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MRP DAM Engine Pre-Implementation Review

Independent Electricity System Operator

As of February 29, 2024

pwc

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 Day-Ahead Market (DAM) Calculation Engine for the IESO Market Renewal Program (MRP). The MRP is intended to enhance Ontario's electricity market design, by improving how electricity is supplied, scheduled, and priced. Specifically, the DAM will enable market participants to submit bids and offers for energy and operating reserve products one day ahead of the real-time market and receive financially binding schedules and prices. It will enhance market efficiency, reduce uncertainty, and risk, and improve operational reliability.

This review of the DAM engine was conducted from September 2023 to February 2024 using the market rules described in Chapter 7, Appendix 7.1A (MR-00458-R00). This review focused on assessing the compliance of the scheduling and pricing algorithms that maximize trade gains for energy and operating reserves and ensure grid reliability against the market rules. All tests were conducted on a non-production landscape using test data provided by the IESO from an October 6, 2023, run of the DAM engine. The purpose of the review was to assess the compliance of the MRP calculation engines against the new market rules.

A suite of automated and scenario tests was developed and executed against the input and output of the Day-Ahead Market Calculation Engine (DAM-CE) to assess the compliance with the applicable market rules. Automated tests were used to screen DAM resource schedules to detect economically sub-optimal dispatches and violations of operational limits for both energy and operating reserves for all resources across all dispatch hours in a 24-hour period. 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 whether the market rules are respected within the calculation engines.

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

Summary of Findings

The following observations were made during the review of the DAM engine:

- The engine 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 quickstart 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.

Three (3) exceptions that were observed in the review are highlighted below.

1. **Resource Cost Exceptions**

   For Non-Quick Start (NQS) resources, the following exceptions were noted:

   - Start-up cost was incorrectly excluded from the mitigated scheduling and pricing steps, and
   - Speed-no-load was incorrectly included in the resource cost calculation for the DAM scheduling and pricing steps.

   A limited number of scenario tests focused on the exceptions described above were performed after the IESO applied a patch to the DAM engine. Based on a sample of resources and intervals observed, these exceptions were resolved.

2. **MPM Exceptions – Conduct Test**

   A subset of resources (i.e., 2 resources) were incorrectly flagged to have passed or failed the **conduct test** for energy resources in a Narrowly Constrained Area (NCA). The IESO indicated 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.

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

   A subset of resources (i.e., 5 resources) were 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. The IESO informed PwC that a patch for these exceptions has been applied, 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 DAM solution, as well as the overall optimality of the Pre-Dispatch (PD) and Real-Time (RT) solutions given that they leverage outputs from DAM.

Note: A separate report provides the results of the independent review for the Pre-Dispatch and the Real-Time calculation engines.

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 DAM-CE was conducted between September 2023 and February 2024.

Overview of the DAM Calculation Engine

The DAM calculation engine produces day-ahead hourly financially binding schedules and prices for energy and operating reserves, generates commitment decisions for eligible Non-Quick Start (NQS) resources, and performs ex-ante Market Power Mitigation (MPM) processes.

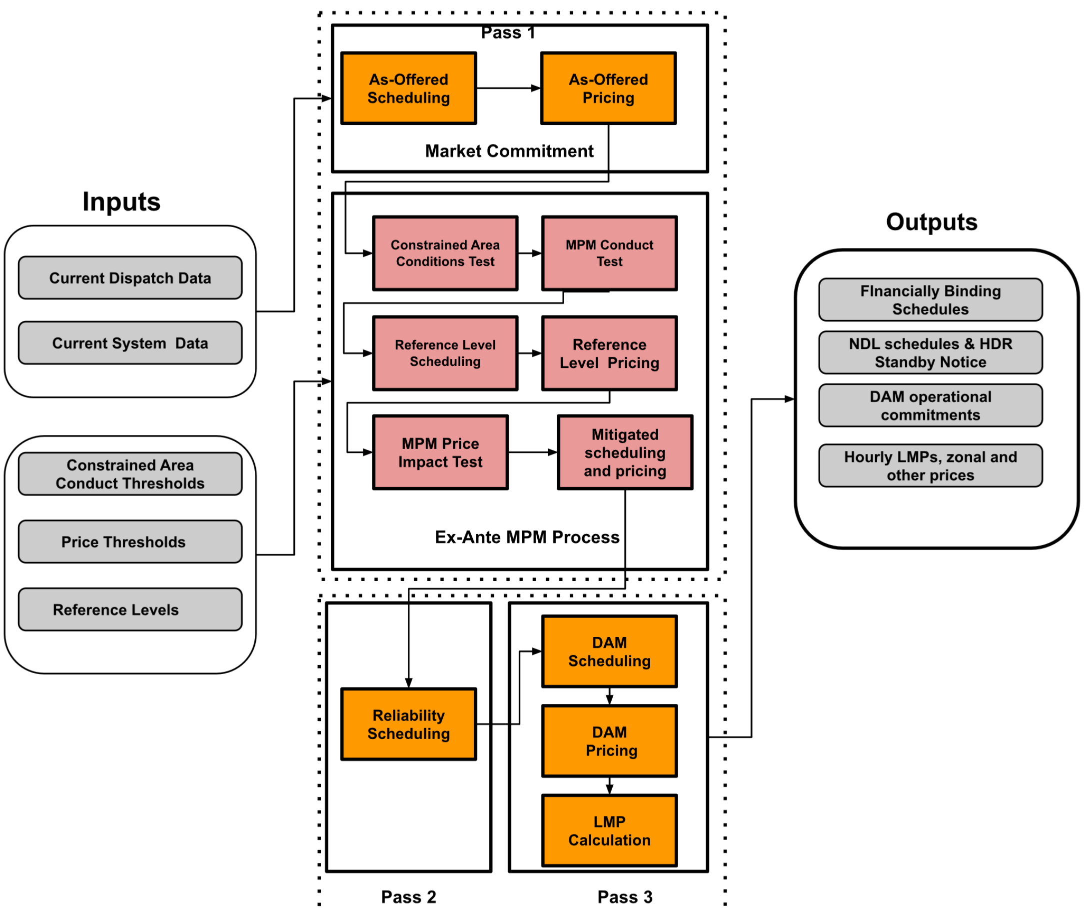
The DAM engine focuses on scheduling and pricing algorithms that maximize trade gains for energy and operating reserves and ensures the reliability and security of the IESO-controlled grid. The key improvements the DAM engine delivers include producing financially binding day-ahead market schedules and prices for participating resources, providing accurate pricing signals aligned with real-time demand and system conditions, encouraging increased participation from imports and exports in the day-ahead timeframe, generating outputs used in the commitment process, ensuring day-ahead schedules are accounted for in the pre-dispatch time frame, and the enforcement of a competitive market in identified constrained areas where there is potential for market participants to exert market power due to limited supply.

The following explains the project objective, scope, approach, and results of developing the DAM calculation engine:

- The objective of the DAM calculation engine is to determine the optimal schedule and price for each market resource and time interval, based on the bids and offers submitted by market participants, the demand forecast, the transmission network constraints, and the security and reliability requirements.
- The scope of the DAM calculation engine covers the formulation and implementation of the mathematical optimization model, inputs, outputs, and integration with other market systems and processes. The DAM engine uses mixed-integer linear programming (MILP) techniques to solve the optimization problem and leverages existing software platforms and tools to implement the solution.
- The engine was designed through extensive stakeholder engagement, consultation, and collaboration to ensure the alignment of the DAM design with the market needs and expectations.
- The results of the DAM calculation engine are the generation of hourly schedules and prices for energy and operating reserve resources, as well as various reports and metrics to support market analysis and settlement. The results also include the evaluation of the performance and benefits of the DAM calculation engine, such as the reduction of uplift payments, the increase of social welfare, and the improvement of price signals and resource adequacy.

Figure 1 provides an overview of the overall process for the DAM calculation engine. The inputs, processes and outputs of the DAM calculation engine are described below. Further details on the inputs and outputs of DAM detail can be found in *Figure 2*.

Figure 1: DAM Scheduling and Pricing Overview Diagram



Inputs to the DAM calculation Engine

The optimization functions, ex-ante MPM process and security assessment functions that make up the DAM 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 IESO inputs, 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), Tie-Breaking Modifier Database (TBMD), 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, and IESO operating security limits, to ensure power flows remain within reliability criteria. The function also leverages the network model as inputs to perform security analysis of the grid.

Operations of the DAM Calculation Engine

Unlike the multiple runs of the existing Day-Ahead Commitment Engine (DACE), the DAM-CE is executed in a single run and occurs in the eastern prevailing time (EPT). The DAM data submission window will be between 06:00 – 10:00 EPT. The engine will run at 10:00 EPT and the DAM schedules, commitments and prices for the next dispatch day will be published at 13:30 EPT, and no later-than 15:30 EPT.

The DAM-CE operates over three passes to determine the least-cost security-constrained solution for a dispatch day based on the day-ahead bids and offers submitted, and operational characteristics of all resources. Each pass ensures the creation of a financially binding DAM schedule and Locational Marginal Prices (LMPs).

The passes perform the following functions:

Pass 1: Determines the hourly commitment statuses and resource schedules to meet the **average** hourly demand and compute the initial set of hourly LMPs.

Pass 2: Determines the hourly commitments statuses and resource schedules required to meet **peak** hourly demand.

Pass 3: Updates the hourly commitment statuses as determined by prior passes (Pass 1 & 2), and computes resource energy schedules and hourly LMPs.

Table 2: DAM Calculation Engine Pass Summary

Pass 1 Market Commitment & MPM	Pass 2 Reliability Scheduling	Pass 3 DAM Scheduling & Pricing
• Determines an initial set of schedules and prices as well as initial commitments for eligible NQS resources • Includes the ex-ante MPM process	• Determines additional NQS resource commitments if required to meet peak forecast demand • Uses as-offered or mitigated dispatch data, resource schedules & LMPs from Pass 1 • Uses IESO's centralized forecast for wind and solar resources • Excludes virtual transactions and bids from price responsive loads	• Determines final financially binding energy and operating reserve schedules and corresponding shadow prices used to calculate settlement-ready LMP's • Uses NQS commitment decisions and import and export schedules determined in Pass 1 and Pass 2 • Uses the same set of market participant and IESO inputs used in Pass 2

Outputs of the DAM Calculation Engine

The result of the DAM calculation engine is a set of financially binding resource schedules, standby notices for hourly-demand resources, and operational commitments, as well as market-settlement ready prices for all resources that are used to meet the IESO average demand forecast for the next dispatch day.

3. Objective and scope of review

Objective

The IESO commissioned the independent pre-implementation review of the DAM Calculation Engine, to assess if it is operating in compliance with the draft Market Rules for the Ontario electricity market as defined in the Market Renewal Program (Chapter 7 - Appendix 7.1A (MR-00458-R00)), and as amended in *Appendix B* of this document.

Scope of review

The tests for the DAM Calculation Engine were conducted using test data extracted by the IESO from an engine run on October 06, 2023.

Scope inclusions

- Results of the DAM 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 Cost, Locational Marginal Prices and other Settlement-Ready Prices were also considered as part of the review.
- Economic efficiency of schedules produced by DAM, 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 DAM inputs were considered to assess the impact of the Market Power Mitigation process on resulting output.

Scope exclusions

The scope does not include:

- Performing any validation on the completeness and accuracy of the input data and whether they were submitted into the DAM Calculation Engine accurately and completely.
- Any review or assessment over the design and operating effectiveness of controls relating to the DAM processes, including issuing any external review opinion.
- Other components within the solution:
  - User interface, DAM Application and any reporting outputs
  - Obligation Indicator Index (OII)

– Flow-limited transmission circuits
– Internal processes of the DAM solution such as the validation of completeness and accuracy of 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) because it is dependent on the network design model that represents the IESO grid.

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 DAM review, our ground-truth was based on Chapter 7 - Appendix 7.1A (MR-00458-R00) of the IESO Market Rules. 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:

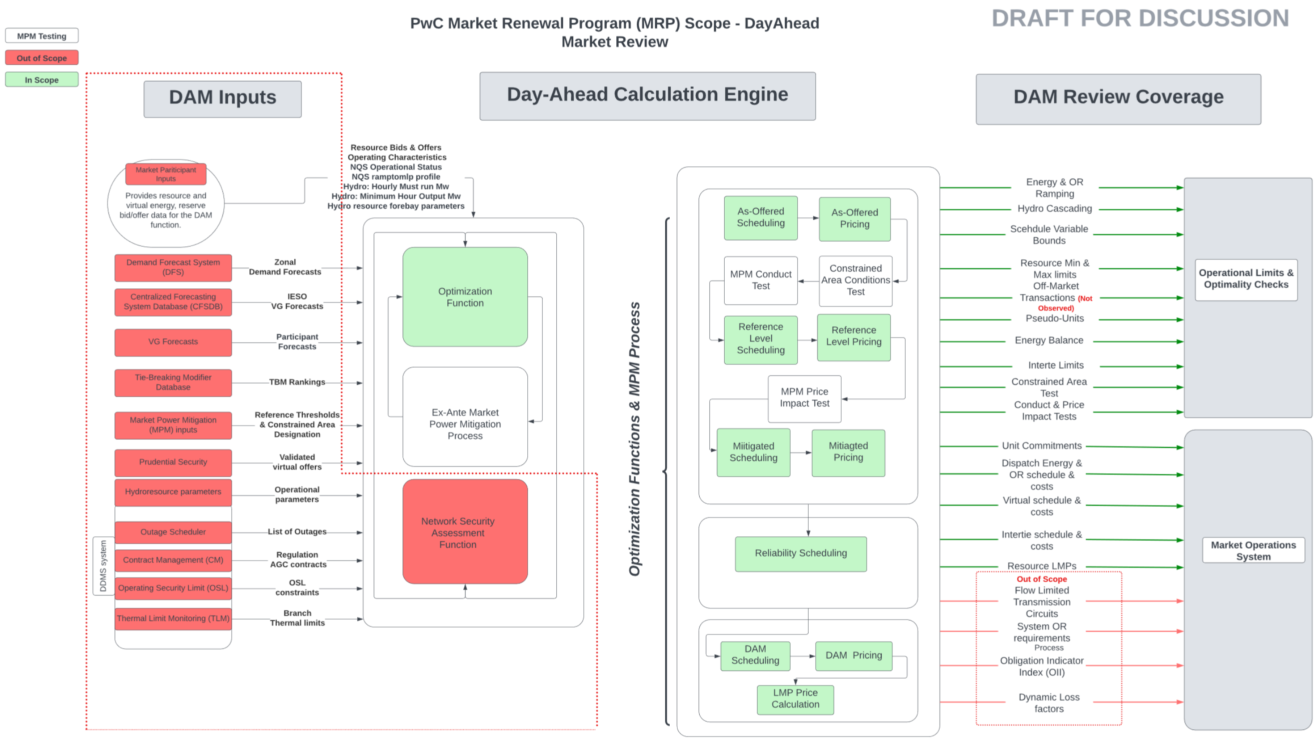
- Off-market transactions, reserve activation and mid-hour import/export schedule changes due to external reliability constraints. Typically, these are tested in a production environment based on actions taken by the control room, but there is no expectation that it can be triggered within the engine 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 and 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 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 2: Overall DAM Calculation Engine Test Scope



4. PwC’s pre-implementation review approach

Review of the DAM Calculation Engine

Our approach to the DAM review was to assess the outputs of the DAM calculation engine for violations of the in-scope Market Rules as drafted in the Market Renewal Program (MRP) Chapter 7 - Appendix 7.1A. 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 24-hours intervals of the base case provided by the IESO.

We developed and executed automated screening tests to assess the schedules produced by the DAM calculation engine for compliance with the market rules related to operational limit violations and economic optimality. The test scripts were executed to cover each hour of the test day for all resources (i.e., ~400) in the IESO-controlled grid.

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 DAM inputs for the save case of the original data and observing the effects on the applicable outputs. Save cases are saved data inputs, intermediate, and final outputs from a DAM calculation engine run. These data extracts allowed us to screen the data that was output from the calculation engine 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 DAM procedural and high-level design documentation; and
- Interviewing IESO personnel responsible for the implementation of the DAM calculation engine.

Automated testing

We developed and executed automated screening tests to assess the DAM calculation engine produced outputs (i.e., schedules, resource costs, commitments, and prices) are compliant with the 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 DAM Calculation Engine output with the mathematical formulations and operational limits as detailed in Appendix 7.1A of the Market Rules drafted for the MRP.

- Analysis of the DAM 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 24-hour intervals in the dispatch day as provided in the base case.
- Review of the DAM 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 DAM calculation engine output.

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

Table 3: Overview of PwC's Automated Tests

Automated Test	Test Objectives
Schedule Variable Bounds	To check if the resources scheduled are within their expected bounds or limits.
Resource Schedule Maximum & Minimum	To check if resource schedules respect the operational minimum and maximum limits.
OR Scheduling & Ramping	To check if the resource operating reserve schedules respect their schedule requirements and operational limits.
Pseudo-Unit Translation & Constraints	To check that a resource's pseudo units are modelled correctly based on the underlying combustion and steam energy components.
Wheeling Through Transactions	To check that the amount of scheduled export energy equals the amount of scheduled import energy.
Energy Ramping - MIO	To check that the dispatch energy schedules respect a resource's ramp capacity throughout its ramp-up and ramp-down periods.
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.
Max Number of Starts, MGBRT, MGBDT - NQS	To check that NQS resource parameters and statuses are respected in the solution.
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.
Total OR balance - Reliability	To check that total resource operating reserve contributions meet the total operating reserve requirements for all the hours.
LMP calculation for Energy and OR	To check that LMPs are being computed consistently in accordance with the market rules.
Resource Cost Calculation	To check that resource costs accurately account for appropriate commitment and dispatch costs in accordance with the applicable market rules.

Automated Test	Test Objectives
MPM Conduct Test	To check if the appropriate conditions were met for resources identified to have passed or failed the DAM conduct test.
MPM Price Impact Test	To check if the appropriate conditions were met for resources identified to have passed or failed the DAM price impact test.

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:

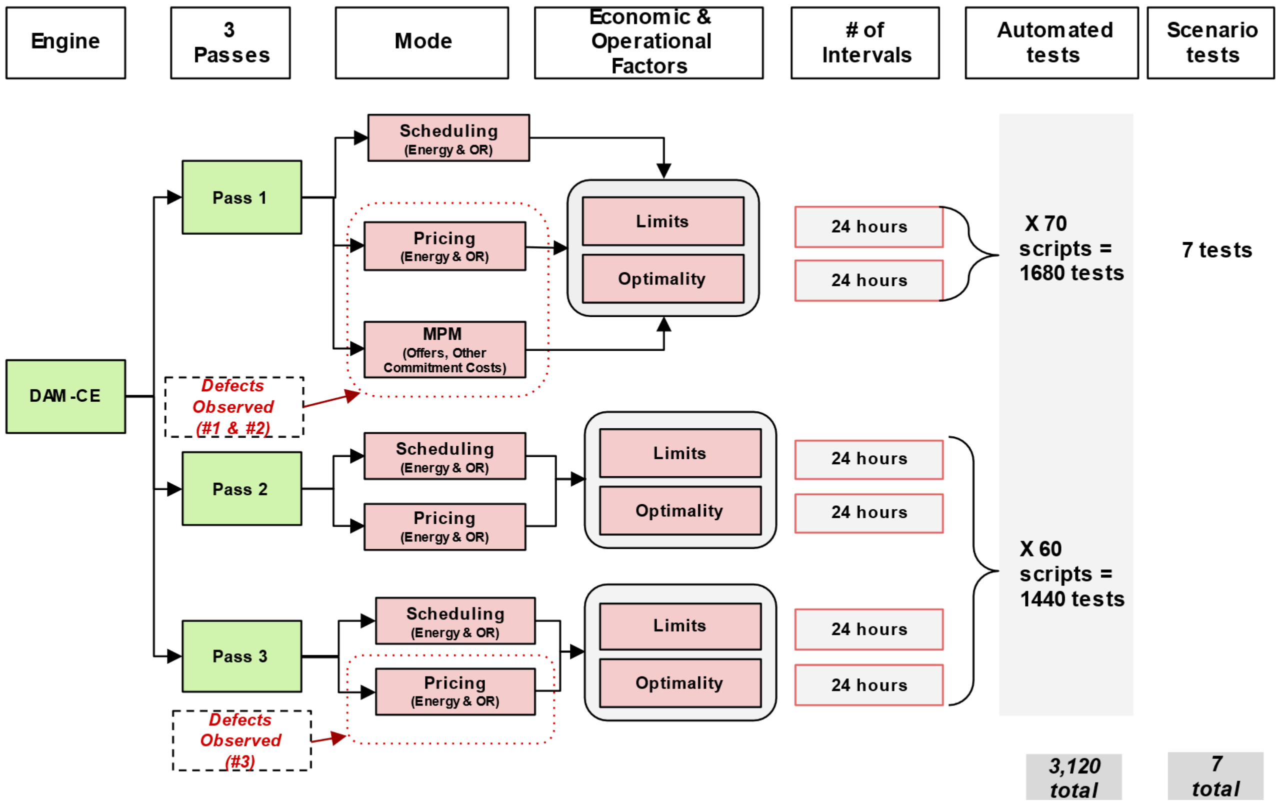
- Triggering changes in penalty factor violations and LMPs.
- Verifying that the scheduled Energy and OR dispatches respect the optimal cost solution.
- Observing potential changes in cost solution.
- Observing the presence of high-cost solutions if NQS resources are not committed.
- Observing energy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

See *Table 4* for a list of scenario tests performed and its objectives.

Table 4: Overview of PwC's Scenario Tests

Scenario Test	Test Objectives
Violation Testing for Penalty Cost Factors and Intertie Limits	To observe violation variables and how they impact LMPs when conditions are not met.
Energy and OR Co-Optimization	To observe if the scheduled energy and operational reserve dispatches respect the optimal cost solution.
Base Case Optimization Testing - (Non-quick start Units)	To observe if the solution cost will be higher when NQS resources are not committed or ifs 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.
Dispatchable Hydroelectric Generation Resources - Schedule Constraints, Forebays, and Cascading.	To observe that all relevant limits relating to forebays, cascade flow and energy generators are applied correctly.
Tie-Breaking Mechanism	To observe the tie breaking mechanism for variable generation resources with equivalent LMPs dispatched for energy and OR.
Objective Function	To re-compute objective functions to incorporate potential costs or resource scenarios not observed during automated testing.

Figure 3: Overview of PwC's DAM 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 4 and 5 show a report of the automated and scenario test results.

Summary of Results

The DAM 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 5* 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 6*, for the results of the scenario tests conducted.
3. For all resources dispatched for energy and/or operating reserves, while recomputing the resource cost to review DSO provided resource cost calculations, some exceptions were identified:
    a. In Pass 1, resource cost calculations did not include appropriate startup cost in mitigated scheduling and pricing steps,
    b. In Pass 3, resource cost calculations incorrectly included speed-no-load cost in the scheduling and pricing steps.

    These exceptions could lead to inaccurate commitment cost values and potentially impact the overall optimality of the DAM solution due to incorrect unit commitments, prices, and dispatch schedules. However, the IESO implemented a patch, and PwC performed limited scenario testing on a sample of resources to observe and confirm that start-up and speed-no-load costs have been accounted correctly for the DAM passes and engine steps impacted.

