and for all $k \in K_{t,b}^{E}$:

$$0 \leq SDG_{t,b,k} \leq OHO^{PDS}_{t,b} \cdot QDG_{t,b,k}.$$

9.8.3.2 For a *dispatchable* hydroelectric *generation resource* with a limited number of starts, such *resource* shall be scheduled such that it is limited to set prices within an operating range consistent with the number of starts utilized by the *resource's* schedule determined by the Pre-Dispatch Scheduling algorithm. The *resource's* schedule shall be between the same *start indication values* as determined in the Pre-Dispatch Scheduling algorithm. For all *dispatchable* hydroelectric *generation resource* 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 $i \in \{1,..,(NStartMW_b\text{-}1)\}$,

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

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq StartMW_{b,NStartMW_b}.$$

9.8.3.3 For a *dispatchable* hydroelectric *generation resource* with a *minimum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the *offer* laminations corresponding to the *energy* schedules calculated in the Pre-Dispatch Scheduling algorithm shall be ineligible to set prices. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such that $MinDEL_{tod,b} > 0$ and

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tod,b} - EngyUsed_b,$$

9.8.3.3.1 the following constraints must hold for all time-steps $t \in TS_{tod}$ and *offer* laminations $k \in K_{t,b}^E$:

$$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}.$$

9.8.3.3.2 If the pre-dispatch look-ahead period spans two *dispatch days*, for all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such that $MinDEL_{tom,b} > 0$ and

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tom,b},$$

9.8.3.3.3 the following constraints must hold for all time-steps $t \in TS_{tom}$ and *offer* laminations $k \in K_{t,b}^E$:

$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}$.

9.8.3.4 For a *dispatchable* hydroelectric *generation resource* with a shared *minimum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the *offer* laminations corresponding to the *energy* schedules calculated for all *resources* in the set $s \in SHE$ in the Pre-Dispatch Scheduling algorithm shall be ineligible to set prices. Thus, for each set $s \in SHE$:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tod,s} - EngyUsedSHE_s,$$

9.8.3.4.1 the following constraints must hold for all time-steps $t \in TS_{tod} \in$:

$$\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) \geq \sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right).$$

9.8.3.4.2 If the pre-dispatch look-ahead period spans two *dispatch days*, then for each set $s \in SHE$:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tom,s}$$

9.8.3.4.3 the following constraints must hold for all time-steps $t \in TS_{tom}$:

$$\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) \geq \sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right).$$

9.8.3.5 For a *dispatchable* hydroelectric *generation resource* with a binding *maximum daily energy limit* in the Pre-Dispatch Scheduling algorithm, the schedules calculated in the Pre-Dispatch Scheduling algorithm shall determine the price-setting eligibility of the *resource's energy* and *operating reserve offer* laminations as described in section 9.8.2.

9.8.3.6 For a *dispatchable* hydroelectric *generation resource* with a shared *maximum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, in each hour, the *offer* laminations up to the sum of *energy* and *operating reserve* schedules calculated in Pre-Dispatch Scheduling algorithm for all *resources* in each set $s \in SHE$ will be eligible to set prices. For each set $s \in SHE$, if there exists $T \in TS_{tod}$ such that:

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}\right)\right)$$

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}^{PDS}\right)\right.$$

$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}^{PDS}\right)\right)=MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

9.8.3.6.1 then the *maximum daily energy limit* constraint is considered to be binding for the current *dispatch day* in the Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints shall apply for all time-steps $t\in TS_{tod}$:

$$\sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\le\sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}+\epsilon,$$

$$\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}+\sum_{k\in K_{t,b}^{10S}}S10SDG_{t,b,k}+\sum_{k\in K_{t,b}^{10N}}S10NDG_{t,b,k}+\sum_{k\in K_{t,b}^{30R}}S30RDG_{t,b,k}\right)$$

$$\le MaxSDEL_{tod,s}-EngyUsedSHE_s-\sum_{b\in B_s^{HE}}\sum_{\tau=2}^{t-1}\sum_{k\in K_{t,b}^{E}}SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3.6.2 If the pre-dispatch look-ahead period spans two *dispatch days*, if there exists a time-step $T\in TS_{tom}$ such that:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}^{PDS}\right)\right)$$

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}^{PDS}\right)\right.$$

$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}^{PDS}\right)\right)=MaxSDEL_{tom,s},$$

9.8.3.6.3 then the *maximum daily energy limit* constraint is considered to be binding for the next *dispatch day* in the Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints shall apply for all time-steps $t\in TS_{tom}$:

$$\sum_{b \in B_s^{HE}} \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq \sum_{b \in B_s^{HE}} \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{b \in B_s^{HE}} \left(\sum_{k \in K_{t,b}^E} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \right) \leq MaxSDEL_{tom,s} - \sum_{b \in B_s^{HE}} \sum_{\tau=tom}^{t-1} \sum_{k \in K_{t,b}^E} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3.7 For a *dispatchable* hydroelectric *generation resource* for which a *MWh ratio* was respected in the Pre-Dispatch Scheduling algorithm, such *resource* shall be scheduled between its Pre-Dispatch Scheduling algorithm schedule plus or minus a tolerance Δ specified by the *IESO*. The *resource* schedule shall be limited by its *offer* quantity bounds, in section 9.5.1, and any applicable *resource* minimum or maximum constraints, in section 9.5.2. For all linked downstream *dispatchable* hydroelectric *generation 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 $t \in TS$:

$$ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^E} SDG_{t,b_2,k}^{PDS} - \Delta \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^E} SDG_{t,b_2,k} \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^E} SDG_{t,b_2,k}^{PDS} + \Delta.$$

9.8.3.7.1 For all linked *dispatchable* hydroelectric *generation 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 $t + LagC_{b1,b2} \leq n_{LAP}$:

$$ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^E} SDG_{t,b_1,k}^{PDS} - \Delta \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^E} SDG_{t,b_1,k} \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^E} SDG_{t,b_1,k}^{PDS} + \Delta.$$

9.9 Outputs

9.9.1 Outputs for the Pre-Dispatch Pricing algorithm include the following:

9.9.1.1 shadow prices;

9.9.1.2 *locational marginal prices* and their components; and

9.9.1.3 sensitivity factors.

10 Constrained Area Conditions Test

10.1 Purpose

10.1.1 The Constrained Area Conditions Test shall:

10.1.1.1 identify when and where competition is restricted; and

10.1.1.2 determine which *resources* shall have their *financial dispatch data parameters* be subject to the Conduct Test in section 11 and the thresholds above the *reference levels* that shall be used in the Conduct Test.

10.2 Information, Sets, Indices and Parameters

10.2.1 The *narrow constrained areas* and *dynamic constrained areas* and the information published therein in accordance with section 22 of Chapter 7 shall be inputs for the Constrained Area Conditions Test.

10.2.2 Information, sets, indices and parameters for the Constrained Area Conditions Test are described in sections 3 and 4. In addition, the following prices produced by the Pre-Dispatch Pricing algorithm shall be used by the Constrained Area Conditions Test:

10.2.2.1 $LMP_{t,b}^{PDP}$, which designates the *locational marginal price* for bus $b \in B$ in time-step $t \in TS$;

10.2.2.2 $PCong_{t,b}^{PDP}$, which designates the congestion component of the *locational marginal price* for bus $b \in B$ in time-step $t \in TS$;

10.2.2.3 $ExtLMP_{t,d}^{PDP}$, which designates the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.4 $PExtCong_{t,d}^{PDP}$, which designates the *intertie* congestion component of the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.5 $PIntCong_{t,d}^{PDP}$, which designates the internal congestion component of the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.6 $IntLMP_{t,d}^{PDP}$, which designates the *intertie border price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.7 $SPNormT_{t,f}^{PDP}$, which designates the shadow price for the precontingency transmission constraint for *facility* $f \in F$ in time-step $t \in TS$;

10.2.2.8 $SPEmT_{h,c,f}^{PDP}$, which designates the shadow price for the postcontingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step $t \in TS$;

10.2.2.9 $SPNIUExtBwdT_t^{PDP}$, which designates the shadow price for the net *interchange schedule* limit constraint limiting increases in net imports between time-step $(t - 1)$ and time-step *t*;

10.2.2.10 $L30RP_{t,b}^{PDP}$, which designates the *locational marginal price* for *thirty minute operating reserve* at bus $b \in B$ in time-step $t \in TS$;

10.2.2.11 $L10NP_{t,b}^{PDP}$, which designates the *locational marginal price* for nonsynchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$; and

10.2.2.12 $L10SP_{t,b}^{PDP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$.

10.3 Variables

10.3.1 The *pre-dispatch calculation engi*ne shall use the constrained area conditions tests in sections 10.4 and 10.5 to identify the *resources* that are part of the following data sets:

10.3.1.1 $BCond_t^{NCA}$, which designates the *resources* in a *narrow constrained are*a that must be checked for local market power for *energy* in timestep $t \in TS$;

10.3.1.2 $BCond_t^{DCA}$, which designates the *resources* in a *dynamic constrained area* that must be checked for local market power for *energy* in timestep $t \in TS$;

10.3.1.3 $BCond_t^{BCA}$, which designates the *resources* in a broad constrained area to be checked for local market power for *energy* in time-step $t \in TS$;

10.3.1.4 $BCond_t^{GMP}$, which designates the *resources* to be checked for global market power for *energy* in time-step $t \in TS$;

10.3.1.5 $BCond_t^{10S}$, which designates that *resources* to be checked for local market power for synchronized *ten-minute operating reserve* in timestep $t \in TS$;

10.3.1.6 $BCond_t^{10N}$, which designates that *resources* to be checked for local market power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$;

10.3.1.7 $BCond_t^{30R}$, which designates that *resources* to be checked for local market power for *thirty-minute operating reserve* in time-step $t \in TS$;

10.3.1.8 $BCond_t^{GMP10S}$, which designates that *resources* to be checked for global market power for synchronized *ten-minute operating reserve* in time-step $t \in TS$;

10.3.1.9 $BCond_t^{GMP10N}$, which designates that *resources* to be checked for global market power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$; and

10.3.1.10 $BCond_t^{GMP30R}$, which designates that *resources* to be checked for global market power for *thirty-minute operating reserve* in time-step $t \in TS$.

10.4 Constrained Area Conditions Test for Local Market Power (Energy)

10.4.1 Constrained Area Conditions Test for *narrow constrained areas* and *dynamic constrained area*

10.4.1.1 If at least one transmission constraint for a *narrow constrained area* or *dynamic constrained area* is binding in the Pre-Dispatch Pricing algorithm, then all *resources* identified within the *narrow constrained area* or *dynamic constrained area* shall undergo the applicable Conduct Test in section 11 and:

10.4.1.1.1 For each $n \in NCA$ and time-step $t \in TS$: For each transmission *facility* that transmits flow into n, $f \in F_n^{NCA}$, if $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{t,c,f}^{PDP} \neq 0$ for the inbound flow limit, the *pre-dispatch calculation engine* will place n in the set NCA_t' and assign the *resources* in n to the set $BCond_t^{NCA}$; and

10.4.1.1.2 For each $d \in DCA$ and time-step $t \in TS$: For each transmission *facility* that transmits flow into d, $f \in F_d^{DCA}$, if $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{t,c,f}^{PDP} \neq 0$ for the inbound flow limit, the *pre-dispatch calculation engine* will place d in the set DCA_t' and assign the *resources* in n to the set $BCond_t^{DCA}$.

10.4.1.2 Each *narrow constrained area* and *dynamic constrained area* that meets the criteria in section 10.4.1.1 shall be assigned to one of the following subsets, as appropriate:

10.4.1.2.1 NCA_t', which designates the *narrow constrained areas* that qualify for market power mitigation for *energy* in time-step $t \in TS$; and

10.4.1.2.2 DCA_t', which designates the *dynamic constrained areas* that qualify for market power mitigation for *energy* in time-step $t \in TS$.

10.4.2 Constrained Area Conditions Test for the Broad Constrained Area

10.4.2.1 If the congestion component of the *locational marginal price* of a *resource* is greater than $BCACondThresh$ and the *resource* is not part of a *narrow constrained area* or *dynamic constrained area* that has a binding transmission constraint, then the *resource* shall be tested using the broad constrained area thresholds. For each time-step $t \in TS$ and bus $b \in B^{DG}$ such that $b \notin BCond^{NCA}{}_t \cup BCond^{DCA}{}_t$, if $PCong_{t,b}^{PDP} > BCACondThresh$, the *pre-dispatch calculation engine* will then place *resource* b in the set $BCond_t^{BCA}$.

10.5 Constrained Area Conditions Test for Global Market Power (Energy)

10.5.1 The *pre-dispatch calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, subject to section 10.5.2, if:

10.5.1.1 the *intertie border prices* at the *global market power reference intertie zones* are greater than the $IBPThresh$ threshold value, indicated in time-step $t \in TS$ by:

10.5.1.1.1 $IntLMP_{t,d}^{PDP} > IBPThresh$ for *bids* and *offers,* $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zones*; and

10.5.1.2 at least one of the following conditions is met:

10.5.1.2.1 import congestion, represented by a negative *intertie* congestion component, is present on all of the *global market power reference intertie zones*, indicated in time-steps $t = \{2,3\}$ by:

10.5.1.2.1.1 $PExtCong_{t,d}^{PDP} < 0$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; or

10.5.1.2.1.2 the net *interchange schedule* limit is binding for imports, represented by a non-zero net *interchange schedule* limit shadow price for incremental imports, indicated in time-steps $t = \{2,3\}$ by:

$$SPNIUExtBwdT_t^{PDP} \neq 0$$

10.5.2 If the conditions in sections 10.5.1 are met, then the *pre-dispatch calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, for each time-step $t \in TS$, place all $b \in B^{DG}$ in the set $BCond_t^{GMP}$, unless they are excluded because one of the following two conditions:

10.5.2.1 the *resource*s in any zone have congestion components at least $1/MWh below the internal congestion component at all of the *global market power reference intertie zones*:

10.5.2.1.1 if $PCong_{t,b}^{PDP} < PIntCong_{t,d}^{PDP} - \$1/MWh$ where $d \in D^{GMPRef}$ is true for all *global market power reference intertie zones*; or

10.5.2.2 the resources can not meet the incremental load because a binding transmission constraint:

10.5.2.2.1 if resources can not meet incremental load because of any binding transmission *facility* where $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{t,c,f}^{PDP} \neq 0$.

10.6 Constrained Area Conditions Test for Local Market Power (Operating Reserve)

10.6.1 Subject to section 10.6.2, for a regional minimum requirement of greater than zero for a specific class of *operating reserve*, then all *resources* within the region with *offers* for classes of *operating reserve* that can satisfy the requirements of the specific class of *operating reserve* shall be tested for local market power:

10.6.1.1 if b is in a region with a non-zero minimum requirement, then bb is subject to the Conduct Test and is placed in the set $BCond_t^{10S}$, $BCond_t^{10N}$,or $BCond_t^{30R}$

10.6.2 A *resource* shall not qualify for local market power mitigation testing for *operating reserve* if the *resource* is located in a region with a binding maximum constraint and for each *resource* $b \in B^{DG} \cup B^{DL}$ and time-step $t \in TS$:

10.6.2.1 if b is in a region with a binding maximum restriction constraint, then b is exempt from the Conduct Test.

10.7 Constrained Area Conditions Test for Global Market Power (Operating Reserve)

10.7.1 A *resource* shall be subject to global market power mitigation testing for *operating reserve* if its offers for a class of *operating reserve* where the *locational marginal price* for that class of *operating reserve* is greater than $ORGCondThresh$.

10.7.2 Subject to section 10.7.3, if the condition in section 10.7.1 has been met for a class of *operating reserve*, then all *resources* with offers for classes of *operating reserve* that can satisfy the requirements of that class of *operating reserve* shall be tested and for each $b \in B^{DG} \cup B^{DL}$ and timestep $t \in TS$:

10.7.2.1 if $L10SP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond^{GMP}{}_t{}^{10S}$;

10.7.2.2 if $L10NP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond^{GMP}{}_t{}^{10N}$; and

10.7.2.3 if $L30RP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond^{GMP}{}_t{}^{30R}$.

10.7.3 If a *resource* is located in a region with a binding regional maximum constraint, then the *resource* shall not qualify for global market power mitigation testing for *operating reserve*:

10.7.3.1 if b is in a region with a binding maximum constraint, then b shall be exempt from the Conduct Test.

10.8 Outputs

10.8.1 Outputs of the Constrained Area Conditions Test include the list of *resources* that will be subject to the Conduct Test in section 11 and the thresholds that will be used in the Conduct Test for those *resources*.

11 Conduct Test

11.1 Purpose

11.1.1 The Conduct Test shall verify whether the *financial dispatch data parameter* values submitted by *registered market participants* for *resources* identified in section 10.8.1 are within the applicable threshold level of the *reference level values* for those *resources*.

11.2 Information, Sets, Indices and Parameters

11.2.1 Information, sets, indices and parameters for the Conduct Test are described in sections 3 and 4. In addition, the list of *resources* produced pursuant to section 10.8.1 shall be used by the Conduct Test.

11.3 Variables

11.3.1 The *pre-dispatch calculation engine* shall apply the Conduct Test set out in sections 11.4 and 11.5 to the *resources* identified by the Constrained Area Conditions Test in accordance with section 10.8, to identify the following data sets:

11.3.1.1 The sets of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter*, where:

11.3.1.1.1 BCT_t^{NCA} designates the *resources* in a *narrow constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.2 BCT_t^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.3 BCT_t^{BCA} designates the *resources* in a broad constrained area that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.4 BCT_t^{GMP} designates the *resources* that failed the global market power for *energy* Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.5 BCT_t^{ORL} designates the *resources* that failed the local market power for *operating reserve* Conduct Test for at least one *dispatch data* parameter in time-step $t \in TS$; and

11.3.1.1.6 BCT_t^{ORG} designates the *resources* that failed the global market power Conduct Test for *operating reserve* for at least one *financial dispatch data parameter* in time-step $t \in TS$.

11.3.1.2 The following *financial dispatch data parameters* for all time-steps $t \in TS$:

11.3.1.2.1 $PARAME_{t,b}$, which designates the set of *dispatch data* parameters that failed the *energy* Conduct Test at bus $b \in \{BCT_t^{NCA} \cup BCT_t^{DCA} \cup BCT_t^{BCA} \cup BCT_t^{GMP}\}$ in time-step *t*, and may include the following *financial dispatch data parameters*:

11.3.1.2.1.1 $EnergyOffer_k$, which designates a non-zero quantity of *energy* above the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{E}$ failed the Conduct Test;

11.3.1.2.2 For all hours prior to and including the last hour where conditions are met for the *energy* Conduct Test:

11.3.1.2.2.1 $EnergyToMLP_{kk}$, which designates the non-zero quantity of *energy* up to the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$ failed the Conduct Test;

11.3.1.2.2.2 $SUOffer$, which designates the *start-up offer* failed the Conduct Test; and

11.3.1.2.2.3 $SNLOffer$, which designates the *speed no-load offer* failed the Conduct Test.

11.3.1.2.3 $PARAMOR_{t,b}$ designates the set of *financial dispatch data parameter* that failed the *operating reserve* Conduct Test for bus $b \in \{BCT_t^{ORL} \cup BCT_t^{ORG}\}$ in time-step t, and may include the following *financial dispatch data parameter*:

11.3.1.2.3.1 $OR10SOffer_k$, which designates the non-zero quantity of synchronized *ten-minute operating reserve* in association with *offer* lamination $k \in K_{t,b}^{10S}$ failed the Conduct Test;

11.3.1.2.3.2 $OR10NOffer_k$, which designates the non-zero quantity of nonsynchronized *ten-minute operating reserve* in association with *offer* lamination $k \in K_{t,b}^{10S}$ failed the Conduct Test; and

11.3.1.2.3.3 $OR30ROffer_k$, which designates the non-zero quantity of *thirty-minute operating reserve* in association with *offer* lamination $k \in K_{t,b}^{30R}$ failed the Conduct Test;

11.3.1.2.4 For all hours prior to and including the last hour where conditions are met for the *operating reserve* Conduct Test:

11.3.1.2.4.1 $SUOffer$, which designates the *start-up offer* failed the Conduct Test;

11.3.1.2.4.2 *SNLOffer*, which designates the *speed no-load offer* failed the Conduct Test; and

11.3.1.2.4.3 $EnergyToMLP_k$, which designates the non-zero quantity of up to the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{E}$ failed the Conduct Test.

11.4 Conduct Test for Energy

11.4.1 The *pre-dispatch calculation engine* shall perform the Conduct Test for *energy* for *resources* in a *narrow constrained area* that were identified pursuant to section 10.8.1 as follows, subject to sections 11.4.2 and 11.4.3. For each time-step $t \in TS$ and $b \in BCond_t^{NCA}$, the *pre-dispatch calculation engine* shall:

11.4.1.1 Evaluate *energy offers* above *minimum loading point*: For all $k \in K^{E}_{t,b}$, if $PDG_{t,b,k} > CTEnMinOffer$ and $PDG_{t,b,k} > \min(PDGRef_{t,b,k`} * (1 + CTEnThresh1^{NCA}), PDGRef_{t,b,k`} + CTEnThresh2^{NCA})$, where $k' \in K'^{E}_{t,b}$, then the Conduct Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $EnergyOffer_k$ to $PARAME_{t,b}$;

11.4.1.2 Evaluate *offers* for *energy* for the range of production up to *minimum loading point*: For all time-steps prior to and including the last timestep where conditions are met for the Constrained Area Conditions Test, for all $k \in K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > \min(PLTMLPRef_{t,b,k`} * (1 + CTEnThresh1^{NCA}), PLTMLPRef_{t,b,k`} + CTEnThresh2^{NCA}$, where $k' \in K_{t,b}'^{E}$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $EnergyToMLP_k$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$;

11.4.1.3 Evaluate *start-up offers*: For all time-steps prior to and including the last time-step t where conditions are met for the Constrained Area Conditions Test in section 10, if $SUDG_{t,b} > SUDGRef_{t,b} * (1 + CTSUThresh^{NCA})$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $SUOffer$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$; and

11.4.1.4 Evaluate *speed no-load offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SNL_{t,b} > SNLRef_{t,b} * (1 + CTSNLThresh^{NCA})$, then the Conduct Test was failed by the *resource* at bus *b* and the *predispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $SNLOffer$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$.

11.4.2 For *resources* identified pursuant to section 10.8.1 in a *dynamic constrained area* or broad constrained area, the *pre-dispatch calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond^{DCA}{}_t$ or $BCond^{BCA}{}_t$, as the case may be, in place of $BCond^{NCA}{}_t$ and using the applicable Conduct Test thresholds $CTEnThresh1^{DCA}$, $CTEnThresh2^{DCA}$, $CTEnThresh1^{BCA}$, $CTEnThresh2^{BCA}$, $CTSUThresh^{DCA}$, $CTSUThresh^{BCA}$, $CTSNLThresh^{DCA}$, $CTSNLThresh^{BCA}$. If any of the *financial dispatch data parameters* of *a resource* fail the Conduct Test, the *resource* shall be assigned to subset $BCT_h{}^{DCA}$ or $BCT_h{}^{BCA}$, as the case may be.

11.4.3 For *resources* identified pursuant to section 10.8.1 that were selected for global market power mitigation testing for *energy*, the *pre-dispatch calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond_t{}^{GMP}$ in place of $BCond^{NCA}{}_t$ and the applicable global market power Conduct Test thresholds $CTEnThresh1^{GMP}$, $CTEnThresh2^{GMP}$, $CTSUThresh^{GMP}$, $CTSNLThresh^{GMP}$. If any of the applicable *financial dispatch data parameters* of a *resource* fails the Conduct Test, the *resource* shall be assigned to subset $BCT_h{}^{GMP}$.

11.4.4 If a *resource* is assigned to more than one of the sets, $BCond^{NCA}{}_t$, $BCond^{DCA}{}_t$, $BCond^{BCA}{}_t$, and $BCond^{GMP}{}_t$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.5 Conduct Test for Operating Reserve

11.5.1 The *pre-dispatch calculation engine* shall perform the Conduct Test for local market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1, as follows, subject to 11.5.3. For each time-step $t \in TS$ and $b \in BCond_t^{10S} \cup BCond_t{}^{10N} \cup BCond_t{}^{30R}$, the pre-dispatch calculation engine shall:

11.5.1.1 Evaluate *offers* for *operating reserve* as follows:

11.5.1.1.1 for all $k \in K_{t,b}{}^{10S}$ such that $P10SDG_{t,b,k} > CTORMinOffer$ and $P10SDG_{t,b,k} > \min(P10SDGRef_{t,b,k`} * (1 + CTORThresh1^{ORL}), P10SDGRef_{t,b,k`} + CTORThresh2^{ORL})$, where $k \in K'_{h,b}{}^{10S}$, then the Conduct Test was failed for the *resource* at bus *b* and the *predispatch calculation engine* shall assign the *resource* to subset $BCT_t{}^{ORL}$ and add $OR10SOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.2 for all $k \in K_{t,b}{}^{10N}$ such that $P10NDG_{t,b,k} > CTORMinOffer$ and $P10NDG_{t,b,k} > \min(P10NDGRef_{t,b,k`} * (1 + CTORThresh1^{ORL}), P10NDGRef_{t,b,k`} + CTORThresh2^{ORL})$, where $k' \in K'^{10N}_{h,b}$, then the Conduct Test was failed for the *resource* at bus *b* and the *predispatch calculation engine* shall assign the *resource* to subset $BCT_t{}^{ORL}$ and add $OR10NOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.3 for all $k \in K_{t,b}{}^{30R}$ such that $P30RDG_{t,b,k} > CTORMinOffer$ and $P30RDG_{t,b,k} > min(P30RDGRef_{t,b,k`} * (1 + CTORThresh1^{ORL}), P30RDGRef_{t,b,k`} + CTORThresh2^{ORL})$, where $k' \in K'^{30}{}_{h,b}{}^{R}$, then the

Conduct Test was failed for the *resource* at bus *b* and the *predispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.4 for all $j \in J_{t,b}^{10S}$ if $P10SDL_{t,b,j} > CTORMinOffer$ and $P10SDL_{t,b,j} > \min(P10SDLRef_{t,b,j'} * (1 + CTORThresh1^{ORL}), P10SDLRef_{t,b,j'} + CTORThresh2^{ORL})$, where $j' \in J_{t,b}^{'10S}$, then the Conduct Test was failed for the *dispatchable load* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.5 for all $j \in J_{t,b}^{10N}$ if $P10NDL_{t,b,j} > CTORMinOffer$ and $P10NDG_{t,b,j} > \min(P10NDLRef_{t,b,j'} * (1 + CTORThresh1^{ORL}), P10NDLRef_{t,b,j'} + CTORThresh2^{ORL})$, where $j' \in J_{t,b}^{'10N}$, then the Conduct Test was failed for the *dispatchable load* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{t,b}$; and

11.5.1.1.6 for all $j \in J_{t,b}^{30R}$ if $P30RDL_{t,b,j} > CTORMinOffer$ and $P30RDL_{t,b,j} > \min(P30RDLRef_{t,b,j'} * (1 + CTORThresh1^{ORL}), P30RDLRef_{t,b,j'} + CTORThresh2^{ORL}$, where $j' \in J_{t,b}^{30R}$, then the Conduct Test was failed for the *dispatchable load* at bus bb and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{t,b}$;

11.5.1.2 Evaluate *start-up offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SUDG_{t,b} > SUDGRef_{t,b} * (1 + CTSUThresh^{ORL})$, then the Conduct Test failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $SUOffer$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$;

11.5.1.3 Evaluate *speed no-load offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SNL_{t,b} > SNLRef_{t,b} * (1 + CTSNLThresh^{ORL})$, then the Conduct Test was failed for the *resource* at bus *b* and the *predispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $SNLOffer$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$; and

11.5.1.4 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, for all $k \in$

$K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > \min(PLTMLPRef_{t,b,k`} * (1 + CTEnThresh1^{ORL}), PLTMLPRef_{t,b,k`} + CTEnThresh2^{ORL}$, where $k' \in K'_{t,b}{}^{E}$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $EnergyToMLP_k$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$.

11.5.2 The *pre-dispatch calculation engine* shall perform the Conduct Test for global market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1. The *pre-dispatch calculation engine* shall use the steps set out in section 11.5.1 using *resources* in $BCond_t^{GMP10S}$, $BCond_t^{GMP10N}$, and $BCond_t^{GMP30R}$ in place of $BCond_t^{10S}$, $BCond_t^{10N}$, and $BCond_t^{30R}$, respectively, and the applicable Conduct Test thresholds ($CTORThresh1^{ORG}$, $CTORThresh2^{ORG}$, $CTSUThresh^{ORG}$, $CTSNLThresh^{ORG}$, $CTEnThresh1^{ORG}$, $CTEnThresh2^{ORG}$). The *resources* shall be assigned to the subset BCT_h^{ORG}.