4. For the Ex-ante MPM, 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, a subset of resources (i.e., 2 resources) in Narrowly Constrained Areas (NCA) were incorrectly flagged to have failed or passed.
    b. For the MPM Price Impact Test for energy, a subset of resources (i.e., 5 resources) in Narrowly Constrained Areas (NCA) were incorrectly flagged to have failed or passed.

    These exceptions could lead to incorrect energy offers being used that can impact the overall optimality of the DAM solution. The IESO informed PwC that patches for these exceptions have been applied and tested, but testing was not re-performed by PwC.

Table 5: Result Overview of PwC's Automated Tests

Automated Test	DAM Test Result	Comments
Objective Functions	No exceptions	NA
Schedule Variable Bounds	No exceptions	NA
Resource Schedule Maximum & Minimum	No exceptions	NA
OR Scheduling & Ramping	No exceptions	NA
Pseudo-Unit Translation & Constraints	No exceptions	NA
Wheeling Through Transactions	No exceptions	NA
Energy Ramping - MIO	No exceptions	NA
OR Ramping - MIO	No exceptions	NA
Max Number of Starts, MGBRT, MGBDT - NQS	No exceptions	NA
Total Energy balance - Reliability	No exceptions	NA
Total OR balance - Reliability	No exceptions	NA
LMP calculation for Energy and OR	No exceptions	NA
Resource Cost Calculation	Exceptions	IESO applied the patch on January 31st, 2024, and PwC performed limited scenario testing on a sample of resources. This has been resolved.
MPM Conduct Test	Exceptions	IESO informed PwC that a patch has been applied and tested, but PwC did not retest.
MPM Price Impact Test	Exceptions	IESO informed PwC that a patch has been applied, and tested but PwC did not retest.

Table 6: Result Overview of PwC's Scenario Tests

Scenario Test	DAM Test Result	Comments
Violation Testing for Penalty Cost Factors and Intertie Limits	No exceptions	NA
Energy and OR Co-Optimization	No exceptions	NA
Base Case Optimization Testing - Test 1 (Non-quick start Units)	No exceptions	NA
Base Case Optimization Testing - Test 2 (Non-quick start Units)	No exceptions	NA
Dispatchable Hydroelectric Generation Resources - Schedule Constraints	No exceptions	NA
Dispatchable Hydroelectric Generation Resources - Energy Limited Resource Schedule Constraints	No exceptions	NA

Scenario Test	DAM Test Result	Comments
Dispatchable Hydroelectric Generation Resources - Forebay Max & Min Energy	No exceptions	NA
Dispatchable Hydroelectric Generation Resources - Cascade Max & Min Energy	No exceptions	NA
Tie-Breaking Mechanism	No exceptions	NA
Objective Function	No exceptions	NA

Appendices

Appendix A – Chapter 7 - Appendix 7.1 (The DAM Calculation Engine)

The Market Rules subject of the review is provided below, extracted from Market Rule Amendment Proposal Form (Identification No. MR-00458-R00) draft published as of July 8, 2022.

1 Appendix 7.1 – The Day-Ahead Market Calculation Engine Process

1.1 Purpose

1.1.1 This appendix describes the process used by the *day-ahead market calculation engine* to determine commitments, schedules and prices for the *day-ahead market.*

2 Day-Ahead Market Calculation Engine

2.1 Passes of the Day-Ahead Market Calculation Engine

2.1.1 The *day-ahead market calculation engine* shall execute three passes to produce *day-ahead schedules*, commitments and *locational marginal prices*.

2.1.1.1 Pass 1, the Market Commitment and Market Power Mitigation Pass in accordance with section 7;

2.1.1.2 Pass 2, the Reliability Scheduling and Commitment Pass in accordance with section 17; and

2.1.1.3 Pass 3, the DAM Scheduling and Pricing Pass, in accordance with section 19.

3 Information Used by the Day-Ahead Market Calculation Engine

3.1.1 The *day-ahead market calculation engine* shall use the information in section 3A.1 of Chapter 7.

4 Sets, Indices and Parameters Used in the Day-Ahead Market 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 $B^{PRL} \subseteq B$ designates the set of buses identifying *price responsive loads*;

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

4.1.5 $B^{HDR} \subseteq B$ designates the set of buses identifying *hourly demand response resources*;

4.1.6 $B^{NDG} \subseteq B$ designates the set of buses identifying *non-dispatchable generation resources*;

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

4.1.8 $B^{NQS} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable non-quick start resources*;

4.1.9 $B^{PSU} \subseteq B^{NQS}$ designates the subset of buses identifying *pseudo-units*;

4.1.10 $B^{VG} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable variable generation resources*;

4.1.11 $B^{ELR} \subseteq B^{DG}$ designates the subset of buses identifying *energy limited resources*;

4.1.12 $B^{HE} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources*;

4.1.13 $B_s^{HE} \subseteq B^{HE}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources* in set s ∈ SHE;

4.1.14 $\wp(B^{HE})$ designates the set of all subsets of the set B^{HE};

4.1.15 $B_{up}^{HE} \subseteq \wp(B^{HE})$ 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*;

4.1.16 $B_{dn}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all downstream d*ispatchable* 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*;

4.1.17 $B_r^{REG} \subseteq B$ designates the set of internal buses in *operating reserve* region r ∈ORREG;

4.1.18 $B^{PST} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* with a share of steam turbine $p \in PST$;

4.1.19 $B^{NO10DF} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* that cannot provide *ten-minute operating reserve* from the duct firing region;

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

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

4.1.22 $D^{GMPRef} \subseteq D$ designates the set of *global market power reference intertie zones*, and *boundary entity resources* for those *interties*;

4.1.23 $D_r^{REG} \subseteq D$ designates the set of *intertie zone* buses identifying *boundary entity resources* in *operating reserve* region $r \in ORREG$;

4.1.24 $DX \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids*;

4.1.25 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

4.1.26 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone* a ∈ A;

4.1.27 $DX_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone* a ∈ A;

4.1.28 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone* a ∈ A;

4.1.29 $DX_h^{EM} \subseteq DX$ designates the *intertie zone* buses corresponding to *emergency energy* export transactions for hour h ∈ {1, . . ,24};

4.1.30 $DX_h^{INP} \subseteq DX$ designates the *intertie zone* buses corresponding to inadvertent *energy* payback export transactions for hour h ∈ {1, . . ,24};

4.1.31 $DI_h^{EM} \subseteq DI$ designates the *intertie zone* buses corresponding to *emergency energy* import transactions for hour h ∈ {1, . . ,24};

4.1.32 $DI_h^{EMNS} \subseteq DI_h^{EM}$ designates the *intertie zone* buses corresponding to emergency energy import transactions that do not support emergency energy export transactions in hour h ∈ {1,..,24};

4.1.33 $DI_h^{INP} \subseteq DI$ designates the *intertie zone* buses corresponding to inadvertent energy payback import transactions for hour h ∈ {1, . . ,24};

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

4.1.35 $F_h \subseteq F$ designates the set of facilities whose pre-contingency limit was violated in hour h as determined by a preceding security assessment function iteration;

4.1.36 $F_{h,c} \subseteq F$ designates the set of *facilities* whose post-contingency limit for contingency c is violated in hour h as determined by a preceding *security* assessment function iteration;

4.1.37 $J_{h,b}^{E}$ designates the set of *bid* laminations for *energy* at $b \in B \cup DX \cup VB$ for hour h ∈ {1,..,24};

4.1.38 $J_{h,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus b ∈ B for hour h ∈ {1, . . ,24};

4.1.39 $J'_{h,b}{}^{10S}$ designates the set of *reference level value* laminations for synchronized *ten-minute operating reserve* at bus b ∈ B for hour h ∈ {1, ...,24};

4.1.40 $J_{h,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus b ∈ B ∪ DX for hour h ∈ {1, . . ,24};

4.1.41 $J'_{h,b}{}^{10N}$ designates the set of *reference level value* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.42 $J_{h,b}{}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus $b \in B \cup$ □X for hour $h \in \{1, . . ,24\}$;

4.1.43 $J'_{h,b}{}^{30R}$ designates the set of *reference level value* laminations for *thirty-minute operating reserve* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.44 $K_{h,b}{}^{E}$ designates the set of *offer* laminations for *energy* at bus $b \in B \cup DI \cup VO$ for hour $h \in \{1, . . ,24\}$;

4.1.45 $K'_{h,b}{}^{E}$ designates the set of *reference level value* laminations for *energy* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.46 $K_{h,b}{}^{DF} \subseteq K_{h,b}{}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$ in hour $h \in \{1, . . ,24\}$;

4.1.47 $K_{h,b}{}^{DR} \subseteq K_{h,b}{}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{\square SU}$ in hour $h \in \{1, . . ,24\}$;

4.1.48 $K_{h,b}{}^{LTMLP}$ designates the set of *offer* laminations for *energy* quantities up to the *minimum loading point* for a *non-quick start resource* at bus $b \in B^{NQS}$ in hour $h \in \{1, . . ,24\}$;

4.1.49 $K'_{h,b}{}^{LTMLP}$ 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 $b \in B^{NQS}$ in hour $h \in \{1, . . ,24\}$;

4.1.50 $K_{h,b}{}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.51 $K'_{h,b}{}^{10S}$ designates the set of *reference level value* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.52 $K_{h,b}{}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B \cup DI$ for hour $h \in \{1, . . ,24\}$;

4.1.53 $K'_{h,b}{}^{10N}$ designates the set of *reference level value* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B$ for hour $h \in \{1, . . ,24\}$;

4.1.54 $K_{h,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus b ∈ B ∪ DI for hour h ∈ {1, . . ,24};

4.1.55 $K'_{h,b}^{30R}$ designates the set of *reference level value* laminations for *thirty-minute operating reserve* at bus b ∈ B for hour h ∈ {1, . . ,24};

4.1.56 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*;

4.1.57 L_y^{NDL} ⊆ L designates the buses contributing to the zonal price for *non-dispatchable load* zone $y \in Y$;

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

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

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

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

4.1.62 BCA designates the set of broad constrained areas;

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

4.1.64 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*;

4.1.65 V designates the set of *offers* and *bids* for *energy* corresponding to *virtual transactions*;

4.1.66 $VB \subseteq V$ designates the set of *bids* for *energy* corresponding to *virtual transactions*;

4.1.67 $VO \subseteq V$ designates the set of *offers* for *energy* corresponding to *virtual transactions;*

4.1.68 $V_m \subseteq V$ designates the set of *offers* and *bids for energy* corresponding to *virtual transactions* at *virtual transaction zone* $m \in M$;

4.1.69 $VB_m \subseteq V_m$ designates the set of *bids for energy* corresponding to virtual transactions at virtual transaction zone $m \in M$;

4.1.70 $VO_m \subseteq V_m$ designates the set of *offers* for *energy* corresponding to virtual transactions at virtual transaction zone $m \in M$;

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

4.1.72 ?? $c h$ 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 $QNDG_{h,b,k}$ designates the maximum incremental quantity of energy that may be scheduled in hour $h \in \{1,..,24\}$ in association with offer lamination $k \in K_{h,b}^E$; and

4.2.1.2 $PNDG_{h,b,k}$ designates the price for the maximum incremental quantity of energy in hour $h \in \{1,..,24\}$ in association with offer lamination $k \in K_{h,b}^E$.

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

4.2.2.1 $MinQDG_b$ designates the minimum loading point;

4.2.2.2 $QDG_{h,b,k}$ designates the maximum incremental quantity of energy above the minimum loading point that may be scheduled in hour $h \in \{1, . . ,24\}$ in association with offer lamination $k \in K_{h,b}^E$;

4.2.2.3 $PDG_{h,b,k}$ designates the price for the maximum incremental quantity of energy in hour $h \in \{1, . . ,24\}$ in association with offer lamination $k \in K_h^{bE}$

4.2.2.4 $Q10SDG_{h,b,k}$ designates the maximum incremental quantity of synchronized ten-minute operating reserve in hour $h \in \{1, . . ,24\}$ in association with offer lamination $k \in K_{hb}^{10S}$;

4.2.2.5 $P10SDG_{h,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in hour $h \in \{1, . . ,24\}$ in association with *offer* lamination $k \in K_{h,b}^{10S;}$

4.2.2.6 $P10NDG_{h,b,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour $h \in \{1, . . ,24\}$ in association with *offer* lamination $k \in K_{h,b}^{10N}$;

4.2.2.7 $P10NDG_{h,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour h ∈{1, . . ,24} in association with *offer* lamination k ∈ $K_{h,b}^{10N}$;

4.2.2.8 $Q30RDG_{h,b,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* in hour h ∈ {1, . . ,24} in association with *offer* lamination k ∈ $K_{h,b}^{30R}$;

4.2.2.9 $P30RDG_{h,b,k}$ designates the price of the maximum incremental quantity of *thirty-minute operating reserve* in hour h ∈ {1, . . ,24} in association with *offer* lamination $k \in K_{h,b}^{30R}$;

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

4.2.2.11 $NumRRDG_{h,b}$ designates the number of ramp rates provided in hour h ∈ {1, . .,24};

4.2.2.12. $RmpRngMaxDG_{h,b,w}$ for w∈ {1,..,$NumRRDG_{h,b}$} designates the w^{th} ramp rate break point in hour h ∈ {1, . . ,24};

4.2.2.13 $URRDG_{h,b,w}$ for $w \in \{1,..,NumRRDG_{h,b}\}$ designates the ramp rate in MW per minute at which the *resource* can increase the amount of energy it supplies in hour h ∈ {1, . . ,24} while operating in the range between $RmpRngMaxDG_{h,b,w-1}$ and $RmpRngMaxDG_{h,b,w}$, where $RmpRngMaxDG_{h,b,0}$ shall be equal to zero;

4.2.2.14. $DRRDG_{h,b,w}$ 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 hour h ∈ {1, . . ,24} while operating in the range between $RmpRngMaxDG_{h,b,w-1}$ and $RmpRngMaxDG_{h,b,w}$ where $RmpRngMaxDG_{h,b,0}$ shall be equal to zero;

4.2.2.15 $RLP30R_{h,b}$ designates the reserve loading point for thirty-minute operating reserve in hour $h \in \{1, . . ,24\}$ and

4.2.2.16 $RLP10S_{h,b}$ designates the reserve loading point for synchronized ten-minute operating reserve in hour $h \in \{1, . . ,24\}$.

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

4.2.3.1 $SUDG_{h,b}$ designates the *start-up offer* in hour $h \in \{1, . . ,24\}$;

4.2.3.2 $SNL_{h,b}$ designates the *speed no-load offer* in hour $h \in \{1, . . ,24\}$;

4.2.3.3 $MGBRTDG_b$ designates the *minimum generation block run-time*;

4.2.3.4 $MGBDTDG_b$ designates the *minimum generation block down-time*;

4.2.3.5 $MaxStartsDG_b$ designates the *maximum number of starts per day*;

4.2.3.6 $RampHrs_b$ designates the *ramp hours to minimum loading point*;

4.2.3.7 $RampE_{b,w}$ designates the *ramp up energy to minimum loading point* for $w \in \{1, . . , RampHrs_b\}$;

4.2.3.8 $QLTMLP_{h,b,k}$ designates the maximum incremental quantity of *energy* up to the *minimum loading point* that may be scheduled in hour h $\in \{1, . . ,24\}$ in association with *offer* lamination $k \in K_{h,b}^{LTMLP}$;

4.2.3.9 $PLTMLP_{h,b,k}$ designates the price for the maximum incremental quantity of *energy* up to the *minimum loading point* that may be scheduled in hour h $\in \{1, . . ,24\}$ in association with *offer* lamination $k \in K_{h,b}^{LTMLP}$; and

4.2.3.10 $MGOD??_{h,b}$ designates the minimum generation cost to operate at *minimum loading point* in hour $h \in \{1, . . ,24\}$. This parameter is calculated as follows:

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

4.2.4 With respect to an *energy limited resource* identified by bus b ∈ BELR:

4.2.4.1 $MaxDEL_b$ designates the *maximum daily energy limit* for a single *resource* with or without a registered *forebay.*

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

4.2.5.1 $MinHMR_{h,b}$ designates the *hourly must-run* value for the *resource* in hour $h \in \{1, . . ,24\}$;

4.2.5.2 $MinHO_{h,b}$ designates the *minimum hourly output* for the *resource* in hour $h \in \{1, . . ,24\}$;

4.2.5.3 $MinDEL_b$ designates the minimum *daily energy limit* for a single *resource* with or without a registered *forebay;*

4.2.5.4 $MaxStartsHE_b$ designates the *maximum number of starts* per day for the *resource*;

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

4.2.5.6 ($ForL_{b,i}$, $ForU_{b,i}$) for ￼ ∈ {1, . . , $NFor_b$} designate the lower and upper limits of the *forbidden regions* and indicate that the *resource* cannot be scheduled between $ForL_{b,i}$ and $ForU_{b,i}$ for all $i \in \{1,..,NFor_b\}$.

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

4.2.6.1 $MaxSDEL_s$ designates the *maximum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$; and

4.2.6.2 $MinSDEL_s$ designates the *minimum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$.

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

4.2.7.1 $LNK \subseteq B_{up}^{HE} \times B_{dn}^{HE}$ *designates the set of linked dispatchable hydroelectric generation resources, where ￼NK is a set with elements of the form (b1, b2) and* $b1 \in B_{up}^{HE}$ *and* $b2 \in B_{dn}^{HE}$*;*

4.2.7.2 $Lag_{b1,b2} \subseteq \{0, \ldots, 23\}$ *designates the time lag in hours between upstream dispatchable hydroelectric generation resources* $b1 \in B_{up}^{HE}$ *and downstream dispatchable hydroelectric generation resources* $b_2 \in B_{dn}^{HE}$ *for* $(b1,b2) \in LNK$*; and*

4.2.7.3 $MWhRatio_{b1,b2}$ *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* $(b1,b2) \in LNK$*.*

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 $RampCT_{b,w}$ *designates the quantity of energy injected* ▯ *hours before the pseudo-unit reaches its minimum loading point that is attributed to the combustion turbine for* $w \in \{1, \ldots, RampHrs_b\}$*; and*

4.2.8.4 Ramp$ST_{b,w}$ designates the quantity of *energy* injected *ww* hours before the *pseudo-unit* reaches its *minimum loading point* that is attributed to the steam turbine for $w \in \{1, \ldots, RampHrs_b\}$.

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

4.2.9.1 $QDL_{h,b,j}$ designates the maximum incremental *quantity* of energy that may be scheduled in hour $h \in \{1, \ldots, 24\}$ in association with *bid* lamination $j \in J_{h,b}^E$;

4.2.9.2 $PDL_{h,b,j}$ designates the price for the maximum incremental quantity of *energy* in hour $h \in \{1, \ldots, 24\}$ in association with *bid* lamination $j \in J_{h,b}^E$;

4.2.9.3 $Q10SDL_{h,b,j}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in hour $h \in \{1, \ldots, 24\}$ in association with *offer* lamination $j \in J_{h,b}^{10S}$;

4.2.9.4 $P10SDL_{h,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in hour $h \in \{1, \ldots, 24\}$ in association with *offer* lamination $j \in J_{h,b}^{10S}$;

4.2.9.5 $Q10NDL_{h,b,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in hour h ∈ {1, . . ,24} in association with *offer* lamination $j \in J_{h,b}^{10N}$;

4.2.9.6 $P10NDL_{h,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour h ∈{1, . . ,24} in association with *offer* lamination $j \in J_{h,b}^{10N}$;

4.2.9.7 $Q30RDL_{h,b,j}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled in hour *h* ∈ {1, . . ,24} in association with *offer* lamination $j \in J_{h,b}^{30R}$;

4.2.9.8 $P30RDL_{h,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in hour h∈ {1, . . ,24} in association with *offer* lamination $j \in J_{h,b}^{30R}$;

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 $NumRRDL_{h,b}$ designates the number of ramp rates provided in hour h ∈ {1, . . ,24};

4.2.9.11 $RmpRngMaxDL_{h,b,w}$ for $w \in \{1,..,NumRRDL_{h,b}\}$ designates the w[th] ramp rate break point in hour h ∈ {1, . . ,24};

4.2.9.12 $URRDL_{h,b,w}$ for w ∈ $\{1,..,NumRRDL_{h,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption in hour h ∈ {1, . . ,24} while operating in the range between $RmpRngMaxDL_{h,b,w-1}$ and $RmpRngMaxDL_{h,b,w}$, where $RmpRngMaxDL_{h,b,0}$ shall be equal to zero;

4.2.9.13 $DRRDL_{h,b,w}$ for w ∈ $\{1,..,NumRRDL_{h,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption in hour h ∈ {1, . . ,24} while operating in the range between $RmpRngMaxDL_{h,b,w-1}$ and $RmpRngMaxDL_{h,b,w}$, where $RmpRngMaxDL_{h,b,0}$ shall be equal to zero; and

4.2.9.14 $QDLFIRM_{h,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in hour h ∈ {1, . . ,24}.

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

4.2.10.1 $QHDR_{h,b,j}$ designates the maximum incremental quantity *of* reduction in *energy* consumption that may be scheduled in hour $h \in \{1, . . ,24\}$ in association with *bid* lamination $j \in J_{h,b}^{E}$

4.2.10.2 *$PHDR_{h,b,j}$ designates the price for the maximum incremental quantity of reduction in energy consumption for hour $h \in \{1, . . ,24\}$ in association with bid lamination $j \in J_{h,b}^{E}$;*

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 price responsive load identified by bus $b \in B^{PRL}$:

4.2.11.1 *$QPRL_{h,b,j}$ designates the maximum incremental quantity of energy that may be scheduled in hour $h \in \{1, . . ,24\}$ in association with bid lamination $j \in J_{h,b}^{E}$;*

4.2.11.2 $PPRL_{h,b,j}$ designates the price for the maximum incremental quantity of energy in hour $h \in \{1, . . ,24\}$ in association with bid lamination $j \in J_{h,b}^{E}$; and

4.2.11.3 $QPRLFIRM_{h,b}$ designates the quantity of energy that is bid at MMCP in hour $h \in \{1, . . ,24\}$.

4.2.12 With respect to a virtual transaction:

4.2.12.1 $QVB_{h,v,j}$ designates the maximum incremental quantity of energy that may be scheduled in hour $h \in \{1, . . ,24\}$ from a virtual zonal resource $v \in VB$ in association with bid lamination $j \in J_{h,v}^{E}$;

4.2.12.2 $PVB_{h,v,j}$ designates the price for the maximum incremental quantity of energy in hour $h \in \{1, . . ,24\}$ froma virtual zonal resourcev $\in VB$ in association with bid lamination $j \in J_{h,v}^{E}$;

4.2.12.3 $QVO_{h,v,k}$ designates the maximum incremental quantity of energy that may be scheduled in hour $h \in \{1, . . ,24\}$ from a *virtual zonal resource* $v \in VO$ in association with *offer* lamination $k \in K_{h,v}^{E}$; and

4.2.12.4 $PVO_{h,v,k}$ designates the price for the maximum incremental quantity of *energy* in hour h ∈ {1, . . ,24} from a *virtual zonal resource* v ∈VO in association with *offer* lamination k ∈ $K_{h,v}^{E}$.