11.5.3 If a *resource* is assigned to more than one of $BCond_t^{GMP10S}$, $BCond_t^{GMP10N}$, and $BCond_t^{GMP30R}$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.6 Outputs

11.6.1 Subject to section 11.6.2, the outputs of the Conduct Test shall include the following for each time-step $t \in TS$:

11.6.1.1 The set of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter* by condition type;

11.6.1.2 The *financial dispatch data parameters* that failed the Conduct Test for the *resource* at bus b; and

11.6.1.3 A revised set of *financial dispatch data parameters* replaced with *reference level values* for *resources* that:

11.6.1.3.1 has one or more *financial dispatch data parameters* that failed a Conduct Test for the current *pre-dispatch calculation engine* run; and

11.6.1.3.2 has one or more *financial dispatch data parameter*s that failed both the Conduct Test and failed the Price Impact Test in previous *predispatch calculation engine* runs.

11.6.1.4 For *offers* for *energy* and *operating reserve* with multiple laminations:

11.6.1.4.1 if the *offer* lamination for *energy* that corresponds to the *minimum loading point* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *energy* up to the *minimum loading point*;

11.6.1.4.2 if one or more offer laminations for *energy* above the *minimum loading point* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *energy* up to and above the *minimum loading point*; and

11.6.1.4.3 if one or more *offer* laminations for *operating reserve* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *operating reserve.*

11.6.1.5 For a *non-quick start resource* whose *start-up offer* failed the Conduct Test, identified in section 11.6.1.1, the *pre-dispatch calculation engine* shall use the *start-up offer reference level value* to evaluate any advancements pursuant to section 5.7.

11.6.2 The *pre-dispatch calculation engine* shall not replace the *financial dispatch data parameter* for a *resource* with that *resource'*s applicable *reference level value* if the *financial dispatch data parameter* is less than the corresponding *reference level value*.

12 Reference Level Scheduling

12.1 Purpose

12.1.1 The *pre-dispatch calculation engine* shall perform the Reference Level Scheduling algorithm where at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test in section 11.

12.1.2 The Reference Level Scheduling algorithm shall perform a *security* constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, including *reference level value* for *resources* subject to 14.7.1.3 and 12.2.2, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

12.2 Information, Sets, Indices and Parameters

12.2.1 Information, sets, indices and parameters used by the Reference Level Scheduling algorithm are described in section 3 and section 4. In addition, the list of *resources* that failed the Conduct Test from section 11.6.1.1 and a revised set of *financial dispatch data parameters* from section 11.6.1.3, for those *resources* shall be used by the Reference Level Scheduling algorithm

12.2.2 The Reference Level Scheduling algorithm shall use the *reference level value* that corresponds to any *financial dispatch data parameter* submitted for a *resource* that failed the Conduct Test.

12.3 Variables and Objective Function

12.3.1 The *pre-dispatch calculation engine* shall solve for the variables listed in section 8.3.1.

12.3.2 The objective function for the Reference Level Scheduling algorithm shall be the same as the objective function in section 8.3.2, subject to section 12.4.

12.4 Constraints

12.4.1 The constraints in sections 8.4 through 8.7 apply in the Reference Level Scheduling algorithm, except that the sensitivities and limits considered for IESO internal transmission limits shall be those provided by the most recent *security* assessment function iteration of the Reference Level Scheduling algorithm.

12.5 Outputs

12.5.1 Outputs of the Reference Level Scheduling algorithm include *resource* schedules and commitments.

13 Reference Level Pricing

13.1 Purpose

13.1.1 The *pre-dispatch calculation engine* shall perform the Reference Level Pricing algorithm whenever the Reference Level Scheduling algorithm has been performed.

13.1.2 The Reference Level Pricing algorithm shall perform a *security* constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, *reference level value* for r*esources* subject to 14.7.1.3 and 13.2.2, and *resource* schedules and commitments produced by the Reference Level Scheduling algorithm, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

13.2 Information, Sets, Indices and Parameters

13.2.1 Information, sets, indices and parameters used by the Reference Level Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedule and commitments from the Reference Level Scheduling algorithm shall be used by the Reference Level Pricing algorithm:

13.2.1.1 $SDG_{t,b,k}^{RLS}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,bE}$;

13.2.1.2 $ODG_{t,b}^{RLS}$, which designates whether a *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$;

13.2.1.3 $S10SDG_{t,b,k}^{RLS}$, which designates the amount of synchronized *ten-minute operating reserve* that a *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 $k \in K_{t,b}^{10S}$;

13.2.1.4 $S10NDG_{t,b,k}^{RLS}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *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 $k \in K_{t,b}^{10N}$

13.2.1.5 $S10RDG_{t,b,k}^{RLS}$, which designates the amount of *thirty-minute operating reserve* that a *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 $k \in K_{t,b}^{30R}$; and

13.2.1.6 $OHO^{RLS}_{t,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at but $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

13.2.2 The Reference Level Pricing algorithm shall use *a resource's reference level value* for any *financial dispatch data parameters* submitted by *registered market participants* that failed the Conduct Test in Section 11.

13.3 Variables and Objective Function

13.3.1 The *pre-dispatch calculation engine* shall solve for the variables set out in section 9.3.1.

13.3.2 The objective function used in the Reference Level Pricing algorithm shall be the same as the objective function set out in section 9.3.2, subject to section 13.4.

13.4 Constraints

13.4.1 The constraints that apply in the Reference Level Pricing algorithm shall be the same as the constraints in sections 9.4 through 9.8, with the following exceptions:

13.4.1.1 the marginal loss factors used in the *energy* balance constraint in section 9.7.1 shall be fixed to the marginal loss factors used in the last optimization function iteration of the Reference Level Scheduling algorithm;

13.4.1.2 the sensitivities and limits in section 9.7.3 shall be replaced with the most recent *security* assessment function iteration of the Reference Level Pricing algorithm; and

13.4.1.3 for the constraints in section 9.8, the outputs from the Pre-Dispatch Scheduling algorithm shall be replaced with the outputs from the Reference Level Scheduling algorithm as follows:

13.4.1.3.1 $SDG_{t,b,k}^{PDS}$ shall be replaced by $SDG_{t,b,k}^{RLS}$ for all $t \in TS$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{t,d}^{E}$

13.4.1.3.2 $ODG_{t,b}^{PDS}$ shall be replaced by $ODG_{t,b}^{RLS}$ for all t ∈ TS, b ∈ B^{DG};

13.4.1.3.3 $IDG_{t,b}^{PDS}$ shall be replaced by $IDG_{t,b}^{RLS}$ for all t ∈ TS, b ∈ B^{DG};

13.4.1.3.4 $S10SDG_{t,b,k}^{PDS}$ shall be replaced by $S10SDG_{t,b,k}^{RLS}$ for all t ∈ TS, b ∈ $B^{ELR} \cup B^{HE}$, k ∈ $K_{t,b}^{10S}$;

13.4.1.3.5 $S10NDG_{t,b,k}^{PDS}$ shall be replaced by $S10NDG_{t,b,k}^{RLS}$ for all t ∈ TS, b ∈ $B^{ELR} \cup B^{HE}$, k ∈ $K_{t,b}^{10N}$;

13.1.4.3.6 $S30RDG_{t,b,k}^{PDS}$ shall be replaced by $S30RDG_{t,b,k}^{RLS}$ for all t ∈ TS, b ∈ $B^{ELR} \cup B^{HE}$, k ∈ $K_{t,b}^{30R}$; and

13.4.1.3.7 $OHO_{t,b}^{PDS}$ shall be replaced by $OHO_{t,b}^{RLS}$ for all t ∈ TS, b ∈ B^{HE}.

13.5 Outputs

13.5.1 Outputs of the Reference Level Pricing algorithm include the following:

13.5.1.1 shadow prices; and

13.5.1.2 *locational marginal prices* and their components.

14 Price Impact Test

14.1 Purpose

14.1.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test whenever at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test.

14.1.2 The Price Impact Test shall:

14.1.2.1 compare the *locational marginal prices* for *energy* or *operating reserve* produced by the Pre-Dispatch Pricing algorithm with those produced by the Reference Level Pricing algorithm; and

14.1.2.2 consider the corresponding *offer* parameters to have failed the price impact test if the difference in price in section 14.1.2.1 is greater than the applicable impact threshold in section 4.3.9.

14.2 Information, Sets, Indices and Parameters

14.2.1 Information, sets, indices and parameters for the Price Impact Test are described in sections 3 and 4. In addition, the following *locational marginal prices* from the Pre-Dispatch Pricing algorithm and the Reference Level Pricing algorithm shall be used:

14.2.1.1 $LMP_{t,b}^{PDP}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.2 $L30RP_{t,b}^{PDP}$, which designates the *locational marginal price* for *thirty minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.3 $L10NP_{t,b}^{PDP}$, which designates the *locational marginal price* for nonsynchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.4 $L10SP_{t,b}^{PDP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.5 $LMP_{t,b}^{RLP}$, which designates the *locational marginal price* for energy at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm;

14.2.1.6 $L30RP_{t,b}^{RLP}$, which designates the *locational marginal price* for *thirtyminute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm;

14.2.1.7 $L10NP_{t,b}^{RLP}$, which designates the *locational marginal price* for nonsynchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm; and

14.2.1.8 $L10SP_{t,b}^{RLP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm.

14.3 Variables

14.3.1 The *pre-dispatch calculation engine* shall apply the Price Impact Test as set out in sections 14.4 and 14.5 for the *resources* identified in accordance with section 10.3.1, to identify:

14.3.1.1 A set of *resources* that failed the Price Impact Test for each condition for all time-steps $t \in TS$, where:

14.3.1.1.1 BIT_t^{NCA} designates the *resources* in a *narrow constrained area* that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.2 BIT_t^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Price Impact Test for *energy locational marginal price*;

14.3.1.1.3 BIT_t^{BCA} designates the *resources* in a broad constrained area that failed Price Impact Test for *energy locational marginal price*;

14.3.1.1.4 BIT_t^{GMP} designates the *resources* that failed the Global Market Power (*energy*) Price Impact Test for *energy locational marginal price*;

14.3.1.1.5 BIT_t^{ORL} designates the *resources* that failed the Local Market Power (*operating reserve*) Price Impact Test for at least one type of *operating reserve locational marginal price*;

14.3.1.1.6 BIT_t^{ORG} designates the *resources* that failed the Global Market Power (*operating reserve*) Price Impact Test for at least one type of *operating reserve locational marginal price*; and

14.3.1.1.7 $LMPIT_{t,b}$ designates the *locational marginal price* that failed the Price Impact Test for bus $b \in BIT_t^{NCA} \cup BIT_t^{DCA} \cup BIT_t^{BCA} \cup BIT_t^{GMP} \cup BIT_t^{ORL} \cup BIT_t^{ORG}$ in time-step $t \in TS$ and

14.3.1.2 *Locational marginal prices* for *energy* and *operating reserve* for each *resource* at bus $b \in B^{DG} \cup B^{DL}$ that failed the Price Impact Test, where:

14.3.1.2.1 $EnergyLMP$ designates that the *locational marginal price* for *energy* failed the Price Impact Test;

14.3.1.2.2 $OR10SLMP$ designates that the synchronized *ten-minute operating reserve locational marginal price* failed the Price Impact Test;

14.3.1.2.3 $OR10NLMP$ designates that the non-synchronized *ten-minute operating reserve locational marginal price* failed the Price Impact Test; and

14.3.1.2.4 $OR30RLMP$ designates that the *thirty-minute operating reserve locational marginal price* failed the Price Impact Test.

14.4 Price Impact Test for Energy

14.4.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *energy* in section 11.6.1.1, as follows:

14.4.1.1 For local market power for *energy*:

14.4.1.1.1 For each time-step $t \in TS$ and $b \in BCT_t^{NCA}$, if $LMP_{t,bPDP} > min(LMP_{t,bRLP} * (1 + ITThresh1_{NCA}), LMP_{t,bRLP} + ITThresh2^{NCA})$, the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{NCA} and add $EnergyLMP$ to $LMPIT_{t,b}$;

14.4.1.1.2 For each time-step $t \in TS$ and $b \in BCT_t^{DCA}$, if $LMP_{t,bPDP} > \mathrm{Min}(LMP_{t,bRLP} * (1 + ITThresh1_{DCA}), LMP_{t,bRLP} + \mathrm{ITThresh2}^{\mathrm{DCA}})$, the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{DCA} and add $EnergyLMP$ to $LMPIT_{t,b}$; and

14.4.1.1.3 For each time-step $t \in TS$ and $b \in BCT_t^{BCA}$, if

$LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{BCA}), LMP_{t,b}^{RLP} + ITThresh2^{BCA})$, the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{BCA} and add $EnergyLMP$ to $LMPIT_{t,b}$; and

14.4.1.2 For global market power for *energy*:

14.4.1.2.1 For each time-step $t \in TS$ and $b \in BCT_t^{GMP}$, if

$LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{GMP}), LMP_{t,b}^{RLP} + ITThresh2^{GMP})$, the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{GMP} and add $EnergyLMP$ to $LMPIT_{t,b}$.

14.5 Price Impact Test for Operating Reserve

14.5.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *operating reserve* in section 11.6.1.1, as follows:

14.5.1.1 For local market power for *operating reserve*, for each time-step $t \in TS$ and $b \in BCT_t^{ORL}$:

14.5.1.1.1 If $L30RP_{t,b}^{PDP} > L30RP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR30RLMP$ to $LMPIT_{t,b}$;

14.5.1.1.2 If $L10NP_{t,b}^{PDP} > L10NP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR10NLMP$ to $LMPIT_{t,b}$; and

14.5.1.1.3 If $L10SP_{t,b}^{PDP} > L10SP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR10SLMP$ to $LMPIT_{t,b}$; and

14.5.1.2 For global market power for *operating reserve*, for each time-step $t \in TS$ and $b \in BCT_t^{ORG}$:

14.5.1.2.1 If $L30RP_{t,b}^{PDP} > \min(L30RP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L30RP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORG} and add $OR30RLMP$ to $LMPIT_{t,b}$;

14.5.1.2.2 If $L10NP_{t,b}^{PDP} > \min(L10NP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}),$

$L10NP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORG} and add $OR10NLMP$ ttt $LMPIT_{t,b}$; and

14.5.1.2.3 If $L10SP_{t,b}^{PDP} > \min(L10SP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L10SP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign *resource* to subset BIT_t^{ORG} and add $OR10SLMP$ to $LMPIT_{t,b}$.

14.6 Revised Financial Dispatch Data Parameter Determination

14.6.1 A *resource* that fails the Price Impact Test in a time-step (tt) shall have its *financial dispatch data parameters* revised as follows:

14.6.1.1 If the *resource* has failed a Price Impact Test for *energy* and is in BIT_t^{NCA}, BIT_t^{DCA}, BIT_t^{BCA}, BIT_t^{GMP}, the *financial dispatch data parameters* in $PARAME_{t,b}$ shall be used to determine the *financial dispatch data parameters* that shall be replaced with the *resource's* applicable *reference level value*.

14.6.1.2 If the *resource* has failed a Price Impact Test for *operating reserve* and is in BIT_t^{ORL} or BIT_t^{ORG}, the *financial dispatch data parameters* in $PARAMOR_{t,b}$ shall be used to determine the *financial dispatch data parameters* that shall be replaced with the *resource's* applicable *reference level value*.

14.6.1.3 If a non-*quick-start resource* has failed a Price Impact Test in any time-step, the *commitment cost parameters* (*start-up offer*, *speed-noload offer*, or *energy offer* associated with the *minimum loading point*) that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that time-step. For any time-steps prior, any *commitment cost parameters* for that *resource* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level value* in those time-steps. This is expressed as:

14.6.1.3.1 For each time-step $t \in TS$ 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 level values*.

14.6.1.4 Section 14.6.1.3 shall apply to the tests for local market power and global market power for *operating reserve*, except $PARAMOR_{T,b}$ shall be checked in place of $PARAME_{T,b}$.

14.6.1.5 If a *resource* is in a *narrow constrained area* or a *dynamic constrained area* and has failed a Price Impact Test, each *resource* in the same *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its *offer* data replaced with its applicable *reference level value* for that hour. For each time-step $t \in TS$:

14.6.1.5.1 if BIT_t^{NCA} includes one or more *resources* in a *narrow constrained area, n*, each *resource* $b \in BCT_t^{NCA}$ for *narrow constrained area, n*, shall have the parameters in $PARAME_{t,b}$ replaced with its *reference level values*; and

14.6.1.5.2 if BIT_t^{DCA} includes one or more *resources* in a *dynamic constrained area, d*, each *resource* $b \in BCT_t^{DCA}$ for *dynamic constrained area*, d, shall have the parameters in $PARAME_{t,b}$ replaced with its *reference level values*.

14.6.1.6 If a *non-quick-start resource* in a *narrow constrained area* or a *dynamic constrained area* has failed a Price Impact Test, each *nonquick-start resource* in the *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its *commitment cost parameters* replaced with its applicable *reference level value* for that time-step. For any time-steps prior, if a *non-quick-start resource* in that *narrow constrained area* or *dynamic constrained area* has a *commitment cost parameter* that failed the Conduct Test, that *commitment cost parameter* shall be replaced with the *resource*'s applicable *reference level value* in those time-steps. This is expressed as:

14.6.1.6.1 For all time-steps up to the time-step in which a *resource* failed the Price Impact Test for a *narrow constrained area*, 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 level values*.

14.6.1.6.2 For all time-steps up to the time-step in which a *resource* failed the Price Impact Test for a *dynamic constrained area*, 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 level values*.

14.6.1.7 If a *resource* fails the local market power for *operating reserve* Price Impact Test, all *resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test for at least one parameter shall have the parameter that failed the Conduct Test replaced with the *resource's* applicable *reference level value* for that hour. This is expressed as:

14.6.1.7.1 For each time-step $t \in TS$, if BIT_t^{ORL} includes one or more *resource* in *operating reserve* region, r, all *resources*, $b \in BIT_t^{ORL}$ for *operating reserve* region r, shall have the parameters in $PARAMOR_{t,b}$ replaced with *reference level values*.

14.6.1.8 If a *non-quick-start resource* fails the local market power for *operating reserve* Price Impact Test in any time-step, the *commitment cost parameters* for all *non-quick-start resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that time-step. For any time-steps prior, any *commitment cost parameters* of *non-quick-start resources* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level value* in those time-steps. This is expressed as:

14.6.1.8.1 For all time-steps up to the time-step 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 level values*.

14.7 Outputs

14.7.1 The *pre-dispatch calculation engine* shall prepare the following outputs, subject to section 14.7.2, for each time-step $t \in TS$:

14.7.1.1 The set of *resources* that failed the Price Impact Test for all time-steps in the pre-dispatch look ahead period, by condition, in accordance to sections 14.4 and 14.5. Those *resources* shall be added to the accumulated set of *resources* from previous *pre-dispatch calculation engine* runs which failed the Price Impact Test in the current time-step $t \in TS$;

14.7.1.2 The *locational marginal prices* for *energy* and *operating reserve* that failed the Price Impact Test for each *resource* at bus bb in accordance to sections 14.4 and 14.5;

14.7.1.3 A revised set of *offer* data to be used by the next *pre-dispatch calculation engine* run and next real-time hour. The revised set of offer data will be for the *resources* that failed the Price Impact Test:

14.7.1.3.1 in current *pre-dispatch calculation engine* run replacing *offer* data that failed the Conduct Test with the applicable *reference level values*, in accordance with section 14.6; and

14.7.1.3.2 in previous *pre-dispatch calculation engine* runs with *financial dispatch data parameters* that were decided to be mitigated in previous *pre-dispatch calculation engine* runs replaced with *reference level values*.

14.7.2 The *pre-dispatch calculation engine* shall not replace *financial dispatch data parameters* from a *resource* with that *resource's* applicable *reference level value* if the *financial dispatch data parameters* is less than the *reference level value*.

15 Pseudo-Unit Modelling

15.1 Pseudo-Unit Model Parameters

15.1.1 The *pre-dispatch calculation engine* shall use the following registration and daily *dispatch data* to determine the underlying relationship between a *pseudo-unit* and the associated physical *resources* for a combined cycle *facility* with KK combustion turbines and one steam turbine:

15.1.1.1 $CMCR_k$ designates the registered *maximum continuous rating* of combustion turbine $k \in \{1,..,K\}$ in MW;

15.1.1.2 $CMLP_k$ designates the *minimum loading point* of combustion turbine $k \in \{1,..,K\}$ in MW;

15.1.1.3 $SMCR$ designates the registered *maximum continuous rating* of the steam turbine in MW;

15.1.1.4 $SMLP$ designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

15.1.1.5 SDF designates the amount of duct firing capacity available on the steam turbine in MW;

15.1.1.6 $STPortion_k$ designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

15.1.1.7 $CSCM_k \in \{0,1\}$ designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in *single cycle mode*, subject to section 15.5.

15.1.2 The *pre-dispatch calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..,K\}$:

15.1.2.1 $MMCR_k$ designates the maximum continuous rating of *pseudo-unit k* and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

15.1.2.2 $MMLP_k$ designates the *minimum loading point* of *pseudo-unit k* and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

15.1.2.3 MDF_k designates the duct firing capacity of *pseudo-unit k* and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

15.1.2.4 MDR_k designates the *dispatchable* capacity of *pseudo-unit k* and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

15.1.3 The *pre-dispatch calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..,K\}$, as follows:

15.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

15.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and $MMLP_k + MDR_k$;

15.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

15.1.4 The *pre-dispatch calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

15.1.4.1 For the *minimum loading point* region:

15.1.4.1.1 Steam turbine share: $STShareMLP_k = \frac{SMLP \cdot (1\text{-}CSCM_k)}{MMLP_k}$;

15.1.4.1.2 Combustion turbine share: $CTShareMLP_k = \frac{CMLP_k}{MMLP_k}$; and

15.1.4.2 For the *dispatchable* region:

15.1.4.2.1 Steam turbine share:

$$STShareDR_k = \frac{(1\text{-}CSCM_k)(SMCR \cdot STPortion_k\text{-}SMLP\text{-}SDF \cdot STPortion_k)}{MDR_k}; \text{ and}$$

15.1.4.2.2 Combustion turbine share: $CTShareDR_k = \frac{CMCR_k\text{-}CMLP_k}{MDR_k}$; and

15.1.4.3 For the duct firing region:

15.1.4.3.1 Steam turbine share shall be equal to 1; and

15.1.4.3.2 Combustion turbine share shall be equal to 0.

15.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

15.2.1 The *pre-dispatch calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

15.2.1.1 $CTCap_{t,k}$ designates the capacity of combustion turbine $k \in \{1,..,K\}$ in time-step *t* as determined by submitted deratings;

15.2.1.2 $STCap_t$ designates the capacity of the steam turbine in time-step t as determined by submitted deratings; and

15.2.1.3 $TotalQ_{t,k}$ designates the total quantity of *energy* for *pseudo-unit* $k \in \{1,..,K\}$ in time-step t.

15.2.2 The *pre-dispatch calculation engine* shall solve for the following operating region parameters for each *pseudo-unit* $k \in \{1,..,K\}$:

15.2.2.1 $MLP_{t,k}$, which designates the *minimum loading point* of *pseudo-unit k* in time-step t;

15.2.2.2 $DR_{t,k}$, which designates the *dispatchable* region capacity of *pseudounit* k in time-step t; and

15.2.2.3 $DF_{t,k}$, which designates the duct firing region capacity of *pseudo-unit k* in time-step t.

15.2.3 Pre-Processing of De-rates

15.2.3.1 The *pre-dispatch calculation engine* shall perform the following preprocessing steps to determine the available operating regions for a *pseudo-unit* based on the combustion turbine and steam turbine share and the application of the *pseudo-unit* deratings. For *pseudo-unit* $k \in \{1,..,K\}$ for time-step $t \in TS$:

15.2.3.1.1 Step 1: Calculate the amount of *offered energy* attributed to each combustion turbine ($CTAmt_{t,k}$) and steam turbine portion ($STAmt_{t,k}$):

If $TotalQ_{t,k} < MMLP_k$ then:

Calculate $CTAmt_{t,k} = 0$; and

Calculate $STAmt_{t,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{t,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{t,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{t,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{t,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{t,k} = CTAmtMLP + CTAmtDR$; and

$STAmt_{t,k} = STAmtMLP + STAmtDR + STAmtDF$.

15.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$$PRSTCap_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}} \right) \cdot STCap_t$$

15.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{t,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $STAmt_{t,k} < SMLP(1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{t,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $PRSTCap_{t,k} < SMLP(1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

15.2.3.1.4 Step 4: Initialize the operating region parameters for time-step $t \in TS$ to the model parameter values:

Set $MLP_{t,k} = MMLP_k$.

Set $DR_{t,k} = MDR_k$.

Set $DF_{t,k} = MDF_k$.

15.2.3.1.5 Step 5: Apply the derating on the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P.CTShareDR_k.MDR_k = CTCap_{t,k}$; and

Set $DR_{t,k} = min(DR_{t,k}, P.MDR_k)$.

15.2.3.1.6 Step 6: Apply the derating on the steam turbine to the duct firing and *dispatchable* regions for *pseudo-units* not operating in *single cycle mode*:

Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{t,k}$.

If $R \leq 1$, update $DF_{t,k} = 0$, and $DR_{t,k} = min(DR_{t,k}, R \cdot MDR_k)$.

If $R > 1$, update $DF_{t,k} = min(DF_{t,k}, PRSTCap_{t,k} - SMLP - STShareDR_k \cdot MDR_k)$.

15.2.4 Available Energy Laminations

15.2.4.1 The *pre-dispatch calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for time-step $t \in TS$ for each *pseudo-unit* $k \in \{1,..,K\}$, subject to section 15.2.4.2, where:

15.2.4.1.1 $QMLP_{t,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

15.2.4.1.2 $QDR_{t,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

15.2.4.1.3 $QDF_{t,k}$ designates the total quantity that may be scheduled in the duct firing region.

15.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$0 \leq QMLP_{t,k} \leq MLP_{t,k}$;

$0 \leq QDR_{t,k} \leq DR_{t,k}$;

$0 \leq QDF_{t,k} \leq DF_{t,k}$;

if $QMLP_{t,k} < MLP_{t,k}$, then the *pseudo-unit* is unavailable and $QDR_{t,k} = QDF_{t,k} = 0$; and if $QDR_{t,k} < DR_{t,k}$, then $QDF_{t,k} = 0$.

15.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

15.3.1 The *pre-dispatch calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

$PSUMin_{t,k}{}^{q}$ designates the minimum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a minimum limitation on *pseudo-unit* k, then $PSUMin_{t,k}{}^{q}$ shall be set equal to 0;

$PSUMax_{t,k}{}^{q}$ designates the maximum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a maximum limitation on *pseudo-unit* k, then $PSUMax_{t,k}{}^{q}$ shall be set equal to $MLP_{t,k}$ $DR_{t,k} + DF_{t,k}$;

$CTCmtd_{t,k}$ designates whether combustion turbine k is considered committed in time-step t TS.

The *pre-dispatch calculation engine* shall calculate the minimum and maximum limitations, subject to section 15.3.3.1, as follows:

Minimum limitation: $MinDG_{t,k}$ $PSUMin_{t,k}{}^{q}$

Maximum limitation: $MaxDG_{t,k} = min_{q \in \{1,..Q\}} PSUMax_{t,k}{}^{q}$

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *pre-dispatch calculation engine*.

15.3.3 Pseudo-Unit Minimum and Maximum Constraints

15.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

15.3.3.1.1 $PSUMin_{t,k} = PMin$, where $PMin$ shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for time-step $t \in TS$; and

15.3.3.1.2 $PSUMax_{t,k} = PMax$, PMax shall be a maximum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for time-step $t \in TS$.

15.3.4 Combustion Turbine Minimum and Maximum Constraints

15.3.4.1 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMin < MLP_{t,k} \cdot CTShareMLP_{k}$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right); \text{ and}$$

$$STMinDR = 0.$$

Otherwise, if $CTMin \geq MLP_{t,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{t,k} \cdot STShareMLP_k; \text{ and}$$

$$STMinDR = \left(CTMin\text{-}MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

Therefore:

$$PSUMin_{t,k} = CTMin + STMinMLP + STMinDR.$$

15.3.4.2 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMin_{t,k} = CTMin.$$

15.3.4.3 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMax < MLP_{t,k} \cdot CTShareMLP_k$, then the *pseudo-unit* is unavailable (i.e. $PSUMax_{t,k} = 0$).

Otherwise, calculate the effect of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions:

$$STMaxMLP = MLP_{t,k} \cdot STShareMLP_k$$

$$STMaxDR = \left(CTMax\text{-}MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{t,k} = CTMax + STMaxMLP + STMaxDR$$

15.3.4.4 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMax_{t,k} = CTMax.$$

15.3.5 Steam Turbine Minimum and Maximum Constraints

15.3.5.1 The *pre-dispatch calculation engine* shall convert a stream turbine minimum constraint to a *pseudo-unit* constraints as follows:

15.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which designates the set of *pseudo-units* to which the constraint may be allocated where *pseudo-unit* $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k = 0$ and $CTCmtd_{t,k} = 1$. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

15.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity of *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{t,k} \cdot STShareMLP_k + QDR_{t,k} \cdot STShareDR_k + QDF_{t,k}.$$

15.3.5.1.3 Step 3: Allocate the $STMin$ constraint to each *pseudo-unit* $k \in A$, where $STMin$ constraint shall be allocated equally to each *pseudo-unit* $k \in A$ and and $STPMin_k$ is limited by $STCap_k$.

15.3.5.1.4 Step 4: The steam turbine portion minimum constraint shall be converted to a *pseudo-unit* constraint,where for each *pseudo-unit* $k \in A$:

If $STPMin_k < MLP_{t,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = STPMin_k \cdot \left(\frac{CTShareMLP_k}{STShareMLP_k}\right); \text{ and}$$

$$CTMinDR_k = 0.$$

Otherwise, if $STPMin_k \geq MLP_{t,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = MLP_{t,k} \cdot CTShareMLP_k; \text{ and}$$

$$CTMinDR_k = \left(STPMin_k \text{-} MLP_{t,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right).$$

Therefore:

$$PSUMin_{t,k} = STPMin_k + CTMinMLP_k + CTMinDR_k.$$

15.3.5.2 If *pseudo-units* with sufficient steam turbine capacity are not commited, then the *pre-dispatch calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudounit* constraints.

15.3.5.3 The steam turbine maximum constraint shall be converted to a *pseudounit* constraint as follows:

$$PRSTMax_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}}\right) \cdot STMax.$$

15.3.5.3.1 If the converted steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{t,k} = 0.$$

15.3.5.3.2 Otherwise, calculate R so that $SMLP + R \cdot STShareDR_k . MDR_k = PRSTMax_{t,k}$:

If $R \leq 1$, set $PSUMax_{t,k} = MLP_{t,k} + min(DR_{t,k}, R \cdot MDR_k)$.

If $R > 1$, set $PSUMax_{t,k} = MLP_{t,k} + DR_{t,k} + PRSTMax_{t,k} \text{-} SMLP \text{-} STShareDR_k \cdot MDR_k$.

15.3.5.4 If the steam turbine minimum and maximum constraints are equal but do not convert to equal *pseudo-unit* minimum and maximum constraints, then the steam turbine minimum constraint conversion in section

15.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

15.4 Steam Turbine Forced Outages

15.4.1 If the steam turbine experiences a *forced outage*, the *pre-dispatch calculation engine* shall evaluate the corresponding *pseudo-units* as *resources* being offered in *single cycle mode*.

15.5 Single-Cycle Mode Flag Across Two Dispatch Days

15.5.1 If the pre-dispatch look-ahead period spans two *dispatch days* and the *single cycle mode* flag across the two *dispatch days* differs, then the *pre-dispatch calculation engine* shall apply the following:

15.5.1.1 If there are no future minimum constraints for the *pseudo-unit* before the end of the first *dispatch day* and if the *IESO's energy* management system indicates that the combustion turbine associated with the *pseudo-unit* is not online, then the *pre-dispatch calculation engine* shall use the *single cycle mode* flag of the second *dispatch day* for the entire pre-dispatch look-ahead period.

15.5.1.2 If there are no minimum *reliability* or commitment constraints on the *pseudo-unit* which cross into the next *dispatch day* and either there is a future minimum *reliability* or commitment constraint on the *pseudo unit* that ends before the end of the first *dispatch day* or if the *IESO's energy* management system indicates that the combustion turbine associated with the *pseudo-unit* is online, then the *pre-dispatch calculation engine* shall:

15.5.1.2.1 use the *single cycle mode* flag of the first *dispatch day* for the pre-dispatch look-ahead period in the first *dispatch day* and use the *single cycle mode* flag of the second *dispatch* day for the pre-dispatch look-ahead period in the second *dispatch* day; and

15.5.1.2.2 schedule the *pseudo-unit* to 0 MW in the first hour of the second *dispatch day*.

15.5.1.3 If there is a minimum *reliability* or commitment constraint on the *pseudo-unit* that crosses into the next *dispatch day*, then *the pre-dispatch calculation engine* shall:

15.5.1.3.1 use the *single cycle mode* flag of the first *dispatch day* for the pre-dispatch look-ahead period in the first *dispatch day* and the beginning hours of the second *dispatch day* to meet such constraint;

15.5.1.3.2 use the *single cycle mode* flag of the second *dispatch day* for pre-dispatch look-ahead period in the second *dispatch day* after such constraint for the *pseudo-unit* has completed; and

15.5.1.3.3 schedule the *pseudo-unit* to 0 MW in the first hour for which no *reliability* or commitment constraint applies in the second *dispatch day*.

15.6 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

15.6.1 For a combined cycle *facility* with K combustion turbines and one steam turbine, the *pre-dispatch calculation engine* shall compute the following *energy* and *operating reserve* schedules for time-step $t \in TS$:

15.6.1.1 $CTE_{t,k}$, which designates the *energy* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.2 $STPE_{t,k}$, which designates the *energy* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.3 STE_t , which designates the *energy* schedule for the steam turbine;

15.6.1.4 $CT10S_{t,k}$, which designates the synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.5 $STP10S_{t,k}$, which designates the synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.6 $ST10S_t$, which designates the synchronized *ten-minute operating reserve* schedule for the steam turbine;

15.6.1.7 $CT10N_{t,k}$, which designates the non-synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.8 $STP10N_{t,k}$, which designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.9 $ST10N_t$, which designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine;

15.6.1.10 $CT30R_{t,k}$, which designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.11 $STP30R_{t,k}$, which designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$; and

15.6.1.12 $ST30R_t$, which designates the *thirty-minute operating reserve* schedule for the steam turbine.

15.6.2 The *pre-dispatch calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo-unit* $k \in \{1,..,K\}$ in time-step $t \in TS$:

15.6.2.1 $SE_{t,k}$, which designates the total amount of *energy* scheduled and $SE_{t,k} = SEMLP_{t,k} + SEDR_{t,k} + SEDF_{t,k}$ where:

15.6.2.1.1 $SEMLP_{t,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \leq SEMLP_{t,k} \leq QMLP_{t,k}$;

15.6.2.1.2 $SEDR_{t,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \leq SEDR_{t,k} \leq QDR_{t,k}$ and $SEDR_{t,k} > 0$ only if $SEMLP_{t,k} = QMLP_{t,k}$;

15.6.2.1.3 $SEDF_{t,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \leq SEDF_{t,k} \leq QDF_{t,k}$ and $SEDF_{t,k} > 0$ only if $SEDR_{t,k} = QDR_{t,k}$;

15.6.2.2 $S10S_{t,k}$, which designates the total amount of synchronized *tenminute operating reserve* scheduled;

15.6.2.3 $S10N_{t,k}$, which designates the total amount of non-synchronized *tenminute operating reserve* scheduled. If the *pseudo-unit* cannot provide *operating reserve* from its duct firing region, then $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} \leq QMLP_{t,k} + QDR_{t,k}$; and

15.6.2.4 $S30R_{t,k}$, which designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} + S30R_{t,k} \leq QMLP_{t,k} + QDR_{t,k} + QDF_{t,k}$.

15.6.3 The *pre-dispatch calculation engine* shall convert *pseudo-unit* schedules to physical generation *resource* schedules for *energy* and *operating reserve*, as follows:

15.6.3.1 If $SE_{h,k} \geq MLP_{h,k}$, then:

$$CTE_{t,k} = SEMLP_{t,k} \cdot CTShareMLP_k + SEDR_{h,k} \cdot CTShareDR_k;$$

$$STPE_{t,k} = SEMLP_{t,k} \cdot STShareMLP_k + SEDR_{t,k} \cdot STShareDR_k + SEDF_{t,k};$$

$$RoomDR_{t,k} = QDR_{t,k} - SEDR_{t,k};$$

$$10SDR_{t,k} = min(RoomDR_{t,k}, S10S_{t,k});$$

$$10NDR_{t,k} = min(RoomDR_{t,k} - 10SDR_{t,k}, S10N_{t,k});$$

$$30RDR_{t,k} = min(RoomDR_{t,k} - 10SDR_{t,k} - 10NDR_{t,k}, S30R_{t,k});$$

$$CT10S_{t,k} = 10SDR_{t,k} \cdot CTShareDR_k;$$

$$STP10S_{t,k} = 10SDR_{t,k} \cdot STShareDR_k + (S10S_{t,k} - 10SDR_{t,k});$$

$$CT10N_{t,k} = 10NDR_{t,k} \cdot CTShareDR_k;$$

$$STP10N_{t,k} = 10NDR_{t,k} \cdot STShareDR_k + (S10N_{t,k} - 10NDR_{t,k});$$

$$CT30R_{t,k} = 30RDR_{t,k} \cdot CTShareDR_k; \text{ and}$$

$$STP30R_{t,k} = 30RDR_{t,k} \cdot STShareDR_k + (S30R_{t,k} - 30RDR_{t,k})$$

15.6.3.2 If $SE_{t,k} < MLP_{t,k}$ and is ramping to *minimum loading point*, then the conversion shall be determined by the *ramp up energy to minimum loading point*.

15.6.3.3 The steam turbines portion schedules from section 15.6.3.1 shall be summed to obtain the steam turbine schedule as follows:

$$STE_t = \sum_{k=1,..,K} STPE_{t,k};$$

$$ST10S_t = \sum_{k=1,..,K} STP10S_{t,k};$$

$$ST10N_t = \sum_{k=1,..,K} STP10N_{t,k}; \text{ and}$$

$$ST30R_t = \sum_{k=1,..,K} STP30R_{t,k}.$$

16 Pricing Formulas

16.1 Purpose

16.1.1 The *pre-dispatch calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

16.2 Sets, Indices and Parameters

16.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Pass 1 shall be used:

16.2.1.1 $SPEmT_{t,c,f}^1$, which designates the Pass 1 shadow price for the post contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step t;

16.2.1.2 $SPExtT_{t,z}^1$, which designates the Pass 1 shadow price for the import or export limit constraint $z \in Z_{Sch}$ in time-step *t*;

16.2.1.3 SPL^1_t, which designates the Pass 1 shadow price for the energy balance constraint in time-step *t*;

16.2.1.4 $SPNIUExtBwdT_t^1$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step $(t-1)$ and time-step *t*;

16.2.1.5 $SPNIDExtBwdT_t^1$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step $(t-1)$ and time-step *t*;

16.2.1.6 $SPNIUExtFwdT_t^1$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step t and time-step $(t+1)$;

16.2.1.7 $SPNIDExtFwdT_t^1$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step *t* and time-step $(t + 1)$;

16.2.1.8 $SPNormT_{t,f}^1$, which designates the Pass 1 shadow price for the precontingency transmission constraint for *facility* $f \in F$ in time-step *t*;

16.2.1.9 $SP10S_t^1$, which designates the Pass 1 shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.10 $SP10R_t^1$, which designates the Pass 1 shadow price for the total *ten-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.11 $SP30R_t^1$, which designates the Pass 1 shadow price for the total *thirty-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.12 $SPREGMin10R_{r,t}^1$, which designates the Pass 1 shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*;

16.2.1.13 $SPREGMin30R_{r,t}^1$, which designates the Pass 1 shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*;

16.2.1.14 $SPREGMax10R_{r,t}^1$, which designates the Pass 1 shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*; and

16.2.1.15 $SPREGMax30R_{r,t}^1$, which designates the Pass 1 shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*.

16.3 Locational Marginal Prices for Energy

16.3.1 Energy Locational Marginal Prices for Delivery Points

16.3.1.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each timestep $t \in TS$ for every bus $b \in L$ where a *non-dispatchable* or *dispatchable generation resource*, a *dispatchable load*, an *hourly demand response resource*, or a *non-dispatchable load* is sited and:

16.3.1.1.1 $LMP_{t,b}^1$ designates the Pass 1 time-step t *locational marginal price* for *energy*;

16.3.1.1.2 $PRef_t^1$ designates the Pass 1 time-step t *locational marginal price* for *energy* at the *reference bus*;

16.3.1.1.3 $PLoss_{t,b}^1$ designates the Pass 1 time-step t loss component; and

16.3.1.1.4 $PCongt_b^1$ designates the Pass 1 time-step t congestion component.

16.3.1.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 at bus $b \in L$ in time-step $t \in TS$, as follows:

$$InitLMP_{t,b}^{1} = InitPRef_{t}^{1} + InitPLoss_{t,b}^{1} + InitPCong_{t,b}^{1}$$

where:

$$InitPRef_{t}^{1} = SPL_{t}^{1};$$

$$InitPLoss_{t,b}^{1} = MglLoss_{t,b}^{1} \cdot SPL_{t}^{1};$$

and

$$InitPCong_{t,b}^{1} = \sum_{f \in F_t} PreConSF_{t,f,b} \cdot SPNormT_{t,f}^{1} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,b} \cdot SPEmT_{t,c,f}^{1}.$$

16.3.1.3 If the initial *locational marginal price* for *energy* at the *reference bus* ($InitPRef_{t}^{1}$) is not within the *settlement* bounds (*EngyPrcFlr, EngyPrcCeil*), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for *energy* at the *reference bus* as follows:

If $InitPRef_{t}^{1} > EngyPrcCeil$, set $PRef_{t}^{1} = EngyPrcCeil$

If $InitPRef_{t}^{1} < EngyPrcFlr$, set $PRef_{t}^{1} = EngyPrcFlr$

Otherwise, set $PRef_{t}^{1} = InitPRef_{t}^{1}$

16.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP^{1}_{t,b}$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP_{t,b}^{1} > EngyPrcCeil$, set $LMP_{t,b}^{1} = EngyPrcCeil$

If $InitLMP_{t,b}^{1} < EngyPrcFlr$, set $LMP_{t,b}^{1} = EngyPrcFlr$

Otherwise, set $LMP_{t,b}^{1} = InitLMP_{t,b}^{1}$

16.3.1.5 The *pre-dispatch calculation engine* shall modify the loss component as follows:

If $PRef_{t}^{1} \neq InitPRef_{t}^{1}$, set $PLoss_{t,b}^{1} = MglLoss_{t,b}^{1} \cdot PRef_{t}^{1}$

Otherwise, set $PLoss_{t,b}^{1} = InitPLoss_{t,b}^{1}$

16.3.1.6 The *pre-dispatch calculation engine* shall modify the congestion component as follows:

If $LMP_{t,b}^{1}$ - $PRef_{t}^{1}$ - $PLoss_{t,b}^{1}$ and $InitPCong_{t,b}^{1}$ have the same mathematical sign, then set $PCong_{t,b}^{1} = LMP_{t,b}^{1} - PRef_{t}^{1} - PLoss_{t,b}^{1}$

Otherwise, set $PCong_{t,b}^{1} = 0$ and set $PLoss_{t,b}^{1} = LMP_{t,b}^{1} - PRef_{t}^{1}$

16.3.2 Energy Locational Marginal Prices for Intertie Metering Points

16.3.2.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each timestep $t \in TS$ for *intertie zone* bus $d \in D$, where:

16.3.2.1.1 $ExtLMP_{t,d}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *energy*;

16.3.2.1.2 $IntLMP_{t,d}^{1}$ designates the Pass 1 time-step t *intertie border price* for *energy*;

16.3.2.1.3 $ICP_{t,d}^{1}$ designates the Pass 1 time-step t *intertie congestion price*;

16.3.2.1.4 $PRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *energy* at the *reference bus*;

16.3.2.1.5 $PLoss_{t,d}^{1}$ designates the Pass 1 time-step t loss component;

16.3.2.1.6 $PIntCong_{t,d}^{1}$ designates the Pass 1 time-step t internal congestion component for *energy*;

16.3.2.1.7 $PExtCong_{t,d}^{1}$ designates the Pass 1 time-step t external congestion component for the *intertie congestion price*; and

16.3.2.1.8 $PNISL^{1}_{t,d}$ designates the Pass 1 time-step t net interchange scheduling limit congestion component for the *intertie congestion price*.

16.3.2.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss components and a congestion components for *energy* for Pass 1 at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in time-step *t* , subject to sections 16.3.2.8 and 16.3.2.9, as follows:

$$InitExtLMP_{t,d}^{1} = InitIntLMP_{t,d}^{1} + InitICP_{t,d}^{1}$$

where:

$$InitPRef_{t}^{1} = SPL_{t}^{1};$$

$$InitPLoss_{t,d}^{1} = MglLoss_{t,d}^{1} \cdot SPL_{t}^{1};$$

$$InitPIntCong_{t,d}^{1} = \sum_{f \in F_t} PreConSF_{t,f,d} \cdot SPNormT_{t,f}^{1} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,d} \cdot SPEmT_{t,c,f}^{1};$$

$$InitIntLMP_{t,d}^{1} = InitPRef_{t}^{1} + InitPLoss_{t,d}^{1} + InitPIntCong_{t,d}^{1};$$

$$InitPExtCong_{t,d}^{1} = \sum_{z \in Z_{sch}} EnCoeff_{a,z} \cdot SPExtT_{t,z}^{1};$$

and

$$InitPNISL_{t,d}^{1} = SPNIUExtBwdT_{t}^{1} - SPNIUExtFwdT_{t}^{1} - SPNIDExtBwdT_{t}^{1} + SPNIDExtFwdT_{t}^{1};$$

$$InitICP_{t,d}^{1} = InitPExtCong_{t,d}^{1} + InitPNISL_{t,d}^{1}$$

16.3.2.3 If the initial *locational marginal price* for *energy* ($InitExtLMP_{t,d}^{1}$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *intertie border price* for *energy*, and its components, as follows:

16.3.2.3.1 The initial *locational marginal price* for the *reference bus* ($InitPRef_{t}^{1}$) shall be modified as per section 16.3.1.3;

16.3.2.3.2 The initial *intertie border price* ($InitIntLMP_{t,d}^{1}$) shall be modified as per section 16.3.1.4, where $InitLMP_{t,b}^{1}$ = $InitIntLMP_{t,d}^{1}$;

16.3.2.3.3 The initial loss component ($InitPLoss_{t,d}^{1}$) shall be modified as per section 16.3.1.5; and

16.3.2.3.4 The initial internal congestion component ($InitPIntCong_{t,d}^{1}$) shall be modified as per section 16.3.1.6, where $InitPCong_{t,b}^{1}$ = $InitPIntCong_{t,d}^{1}$.

16.3.2.4 If the initial *locational marginal price* for *energy* ($InitExtLMP_{t,d}^{1}$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $InitExtLMP_{t,d}^{1} > EngyPrcCeil$, set $ExtLMP_{t,d}^{1} = EngyPrcCeil$

If $InitExtLMP_{t,d}^{1} < EngyPrcFlr$, set $ExtLMP_{t,d}^{1} = EngyPrcFlr$

Otherwise, set $ExtLMP_{t,d}^{1} = InitExtLMP_{t,d}^{1}$

16.3.2.5 If the modified *locational marginal price* for *energy* ($ExtLMP_{t,d}^{1}$) is equal to the *intertie border price* for *energy* ($IntLMP_{t,d}^{1}$), then the *predispatch calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{t,d}^{1} = IntLMP_{t,d}^{1}$, set $PExtCong_{t,d}^{1} = 0$ and $PNISL^{1}_{t,d} = 0$

16.3.2.6 If the modified *locational marginal price* for *energy* ($ExtLMP^{1}_{t,d}$) is not equal to the *intertie border price* for *energy* ($IntLMP^{1}_{t,d}$), then the *pre-dispatch calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{t,d}^{1} \neq IntLMP_{t,d}^{1}$, set

$$PNISL_{t,d}^{1} = (ExtLMP_{t,d}^{1} - IntLMP_{t,d}^{1}) \cdot \left(\frac{InitPNISL_{h,d}^{1}}{InitPNISL_{t,d}^{1} + InitPExtCong_{t,d}^{1}}\right).$$

If $PNISL_{t,d}^{1} > NISLPen$, set $PNISL_{t,d}^{1} = NISLPen$

If $PNISL_{t,d}^{1} < (-1) \cdot NISLPen$, set $PNISL_{t,d}^{1} = (-1) \cdot NISLPen$

Then $PExtCong_{t,d}^{1} = ExtLMP_{t,d}^{1} - IntLMP_{t,d}^{1} - PNISL_{t,d}^{1}$

.

16.3.2.7 The *pre-dispatch calculation engine* shall calculate the *intertie congestion price* as follows:

$$ICP_{t,d1} = PExtCong_{t,d1} + PNISL1_{t,d}$$

16.3.2.8 The *locational marginal price* for *energy* calculated by the *predispatch calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. *Intertie* transactions associated with the same *boundary entity resource* bus, but specified as occurring at different *intertie zones*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these transactions shall utilize shadow prices associated with the internal transmission constraints, *intertie* limits and transmission losses applicable to the path associated to the relevant *intertie zone*.

16.3.2.9 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all import and export *boundary entity resources* for that *intertie zone* will receive a zero schedule and the *locational marginal price* for *energy* shall be set to the *intertie border price* for *energy*.

16.3.3 Zonal Prices for Energy

16.3.3.1 The *pre-dispatch calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each time-step t for each *virtual transaction zone* m∈ M, as follows:

$$VZonalP_{t,m}^{1} = PRef_{t}^{1} + VZonalPLoss_{t,m}^{1} + VZonalPCong_{t,m}^{1}$$ where

$$VZonalPLoss_{t,m}^{1} = \sum_{b \in L_{m}^{VIRT}} WF_{t,m,b}^{VIRT} \cdot PLoss_{t,b}^{1}$$

and

$$VZonalPCong_{t,m}^{1} = \sum_{b \in L_{m}^{VIRT}} WF_{t,m,b}^{VIRT} \cdot PCong_{t,b}^{1}$$

16.3.3.2 The *pre-dispatch calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each time-step t for each *non-dispatchable load* zone y ∈ Y, as follows:

$$ZonalP_{t,y}^{1} = PRef_{t}^{1} + ZonalPLoss_{t,y}^{1} + ZonalPCong_{t,y}^{1}$$

where:

$$ZonalPLoss_{t,y}^{1} = \sum_{b \in L_y^{NDL}} WF_{t,y,b}^{NDL} \cdot PLoss_{t,b}^{1}$$

and

$$ZonalPCong_{t,y}^{1} = \sum_{b \in L_y^{NDL}} WF_{t,y,b}^{NDL} \cdot PCong_{t,b}^{1}$$

16.3.3.3 The *Ontario zonal price* is calculated per section 16.3.3.2 where the *non-dispatchable load* zone is comprised of all *non-dispatchable loads* within Ontario.

16.3.4 Pseudo-Unit Pricing

16.3.4.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each timestep *t* for every *pseudo-unit* $k \in \{1,..,K\}$, where:

16.3.4.1.1 $CTMglLoss_{t,k}^{1}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit k* for time-step t in Pass 1;

16.3.4.1.2 $STMglLoss_{t,k}^{p}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit k* for time-step t in Pass 1;

16.3.4.1.3 $CTPreConSF_{t,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit k* on *facility f* during time-step t under pre-contingency conditions;

16.3.4.1.4 $STPreConSF_{t,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit k* on *facility f* during time-step t under pre-contingency conditions;

16.3.4.1.5 $CTSF_{t,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit k* on *facility f* during time-step t under post-contingency conditions for contingency *c*; and

16.3.4.1.6 $STSF_{t,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit k* on *facility f* during timestep t under post-contingency conditions for contingency *c*.

16.3.4.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 and each time-step *t* for every *pseudo-unit* $k \in \{1,..,K\}$, as follows:

$$InitLMP^{1}_{t,k} = InitPRef^{1}_{t} + InitPLoss^{1}_{t,k} + InitPCong^{1}_{t,k}$$

where:

$$InitPRef^{1}_{t} = SPL^{1}_{t};$$

$$InitPLoss^{1}_{t,k} = MglLoss^{1}_{t,k} \cdot SPL^{1}_{t};$$

and

$$InitPCong^{1}_{t,k} = \sum_{f \in F_t} PreConSF_{t,f,k} \cdot SPNormT^{1}_{t,f} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,k} \cdot SPEmT^{1}_{t,c,f}$$

16.3.4.3 If *pseudo-unit* k $\in \{1,..,K\}$ is scheduled within its *minimum loading point range* or not scheduled at all, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = CTShareMLP_k \cdot CTMglLoss^{1}_{t,k} + STShareMLP_k \cdot STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = CTShareMLP_k \cdot CTPreConSF_{t,f,k} + STShareMLP_k \cdot STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = CTShareMLP_k \cdot CTSF_{t,c,f,k} + STShareMLP_k \cdot STSF_{t,c,f,k}$$

16.3.4.4 If *pseudo-unit* k $\in \{1,..,K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = CTShareDR_k \cdot CTMglLoss^{1}_{t,k} + STShareDR_k \cdot STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = CTShareDR_k \cdot CTPreConSF_{t,f,k} + STShareDR_k \cdot STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = CTShareDR_k \cdot CTSF_{t,c,f,k} + STShareDR_k \cdot STSF_{t,c,f,k}$$

16.3.4.5 If *pseudo-unit* k $\in \{1,..,K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = STSF_{t,c,f,k}$$

16.4 Locational Marginal Prices for Operating Reserve

16.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

16.4.1.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for Pass 1 and each time-step *t* for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$, where:

16.4.1.1.1 $L30RP_{t,b}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve*;

16.4.1.1.2 $P30RRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

16.4.1.1.3 $P30RCong_{t,b}^{1}$ designates the Pass 1 time-step t congestion component for *thirty-minute operating reserve*;

16.4.1.1.4 $L10NP_{t,b}^{1}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve*;

16.4.1.1.5 $P10NRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.1.6 $P10NCong_{t,b}^{1}$ designates the Pass 1 time-step t congestion component for non-synchronized *ten-minute operating reserve*;

16.4.1.1.7 $L10SP_{t,b}^{1}$ designates the Pass 1 time-step t *locational marginal price* for synchronized *ten-minute operating reserve*;

16.4.1.1.8 $P10SRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal prices* for synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.1.9 $P10SCong_{t,b}^{1}$ designates the Pass 1 time-step t congestion component for synchronized *ten-minute operating reserve*; and

16.4.1.1.10 $ORREG_{b} \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus b.

16.4.1.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass 1 for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$ in time-step $t \in TS$, for each class of *operating reserve*, as follows:

$$InitL30RP_{t,b}^{1} = InitP30RRef_{t}^{1} + InitP30RCong_{t,b}^{1}$$

where

$$InitP30RRef_t^1 = SP30R_t^1$$

and

$$InitP30RCong_{t,b}^1 = \sum_{r \in ORREG_b} SPREGMin30R_{t,r}^1 - \sum_{r \in ORREG_b} SPREGMax30R_{t,r}^1$$

$$InitL10NP_{t,b}^1 = InitP10NRef_t^1 + InitP10NCong_{t,b}^1$$

where

$$InitP10NRef_t^1 = SP10R_t^1 + SP30R_t^1$$

and

$$InitP10NCong_{t,b}^1 = \sum_{r \in ORREG_b} \left(SPREGMin10R_{r,t}^1 + SPREGMin30R_{r,t}^1\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{r,t}^1 + SPREGMax30R_{r,t}^1\right)$$

$$InitL10SP_{t,b}^1 = InitP10SRef_t^1 + InitP10SCong_{t,b}^1$$

where

$$InitP10SRef_t^1 = SP10S_t^1 + SP10R_t^1 + SP30R_t^1$$

and

$$InitP10SCong_{t,b}^1 = \sum_{r \in ORREG_b} \left(SPREGMin10R_{r,t}^1 + SPREGMin30R_{r,t}^1\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{r,t}^1 + SPREGMax30R_{r,t}^1\right)$$

16.4.1.3 If the initial *locational marginal price* at the *reference bus* ($InitP30RRef_t^1$, $InitP10NRef_t^1$, or $InitP10SRef_t^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* at the *reference bus* for each class of *operating reserve* as follows:

If $InitP30RRef_t^1 > ORPrcCeil$, set $P30RRef_t^1 = ORPrcCeil$;

If $InitP30RRef_t^1 < ORPrcFlr$, set $P30RRef_t^1 = ORPrcFlr$;

Otherwise, set $P30RRef_t^1 = InitP30RRef_t^1$.