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

4.2.13.1 $QIG_{h,d,k}$ designates the maximum incremental quantity of energy that may be scheduled to import in hour h ∈ {1, . . ,24} in association with offer lamination k ∈ $K_{h,d}^{E}$;

4.2.13.2 $PIG_{h,d,k}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to import in hour h ∈ {1, . . ,24} in association with *offer* lamination $k \in K_{h,d}^{E}$;

4.2.13.3 $Q10NIG_{h,d,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled to provide in hour h ∈ {1, . . ,24} in association with *offer* lamination k ∈ $K_{h,d}^{10N}$;

4.2.13.4 $P10NIG_{h,d,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour h ∈{1, . . ,24} in association with *offer* lamination k∈ $K_{h,d}^{10N}$;

4.2.13.5 $Q30RIG_{h,d,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled to provide in hour h ∈ {1, . . ,24} in association with *offer* lamination k ∈ $K_{h,d}^{30R}$; and

4.2.13.6 $P30RIG_{h,d,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in hour *h* ∈ {1, . . ,24} in association with *offer* lamination k ∈ $K_{h,d}^{30R}$.

4.2.14 With respect to a *boundary entity resource* export to *intertie zone* bus d ∈ DX, where the *locational marginal price* represents the price for the *intertie metering point*:

4.2.14.1 $QXL_{h,d,j}$ designates the maximum incremental quantity of energy that may be scheduled to export in hour *h* ∈ {1, . . ,24}in association with bid lamination $j \in J_{h,d}^{E}$;

4.2.14.2 $PXL_{h,d,j}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to export in hour $h \in \{1,..,24\}$ in association with *bid* lamination $j \in J_{h,d}{}^{E}$;

4.2.14.3 $Q10NXL_{h,d,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled to provide in hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,\square}{}^{10\square}$;

4.2.14.4 $P10NXL_{h,d,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$ in association with offer lamination $j \in J_{h,d}{}^{10N}$;

4.2.14.5 $Q30RXL_{h,d,j}$ designates the maximum incremental quantity of thirty- minute operating reserve that may be scheduled to provide in hour h $\in \{1,..,24\}$ in association with offer lamination $j \in J_{h,d}{}^{30R}$; and

4.2.14.6 $P30RXL_{h,d,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in hour h $\in \{1,..,24\}$ in association with offer lamination $j \in J_{h,d}{}^{30R}$.

4.2.15 With respect to a wheeling through transaction:

4.2.15.1 $Lh \subseteq DX \times DI$ designates the set of linked *boundary entity resource* import and export buses corresponding to *wheeling through transactions,* where L_h is a set with elements of the form (dx, di) and $dx \in DX$ and $di \in DI$.

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

4.3.1.1 $FG_{h,b}$ designates the *IESO*'s centralized variable generation forecast for *a variable generation resource* identified by bus $b \in B^{VG}$ in hour $h \in \{1,..,24\}$.

4.3.2 Variable Generation Tie-Breaking

4.3.2.1 $NumVG$ designates the number of *variable generation resources* in the daily *dispatch* order; and

4.3.2.2 $TBM_b \in \{1, . . , NumVG\}$ designates the tie-breaking modifier for the *variable generation resource* at bus b ∈ B^{VG}.

4.3.3 Operating Reserve Requirements

4.3.3.1 $TOT10S_h$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.3.2 $TOT10R_h$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.3.3 $TOT30R_h$ designates the thirty-minute operating reserve requirement;

4.3.3.4 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.3.5 $REGMin10R_{h,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in hour h $\in \{1, . . ,24\}$;

4.3.3.6 $REGMin30R_{h,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region r ∈ ORREG in hour h $\in \{1, . . ,24\}$;

4.3.3.7 $REGMax10R_{h,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$; and

4.3.3.8 $REGMax30R_{h,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$.

4.3.4 Intertie Limits

4.3.4.1 $EnCoeff_{a,z}$ 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;

4.3.4.2 $MaxExtSch_{h,z}$ designates the maximum flow limit for *intertie* flow constraint z $\in Z_{Sch}$ in hour h $\in \{1, . . ,24\}$;

4.3.4.3 $ExtDSC_h$ designates the net interchange scheduling limit for when the net flows over all *interties* from hour $(h - 1)$ to hour h decrease; and

4.3.4.4 $ExtUSC_h$ designates the net interchange scheduling limit for when the net flows over all *interties* from hour $(h - 1)$ to hour h increase.

4.3.5 Resource Minimum and Maximum Constraints

4.3.5.1 Where applicable the minimum or maximum output of a *dispatchable generation resource* or a *non-dispatchable generation resource* and minimum or maximum consumption of a *dispatchable load* may be limited due to *reliability* constraints, applicable *contracted ancillary services*, *outages,* derates, and other constraints, such that:

4.3.5.1.1 $MinDL_{h,b}$ designates the most restrictive minimum consumption limit for the *dispatchable load* in hour h at bus $b \in B_{DL}$;

4.3.5.1.2 $MaxDL_{h,b}$ designates the most restrictive maximum consumption limit for the *dispatchable load* in hour h at bus $b \in B_{DL}$;

4.3.5.1.3 $MinNDG_{h,b}$ designates the most restrictive minimum output limit for the *non-dispatchable generation resource* in hour h at bus $b \in B_{NDG}$;

4.3.5.1.4 $MaxNDGh,b$ designates the most restrictive maximum output limit for the *non-dispatchable generation resource* in hour h at bus $b \in B_{NDG}$;

4.3.5.1.5 $MinDG_{h,b}$ designates the most restrictive minimum output limit for the *dispatchable generation resource* in hour h at bus $b \in B_{DG}$;

4.3.5.1.6 $MaxDG_{h,b}$ designates the most restrictive maximum output limit for the *dispatchable generation resource* in hour h at bus $b \in B^{DG}$;

4.3.5.1.7 $MaxMLP_{h,b}$ designates the maximum output limit in hour h for the *minimum loading point* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.5.1.8 $MaxDR_{h,b}$ designates the maximum output limit in hour h for the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$; and

4.3.5.1.9 $MaxDF_{h,b}$ designates the maximum output limit in hour h for the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$.

4.3.6 Constraint Violation Penalties

4.3.6.1 $(PLdViolSch_{h,i}, QLdViolSch_{h,i})$ for $i \in \{1, .., N_{LdViolh}\}$ designate the price-quantity segments of the penalty curve for under generation used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.2 $(PLdViolPrc_{h,i}, QLdViolPrc_{h,i})$ for $i \in \{1, .., N_{LdViolh}\}$ designate the price-quantity segments of the penalty curve for under generation used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.3 $(PGenViolSch_{h,i}, QGenViolSch_{h,i})$ for $i \in \{1, .., N_{GenViolh}\}$ designate the price-quantity segments of the penalty curve for over generation used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.4 $(PGenViolPrc_{h,i}, QGenViolPrc_{h,i})$ for $i \in \{1, .., N_{GenViolh}\}$ designate the price-quantity segments of the penalty curve for over generation used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.5 $(P10SViolSch_{h,i}, Q10SViolSch_{h,i})$ for $i \in \{1, .., N_{10SViolh}\}$ designate the price-quantity segments of the penalty curve for the synchronized ten-minute operating reserve requirement used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.6 $(P10SViolPrc_{h,i}, Q10SViolPrc_{h,i})$ for $i \in \{1, .., N_{10SViolh}\}$ designate the price-quantity segments of the penalty curve for the synchronized ten-minute operating reserve requirement used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.7 $(P10RViolSch_{h,i}, Q10RViolSch_{h,i})$ for $i \in \{1, .., N_{10RViolh}\}$ designate the price-quantity segments of the penalty curve for the total ten-minute operating reserve requirement used by the As-Offered

Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.8 ($P10RViolPrc_{h,i}$,$Q10RViolPrc_{h,i}$) for i ∈ {1, . . , $N_{10RViolh}$} designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.9 ($P30RViolSch_{h,i}$,$Q30RViolSch_{h,i}$) for i∈{1, . . ,$N_{30RViolh}$} 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 As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.10 ($P30RViolPrc_{h,i}$,$Q30RViolPrc_{h,i}$) for i∈{1, . . ,$N_{30RViolh}$} 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 As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.11 ($PREG10RViolSch_{h,i}$,$QREG10RViolSch_{h,i}$) for i∈{1, . . ,$N_{REG10RViolh}$} designate the price-quantity segments of the penalty curve for area total ten-minute operating reserve minimum requirements used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.12 ($PREG10RViolPrc_{h,i}$,$QREG10RViolPrc_{h,i}$) for i∈{1, . . ,$N_{REG10RViolh}$} designate the price-quantity segments of the penalty curve for area total ten-minute operating reserve minimum requirements used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.13 ($PREG30RViolSch_{h,i}$,$QREG30RViolSch_{h,i}$) for i ∈ {1, . . , $N_{REG30RViolh}$} designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.14 ($PREG30RViolPrc_{h,i}$,$QREG30RViolPrc_{h,i}$) for i∈{1, . . , $N_{REG30RViolh}$} designate the price-quantity segments of the penalty curve for area thirty-minute operating reserve minimum requirements used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.15 ($PXREG10RViolSch_{h,i}$,$QXREG10RViolSch_{h,i}$) for i ∈ {1, . . , $N_{XREG10RViolh}$} designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.16 ($PXREG10RViolPrc_{h,i}$,$QXREG10RViolPrc_{h,i}$) for i ∈{1, . . ,$N_{XREG10RViolh}$} designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.17 ($PXREG30RViolSch_{h,i}$,$QXREG30RViolSch_{h,i}$) for i ∈ {1, . . , $N_{XREG30RViolh}$} designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.18 ($PXREG30RViolPrc_{h,i}$,$QXREG30RViolPrc_{h,i}$) for i ∈ {1, . . , $N_{XREG30RViolh}$} designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.19 $(PPreITLViolSch_{f,h,i}, QPreITLViolSch_{f,h,i})$ for i ∈ $\{1, . . , N_{PreITLViolf,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* f ∈ F used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.20 $(PPreITLViolPrc_{f,h,i}, QPreITLViolPrc_{f,h,i})$ for i ∈ $\{1, . . , N_{PreITLViolf,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* f ∈ F used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.21 $(PITLViolSch_{c,f,h,i}, QITLViolSch_{c,f,h,i})$ for $i \in \{1, . . , N_{ITLViolc,f,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the contingency c ∈ C post-contingency limit of the transmission constraint for *facility* f ∈ F used by As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.22 $(PITLViolPrc_{c,f,h,i}, QITLViolPrc_{c,f,h,i})$ for i ∈ $\{1, . . , N_{ITLViolc,f,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the contingency c ∈ C post-contingency limit of the transmission constraint for *facility* f ∈ F used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.22 $(PPreXTLViolSch_{z,h,i}, QPreXTLViolSch_{z,h,i})$ for i ∈ $\{1, . . , N_{ITLViolc,f,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by z ∈ Z_{Sch} used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.23 $(PPreXTLViolPrc_{z,h,i}, QPreXTLViolPrc_{z,h,i})$ for i ∈ $\{1, .. , N_{PreXTLViolz,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by z ∈ Z_{Sch} used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.24 $(PPreXTLViolPrc_{z,h,i}, QPreXTLViolPrc_{z,h,i})$ for $i \in \{1, .. , N_{PreXTLViolz,h}\}$ designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by z ∈ Z_{Sch} used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.25 $(PNIUViolSch_{h,i}, QNIUViolSch_{h,i})$ for $i \in \{1,..,N_{NIUViolh}\}$ designate the price-quantity segments of the penalty curve for exceeding the hour h net interchange increase constraint between hours $(h-1)$ and h used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.26 $(PNIUViolPrc_{h,i}, QNIUViolPrc_{h,i})$ for $i \in \{1,..,$ ⍰ $_{NIUViolh}\}$ designate the price-quantity segments of the penalty curve for exceeding the hour h net interchange increase constraint between hours $(h-1)$ and h used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.27 $(PNIDViolSch_{h,i}, QNIDViolSch_{h,i})$ for $i \in \{1,..,N_{NIDViolh}\}$ designate the price-quantity segments of the penalty curve for exceeding the hour h net interchange decrease constraint between hours $(h-1)$ and h used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.28 $(PNIDViolPrc_{h,i}, QNIDViolPrc_{h,i})$ for $i \in \{1,..,N_{NIDViolh}\}$ designate the price-quantity segments of the penalty curve for exceeding the hour h net interchange decrease constraint between hours $(h-1)$ and h used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.29 ($PMaxDelViolSch_{h,i}$,$QMaxDelViolSch_{h,i}$)for i ∈ {1, . . ,$N_{MaxDelViolh}$} designate the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.30 ($PMaxDelViolPrc_{h,i}$,$QMaxDelViolPrc_{h,i}$) for *i* ∈ {1, . . ,$N_{MaxDelViolh}$} designate the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.31 ($PMinDelViolSch_{h,i}$,$QMinDelViolSch_{h,i}$) for *i* ∈ {1, . . ,$N_{MinDelViolh}$} designate the price-quantity segments of the penalty curve for under-scheduling a resource's minimum daily energy limit used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.32 ($PMinDelViolPrc_{h,i}$,$QMinDelViolPrc_{h,i}$) for *i* ∈{1, . . ,$N_{MinDelViolh}$} designate the price-quantity segments of the penalty curve for under-scheduling a resource's minimum daily energy limit used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.33 ($PSMaxDelViolSch_{h,i}$,$QSMaxDelViolSch_{h,i}$) for *i* ∈{1, . . ,$N_{SMaxDelViolh}$} designate the price-quantity segments of the penalty curve for exceeding a shared maximum daily energy limit used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.34 ($PSMaxDelViolPrc_{h,i}$,$QSMaxDelViolPrc_{h,i}$) for i ∈{1, . . ,$N_{MaxDelViolh}$} designate the price-quantity segments of the penalty curve for exceeding a shared maximum daily energy limit used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.35 ($PSMinDelViolSch_{h,i}$, $QSMinDelViolSch_{h,i}$) for i ∈{1, . . , $N_{SMinDelViolh}$} designate the price-quantity segments of the penalty curve for under-scheduling a shared minimum daily energy limit used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.36 ($PSMinDelViolPrc_{h,i}$, $QSMinDelViolPrc_{h,i}$) for i ∈{1, . . , $N_{SMinDelViolh}$} designate the price-quantity segments of the penalty curve for under-scheduling a shared *minimum daily energy limit* used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.37 ($POGenLnkViolSch_{h,i}$, $QOGenLnkViolSch_{h,i}$) for i ∈{1, . . , $N_{OGenLnkViolh}$} designate the price-quantity segments of the penalty curve for over generation on a downstream *resource* used by the As-Offered. Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.38 ($PUGenLnkViolSch_{h,i}$, $QUGenLnkViolSch_{h,i}$) for i∈{1,....,$N_{UGenLnkViolh}$} designate the price-quantity segments of the penalty curve for under generation on a downstream resource used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20; and

4.3.6.39 *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*;

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.

4.3.8 Ex-ante Market Power Mitigation

4.3.8.1 *BCACondThresh* designates the threshold for the congestion component of a *resource's locational marginal price* for *energy* and is equal to $25/MWh;

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

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

4.3.8.4 $PDGRef_{h,b,k'}$ designates the reference level value for energy lamination $K' \in K'_{h,b}{}^{E}$ for the resource at bus $b \in B^{DG}$ in hour $h \in \{1,..,24\}$;

4.3.8.5 $P10SDGRef_{h,b,k'}$ designates the reference level value for synchronized ten-minute operating reserve lamination $k' \in K'_{h,b}{}^{10S}$ for the resource at bus $b \in B^{DG}$ in hour $h \in \{1,..,24\}$;

4.3.8.6 $P10NDGRef_{h,b,k'}$ designates the *reference level value* for non-synchronized *ten-minute operating reserve* lamination $k' \in K'_{h,b}{}^{10N}$ for the *resource* at bus $b \in B_{DG}$ in hour $h \in \{1,..,24\}$;

4.3.8.7 $P30RDGRef_{h,b,k'}$ designates the *reference level value* for *thirty-minute operating reserve* lamination $k' \in K'_{h,b}{}^{30R}$ for the *resource* at bus $b \in B^{DG}$ in hour $h \in \{1,..,24\}$;

4.3.8.8 $P10SDLRef_{h,b,j'}$ designates the *reference level value* for synchronized *ten-minute operating reserve* lamination $j' \in J'_{h,b}{}^{10S}$ for the *resource* at bus $b \in B^{DL}$ in hour $h \in \{1,..,24\}$;

4.3.8.9 $P10NDLRef_{h,b,j'}$ designates the *reference level value* for non-synchronized *ten-minute operating reserve* lamination $j' \in J'_{h,b}{}^{10N}$ for the *resource* at bus $b \in B^{DL}$ in hour $h \in \{1,..,24\}$;

4.3.8.10 $P30RDLRef_{h,b,j'}$ designates the reference level value for thirty-minute operating reserve lamination $j' \in J'_{h,b}{}^{30R}$ for the resource at bus $b \in B^{DG}$ in hour $h \in \{1,..,24\}$

4.3.8.11 *SUDGRef*$_{h,b}$ designates the *reference level value* for the *start-up offer* for the *resource* at bus b ∈ B_{NQS} in hour $h \in \{1, . . ,24\}$;

4.3.8.12 *SNLRef*$_{h,b}$ designates the *reference level value* for the *speed no-load offer* for the *resource* at bus b ∈ B_{NQS} in hour $h \in \{1, . . ,24\}$;

4.3.8.13 *PLTMLPRef*$_{h,b,k'}$ designates the *reference level value* for the *energy* up to the *minimum loading point reference level* lamination k' ∈ $K'^{LTMLP}_{h,b}$ of the *offer* for the *resource* at bus b ∈ B^{DG} in hour $h \in \{1, . ..,24\}$;

4.3.8.14 *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%;

4.3.8.15 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;

4.3.8.16 *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%;

4.3.8.17 *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%;

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

4.3.8.19 *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;

4.3.8.20 *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%;

4.3.8.21 *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%;

4.3.8.22 $CTEnThresh1^{BCA}$ 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%;

4.3.8.23 $CTEnThresh2^{BCA}$ 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;

4.3.8.24 $CTSUThresh^{BCA}$ 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%;

4.3.8.25 $CTSNLThresh^{BCA}$ 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%;

4.3.8.26 $CTEnThresh1^{GMP}$ 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%;

4.3.8.27 $CTEnThresh2^{GMP}$ 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;

4.3.8.28 $CTSUThresh^{GMP}$ 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%;

4.3.8.29 $CTSNLThresh^{GMP}$ 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%;

4.3.8.30 $CTORThresh1^{ORL}$ 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%;

4.3.8.31 $CTORThresh2^{ORL}$ 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;

4.3.8.32 $CTEnThresh1^{ORL}$ designates the local 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 10%;

4.3.8.33 $CTEnThresh2^{ORL}$ 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;

4.3.8.34 $CTSUThresh^{ORL}$ 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%;

4.3.8.35 $CTSNLThresh^{ORL}$ 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%;

4.3.8.36 $CTORThresh1^{ORG}$ 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%;

4.3.8.37 $CTORThresh2^{ORG}$ 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;

4.3.8.38 $CTEnThresh1^{ORG}$ 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%;

4.3.8.39 $CTEnThresh2^{ORG}$ 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;

4.3.8.40 *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%;

4.3.8.41 *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%;

4.3.8.42 *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;

4.3.8.43 *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;

4.3.8.44 *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%;

4.3.8.45 *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;

4.3.8.46 *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%;

4.3.8.47 *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;

4.3.8.48 *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%;

4.3.8.49 $ITThresh2^{BCA}$ 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;

4.3.8.50 $ITThresh1^{GMP}$ 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%;

4.3.8.51 $TThresh2^{GMP}$ 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;

4.3.8.52 $ITThresh1^{ORG}$ 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

4.3.8.53 $ITThresh2^{ORG}$ 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.

4.3.9 Weighting Factors for Zonal Prices

4.3.9.1 $WF_{h,m,b}^{VIRT}$ designates the weighting factor for bus $b \in \square_{\square}^{\square IRT}$ used to calculate the price for *virtual transaction zone* $m \in M$ for hour $h \in \{1,..,24\}$;

4.3.9.2 $\square F_{h,y,b}^{VIRT}$ designates the weighting factor for bus $b \in \square_{m}^{VIRT}$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for hour $h \in \{1,..,24\}$; and

4.3.9.3 The weighting factors in section 4.3.9.1 and section 4.3.9.2 shall be obtained by renormalizing the load distribution factors so that for a given hour the sum of weighting factors for a *non-dispatchable load* zone or for a *virtual transaction zone* is one.

4.4 Other Data Parameters

4.4.1 Non-Dispatchable Demand Forecast

4.4.1.1 AFL_h designates the average province-wide *non-dispatchable demand* forecast for hour h ∈ {1, . . , 24} calculated by the *security* assessment function; and

4.4.1.2 PFL_h designates the peak province-wide non-*dispatchable demand* forecast for hour h ∈ {1, . . , 24} calculated by the *security* assessment function.

4.4.2 Variable Generation

4.4.2.1 $AFG_{h,b}$ designates the alternative forecast for a *variable generation resource* identified by bus b ∈ B_{VG} in hour h ∈ {1, . . , 24}, which is either the *registered market participant*-submitted forecast or the *IESO*'s centralized forecast.

4.4.3 Internal Transmission Constraints

4.4.3.1 $PreConSF_{h,f,b}$ designates the pre-contingency sensitivity factor for bus b ∈ B ∪ D indicating the fraction of *energy* injected at bus *b* which flows on *facility f* during hour *h* under pre-contingency conditions;

4.4.3.2 $VPreConSF_{h,f,m}$ designates the pre-contingency sensitivity factor for *virtual transaction zonem m* ∈ *M* indicating the effect of scheduled *energy* at *mm* to flows on *facility f* ∈ F_h in hour *h* under pre-contingency conditions. It shall be determined as the weighted average of the pre-contingency sensitivity factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF_{h,m,b}{}^{VIRT}$ for *virtual transactions*;

4.4.3.3 $AdjNormMaxFlow_{h,f}$ designates the limit corresponding to the maximum flow allowed on *facility f* in hour *h* under pre-contingency conditions;

4.4.3.4 $SF_{h,c,f,b}$ designates the post-contingency sensitivity factor for bus b ∈ B ∪ D indicating the fraction of *energy* injected at bus *b* which flows on *facility f* during hour *h* under post-contingency conditions for contingency *c*;

4.4.3.5 $VSF_{h,c,f,m}$ designates the post-contingency sensitivity factor for *virtual transaction zone m* ∈ *M* indicating the effect of scheduled *energy* at *m* to flows on *facility* f ∈ $F_{h,c}$ in hour *h* under post-contingency conditions for contingency *cc*. It shall be determined as the weighted average of the post-contingency sensitivity factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF_{h,m,b}^{VIRT}$ for *virtual transactions*; and

4.4.3.6 $AdjEmMaxFlow_{h,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in hour h under post-contingency conditions for contingency c.

4.4.4 Transmission Losses

4.4.4.1 $LossAdj_h$ designates any adjustment needed for hour $h \in \{1, .., 24\}$ 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.

4.4.4.2 $MglLoss_{h,b}$ designates the marginal loss factor and represent 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 hour $h \in \{1, .., 24\}$; and

4.4.4.3 $VMglLoss_{h,m}$ designates the marginal loss factor for *virtual transaction zone* $m \in M$ in hour $h \in \{1, .., 24\}$. It shall be determined as the weighted average of the marginal loss factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF_{h,m,b}^{VIRT}$ for *virtual transactions.*

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 *day-ahead market calculation engine* described in section 2.1.1 above.

5.2 Reference Bus

5.2.1 The *IESO* shall use Richview Transformer Station as the *day-ahead market 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 *day-ahead market 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 hour $h \in \{1, . . , 24\}$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K_{h,b}^{E}$, the *offer* price $PDG_{h,b,k}$ shall be modified to $PDG_{h,b,k} - (TBM_b/NumVG)\ \rho$, 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 22.

5.6 Initial Scheduling Assumptions

5.6.1 Initial Schedules

5.6.1.1 The following parameters designate the initial *energy* schedules used for hour 0 in the optimization of the next *dispatch day* and shall be based on the hour ending 24 schedules of the most recent execution of the *pre-dispatch calculation engine* prior to the execution of the *day ahead market calculation engine*:

5.6.1.1.1 $SDL_{0,b,j}$, which designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$;

5.6.1.1.2 $SHDR_{0,b,j}$, which designates the amount of *energy* an *hourly demand response resource* is scheduled to reduce consumption at bus $b \in B^{\square D\square}$;

5.6.1.1.3 $SXL_{0,d,j}$, which designates the amount of *energy* a *boundary entity resource* is scheduled to export at bus d ∈ DX;

5.6.1.1.4 $SDG_{0,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{□G}$;

5.6.1.1.5 $SCT_{0,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{□SU}$;

5.6.1.1.6 $SST_{0,p}$, which designates the schedule of steam turbine $p \in PST$

5.6.1.1.7 $SIG_{0,d,k}$, which *designates* the amount of *energy* that a *boundary entity resource is* scheduled to import from *intertie zone* bus $d \in DI$;

5.6.1.2 The initial schedules for *non-quick start resources* shall be determined to align with the commitment status logic described in section 5.6.2.

5.6.2 The following parameters designate the initial commitment status and number of hours in operation used for hour 0 in the optimization of the next *dispatch day*:

5.6.2.1 $ODG_{0,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{NQS}$ has been scheduled at or above its *minimum loading point*;

5.6.2.2 $InitOperHrs_b$, which designates the number of consecutive hours at the end of previous day for which the *resource* at bus $b \in B_{NQS}$ was scheduled to operate at or above its *minimum loading point*. For *resources* with $ODG_{0,b} = 0$, $InitOperHrs_b$ shall be set to zero.

5.6.3 Initial Net Interchange Schedule

5.6.3.1 The initial net *interchange schedule* value shall be the difference between all imports to Ontario and all exports from Ontario in the last hour of the previous day. By default, this value will be based on the most recent schedules from the *pre-dispatch calculation engine*.

6 Security Assessment Function

6.1 Interaction between the Security Assessment Function and Optimization Functions

6.1.1 The scheduling and pricing algorithms of the *day-ahead market 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 All three passes of the *day-ahead market calculation engine* shall use the *security* assessment function.

6.1.4 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* average and peak *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 in Pass 1 and Pass 3:

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

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

6.2.2.3 the schedules for *boundary entity resources* at each *intertie zone*; and the net schedules for *virtual transactions* for each *virtual transaction zone*.

6.2.3 The *security* assessment function shall also use the following outputs of the optimization functions in Pass 2:

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

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

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

6.3 Security Assessment Function Processing

6.3.1 In Pass 1 and Pass 3 of the *day-ahead market calculation engine*, the *security* assessment function shall determine the average province-wide non-*dispatchable demand* forecast for hour h, AFL_h, as follows:

6.3.1.1 determine forecast MW quantities for all *load resources* and losses using the *IESO* average *demand* forecasts for *demand* forecast areas, load distribution factors, 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 AFL_h by adding the forecast MW quantities determined for each *non-dispatchable load,* including forecast MW losses in the *demand* forecast areas.

6.3.2 In Pass 2 of the *day-ahead market calculation engine*, the *security* assessment function shall determine the peak province-wide non-*dispatchable demand* forecast for hour *h*, PFL_h, as follows:

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

6.3.2.2 determine PFL_h by adding the forecast MW quantities determined for each *non-dispatchable load*, *each price responsive load,* and each *dispatchable load* with no *bid* for *energy,* including forecast MW losses in the *demand* forecast areas.

6.3.3 In Passes 1 and 3 of the *day-ahead market calculation engine*, the *security* assessment function shall distribute the net schedules for *virtual transactions* in each *virtual transaction zone* to *non-dispatchable loads*, *dispatchable loads hourly demand response resources*, and *price* *responsive loads* within the *virtual transaction zone* using the weighting factors ($WF_{h,m,b}^{VIRT}$) for *virtual transactions*. In the *security* assessment function, the total MW quantity allocated to:

6.3.3.1 a *dispatchable load*, an *hourly demand response resource* or a *price responsive load* shall be equal to the schedule determined by the optimization functions plus the amount allocated in the distribution of the net schedules for *virtual transactions*; and

6.3.3.2 a *non-dispatchable load* shall be equal to its forecast MW quantity plus the amount allocated in the distribution of the net schedules for *virtual transactions*.

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

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

6.3.4.2 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.

6.3.4.3 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.

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

6.3.4.5 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.

6.3.4.6 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.

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

6.3.4.8 The base case solution shall be used to calculate Ontario *transmission system* losses, marginal loss factors and loss adjustment for each hour. 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.

6.3.4.9 The As-Offered Scheduling, Reference Level Scheduling, Mitigated Scheduling, Reliability Scheduling and DAM Scheduling algorithms described in sections 8, 12, 15, 18 and 20, respectively, shall use the marginal loss factors for each hour calculated by the *security* assessment function.

6.3.4.10 The As-Offered Pricing, Reference Level Pricing, Mitigated Pricing, and DAM Pricing algorithms described in sections 9, 13, 16 and 21, 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 hour. The sensitivities and limits associated with the constraints shall be those provided by the most recent s*ecurity* assessment function iteration;

6.4.1.2 pre-contingency and post-contingency sensitivity factors for each hour;

6.4.1.3 the marginal loss factors as described in sections 6.3.4.8-6.3.4.10; and

6.4.1.4 loss adjustment quantity for each hour.

7 Pass 1: Market Commitment and Market Power Mitigation Pass

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 commitments. Pass 1 shall consist of the following algorithms and tests:

- the As-Offered Scheduling algorithm described in section 8;
- the As-Offered 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;
- the Price Impact Test described in section 14;
- the Mitigated Scheduling algorithm described in section 15; and
- the Mitigated Pricing algorithm described in section 16.

8 As-Offered Scheduling

8.1 Purpose

8.1.1 The As-Offered 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* to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*.

8.2 Information, Sets, Indices and Parameters

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

8.3 Variables and Objective Function

8.3.1 The As-Offered Scheduling algorithm shall solve for the following variables:

8.3.1.1 $SPRL_{h,b,j}$, which designates the amount of energy that a price, responsive load is scheduled to consume at bus $b \in B^{PRL}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J_{h,b}{}^{E}$;

8.3.1.2 $SDL_{h,b,j}$, which designates the amount of energy that a dispatchable, load is scheduled to consume at bus $\mathrm{b} \in \mathrm{B}^{\mathrm{DL}}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J_{h,b}{}^{E}$;

8.3.1.3 $S10SDL_{h,b,j}$, which designates the amount of synchronized ten-minute operating reserve that a dispatchable load is scheduled to provide at bus $\mathrm{b} \in \mathrm{B}^{\mathrm{DL}}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J_{h,b}{}^{10S}$;

8.3.1.3 $S10NDL_{h,b,j}$, 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 hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J_{h,b}{}^{10N}$;

8.3.1.4 $S10NDL_{h,b,j}$, 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 hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J_{h,b}{}^{10N}$;

8.3.1.5 *$S30RDL_{h,b,j}$*, which designates the amount of thirty-minute operating reserve that a dispatchable load is scheduled to provide at bus $b \in B^{DL}$ in hour h ∈ {1, . . , 24} in association with lamination $j \in J_{h,b}^{30R}$;

8.3.1.6 *$SHDR_{h,b,j}$* , which designates the amount of energy reduction scheduled for an hourly demand response resource at bus $b \in B^{HDR}$ in hour $h \in$ {1, . . , 24} in association with lamination $j \in J_{h,b}^{E}$;

8.3.1.7 *$SVB_{h,v,j}$*, which designates the amount of energy a virtual zonal resource ⍰ ∈ V*B* is scheduled to consume in hour h ∈ {1, . . , 24} in association with lamination $j \in J_{h,v}^{E}$;

8.3.1.8 *$SXL_{h,d,j}$*, which designates the amount of energy a boundary entity resource is scheduled to export at bus d ∈ DX in hour h ∈ {1, . . , 24} in association with lamination $j \in J_{h,d}^{E}$;

8.3.1.9 *$S10NXL_{h,d,j}$*, which designates the amount of non-synchronized *ten-minute operating reserve* scheduled that a *boundary entity resource* is scheduled to provide at bus d ∈ DX in hour h ∈ {1, . . , 24} in association with lamination $j \in J_{h,d}^{10N}$;

8.3.1.10 *$S30RXL_{h,d,j}$*, which designates the amount of *thirty-minute operating reserve* scheduled that a *boundary entity resource* is scheduled to provide at bus d ∈ DX in hour h ∈ {1, . . , 24} in association with lamination $j \in J_{h,d}^{30R}$;

8.3.1.11 *$SNDG_{h,b,k}$*, which designates the amount of *energy that a non-dispatchable generation resource is scheduled to provide at bus* $b \in B^{NDG}$ *in hour h ∈ {1, . . , 24} in association with lamination* $k \in K_{h,b}^{E}$;

8.3.1.12 *$SDG_{h,b,k}$*, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above *$MinQDG_b$* at bus $b \in B^{DG}$ *in hour h ∈ {1, . . , 24} in association with lamination* $k \in K_{h,b}\ E$;

8.3.1.13 *$ODG_{h,b}$*, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled at or above its *minimum loading point* in hour h ∈ {1, . . , 24};

8.3.1.14 *$IDG_{h,b}$*, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled to reach its *minimum loading point* in hour h ∈ {1, . . , 24};

8.3.1.15 $S10SDG_{h,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus b ∈ B^{DG} in hour h ∈ {1, . . , 24} in association with lamination k ∈ $K_{h,b}^{10S;}$

8.3.1.16 $S10NDG_{h,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus b ∈ B^{DG} in hour h ∈ {1, . . , 24} in association with lamination k ∈ $K_{h,b}^{10N}$;

8.3.1.17 $S30RDG_{h,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus b ∈ B^{DG} in hour h ∈ {1, . . , 24} in association with lamination $k \in K_{h,b}^{30R}$;

8.3.1.18 $SCT_{h,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in BPSU$ in hour $h \in \{1, . . , 24\}$;

8.3.1.19 $SST_{h,p}$, which designates the schedule of steam turbine $p \in PST$ in hour h ∈ {1, . . , 24};

8.3.1.20 $O10R_{h,b}$, which designates whether the *pseudo-unit* at bus $b \in B^{NO10DF}$ has been scheduled for *ten-minute operating reserve* in hour $h \in \{1, . . , 24\}$;

8.3.1.21 $OHO_{h,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour h ∈ {1, . . , 24};

8.3.1.22 $OFRh,b,i$ for i ∈ {1, . . ,$NFor_b$}, which designates whether the *dispatchable* hydroelectric *generation resource* at bus b ∈ BHE has been scheduled at or below $ForL_{b,i}$, or, at or above $ForU_{b,i}$ in hour h ∈ {1, . . , 24};

8.3.1.23 $IHE_{h,b,i}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus b ∈ B^{HE} registered a start between hours $(h - 1)$ and h ∈ {1, . . , 24} as a result of its schedule increasing from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$ for i ∈{1, . .,$NStartMW_b$};

8.3.1.24 *$SVO_{h,v,k}$, which designates the amount of energy a virtual zonal resource v ∈ VO is scheduled to provide in hour h∈{1, . . , 24} in association with lamination k ∈ $K_{h,?}^{E}$;*

8.3.1.25 $SIG_{h,d,k}$, which designates the amount of energy that a boundary entity resource is scheduled to import from intertie zone bus d ∈ DI in hour h ∈ { 1, . . , 24} in association with lamination k ∈ $K_{h,d}^{E}$;

8.3.1.26 $S10NIG_{h,d,k}$, which designates the amount of non-synchronized ten-*minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* bus d ∈ DI in hour h ∈ {1, . . , 24} in association with lamination k ∈ $K_{h,\square}^{10\square}$;

8.3.1.27 $S30RIG_{h,d,k}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* bus d ∈ DI in hour h ∈ {1, . . , 24} in association with lamination k ∈ $K_{h,d}^{30R}$;

8.3.1.28 TB_h, which designates any adjustment to the objective function to facilitate pro-rata tie-breaking in hour h ∈ {1, . . , 24}, as described in section 8.3.2.1; and

8.3.1.29 $ViolCost_h$, which designates the cost incurred in order to avoid having the schedules violate constraints for hour h ∈ {1, . . , 24}, as described in section 8.3.2.3.

8.3.2 The objective function for the As-Offered Scheduling algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{h=1,..,24}\begin{pmatrix}ObjPRL_h + ObjDL_h - ObjHDR_h + ObjVB_h + ObjXL_h - ObjNDG_h \\ - ObjDG_h - ObjVO_h - ObjIG_h - TB_h - ViolCost_h\end{pmatrix}$$

Where

$$ObjPRL_h = \sum_{b\in B^{PRL}}\left(\sum_{j\in J^E_{h,b}} SPRL_{h,b,j}\cdot PPRL_{h,b,j}\right)$$

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

$$ObjHDR_h = \sum_{b\in B^{HDR}}\left(\sum_{j\in J^E_{h,b}} SHDR_{h,b,j}\cdot PHDR_{h,b,j}\right)$$

$$ObjVB_h = \sum_{v\in VB}\left(\sum_{j\in J^E_{h,v}} SVB_{h,v,j}\cdot PVB_{h,v,j}\right)$$

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

$$ObjNDG_h = \sum_{b\in B^{NDG}}\left(\sum_{k\in K^E_{h,b}} SNDG_{h,b,k}\cdot PNDG_{h,b,k}\right)$$

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

$$ObjVO_h = \sum_{v \in VO} \left(\sum_{k \in K_{h,v}^{E}} SVO_{h,v,k} \cdot PVO_{h,v,k} \right)$$

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

8.3.2.1 The tie-breaking term (□□h) 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:

$$TB_h = TBPRL_h + TBDL_h + TBHDR_h + TBVB_h + TBXL_h + TBNDG_h + TBDG_h + TBVO_h + TBIG_h$$

Where:

$$TBPRL_h = \sum_{b \in B^{PRL}} \left(\sum_{j \in J_{h,b}^{E}} \frac{\left(SPRL_{h,b,j}\right)^2 \cdot TBPen}{QPRL_{h,b,j}} \right);$$

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

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

$$TBVB_h = \sum_{v \in VB} \left(\sum_{j \in J_{h,v}^{E}} \frac{\left(SVB_{h,v,j}\right)^2 \cdot TBPen}{QVB_{h,v,j}} \right);$$

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

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

$$TBDG_h = \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K_{h,b}^{E}} \left(\frac{\left(SDG_{h,b,k}\right)^2 \cdot TBPen}{QDG_{h,b,k}} \right) + \sum_{k \in K_{h,b}^{10S}} \left(\frac{\left(S10SDG_{h,b,k}\right)^2 \cdot TBPen}{Q10SD_{h,b,k}} \right) + \\ \sum_{k \in K_{h,b}^{10N}} \left(\frac{\left(S10NDG_{h,b,k}\right)^2 \cdot TBPen}{Q10NDG_{h,b,k}} \right) + \sum_{k \in K_{h,b}^{30R}} \left(\frac{\left(S30RDG_{h,b,k}\right)^2 \cdot TBPen}{Q30RDG_{h,b,k}} \right) \end{array} \right);$$

$$TBVO_h = \sum_{v \in VO} \left(\sum_{k \in K_{h,v}^{E}} \frac{\left(SVO_{h,v,k}\right)^2 \cdot TBPen}{QVO_{h,v,k}} \right);$$

and

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

8.3.2.2 $ViolCost_h$ shall be calculated for hour $h \in \{1, . . , 24\}$ using the following variables:

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

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

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

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

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

8.3.2.2.6 $SREG10RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{REG10RViolh}\}$ 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 $SREG30RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{REG30RViolh}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{XREG10RViolh}\}$ 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 $SXREG30RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{XREG30RViolh}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region r ∈ ORREG;

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

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

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

8.3.2.2.13 $SNIUViol_{h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{NIUViolh}\}$ of the penalty curve for exceeding the net interchange increase limit between hours $(h - 1)$ and h;

8.3.2.2.14 $SNIDViol_{h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{NIDViolh}\}$ of the penalty curve for exceeding the net interchange decrease limit between hours $(h - 1)$ and h;

8.3.2.2.15 $SMaxDelViol_{h,b,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{MaxDelViolh}\}$ of the penalty curve for exceeding the *maximum daily energy limit* constraint for a *resource* at bus b ∈ BELR;

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

8.3.2.2.17 $SSMaxDelViol_{h,s,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{SMaxDelViolh}\}$ 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 $SSMinDelViol_{h,s,i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{SMinDelViolh}\}$ of the penalty curve for violating the shared *minimum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set s ∈ SHE;

8.3.2.2.19 $SOGenLnkViol_{h,(b1,b2),i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{OGenLnkViolh}\}$ 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 $b_1 \in B_{up\ HE}$ and $b_2 \in B_{dn\ HE}$; and

8.3.2.2.20 $SUGenLnkViol_{h,(b1,b2),i}$, which designates the violation variable associated with segment $i \in \{1, . . , N_{UGenLnkViolh}\}$ 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 $b_1 \in B_{up\ HE}$ and $b_2 \in B_{dn}^{HE}$.

8.3.2.3 $\square iolCost_h$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_h = & \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} \cdot PLdViolSch_{h,i} \\
& - \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} \cdot PGenViolSch_{h,i} \\
& + \sum_{i=1..N_{10SViol_h}} S10SViol_{h,i} \cdot P10SViolSch_{h,i} \\
& + \sum_{i=1..N_{10RViol_h}} S10RViol_{h,i} \cdot P10RViolSch_{h,i} \\
& + \sum_{i=1..N_{30RViol_h}} S30RViol_{h,i} \cdot P30RViolSch_{h,i} \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_h}} SREG10RViol_{r,h,i} \cdot PREG10RViolSch_{h,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_h}} SREG30RViol_{r,h,i} \cdot PREG30RViolSch_{h,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_h}} SXREG10RViol_{r,h,i} \cdot PXREG10RViolSch_{h,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_h}} SXREG30RViol_{r,h,i} \cdot PXREG30RViolSch_{h,i} \right) \\
& + \sum_{f \in F_h} \left(\sum_{i=1..N_{PreITLViol_{f,h}}} SPreITLViol_{f,h,i} \cdot PPreITLViolSch_{f,h,i} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{h,c}} \left(\sum_{i=1..N_{ITLViol_{c,f,h}}} SITLViol_{c,f,h,i} \right.
\end{aligned}
$$

$$\cdot PITLViolSch_{c,f,h,i}\Bigg)$$

$$+ \sum_{z \in Z_{Sch}} \left(\sum_{i=1..N_{PreXTLViol_{z,h}}} SPreXTLViol_{z,h,i} \cdot PPreXTLViolSch_{z,h,i} \right)$$

$$+ \sum_{i=1..N_{NIUViol_h}} SNIUViol_{h,i} \cdot PNIUViolSch_{h,i}$$

$$+ \sum_{i=1..N_{NIDViol_h}} SNIDViol_{h,i} \cdot PNIDViolSch_{h,i}$$

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

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

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

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

$$+ \sum_{(b_1,b_2) \in LNK} \left(\sum_{i=1..N_{OGenLnkViol_h}} SOGenLnkViol_{h,(b_1,b_2),i} \cdot POGenLnkViolSch_{h,i} \right)$$

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

8.4 Constraints

8.4.1 The constraints described in sections 8.5, 8.6 and 8.7 apply to the optimization function in the As-Offered Scheduling algorithm.

8.5 Dispatch Data Constraints Applying to Individual Hours

8.5.1 Scheduling Variable Bounds

8.5.1.1 A Boolean variable, $ODG_{h,b}$, shall indicate whether the *resource* at bus $b \in B^{DG}$ is committed in hour $h \in \{1, . . , 24\}$. A value of zero shall indicate that a *resource* is not committed, while a value of one shall indicate that it is committed. Therefore:

8.5.1.1.1 $ODG_{h,b} \in \{0,1\}$ for all hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$.

8.5.1.2 *Reliability must-run resources* shall be 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 run-times* 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 hour $h \in \{1, . . , 24\}$, then:

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

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:

$0 \leq SPRL_{h,b,j} \leq QPRL_{h,b,j}$ for all $b \in B^{PRL}, j \in J^{E}_{h,b}$;

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

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

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

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

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

$0 \leq SVB_{h,v,j} \leq QVB_{h,v,j}$ for all $v \in VB$, $j \in J^{E}_{h,v}$;

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

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

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

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

$0 \leq SVO_{h,v,k} \leq QVO_{h,v,k}$ for all $v \in VO$, $k \in K^{E}_{h,v}$;

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

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

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

for all hours $h \in \{1, \ldots, 24\}$.

8.5.1.7 *Generation resources* may be scheduled for *energy* and/or *operating reserve* only if $ODG_{h,b} = 1$. Therefore, for all hours $h \in \{1, \ldots, 24\}$:

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

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

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

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

8.5.2 Resource Minimums and Maximums for Energy

8.5.2.1 The non-*dispatchable* portion of *price responsive loads* shall always be scheduled. For all hours $h \in \{1, \ldots, 24\}$ and all buses $b \in B^{PRL}$:

$$\sum_{j \in J^{E}_{h,b}} SPRL_{h,b,j} \geq QPRLFIRM_{h,b}.$$

8.5.2.2 A constraint shall limit schedules for *dispatchable loads* within their minimum and maximum consumption for an hour. For all hours $h \in \{1, \ldots, 24\}$ and all buses $b \in B^{DL}$:

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

8.5.2.3 The non-*dispatchable* portion of *dispatchable loads* shall always be scheduled. For all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DL}$:

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

8.5.2.4 A constraint shall limit schedules for *non-dispatchable generation resources* within their minimum and maximum output for an hour. For all hours h $\in \{1, .., 24\}$ and all buses $b \in B^{NDG}$:

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

8,5,2,5 A constraint shall limit schedules for *dispatchable generation resources* within their minimum and maximum output for an hour. For a *dispatchable variable generation resource,* the maximum schedule shall be limited by its forecast. That is:

For all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DG}$,

$$AdjMaxDG_{h,b} = \begin{cases} \min(MaxDG_{h,b}, AFG_{h,b}) & if\ b \in B^{VG} \\ MaxDG_{h,b} & otherwise \end{cases}$$

and

$$AdjMinDG_{h,b} = min(MinDG_{h,b}, AdjMaxDG_{h,b}).$$

For all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DG}$:

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

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

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

8.5.3 Off-Market Transactions

8.5.3.1 For all hours $h \in \{1,..,24\}$ and all *intertie zone* buses corresponding to an inadvertent *energy* payback export transaction $d \in DX_h^{INP}$:

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

8.5.3.2 For all hours $h \in \{1,..,24\}$ and all *intertie zone* buses corresponding to an inadvertent *energy* payback import transaction $d \in DI_h^{INP}$:

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

8.5.3.3 For all hours $h \in \{1,..,24\}$ and all *intertie zone* buses corresponding to an *emergency energy* export $d \in DX_h^{EM}$:

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

8.5.3.4 For all hours $h \in \{1,..,24\}$ and all *intertie zone* buses corresponding to *emergency energy* import $d \in DI_h^{EM}$:

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

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 load 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.