If $InitP10NRef_t^1 > ORPrcCeil$, set $P10NRef_t^1 = ORPrcCeil$

If $InitP10NRef_t^1 < ORPrcFlr$, set $P10NRef_t^1 = ORPrcFlr$

Otherwise, set $P10NRef_t^1 = InitP10NRef_t^1$

If $InitP10SRef_t^1, ORPrcFlr > ORPrcCeil$, set $10SRef_t^1 = ORPrcCeil$

If $InitP10SRef_t^1$, $ORPrcFlr < ORPrcFlr$, set $10SRef_t^1 = ORPrcFlr$

Otherwise, set $10SRef_t^1 = InitP10SRef_t^1$

16.4.1.4 If the *initial locational marginal price* ($InitL30RP_{t,b}^1$, $InitL10NP_{t,b}^1$, or $InitL10SP_{t,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{t,b}^1 > ORPrcCeil$, set $L30RP_{t,b}^1 = ORPrcCeil$;

If $InitL30RP_{t,b}^1 < ORPrcFlr$, set $L30RP_{t,b}^1 =$

$ORPrcFlr$; Otherwise, set $L30RP_{t,b}^1 = InitL30RP_{t,b}^1$.

If $InitL10NP_{t,b}^1 > ORPrcCeil$, set $L10NP_{t,b}^1 = ORPrcCeil$;

If $InitL10NP_{t,b}^1 < ORPrcFlr$, set $L10NP_{t,b}^1 =$

$ORPrcFlr$; Otherwise, set $L10NP_{t,b}^1 = InitL10NP_{t,b}^1$.

If $InitL10SP_{t,b}^1 > ORPrcCeil$, set $L10SP_{t,b}^1 = ORPrcCeil$;

If $InitL10SP_{t,b}^1 < ORPrcFlr$, set $L10SP_{t,b}^1 = ORPrcFlr$;

Otherwise, set $L10SP_{t,b}^1 = InitL10SP_{t,b}^1$.

16.4.1.5 If the initial *locational marginal price* ($InitL30RP_{t,b}^1$, $InitL10NP_{t,b}^1$, $InitL10SP_{t,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the congestion component for each class of *operating reserve* as follows:

Set $P30RCong_{t,b}^1 = L30RP_{t,b}^1 - P30RRef_t^1$;

Set $P10NCong_{t,b}^1 = L10NP_{t,b}^1 - P10NRef_t^1$; and

Set $P10SCong_{t,b}^1 = L10SP_{t,b}^1 - P10SRef_t^1$.

16.4.1.6 Operating Reserve Locational Marginal Prices for Intertie Metering Points

16.4.1.7 The *pre-dispatch calculation engine* shall calculate *a locational marginal price* and components for *operating reserve* for Pass 1 and each time-step $t \in TS$ for *intertie zone bus* $d \in D$, where:

16.4.1.7.1 $ExtL30RP_{t,d}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve*;

16.4.1.7.2 $P30RRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

16.4.1.7.3 $P30RIntCong_{t,d}^{1}$ designates the Pass 1 time-step t internal congestion component *for thirty-minute operating reserve*;

16.4.1.7.4 $P30RExtCong_{t,d}^{1}$ designates the Pass 1 time-step t *intertie* congestion component *thirty-minute operating reserve*;

16.4.1.7.5 $ExtL10NP_{t,d}^{1}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve*;

16.4.1.7.6 $P10NRef_{t}^{1}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.7.7 $P10NIntCong_{t,d}^{1}$ designates the Pass 1 time-step t internal congestion component for non-synchronized *ten-minute operating reserve*;

16.4.1.7.8 $P10NExtCong_{t,d}^{1}$ designates the Pass 1 time-step t external congestion component for non-synchronized *ten-minute operating reserve*; and

16.4.1.7.9 $ORREG_{d} \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus d.

16.4.1.8 The *pre-dispatch calculation engine* shall calculate initial *locational marginal price*, *locational marginal price* at the *reference bus*, internal congestion component and external congestion component for Pass 1 at *intertie zone bus* $d \in D_a$ in *intertie zone* $a \in A$ in time-step $t \in TS$, for each class of *operating reserve*, subject to sections 16.4.1.11 and 16.4.1.12, as follows:

$$InitExtL30RP_{t,d}^{1} = InitP30RRef_{t}^{1} + InitP30RIntCong_{t,d}^{1} + InitP30RExtCong_{t,d}^{1}$$

where:

$$InitP30RRef_{t}^{1} = SP30R_{t}^{1};$$

$$InitP30RIntCong_{t,d}^{1} = \sum_{r \in ORREG_d} SPREGMin30R_{t,r}^{1} - \sum_{r \in ORREG_d} SPREGMax30R_{t,r}^{1};$$

and

$$InitP30RExtCong_{t,d}^{1} = -\sum_{z \in Z_{Sch}} 0.5 \cdot \left(EnCoeff_{a,z} + 1\right) \cdot SPExtT_{t,z}^{1}.$$

$$InitExtL10NP_{t,d}^{1} = InitP10NRef_{t}^{1} + InitP10NIntCong_{t,d}^{1} + InitP10NExtCong_{t,d}^{1}$$

where:

$$InitP10NRef_{t}^{1} = SP10R_{t}^{1} + SP30R_{t}^{1};$$

$$InitP10NIntCong_{t,d}^{1} = \sum_{r \in ORREGd} SPREGMin10R_{r,t}^{1} + SPREGMin30R_{r,t}^{1} -$$

$$\sum_{r \in ORREGd} SPREGMax10R_{r,t1} +$$

$SPREGMax30R_{r,t1}$; and

$$InitP10NExtCong_{t,d}^{1} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT_{t,z}^{1}$$

16.4.1.9 If the initial *locational marginal price* ($InitExtL30RP_{t,b}^{1}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the external congestion component for *thirty-minute operating reserve* as follows:

$$IntL30R = InitP30RRef_{t}^{1} + InitP30RIntCong_{t,d}^{1};$$

If $InitP30RRef_{t}^{1} > ORPrcCeil$, set $P30RRef_{t}^{1} = ORPrcCeil$;

If $InitP30RRef_{t}^{1} < ORPrcFlr$, set $P30RRef_{t}^{1} = ORPrcFlr$;

Otherwise, set $P30RRef_{t}^{1} = InitP30RRef_{t}^{1}$;

Set $P30RIntCong_{t,d}^{1} = ExtL30RP_{t,b}^{1} - P30RRef_{t}^{1}$;

If $InitExtL30RP_{t,b}^{1} > ORPrcCeil$, set $ExtL30RP_{t,b}^{1} = ORPrcCeil$;

If $InitExtL30RP_{t,b}^1 < ORPrcFlr$, set $ExtL30RP_{t,b}^1 = ORPrcFlr$;

Otherwise, $ExtL30RP_{t,b}^1 = InitExtL30RP_{t,b}^1$; and

Set $P30RExtCong_{t,d}^1 = ExtL30RP_{t,b}^1 - P30RRef_t^1 - P30RIntCong_{t,d}^1$

16.4.1.10 If the initial *locational marginal price* ($InitExtL10NP_{t,b}^1$) is not within the *settlement* bounds ($ORPrcFlr, ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the initial *locational marginal price*, *locational marginal price* at the *reference bus*, and the external congestion component for *ten-minute operating reserve* as follows:

$$IntL10N = InitP10NRef_t^1 + InitP10NIntCong_{t,d}^1 ;$$

If $InitP10NRef_t^1 > ORPrcCeil$, set $P10NRef_t^1 = ORPrcCeil$;

If $InitP10NRef_t^1 < ORPrcFlr$, set $P10NRef_t^1 = ORPrcFlr$;

Otherwise, $P10NRef_t^1 = InitP10NRef_t^1$; and

Set $P10NIntCong_{t,d}^1 = L10NP_{t,b}^1 - P10NRef_t^1$;

If $InitExtL10NP_{t,b}^1 > \mathrm{ORPrcCeil}$, set $ExtL10NP_{t,b}^1 = \mathrm{ORPrcCeil}$;

If $InitExtL10NP_{t,b}^1 < \mathrm{ORPrcFlr}$, set $ExtL10NP_{t,b}^1 = \mathrm{ORPrcFlr}$;

Otherwise, $ExtL30RP_{t,b}^1 = InitExtL10NP_{t,b}^1$; and

Set $P10NExtCong_{t,d}^1 = ExtL10NP_{t,b}^1 - P10NRef_t^1 - P10NIntCong_{t,d}^1$

16.4.1.11 The *locational marginal price* calculated by the *pre-dispatch calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. Reserve imports associated with the same *boundary entity resource* bus, but specified as ocurring at a different *intertie zone*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these reserve imports shall utilize shadow prices associated with *intertie* limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

16.4.1.12 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all *boundary entity resources* for that *intertie zone* will receive a zero schedule for *energy* and *operating reserve* and the *intertie operating reserve* prices shall be set equal to the *locational marginal price* for the *reference bus* for that class of *operating reserve* plus the applicable shadow prices associated with regional minimum and maximum *operating reserve* requirements.

16.5 Pricing for Islanded Nodes

16.5.1 For *non-quick start resources* that are not connected to the *main island*, the *pre-dispatch calculation engine* may use the following reconnection logic where enabled by the *IESO* in the order set out below to calculate the *locational marginal prices* for *energy*:

16.5.1.1 Determine the connection paths over open switches that connect the *non-quick start resource* to the *main island*;

16.5.1.2 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; and

16.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

16.5.2 For all (i) *resources* other than those specified in section 16.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 16.5.1; the *pre-dispatch calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices* for *energy*, using a node-level and *facility*-level substitution list determined by the *IESO*:

16.5.2.1 Use the *locational marginal price* for *energy* at a node in the node level substitution list where defined and enabled by the *IESO*, provided such node is connected to the *main island*;

16.5.2.2 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes at the same voltage level within the same *facility* that are connected to the *main island*;

16.5.2.3 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes within the same *facility* that are connected to the *main island*;

16.5.2.4 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes from another *facility* that is connected to the *main island*, as determined by the *facility*-level substitution list where defined and enabled by the *IESO*; and

16.5.2.5 If a price is unable to be determined in accordance with sections 16.5.2.2 through 16.5.2.4, use the *locational marginal price* for *energy* for the *reference bus*.

Appendix B – IESO Proposed Chapter 7 Amendment - Appendix 7.1 (sections 11.4.1 and 14.4.1)

The amendments to sections 11.4.1 and 14.4.1 of the Market Rules are provided below.

11.4 Conduct Test for Energy

11.4.1 The *day-ahead market calculation engine* shall perform the Conduct Test for *energy* for *resources* in a *narrow constrained area* that were identified pursuant to section 10.8.1 as follows, subject to sections 11.4.2 and 11.4.3. For each hour h ∈ {1, . . , 24} and b ∈ $BCond_h^{NCA}$, the *day-ahead market calculation engine* shall:

11.4.1.1 Evaluate offers for *energy* above the *minimum loading point*: For all $k \in K_{h,b}^E$, if $PDG_{h,b,k} > CTEnMinOffer$ and $PDG_{h,b,k} > min(PDGRef_{h,b,k} + (abs(PDGRef_{h,b,k}) * CTEnThresh1^{NCA}), PDGRef_{h,b,k`} + CTEnThresh2^{NCA})$, where $k' \in K'_{h,b}{}^E$, then the Conduct Test was failed for the *resource* at bus *bb* and the day-ahead market *calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $EnergyOffer_k$ to $PARAME_{h,b}$;

14.4 Price Impact Test for Energy

14.4.1 The *day-ahead market calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *energy* in section 11.6.1.1, as follows:

14.4.1.1 For local market power for *energy*:

14.4.1.1.1 For each hour $h \in \{1, . . . , 24\}$ and $b \in BCT_h^{NCA}$, *if* $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} + (abs(LMP_{h,b}^{RLP}) * ITThresh1^{NCA}), LMP_{h,b}^{RLP} + ITThresh2^{NCA})$, the Price Impact Test was failed by the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{NCA} and add *EnergyLMP* to $LMPIT_{h,b}$;

Appendix C – Chapter 7 - Appendix 7.3 (The RT Calculation Engine)

Appendix Description:

This is from the Market Rule Amendment Proposal Form (Identification No. MR-00460-R00) draft as published as of July 8, 2022.

1 Appendix 7.3 – The Real-Time Calculation Engine Process

1.1 Purpose

1.1.1 This appendix describes the process used by the *real-time calculation engine* to determine schedules and prices for the *real-time market* and real-time look-ahead period.

2 Real-Time Calculation Engine

2.1 Real-Time Look-Ahead Period

2.1.1 The real-time look-ahead period is the time horizon of the multi-interval optimization that includes the *dispatch interval* and the subsequent ten five-minute intervals.

2.2 Real-Time Calculation Engine Pass

2.2.1 The *real-time calculation engine* shall execute one pass, Pass 1, the Real-Time Scheduling and Pricing Pass in accordance with section 7, to produce *real-time schedules* and *locational marginal prices*.

3 Information Used by the Real-Time Calculation Engine

3.1.1 The *real-time calculation engine* shall use the information in section 3A.1 of Chapter 7.

4 Sets, Indices and Parameters Used by the Real-Time Calculation Engine

4.1 Fundamental Sets and Indices

4.1.1 A designates the set of all *intertie zones*;

4.1.2 B designates the set of buses identifying all *dispatchable* and non-*dispatchable resources* within Ontario;

4.1.3 $B^{DG} \subseteq B$ designates the set of buses identifying *dispatchable generation resources*;

4.1.4 $B^{DL} \subseteq B$ designates the set of buses identifying *dispatchable loads*;

4.1.5 $B^{\mathrm{HDR}} \subseteq B$ designates the set of buses identifying *hourly demand response resources*;

4.1.6 $B^{HE} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources*;

4.1.7 $B^{NDG} \subseteq B$ designates the set of buses identifying *non-dispatchable generation resources*;

4.1.8 $B^{NoBid} \subseteq \mathrm{B}$ designates the set of buses identifying *dispatchable loads* with no *bid* for *energy*;

4.1.9 $B^{NoOffer} \subseteq \mathrm{B}$ designates the set of buses identifying *generation resources* with no *offer* for *energy*;

4.1.10 $B^{NO10DF} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* that cannot provide *ten-minute operating reserve* from the duct firing region;

4.1.11 $B^{NQS} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable non-quick start resources*;

4.1.12 $B^{PSU} \subseteq B^{NQS}$ designates the subset of buses identifying *pseudounits*;

4.1.13 $B_r^{REG} \subseteq \mathrm{B}$ designates the set of internal buses in *operating reserve* region $\mathrm{r} \in ORREG$;

4.1.14 $B_p^{ST} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* with a share of steam turbine $\mathrm{p} \in PST$;

4.1.15 $B^{VG} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable variable generation resources*;

4.1.16 C designates the set of contingencies that shall be considered in the *security* assessment function;

4.1.17 D designates the set of buses outside Ontario, corresponding to imports and exports at *intertie zones*;

4.1.18 $D_{\mathrm{r}}^{REG} \subseteq D$ designates the set of *intertie zone* buses identifying *boundary entity resources* in *operating reserve* region $\mathrm{r} \in ORREG$;

4.1.19 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone* $\mathrm{a} \in \mathrm{A}$;

4.1.20 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

4.1.21 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone* $\mathrm{a} \in \mathrm{A}$;

4.1.22 $DX \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids*;

4.1.23 $DX_{\mathrm{a}} \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone* $\mathrm{a} \in \mathrm{A}$;

4.1.24 F designates the set of *facilities* and groups of *facilities* for which transmission constraints may be identified;

4.1.25 $F_i \subseteq F$ designates the set of *facilities* whose pre-contingency limit was violated in interval *i* as determined by a preceding *security* assessment function iteration;

4.1.26 $F_{i,\mathrm{c}} \subseteq F$ designates the set of *facilities* whose post-contingency limit for contingency *c* is violated in interval *i* as determined by a preceding *security* assessment function iteration;

4.1.27 $I = \{1,..,n_I\}$ designates the set of all intervals, where nn_{II} designates the number of five-minute intervals considered within the real-time look-ahead period;

4.1.28 $J_{i,\mathrm{b}}{}^{\mathrm{E}}$ designates the set of *bid* laminations for *energy* at $b \in B^{DL}$ for interval $\mathrm{i} \in \mathrm{I}$;

4.1.29 $J_{I,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DL}$ for interval $i \in I$;

4.1.30 $J_{i,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B^{DL}$ for interval I;

4.1.31 $J_{I,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus B^{DL} for interval I;

4.1.32 $K_{i,b}^{DF}$ $K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the duct firing region of a *pseudo-unit* at bus B^{PSU} in interval I;

4.1.33 $K_{i,b}^{DR} \subseteq K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *dispatchable* region of a *pseudo-unit* at bus b B^{PSU} in interval I;

4.1.34 $K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* at B^{NDG} B^{DG} for interval i I;

4.1.35 $K_{i,b}^{MLP}$ $K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *minimum loading point* region of a *pseudo-unit* at bus B^{PSU} in interval $i \in I$;

4.1.36 $K_{i,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus B^{DG} for interval i I;

4.1.37 $K_{i,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus B^{DG} for interval $i \in I$;

4.1.38 $K_{i,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus B^{DG} for interval i I;

4.1.39 L designates the set of buses where the *locational marginal prices* represent prices for *delivery points* associated with non-*dispatchable* and *dispatchable generation resources*, *dispatchable loads*, *hourly demand response resources*, *price responsive loads* and *non-dispatchable loads;*

4.1.40 $L_m^{VIRT} \subseteq L$ designates the buses contributing to the *virtual zonal price* for *virtual transaction zone* $m \in M$;

4.1.41 $L_y^{NDL} \subseteq L$ designates the buses contributing to the zonal price for *non-dispatchable load* zone $y \in Y$;

4.1.42 M designates the set of *virtual transaction zones*;

4.1.43 PST designates the set of steam turbines *offered* as part of a *pseudo-unit*;

4.1.44 Y designates the *non-dispatchable load* zones in Ontario.

4.2 Market Participant Data Parameters

4.2.1 With respect to a *non-dispatchable generation resource* identified by bus $b \in B^{NDG}$:

4.2.1.1 $FNDG_{i,b}$ designates the fixed quantity of *energy* scheduled for interval $i \in I$;

4.2.1.2 $PNDG_{i,b,k}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^E$; and

4.2.1.3 $QNDG_{i,b,k}$ designates the maximum incremental quantity of *energy* that may be scheduled in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}E$.

4.2.2 With respect to a *dispatchable generation resource* identified by bus $b \in B^{DG}$:

4.2.2.1 $DRRDG_{i,b,w}$ for $w \in \{1,..,NumRRDG_{i,b}\}$ designates the ramp rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies in interval $i \in I$ while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$;

4.2.2.2 $NumRRDG_{i,b}$ designates the number of ramp rates provided for interval $i \in I$;

4.2.2.3 $ORRDG_b$ designates the maximum *operating reserve* ramp rate in MW per minute;

4.2.2.4 $PDG_{i,b,k}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^E$;

4.2.2.5 $P10SDG_{i,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10S}$;

4.2.2.6 $P10NDG_{i,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10N}$;

4.2.2.7 $P30RDG_{i,b,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{30R}$;

4.2.2.8 $QDG_{i,b,k}$ designates the maximum incremental quantity of *energy* above the *minimum loading point* that may be scheduled in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{E}$;

4.2.2.9 $Q10SDG_{i,b,k}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{10}{}_{i,b}{}^{S}$;

4.2.2.10 $Q10NDG_{i,b,k}$ designates the maximum incremental quantity of nonsynchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{10}{}_{i,b}{}^{N}$;

4.2.2.11 $Q30RDG_{i,b,k}$ designates the maximum incremental quantity of *thirty minute operating reserve* in interval $i \in I$ in association with *offer* lamination ${}_{i,b}{}^{R}$;

4.2.2.12 $RLP30R_{i,b}$ designates the *reserve loading point* for *thirty-minute operating reserve* in interval $i \in I$;

4.2.2.13 $RLP10S_{i,b}$ designates the *reserve loading point* for synchronized *ten minute operating reserve* in interval I;

4.2.2.14 $RmpRngMaxDG_{i,b,w}$ for w $\{1..,NumRRDG_{i,b}\}$ designates the w^th ramp rate break point for interval I;

4.2.2.15 $URRDG_{i,b,w}$ for w $\{1,..,NumRRDGi,b\}$ designates the ramp rate in MW per minute at which the *resource* can increase the amount of *energy* it supplies in interval I while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$, where $RmpRngMaxDG_{i,b,0}$ shall be equal to zero.

4.2.3 With respect to a *dispatchable non-quick start resource* identified by bus $b \in B^{NQS}$:

4.2.3.1 $MinQDG_{b}$ designates the *minimum loading point* indicating the minimum output at which the *resource* must be scheduled except for times when the *resource* is starting up or shutting down.

4.2.4 With respect to a *dispatchable* hydroelectric *generation resource* identified by bus $b \in B^{HE}$:

4.2.4.1 $(ForL_{i,b,w}, ForU_{i,b,w})$ for $w \in \{1,..,NFor_{i,b}\}$ designate the lower and upper limits of the *forbidden regions* in interval $i \in I$ and indicate that the *resource* cannot be scheduled between $ForL_{i,b,w}$ and $ForU_{i,b,w}$ for all $w \in \{1,..,NFor_{i,b}\}$.

4.2.5 With respect to a *pseudo-unit* identified by bus $b \in B^{PSU}$:

4.2.5.1 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region; and

4.2.5.2 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region.

4.2.6 With respect to a *generation resource* with no *offer* for *energy* identified by bus $b \in B^{NoOffer}$:

4.2.6.1 $FNOG_{i,b}$ designates the fixed quantity of *energy* scheduled for injection for interval $i \in I$ determined by the *IESO*'s *energy* management system.

4.2.7 With respect to a *dispatchable load* identified by bus $b \in B^{DL}$:

4.2.7.1 $DRRDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption in interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$;

4.2.7.2 $NumRRDL_{i,b}$ designates the number of ramp rates provided for interval $i \in I$;

4.2.7.3 $ORRDL_b$ designates the *operating reserve* ramp rate in MW per minute for reductions in load consumption;

4.2.7.4 $PDL_{i,b,j}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *bid* lamination $j \in J_{i,b}^{E}$;

4.2.7.5 $P10NDL_{i,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

4.2.7.6 $P10SDL_{i,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

4.2.7.7 $P30RDL_{i,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

4.2.7.8 $QDL_{i,b,j}$ designates the maximum incremental quantity of *energy* that may be scheduled in interval $i \in I$ in association with *bid* lamination $j \in J_{i,bE}$;

4.2.7.9 $QDLFIRM_{i,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in interval $i \in I$;

4.2.7.10 $Q10NDL_{i,b,j}$ designates the maximum incremental quantity of nonsynchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

4.2.7.11 $Q10SDL_{i,b,j}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

4.2.7.12 $Q30RDL_{i,b,j}$ designates the maximum incremental quantity of *thirty minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

4.2.7.13 $RmpRngMaxDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the w[th] ramp rate break point for interval $i \in I$;

4.2.7.14 $URRDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption in interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$, where $RmpRngMaxDL_{i,b,0}$ shall be equal to zero.

4.2.8 With respect to an *hourly demand response resource* identified by bus $b \in B^{HDR}$:

4.2.8.1 $FHDR_{i,b}$ designates the fixed schedule of *energy* consumption for interval $i \in I$ determined by the activation of the *hourly demand response resource*.

4.2.9 With respect to a *dispatchable load* with no *bid* for *energy* at bus $b \in B^{NoBid}$:

4.2.9.1 $FNBL_{i,b}$ designates the fixed quantity of *energy* scheduled for consumption for interval $i \in I$ determined by the *IESO*'s *energy* management system.

4.2.10 With respect to a *boundary entity resource* import at *intertie zone* bus $d \in DI$, where the *locational marginal price* represents the price for the *intertie metering point* and its fixed schedules are the most recent *interchange schedules*:

4.2.10.1 $FIGPrc_{i,d}$ designates the fixed quantity of *energy* scheduled to import for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.10.2 $FIGSch_{i,d}$ designates the fixed quantity of *energy* scheduled to import for interval $i \in I$ and used for determining schedules;

4.2.10.3 $F10NIGPrc_{i,d}$ designates the fixed quantity of non-synchronized *ten minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational market prices*;

4.2.10.4 $F10NIGSch_{i,d}$ designates the fixed quantity of non-synchronized *ten minute operating reserve* scheduled for in interval $i \in I$ and used for determining schedules;

4.2.10.5 $F30RIGPrc_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*; and

4.2.10.6 $F30RIGSch_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules.

4.2.11 With respect to a *boundary entity resource* export at *intertie zone* bus $d \in DX$, where the *locational marginal price* represents the price for the *intertie metering point* and its fixed schedules are the most recent *interchange schedules*:

4.2.11.1 $FXLPrc_{i,d}$ designates the fixed quantity of *energy* scheduled to export for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.11.2 $FXLSch_{i,d}$ designates the fixed quantity of *energy* scheduled to export for interval $i \in I$ and used for determining schedules;

4.2.11.3 $F10NXLPrc_{i,d}$ designates the fixed quantity of non-synchronized *ten minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.11.4 $F10NXLSch_{i,d}$ designates the fixed quantity of non-synchronized *ten minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules;

4.2.11.5 $F30RXLPrc_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*; and

4.2.11.6 $F30RXLSch_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules.

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

4.3.1.1 $FG_{i,b}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus $b \in B^{VG}$ for interval $i \in I$.

4.3.2 Variable Generation Tie-Breaking

4.3.2.1 $NumVG_i$ designates the number of *variable generation resources* in the daily *dispatch* order for interval $i \in I$; and

4.3.2.2 $TBM_{i,b} \in \{1,..,NumVG_i\}$ designates the tie-breaking modifier for the *variable generation resource* at bus $b \in B^{VG}$ for interval $i \in I$.

4.3.3 Operating Reserve Requirements

4.3.3.1 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.3.2 $REGMin10R_{i,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in interval $i \in I$;

4.3.3.3 $REGMin30R_{i,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region $r \in ORREG$ in interval $i \in I$;

4.3.3.4 $REGMax10R_{i,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in interval $i \in I$;

4.3.3.5 $REGMax30R_{i,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in interval $i \in I$;

4.3.3.6 $TOT10S_i$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.3.7 $TOT10R_i$ designates the total *ten-minute operating reserve* requirement; and

4.3.3.8 $TOT30R_i$ designates the *thirty-minute operating reserve* requirement.

4.3.4 Resource Minimums and Maximums

4.3.4.1 Where applicable the minimum or maximum output of a *dispatchable generation resource* and minimum or maximum consumption of a *dispatchable load* may be limited due to *reliability* constraints, applicable *contracted ancillary* *services*, day-ahead operational commitments, pre-dispatch operational commitments, *outages,* derates, *operating reserve* activation, and other constraints, such that:

4.3.4.1.1 $MaxDF_{i,b}$ designates the maximum output limit in interval i for the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.4.1.2 $MaxDG_{i,b}$ designates the most restrictive maximum output limit for the *dispatchable generation resource* in interval *i* at bus $b \in B^{DG}$;

4.3.4.1.3 $MaxDL_{i,b}$ designates the most restrictive maximum consumption limit for the *dispatchable load* in interval *i* at bus $b \in B^{DL}$;

4.3.4.1.4 $MaxDR_{i,b}$ designates the maximum output limit in interval *i* for the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.4.1.5 $MinDG_{i,b}$ designates the most restrictive minimum output limit for the *dispatchable generation resource* in interval *i* at bus $b \in B^{DG}$; and

4.3.4.1.6 $MinDL_{i,b}$ designates the most restrictive minimum consumption limit for the *dispatchable load* in interval *i* at bus $b \in B^{DL}$.

4.3.5 Control Action Adjustments for Pricing

4.3.5.1 $CAAdj_i$ designates the *demand* adjustment required to calculate *locational marginal prices* appropriately when voltage reduction or load shedding has been implemented.