These restrictions shall be enforced by the following constraints for all hours h ∈ {1, . . , 24} and all buses b ∈ ▯^{DL}:

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

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

and

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

8.5.4.2 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 hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DL}$:

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

8.5.4.3 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 hours $h \in \{1, . . , 24\}$ and all *intertie zone* export buses $d \in DX$:

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

8.5.4.4 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 hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$:

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

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

and

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

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 hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$:

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

8.5.4.6 The amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* may be 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 hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$ with RLP$10S_{h,b}$ > 0:

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

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 hours h ∈ $\{1, .., 24\}$ and all buses b ∈ B^{DG} with $RLP30R_{h,b} > 0$:

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

8.5.4.8 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 hours $h \in \{1, .., 24\}$ and all *intertie zone* import buses $d \in DI$:

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

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 shares in the operating regions of the *pseudo-unit* determined in section 22. For all hours $h \in \{1, . . , 24\}$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$SCT_{h,b} = (1 - STShareMLP_b) \cdot MinQDG_b \cdot ODG_{h,b}$$

$$+(1 - STShareDR_b) \cdot \left(\sum_{k \in K_{h,b}^{DR}} SDG_{h,b,k} \right),$$

and for all hours h ∈ {1, . . , 24} and steam turbines $p \in PST$:

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

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 hours $h \in \{1, . . , 24\}$ and *pseudo-unit* buses $b \in B^{\square SU}$:

$$MinQDG_b \cdot ODG_{h,b} \leq MaxMLP_{h,b},$$

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

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

and

$$\sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k}$$

$$+ \sum_{k \in K_{h,b}^{30R}} S30RDG_{h,b,k} \leq MaxDR_{h,b} + MaxDF_{h,b}$$

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 in its duct firing region whenever the *pseudo-unit* is scheduled for *ten-minute operating reserve.* For all hours h ∈ {1, . . , 24} and *pseudo-unit* buses b ∈ B^{NO10DF}:

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

and

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

8.5.5.4 For all hours h ∈ {1, . . , 24}, *pseudo-unit* buses b ∈ B^{NO10DF}, and laminations k ∈ $K_{h,b}^{10S}$:

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

8.5.5.5 For all hours h ∈ {1, . . , 24}, *pseudo-unit* buses b ∈ B^{NO10DF}, and laminations k ∈ $K_{h,b}^{10N}$:

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

8.5.5.6 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 $b \in B^{\square SU}$ in hour $h \in \{1, . . ,24\}$ shall be equal to:

8.5.5.6.1 $SCT_{h,b}$ if the *pseudo-unit* is scheduled at or above *minimum loading point*,

8.5.5.6.2 $RampCT_{b,w}$ if the *pseudo-unit* is scheduled to reach *minimum loading point* in hour (h + w) for w ∈ {1,..,$RampHrs_b$}, or

8.5.5.6.3 0 otherwise.

8.5.5.7 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 ∈ *PST* shall be equal to $SST_{h,p}$ plus any contribution from *pseudo unit* b ∈ B_p^{ST} ramping to *minimum loading point* as given by $RampST_{b,w}$ for a *pseudo-unit* scheduled to reach *minimum loading point* in hour *(h + w)* for $w \in \{1, . . ,RampHrs_b\}$.

8.5.6 Dispatchable Hydroelectric Generation Resources

8.5.6.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled to at least its *hourly must run* quantity. For all hours h ∈

$\{1, .., 24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k} \geq MinHMR_{h,b}$$

8.5.6.2 A dispatchable hydroelectric *generation resource* shall either be scheduled to 0 or to at least its *minimum hourly output.* For all hours $h \in \{1, . . . , 24\}$ and all *dispatchable hydroelectric generation* resource buses $b \in B^{HE}$:

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

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

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

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

8.5.6.3 A *dispatchable* hydroelectric *generation resource* shall not be scheduled within its *forbidden regions*. For all hours $h \in \{1, .. 24\}$, all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ and all $i \in \{1, .., NFor_b\}$:

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

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

and

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

8.5.7 Wheeling Through Transactions

8.5.7.1 The amount of scheduled export *energy* must be equal to the amount of scheduled import *energy* for *wheeling through transactions*. For all hours $h \in \{1, .., 24\}$ and all linked *boundary entity resource* buses $(dx, di) \in L_h$:

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

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 $URRDL_{h,b,w}$ and use $DRRDL_b$ to represent a ramp down rate selected from $DRRDL_{h,b,w}$.

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 $URRDG_{h,b,w}$ and use $DRRDG_b$ to represent a ramp down rate selected from $DRRDG_{h,b,w}$.

8.6.1.3 The *day-ahead market 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 hour 0 are obtained from the initial scheduling assumptions in section 5.6. For all hours $h \in \{1, . . , 24\}$ the ramping rates in all ramping constraints must be adjusted to allow the applicable *resource* to:

8.6.1.4.1 ramp down from its lower limit in hour $(h - 1)$ to its upper limit in hour h; and

8.6.1.4.2 ramp up from its upper limit in hour $(h - 1)$ to its lower limit in hour h.

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 hours h $\in \{1, . . , 24\}$ and buses b $\in B^{DL}$:

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

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 hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{HDR}$:

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

8.6.1.7 *Energy* schedules for a *dispatchable generation resource* cannot vary by more than an hour's ramping capability for the applicable *resource.* For all hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$:

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

$$0 \leq \sum_{k \in K^E_{h,b}} SDG_{h,b,k} \leq 30 \cdot URRDG_b$$

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

$$\sum_{k \in K^E_{h-1,b}} SDG_{h-1,b,k} - 60 \cdot DRRDG_b \leq \sum_{k \in K^E_{h,b}} SDG_{h,b,k} \leq \sum_{k \in K^E_{h-1,b}} SDG_{h-1,b,k} + 60 \cdot URRDG_b$$

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

$$0 \leq \sum_{k \in K^E_{h,b}} SDG_{h,b,k} \leq 30 \cdot DRRDG_b$$

5.6.1.8 *The constrai*nts in sections 8.6.1.7.1 and 8.6.1.7.3 do not apply to a *quick start resource*.

5.6.1.9 For hours where *non-quick start resources* are ramping up to *minimum loading point*, *energy* shall be scheduled 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 hours h $\in \{1, .., 24\}$and all buses $b \in B^{DL}$:

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

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 hours h $\in \{1, .., 24\}$ and all buses $b \in B^{DG}$:

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

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

where n is the hour of the last start before or in hour h; and

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

.

where m is the hour of the last shutdown in or after hour h.

8.6.3 Non-Quick Start Resource

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

8.6.3.2 A *resource*'s previous day's schedule shall be evaluated to determine any remaining *minimum generation block run-time* constraints to enforce and determine the commitment status of the *resource* in hour 0. If $0 < InitOperHrs_b < MGBRTDG_b$, then the *resource* at bus $b \in B^{NQS}$ has yet to complete its *minimum generation block run-time*, and:

$$ODG_{1,b}, ODG_{2,b}, \ldots, ODG_{\min(24, MGBRTDG_b - InitOperHrs_b),b} = 1$$

8.6.3.3 If $ODG_{h-1,b} = 0$, $ODG_{h,b} = 1$, and $MGBRTDG_b > 1$ for hour $h \in \{1, . . , 24\}$, then the *resource* at bus □ ∈ $B^{□QS}$ has been scheduled to start up during hour h and shall be scheduled to remain in operation until it has completed its *minimum generation block run-time* or to the end of the day. Therefore:

$$ODG_{h+1,b}, ODG_{h+2,b}, \ldots, ODG_{min(24, h\, +\, MGBRTDG_b - 1),b} = 1$$

8.6.3.4 If $ODG_{h-1,b} = 1$, $ODG_{h,b} = 0$, and $MGBDTDG_b > 1$ for hour $h \in \{1, . . , 24\}$, then the *resource* at bus $b \in B^{NQS}$ has been scheduled to shut down during hour h and shall be scheduled to remain off until it has completed its *minimum generation block down time* or to the end of the day. Therefore:

$$ODG_{h+1,b}, ODG_{h+2,b}, \ldots, ODG_{min(24, h\, +\, MGBDTDG_b - 1),b} = 0$$

8.6.3.5 *The day-ahead market calculation engine* shall not consider *start-up offers* for *non-quick start resources* to be scheduled in the first hour of the day if the *resource* is expected to be scheduled as a result of an operational constraint.

8.6.3.6 A Boolean variable, I□□$_{h,□}$ indicates that the *non-quick start resource* at bus $b \in B_{NPS}$ is scheduled to reach its *minimum loading point* in hour $h \in \{1, . . , 24\}$ after being scheduled below its *minimum loading point* in the preceding hour. A value of zero shall indicate 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.* For all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{NQS}$:

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

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 $b \in B^{NQS}$:

$$\sum_{h=1..24} IDG_{h,b} \leq MaxStartsDG_b$$

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, for all buses $b \in BELR$ where an *energy limited resource* is located and all hours $H \in \{1, .., 24\}$:

$$\sum_{h=1..H} \left(ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K^{E}_{h,b}} SDG_{h,b,k} \right) + 10ORConv \left(\sum_{k \in K^{10S}_{H,b}} S10SDG_{H,b,k} + \sum_{k \in K^{10N}_{H,b}} S10NDG_{H,b,k} \right) + 30ORConv \left(\sum_{k \in K^{30R}_{H,b}} S30RDG_{H,b,k} \right) - \sum_{i=1..N_{MaxDelViol_H}} SMaxDelViol_{H,b,i} \leq MaxDEL_b$$

where the factors $10ORCon\nu$ and $30ORCon\nu$ 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 *day-ahead market calculation engine* to find a solution.

8.6.5 Dispatchable Hydroelectric Generation Resources

8.6.5.1 *Dispatchable* hydroelectric *generation resources* shall be scheduled for at least their *minimum daily energy limit*. Violation variables for under-scheduling a *resource's minimum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$\sum_{h=1..24}\left(ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k} + \sum_{i=1..N_{MinDelViol_h}} SMinDelViol_{h,b,i}\right) \geq MinDEL_b$$

8.6.5.2 A Boolean variable, $IHE_{h,b,i}$ shall indicate that a start for the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ was counted in hour $h \in \{1,..24\}$ 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 value* for $i \in \{1,..,NStartMW_b\}$. A value of zero shall indicate that a start was not counted, while a value of one indicates that a start was counted.

Therefore, for all hours $h \in \{1,..,24\}$, buses $b \in B^{HE}$ and *start indication values* $i \in \{1,..,NStartMW_b\}$:

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

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. The following constraint shall apply for all buses b ∈ BHE:*

$$\sum_{h=1..24}\left(\sum_{i=1..NStartMW_b} IHE_{h,b,i}\right) \leq MaxStartsHE_b$$

8.6.5.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not exceed shared *maximum daily energy limits*. Violation variables for over-scheduling the *maximam daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all sets s ∈ SHE and all hours H ∈ {1,..,24}:

$$\sum_{h=1..H}\left(\sum_{b\,\in B_s^{HE}}\left(ODG_{h,b}\cdot MinQDG_b + \sum_{k\in K_{h,b}^{E}} SDG_{h,b,k}\right)\right)$$
$$+\sum_{b\,\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{H,b}^{10S}} S10SDG_{H,b,k}\right.\right.$$
$$\left.+\sum_{k\in K_{H,b}^{10N}} S10NDG_{H,b,k}\right)$$
$$\left.\left.+\,30ORConv\left(\sum_{k\in K_{H,b}^{30R}} S30RDG_{H,b,k}\right)\right)\right)$$
$$-\sum_{i=1..N_{SMaxDelViol_H}} SSMaxDelViol_{H,s,i}$$
$$\leq MaxSDEL_s$$

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.

8.6.5.5 Schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *minimum daily energy limits*. Violation variables for under-scheduling the *minimum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all sets s ∈ SHE:

$$\sum_{h=1..24}\left(\sum_{b\in B_s^{HE}}\left(ODG_{h,b}\cdot MinQDG_b+\sum_{k\in K_{h,b}^E}SDG_{h,b,k}\right)+\sum_{i=1..N_{SMinDelViol_h}}SSMinDelViol_{h,s,i}\right)\geq MinSDEL_s$$

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

8.6.5.7 For all linked dispatchable hydroelectric generation resources between upstream resources $b_1 \in B_{up}^{HE}$ and downstream resources $b2 \in B_{dn}^{HE}$ for $(b1,b2) \in LNK$ and hours $h \in \{1, ..., 24\}$ such that $h + Lag_{b1,b2} \leq 24$:

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

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 ∈ B in hour h ∈ {1, . . , 24}, $With_{h,b}$ shall be:

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

8.7.1.2 The net *energy* withdrawal for *virtual transaction zone* m ∈ M in hour h ∈ {1, . . , 24}, $VWith_{h,m}$, as all *bids* scheduled from *virtual transactions* for *energy* less all *offers* scheduled from *virtual transaction* for *energy* shall be:

$$VWith_{h,m} = \left(\sum_{v \in VB_m} \sum_{j \in J_{h,v}^{E}} SVB_{h,v,j} \right) - \left(\sum_{v \in VO_m} \sum_{k \in K_{h,v}^{E}} SVO_{h,v,k} \right)$$

8.7.1.3 The total amount of export *energy* scheduled at *intertie zone* bus $d \in DX$ in hour $h \in \{1, . . , 24\}$, $With_{h,d}$, as the exports from Ontario to the *intertie zone* bus shall be:

$$With_{h,d} = \sum_{j \in J^E_{h,d}} SXL_{h,d,j}$$

8.7.1.4 The total amount of injections scheduled at internal bus $b \in B$ in hour $h \in \{1, . . , 24\}$, $Inj_{h,b}$, shall be:

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

where

$$OfferInj_{h,b} = \begin{cases} \sum_{k \in K^E_{h,b}} SNDG_{h,b,k} & if\ b \in B^{NDG} \\ ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG_{h,b,k} & if\ b \in B^{DG} \end{cases}$$

and

$$RampInj_{h,b} = \begin{cases} \sum_{w=1..min(RampHrs_b, 24-h)} RampE_{b,w} \cdot IDG_{h+w,b} & if\ b \in B^{NQS} \\ 0 & otherwise \end{cases}$$

8.7.1.5 The total amount of import *energy* scheduled at *intertie zone* bus $d \in DI$ in hour $h \in \{1, . . , 24\}$, $Inj_{h,d}$, as the imports into Ontario from that *intertie zone* bus shall be:

$$Inj_{h,d} = \sum_{k \in K^E_{h,d}} SIG_{h,d,k}$$

8.7.1.6 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 *day-ahead market calculation engine* to produce a solution. For hour h ∈ {1, . . , 24}, the *energy* balance shall be:

$$
\begin{aligned}
AFL_h + \sum_{b \in B^{PRL} \cup B^{DL} \cup B^{HDR}} (1 + MglLoss_{h,b}) \cdot With_{h,b} \\
+ \sum_{m \in M} (1 + VMglLoss_{h,m}) \cdot VWith_{h,m} \\
+ \sum_{d \in DX} (1 + MglLoss_{h,d}) \cdot With_{h,d} \\
- \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} \\
= \sum_{b \in B^{NDG} \cup B^{DG}} (1 + MglLoss_{h,b}) \cdot Inj_{h,b} \\
+ \sum_{d \in DI} (1 + MglLoss_{h,d}) \cdot Inj_{h,d} \\
- \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} + LossAdj_h
\end{aligned}
$$

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 hour h ∈{1, . . 24}:

$$\sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{10S}} S10SDL_{h,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{10S}} S10SDG_{h,b,k}\right) + \sum_{i=1..N_{10SViol_h}} S10SViol_{h,i} \ \geq\ TOT10S_h;$$

$$\sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{10S}} S10SDL_{h,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{10S}} S10SDG_{h,b,k}\right) + \sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{10N}} S10NDL_{h,b,j}\right)+\sum_{d\in DX}\left(\sum_{j\in J_{h,d}^{10N}} S10NXL_{h,d,j}\right) + \sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{10N}} S10NDG_{h,b,k}\right)+\sum_{d\in DI}\left(\sum_{k\in K_{h,d}^{10N}} S10NIG_{h,d,k}\right) + \sum_{i=1..N_{10RViol_h}} S10RViol_{h,i} \ \geq\ TOT10R_h;$$

and

$$\sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{10S}} S10SDL_{h,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{10S}} S10SDG_{h,b,k}\right) + \sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{10N}} S10NDL_{h,b,j}\right)+\sum_{d\in DX}\left(\sum_{j\in J_{h,d}^{10N}} S10NXL_{h,d,j}\right) + \sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{10N}} S10NDG_{h,b,k}\right)+\sum_{d\in DI}\left(\sum_{k\in K_{h,d}^{10N}} S10NIG_{h,d,k}\right) + \sum_{b\in B^{DL}}\left(\sum_{j\in J_{h,b}^{30R}} S30RDL_{h,b,j}\right)+\sum_{d\in DX}\left(\sum_{j\in J_{h,d}^{30R}} S30RXL_{h,d,j}\right) + \sum_{b\in B^{DG}}\left(\sum_{k\in K_{h,b}^{30R}} S30RDG_{h,b,k}\right)+\sum_{d\in DI}\left(\sum_{k\in K_{h,d}^{30R}} S30RIG_{h,d,k}\right) + \sum_{i=1..N_{30RViol_h}} S30RViol_{h,i} \ \geq\ TOT30R_h$$

8.7.2.3 The following constraints shall be applied for each hour h $\in \{1,..24\}$ and each region $r \in ORREG$:

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10S}} S10SDL_{h,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10N}} S10NDL_{h,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{h,d}^{10N}} S10NIG_{h,d,k} \right) + \sum_{i=1..N_{REG10RViol_h}} SREG10RViol_{r,h,i} \ \geq \ REGMin10R_{h,r};$$

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10S}} S10SDL_{h,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10N}} S10NDL_{h,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{h,d}^{10N}} S10NIG_{h,d,k} \right) - \sum_{i=1..N_{XREG10RViol_h}} SXREG10RViol_{r,h,i} \leq \ REGMax10R_{h,r};$$

$$
\begin{aligned}
&\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{h,b}^{10S}} S10SDL_{h,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{h,b}^{10S}} S10SDG_{h,b,k}\right)\\
&\quad+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{h,b}^{10N}} S10NDL_{h,b,j}\right)\\
&\quad+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{h,d}^{10N}} S10NXL_{h,d,j}\right)\\
&\quad+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{h,b}^{10N}} S10NDG_{h,b,k}\right)\\
&\quad+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{h,d}^{10N}} S10NIG_{h,d,k}\right)\\
&\quad+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{h,b}^{30R}} S30RDL_{h,b,j}\right)\\
&\quad+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{h,d}^{30R}} S30RXL_{h,d,j}\right)\\
&\quad+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{h,b}^{30R}} S30RDG_{h,b,k}\right)\\
&\quad+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{h,d}^{30R}} S30RIG_{h,d,k}\right)\\
&\quad+\sum_{i=1..N_{REG30RViol_h}} SREG30RViol_{r,h,i} \;\geq\; REGMin30R_{h,r};
\end{aligned}
$$

and

$$
\begin{aligned}
&\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10S}} S10SDL_{h,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} \right) \\
&+ \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{10N}} S10NDL_{h,b,j} \right) \\
&+ \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \right) \\
&+ \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} \right) \\
&+ \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{h,d}^{10N}} S10NIG_{h,d,k} \right) \\
&+ \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{h,b}^{30R}} S30RDL_{h,b,k} \right) \\
&+ \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{h,d}^{30R}} S30RXL_{h,d,j} \right) \\
&+ \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{h,b}^{30R}} S30RDG_{h,b,k} \right) \\
&+ \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{h,d}^{30R}} S30RIG_{h,d,k} \right) \\
&- \sum_{i=1..N_{XREG30RViol_h}} SXREG30RViol_{r,h,i} \\
&\leq REGMax30R_{h,r}.
\end{aligned}
$$

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 8.7.1.6, shall be used to produce these schedules.

8.7.3.2 Pre-contingency, $SPreITLViol_{f,h,i}$, and post-contingency, $SITLViol_{c,f,h,i}$, transmission limit violation variables shall allow the *day-ahead market calculation engine* to find a solution.

8.7.3.3 For all hours $h \in \{1, \ldots, 24\}$ and *facilities* f $\in F_h$, the linearized constraints for violated pre-contingency limits obtained from the *security* assessment function shall take the form:

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

8.7.3.4 For all hours $h \in \{1, \ldots, 24\}$, contingencies $c \in C$, and *facilities* $f \in F_{h,c}$, the linearized constraints for violated post-contingency limits obtained from the *security* assesment function shall take the form:

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

8.7.4 Intertie Limits

8.7.4.1 A set of *energy* and *operating reserve* schedules shall be produced that respect any *security limits* associated with *interties* between Ontario and *intertie zones*. For all hours $h \in \{1,..,24\}$ and all constraints $z \in Z_{Sch}$:

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

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 *intertie zones* shall not exceed the net interchange scheduling limit. The net import schedule shall be summed over all *intertie zones* for a given hour to obtain the net *interchange schedule* for the hour as follows:

8.7.4.2.1 It shall not exceed the net *interchange schedule* for the previous hour plus the net interchange scheduling limit;

8.7.4.2.2 It shall not be less than the net *interchange schedule* for the previous hour minus the net interchange scheduling limit; and

8.7.4.3 Violation variables may be used for both the up and down ramp limits to allow the *day-ahead market calculation engine* to find a solution and for all hours $h \in \{1, .., 24\}$:

$$\sum_{d \in DI} \sum_{k \in K^E_{h-1,d}} SIG_{h-1,d,k} - \sum_{d \in DX} \sum_{j \in J^E_{h-1,d}} SXL_{h-1,d,j} - ExtDSC_h - \sum_{i=1..N_{NIDViol_h}} SNIDViol_{h,i} \leq \sum_{d \in DI} \sum_{k \in K^E_{h,d}} SIG_{h,d,k} - \sum_{d \in DX} \sum_{j \in J^E_{h,d}} SXL_{h,d,j} \leq \sum_{d \in DI} \sum_{k \in K^E_{h-1,d}} SIG_{h-1,d,k} - \sum_{d \in DX} \sum_{j \in J^E_{h-1,d}} SXL_{h-1,d,j} + ExtUSC_h + \sum_{i=1..N_{NIUViol_h}} SNIUViol_{h,i}$$

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 As-Offered Scheduling algorithm and for all hours $h \in \{1, .., 24\}$:

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

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

$0 \leq S10SViol_{h,i} \leq Q10SViolSch_{h,i}$ for all $i \in \{1, . . , N_{10SViol_h}\}$;

$0 \leq S10RViol_{h,i} \leq Q10RViolSch_{h,i}$ for all $i \in \{1, . . , N_{10RViol_h}\}$;

$0 \leq S30RViol_{h,i} \leq Q30RViolSch_{h,i}$ for all $i \in \{1, . . , N_{30RViol_h}\}$;

$0 \leq SREG10RViol_{r,h,i} \leq QREG10RViolSch_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{REG10RViol_h}\}$;

$0 \leq SREG30RViol_{r,h,i} \leq QREG30RViolSch_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{REG30RViol_h}\}$;

$0 \leq SXREG10RViol_{r,h,i} \leq QXREG10RViolSch_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{XREG10RViol_h}\}$;

$0 \leq SXREG30RViol_{r,h,i} \leq QXREG30RViolSch_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{XREG30RViol_h}\}$;

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

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

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

$0 \leq SNIUViol_{h,i} \leq QNIUViolSch_{h,i}$ for all $i \in \{1, \ldots, N_{NIUViol_h}\}$;

$0 \leq SNIDViol_{h,i} \leq QNIDViolSch_{h,i}$ for all $i \in \{1, \ldots, N_{NIDViol_h}\}$;

$0 \leq SMaxDelViol_{h,b,i} \leq QMaxDelViolSch_{h,i}$ for all $b \in B^{ELR}$, $i \in \{1, \ldots, N_{MaxDelViol_h}\}$;

$0 \leq SMinDelViol_{h,b,i} \leq QMinDelViolSch_{h,i}$ for all $b \in B^{HE}$, $i \in \{1, \ldots, N_{MinDelViol_h}\}$;

$0 \leq SSMaxDelViol_{h,s,i} \leq QSMaxDelViolSch_{h,i}$ for all $s \in SHE$, $i \in \{1, \ldots, N_{SMaxDelViol_h}\}$;

$0 \leq SSMinDelViol_{h,s,i} \leq QSMinDelViolSch_{h,i}$ for all $s \in SHE$, $i \in \{1, \ldots, N_{SMinDelViol_h}\}$;

$0 \leq SOGenLnkViol_{h,(b_1,b_2),i} \leq QOGenLnkViol_{h,i}$ for all $(b_1, b_2) \in LNK$, $i \in \{1, \ldots, N_{OGenLnkViol_h}\}$; and

$0 \leq SUGenLnkViol_{h,(b_1,b_2),i} \leq QUGenLnkViol_{h,i}$ for all $(b_1, b_2) \in LNK$, $i \in \{1, \ldots, N_{UGenLnkViol_h}\}$

8.8 Outputs

8.8.1 Outputs for the As-Offered Scheduling algorithm include *resource* schedules and commitments.

9 As-Offered Pricing

9.1 Purpose

9.1.1 The As-Offered Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants,* including *resource* schedules and commitments produced by the As-Offered Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*.

9.2 Information, Sets, Indices and Parameters

9.2.1 Information sets, indices and parameters used by the As-Offered Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedules and commitments from the As-Offered Scheduling algorithm in section 8 shall be used by the As-Offered Pricing algorithm:

9.2.1.1 $SDG_{h,b,k}^{AOS}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ *at* bus b $\in B^{ELR} \cup B^{HE}$ in hour h $\in \{1, . . . , 24\}$ in association with lamination k $\in K_{h,b}^{E}$;

9.2.1.2 $ODG_{h,b}^{AOS}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour h $\in \{1, . . , 24\}$;

9.2.1.3 $S10SDG_{h,b,k}^{AOS}$, 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 hour $h \in \{1, .., 24\}$ in association with lamination $k \in K_{h,b}^{10S}$;

9.2.1.4 $S10NDG_{h,b,k}^{AOS}$, 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 hour $h \in \{1, .., 24\}$ in association with lamination $k \in K_{h,b}^{10N}$;

9.2.1.5 $S30RDG_{h,b,k}^{AOS}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in BELR \cup BHE$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K_{h,b}^{30R}$; and

9.2.1.6 $OHO_{h,b}^{AOS}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour $h \in \{1, .., 24\}$.

9.3 Variables and Objective Function

9.3.1 The *day-ahead market calculation engine* shall solve for the same variables as in the As-Offered Scheduling algorithm, section 8.3.1, with the following exceptions:

9.3.1.1 $IDG_{h,b}$ for bus $b \in B^{DG}$ and hour $h \in \{1, .., 24\}$ shall not appear in the formulation;

9.3.1.2 $ODG_{h,b}$ for bus $b \in B^{DG}$ and hour $h \in \{1, .., 24\}$ shall be fixed to a constant value;

9.3.1.3 $OHO_{h,b}$ for bus $b \in B^{HE}$ and hour $h \in \{1, .., 24\}$ shall be fixed to a constant value;

9.3.1.4 $IHE_{h,b,i}$ for bus $b \in B^{HE}$, hour $h \in \{1, .., 24\}$ and *start indication value* $i \in \{1, .., NStartMW_b\}$ shall not appear in the formulation;

9.3.1.5 $SOGenLnkViol_{h,(b1,b2),i}$ for $(b1, b2) \in LNK$ such that $b1 \in B_{up}^{HE}$ and $b2 \in B_{dn}^{HE}$, hour $h \in \{1, .., 24\}$ and $i \in \{1, .., N_{OGenLnkViolh}\}$ shall not appear in the formulation; and

9.3.1.6 $SUGenLnkViolh,(b1,b2),i$ for $(b1,b2) \in LNK$ such that $b1 \in B_{up}^{HE}$ and $b2 \in B_{dn}^{HE}$, hour $h \in \{1, .., 24\}$ and $i \in \{1, .., N_{UGenLnkViolh}\}$ shall not appear in the formulation.

9.3.2 The objective function for the As-Offered Pricing algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{h=1,\dots,24}\begin{pmatrix} ObjPRL_h + ObjDL_h - ObjHDR_h + ObjVB_h + ObjXL_h - ObjNDG_h \\ - ObjDG_h - ObjVO_h - ObjIG_h - TB_h - ViolCost_h \end{pmatrix}$$

where:

$$ObjPRL_h = \sum_{b \in B^{PRL}} \left(\sum_{j \in J^{E}_{h,b}} SPRL_{h,b,j} \cdot PPRL_{h,b,j} \right)$$

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

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

$$ObjVB_h = \sum_{v \in VB} \left(\sum_{j \in J^{E}_{h,v}} SVB_{h,v,j} \cdot PVB_{h,v,j} \right)$$

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

$$ObjNDG_h = \sum_{b \in B^{NDG}} \left(\sum_{k \in K^{E}_{h,b}} SNDG_{h,b,k} \cdot PNDG_{h,b,k} \right)$$

$$ObjDG_h = \sum_{b \in B^{DG}} \begin{pmatrix} \sum_{k \in K^{E}_{h,b}} SDG_{h,b,k} \cdot PDG_{h,b,k} + \sum_{k \in K^{10S}_{h,b}} S10SDG_{h,b,k} \cdot P10SDG_{h,b,k} + \\ \sum_{k \in K^{10N}_{h,b}} S10NDG_{h,b,k} \cdot P10NDG_{h,b,k} + \sum_{k \in K^{30R}_{h,b}} S30RDG_{h,b,k} \cdot P30RDG_{h,b,k} \end{pmatrix}$$

$$ObjVO_h = \sum_{v \in VO} \left(\sum_{k \in K^{E}_{h,v}} SVO_{h,v,k} \cdot PVO_{h,v,k} \right)$$

$$ObjIG_h = \sum_{d \in DI} \begin{pmatrix} \sum_{k \in K^{E}_{h,d}} SIG_{h,d,k} \cdot PIG_{h,d,k} + \sum_{k \in K^{10N}_{h,d}} S10NIG_{h,d,k} \cdot P10NIG_{h,d,k} \\ + \sum_{k \in K^{30R}_{h,d}} S30IG_{h,d,k} \cdot P30RIG_{h,d,k} \end{pmatrix}$$

9.3.2.1 The tie-breaking term (TB_h) shall be the same term described in section 8.3.2.1.

9.3.2.2 ViolCosth shall be calculated as follows:

$$
\begin{aligned}
ViolCost_h = & \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} \cdot PLdViolPrc_{h,i} \\
& - \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} \cdot PGenViolPrc_{h,i} \\
& + \sum_{i=1..N_{10SViol_h}} S10SViol_{h,i} \cdot P10SViolPrc_{h,i} \\
& + \sum_{i=1..N_{10RViol_h}} S10RViol_{h,i} \cdot P10RViolPrc_{h,i} \\
& + \sum_{i=1..N_{30RViol_h}} S30RViol_{h,i} \cdot P30RViolPrc_{h,i} \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_h}} SREG10RViol_{r,h,i} \cdot PREG10RViolPrc_{h,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_h}} SREG30RViol_{r,h,i} \cdot PREG30RViolPrc_{h,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_h}} SXREG10RViol_{r,h,i} \cdot PXREG10RViolPrc_{h,i} \right)
\end{aligned}
$$

$$+ \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_h}} SXREG30RViol_{r,h,i} \cdot PXREG30RViolPrc_{h,i} \right)$$

$$+ \sum_{f \in F_h} \left(\sum_{i=1..N_{PreITLViol_{f,h}}} SPreITLViol_{f,h,i} \right.$$

$$\cdot PPreITLViolPrc_{f,h,i}\Bigg)$$

$$+\sum_{c\in C}\sum_{f\in F_{h,c}}\left(\sum_{i=1..N_{ITLViol_{c,f,h}}} SITLViol_{c,f,h,i}\right.$$

$$\left.\cdot PITLViolPrc_{c,f,h,i}\right)$$

$$+\sum_{z\in Z_{Sch}}\left(\sum_{i=1..N_{PreXTLViol_{z,h}}} SPreXTLViol_{z,h,i}\right.$$

$$\left.\cdot PPreXTLViolPrc_{z,h,i}\right)$$

$$+\sum_{i=1..N_{NIUViol_h}} SNIUViol_{h,i}\cdot PNIUViolPrc_{h,i}$$

$$+\sum_{i=1..N_{NIDViol_h}} SNIDViol_{h,i}\cdot PNIDViolPrc_{h,i}\cdot$$

$$+\sum_{b\in B^{ELR}}\left(\sum_{i=1..N_{MaxDelViol_h}} SMaxDelViol_{h,b,i}\cdot PMaxDelViolPrc_{h,i}\right)$$

$$+\sum_{b\in B^{HE}}\left(\sum_{i=1..N_{MinDelViol_h}} SMinDelViol_{h,b,i}\cdot PMinDelViolPrc_{h,i}\right)$$

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

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

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 As-Offered Pricing algorithm.

9.5 Dispatch Data Constraints Applying to Individual Hours

9.5.1 Scheduling Variable Bounds

9.5.1.1 No schedule shall be negative, nor shall any schedule exceed the quantity respectively *offered* for *energy* and *operating reserve*. For all hours $h \in \{1, .., 24\}$:

$0 \leq SPRL_{h,b,j} \leq QPRL_{h,b,j}$ for all $b \in B^{PRL}, j \in J^{E}_{h,b}$;

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

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

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

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

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

$0 \leq SVB_{h,v,j} \leq QVB_{h,v,j}$ for all $v \in VB, j \in J^{E}_{h,v}$;

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

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

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

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

$0 \leq SVO_{h,v,k} \leq QVO_{h,v,k}$ for all $v \in VO, k \in K^{E}_{h,v}$;

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

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

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

9.5.1.2 A *dispatchable generation resource* can be scheduled for *energy* and *operating reserve* only if its commitment status variable is equal to 1. For all hours $h \in \{1, . . , 24\}$:

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

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

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

and

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

where

$ODG_{h,b}$ is a fixed constant in the above constraints as per section 9.8.1.

9.5.2 Resource Minimums and Maximums

9.5.2.1 The constraints in section 8.5.2 shall apply in the As-Offered Pricing algorithm.

9.5.3 Off-Market Transactions

9.5.3.1 The constraints in section 8.5.3.1 and 8.5.3.2 shall apply in the As-Offered 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 As-Offered Pricing algorithm.

9.5.3.3 For all hours h $\in \{1, . . , 24\}$ and all *intertie zone* buses scheduled to import *emergency energy* that does not support an export d $\in DI_h^{EMNS}$:

$$\sum_{k \in K^{E}_{h,d}} SIG_{h,d,k} = 0.$$

9.5.4 Operating Reserve Requirements

9.5.4.1 The constraints in section 8.5.4 shall apply in the As-Offered Pricing algorithm.

9.5.5 Pseudo-Units

9.5.5.1 The constraints in section 8.5.5 shall apply in the As-Offered Pricing algorithm.

9.5.6 Dispatchable Hydroelectric Generation Resources

9.5.6.1 The constraints in section 8.5.6 shall apply in the As-Offered Pricing algorithm, with the following exceptions:

9.5.6.1. 1 *offer* laminations for *energy* corresponding to the *hourly must-run* amount shall be ineligible to set prices;

9.5.6.1. 2 *minimum hourly output* constraints shall be replaced by the constraints in section 9.8; and

9.5.6.1. 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.

9.5.7 Wheeling Through Transactions

9.5.7.1 The constraints in section 8.5.7 shall apply in the As-Offered Pricing algorithm.

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 As-Offered Pricing algorithm.

9.6.2 Operating Reserve Ramping

9.6.2.1 The constraints in section 8.6.1.1 shall apply in the As-Offered Pricing algorithm.

9.6.3 Energy Limited Resources

9.6.3.1 The constraints in section 8.6.4 shall apply to *energy limited resources*. If the *maximum daily energy limit* is binding, then the constraints in section 9.8 shall 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 scheduling a *resource* below its *minimum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses b ∈ BHE:

$$\sum_{h=1..24}\left(ODG_{h,b}\cdot MinQDG_b+\sum_{k\in K^E_{h,b}}SDG_{h,b,k}+\sum_{i=1..N_{MinDelViol_h}}SMinDelViol_{h,b,i}\right)\geq MinDEL_b$$

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 As-Offered Scheduling algorithm in section 8.

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 m*aximum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all sets s ∈ *SHE* and all hours H ∈ {1, . . ,24}:

$$\sum_{h=1..H}\left(\sum_{b\,\in B_s^{HE}}\left(ODG_{h,b}\cdot MinQDG_b+\sum_{k\in K^E_{h,b}}SDG_{h,b,k}\right)\right)+\sum_{b\,\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K^{10S}_{H,b}}S10SDG_{H,b,k}+\sum_{k\in K^{10N}_{H,b}}S10NDG_{H,b,k}\right)+30ORConv\left(\sum_{k\in K^{30R}_{H,b}}S30RDG_{H,b,k}\right)\right)-\sum_{i=1..N_{SMaxDelViol_H}}SSMaxDelViol_{H,s,i}\leq MaxSDEL_s$$

where the factors $10ORConv$ and $30ORConv$ shall be applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy limited resources* 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 *day-ahead market calculation engine* to find a solution. For all sets $s \in SHE$:

$$\sum_{h=1..24}\left(\sum_{b\in B_s^{HE}}\left(ODG_{h,b}\cdot MinQDG_b+\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}\right)+\sum_{i=1..N_{SMinDelViol_h}}SSMinDelViol_{h,s,i}\right)\geq MinSDEL_s$$

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 As-Offered Pricing algorithm, except the marginal loss factors used in the *energy* balance constraint in the As-Offered Pricing algorithm shall be fixed to the marginal loss factors used in the last optimization function iteration of the As-Offered Scheduling algorithm.

9.7.2 Operating Reserve Requirements

9.7.2.1 The constraints in section 8.7.2 shall apply in the As-Offered Pricing algorithm.

9.7.3 IESO Internal Transmission Limits

9.7.3.1 The constraints in section 8.7.3 shall apply in the As-Offered Pricing algorithm, except the sensitivities and limits considered shall be those provided by the most recent *security* assessment function iteration of the As-Offered Pricing algorithm.

9.7.4 Intertie Limits

9.7.4.1 The constraints in section 8.7.4 shall apply in the As-Offered 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 $h \in \{1, .., 24\}$:

$0 \leq SLdViol_{h,i} \leq QLdViolPrc_{h,i}$ for all i $\in \{1, . . , N_{LdViol_h}\}$;

$0 \leq SGenViol_{h,i} \leq QGenViolPrc_{h,i}$ for all $i \in \{1, .., N_{GenViol_h}\}$;

$0 \leq S10SViol_{h,i} \leq Q10SViolPrc_{h,i}$ for all $i \in \{1, . . , N_{10SViol_h}\}$;

$0 \leq S10RViol_{h,i} \leq Q10RViolPrc_{h,i}$ for all $i \in \{1, . . , N_{10RViol_h}\}$;

$0 \leq S30RViol_{h,i} \leq Q30RViolPrc_{h,i}$ for all $i \in \{1, . . , N_{30RViol_h}\}$;

$0 \leq SREG10RViol_{r,h,i} \leq QREG10RViolPrc_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{REG10RViol_h}\}$;

$0 \leq SREG30RViol_{r,h,i} \leq QREG30RViolPrc_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{REG30RViol_h}\}$;

$0 \leq SXREG10RViol_{r,h,i} \leq QXREG10RViolPrc_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{XREG10RViol_h}\}$;

$0 \leq SXREG30RViol_{r,h,i} \leq QXREG30RViolPrc_{h,i}$ for all $r \in ORREG$, $i \in \{1, . . , N_{XREG30RViol_h}\}$;

$0 \leq SPreITLViol_{f,h,i} \leq QPreITLViolPrc_{f,h,i}$ for all $f \in F_h$, $i \in \{1, . . , N_{PreITLViol_{f,h}}\}$;

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

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

$0 \leq SNIUViol_{h,i} \leq QNIUViolPrc_{h,i}$ for all $i \in \{1, . . , N_{NIUViol_h}\}$;

$0 \leq SNIDViol_{h,i} \leq QNIDViolPrc_{h,i}$ for all $i \in \{1, . . , N_{NIDViol_h}\}$;

$0 \leq SMaxDelViol_{h,b,i} \leq QMaxDelViolPrc_{h,i}$ for all $b \in B^{ELR}$, $i \in \{1, . . , N_{MaxDelViol_h}\}$;

$0 \leq SMinDelViol_{h,b,i} \leq QMinDelViolPrc_{h,i}$ for all $b \in B^{HE}$, i $\in \{1, . . , N_{MinDelViol_h}\}$;

$0 \leq SSMaxDelViol_{h,s,i} \leq QSMaxDelViolPrc_{h,i}$ for all s ∈ SHE, $i \in \{1, . . , N_{SMaxDelViol_h}\}$; and

$0 \leq SSMinDelViol_{h,s,i} \leq QSMinDelViolPrc_{h,i}$ for all s ∈ SHE $i \in \{1, . . , N_{SMinDelViol_h}\}$.

9.8 Constraints to Ensure the Price Setting Eligibility Reflect 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 As-Offered Scheduling algorithm in section 8. For all hours h ∈ {1, . . , 24} and all buses $b \in B^{DG}$:

$$ODG_{h,b} = ODG^{AOS}_{h,b}$$

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 As-Offered Scheduling algorithm in section 8, the schedules calculated in the As-Offered Scheduling algorithm shall determine the price-setting eligibility of the *resource's energy* and *operating reserve offer* laminations. In each hour, *energy* or *operating reserve* laminations up to the total amount of *energy* and *operating reserve* scheduled in the As-Offered Scheduling algorithm shall be eligible to set prices. For bus $b \in B^{ELR}$, if there exists an hour $H \in \{1, .. ,24\}$ such that:

$$\sum_{h=1..H} \left(ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^{E}_{h,b}} SDG^{AOS}_{h,b,k} \right) + 10ORConv \left(\sum_{k \in K^{10S}_{H,b}} S10SDG^{AOS}_{H,b,k} + \sum_{k \in K^{10N}_{H,b}} S10NDG^{AOS}_{H,b,k} \right) + 30ORConv \left(\sum_{k \in K^{30R}_{H,b}} S30RDG^{AOS}_{H,b,k} \right) = MaxDEL_{b},$$

then the *maximum daily energy limit* constraint shall be considered binding in the As-Offered Scheduling algorithm. In such circumstances, the following constraints must hold for bus $b \in B^{ELR}$ for all hours $h \in \{1, . . , 24\}$:

$$\sum_{k \in K^{E}_{h,b}} SDG_{h,b,k} \leq \sum_{k \in K^{E}_{h,b}} SDG^{AOS}_{h,b,k} + \epsilon$$

$$\sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} + \sum_{k \in K_{h,b}^{30R}} S30RDG_{h,b,k} \leq MaxDEL_b - \sum_{\tau=1}^{h-1} \sum_{k \in K_{h,b}^{E}} SDG_{\tau,b,k}^{AOS}$$

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 As-Offered Scheduling algorithm in section 8, such *resource* shall also be scheduled at or above its *minimum hourly output* in the As-Offered 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 As-Offered Scheduling algorithm, the *resource* shall also receive a zero schedule in the As-Offered Pricing algorithm and shall be ineligible to set prices in the *energy market*. For all hours $h \in \{1, \ldots, 24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in BHE$:

$$ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} \geq MinHO_{h,b} \cdot OHO_{h,b}^{AOS}$$

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

$$0 \leq SDG_{h,b,k} \leq OHO_{h,b}^{AOS} \cdot QDG_{h,b,k}$$

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 As-Offered Scheduling algorithm in section 8. The *resource's* schedule shall be between the same *start indication value*s as determined in the As-Offered Scheduling algorithm. For all hydroelectric buses $b \in B^{HE}$ and all hours $h \in \{1, . . , 24\}$:

If $0 \leq ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k}^{AOS} < StartMW_{b,1}$,

then

$$0 \leq ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k} \leq StartMW_{b,1} - 0.1$$

If $StartMW_{b,i} \leq ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k}^{AOS} < StartMW_{b,i+1}$ for i $\in \{1, . . , (NStartMW_b - 1)\}$,

then

$$StartMW_{b,i} \leq ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k} \leq StartMW_{b,i+1} - 0.1$$

If $ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k}^{AOS} \geq StartMW_{b,NStartMW_b}$,

then

$$ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k} \geq StartMW_{b,NStartMW_b}$$

9.8.3.3 For a *dispatchable* hydroelectric *generation resource* with a *minimum daily energy limit* that was binding in the As-Offered Scheduling algorithm in section 8, the *energy* schedules calculated in the As-Offered Scheduling algorithm shall be ineligible to set prices. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such that $MinDEL_b > 0$ and

$$\sum_{h=1..24} \left(ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^E} SDG_{h,b,k}^{AOS} \right) \leq MinDEL_b$$

the following constraints shall apply for all hours $h \in \{1, . . , 24\}$ and offer laminations $k \in K_{h,b}^E$:

$$SDG_{h,b,k} \geq SDG_{h,b,k}^{AOS}$$

9.8.3.4 For a *dispatchable* hydroelectric *generation resource* with a shared *minimum daily energy limit* that was binding in the As-Offered Scheduling algorithm in section 8, the *energy* schedules calculated for all *resources* in the set $s \in SHE$ in the As-Offered Scheduling algorithm shall be ineligible to set prices. Thus, for all sets $s \in SHE$ such that:

$$\sum_{h=1..24}\left(\sum_{b\in B_s^{HE}}\left(ODG_{h,b}^{AOS}\cdot MinQDG_b+\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}^{AOS}\right)\right)\leq MinSDEL_s$$

the following constraints shall apply for all hours $h \in \{1,..,24\}$:

$$\sum_{b\in B_s^{HE}}\left(ODG_{h,b}\cdot MinQDG_b+\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}\right)\geq\sum_{b\in B_s^{HE}}\left(ODG_{h,b}^{AOS}\cdot MinQDG_b+\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}^{AOS}\right)$$