4.3.6 Constraint Violation Penalties for interval $i \in I$:

4.3.6.1 $(PLdViolSch_{i,w}, QLdViolSch_{i,w})$ for $w \in \{1,..,N_{LdViol_i}\}$ designate the price quantity segments of the penalty curve for under *generation* used by the Real-Time Scheduling algorithm in section 8;

4.3.6.2 $(PLdViolPrc_{i,w}, QLdViolPrc_{i,w})$ for $w \in \{1,..,N_{LdViol_i}\}$ designate the price quantity segments of the penalty curve for under *generation* used by the Real-Time Pricing algorithm in section 9;

4.3.6.3 $(PGenViolSch_{i,w}, QGenViolSch_{i,w})$ for $w \in \{1,..,N_{GenViol_i}\}$ designate the price-quantity segments of the penalty curve for over *generation* used by the Real-Time Scheduling algorithm in section 8;

4.3.6.4 $(PGenViolPrc_{i,w}, QGenViolPrc_{i,w})$ for $w \in \{1,..,N_{GenViol i}\}$ designate the price-quantity segments of the penalty curve for over *generation* used by the Real-Time Pricing algorithm in section 9;

4.3.6.5 $(P10SViolSch_{i,w}, Q10SViolSch_{i,w})$ for $w \in \{1,..,N_{10SViol i}\}$ designate the price-quantity segments of the penalty curve for the synchronized *ten minute operating reserve* requirement used by the Real-Time Scheduling algorithm in section 8;

4.3.6.6 $(P10SViolPrc_{i,w}, Q10SViolPrc_{i,w})$ for $w \in \{1,..,N_{10SViol i}\}$ designate the price-quantity segments of the penalty curve for the synchronized *ten minute operating reserve* requirement used by the Real-Time Pricing algorithm in section 9;

4.3.6.7 $(P10RViolSch_{i,w}, Q10RViolSch_{i,w})$ for $w \in \{1,..,N_{10RViol i}\}$ designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Real-Time Scheduling algorithm in section 8;

4.3.6.8 $(P10RViolPrc_{i,w}, Q10RViolPrc_{i,w})$ for $w \in \{1,..,N_{10RViol i}\}$ designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Real-Time Pricing algorithm in section 9;

4.3.6.9 $(P30RViolSch_{i,w}, Q30RViolSch_{i,w})$ for $w \in \{1,..,N_{30RViol i}\}$ 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 by the Real-Time Scheduling algorithm in section 8;

4.3.6.10 $(P30RViolPrc_{i,w}, Q30RViolPrc_{i,w})$ for $w \in \{1,..,N_{30RViol i}\}$ 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 by the Real-Time Pricing algorithm in section 9;

4.3.6.11 $(PREG10RViolSch_{i,w}, QREG10RViolSch_{i,w})$ for $w \in \{1,..,N_{REG10RViol i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Real Time Scheduling algorithm in section 8;

4.3.6.12 $(PREG10RViolPrc_{i,w}, QREG10RViolPrc_{i,w})$ for $w \in \{1,..,N_{REG10RViol i}\}$ *designate* the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Real Time Pricing algorithm in section 9;

4.3.6.13 $(PREG30RViolSch_{i,w}, QREG30RViolSch_{i,w})$ for $w \in \{1,..,N_{REG30RViol i}\}$ designate the price-quantity segments of the penalty curve for area *thirty minute operating reserve* minimum requirements used by the Real-Time Scheduling algorithm in section 8;

4.3.6.14 $(PREG30RViolPrc_{i,w}, QREG30RViolPrc_{i,w})$ for $w \in \{1,..,N_{REG30RViol\,i}\}$ designate the price-quantity segments of the penalty curve for area *thirty minute operating reserve* minimum requirements used by the Real-Time Pricing algorithm in section 9;

4.3.6.15 $(PXREG10RViolSch_{i,w}, QXREG10RViolSch_{i,w})$ for $w \in \{1,..,N_{XREG10RViol\,i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Real Time Scheduling algorithm in section 8;

4.3.6.16 $(PXREG10RViolPrc_{i,w}, QXREG10RViolPrc_{i,w})$ for $w \in \{1,..,N_{XREG10RViol\,i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Real-Time Pricing algorithm in section 9;

4.3.6.17 $(PXREG30RViolSch_{i,w}, QXREG30RViolSch_{i,w})$ for $w \in \{1,..,N_{XREG30RViol\,i}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Real Time Scheduling algorithm in section 8;

4.3.6.18 $(PXREG30RViolPrc_{i,w}, QXREG30RViolPrc_{i,w})$ for $w \in \{1,..,N_{XREG30RViol\,i}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Real Time Pricing algorithm in section 9;

4.3.6.19 $(PPreITLViolSch_{f,i,w}, QPreITLViolSch_{f,i,w})$ for $w \in \{1,..,N_{PreITLViol\,f,i}\}$ 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 by the Real-Time Scheduling algorithm in section 8;

4.3.6.20 $(PPreITLViolPrc_{f,i,w}, QPreITLViolPrc_{f,i,w})$ for $w \in \{1,..,N_{PreITLViol\,f,i}\}$ 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 by the Real-Time Pricing algorithm in section 9;

4.3.6.21 $(PITLViolSch_{c,f,i,w}, QITLViolSch_{c,f,i,w})$ for $w \in \{1,..,N_{ITLViol\,c,f,i}\}$ 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 by the Real-Time Scheduling algorithm in section 8;

4.3.6.22 $(PITLViolPrc_{c,f,i,w}, QITLViolPrc_{c,f,i,w})$ for $w \in \{1,..,N_{ITLViolc,f,i}\}$ 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 by the Real-Time Pricing algorithm in section 9; and

4.3.6.23 $NISLPen$ designates the net interchange scheduling limit constraint violation penalty price for *locational marginal pricing*.

4.3.7 Price Bounds

4.3.7.1 $EngyPrcCeil$ designates and is equal to the *maximum market clearing price* for *energy*;

4.3.7.2 $EngyPrcFlr$ designates and is equal to the *settlement floor price* for *energy*;

4.3.7.3 $ORPrcCeil$ designates and is equal to the *maximum operating reserve price* for all classes of *operating reserve*; and

4.3.7.4 $ORPrcFlr$ designates the minimum price for all classes of *operating reserve* and is equal to $0/MW.

4.3.8 Weighting Factors for Zonal Prices

4.3.8.1 $WF_{i,m,b}^{VIRT}$ designates the weighting factor for bus $b \in L_m^{VIRT}$ used to calculate the price for *virtual transaction zone* $m \in M$ for interval $i \in I$ and shall be equal to the weighting factor used in the *day-ahead market* for the applicable hour;

4.3.8.2 $WF_{i,y,b}^{NDL}$ designates the weighting factor for bus $b \in L_y^{NDL}$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for interval $i \in I$ and shall be obtained by renormalizing the load distribution factors so that the sum of weighting factors for a *non-dispatchable load* zone and for a given interval is one.

4.4 Other Data Parameters

4.4.1 Non-Dispatchable Demand Forecast

4.4.1.1 FL_i designates the five-minute province-wide non-*dispatchable demand* forecast for interval $i \in I$ calculated by the *security* assessment function.

4.4.2 Internal Transmission Constraints

4.4.2.1 $PreConSF_{i,f,b}$ designates 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 interval i under pre-contingency conditions;

4.4.2.2 $AdjNormMaxFlow_{i,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in interval i under pre-contingency conditions;

4.4.2.3 $SF_{i,c,f,b}$ designates 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 interval i under post-contingency conditions for contingency cc; and

4.4.2.4 $AdjEmMaxFlow_{i,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in interval i under post-contingency conditions for contingency c.

4.4.3 Transmission Losses

4.4.3.1 $LossAdj_i$ designates any adjustment needed for interval $i \in I$ 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; and

4.4.3.2 $MglLoss_{i,b}$ designates the marginal loss factor and represents 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 interval $i \in I$.

5 Initialization

5.1 Purpose

5.1.1 The initialization processes set out in this section shall occur prior to the execution of the *real-time calculation engine* described in section 2.2.1 above.

5.2 Reference Bus

5.2.1 The *IESO* shall use Richview Transformer Station as the *real-time calculation engine's* default *reference bus* for the calculation of *locational marginal prices*.

5.2.2 If the default *reference bus* is out of service, another in-service bus shall be selected.

5.3 Islanding Conditions

5.3.1 In the event of a network split, the *real-time calculation engine* shall:

5.3.1.1 only evaluate *resources* that are within the *main island*;

5.3.1.2 use only forecasts of *demand* forecast areas in the *main island*; and

5.3.1.3 use a bus within the *main island* in place of the *reference bus* if the *reference bus* does not fall within the *main island*.

5.4 Variable Generation Tie-Breaking

5.4.1 For each interval $i \in \mathrm{I}$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K^{E}_{i,b}$, the *offer* price $PDG_{i,\mathrm{b,k}}$ shall be updated to $PDG_{i,\mathrm{b,k}} - (TBM_{i,\mathrm{b}}/NumVG_i)$ ρ, where ρ is a small nominal value of order 10^{-4}

5.5 Pseudo-Unit Constraints

5.5.1 Constraints for *pseudo-units* corresponding to the minimum and maximum constraints on physical *resources* shall be determined in accordance with section 10.

5.6 Initial Scheduling Assumptions

5.6.1 Initial Schedules

5.6.1.1 Initial *energy* schedules shall be based on the values deteremined by the *IESO's energy* management system and the schedules from the previous *real-time calculation engine* run, where:

5.6.1.1.1 $RTDLTel_{-1,\mathrm{b}}$ designates the *energy* management system MW value for the *dispatchable load* at bus $b \in B^{DL}$;

5.6.1.1.2 $SDLSch_{0,\mathrm{b}}^{\mathrm{Prev}}$ designates the schedule determined for the *dispatchable load* at bus $b \in B^{DL}$ by the Real-Time Scheduling algorithm in section 8, of the previous *real-time calculation engine* run;

5.6.1.1.3 $RTDGTel_{-1,\mathrm{b}}$ designates the *energy* management system MW value for the *dispatchable generation resource* at bus $b \in B^{DG}$;

5.6.1.1.4 $SDGSch^{Prev}_{0,\mathrm{b}}$ designates the schedule determined for the *dispatchable generation resource* at bus $b \in B^{DG}$ by the Real-Time Scheduling algorithm in section 8, of the previous *real-time calculation engine* run;

5.6.1.1.5 $SDLPrc^{Prev}_{0,\mathrm{b}}$ designates the schedule determined for the *dispatchable load* at bus $b \in B^{DL}$ by the Real-Time Pricing algorithm in section 9, of the previous *real-time calculation engine* run; and

5.6.1.1.6 $SDGPrc^{Prev}_{0,\mathrm{b}}$ designates the schedule determined for the *dispatchable generation resource* at bus $b \in B^{DG}$ by the Real-Time Pricing algorithm in section 9, of the previous *real-time calculation engine* run.

5.6.1.2 For the *dispatchable load* at bus b, the intitial schedule, $SDLInitSch_{0,b}$, for the Real-Time Scheduling algorithm in section 8, shall be determined as follows:

5.6.1.2.1 Step 1: Calculate $TelUp_{0,b}$ using the submitted up ramp rates and break points to determine the maximum consumption level the *dispatchable load* can achieve in five minutes from $RTDLTel_{-1,b}$;

5.6.1.2.2 Step 2: Calculate $TelDown_{0,b}$ using the submitted down ramp rates and break points to determine the minimum consumption level the *dispatchable load* can achieve in five minutes from $RTDLTel_{-1,b}$; and

5.6.1.2.3 Step 3: If the schedule from the previous *real-time calculation engine* run is achievable by ramping from the $RTDLTel_{-1,b}$, then set the initial schedule to the schedule from the previous *real-time calculation engine* run. Otherwise, set the initial schedule to the nearest boundary:

If $TelDown_{0,b} \leq SDLSch^{Prev}_{0,b} \leq TelUp_{0,b}$, then set

$SDLInitSch_{0,b} = SDLSch_{0,b}^{Prev}$

If $SDLSch_{0,b}^{Prev} < TelDown_{0,b}$, then set $SDLInitSch_{0,b} = TelDown_{0,b}$

Otherwise, set $SDLInitSch_{0,b} = TelUp_{0,b}$.

5.6.1.3 For the *dispatchable generation resource* at bus b, the initial schedule, $SDGInitSch_{0,b}$, for the Real-Time Scheduling algorithm in section 8, shall be determined as follows:

5.6.1.3.1 Step 1: Calculate $TelUp_{0,b}$ using the submitted up ramp rates and break points to determine the maximum production level the *resource* can achieve in five minutes from $RTDGTel_{-1,b}$;

5.6.1.3.2 Step 2: Calculate $TelDownn_{0,b}$ using the submitted down ramp rates and break points to determine the minimum production level the *resource* can achieve in five minutes from $RTDGTel_{-1,b}$; and

5.6.1.3.3 Step 3: If the schedule from the previous *real-time calculation engine* run is achievable by ramping from the $RTDGTel_{-1,b}$, then set the initial schedule to the schedule from the previous *real-time calculation engine* run. Otherwise, set the initial schedule to the nearest boundary:

If $TelDown_{0,b} \leq SDGSch_{0,b}^{Prev} \leq TelUp_{0,b}$ then set

$SDGInitSch_{0,b} = SDGSch^{Prev}_{0,b}$

If $SDGSch_{0,b}^{Prev} < TelDown_{0,b}$ then set $SDGInitSch_{0,b} = TelDown_{0,b}$

Otherwise, set $SDGInitSch_{0,b} = TelUp_{0,b}$.

5.6.1.4 For the *dispatchable load* at bus b, the intitial schedule, $SDLInitPrc_{0,b}$, for the Real-Time Pricing algorithm in section 9, shall be determined as follows:

If $SDLSch^{Prev}_{0,b} \leq SDLPrc^{Prev}_{0,b} \leq SDLInitSch_{0,b}$ or $SDLInitSch_{0,b} \leq SDLPrc^{Prev}_{0,b} \leq SDLSch^{Prev}_{0,b}$, then set $SDLInitPrc_{0,b} = SDLInitSch_{0,b}$;

Otherwise set $SDLInitPrc_{0,b} = SDLPrc^{Prev}_{0,b}$.

5.6.1.5 For the *dispatchable generation* at bus *b*, the intitial schedule $SDGInitPrc_{0,b}$, for the Real-Time Pricing algorithm in section 9, designates the initial schedule for the *dispatchable generation resource* at bus *b* and is determined as follows:

If $SDGSch^{Prev}_{0,b} \leq SDGPrc^{Prev}_{0,b} \leq SDGInitSch_{0,b}$ or $SDGInitSch_{0,b} \leq SDGPrc^{Prev}_{0,b} \leq SDGSch^{Prev}_{0,b}$ then set $SDGInitPrc_{0,b} = SDGInitSch_{0,b}$;

Otherwise set $SDGInitPrc_{0,b} = SDGPrc^{Prev}_{0,b}$.

5.6.2 Start-up and Shutdown for Non-Quick Start Resources

5.6.2.1 The start-up and shutdown for *non-quick start resources* at bus $b \in B^{NQS}$ and interval $i \in I$ shall be based on the following parameters that are determined based on observed *resource* operation as well as confirmed start-up and shutdown times:

5.6.2.1.1 $AtZero_{i,b} \in \{0,1\}$, which designates that the *resource* is scheduled to be offline;

5.6.2.1.2 $SU_{i,b}$, which designates that the *resource* must be scheduled on its start-up trajectory. This input may indicate an upcoming confirmed start-up or that the *resource* has started ramping up already;

5.6.2.1.3 $AtMLP_{i,b} \in \{0,1\}$, which designates that the *resource* is scheduled to operate at or above its *minimum loading point* due to a minimum generation constraint or the *resource* shutdown has yet to be confirmed by the *IESO*;

5.6.2.1.4 $EvalSD_{i,b} \in \{0,1\}$, which designates that the *resource* has been decommitted by the *pre-dispatch calculation engine*, such decommitment has been confirmed by the *IESO,* and the *resource* can be evaluated for *energy* schedules below its *minimum loading point* but can still be scheduled at or above its *minimum loading point*; and

5.6.2.1.5 $SD_{i,b} \in \{0,1\}$, which designates that the *resource* must be scheduled on its shutdown trajectory. This input may indicate an upcoming mandatory shutdown or that the *resource* has already started ramping down.

5.6.2.2 For all parameters in section 5.6.2.1:

$$AtZero_{i,b} + SU_{i,b} + AtMLP_{i,b} + EvalSD_{i,b} + SD_{i,b} = 1.$$

6 Security Assessment Function in the Real-Time Calculation Engine

6.1 Interaction between the Security Assessment Function and Optimization Functions

6.1.1 The scheduling and pricing algorithms of the *real-time calculation engine* pass shall perform multiple iterations of the optimization functions and the *security* assessment function to check for violations of monitored thermal limits and operating *security limits* using the schedules produced by the optimization functions.

6.1.2 As multiple iterations are performed, the transmission constraints produced by the *security* assessment function shall be used by the optimization functions.

6.1.3 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudo-units*.

6.2 Inputs into the Security Assessment Function

6.2.1 The *security* assessment function shall use the following inputs:

6.2.1.1 the *IESO demand* forecasts; and

6.2.1.2 applicable *IESO-controlled grid* information pursuant to section 3A.1 of Chapter 7.

6.2.2 The *security* assessment function shall also use the following outputs of the optimization functions:

6.2.2.1 the schedules for *dispatchable loads* and *hourly demand response resources*;

6.2.2.2 the schedules for *non-dispatchable generation resources* and *dispatchable generation resources*; and

6.2.2.3 the schedules for *boundary entity resources* at each *intertie* zone.

6.3 Security Assessment Function Processing

6.3.1 The *security* assessment function shall determine the province-wide non *dispatchable demand* forecast quantity, $FFLL_{ii}$, using *demand* forecasts for *demand* forecast areas, the *IESO's energy* management system MW quantities and the scheduled quantities from the previous *real-time calculation engine* run as follows:

6.3.1.1 sum the *IESO* five-minute *demand* forecasts for *demand* forecast areas;

6.3.1.2 subtract the expected consumption of all physical *hourly demand response resources*;

6.3.1.3 subtract the expected consumption of all virtual *hourly demand response resources*; and

6.3.1.4 subtract the expected consumption of all *dispatchable loads*.

6.3.2 The *security* assessment function shall perform the following calculations and analyses:

6.3.2.1 A base case solution function shall prepare a power flow solution for each interval in the real-time look-ahead period. The base case solution function shall select the power system model state applicable to the forecast of conditions for the interval and input schedules.

6.3.2.2 The base case solution function shall use an AC power flow analysis. If the AC power flow analysis fails to converge, the base case solution function shall use a non-linear DC power flow analysis. If the non-linear DC power flow analysis fails to converge, the base case solution function shall use a linear DC power flow analysis.

6.3.2.3 If the AC or non-linear DC power flow analysis converges, continuous thermal limits for all monitored equipment and operating *security limits* shall be monitored to check for pre-contingency limit violations.

6.3.2.4 Violated pre-contingency limits shall be linearized using pre-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.5 If the linear DC power flow analysis is used, the pre-contingency *security* assessment may develop linear constraints to facilitate the convergence of the AC or non-linear DC power flow analysis in the subsequent iterations.

6.3.2.6 A linear power flow analysis shall be used to simulate contingencies, calculate post-contingency flows and check all monitored equipment for limited-time thermal limit violations.

6.3.2.7 Violated post-contingency limits shall be linearized using post-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.8 The base case solution shall be used to calculate Ontario *transmission system* losses, marginal loss factors and loss adjustment for each interval. The impact of losses on branches between the *resource* bus and the *resource connection point* to the *IESO-controlled grid* and losses on branches outside Ontario shall be excluded when determining marginal loss factors.

6.3.2.9 The *real-time calculation engine* shall use a set of fixed marginal loss factors for each *dispatch hour*. The same set of fixed marginal loss factors shall apply to all five-minute intervals that fall in the *dispatch hour.* The set of fixed marginal loss factors for each *dispatch hour* shall be determined based on the marginal loss factors calculated in the previous hour by the Real-Time Scheduling algorithm in section 8 of the *real-time calculation engine*.

6.3.2.10 The marginal loss factors for the advisory intervals that fall in the hour following the *dispatch hour* shall be determined based on the fixed marginal loss factors for the *dispatch hour* described in section 6.3.2.9 and the marginal loss factors calculated by the Real-Time Scheduling algorithm in section 8 of the previous *real-time calculation engine* run*.*

6.3.2.11 The Real-Time Scheduling and Real-Time Pricing algorithms in sections 8 and 9, respectively, shall use the same set of marginal loss factors.

6.4 Outputs from the Security Assessment Function

6.4.1 The outputs of the *security* assessment function used in the optimization functions include the following:

6.4.1.1 a set of linearized constraints for all violated pre-contingency and post-contingency limits for each interval. The sensitivities and limits associated with the constraints shall be those provided by the most recent *security* assessment function iteration;

6.4.1.2 pre-contingency and post-contingency sensitivity factors for each interval;

6.4.1.3 the marginal loss factors as described in sections 6.3.2.8 – 6.3.2.11; and

6.4.1.4 loss adjustment quantity for each interval.

7 Pass 1: Real-Time Scheduling and Pricing

7.1.1 Pass 1 shall use *market participant* and *IESO* inputs and *resource* and system constraints to determine a set of *resource* schedules and *locational marginal prices*. Pass 1 shall consist of the following algorithms:

- the Real-Time Scheduling algorithm described in section 8;
- the Real-Time Pricing algorithm described in section 9;

8 Real-Time Scheduling

8.1 Purpose

8.1.1 The Real-Time Scheduling algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants* or where applicable, the *reference level values* for *financial dispatch data parameters* mitigated in previous *pre-dispatch calculation engine* runs in accordance with Appendix 7.2A, section 14.7, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each interval of the real-time look-ahead period.

8.2 Information, Sets, Indices and Parameters

8.2.1 Information, sets, indices and parameters used by Real-Time Scheduling algorithm are described in sections 3 and 4.

8.3 Variables and Objective Function

8.3.1 The Real-Time Scheduling algorithm shall solve for the following variables:

8.3.1.1 $SDL_{i,b,j}$, which designates the amount of *energy* that a *dispatchable load* scheduled at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{E}$;

8.3.1.2 $S10SDL_{i,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{10S}$;

8.3.1.3 $S10NDL_{i,b,j}$, which designates the amount of non-synchronized *tenminute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{10N}$;

8.3.1.4 $S30RDL_{i,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{30R}$;

8.3.1.5 $SNDG_{i,b,k}$, which designates the amount of *energy* that a *non-dispatchable generation resource* scheduled at bus $b \in B^{NDG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{E}$;

8.3.1.6 $SDG_{i,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{E}$;

8.3.1.7 $S10SDG_{i,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b10S}$;

8.3.1.8 $S10NDG_{i,b,k}$, which designates the amount of non-synchronized *tenminute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b10N}$;

8.3.1.9 $S30RDG_{i,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{30R}$;

8.3.1.10 $SCT_{i,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$;

8.3.1.11 $SST_{i,p}$, which designates the schedule of steam turbine $p \in PST$ in interval $i \in I$;

8.3.1.12 TB_i, which designates any adjustment to the objective function to facilitate pro-rata tie-breaking in interval $i \in I$, as described in section 8.3.2.1; and

8.3.1.13 $ViolCost_i$, which designates the cost incurred in order to avoid having the schedules violate constraints for interval $i \in I$, as described in section 8.3.2.3.

8.3.2 The objective function for the Real-Time Scheduling algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{i=1..n_I} (ObjDL_i - ObjNDG_i - ObjDG_i - TB_i - ViolCost_i)$$

where:

$$ObjDL_i = \sum_{b \in B^{DL}} \left(\begin{array}{l} \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} \cdot PDL_{i,b,j} - \sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \cdot P10SDL_{i,b,j} - \\ \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \cdot P10NDL_{i,b,j} - \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \cdot P30RDL_{i,b,j} \end{array} \right);$$

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

and

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

8.3.2.1 The tie-breaking term (TB_i) shall sum a term for each *bid* or *offer* lamination. For each lamination, this term shall be the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost shall be 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. That is:

$$TB_i = TBDL_i + TBNDG_i + TBDG_i$$

where:

$$TBDL_i = \sum_{b \in B^{DL}} \left(\begin{array}{l} \sum_{j \in J_{i,b}^{E}} \left(\frac{(SDL_{i,b,j})^2 \cdot TBPen}{QDL_{i,b,j}} \right) + \sum_{j \in J_{i,b}^{10S}} \left(\frac{(S10SDL_{i,b,j})^2 \cdot TBPen}{Q10SDL_{i,b,j}} \right) + \\ \sum_{j \in J_{i,b}^{10N}} \left(\frac{(S10NDL_{i,b,j})^2 \cdot TBPen}{Q10NDL_{i,b,j}} \right) + \sum_{j \in J_{i,b}^{30R}} \left(\frac{(S30RDL_{i,b,j})^2 \cdot TBPen}{Q30RDL_{i,b,j}} \right) \end{array} \right);$$

$$TBNDG_i = \sum_{b \in B^{NDG}} \left(\sum_{k \in K^E_{i,b}} \left(\frac{\left(SNDG_{i,b,k}\right)^2 \cdot TBPen}{QNDG_{i,b,k}} \right) \right);$$

and

$$TBDG_i = \sum_{b \in B^{DG}} \left(\begin{array}{l} \sum_{k \in K^E_{i,b}} \left(\frac{\left(SDG_{i,b,k}\right)^2 \cdot TBPen}{QDG_{i,b,k}} \right) + \sum_{k \in K^{10S}_{i,b}} \left(\frac{\left(S10SDG_{i,b,k}\right)^2 \cdot TBPen}{Q10SDG_{i,b,k}} \right) + \\ \sum_{k \in K^{10N}_{i,b}} \left(\frac{\left(S10NDG_{i,b,k}\right)^2 \cdot TBPen}{Q10NDG_{i,b,k}} \right) + \sum_{k \in K^{30R}_{i,b}} \left(\frac{\left(S30RDG_{i,b,k}\right)^2 \cdot TBPen}{Q30RDG_{i,b,k}} \right) \end{array} \right).$$

8.3.2.2 $ViolCost_i$ shall be calculated for interval $i \in I$ using the following variables:

8.3.2.2.1 $SLdViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{LdVioli}\}$ of the penalty curve for the *energy* balance constraint allowing undergeneration;

8.3.2.2.2 $SGenViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{GenVioli}\}$ of the penalty curve for the *energy* balance constraint allowing overgeneration;

8.3.2.2.3 $S10SViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{10SVioli}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;

8.3.2.2.4 $S10RViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{10RVioli}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;

8.3.2.2.5 $S30RViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{30RVioli}\}$ of the penalty curve for the *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;

8.3.2.2.6 $SREG10RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{REG10RVioli}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.7 $SREG30RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{REG30RVioli}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{XREG10RVioli}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.9 $SXREG30RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{XREG30RVioli}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.10 $SPreITLViol_{f,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{PreITLViolf,i}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$; and

8.3.2.2.11 $SITLViol_{c,f,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,...,N_{ITLViolc,f,i}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$.

8.3.2.3 $ViolCost_i$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_i = & \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \cdot PLdViolSch_{i,w} \\
& - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \cdot PGenViolSch_{i,w} \\
& + \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \cdot P10SViolSch_{i,w} \\
& + \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \cdot P10RViolSch_{i,w} \\
& + \sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \cdot P30RViolSch_{i,w} \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \cdot PREG10RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \cdot PREG30RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \cdot PXREG10RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w} \cdot PXREG30RViolSch_{i,w} \right)
\end{aligned}
$$

$$
\begin{aligned}
& + \sum_{f \in F_i} \left(\sum_{w=1..N_{PreITLViol_{f,i}}} SPreITLViol_{f,i,w} \cdot PPreITLViolSch_{f,i,w} \right) \\
& \quad + \sum_{c \in C} \sum_{f \in F_{i,c}} \left(\sum_{w=1..N_{ITLViol_{c,f,i}}} SITLViol_{c,f,i,w} \cdot PITLViolSch_{c,f,i,w} \right).
\end{aligned}
$$

8.4 Constraints

8.4.1 The Real-Time Scheduling algorithm optimization function shall apply the constraints described in sections 8.5 – 8.7.

8.5 Dispatch Data Constraints Applying to Individual Intervals

8.5.1 Scheduling Variable Bounds

8.5.1.1 No schedule shall be negative, nor shall any schedule exceed the quantity *offered* for *energy* and *operating reserve* respectively. Therefore:

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

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

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

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

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

$$0 \leq SDG_{i,b,k} \leq QDG_{i,b,k} \quad \text{for all } b \in B^{DG}, k \in K^{E}_{i,b};$$

$$0 \leq S10SDG_{i,b,k} \leq Q10SDG_{i,b,k} \quad \text{for all } b \in B^{DG}, k \in K^{10S}_{i,b};$$

$$0 \leq S10NDG_{i,b,k} \leq Q10NDG_{i,b,k} \quad \text{for all } b \in B^{DG}, k \in K^{10N}_{i,b}; \text{ and}$$

$$0 \leq S30RDG_{i,b,k} \leq Q30RDG_{i,b,k} \quad \text{for all } b \in B^{DG}, k \in K^{30R}_{I,b}$$

for all intervals $i \in I$.