9.8.3.5 For a *dispatchable* hydroelectric *generation resource* with a binding *maximum daily energy limit* in the As-Offered Scheduling algorithm in section 8, the schedules calculated in the As-Offered 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 As-Offered Scheduling algorithm in section 8, the schedules calculated in the As-Offered Scheduling algorithm shall determine the price-setting eligibility of the *resource's offer* laminations for *energy* and *operating reserve*. In each hour, the sum of *energy* schedules calculated in As-Offered Scheduling algorithm for all *resources* in each set s ∈ SHE will be eligible to set prices. For each set s ∈ SHE, if there exists

H ∈ {1,..,24} such

$$\sum_{h=1..H}\left(\sum_{b\in B_s^{HE}}\left(ODG_{h,b}^{AOS}\cdot MinQDG_b+\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}^{AOS}\right)\right)$$
$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{H,b}^{10S}}S10SDG_{H,b,k}^{AOS}\right.\right.$$
$$\left.+\sum_{k\in K_{H,b}^{10N}}S10NDG_{H,b,k}^{AOS}\right)$$
$$\left.+30ORConv\left(\sum_{k\in K_{H,b}^{30R}}S30RDG_{H,b,k}^{AOS}\right)\right)$$
$$=MaxSDEL_s$$

then the *maximum daily energy limit* constraint shall be considered binding in the As-Offered Scheduling algorithm in section 8. In such circumstances, the following constraints shall apply for hours h ∈ {1, . . , 24}:

$$\sum_{b \in B_s^{HE}} \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} \le \sum_{b \in B_s^{HE}} \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k}^{AOS} + \epsilon,$$

$$\sum_{b \in B_s^{HE}} \left(\sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} + \sum_{k \in K_{h,b}^{30R}} S30RDG_{h,b,k} \right) \le MaxSDEL_s - \sum_{b \in B_s^{HE}} \sum_{\tau=2}^{h-1} \sum_{k \in K_{h,b}^{E}} SDG_{\tau,b,k}^{AOS}.$$

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 As-Offered Scheduling algorithm in section 8, such *resource* shall be scheduled between its As-Offered Scheduling algorithm schedule plus or minus a tolerance Δ specified by the *IESO*. The *resource* schedule shall continue to 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 hours $h \in \{1, .., 24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in$ ⍰⍰^{E} such $b \in \{b1, b2\}$ where $b1 \in B_{up}^{HE}$ and $b2 \in B_{dn}^{HE}$ for some $(b1,b2) \in LNK$ with $h + Lag_{b1,b2} \le 24$:

$$max\left(0\,, ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k}^{AOS} - \Delta\,, AdjMinDG_{h,b}\right)$$

$$\le ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k}$$

$$\le min\left(MinQDG_b + \sum_{k \in K_{h,b}^{E}} QDG_{h,b,k}\,,\quad ODG_{h,b}^{AOS} \cdot MinQDG_b + \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k}^{AOS} + \Delta\,, AdjMaxDG_{h,b}\right)$$

9.9 Outputs

9.9.1 Outputs for the As-Offered 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 sets and parameters associated with *narrow constrained areas* and *dynamic constrained areas* shall be identified in accordance with Appendix 7.8 and used by 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 As-Offered Pricing algorithm shall be used by the Constrained Area Conditions Test:

10.2.2.1 $LMP_{h,b}^{AOP}$, which designates the *locational marginal price* for bus b ∈ B in hour $h \in \{1,..,24\}$;

10.2.2.2 $PCong_{h,b}^{AOP}$, which designates the congestion component of the *locational marginal price* for bus $b \in B$ in hour $h \in \{1,..,24\}$;

10.2.2.3 $ExtLMP_{h,d}^{AOP}$, which designates the *locational marginal price* for *intertie zone* bus $d \in D$ in hour $h \in \{1,..,24\}$;

10.2.2.4 $PExtCong_{h,d}^{AOP}$, which designates the *intertie* congestion component of the *locational marginal price* for *intertie zone* bus $d \in D$ in hour $h \in \{1, .., 24\}$;

10.2.2.5 $PIntCong_{h,d}^{AOP}$, which designates the internal congestion component of the *locational marginal price* for *intertie zone* bus $d \in D$ in hour $h \in \{1, .., 24\}$;

10.2.2.6 $IntLMP_{h,d}^{AOP}$, which designates the *intertie border price* for *intertie zone* bus $d \in D$ in hour $h \in \{1, .., 24\}$;

10.2.2.7 $SPNormT_{h,f}^{AOP}$, which designates the shadow price for the pre-contingency transmission constraint for *facility* f ∈ F in hour $h \in \{1, .., 24\}$;

10.2.2.8 $SPEmT_{h,c,f}^{AOP}$, which designates the shadow price for the post-contingency transmission constraint for *facility* f ∈ F in contingency $c \in C$ in hour h;

10.2.2.9 $SPNIUExtBwdT_{h}^{AOP}$, which designates the shadow price for the net interchange scheduling limit constraint limiting increases in net imports between hour $(h - 1)$ and hour h;

10.2.2.10 $L30RP_{h,b}^{AOP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, .., 24\}$;

10.2.2.11 $L10NP_{h,b}^{AOP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in hour h ∈ $\{1, .., 24\}$; and

10.2.2.12 $L10SP_{h,b}^{AOP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour h ∈ $\{1, .., 24\}$.

10.3 Variables

10.3.1 The *day-ahead market calculation engine* shall use the constrained area conditions in sections 10.4 and 10.5 to identify the *resources* that are part of the following data sets:

10.3.1.1 $B\text{Cond}_{h}^{NCA}$, which designates the *resources* in a *narrow constrained area* that must be checked for local market power for *energy* in hour h ∈ $\{1, .., 24\}$;

10.3.1.2 $BCond_h^{DCA}$, which designates the *resources* in a *dynamic constrained area* that must be checked for local market power for *energy* in hour h ∈ {1, . . , 24};

10.3.1.3 $BCond_h^{BCA}$, which designates the *resources* in a broad constrained area that must be checked for local market power for *energy* in hour h ∈ {1, . . , 24};

10.3.1.4 $BCond_h^{GMP}$, which designates the *resources* that must be checked for global market power for *energy* in hour h ∈ {1, . . , 24};

10.3.1.5 $BCond_h^{10S}$, which designates the *resources* that must be checked for local market power for synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24};

10.3.1.6 $BCond_h^{10N}$, which designates the *resources* that must be checked for local market power for non-synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24};

10.3.1.7 $BCond_h^{30R}$, which designates the *resources* that must be checked for local market power for *thirty-minute operating reserve* in hour h ∈ {1, . . , 24};

10.3.1.8 $BCond_h^{GMP10S}$, which designates the *resources* that must be checked for global market power for synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24};

10.3.1.9 $BCond_h^{GMP10N}$, which designates the *resources* that must be checked for global market power for non-synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24}; and

10.3.1.10 $BCond_h^{GMP30R}$, which designates the *resources* that must be checked for global market power for *thirty minute operating reserve* in hour h ∈ {1, . . , 24}.

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 Areas

10.4.1.1 If at least one transmission constraint for a *narrow constrained area* or *dynamic constrained area* is binding in the As-Offered 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 ∈ NCA and hour $h \in \{1, . . , 24\}$: For each transmission *facility* that transmits flow into n, $f \in F_n^{NCA}$, check if $SPNormT_{h,f}^{AOP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit, the *day-ahead market calculation engine* will place n in the set NCA_h' and assign the *resources* in n to the set $BCond_h^{NCA}$; and

10.4.1.1.2 For each $d \in DCA$ and hour $h \in \{1, . . , 24\}$: For each transmission *facility* that transmits flow into d, $f \in F_d^{DCA}$, check if $SPNormT_{h,f}^{AOP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit, *the day-ahead market calculation engine* will place d in the set $DCAh'$ and assign the *resources* in dd to the set $BCond_h^{DCA}$.

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_h' designates the *narrow constrained areas* that qualify for market power mitigation for *energy* in hour $h \in \{1, . . , 24\}$; and

10.4.1.2.2 DCA_h' designates the *dynamic constrained areas* that qualify for market power mitigation for *energy* in hour $h \in \{1, . . ,24\}$.

10.4.2 Constrained Area Conditions Test for Broad Constrained Areas

10.4.2.1 If the congestion component of the *locational marginal price* for 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 for Conduct Test under the broad constrained area thresholds. For each hour $h \in \{1, . . , 24\}$ and bus $b \in B^{DG}$ such that $b \notin BCond_h^{NCA} \cup BCond_h^{DCA}$, if $PCong_{h,b}^{AOP} > BCACondThresh$, *the day-ahead market calculation engine* will place *resourcebb* in the set $BCond_h^{BCA}$.

10.5 Constrained Area Conditions Test for Global Market Power (Energy)

10.5.1 The *day-ahead market calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, subject to 10.5.2, if:

10.5.1.1 the *intertie border prices* at the *global market power reference intertie zones* are greater than the specified threshold value, indicated in hour h ∈ {1, . . , 24} by $IntLMP_{h,?}^{AOP} > IBPThresh$ for *bids* and *offers*, $d \in ?^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; 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 interties*, indicated in hour $h \in \{1, . . , 24\}$ by: $PExtCong_{h,d}^{AOP} < 0$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; or

10.5.1.2.2 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 hour $h \in \{1, . . , 24\}$ by: $SPNIUExtBwdT_h^{AOP} \neq 0$.

10.5.2 If the conditions in sections 10.5.1 are met, then the *day-ahead market calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, for each hour $h \in \{1, . . , 24\}$, place all $b \in B^{DG}$ in the set $BCond_h^{GMP}$, unless they are excluded because one of the following two conditions:

10.5.2.1 the *resources* 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 $PCong_{h,b}^{AOP} < PIntCong_{h,d}^{AOP} - \$1/MWh$ 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 $SPNormT_{h,f}^{AOP} \neq 0$ *or* $SPEmT_{h,c,f}^{AOP} \neq 0$.

10.6 Constrained Area Conditions Test for Local Market Power (Operating Reserve)

10.6.1 Subject to section 10.6.1.3 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 A *resource* shall not qualify for local market power mitigation test 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 hour $h \in \{1, .., 24\}$:

10.6.1.2 subject to section 10.6.1.3, if bb is in a region with a non-zero minimum requirement, then b is subject to the Conduct Test and is placed in the set $BCond_h^{10S}$, $BCon?_h^{10N}$, or $BCond_h^{30?}$; and

10.6.1.3 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 hour $h \in \{1, .., 24\}$:

10.7.2.1 if $L10SP_{t,b}^{PDP} > ORGCondThresh$, the *day-ahead market* calculation engine shall add resource b to $BCond_t^{GMP10S}$;

10.7.2.2 if $L10NP_{t,b}^{PDP} > ORGCondThresh$, the *day-ahead market calculation engine* shall add *resource b* to $BCond_t^{GMP10N}$; and

10.7.2.3 if $L30RP_{t,b}^{PDP} > ORGCondThresh$, the *day-ahead market calculation engine* shall add *resource b* to $BCond_t^{GMP30R.}$

10.7.3 If b is in a region with a binding maximum constraint, then b shall be exempt from the Conduct Test.

10.7.3.1 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*.

10.8 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 corresponding *reference level values* for those *resources*.

11.2 Information, Sets, Indices and Parameters

11.2.1 Information, sets, indices and parameters used by the Conduct Test in section 11 are described in section 3. In addition, the list of *resources* produced pursuant to section 10.8.1 shall also be used by the Conduct Test.

11.3 Variables

11.3.1 The *day-ahead market 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_h^{NCA} designates the *resources* in a *narrow constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in hour h $\in \{1, .., 24\}$;

11.3.1.1.2 BCT_h^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in hour h $\in \{1, .., 24\}$;

11.3.1.1.3 BCT_h^{BCA} designates the *resources* in a broad constrained area that failed the Conduct Test for at least one *financial dispatch data parameter* in hour h ∈ {1, . . , 24};

11.3.1.1.4 BCT_h^{GMP} designates the *resources* that failed the global market power for *energy* Conduct Test for at least one *financial dispatch data parameter* in hour h ∈ {1, . . , 24};

11.3.1.1.5 BCT_h^{ORL} designates the *resources* that failed the local market power for *operating reserve* Conduct Test for at least one *financial dispatch data parameter* in hour h ∈ {1, . . , 24}; and

11.3.1.1.6 BCT_h^{ORG} designates the *resources* that failed the global market power Conduct Test for *operating reserve* for at least one *financial dispatch data parameter* in hour $h \in \{1, . . ,24\}$;

11.3.1.2 The following *financial dispatch data parameters* for all hours h ∈ {1, . . , 24}:

11.3.1.2.1 $PARAME_{h,b}$ designates the set of *dispatch data* parameters that failed the *energy* Conduct Test at bus $b \in BCT_h^{NCA} \cup BCT_h^{DCA} \cup BCT_h^{BCA} \cup BCT_h^{GMP}$ in hour h, and may include the following dispatch data parameters:

11.3.1.2.1.1 $EnergyOffer_k$ designates the non-zero quantity of *energy* above the *minimum loading point* in association with *offer* lamination $k \in K_{h,b}^E$ 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 $EnergyToMLP_k$ designates the non-zero quantity of energy up to the minimum loading point in association with offer lamination $k \in K_{h,b}^{LTMLP}$ failed the Conduct Test;

11.3.1.2.2.2 *SUOffer* designates the *start-up offer* failed the Conduct Test; and

11.3.1.2.2.3 *SNLOffer* designates the *speed no-load offer* failed the Conduct Test;

11.3.1.2.3 $PARAMOR_{h,b}$ designates the set of *dispatch data* parameters that failed the *operating reserve* Conduct Test at bus $b \in BCT_{h}^{ORL} \cup$

BCT_h^{ORG} in hour h, and may include the following *dispatch data* parameters:

11.3.1.2.3.1 $OR10SOffer_k$ designates the non-zero quantity of synchronized *ten-minute operating reserve* in association with *offer* lamination k ∈ $K_{h,b}^{10S}$ failed the Conduct Test;

11.3.1.2.3.2 $OR10NOffer_k$ designates the non-zero quantity of non-synchronized *ten-minute operating reserve* in association with offer lamination k ∈ $K_{h,b}^{10N}$ failed the Conduct Test;

11.3.1.2.3.3 $OR30ROffer_k$ designates the non-zero quantity of *thirty-minute operating reserve* in association with *offer* lamination k ∈ $K_{h,b}^{30R}$ failed the Conduct Test; and

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* designates the *start-up offer* failed the Conduct Test;

11.3.1.2.4.2 *SNLOffer* designates the *speed no-load offer* failed the Conduct Test; and

11.3.1.2.4.3 $EnergyToMLP_k$ designates the non-zero quantity of energy up to the *minimum loading point* in association with *offer* lamination k ∈ $K_{h,b}^{E}$ failed the Conduct Test.

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 $PDG_{h,b,k} > \min(PDGRef_{h,b,k`} * (1 + CTEnThresh1^{NCA}), PDGRef_{h,b,k`} + CTEnThresh2^{NCA})$, where $k' \in K'_{h,b}^E$, then the Conduct Test was failed for the *resource* at bus □□ and the day-ahead market *calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $EnergyOffer_k$ to $PARAME_{h,b}$;

11.4.1.2 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all hours prior to and including the hour that qualified to be tested under the Constrained Area Conditions Test, for all $k \in K_{h,b}^{LTMLP}$, if $PLTMLP_{h,b,k} > CTEnMinOffer$ and $PLTMLP_{h,b,k} > \min(PLTMLPRef_{h,b,k'} * (1+CTEnThresh1^{NCA}), PLTMLPRef_{h,b,k'} + CTEnThresh2^{NCA})$, 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* $EnergyToMLP_k$ *to* $PARAME_{h,b}$ *and* $PARAMOR_{h,b}$;

11.4.1.3 Evaluate *start-up offers*: For all hours prior to and including the hour where conditions are met for the Constrained Area Conditions Test in section 10 , if $SUDG_{h,b} > SUDGRef_{h,b} * (1 + CTSUThresh^{NCA})$, then the Conduct Test was failed for the *resource* at bus and the *day-ahead market calculation engine* shall assign the resource to subset BCT_h^{NCA} and add *SUOffer* to $PARAME_{h,b}$ and $PARAMOR_{h,b}$; and

11.4.1.4 Evaluate speed *no-load offers*: For all hours prior to and including the hour that meets the conditions test, if $SNL_{h,b} > SNLRef_{h,b} * (1 + CTSNLThresh^{NCA})$, then the Conduct Test was failed for the resource at bus and the *day-ahead market calculation engine* shall *assign* the *resource* to subset BCT_h^{NCA} and add *SNLOffer* to $PARAME_{h,b}$ and $PARAMOR_{h,b}$.

11.4.2 For *resources* identified pursuant to section 10.8.1 in a *dynamic constrained area* or broad constrained area, the *day-ahead market calculation engine* shall use the steps in section 11.4.1 , using *resources* in $BCond_h^{DCA}$ or $BCond_h^{BCA}$, as he case may be, in place of $BCond_h^{NCA}$ and using the applicable Conduct Test thresholds $CTEnThresh1^{DCA}$, $CTEnThresh2^{DCA}$, $CTEnThresh1^{BCA}$, $CTEnThresh2B^{CA}$, $CTSUThresh^{DCA}$, $CTSUThresh^{BCA}$, $CTSNLThresh^{DCA}$, $CTSNLThresh^{BCA}$. 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 section10.8.1 that were selected for global market power mitigation testing for *energy,* the *day-ahead market calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond_h^{GMP}$ in place of $BCond_h^{NCA}$ 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^{G}.

11.4.4 If a *resource* is assigned to more than one of the sets, *BCondh NCA,* $BCond_h^{DCA}$, $BCond_h^{BCA}$, *and* $BCond_h^{GMP}$, 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 *day-ahead market 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 hour $h \in \{1,..,24\}$ and $b \in BCond_h^{10S} \cup BCond_h^{10N} \cup BCond_h^{30R}$, the *day-ahead market calculation engine* shall:

11.5.1.1 Evaluate *offers* for *operating reserve* as follows:

11.5.1.1.1 for all $k \in K_{h,b}^{10S}$ if $P10SDG_{h,b,k} > CTORMinOffer$ and $P10SDG_{h,b,k} > min(P10SDGRef_{h,b,k'} * (1 + CTORThresh1^{ORL}), P10SDGRef_{h,b,k'} + CTORThresh2^{ORL})$, where $k' \in K'_{h,b}{}^{10S}$, then the Conduct Test was failed for the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.2 for all $k \in K_{h,b}^{10N}$ if $P10NDG_{h,b,k} > CTORMinOffer$ and $P10NDG_{h,b,k} > min(P10NDGRef_{h,b,k'} * (1 + CTORThresh1^{ORL}), P10NDGRef_{h,b,k'} + CTORThresh2^{ORL})$, where $k' \in K'_{h,b}{}^{10N}$, the the Conduct Test was failed for the *source* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{h,b}$; and

11.5.1.1.3 for all $k \in K_{h,b}^{30R}$ if $P30RDG_{h,b,k} > CTORNMinOffer$ and $P30RDG_{h,b,k} > min(P30RDGRef_{h,b,k'} * (1 + CTORThresh1^{ORL}), P30RDGRef_{h,b,k'} + CTORThresh2^{ORL})$ where $k' \in K'_{h,b}{}^{30R}$, then the Conduct Test was failed for the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.4 for all $j \in J_{h,b}^{10S}$ if $P10SDL_{h,b,j} > CTORMinOffer$ *and* $P10SDL_{h,b,j} > min(P10SDLRef_{h,b,j'} * (1 + CTORThresh1^{ORL}), P10SDLRef_{h,b,j'} + CTORThresh2^{ORL})$, where $j' \in J_{h,b}{}'^{10S}$, 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_h^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.5 for all $j \in J_{h,b}^{10N}$ if $P10NDL_{h,b,j} > CTORMinOffer$ and $P10NDG_{h,b,j} > min(P10NDLRef_{h,b,j'} * (1 + CTORThresh1^{ORL}), P10NDLRef_{h,b,j'} + CTORThresh2^{ORL})$, where $j' \in J'_{h,b}{}^{10N}$, 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_h^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{h,b}$; and

11.5.1.1.6 for all $j \in J_{h,b}{}^{30R}$ if $P30RDL_{h,b,j} > CTORMinOffer$ and $P30RDL_{h,b,j} >$ min $(P30RDLRef_{h,b,j`}*(1 + CTORThresh1^{ORL}), P30RDLRef_{h,b,j`} + CTORThresh2^{ORL})$, where $j' \in J'_{h,b}{}^{30R}$, 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 $BCT_h ORL$ and add $OR30ROffer_k$ to $PARAMOR_{h,b}$;

11.5.1.2 Evaluate *start-up offers*: For all hours prior to and including the hour that meets the Constrainted Area Conditions Test, if $SUDG_{h,b} > SUDGRef_{h,b}*(1 + CTSUThres_h^{ORL})$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine shall assign the resource to subset* BCT_h^{ORL} *and* add $SUOffer$ *to* $PARAMOR_{h,b}$ and $PARAME_{h,b}$;

11.5.1.3 Evaluate *speed no-load offers*: For all hours prior to and including the hour that meets the conditions test, if $SNL_{h,b} > SNLRef_{h,b} * (1 + CTSNLThresh^{ORL})$, 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^{ORL} and add $SNLOffer$ to $PARAMOR_{h,b}$ and $PARAME_{h,b}$; and

11.5.1.4 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all hours prior to and including the hour that meets the conditions test, for all $k \in K_{h,b}{}^{LTMLP}$, if $PLTMLP_{h,b,k} > CTEnMinOffer$ and $PLTMLP_{h,b,k} > min\ (PLTMLPRef_{h,b,k`}*(1 + CTEnThresh1^{ORL}), PLTMLPRef_{h,b,k`} + CTEnThresh2^{ORL})$, 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^{ORL} and add $EnergyToMLP_k$ to $PARAMOR_{h,b}$ and $PARAMEh,b$.

11.5.2 The *day-ahead market calculation engin*e shall perform the Conduct Test for global market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1. The *day-ahead market calculation engine* shall use the steps set out in section 11.5.1 using *resources* in $BCond_h^{GMP10S}$, $BCond_h^{GMP10N}$, *and* $BCond_h^{GMP30R}$ in place of $BCond_h^{10S}$, $BCond_h{}^{10N}$, and $BCond\ h\ 30R$, respectively, and the applicable Conduct Test thresholds $CTORThresh1^{ORG}$, $CTORThresh2^{ORG}$, $CTSUThresh^{ORG}$, $CTSNLThresh^{ORG}$, *CTEnThresh1ORG, CTEnThresh2ORG.* The *resources* shall be assigned to the subset $BCT_h{}^{ORG}$.

11.5.3 If a *resource* is assigned to more than one of $BCond_h^{GMP10S}$, $BCond_h^{GMP10N}$, and $BCond_h^{GMP30R}$, 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 hour $h \in \{1, .., 24\}$:

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* for *resources* that failed a Conduct Test with *dispatch data* parameters that failed the Conduct Test replaced with *reference level values*. For *offers* for *energy* and *operating reserve* with multiple laminations:

11.6.1.3.1 if the *offer* lamination for *energy* that corresponds to the *minimum loading point* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *energy* up to the *minimum loading point*;

11.6.1.3.2 if one or more *offer* laminations for *energy* above the *minimum loading point* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *energy* up to and above the *minimum loading point*; and

11.6.1.3.3 if one or more *offer* laminations for *operating reserve* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *operating reserve*.