8.5.1.2 A *non-quick start resource* cannot provide *energy* when it is scheduled to be offline. Therefore, for all intervals $i \in I$, *non-quick start resource* buses $b \in B^{NQS}$, and *offer* laminations $k \in K^{E}{}_{i,b}$:

$$0 \leq SDG_{i,b,k} \leq (1\text{-}AtZero_{i,b}) \cdot QDG_{i,b,k}.$$

8.5.1.3 A *non-quick start resource* cannot provide *operating reserve* unless it is scheduled at or above its *minimum loading point*. Therefore, for all intervals $i \in \mathrm{I}$ and *non-quick start resource* buses $b \in B^{NQS}$:

$$0 \leq S10SDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q10SDG_{i,b,k} \quad \text{for all } k \in K^{10S}_{i,b};$$

$$0 \leq S10NDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q10NDG_{i,b,k} \quad \text{for all } k \in K^{10N}_{i,b}; \text{ and}$$

$$0 \leq S30RDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q30RDG_{i,b,k} \quad \text{for all } k \in K^{30R}_{i,b}.$$

8.5.2 Resource Initial Conditions

8.5.2.1 The initial schedule for a *dispatchable load* at bus $b \in B^{DL}$ shall be fixed to the *resource* initial schedules. For all *dispatchable load* buses $b \in B^{DL}$:

$$\sum_{j \in J^{E}_{0,b}} SDL_{0,b,j} = SDLInitSch_{0,b}$$

8.5.2.2 The initial schedule for a *dispatchable generation resource* at bus $b \in \mathrm{B}^{DG}$ shall be fixed to the *resource* initial schedules. For all *dispatchable generation resource* buses $b \in B^{DG}$:

$$\sum_{k \in K^{E}_{0,b}} SDG_{0,b,k} = SDGInitSch_{0,b}$$

8.5.3 Resource Minimums and Maximums for Energy

8.5.3.1 A constraint shall limit schedules for *dispatchable loads* within their minimum and maximum consumption for an interval. For all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$MinDL_{i,b} \leq \sum_{j \in J_{i,b}^{B}} SDL_{i,b,j} \leq MaxDL_{i,b}.$$

8.5.3.2 The non-*dispatchable* portion of a *dispatchable load* shall always be scheduled. For all intervals $i \in \mathrm{I}$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{B}} SDL_{i,b,j} \geq QDLFIRM_{i,b}.$$

8.5.3.3 The *non-dispatchable generation resources* shall be scheduled to the fixed quantity determined by their observed output. For all intervals $i \in \mathrm{I}$ and all buses $b \in B^{NDG}$:

$$\sum_{k \in K_{i,b}^{B}} SNDG_{i,b,k} = FNDG_{i,b}.$$

8.5.3.4 A constraint shall limit schedules for *dispatchable generation resources* within their minimum and maximum output for an interval. For a *dispatchable variable generation resource*, the maximum schedule shall be limited by its forecast. That is:

8.5.3.4.1 For all intervals $i \in \mathrm{I}$ and all buses $b \in B^{DG}$,

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

and

$$AdjMinDG_{i,b} = min\left(MinDG_{i,b}, AdjMaxDG_{i,b}\right).$$

8.5.3.4.2 For all intervals $i \in \mathrm{I}$ and all buses $b \in B^{DG}$:

$$AdjMinDG_{i,b} \leq \sum_{k \in K_{i,b}^{B}} SDG_{i,b,k} \leq AdjMaxDG_{i,b}.$$

8.5.3.5 A constraint shall limit the schedule for a *non-quick start resource* at or above its *minimum loading point* when such *resource* is committed or when the *resource* shutdown is yet to be confirmed by the *IESO*. For all *non-quick start resource* buses $b \in B^{NQS}$ and intervals $i \in I$:

$$\sum_{k \in K_{i,b}^{B}} SDG_{i,b,k} \geq AtMLP_{i,b} \cdot MinQDG_{b}.$$

8.5.4 Operating Reserve Requirements

8.5.4.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled from a *dispatchable load* shall not exceed:

8.5.4.1.1 the *dispatchable load's* ramp capability over 30 minutes;

8.5.4.1.2 the total scheduled consumption less the non-*dispatchable* portion; and

8.5.4.1.3 the remaining portion of its capacity that is *dispatchable* after considering minimum load consumption constraints.

8.5.4.2 These restrictions shall be enforced by the following constraints for all intervals $i \in \mathrm{I}$ and all buses $b \in \mathrm{B}^{\mathrm{DL}}$:

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

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

and

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

8.5.4.3 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide shall not exceed the amount by which the *dispatchable load* can decrease its consumption over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all intervals $\mathrm{i} \in \mathrm{I}$ and all buses $b \in B^{DL}$:

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

8.5.4.4 The total *operating reserve* scheduled from a *dispatchable generation resource* shall not exceed the *resource*'s ramp capability over 30 minutes, its remaining capacity, and its unscheduled capacity. These restrictions shall be enforced by the following constraints for all intervals $\mathrm{i} \in \mathrm{I}$ and all buses $b \in B^{DG}$:

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

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

and

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

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

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

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

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

8.5.4.7 The amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for *thirty-minute operating reserve*. This restriction shall be enforced by the following constraint for all intervals $i \in I$ and all buses $b \in B^{DG}$ with $RLP30R_{i,b} > 0$:

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

8.5.5 Pseudo-Units

8.5.5.1 A constraint shall be required to calculate physical *generation resource* schedules from *pseudo-unit* schedules using the steam turbine

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

shares in the operating regions of the *pseudo-unit* determined in section 10. For all intervals $i \in I$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$SCTMod_{i,b} = (1 - STShareMLP_b) \cdot \left(\sum_{k \in K_{i,b}^{MLP}} SDG_{i,b,k} \right) + (1 - STShareDR_b) \cdot \left(\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} \right),$$

8.5.5.1.1 and for all intervals $i \in I$ and steam turbines $p \in PST$:

8.5.5.2 Maximum constraints shall be enforced on the operating region to which they apply for both *energy* and *operating reserve* schedules. For all intervals $i \in I$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} \leq MaxDR_{i,b},$$

$$\sum_{k \in K_{i,b}^{DF}} SDG_{i,b,k} \leq MaxDF_{i,b},$$

and

$$\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} + \sum_{k \in K_{i,b}^{DF}} SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}.$$

8.5.5.3 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, constraints shall limit the *pseudo-unit* from being scheduled to provide *ten-minute operating reserve* whenever the *pseudo unit* is scheduled for *energy* in its duct firing region.

8.5.5.4 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the combustion turbine schedule for the *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$, $SCT_{i,b}$ shall be equal to:

8.5.5.4.1 $SCTMod_{i,b}$ if the *pseudo-unit* is scheduled at or above *minimum loading point*;

8.5.5.4.2 the portion of $UpTraj_{i,b}$ or $DnTraj_{i,b}$ defined in the section 8.6.2 that was allocated to the combustion turbine in accordance with section 10.6 if the *resource* is ramping to or ramping from its *minimum loading point*; or

8.5.5.4.3 0 otherwise.

8.5.5.5 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the steam turbine schedule for $p \in PST$, $SST_{i,p}$ shall be equal to $SSTMod_{i,p}$ where $SST_{i,p}$ will be corrected to account for the contribution from *pseudo-units* $b \in B_p^{ST}$ ramping to or ramping from *minimum loading point* as determined by the allocation of $UpTraj_{i,b}$ or $DnTraj_{i,b}$ in accordance with section 10.6.

8.5.6 Dispatchable Hydroelectric Generation Resources

8.5.6.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled within its *forbidden region* if the *resource* is being ramped through the *forbidden region* at its maximum *offered* ramp capability.

8.6 Dispatch Data Inter-Interval/Multi-Interval Constraints

8.6.1 Energy Ramping

8.6.1.1 For *disptachable loads*, the ramping constraint in section 8.6.1.4 uses $URRDL_b$ to represent a ramp up rate selected from $URRDL_{i,\mathrm{b,w}}$ and uses $DRRDL_b$ to represent a ramp down rate selected from $DRRDL_{i,\mathrm{b,w}}$.

8.6.1.2 For *disptachable generation resources*, the ramping constraint in section 8.6.1.5 uses $URRDG_b$ to represent a ramp up rate selected from $URRDG_{i,\mathrm{b,w}}$ and uses $DRRDG_b$ to represent a ramp down rate selected from $DRRDG_{i,\mathrm{b,w}}$.

8.6.1.3 The *real-time calculation engine* shall respect the ramping restrictions determined by the up to five *offered* MW quantity, ramp up rate and ramp down rate value sets.

8.6.1.4 In the case of *dispatchable loads*, *energy* schedules cannot vary by more than an interval's ramping capability for that *resource*. This constraint shall be enforced by the following for all intervals $\mathrm{i} \in \mathrm{I}$ and buses $\mathrm{b} \in \mathrm{B}_{\mathrm{DL}}$:

$$\sum_{j \in J^E_{i-1,b}} SDL_{i-1,b,j} - 5 \cdot DRRDL_b \leq \sum_{j \in J^E_{i,b}} SDL_{i,b,j} \leq \sum_{j \in J^E_{i-1,b}} SDL_{i-1,b,j} + 5 \cdot URRDL_b.$$

8.6.1.5 *Energy* schedules for a *dispatchable generation resource* cannot vary by more than an interval's ramping capability for that *resource*. This constraint shall be enforced by the following for all intervals $\mathrm{i} \in \mathrm{I}$ and buses $\mathrm{b} \in \mathrm{B}^{\mathrm{DG}}$:

$$\sum_{k \in K^E_{i-1,b}} SDG_{i-1,b,k} - 5 \cdot DRRDG_b \leq \sum_{k \in K^E_{i,b}} SDG_{i,b,k} \leq \sum_{k \in K^E_{i-1,b}} SDG_{i-1,b,k} + 5 \cdot URRDG_b.$$

8.6.2 Non-Quick Start Resource Start-up and Shutdown

8.6.2.1 For all intervals in the real-time look-ahead period in which a *non-quick start resource* is scheduled to start-up, such *resource* shall be scheduled on a fixed ramp-up trajectory as determined by its *offered* ramp rates. The ramp-up trajectory ($UpTraj_{i,\mathrm{b}}$) for interval $\mathrm{i} \in \mathrm{I}$ such that $SU_{i,\mathrm{b}}=1$ is determined as follows:

8.6.2.1.1 If $\mathrm{i} = 1$, then $UpTraj_{i,\mathrm{b}}$ shall be determined from the *resource* initial schedule and the *offered* ramp up capability;

8.6.2.1.2 If $i>1$ and $SU_{i-1,b} = 0$, then $UpTraj_{i,b}$ shall be determined from the *offered* ramp up capability from 0; and 8.6.2.1.3 For all intervals $i \in I$ such that $SU_{i,b}=1$:

$$\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} = UpTraj_{i,b}.$$

8.6.2.2 For all intervals in the real-time look-ahead period in which a *non-quick start resource* is scheduled to shutdown, such *resource* shall be scheduled on a fixed ramp-down trajectory as determined by its *offered* ramp rates. The ramp-down trajectory ($DnTraj_{i,b}$) for interval $i \in I$ such that $SD_{i,b} = 1$ is determined as follows:

8.6.2.2.1 If $i = 1$, then $DnTraj_{i,b}$ shall be determined from the *resource* initial schedule and the *offered* ramp down capability;

8.6.2.2.2 If $i > 1$ and $SD_{i-1,b} = 0$, then $DnTraj_{i,b}$ shall be $MinQDG_b$; and

8.6.2.2.3 If $i > 1$ and $SD_{i-1,b} = 1$, then $DnTraj_{i,b}$ shall be determined from the *offered* ramp down capability from $DnTraj_{i-1,b}$.

8.6.2.2.4 For all intervals $i \in I$ such that $SD_{i,b} = 1$:

$$\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} = DnTraj_{i,b}.$$

8.6.3 Operating Reserve Ramping

8.6.3.1 Constraints shall be applied to recognize that interval to interval changes to a *dispatchable load*'s schedule for *energy* may modify the amount of *operating reserve* that the *resource* can provide. For all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \leq - \sum_{j \in J_{i-1,b}^{E}} SDL_{i-1,b,j} + \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} + 30 \cdot ORRDL_b$$

and

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \leq - \sum_{j \in J_{i-1,b}^{E}} SDL_{i-1,b,j} + \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} + 10 \cdot ORRDL_b.$$

8.6.3.2 Constraints shall be applied to recognize that interval to interval changes in a *dispatchable generation resource's* schedule for *energy* may modify the amount of *operating reserve* that the *resource* can provide. For all intervals $i \in I$ and all buses $b \in B^{DG}$:

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

and

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \leq \sum_{k \in K_{i-1,b}^{E}} SDG_{i-1,b,k} - \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} + 10 \cdot ORRDG_b.$$

8.7 Constraints for Reliability Requirements

8.7.1 Energy Balance

8.7.1.1 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in interval $i \in I$, $With_{i,b}$ shall be:

$$With_{i,b} = \begin{cases} \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} & if\ b \in B^{DL} \\ FHDR_{i,b} & if\ b \in B^{HDR} \\ FNBL_{i,b} & if\ b \in B^{NoBid} \end{cases}$$

8.7.1.2 The total amount of export *energy* scheduled at *intertie zone* bus $d \in DX$ in interval $i \in I$, $With_{i,d}$, as the fixed exports from Ontario to the *intertie zone* export bus shall be:

$$With_{i,d} = FXLSch_{i,d}.$$

8.7.1.3 The total amount of injections scheduled at internal bus $b \in B$, in interval $i \in I$, $Inj_{i,b}$ shall be:

$$Inj_{i,b} = \begin{cases} \sum_{k \in K_{i,b}^{E}} SNDG_{i,b,k} & if\ b \in B^{NDG} \\ \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} & if\ b \in B^{DG} \\ FNOG_{i,b} & if\ b \in B^{NoOffer} \end{cases}$$

8.7.1.4 The total amount of import *energy* scheduled at *intertie zone* bus $d \in DI$ in interval $i \in I$, $Inj_{i,d}$, as the imports into Ontario from that *intertie zone* bus shall be:

$$Inj_{i,d} = FIGSch_{i,d}.$$

8.7.1.5 Injections and withdrawals at each bus shall 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 shall be subtracted from the total load or generation for the *real-time calculation engine* to produce a solution.

For interval $i \in I$, the *energy* balance shall be:

$$\begin{aligned} FL_i + \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} (1 + MglLoss_{i,b}) \cdot With_{i,b} \\ + \sum_{d \in DX} (1 + MglLoss_{i,d}) \cdot With_{i,d} - \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \\ = \sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} \left(1 + MglLoss_{i,b}\right) \cdot Inj_{i,b} \\ + \sum_{d \in DI} \left(1 + MglLoss_{i,d}\right) \cdot Inj_{i,d} - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \\ + LossAdj_i. \end{aligned}$$

8.7.2 Operating Reserve Requirements

8.7.2.1 *Operating reserve* shall be scheduled to meet system-wide requirements for synchronized *ten-minute operating reserve*, total *ten-minute operating reserve*, and *thirty-minute operating reserve* while respecting all applicable regional minimum requirements and regional maximum restrictions for *operating reserve*.

8.7.2.2 Constraint violation penalty curves shall 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. Full *operating reserve* requirements shall be scheduled unless the cost of doing so would be higher than the applicable penalty cost. For each interval $i \in I$:

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \geq TOT10S_i;$$

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \right) + \sum_{d \in DX} F10NXLSch_{i,d} + \sum_{d \in DI} F10NIGSch_{i,d} + \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \geq TOT10R_i;$$

and

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \right) + \sum_{d \in DX} F10NXLSch_{i,d} + \sum_{d \in DI} F10NIGSch_{i,d} + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \right) + \sum_{d \in DX} F30RXLSch_{i,d} + \sum_{d \in DI} F30RIGSch_{i,d} + \sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \geq TOT30R_i.$$

8.7.2.3 The following constraints shall be applied for each interval $i \in I$ and each region $r \in ORREG$:

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)$$
$$+\sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d}$$
$$+\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \geq REGMin10R_{i,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)$$
$$+\sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d}$$
$$-\sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \leq REGMax10R_{i,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)$$
$$+\sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d}$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{30R}} S30RDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{30R}} S30RDG_{i,b,k}\right)$$
$$+\sum_{d\in D_r^{REG}\cap DX} F30RXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F30RIGSch_{i,d}$$
$$+\sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \geq REGMin30R_{i,r};$$

and

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)$$
$$+\sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d}$$
$$+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{30R}} S30RDL_{i,b,j}\right)$$
$$+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{30R}} S30RDG_{i,b,k}\right)+\sum_{d\in D_r^{REG}\cap DX} F30RXLSch_{i,d}$$
$$+\sum_{d\in D_r^{REG}\cap DI} F30RIGSch_{i,d}$$
$$-\sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w}$$
$$\leq REGMax30R_{i,r}.$$

8.7.3 IESO Internal Transmission Limits

8.7.3.1 A set of *energy* schedules shall be produced that do not violate any *security* limits in the pre-contingency state and the post-contingency state subject to the remainder of this section 8.7.3. The total amount of *energy* scheduled to be injected and withdrawn at each bus used by the *energy* balance constraint in section 8.7.1.5, shall be used to produce these schedules.

8.7.3.2 Pre-contigency, $SPreITLViol_{f,i,w}$, and post-contingency, $SITLViol_{c,f,i,w}$, transmission limit violation variables shall allow the *real-time calculation engine* to find a solution.

8.7.3.3 For all intervals $i \in \mathrm{I}$ and *facilities* $f \in \mathrm{F}_i$, the linearized constraints for violated pre-contingency limits obtained from the *security* assessment function shall take the form:

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

8.7.3.4 For all intervals $i \in I$, contingencies $c \in C$, and *facilities* $f \in F_{i,c}$, the linearized constraints for violated post-contingency limits obtained from the *security* assessment function shall take the form:

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

8.7.4 Penalty Price Variable Bounds

8.7.4.1 Penalty price variables shall be restricted to the ranges determined by the constraint violation penalty curves for the Real-Time Scheduling algorithm and for all intervals $i \in I$:

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

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

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

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

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

$0 \le SREG10RViol_{r,i,w} \le QREG10RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG10RViol_i}\}$;

$0 \le SREG30RViol_{r,i,w} \le QREG30RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG30RViol_i}\}$;

$0 \le SXREG10RViol_{r,i,w} \le QXREG10RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG10RViol_i}\}$;

$0 \le SXREG30RViol_{r,i,w} \le QXREG30RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG30RViol_i}\}$;

$0 \le SPreITLViol_{f,i,w} \le QPreITLViolSch_{f,i,w}$ for all $f \in F_i$, $w \in \{1,..,N_{PreITLViol_{f,i}}\}$;

and

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

8.8 Outputs

8.8.1 Outputs for the Real-Time Scheduling algorithm includes resource schedules.

9 Real-Time Pricing

9.1 Purpose

9.1.1 The Real-Time Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade to meet the *IESO's* province-wide non-*dispatchable demand* forecast and the *IESO*-specified *operating reserve* requirements for each interval of the real-time look-ahead period.

9.2 Information, Sets, Indices and Parameters

9.2.1 Information, sets, indices and parameters used by the Real-Time Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedules from the Real-Time Scheduling algorithm in section 8 shall be used in the Real-Time Pricing algorithm:

9.2.1.1 $SD_{i,b}^{RTS} \in \{0,1\}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{NQS}$ was scheduled on a shutdown trajectory in interval $i \in I$ such that $EvalSD_{i,b} = 1$;

9.2.1.2 $SDLInitSch_{0,b}$, which designates the initial schedule for the *dispatchable load* at bus $b \in B^{DL}$ used in the Real-Time Scheduling algorithm in section 8; and

9.2.1.3 $SDGInitSch_{0,b}$, which designates the initial schedule for the *dispatchable generation resource* at bus $b \in B^{DG}$ used in the Real-Time Scheduling algorithm in section 8.

9.3 Variables and Objective Function

9.3.1 The Real-Time Pricing algorithm shall solve for the same variables as the Real Time Scheduling algorithm in section 8.3.1.

9.3.2 The objective function for the Real-Time Pricing algorithm shall maximize gains from trade by maximizing the expression in section 8.3.2 for the Real-Time Scheduling algorithm.

9.3.3 $ViolCost_i$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_i = &\sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \cdot PLdViolPrc_{i,w} \\
&- \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \cdot PGenViolPrc_{i,w} \\
&+ \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \cdot P10SViolPrc_{i,w} \\
&+ \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \cdot P10RViolPrc_{i,w} \\
&+ \sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \cdot P30RViolPrc_{i,w} \\
&+ \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \cdot PREG10RViolPrc_{i,w} \right) \\
&+ \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \cdot PREG30RViolPrc_{i,w} \right) \\
&+ \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \cdot PXREG10RViolPrc_{i,w} \right) \\
&+ \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w} \cdot PXREG30RViolPrc_{i,w} \right) \\
&+ \sum_{f \in F_i} \left(\sum_{w=1..N_{PreITLViol_{f,i}}} SPreITLViol_{f,i,w} \cdot PPreITLViolPrc_{f,i,w} \right) \\
&+ \sum_{c \in C} \sum_{f \in F_{i,c}} \left(\sum_{w=1..N_{ITLViol_{c,f,i}}} SITLViol_{c,f,i,w} \cdot PITLViolPrc_{c,f,i,w} \right).
\end{aligned}
$$

9.3.3.1 The constraints in section 9.4 shall apply to the Real-Time Pricing algorithm.

9.4 Constraints

9.4.1 The Real-Time Pricing algorithm optimization function shall apply the constraints described in sections 9.5 – 9.8.

9.5 Dispatch Data Constraints Applying to Individual Intervals

9.5.1 Scheduling Variable Bounds

9.5.1.1 The constraints in section 8.5.1 shall apply in the Real-Time Pricing algorithm, with the following exceptions for a *non-quick start resource* bus $b \in B^{NQS}$ and interval $i \in I$, where:

9.5.1.1.1 $AtZero_{i,b}$ shall be replaced by $AtZero_{i,b}^{RTP}$;

9.5.1.1.2 $AtMLP_{i,b}$ shall be replaced by $AtMLP_{i,b}^{RTP}$; and

9.5.1.1.3 $EvalSD_{i,b}$ shall be replaced by $EvalSD_{i,b}^{RTP}$.

9.5.2 Resource Initial Conditions

9.5.2.1 The initial schedule for a *dispatchable load* at bus $b \in B^{DL}$ shall be fixed to the *resource* initial schedules. For all *dispatchable load* buses $b \in B^{DL}$:

$$\sum_{j \in J_{0,b}^{E}} SDL_{0,b,j} = SDLInitPrc_{0,b}$$

9.5.2.2 The initial schedule for a *dispatchable generation resource* at bus $b \in B^{DG}$ shall be fixed to the *resource* initial schedules. For all *dispatchable generation resource* buses $b \in B^{DG}$:

$$\sum_{k \in K_{0,b}^{E}} SDG_{0,b,k} = SDGInitPrc_{0,b}$$

9.5.3 Resource Minimums and Maximums

9.5.3.1 The constraints in section 8.5.3 shall apply in the Real-Time Pricing algorithm, with the following exception:

9.5.3.1.1 $AtMLP_{i,b}$ shall be replaced by $AtMLP_{i,b}^{RTP}$ where $AtMLP_{i,b}^{RTP}$ is determined in accordance with section 9.8.1.

9.5.4 Operating Reserve Requirements

9.5.4.1 The constraints in section 8.5.4 shall apply in the Real-Time Pricing algorithm.

9.5.5 Pseudo-Units

9.5.5.1 The constraints in section 8.5.5 shall apply in the Real-Time Pricing algorithm.

9.5.6 Dispatchable Hydroelectric Generation Resources

9.5.6.1 The constraints in section 8.5.6 shall apply in the Real-Time Pricing algorithm.

9.6 Dispatch Data Inter-Interval/Multi-Interval Constraints

9.6.1 Energy Ramping

9.6.1.1 The constraints in section 8.6.1 shall apply in the Real-Time Pricing algorithm.

9.6.2 Non-Quick Start Resource Start-up and Shutdown

9.6.2.1 The constraints in section 8.6.2 shall apply in the Real-Time Pricing algorithm, with the exception of the *non-quick start resource* start-up and shutdown statuses, which are determined in accordance with section 9.8.1.

9.6.3 Operating Reserve Ramping

9.6.3.1 The constraints in section 8.6.3 shall apply in the Real-Time Pricing algorithm.

9.7 Constraints for Reliability Requirements

9.7.1 Energy Balance

9.7.1.1 The constraint in section 8.7.1 shall apply in the Real-Time Pricing algorithm, with the following exceptions:

9.7.1.1.1 $FXLSch_{i,d}$ shall be replaced by $FXLPrc_{i,d}$ in section 8.7.1.2;

9.7.1.1.2 $FIGSch_{i,d}$ shall be replaced by $FIGPrc_{i,d}$ in section 8.7.1.4; and

9.7.1.1.3 The *energy* balance constraint in section 8.7.1.5 shall be modified to account for the *demand* adjustment required to calculate *locational marginal prices* when a voltage reduction or load shedding has been implemented, as follows:

$$
\begin{aligned}
FL_i + CAAdj_i + \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} (1 + MglLoss_{i,b}) \cdot With_{i,b} \\
+ \sum_{d \in DX} (1 + MglLoss_{i,d}) \cdot With_{i,d} \\
- \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \\
= \sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} (1 + MglLoss_{i,b}) \cdot Inj_{i,b} \\
+ \sum_{d \in DI} (1 + MglLoss_{i,d}) \cdot Inj_{i,d} \\
- \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} + LossAdj_i.
\end{aligned}
$$

9.7.2 Operating Reserve Requirements

9.7.2.1 The constraint in section 8.7.2 shall apply in the Real-Time Pricing algorithm, with the following exceptions:

9.7.2.1.1 $F10NXLSch_{i,d}$ shall be replaced by $F10NXLPrc_{i,d}$ for all $d \in DX$;

9.7.2.1.2 $F10NIGSch_{i,d}$ shall be replaced by $F10NIGPrc_{i,d}$ for all $d \in DI$;

9.7.2.1.3 $F30RXLSch_{i,d}$ shall be replaced by $F30RXLPrc_{i,d}$ for all $d \in DX$; and

9.7.2.1.4 $F30RIGSch_{i,d}$ shall be replaced by $F30RIGPrc_{i,d}$ for all $d \in DI$.

9.7.3 IESO Internal Transmission Limits

The constraints in section 8.7.3 shall apply in the Real-Time Pricing algorithm except the sensitivities and limits considered shall be those provided by the most recent *security* assessment function iteration of the Real-Time Pricing algorithm.

9.7.4 Penalty Price Variable Bounds

9.7.4.1 The following constraints shall restrict the penalty price variables to the ranges determined by the constraint violation penalty curves. For all intervals $i \in I$:

$0 \leq SLdViol_{i,w} \leq QLdViolPrc_{i,w}$	for all $w \in \{1,..,N_{LdViol_i}\}$;
$0 \leq SGenViol_{i,w} \leq QGenViolPrc_{i,w}$	for all w $\in \{1,..,N_{GenViol_i}\}$;
$0 \leq S10SViol_{i,w} \leq Q10SViolPrc_{i,w}$	for all $w \in \{1,..,N_{10SViol_i}\}$;
$0 \leq S10RViol_{i,w} \leq Q10RViolPrc_{i,w}$	for all $w \in \{1,..,N_{10RViol_i}\}$;
$0 \leq S30RViol_{i,w} \leq Q30RViolPrc_{i,w}$	for all $w \in \{1,..,N_{30RViol_i}\}$;
$0 \leq SREG10RViol_{r,i,w} \leq QREG10RViolPrc_{i,w}$	for all $r \in ORREG$, $w \in \{1,..,N_{REG10RViol_i}\}$;
$0 \leq SREG30RViol_{r,i,w} \leq QREG30RViolPrc_{i,w}$	for all $r \in ORREG$, $w \in \{1,..,N_{REG30RViol_i}\}$;
$0 \leq SXREG10RViol_{r,i,w} \leq QXREG10RViolPrc_{i,w}$	for all $r \in ORREG$, $w \in \{1,..,N_{XREG10RViol_i}\}$;
$0 \leq SXREG30RViol_{r,i,w} \leq QXREG30RViolPrc_{i,w}$	for all $r \in ORREG$, $w \in \{1,..,N_{XREG30RViol_i}\}$;
$0 \leq SPreITLViol_{f,i,w} \leq QPreITLViolPrc_{f,i,w}$	for all $f \in F_i$, $w \in \{1,..,N_{PreITLViol_{f,i}}\}$; and
$0 \leq SITLViol_{c,f,i,w} \leq QITLViolPrc_{c,f,i,w}$	for all $c \in C, f \in F_{i,c}$, $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$.

9.8 Constraints to Ensure the Price Setting Eligibility of Offer/Bid Laminations

9.8.1 Non-Quick Start Resources

9.8.1.1 The Real-Time Pricing algorithm shall modify the following start-up and shutdown statuses for a *non-quick start resource* at bus $b \in B^{NQS}$ and interval $i \in I$:

9.8.1.1.1 $AtZero_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* is not scheduled and is calculated as follows:

$$AtZero_{i,b}^{RTP} = AtZero_{i,b}.$$

9.8.1.1.2 $SU_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* must be scheduled for *energy* on its start-up trajectory and is calculated as follows:

$$SU_{i,b}^{RTP} = SU_{i,b}.$$

9.8.1.1.3 $AtMLP_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* is scheduled for *energy* at or above the *minimum loading point* and is calculated as follows:

$$AtMLP_{i,b}^{RTP} = \begin{cases} AtMLP_{i,b} & if\ EvalSD_{i,b} = 0 \\ 1 - SD_{i,b}^{RTS} & if\ EvalSD_{i,b} = 1 \end{cases}$$

9.8.1.1.4 $EvalSD_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* can be

scheduled for *energy* below the *minimum loading point* and is calculated as follows:

$$EvalSD_{i,b}^{RTP} = 0.$$

9.8.1.1.5 $SD_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* must be scheduled for *energy* on its shutdown trajectory and is calculated as follows:

$$SD_{i,b}^{RTP} = \begin{cases} SD_{i,b} & if\ EvalSD_{i,b} = 0 \\ SD_{i,b}^{RTS} & if\ EvalSD_{i,b} = 1 \end{cases}$$

9.9 Outputs

9.9.1 Outputs for the Real-Time Pricing algorithm include:

9.9.1.1 shadow prices;

9.9.1.2 *locational marginal prices* and their components; and

9.9.1.3 sensitivity factors.

10 Pseudo-Unit Modelling

10.1 Pseudo-Unit Model Parameters

10.1.1 The *real-time calculation engine* shall use the following registration and *dispatch data* to determine the underlying relationship between a *pseudo-unit* and the associated physical *resources* for a combined cycle *facility* with KK combustion turbines and one steam turbine:

10.1.1.1 $CMCR_k$, which designates the registered *maximum continuous rating* of combustion turbine $k \in \{1,..,K\}$ in *MW*;

10.1.1.2 $CMLP_k$, which designates the *minimum loading point* of combustion turbine $k \in \{1,..,K\}$ in *MW*;

10.1.1.3 $SMCR$, which designates the registered *maximum continuous rating* of the steam turbine in *MW*;

10.1.1.4 $SMLP$, which designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

10.1.1.5 SDF, which designates the amount of duct firing capacity available on the steam turbine in *MW*;

10.1.1.6 $STPortion_k$, which designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

10.1.1.7 $CSCM_k \in \{0,1\}$, which designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in *single cycle mode*.

10.1.2 The *real-time calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..K\}$:

10.1.2.1 $MMCR_k$, which designates the *maximum continuous rating* of *pseudo-unit* k and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

10.1.2.2 $MMLP_k$, which designates the *minimum loading point* of *pseudo-unit* k and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

10.1.2.3 MDF_k, which designates the duct firing capacity of *pseudo-unit* k and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

10.1.2.4 MDR_k, which designates the *dispatchable* capacity of *pseudo-unit* k and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

10.1.3 The *real-time calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

10.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

10.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and

$MMLP_k + MDR_k$;

10.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

10.1.4 The *real-time calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

10.1.4.1 For the minimum loading point region:

10.1.4.1.1 Steam turbine share: $STShareMLP_k = \frac{SMLP \cdot (1-CSCM_k)}{MMLP_k}$;

10.1.4.1.2 Combustion turbine share: $CTShareMLP_k = \frac{CMLP_k}{MMLP_k}$; and

10.1.4.2 For the *dispatchable* region:

10.1.4.2.1 Steam turbine share:

$$STShareDR_k = \frac{(1-CSCM_k)(SMCR \cdot STPortion_k - SMLP\text{-}SDF \cdot STPortion_k)}{MDR_k};\ \text{and}$$

10.1.4.2.2 Combustion turbine share:

$$CTShareDR_k = \frac{CMCR_k - CMLP_k}{MDR_k};\ \text{and}$$

10.1.4.3 For the duct firing region:

10.1.4.3.1 Steam turbine share shall be equal to 1; and

10.1.4.3.2 Combustion turbine share shall be equal to 0.

10.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

10.2.1 The *real-time calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

10.2.1.1 $CTCap_{i,k}$ designates the capacity of combustion turbine $k \in \{1,..,K\}$ in interval i as determined by submitted deratings;

10.2.1.2 $STCap_i$ designates the capacity of the steam turbine in interval i as determined by submitted deratings; and

10.2.1.3 $TotalQ_{i,k}$ designates the total *offered* quantity of *energy* for *pseudo-unit* $k \in \{1,..,K\}$ in interval i.

10.2.2 The *real-time calculation engine* shall solve for the following operating region parameters for each *pseudo-unit* $k \in \{1,..,K\}$:

10.2.2.1 $MLP_{i,k}$ designates the *minimum loading point* of *pseudo-unit* k in interval i;

10.2.2.2 $DR_{i,k}$ designates the *dispatchable* capacity region of *pseudo-unit* k in interval i; and

10.2.2.3 $DF_{i,k}$ designates the duct firing capacity region of *pseudo-unit* k in interval i.

10.2.3 Pre-Processing of De-rates

10.2.3.1 The *real-time calculation engine* shall perform the following preprocessing steps to determine the available operating regions for a *pseudo-unit* based on the combustion turbine and steam turbine share and the application of the *pseudo-unit* deratings. For *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$:

10.2.3.1.1 Step 1: Calculate the amount of the *offer* for *energy* that is attributed to each combustion turbine ($CTAmt_{i,k}$) and steam turbine portion ($STAmt_{i,k}$):

If $TotalQ_{i,k} < MMLP_k$, then:

Calculate $CTAmt_{i,k} = 0$;

and Calculate $STAmt_{i,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{i,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{i,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{i,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{i,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{i,k} = CTAmtMLP + CTAmtDR$; and

$STAmt_{i,k} = STAmtMLP + STAmtDR + STAmtDF$.

10.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$$PRSTCap_{i,k} = \left(\frac{STAmt_{i,k}}{\sum_{w \in \{1,..,K\}} STAmt_{i,w}}\right) \cdot STCap_i$$

10.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{i,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $STAmt_{i,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{i,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $PRSTCap_{i,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

10.2.3.1.4 Step 4: Initialize the operating region parameters for interval $i \in I$ to the model parameter values:

Set $MLP_{i,k} = MMLP_k$.

Set $DR_{i,k} = MDR_k$.

Set $DF_{i,k} = MDF_k$.

10.2.3.1.5 Step 5: Apply the derating for the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k =$ $CTCap_{i,k}$; and

Set $DR_{i,k} = min(DR_{i,k}, P \cdot MDR_k)$.

10.2.3.1.6 Step 6: Apply the derating for the steam turbine to the duct firing and *dispatchable* regions for *pseudo-units* not operating in *single cycle mode*:

Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{i,k}$.

If $R \leq 1$, update $DF_{i,k} = 0$, and $DR_{i,k} = min(DR_{i,k}, R \cdot MDR_k)$.

If $R > 1$, update $DF_{i,k} = min(DF_{i,k}, PRSTCap_{i,k} - SMLP - STShareDR_k \cdot MDR_k)$.

10.2.4 Available Energy Laminations

10.2.4.1 The *real-time calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for interval $i \in I$ for each *pseudo-unit* $k \in \{1,..,K\}$, subject to section 10.2.4.2, where:

10.2.4.1.1 $QMLP_{i,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

10.2.4.1.2 $QDR_{i,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

10.2.4.1.3 $QDF_{i,k}$ designates the total quantity that may be scheduled in the duct firing region.

10.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$0 \leq QMLP_{i,k} \leq MLP_{i,k};$

$0 \leq QDR_{i,k} \leq DR_{i,k};$

$0 \leq QDF_{i,k} \leq DF_{i,k};$

if $QMLP_{i,k} < MLP_{i,k}$, then the *pseudo-unit* is unavailable and $QDR_{i,k} = QDF_{i,k} = 0$; and

if $QDR_{i,k} < DR_{i,k}$, then $QDF_{i,k} = 0$.

10.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

10.3.1 The *real-time calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

10.3.1.1 $PSUMin_{i,k}$ designates the minimum limitation on *pseudo-unit* k determined by translating constraint q. When constraint *q* does not provide a minimum limitation on *pseudo-unit* k, then $PSUMin_{i,k}^{q}$ shall be set equal to 0;

10.3.1.2 $PSUMax_{i,k}^{q}$ designates the maximum limitation on *pseudo-unit* k determined by translating constraint q. When constraint *q* does not provide a maximum limitation on *pseudo-unit* k, then $PSUMax_{i,k}^{q}$ shall be set equal to $MLP_{i,k}+DR_{i,k}+DF_{i,k}$; and

10.3.1.3 $CTCmtd_{i,k} \in \{0,1\}$ designates whether combustion turbine $k \in \{1,..K\}$ is considered committed in interval $i \in I$.

10.3.2 The *real-time calculation engine* shall calculate the minimum and maximum limitations, subject to section 10.3.3.1, as follows:

10.3.2.1 Minimum limitation: $MinDG_{i,k} = max_{q \in \{1,..Q\}} PSUMin_{i,k}^{q}$

10.3.2.2 Maximum limitation: $MaxDG_{i,k} = min_{q \in \{1,..Q\}} PSUMax_{i,k}^{q}$

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *real-time calculation engine*.

10.3.3 Pseudo-Unit Minimum and Maximum Constraints

10.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

10.3.3.1.1 $PSUMin_{i,k} = PMin$ where $PMin$ shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$; and

10.3.3.1.2 $PSUMax_{i,k} = PMax$ where $PMax$ shall be a maximum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$.

10.3.4 Combustion Turbine Minimum and Maximum Constraints

10.3.4.1 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo unit* constraint as follows:

If $CTMin < MLP_{i,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right),$$

$$STMinDR = 0.$$

Otherwise, if $CTMin \geq MLP_{i,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{i,k} \cdot STShareMLP_k,$$

$$STMinDR = (CTMin - MLP_{i,k} \cdot CTShareMLP_k) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

Therefore:

$$PSUMin_{i,k} = CTMin + STMinMLP + STMinDR.$$

10.3.4.2 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMin_{i,k} = CTMin.$$

10.3.4.3 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudounit* constraint as follows:

If $CTMax < MLP_{i,k} . CTShareMLP_k$, then $PSUMax_{i,k} = 0$ and the *pseudo-unit* is unavailable.

Otherwise, calculate the value of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions:

$$STMaxMLP = MLP_{i,k} \cdot STShareMLP_k$$

$$STMaxDR = (CTMax\text{-}MLP_{i,k} \cdot CTShareMLP_k) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{i,k} = CTMax + STMaxMLP + STMaxDR$$

10.3.4.4 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudounit* constraint as follows:

$$PSUMax_{i,k} = CTMax.$$

10.3.5 Steam Turbine Minimum and Maximum Constraints

10.3.5.1 The *real-time calculation engine* shall convert a stream turbine minimum constraint to a *pseudo-unit* constraints as follows:

10.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which designates the set of *pseudo-units* to which the constraint may be allocated where *pseudo-unit* $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k = 0$ and $CTCmtd_{i,k} = 1$. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

10.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity for *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{i,k} . STShareMLP_k + QDR_{i,k} . STShareDR_k + QDF_{i,k}.$$

10.3.5.1.3 Step 3: Allocate the $STMin$ constraint to each *pseudo-unit* $k \in A$, where $STMin$ constraint shall be allocated equally to each *pseudounit* $k \in A$, where $STPMin_k$ is limited by $STCap_k$.

10.3.5.1.4 Step 4: The steam turbine portion minimum constraint shall be converted to a *pseudo-unit* constraint ,where for each *pseudo-unit* $k \in A$:

If $STPMin_k < MLP_{i,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = STPMin_k \cdot \left(\frac{CTShareMLP_k}{STShareMLP_k}\right)$$; and

$$CTMinDR_k = 0.$$

Otherwise, if $STPMin_k \geq MLP_{i,k} \cdot STShareMLP_k$, then set

$CTMinMLP_k = MLP_{i,k} \cdot CTShareMLP_k$; and

$$CTMinDR_k = \left(STPMin_k - MLP_{i,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right).$$

Therefore:

$$PSUMin_{i,k} = STPMin_k + CTMinMLP_k + CTMinDR_k.$$

Therefore:

$$PSUMin_{i,k} = STPMin_k + CTMinMLP_k + CTMinDR_k.$$

10.3.5.1.4 If *pseudo-units* with sufficient steam turbine capacity are not commited, then the *real-time calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudo-unit* constraints.

10.3.5.2 The steam turbine maximum constraint shall be converted to a *pseudounit* constraint as follows:

$$PRSTMax_{i,k} = \left(\frac{STAmt_{i,k}}{\sum_{w \in \{1,..,K\}} STAmt_{i,w}}\right) \cdot STMax.$$

If the converted steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{i,k} = 0.$$

Otherwise, calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTMax_{i,k}$

If $R \leq 1$, set $PSUMax_{i,k} = MLP_{i,k} + \min(DR_{i,k}, R \cdot MDR_k)$.

If RR , set $PSUMax_{i,k} = MLP_{i,k} + DR_{i,k} + PRSTMax_{i,k} - SMLPSTShareDR_k \cdot MDR_k$.

10.3.5.3 If the steam turbine minimum and maximum constraints are equal but do not convert to equal *pseudo-unit* minimum and maximum constraints, then the steam turbine minimum constraint conversion in section 10.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

10.4 Steam Turbine Forced Outages

10.4.1 If the steam turbine experiences a *forced outage*, the *real-time calculation engine* shall evaluate the corresponding *pseudo-units* as being *offered* in *single cycle mode*.

10.5 Determination of Energy Management System MW Values for Pseudo-Units

10.5.1 The *real-time calculation engine* shall determine the effective *energy* management system MW value for each *pseudo-unit* from the *IESO's energy* management system MW values for the corresponding physical *resources*, where:

10.5.1.1 $CTTel_k$ designates the *energy* management system MW value for combustion turbine $k \in \{1,..,K\}$;

10.5.1.2 $STTel$ designates the *energy* management system MW value for the steam turbine;

10.5.1.3 $PSUTel_k$ designates the effective *energy* management system MW value for *pseudo-unit* $k \in \{1,..,K\}$;

10.5.1.4 $TMLP_k$ designates the effective *minimim loading point* operating range for the time at which *energy* management system MW value was determined;

10.5.1.5 TDR_k designates the effective *dispatchable* region operating range for the time at which *energy* management system MW value was determined; and

10.5.1.6 TDF_k, designates the effective duct firing region operating range for the time at which *energy* management system MW value was determined.

10.5.2 The *real-time calculation engine* shall determine the effective *energy* management system MW values for *pseudo-units* as follows:

10.5.2.1 Step 1: For all combustion turbines, assign the following *energy* management system MW values to the corresponding *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.1.1 $CTMLPTel_k$, which designates the MW value assigned to the combustion turbine's share of the *minimum loading point* region and is calculated as follows:

$$CTMLPTel_k = \min\{CTTel_k ,CTShareMLP_k \cdot TMLP_k\}.$$

10.5.2.1.2 $CTDRTel_k$, which designates the MW value assigned to the combustion turbine's share of the *dispatchable* region and is calculated as follows:

If $CTMLPTel_k < CTTel_k$, then set $CTDRTel_k = \min\{(CTTel_k CTMLPTel_k), CTShareDR_k \cdot TDR_k\}$

Otherwise, set $CTDRTel_k = 0$.

10.5.2.2 Step 2: Determine the maximum *energy* management system MW value for the steam turbine that may be assigned to the steam turbine's share of the *pseudo-unit's minimum loading point* and *dispatchable* regions based on the amount assigned to the combustion turbine's share of the *minimum loading point* and *dispatchable* regions. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.2.1 $STMLPMax_k$ designates the maximum MW value that may be assigned to the steam turbine's share of the *minimum loading point* region and is calculated as follows:

$$STMLPMax_k = CTMLPTel_k \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right).$$

10.5.2.2.2 $STDRMax_k$ designates the maximum MW value that may be assigned to the steam turbine's share of the *dispatchable* region and is calculated as follows:

$$STDRMax_k = CTDRTel_k \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

10.5.2.3 Step 3: Allocate the *energy* management system MW value for the steam turbine to the *minimum loading point* and *dispatchable* regions of the *pseudo-unit* in proportion to the maximum amount that may be allocated.
For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.3.1 $STMLPTel_k$ designates the MW value assigned to the steam turbine share of the *minimum loading point* region and is calculated as follows:

$$STMLPTel_k = min\left\{STMLPMax_k, \left(\frac{STMLPMax_k}{\sum_{w=1..K}(STMLPMax_w + STDRMax_w)}\right) \cdot STTel\right\}.$$

10.5.2.3.2 $STDRTel_k$ designates the MW value assigned the steam turbine share of the *dispatchable* region and is calculated as follows

$$STDRTel_k = min\left\{STDRMax_k, \left(\frac{STDRMax_k}{\sum_{w=1..K}(STMLPMax_w + STDRMax_w)}\right) \cdot STTel\right\}.$$

10.5.2.4 Step 4: Determine the remaining portion of the *energy* management system MW value for the steam turbine that is yet to be distributed ($STRemTel$) as follows:

$$STRemTel = STTel - \sum_{k=1..K}(STMLPTel_k + STDRTel_k).$$

10.5.2.5 Step 5: Determine the maximum *energy* management system MW value for the remaining steam turbine that may be assigned to the duct firing region for the *pseudo-unit* based on whether the *pseudo-unit* is fully loaded for its *minimum loading point* and *dispatchable* regions. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.5.1 $STDFMax_k$ designates the maximum MW value that may be assigned to the duct firing region and is calculated as follows:

If $(CTMLPTel_k + CTDRTel_k + STMLPTel_k + STDRTel_k) \geq TMLP_k + TDR_k$,

then set $STDFMax_k = TDF_k$ Otherwise, set $STDFMax_k = 0$.

10.5.2.6 Step 6: Distribute the remaining portion of the *energy* management system MW value for the steam turbine to the duct firing regions of the *pseudo-unit* in proportion to the maximum amount that may be allocated. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.6.1 *STDFTelk* designates the MW value assigned to the duct firing region and is calculated as follows:

$$STDFTel_k = min\left\{STDFMax_k, \left(\frac{STDFMax_k}{\sum_{w=1..K} STDFMax_w}\right) \cdot STRemTel\right\}.$$

10.5.2.7 Step 7: Determine the effective real-time *energy* management system MW value for the *pseudo-unit* by summing the MW values assigned to operating regions of the *pseudo-unit*. For *pseudo-unit* $k \in \{1,..,K\}$:

$$PSUTel_k = CTMLPTel_k + CTDRTel_k + STMLPTel_k + STDRTel_k + STDFTel_k.$$

10.6 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

10.6.1 For a combined cycle *facility* with K combustion turbines and one steam turbine, the *real-time calculation engine* shall compute the following *energy* and *operating reserve* schedules for interval $i \in I$:

10.6.1.1 $CTE_{i,k}$ designates the *energy* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.2 $STPE_{i,k}$ designates the *energy* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

STE_i designates the *energy* schedule for the steam turbine;

10.6.1.4 $CT10S_{i,k}$ designates the synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.5 $STP10S_{i,k}$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

10.6.1.6 $ST10S_i$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine;

10.6.1.7 $CT10N_{i,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.8 $STP10N_{i,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

10.6.1.9 $ST10N_i$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine;

10.6.1.10 $CT30R_{i,k}$ designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.11 $STP30R_{i,k}$ designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$; and

10.6.1.12 $ST30R_i$ designates the *thirty-minute operating reserve* schedule for the steam turbine.

10.6.2 The *real-time calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo-unit* $k \in \{1,..,K\}$ in interval $i \in I$:

10.6.2.1 $SE_{i,k}$ designates the total amount of *energy* scheduled and $SE_{i,k} = SEMLP_{i,k} + SEDR_{i,k} + SEDF_{i,k}$, where:

10.6.2.1.1 $SEMLP_{i,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \le SEMLP_{i,k} \le QMLP_{i,k}$;

10.6.2.1.2 $SEDR_{i,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \le SEDR_{i,k} \le QDR_{i,k}$ and $SEDR_{i,k} > 0$ only if $SEMLP_{i,k} = QMLP_{i,k}$;

10.6.2.1.3 $SEDF_{i,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \le SEDF_{i,k} \le QDF_{i,k}$ and $SEDF_{i,k} > 0$ only if $SEDR_{i,k} = QDR_{i,k}$;

10.6.2.2 $S10S_{i,k}$ designates the total amount of synchronized *ten-minute operating reserve* scheduled;

10.6.2.3 $S10N_{i,k}$ designates the total amount of non-synchronized *ten-minute operating reserve* scheduled. If the *pseudo-unit* cannot provide *operating reserve* from its duct firing region, then $0 \leq SE_{i,k} + S10S_{i,k} + S10N_{i,k} \leq QMLP_{i,k} + QDR_{i,k}$; and

10.6.2.4 $S30R_{i,k}$ designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{i,k} + S10S_{i,k} + S10N_{i,k} + S30R_{i,k} \leq QMLP_{i,k} + QDR_{i,k} + QDF_{i,k}$.

10.6.3 The *real-time calculation engine* shall convert *pseudo-unit* schedules to physical *generation resource* schedules for *energy* and *operating reserve*, where:

10.6.3.1 $STOn \in \{0,1\}$ designates whether the steam turbine is currently online;

10.6.3.2 $CTE_{0,k}$ designates the initial *energy* schedule allocated to the combustion turbine $k \in \{1,..,K\}$; and

10.6.3.3 $STPE_{0,k}$ designates the initial *energy* schedule allocated to the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$.

10.6.4 The *real-time calculation engine* shall convert *pseudo-unit* schedules to physical *resource* schedules for *energy* and *operating reserve*, as follows:

10.6.4.1 If $SE_{i,k} \geq MLP_{i,k}$, then:

$$CTE_{i,k} = SEMLP_{i,k} \cdot CTShareMLP_k + SEDR_{i,k} \cdot CTShareDR_k;$$

$$STPE_{i,k} = SEMLP_{i,k} \cdot STShareMLP_k + SEDR_{i,k} \cdot STShareDR_k + SEDF_{i,k};$$

$$RoomDR_{i,k} = QDR_{i,k} - SEDR_{i,k};$$

$$10SDR_{i,k} = \min(RoomDR_{i,k}, S10S_{i,k});$$

$$10NDR_{i,k} = \min(RoomDR_{i,k} - 10SDR_{i,k}, S10N_{i,k});$$

$$30RDR_{i,k} = \min(RoomDR_{i,k} - 10SDR_{i,k} - 10NDR_{i,k}, S30R_{i,k});$$

$$CT10S_{i,k} = 10SDR_{i,k} \cdot CTShareDR_k;$$

$$STP10S_{i,k} = 10SDR_{i,k} \cdot STShareDR_k + (S10S_{i,k} - 10SDR_{i,k});$$

$$CT10N_{i,k} = 10NDR_{i,k} \cdot CTShareDR_k;$$

$$STP10N_{i,k} = 10NDR_{i,k} \cdot STShareDR_k + (S10N_{i,k} - 10NDR_{i,k});$$

$$CT30R_{i,k} = 30RDR_{i,k} \cdot CTShareDR_k; \text{ and}$$

$$STP30R_{i,k} = 30RDR_{i,k} \cdot STShareDR_k + (S30R_{i,k} - 30RDR_{i,k}).$$

10.6.4.2 If $SE_{i,k} < MLP_{i,k}$ and is on a ramp up trajectory, then the *energy* schedules for the combustion turbine and steam turbine are determined as follows:

10.6.4.3 If the steam turbine is not online, then the *pseudo-unit* schedule will be assigned to the combustion turbine as follows: $CTEi_{,k} = SEi_{,k}$; and $STPE_{i,k} = 0$.

10.6.4.4 If the steam turbine is online, the incremental *pseudo-unit* schedule will be assigned to the steam turbine until the assigned combustion turbine and steam turbine schedules adhere to the *pseudo-unit* model as follows:

$$\text{If } \left(\frac{STPE_{i\text{-}1,k}}{STPE_{i\text{-}1,k}+CTE_{i\text{-}1,k}}\right) < STShareMLP_k, \text{ then}$$

$$CTE_{i,k} = CTE_{i\text{-}1,k},$$

$$STPE_{i,k} = SE_{i,k} - CTE_{i\text{-}1,k}.$$

Otherwise:

$$CTE_{i,k} = SE_{i,k} \cdot CTShareMLP_k; \text{ and}$$

$$STPE_{i,k} = SE_{i,k} \cdot STShareMLP_k.$$

10.6.4.5 If $SE_{i,k} < MLP_{i,k}$ and is on a ramp-down trajectory, then the *energy* schedules for the combustion turbine and steam turbine are determined as follows:

10.6.4.6 If the steam turbine is not online, then the *pseudo-unit* schedule will be assigned to the combustion turbine as follows: $CTE_{i,k} = SE_{i,k}$; and $STPE_{i,k} = 0$.

10.6.4.7 If the steam turbine is online, the *pseudo-unit* schedule will be assigned according to the *pseudo-unit* model as follows $CTE_{i,k} = SE_{i,k} \cdot CTShareMLP_k$; and $STPE_{i,k} = SE_{i,k} \cdot STShareMLP_k$.

10.6.4.8 If $SE_{i,k} < MLP_{i,k}$, then the *operating reserve* schedules for the combustion turbine and steam turbine are as follows:

$$S10S_{i,k} = S10N_{i,k} = S30R_{i,k} = 0;$$

$$CT10S_{i,k} = 0;$$

$$SSTTSS10SS_{ii,kk} = 0;$$

$$CT10N_{i,k} = 0;$$

$$STP10N_{i,k} = 0;$$

$CT30R_{i,k} = 0$;

and $STP30R_{i,k} =$

0.

10.6.4.9 The steam turbines portion schedules from section 10.6.4.1 through 10.6.4.8 shall be summed to obtain the steam turbine schedule as follows:

$$STE_i = \sum_{k=1,..,K} STPE_{i,k} \, ;$$

$$ST10S_i = \sum_{k=1,..,K} STP10S_{i,k} \, ;$$

$$ST10N_i = \sum_{k=1,..,K} STP10N_{i,k} \, ;$$

and

$$ST30R_i = \sum_{k=1,..,K} STP30R_{i,k} \, ;$$

11 Pricing Formulas

11.1 Purpose

11.1.1 The *real-time calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

11.2 Sets, Indices and Parameters

11.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Pass 1 shall be used:

11.2.1.1 $SPEmT_{i,c,f}^1$ designates the Pass 1 shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in interval i;

11.2.1.2 SPL_i^1 designates the Pass 1 shadow price for the *energy* balance constraint in interval i;

11.2.1.3 $SPNormT_{i,f}^1$ designates the Pass 1 shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in interval i;

11.2.1.4 $SP10S_i^1$ designates the Pass 1 shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in interval i;

11.2.1.5 $SP10R_i^1$ designates the Pass 1 shadow price for the total *ten-minute operating reserve* requirement constraint in interval i;

11.2.1.6 $SP30R_i^1$ designates the Pass 1 shadow price for the total *thirty-minute operating reserve* requirement constraint in interval i;

11.2.1.7 $SPREGMin10R_{i,r}^1$ designates the Pass 1 shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.8 $SPREGMin30R_{i,r}^1$ designates the Pass 1 shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.9 $SPREGMax10R_{i,r}^1$ designates the Pass 1 shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.10 $SPREGMax30R_{i,r}^1$ designates the Pass 1 shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in interval i.

11.3 Locational Marginal Prices for Energy

11.3.1 Energy Locational Marginal Prices for Delivery Points

11.3.1.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for every bus $b \in L$ and:

11.3.1.1.1 $LMP_{i,b}^1$ designates the Pass 1 interval i *locational marginal price* for *energy*;

11.3.1.1.2 $PRef_i^1$ designates the Pass 1 interval i *locational marginal price* for *energy* at the *reference bus*;

11.3.1.1.3 $PLoss_{i,b}^1$ designates the Pass 1 interval i loss component; and

11.3.1.1.4 $PCong_{i,b}^1$ designates the Pass 1 interval i congestion component.

11.3.1.2 The *real-time calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 at bus $b \in L$ in interval $i \in I$, as follows:

$$InitLMP_{i,b}^{1} = InitPRef_{i}^{1} + InitPLoss_{i,b}^{1} + InitPCong_{i,b}^{1}$$

where:

$$InitPRef_{i}^{1} = SPL_{i}^{1};$$

$$InitPLoss_{i,b}^{1} = MglLoss_{i,b} \cdot SPL_{i}^{1};$$

and

$$InitPCong_{i,b}^{1} = \sum_{f \in F_i} PreConSF_{i,f,b} \cdot SPNormT_{i,f}^{1} + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,b} \cdot SPEmT_{i,c,f}^{1}.$$

11.3.1.3 If the initial *locational marginal price* for *energy* at the *reference bus* ($InitPRef_i^1$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* for *energy* at the *reference bus* as follows:

If $InitPRef_i^1 > EngyPrcCeil$, set $PRef_i^1 = EngyPrcCeil$ If $InitPRef_i^1 < EngyPrcFlr$, set $PRef_i^1 = EngyPrcFlr$

Otherwise, set $PRef_i^1 = InitPRef_i^1$

11.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP_{i,b}^1$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *real time calculation engine* shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP_{i,b}^1 > EngyPrcCeil$, set $LMP_{i,b}^1 = EngyPrcCeil$.

If $InitLMP_{i,b}^1 < EngyPrcFlr$, set $LMP_{i,b}^1 = EngyPrcFlr$.

Otherwise, set $LMP_{i,b}^1 = InitLMP_{i,b}^1$

11.3.1.5 The *real-time calculation engine* shall modify the loss component as follows:

If $PRef_i^1 \neq InitPRef_i^1$, set $PLoss_{i,b}^1 = MglLoss_{i,b} . PRef_i^1$

Otherwise, set $PLoss_{i,b}^1 = InitPLoss_{i,b}^1$

11.3.1.6 The *real-time calculation engine* shall modify the congestion component as follows:

If $LMP_{i,b}{}^1 - PRef_i{}^1 - PLoss_{i,b}{}^1$ and $InitPCong_{i,b}{}^1$ have the same mathematical sign, then set $PCong_{i,b}{}^1 = LMP_{i,b}{}^1 - PRef_i{}^1 - PLoss_{i,b}{}^1$

Otherwise, set $PCong_{i,b}{}^1 = 0$ and set $PLoss_{i,b}{}^1 = LMP_{i,b}{}^1 - PRef_i{}^1$

11.3.2 Energy Locational Marginal Prices for Intertie Metering Points

11.3.2.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for *intertie zone* bus $d \in D$, where:

11.3.2.1.1 $ExtLMP_{i,d}{}^{PD}$ designates the *locational marginal price* for *energy* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.2 $ICP_{i,d}{}^1$ designates the Pass 1 interval i *intertie congestion price*;

11.3.2.1.3 $ICP_{i,d}{}^{PD}$ designates the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.4 $IntLMP_{i,d}{}^1$ designates the Pass 1 interval i *intertie border price* for *energy*;

11.3.2.1.5 $ExtLMP_{i,d}{}^1$ designates the Pass 1 interval i *locational marginal price* for *energy*;

11.3.2.1.6 $PExtCong_{i,d}{}^1$ designates the Pass 1 interval i external congestion component for the *intertie congestion price*;

11.3.2.1.7 $PExtCong_{i,d}{}^{PD}$ designates the external congestion component for the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.8 $PIntCong_{i,d}{}^1$ designates the Pass 1 interval i internal congestion component for *energy*;

11.3.2.1.9 $PLoss_{i,d}{}^1$ designates the Pass 1 interval i loss component;

11.3.2.1.10 $PNISL^{1}{}_{i,\mathrm{d}}$ designates the Pass 1 interval i net interchange scheduling limit congestion component for the *intertie congestion price*;

11.3.2.1.11 $PNISL^{PD}{}_{i,\mathrm{d}}$ designates the net interchange scheduling limit congestion component for the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*; and

11.3.2.2 The *real-time calculation engine* shall calculate an *intertie border price* for *energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss component and a congestion component for *energy* for Pass 1 at *intertie zone* bus d∈ D_a in *intertie zone* *a* ∈A in interval i ∈I, subject to section 11.3.2.11, as follows:

$$InitIntLMP_{i,\mathrm{d}}^{1} = InitPRef_{i}^{1} + InitPLoss_{i,\mathrm{d}}^{1}$$

$$+ InitPIntCong_{i,\mathrm{d}}^{1}$$ where

$$InitPRef_{i}^{1} = SPL^{1}{}_{i}$$

; $InitPLoss_{i,\mathrm{d}}^{1}$

$$= MglLoss_{i,} \cdot SPL_{i}^{1};$$

and

$$InitPIntCong_{i,d}^{1} = \sum_{f \in F_i} PreConSF_{i,f,d} \cdot SPNormT_{i,f}^{1} + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,d} \cdot SPEmT_{i,c,f}^{1}$$

11.3.2.3 If there is import congestion in pre-dispatch such that $ICP_{i,\mathrm{d}}^{\mathrm{PD}} < 0$, the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus d ∈ D in interval i ∈ I as follows:

$$InitExtLMP_{i,\mathrm{d}}^{1} = min InitIntLMP_{i,\mathrm{d}}^{1}, ExtLMP_{i,\mathrm{d}}^{\mathrm{PD}};$$

$$InitICP_{i,\mathrm{d}}^{1} = InitExtLMP_{i,\mathrm{d}}^{1} -$$

$InitIntLMP_{i,\mathrm{d}}^{1}$; where:

If $InitExtLMP_{i,\mathrm{d}}^{1} = InitIntLMP_{i,\mathrm{d}}^{1}$, then

$InitICP_{i,\mathrm{d}}^{1} = 0$ and $InitPNISL^{1}{}_{i,\mathrm{d}} = 0$; and

If $InitExtLMP_{i,d}^{1} = ExtLMP_{i,d}^{PD}$, then $InitICP_{i,d}^{1}$ and $InitPNISL^{1}_{i,d}$ shall be prorated based on their pre-dispatch magnitudes so that their sum equals the effective real-time *intertie congestion price*.

11.3.2.4 If there is export congestion in pre-dispatch such that $ICP_{i,d}^{PD} > 0$, the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows: $InitExtLMP_{i,d}^{1} = InitIntLMP_{i,d}^{1} + InitICP_{i,d}^{1}$ where:

$InitICP_{i,d}^{1} = InitPExtCong_{i,d}^{1}$

$+ InitPNISL^{1}_{i,d}$;

$InitPExtCong_{i,d}^{1} =$

$PExtCong_{i,d}^{PD}$; and

$InitPNISL^{1}_{i,d} = PNISL^{PD}_{i,d}$.

11.3.2.5 If there is no *intertie* congestion in pre-dispatch such that $ICP_{i,d}^{PD} = 0$ or an *intertie zone* is out-of-service in real-time, then the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows: $InitExtLMP_{i,d}^{1} = InitIntLMP_{i,d}^{1} + InitICP_{i,d}^{1}$ where

$InitICP_{i,d}^{1} = InitPExtCong_{i,d}^{1} + InitPNISL^{1}_{i,d} = 0$

$InitPExtCong_{i,d}^{1}$

$= PExtCong_{i,d}^{PD}$; and

$InitPNISL^{1}_{i,d} = PNISL^{PD}_{i,d}$.

11.3.2.6 If the *intertie border price* for *energy* ($InitIntLMP_{i,d}^{1}$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *real-time calculation engine* shall modify the *intertie border price* for *energy*, and its components, as follows:

11.3.2.6.1 The initial *locational marginal price* for the *reference bus* ($InitPRef_i^1$) shall be modified as per section 11.3.1.3;

11.3.2.6.2 The initial *intertie border price* ($InitIntLMP_{i,d}^1$) shall be modified as per section 11.3.1.4, where $InitLMP_{i,b}^1 = InitIntLMP_{i,d}^1$;

11.3.2.6.3 The initial loss component ($InitPLoss_{i,d}^1$) shall be modified as per section 11.3.1.5; and

11.3.2.6.4 The initial internal congestion component ($InitPIntCong_{i,d}^1$) shall be modified as per section 11.3.1.6, where $InitPCong_{i,b}^1 = InitPIntCong_{i,d}^1$.

11.3.2.7 If the initial *locational marginal price* for *energy* ($InitExtLMP_{i,d}^1$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *real time calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $InitExtLMP_{i,d}^1 > EngyPrcCeil$, set $ExtLMP_{i,d}^1 = EngyPrcCeil$.

If $InitExtLMP_{i,d}^1 < EngyPrcFlr$, set $ExtLMP_{i,d}^1 = EngyPrcFlr$.

Otherwise, set $ExtLMP_{i,d}^1 = InitExtLMP_{i,d}^1$.

11.3.2.8 If the modified *locational marginal price* for *energy* ($ExtLMP_{i,d}^1$) determined in section 11.3.2.7 is equal to the *intertie border price* for *energy* ($IntLMP_{i,d}^1$), then the *real-time calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{i,d}^1 = IntLMP_{i,d}^1$, set $PExtCong_{i,d}^1 = 0$ and $PNISL^1{}_{i,d} = 0$.

11.3.2.9 If the modified *locational marginal price* for *energy* ($ExtLMP_{i,d}^1$) determined in section 11.3.2.7 is not equal to the *intertie border price* for *energy* ($IntLMP_{i,d}^1$), then the *real-time calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP^1_{i,d} \neq IntLMP^1_{i,d}$, then set

$$PNISL^1_{i,d} = (ExtLMP^1_{i,d} - IntLMP^1_{i,d}) \cdot \left(\frac{InitPNISL^1_{i,d}}{InitPNISL^1_{i,d} + InitPExtCong^1_{i,d}}\right).$$

If $PNISL^1_{i,d} > NISLPen$, then set $PNISL^1_{i,d} = NISLPen$;

If $PNISL^1_{i,d} < (-1) \cdot NISLPen$, then set $PNISL^1_{i,d} = (-1) \cdot NISLPen$; and

Set $PExtCong^1_{i,d} = ExtLMP^1_{i,d} - IntLMP^1_{i,d} - PNISL^1_{i,d}$

11.3.2.10 The *real-time calculation engine* shall calculate the *intertie congestion price* as follows:

$$ICP_{i,d}{}^1 = PExtCong_{i,d}{}^1 + PNISL^1{}_{i,d}.$$

11.3.2.11 The *locational marginal price* for *energy* calculated by the *real-time calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. *Intertie* transactions associated with the same *boundary entity resource* bus, but specified as occurring at different *intertie zones*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these transactions shall utilize shadow prices associated with the internal transmission constraints, *intertie* limits and transmission losses applicable to the path associated to the relevant *intertie zone*.

11.3.3 Zonal Prices for Energy

11.3.3.1 The *real-time calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each interval $i \in I$, the *energy* price for *virtual transaction zone* $m \in M$, as follows:

$$VZonalP^1_{i,m} = PRef^1_i + VZonalPLoss^1_{i,m} + VZonalPCong^1_{i,m}$$

where:

$$VZonalPLoss^1_{i,m} = \sum_{b \in L^{VIRT}_m} WF^{VIRT}_{i,m,b} \cdot PLoss^1_{i,b}$$

$$VZonalPCong^1_{i,m} = \sum_{b \in L^{VIRT}_m} WF^{VIRT}_{i,m,b} \cdot PCong^1_{i,b}$$

11.3.3.2 The *real-time calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each interval $i \in I$ for *nondispatchable load* zone $y \in Y$, as follows:

$$ZonalP_{i,y}^{1} = PRef_{i}^{1} + ZonalPLoss_{i,y}^{1} + ZonalPCong_{i,y}^{1}$$

where:

$$ZonalPLoss_{i,y}^{1} = \sum_{b \in L_{y}^{NDL}} WF_{i,y,b}^{NDL} \cdot PLoss_{i,b}^{1}$$

and

$$ZonalPCong_{i,y}^{1} = \sum_{b \in L_{y}^{NDL}} WF_{i,y,b}^{NDL} \cdot PCong_{i,b}^{1}$$

11.3.3.3 The *Ontario zonal price* is calculated per section 11.3.3.2 where the *nondispatchable load* zone is comprised of all *non-dispatchable loads* within Ontario.

11.3.4 Pseudo-Unit Pricing

11.3.4.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for every *pseudo-unit* $k \in \{1,..,K\}$, where:

11.3.4.1.1 $CTMglLoss_{i,k}^{1}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit* k for each interval i in Pass 1;

11.3.4.1.2 $STMglLossi_{,k}^{p}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit* k for each interval i in Pass 1;

11.3.4.1.3 $CTPreConSF_{i,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during interval ii under precontingency conditions;

11.3.4.1.4 $STPreConSF_{i,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during interval i under pre-contingency conditions;

11.3.4.1.5 $CTSF_{i,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudounit* k on *facility* f during interval i under post-contigency conditions for contingency c; and

11.3.4.1.6 $STSF_{i,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during interval i under post-contingency conditions for contingency c.

11.3.4.2 The *real-time calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 and each interval i for every *pseudo-unit* $k \in \{1,..,K\}$, as follows:

$$InitLMP_{i,k}^{1} = InitPRef_{i}^{1} + InitPLoss_{i,k}^{1} + InitPCong_{i,k}^{1}$$

where:

$$InitPRef_{i}^{1} = SPL_{i}^{1}; \quad InitPLoss_{i,k}^{1} = MglLoss_{i,k}^{1} \cdot SPL_{i}^{1};$$

and

$$InitPCong_{i,k}^{1} = \sum_{f \in F_i} PreConSF_{i,f,k} \cdot SPNormT_{i,f}^{1} + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,k} \cdot SPEmT_{i,c,f}^{1}$$

11.3.4.3 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *minimum loading point* range or not scheduled at all, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^{1} = CTShareMLP_{k} \cdot CTMglLoss_{i,k}^{1} + STShareMLP_{k} \cdot STMglLoss_{i,k}^{1}$$

$$PreConSF_{i,f,k} = CTShareMLP_{k} \cdot CTPreConSF_{i,f,k} + STShareMLP_{k} \cdot STPreConSF_{i,f,k}$$

$$SF_{i,c,f,k} = CTShareMLP_{k} \cdot CTSF_{i,c,f,k} + STShareMLP_{k} \cdot STSF_{i,c,f,k}$$

11.3.4.4 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^{1} = CTShareDR_{k} \cdot CTMglLoss_{i,k}^{1} + STShareDR_{k} \cdot STMglLoss_{i,k}^{1}$$

$$PreConSF_{i,f,k} = CTShareDR_{k} \cdot CTPreConSF_{i,f,k} + STShareDR_{k} \cdot STPreConSF_{i,f,k}$$

$$SF_{i,c,f,k} = CTShareDR_{k} \cdot CTSF_{i,c,f,k} + STShareDR_{k} \cdot STSF_{i,c,f,k}$$

11.3.4.5 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^{1} = STMglLoss_{i,k}^{1}$$

$$PreConSF_{i,f,k} = STPreConSF_{i,f,k}$$

$$SFi_{,c,f,k} = STSFi_{,c,f,k}$$

11.4 Locational Marginal Prices for Operating Reserve

11.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

11.4.1.1 The *real-time calculation engine* shall calculate *locational marginal prices* and components for *operating reserve* for Pass 1 and each interval i for a *delivery point* associated with the *dispatchable generation resource* or *dispatchable load* bus $b \in B$, where:

11.4.1.1.1 $L30RP_{i,b}^{1}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve*;

11.4.1.1.2 $P30RRef_{i}^{1}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

11.4.1.1.3 $P30RCong_{i,b}^{1}$ designates the Pass 1 interval i congestion component for *thirty-minute operating reserve*;

11.4.1.1.4 $L10NP_{i,b}^{1}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve*;

11.4.1.1.5 $P10NRef_{i}^{1}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

11.4.1.1.6 $P10NCong_{i,b}^{1}$ designates the Pass 1 interval i congestion component for non-synchronized *ten-minute operating reserve*;

11.4.1.1.7 $L10SP_{i,b}^{1}$ designates the Pass 1 interval i *locational marginal price* for synchronized *ten-minute operating reserve*;

11.4.1.1.8 $P10SRef_i^1$ designates the Pass 1 interval i *locational marginal price* for synchronized *ten-minute operating reserve* at the *reference bus*;

11.4.1.1.9 $P10SCong_{i,b}^1$ designates the Pass 1 interval i congestion component for synchronized *ten-minute operating reserve*; and

11.4.1.1.10 $ORREG_b \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus b.

11.4.1.2 The *real-time calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass 1 for a *delivery point* associated with the *dispatchable generation resource* or *dispatchable load* at bus $b \in B$ in interval $i \in I$ for each class of *operating reserve*, as follows:

$$InitL30RP_{i,b}^1\ InitP30RRef_i^1 + InitP30RCong_{i,b}^1$$

where:

$$InitP30RRef_i^1 =$$

$SP30R_i^1$ and

$$InitP30RCong_{i,b}^1 = \sum_{r \in ORREG_b} SPREGMin30R_{i,r}^1 - \sum_{r \in ORREG_b} SPREGMax30R_{i,r}^1$$

$$InitL10NP_{i,b}^1 = InitP10NRef_i^1 + InitP10NCong_{i,b}^1$$

where:

$$InitP10NRef_i^1 = SP10R_i^1 + SP30R_i^1$$

and

$$InitP10NCong_{i,b}^1 = \sum_{r \in ORREG_b} \left(SPREGMin10R_{i,r}^1 + SPREGMin30R_{i,r}^1\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{i,r}^1 + SPREGMax30R_{i,r}^1\right)$$

$$InitL10SP_{i,b}^1 = InitP10SRef_i^1 + InitP10SCong_{i,b}^1$$

where:

$$InitP10SRef_i^1 = SP10S_i^1 + SP10R_i^1 + SP30R_i^1$$

and

$$InitP10SCong_{i,b}^{1} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{i,r}^{1} + SPREGMin30R_{i,r}^{1}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{i,r}^{1} + SPREGMax30R_{i,r}^{1}\right)$$

11.4.1.4 If the initial *locational marginal price* at the *reference bus* ($InitP30RRef_i^1$, $InitP10NRef_i^1$ or $InitP10SRef_i^1$,) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* at the *reference bus* for each class of *operating reserve* as follows:

If $InitP30RRef_{i,}^1 > ORPrcCeil$, set $P30RRef_{i,}^1 = ORPrcCeil$;

If $InitP30RRef_{i,}^1 < ORPrcFlr$,set $P30RRef_{i,}^1 =$

$ORPrcFlr$; Otherwise, set $P30RRef_t^1 = InitP30RRef_i^1$.

If $InitP10NRef_i^1 > ORPrcCeil$, set $P10NRef_i^1 = ORPrcCeil$

If $InitP10NRef_i^1 < ORPrcFlr$, set $P10NRef_i^1 = ORPrcFlr$

Otherwise, set $P10NRef_i^1 = InitP10NRef_i^1$

If $InitP10SRef_i^1, ORPrcFlr > ORPrcCeil$, set $P10SRef_i^1 = ORPrcCeil$

If $InitP10SRef_i^1, ORPrcFlr < ORPrcFlr$, set $P10SRef_i^1 = ORPrcFlr$

Otherwise, set $P10SRef_i^1 = InitP10SRef_i^1$

11.4.1.4 If the initial *locational marginal price* ($InitL30RP_{i,b}^1$, $InitL10NP_{i,b}^1$, or $InitL10SP_{i,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{i,b}^1 > ORPrcCeil$, set $L30RP_{i,b}^1 = ORPrcCeil$;

If $InitL30RP_{i,b}^1 < ORPrcFlr$, set $L30RP_{i,b}^1 = ORPrcFlr$; Otherwise, set $L30RP_{i,b}^1 = InitL30RP_{i,b}^1$.

If $InitL10NP_{i,b}^1 > ORPrcCeil$, set $L10NP_{i,b}^1 = ORPrcCeil$;

If $InitL10NP_{i,b}^1 < ORPrcFlr$, set $L10NP_{i,b}^1 = ORPrcFlr$;

Otherwise, set $L10NP_{i,b}^1 = InitL10NP_{i,b}^1$.

If $InitL10SP_{i,b}^1 > ORPrcCeil$, set $L10SP_{i,b}^1 = ORPrcCeil$;

If $InitL10SP_{i,b}^1 < ORPrcFlr$, set $L10SP_{i,b}^1 = ORPrcFlr$;

Otherwise, set $L10SP_{i,b}^1 = InitL10SP_{i,b}^1$.

11.4.1.5 If the initial *locational marginal price* ($InitL30RP_{i,b}^1$, $InitL10NP_{i,b}^1$, or $InitL10SP_{i,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the congestion component for each class of *operating reserve* as follows:

Set $P30RCong_{i,b}^1 = L30RP_{i,b}^1 - P30RRef_i^1$;

Set $P10NCong_{i,b}^1 = L10NP_{i,b}^1 - P10NRef_i^1$; and

Set $P10SCong_{i,b}^1 = L10SP_{i,b}^1 - P10SRef_i^1$.

11.4.2 Operating Reserve Locational Marginal Prices for Intertie Metering Points

11.4.2.1 The *real-time calculation engine* shall calculate *locational marginal prices* and components for *operating reserve* for Pass 1 and each interval $i \in I$, for *intertie zone* bus $d \in D$, where:

11.4.2.1.1 $ExtL30RP_{i,d}^1$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve*;

11.4.2.1.2 $ExtL30RP_{i,d}^{PD}$ designates the *locational marginal price* for *thirty-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.3 $P30RExtCong_{i,d}^1$ designates the Pass 1 interval i *intertie* congestion component for *thirty-minute operating reserve*;

11.4.2.1.4 $P30RExtCong_{i,d}^{PD}$ designates the *intertie* congestion component for *thirty-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.5 $ExtL10NP_{i,d}^{1}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve*;

11.4.2.1.6 $ExtL10NP_{i,d}^{PD}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.7 $P30RRef_{i}^{1}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

11.4.2.1.8 $P30RIntCong_{i,d}^{1}$ designates the Pass 1 interval i internal congestion component for *thirty-minute operating reserve*;

11.4.2.1.9 $P10NRef_{i}^{1}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

11.4.2.1.10 $P10NIntCong_{i,d}^{1}$ designates the Pass 1 interval i internal congestion component for non-synchronized *ten-minute operating reserve*;

11.4.2.1.11 $P10NExtCong_{i,d}^{1}$ designates the Pass 1 interval i *intertie* congestion component for non-synchronized *ten-minute operating reserve*; and

11.4.2.1.12 $P10NExtCong_{i,d}^{PD}$ designates the *intertie* congestion component for non-synchronized *ten-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*.

11.4.2.2 The *real-time calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, an internal congestion component and an *intertie* congestion component for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$, for each class of *operating reserve*, subject to section 11.4.2.8, as follows:

$InitIntL30RP_{i,d}^{1} = InitP30RRef_{i}^{1} + InitP30RIntCong_{i,d}^{1}$ where:

$InitP30RRef_{i}^{1} = SP30R_{i}^{1}$ and

$$InitP30RIntCong_{i,d}^{1} = \sum_{r \in ORREG_d} SPREGMin30R_{i,r}^{1} - \sum_{r \in ORREG_d} SPREGMax30R_{i,r}^{1}$$

$$InitIntL10NP_{i,d}^{1} = InitP10NRef_{i}^{1} + InitP10NIntCong_{i,d}^{1}$$

where:

$$InitP10NRef_{i}^{1} = SP10R_{i}^{1} + SP30R_{i}^{1}$$

and

$$InitP10NIntCong_{i,d}^{1} = \sum_{r \in ORREG_d} \left(SPREGMin10R_{i,r}^{1} + SPREGMin30R_{i,r}^{1}\right) - \sum_{r \in ORREG_d} \left(SPREGMax10R_{i,r}^{1} + SPREGMax30R_{i,r}^{1}\right)$$

11.4.2.3 The *real-time calculation engine* shall calculate initial *locational marginal prices*, and its components for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ for each class of *operating reserve* as follows:

11.4.2.3.1 If the *intertie* is import congested in pre-dispatch ($P30RExtCong_{i,d}^{PD} < 0$ or $P10NExtCong_{i,d}^{PD} < 0$), then the prices and components are determined in accordance with section 11.4.2.4;

11.4.2.3.2 If the *intertie* is not import congestion in pre-dispatch ($P30RExtCong_{i,d}^{PD} \geq 0$ or $P10NExtCong_{i,d}^{PD} \geq 0$) or if an *intertie zone* is out-of-service, then the prices and components are determined in accordance with section 11.4.2.5.

11.4.2.4 The *real-time calculation engine* shall calculate an initial *locational marginal price* and an external congestion component for the *intertie congestion price* for each class of *operating reserve* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$InitExtL30RP_{i,d}^{1} = min(InitIntL30RP_{i,d}^{1}$,

$ExtL30RP_{i,d}^{PD}$); and

$$InitP30RExtCong_{i,d}^{1} = InitExtL30RP_{i,d}^{1} - InitIntL30RP_{i,d}^{1}.$$

$InitExtL10NP_{i,d}^{1} = min(InitIntL10NP_{i,d}^{1}$,

$ExtL10NP_{i,d}^{PD}$); and

$$InitP10NExtCong_{i,d}^{1} = InitExtL10NP_{i,d}^{1} - InitIntL10NP_{i,d}^{1}.$$

11.4.2.5 The *real-time calculation engine* shall calculate an initial *locational marginal price* and an external congestion component for the *intertie congestion price* for each class of *operating reserve* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$InitExtL30RP_{i,d}^{1} = InitIntL30RP_{i,d}^{1}$; and

$InitP30RExtCong_{i,d}^{1} = 0.$

$InitExtL10NP_{i,d}^{1} = InitIntL10NP_{i,d}^{1}$;

and

$InitP10NExtCongi,d1 = 0.$

11.4.2.6 If the initial *locational marginal price* ($InitExtL30RP_{i,b}^{1}$) is not within the *settlement* bounds ($ORPrcFlr, ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the congestion components for *thirty-minute operating reserve* as follows:

$$IntL30R = InitP30RRef_{i}^{1} + InitP30RIntCong_{i,d}^{1}$$

If $InitP30RRef_{i}^{1} > ORPrcCeil$, set $P30RRef_{i}^{1} = ORPrcCeil$;

If $InitP30RRef_{i}^{1} < ORPrcFlr$, set $P30RRef_{i}^{1} = ORPrcFlr$;

Otherwise, set $P30RRef_{i}^{1} = InitP30RRef_{i}^{1}$;

Set $P30RIntCong_{i,d}^{1} = ExtL30RP_{i,b}^{1} - P30RRef_{i}^{1}$;

If $InitExtL30RP_{i,b}^{1} > ORPrcCeil$, set $ExtL30RP_{i,b}^{1} = ORPrcCeil$;

If $InitExtL30RP_{i,b}^1 < ORPrcFlr$, set $ExtL30RP_{i,b}^1 = ORPrcFlr$;

Otherwise, $ExtL30RP_{i,b}^1 = InitExtL30RP_{i,b}^1$; and

Set $P30RExtCong_{i,d}^1 = ExtL30RP_{i,b}^1 - P30RRef_i^1 - P30RIntCong_{i,d}^1$

11.4.2.7 If the initial *locational marginal price* ($InitExtL10NP_{i,d}^1$) is not within the *settlement* bounds ($ORPrcFlr, ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the congestion components for *ten-minute operating reserve* as follows:

$$IntL10N = InitP10NRef_i^1 + InitP10NIntCong_{i,d}^1$$

If $InitP10NRef_i^1 > ORPrcCeil$, set $P10NRef_i^1 = ORPrcCeil$;
If $InitP10NRef_i^1 < ORPrcFlr$, set $P10NRef_i^1 = ORPrcFlr$;

Otherwise, $P10NRef_i^1 = InitP10NRef_i^1$; and

Set $P10NIntCong_{i,d}^1 = L10NP_{i,b}^1 - P10NRef_i^1$

If $InitExtL10NP_{i,b}^1 > ORPrcCeil$, set $ExtL10NP_{i,b}^1 = ORPrcCeil$;

If $InitExtL10NP_{i,b}^1 < ORPrcFlr$, set $ExtL10NP_{i,b}^1 = ORPrcFlr$;

Otherwise, $ExtL30RP_{i,b}^1 = InitExtL10NP_{i,b}^1$; and

Set $P10NExtCong_{i,d}^1 = ExtL10NP_{i,b}^1 - P10NRef_i^1 - P10NIntCong_{i,d}^1$

11.4.2.8 The *locational marginal price* calculated by the *real-time calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. Reserve imports associated with the same *boundary entity resource* bus, but specified as ocurring at a different *intertie zone*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these reserve imports shall utilize shadow prices associated with *intertie* limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

11.5 Pricing for Islanded Nodes

11.5.1 For *non-quick start resources* that are not connected to the *main island*, the *real time calculation engine* shall use the following reconnection logic where enabled by the *IESO* in the order set out below to calculate the *locational marginal prices* for *energy*:

11.5.1.1 Determine the connection paths over open switches that connect the *non quick start resource* to the *main island*;

11.5.1.2 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; and

11.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

11.5.2 For all (i) *resources* other than those specified in section 11.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 11.5.1; the *real-time calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices* for *energy*, using a node-level and *facility*-level substitution list determined by the *IESO*:

11.5.2.1 Use the *locational marginal price* for *energy* at a node in the node-level substitution list where defined and enabled by the *IESO*, provided such node is connected to the *main island*;

11.5.2.2 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes at the same voltage level within the same *facility* that are connected to the *main island*;

11.5.2.3 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes within the same *facility* that are connected to the *main island*;

11.5.2.4 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes from another *facility* that is connected to the *main island*, as determined by the *facility*-level substitution list where defined and enabled by the *IESO*; and

11.5.2.5 If a price is unable to be determined in accordance with sections 11.5.2.1 through 11.5.2.4, use the locational margi*nal price* for *energy* for the *reference bus*.