11.6.2 The *day-ahead market 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 *day-ahead market 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 section 12.2.2, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*.

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 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 *day-ahead market 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 *day-ahead market 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 values* for *resources* subject to section 13.2.2, and *resource* schedules and commitments produced by the Reference Level Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

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 $SDG_{h,b,k}^{RLS}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour h $\in \{1, . . . , 24\}$ in association with lamination $k \in K_{h,b}^{E}$;

13.2.1.2 $ODG_{h,b}^{RLS}$ designates whether the dispatchable generation resource at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1, . . , 24\}$;

13.2.1.3 $S10SDG_{h,b,k}^{RLS}$, 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 hour h $\in \{1, . . , 24\}$ in association with lamination $k \in K_{h,b}$ *10S;*

13.2.1.4 $S10NDG_{h,b,k}^{RLS}$, 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 hour h $\in \{1,.. , 24\}$ in association with lamination $k \in K_{h,b}^{10N}$;

13.2.1.5 $S30RDG_{h,b,k}^{RLS}$, 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 hour $h \in \{1, . . , 24\}$in association with lamination $k \in K_{h,b}^{30R}$; and

13.2.1.6 $OHO_{h,b}^{RLS}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus b ∈ B^{HE} has been scheduled at or above $MinHO_{h,b}$ in hour h ∈ {1, . . , 24}.

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.

13.3 Variables and Objective Function

13.3.1 The *day-ahead market 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 As-Offered Scheduling algorithm shall be replaced with the outputs from the Reference Level Scheduling algorithm as follows:

13.4.1.3.1 $SDG_{h,b,k}^{AOS}$ shall be replaced by $SDG_{h,b,k}^{RLS}$ for all h ∈ {1, . . , 24}, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{E}$;

13.4.1.3.2 $ODG_{h,b}^{AOS}$ shall be replaced by $ODG_{h,b}^{RLS}$ for all h ∈ {1, . . , 24}, $b \in B^{DG}$;

13.4.1.3.3 $S10SDG_{h,b,k}^{AOS}$ shall be replaced by $S10SDG_{h,b,k}^{RLS}$ for all $h \in \{1,.., 24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{10S}$;

13.4.1.3.4 $S10NDG_{h,b,k}{}^{AOS}$ shall be replaced by $S10NDG_{h,b,k\,RLS}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}{}^{10N}$;

13.4.1.3.5. $S30RDG_{h,b,k}{}^{AOS}$ shall be replaced by $S30RDG_{h,b,k}{}^{RLS}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}{}^{30R}$; and

13.4.1.3.6 $OHO_{h,b}{}^{AOS}$ shall be replaced by $OHO_{h,b}{}^{RLS}$ for all $h \in \{1,...,24\}$, $b \in \square^{\square E}$.

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 *day-ahead market 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 As-Offered Pricing algorithm with those produced by the Reference Level Pricing algorithm; and

14.1.212 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 4.3.8.

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 As-Offered Pricing algorithm and the Reference Level Pricing algorithm shall be used by the Price Impact Test:

14.2.1.1 $LMP_{h,□}^{□O□}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the As-Offered Pricing algorithm;

14.2.1.2 $L30RP_{h,b}^{AOP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the As-Offered Pricing algorithm;

14.2.1.3 $L10NP_{h,b}^{AOP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the As-Offered Pricing algorithm;

14.2.1.4 $L10SP_{h,b}^{AOP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the As-Offered Pricing algorithm;

14.2.1.5 $LMP_{h,b}^{RLP}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the Reference Level Pricing algorithm;

14.2.1.6 $L30RP_{h,b}^{RLP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the Reference Level Pricing algorithm;

14.2.1.7 $L10NP_{h,b}^{RLP}$, which designates the *locational marginal price* for non synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the Reference Level Pricing algorithm; and

14.2.1.8 $L10SP_{h,b}^{RLP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1, . . , 24\}$ from the Reference Level Pricing algorithm.

14.3 Variables

14.3.1 The *day-ahead market 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 hours $h \in \{1, . . , 24\}$, where:

14.3.1.1.1 BIT_h^{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_h^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.3 BIT_h^{BCA} designates the *resources* in a broad constrained area that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.4 BIT_h^{GMP} designates the *resources* that failed the global market power (*energy*) Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.5 BIT_h^{ORL} designates the *resources* that failed the local market power (*operating reserve*) Price Impact Test for at least one type of *locational marginal price* for *operating reserve*;

14.3.1.1.6 BIT_h^{ORG} designates the *resources* that failed the global market power (*operating reserve*) Price Impact Test for at least one type of *locational marginal price* for *operating reserve*; and

14.3.1.1.7 $LMPIT_{h,b}$ designates the *locational marginal price* that failed the Price Impact Test for bus $b \in BIT_h^{NCA} \cup BIT_h^{DCA} \cup BIT_h^{BCA} \cup BIT_h^{GMP} \cup BIT_h^{ORL} \cup BIT_h^{ORG}$ in hour h; 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 *locational marginal price* for synchronized *ten-minute operating reserve* failed the Price Impact Test;

14.3.1.2.3 *OR10NLMP* designates that the *locational marginal price* for non-synchronized *ten-minute operating reserve* failed the Price Impact Test; and

14.3.1.2.4 *OR30RLMP* designates that the *locational marginal price* for *thirty-minute operating reserve* failed the Price Impact Test.

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 $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP}*(1+ITThresh1^{NCA}), LMP_{h,b}^{RLP} + ITThresh2^{NCA})$, 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 $LMPIT_{h,b}$;

14.4.1.1.2 For each hour $h\in \{1, . . , 24\}$ and $b \in BCT_h^{DCA}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} (1+ITThresh1^{DCA}), LMP_{h,b}^{RLP}+ITThresh2^{DCA})$, the Price Impact Test was failed by the *resource* at bus bb and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{DCA} and add *EnergyLMP* to $LMPIT_{h,b}$; and

14.4.1.1.3 For each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{BCA}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP}*(1+ITThresh1^{BCA}), LMP_{h,b}^{RLP}+ITThresh2^{BCA})$, 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^{BCA} and add *EnergyLMP* to $LMPIT_{h,b}$.

14.4.1.2. For global market power for *energy*:

14.4.1.2.1 For each hour $h \in \{1, . . , 24\}$ and $b \in BCTh\ GMP$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP}*(1+ITThresh1^{GMP}), LMP_{h,b}^{RLP}+ITThresh2^{GMP})$, 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^{GMP} *and add EnergyLMP to* $LMPIT_{h,b}$

14.5 Price Impact Test for Operating Reserve

14.5.1 The *day-ahead market 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 hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{ORL}$:

14.5.1.1.1 If $L30RP_{h,b}^{AOP} > L30RP_{h,b}^{RLP}$, then 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^{ORL} and add OR30RLMP to $LMPIT_{h,b}$;

14.5.1.1.2 If $L10NP_{h,b}^{AOP} > L10NP_{h,b}^{RLP}$, then 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^{ORL} and add OR10NLMP to $LMPIT_{h,b}$; and

14.5.1.1.3 If $L10SP_{h,b}^{AOP} > L10SP_{h,b}^{RLP}$, then 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^{ORL} and add *OR10SLMP* to $LMPIT_{h,b}$.

14.5.1.2 For global market power for *operating reserve*, for each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{ORG}$:

14.5.1.2.1 If $L30RP_{h,b}^{AOP} > \min(L30RP_{h,b}^{RLP}*(1+ITThresh1^{ORG}), L30RP_{h,b}^{RLP}+ITThresh2^{ORG})$, then 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^{ORG} and add *R30RLMP* to $LMPIT_{h,b}$;

14.5.1.2.2 If $L10NP_{h,b}^{AOP} > \min(L10NP_{h,b}^{RLP}*(1+ITThresh1^{ORG}), L10NP_{h,b}^{RLP}+ITThresh2^{ORG})$, then 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^{ORG} and add *OR10NLMP* to $LMPIT_{h,b}$; and

14.5.1.2.3 If $L10SP_{h,b}^{AOP} > \min(L10SP_{h,b}^{RLP}*(1+ITThresh1^{ORG}), L10SP_{h,b}^{RLP}+ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* BIT_h^{ORG} and add *OR10SLMP* to $LMPIT_{h,b}$.

14.6 Revised Financial Dispatch Data Parameter Determination

14.6.1 A *resource* that fails the Price Impact Test 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_h^{NCA}, BIT_h^{DCA}, BIT_h^{BCA}, or BIT_h^{GMP}, the *dispatch data* parameters in $PARAME_{h,b}$ shall be used to determine the dispatch data parameters that shall be replaced.

14.6.1.2 If the *resource* has failed a Price Impact Test for *operating reserve* and is in BIT_h^{ORL} or BIT_h^{ORG}, the *dispatch data* parameters in $PARAMOR_{h,b}$ shall be used to determine the *dispatch data* parameters that shall be replaced.

14.6.1.3 If a *non-quick-start resource* has failed a Price Impact Test in any hour, the *commitment cost parameters* that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that hour. For any hours prior, any *commitment cost parameters* for that *resource* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level values* in those hours. This is expressed as:

14.6.1.3.1 For each hour $h \in \{1, \ldots, 24\}$ and all $b \in B_{NQS}$ such that $b \in BIT_h^{NCA} \cup BIT_h^{DCA} \cup BIT_h^{BCA} \cup BIT_h^{GMP}$, for hours prior to and including the hour that failed the Price Impact Test, $H \in \{1, \ldots, h\}$, *if* $b \in BCT_H^{NCA} \cup BCT_H^{DCA} \cup BCT_H^{BCA} \cup BCT_H^{GMP}$ and $PARAME_{H,b}$ contains any of the *commitment cost parameters SUOffer*, *SNLOffer*, or $EnergyToMLP_k$, these parameters shall be replaced with *reference levels*.

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 $PARAMOR_{H,b}$ shall be checked in place of $PARAME_{H,b}$.

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 hour $h \in \{1, \ldots, 24\}$:

14.5.1.5.1.1 if BIT_h^{NCA} includes one or more *resource* in a *narrow constrained area*, n, each *resource* $b \in BCT_h^{NCA}$ for the *narrow constrained area*, *RR*, shall have the parameters in $PARAME_{h,b}$ replaced with its *reference level values*; and

14.5.1.5.1.2 if BIT_h^{DCA} includes one or more *resources* in a *dynamic constrained area*, *d*, each *resource* $b \in BCT_h^{DCA}$ for *dynamic constrained area*, *d*, shall have the parameters in $PARAME_{h,b}$ 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 *non-quick 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 hour. For any hours 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 hours. This is expressed as:

14.6.1.6.1 For all hours up to the hour in which a *resource* failed the Price Impact Test for a *narrow constrained area*, for all b ∈ $BCT_{h\ NCA}$ if $PARAME_{h,b}$ contains any of the *commitment cost parameters SUOffer, SNLOffer, or EnergyToMLPk*, replace these parameters with *reference level values*.

14.6.1.6.2 For all hours up to the hour in which a *resource* failed the Price Impact Test for a *dynamic constrained area*, for all b ∈ BCT_{h}^{NCA}, if $PARAME_{h,b}$ 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 hour h ∈ {1, . . , 24}, if $BIT_{h\ ORL}$ includes one or more *resources* in *operating reserve* region, r, all *resources*, b ∈ $BI?_{h\ ORL}$ for *operating reserve* region, r, shall have the parameters in $PARAMOR_{h,b}$ 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 hour, 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 hour. For any hours 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 hours. This is expressed as:

14.6.1.8.1 For all hours up to the hour in which a *resource* failed the Price Impact Test for P, for all b ∈ BCT_h^{ORL}, if $PARAME_{h,b}$ 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 *day-ahead market calculation engine* shall prepare the following outputs for each hour h ∈ {1, . . , 24}:

14.7.1.1 The set of *resources* that failed the Price Impact Test, by condition, in accordance to sections 14.4 and 14.5;

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 according to sections 14.4 and 14.5; and

14.7.1.3 A revised set of *offer* data for *resources* that failed the Price Impact Test, replacing *offer* data that failed the Conduct Test with the applicable *reference level values*, in accordance with section 14.6.

14.7.2 The *day-ahead market calculation engine* shall not replace *financial dispatch data parameters* for a *resource* with that *resource'*s applicable *reference level value* if the *dispatch data* is less than the *reference level value*.

15 Mitigated Scheduling

15.1 Purpose

15.1.1 The *day-ahead market calculation engine* shall perform the Mitigated Scheduling algorithm if at least one *resource* failed the Price Impact Test in section 14.

15.1.2 The Mitigated 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 *resource reference level values* subject to section 15.2.2, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

15.2 Information, Sets, Indices and Parameters

15.2.1 Information, sets, indices and parameters used by the Mitigated Scheduling algorithm are described in section 3 and 4. In addition, the Mitigated Scheduling algorithm shall use the list of *resources* that failed the Price Impact Test and a revised set of *financial dispatch data parameters* for those *resources*.

15.2.2 For *resources* identified in section 14.7.1, the Mitigated Scheduling algorithm shall use *reference level value* for any *financial dispatch data parameters* that failed the Conduct Test.

15.3 Variables, Objective Function and Constraints

15.3.1 The *day-ahead market calculation engine* shall solve for the variables set out in section 8.3.1.

15.3.2 The objective function for the Mitigated Scheduling algorithm shall be the same as the objective function in section 8.3.2, subject to the constraints in sections 8.4 through 8.7. The sensitivities and limits used in section 8.7.3 shall be replaced with those provided by the most recent *security* assessment function iteration in the Mitigated Scheduling algorithm.

15.4 Outputs

15.4.1 Outputs of the Mitigated Scheduling algorithm include *resource* schedules and commitments.

16 Mitigated Pricing

16.1 Purpose

16.1.1 The *day-ahead market calculation engine* shall perform the Mitigated Pricing algorithm if the *day-ahead market calculation engine* performs the Mitigated Scheduling algorithm.

16.1.2 The Mitigated Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, resource reference level value* subject to section 16.2.2, and *resource* schedules and commitments produced by the Mitigated Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

16.2 Information, Sets, Indices and Parameters

16.2.1 Information, sets, indices and parameters used by the Mitigated Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedule and commitments from the Mitigated Scheduling algorithm shall be used by the Mitigated Pricing algorithm

16.2.1.1 $SDG_{h,b,k}^{MS}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $k \in K_{h,b}^{E}$;

16.2.1.2 $ODG_{h,b}^{MS}$ designates whether a *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1, . . , 24\}$;

16.2.1.3 $S10SDG_{h,b,k}^{MS}$ 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 hour $h \in \{1, ., 24\}$ in association with lamination $k \in K_{h,b}^{10S}$;

16.2.1.4 $S10NDG_{h,b,k}^{MS}$ 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 hour $h \in \{1, . . , 24\}$ in association with lamination $k \in K_{h,b}^{10N}$;

16.2.1.5 $S30RDG_{h,b,k}^{MS}$ 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 hour $h \in \{1, . . , 24\}$in association with lamination $k \in K_{h,b}^{30R}$; and

16.2.1.6 $OHO_{h,b}^{MS}$ designates whether a *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour $h \in \{1, . . , 24\}$.

16.2.2 For each *resource* identified in section 14.7.1, the Mitigated Pricing algorithm shall use such *resource's reference level value* for any *financial dispatch data parameters* that failed the Conduct Test.

16.3 Variables and Objective Function

16.3.1 The *day-ahead market calculation engine* shall solve for the variables listed in section 9.3.1.

16.3.2 The objective function for the Mitigated Pricing algorithm shall be the same as the objective function in section 9.3.2, subject to section 16.4.

16.4 Constraints

16.4.1 The constraints that apply in the Mitigated Pricing algorithm shall be the same as the constraints in sections 9.4 through 9.8, with the following exceptions:

16.4.1.1 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 iteration of the optimization function in the Mitigated Scheduling algorithm.

16.4.1.2 The sensitivities and limits used in section 9.7.3 shall be replaced with those provided by the most recent *security* assessment function iteration in the Mitigated Pricing algorithm.

16.4.1.3 For the constraints in section 9.8, the outputs from the As-Offered Scheduling algorithm shall be replaced with the outputs from the Mitigated Scheduling algorithm as follows:

16.4.1.3.1 $SDG_{h,b,k}^{AOS}$ shall be replaced by $SDG_{h,b,k}^{MS}$ for all h $\in \{1, .., 24\}$, b $\in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{E}$;

16.4.1.3.2 $ODG_{h,b}^{AOS}$ shall be replaced by $ODG_{h,b}^{MS}$ for all h $\in \{1, .., 24\}$, b $\in B^{DG}$;

16.4.1.3.3 $S10SDG_{h,b,k}^{AOS}$ shall be replaced by $S10SDG_{h,b,k}^{MS}$ for all h $\in \{1, .., 24\}$, $b \in B^{ELR} \cup B^{HE,}$ k $\in$ $K_{h,b}^{10S}$;

16.4.1.3.4 $S10NDG_{h,b,k}^{AOS}$ shall be replaced by $S10NDG_{h,b,k}^{MS}$ for all h $\in \{1, .., 24\}$, b $\in$ $BELR \cup BHE, k \in Kh,b\ 10N;$

16.4.1.3.5 $S30RDGh,b,k\ AOS$ shall be replaced by $S30RDGh,b,k\ MS$ for all $h \in \{1, \ldots, 24\}$, $b \in BELR \cup BHE$, $k \in Kh,b\ 30R$; and

16.4.1.3.6 $OHOh,b\ AOS$ shall be replaced by $OHOh,b\ MS$ for all $h \in \{1, \ldots, 24\}$, $b \in BHE$.

16.5 Outputs

16.5.1 Outputs of the Mitigated Pricing algorithm include the following:

16.5.1.1 Shadow prices; and

16.5.1.2 *Locational marginal prices* and their components.

17 Pass 2: Reliability Scheduling and Commitment

17.1 Purpose

17.1.1 Pass 2 shall use *market participant* and *IESO* inputs along with *resource* and system constraints to determine a set of *resource* schedules and commitments. Pass 2 shall consist of the Reliability Scheduling algorithm described in section 18.

18 Reliability Scheduling

18.1 Purpose

18.1.1 The Reliability Scheduling algorithm shall use *dispatch data* submitted by *registered market participants* and perform a *security*-constrained unit commitment and economic *dispatch* to meet the *IESO's* peak province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next day to minimize the cost of additional commitments.

18.2 Information, Sets, Indices and Parameters

18.2.1 Information sets, indices and parameters used by the Reliability Scheduling algorithm are described in sections 3 and 4. The Reliability Scheduling algorithm shall also use the following:

18.2.1.1 *resource* schedules, commitments, and *locational marginal prices* from Pass 1, where:

18.2.1.1.1 $SXL_{h,d,j}^{1}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to export at *intertie zone* bus $d \in DX$ in hour h $\in \{1, .., 24\}$ in association with lamination j $\in J_{h,d}^{E}$;

18.2.1.1.2 $SDG_{h,b,k}^{1}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_{b}$ *at* bus b $\in B^{ELR} \cup B^{HE}$ in hour h $\in \{1, . . . , 24\}$ in association with lamination k $\in K_{h,b}^{E}$;

18.2.1.1.3 $ODG_{h,b}^{1}$ designates whether a dispatchable generation resource at bus $b \in B^{DG}$ was scheduled at or above its minimum loading point in hour $h \in \{1, . . . , 24\}$;

18.2.1.1.4 $S10SDG_{h,b,k}^{1}$ 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 hour $h \in \{1, . . . , 24\}$ in association with lamination $k \in K_{h,b}^{10S}$;

18.2.1.1.5 $S10NDG_{h,b,k}^{1}$ *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 hour $h \in \{1, .., 24\}$ in association with lamination $k \in K_{h,b}^{10N}$;

18.2.1.1.6 $S30RDG_{h,b,k}^{1}$ designates the amount of *thirty-minute operating reserve* that a qualified *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K_{h,b}^{30R}$;

18.2.1.1.7 $SIG_{h,d,k}^{1}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to import at *intertie zone* bus $d \in DI$ in hour $h \in \{1, .., 24\}$ in association with lamination k $\in K_{h,d}^{E}$; and

18.2.1.1.8 $LMP_{h,b}^{1}$ designates the *locational marginal price* in hour h $\in \{1, .., 24\}$ at bus b $\in B^{ELR} \cup B^{HE}$; and

18.2.1.2 The buses identifying either single *energy limited resources* or multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay*, and the subset of *resources* with a binding *maximum daily energy limit* constraint from Pass 1

18.2.1.2.1 $B^{LIM} = B^{ELR} \cup \{B_s^{HE}$ for all $s \in SHE\}$ designates the set of buses identifying either *energy limited resources* or *dispatchable* hydroelectric *generation resources* sharing a *maximum daily energy limit*; and

18.2.1.2.2 $B^{BND} \subseteq B^{LIM}$ designates the subset of buses identifying either *energy limited resources*, or *dispatchable* hydroelectric *generation resources* sharing a *maximum daily energy limit*, with a binding *maximum daily energy limit* constraint from Pass 1, where: a *maximum daily energy limit* shall be considered binding if the criteria in sections 9.8.2 and 9.8.3.6 are met using $ODG_{h,b}^1$, $SDG_{h,b,k}^1$, $S10NDG_{h,b,k}^1$ and $S30RDG_{h,b,k}^1$

18.2.2 The Reliability Scheduling algorithm shall use *reference level value* for any *financial dispatch data parameters* that failed the Conduct Test associated with *resources* identified in section 14.7.

18.2.3 *Dispatchable loads*, *non-dispatchable generation resources*, and the *energy offered* above *minimum loading point* for *dispatchable generation resources* shall be evaluated in the *Reliability* Scheduling algorithm as follows:

18.2.3.1 $PRucDL_{h,b,j}$ designates the *energy* price for incremental *energy* consumption in hour h ∈ {1, . . , 24} at *dispatchable load* bus b ∈ B_{DL} in association with *bid* lamination $j \in J_{h,b}^E$, where:

$$PRucDL_{h,b,j} = min(n, PDL_{h,b,j});$$

18.2.3.2 $PRuc10SDL_{h,?,?}$ designates the price of being scheduled to provide synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable load* bus $b \in ?^{DL}$ in association with *offer* lamination $j \in J_{h,b}^{10S}$, where:

$$PRuc10SDL_{h,b,j} = min(n, P10SDL_{h,b,j});$$

18.2.3.3 $PRuc10NDL_{h,b,j}$ designates the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable load* bus b ∈ B_{DL} in association with *offer* lamination $j \in J_{h,b}^{10N}$, where:

$PRuc10NDL_{h,b,j} = min(n, P10NDL_{h,b,j})$;

18.2.3.4 $PRuc30RDL_{h,b,j}$ designates the price of being scheduled to provide *thirty-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable load* bus b ∈ B_{DL} in association with *offer* lamination j ∈ $J_{h,b}^{30R}$, where:

$PRuc10NDL_{h,?,?}$ = ??$n(n,$?$10NDL_{h,b,j}$);

18.2.3.5 $PRucNDG_{h,b,k}$ designates the *energy* price for incremental generation in hour h ∈ {1, . . , 24} at *non-dispatchable generation resource* bus *b* ∈ B_{NDG} in association with *offer* lamination k ∈ $K_{h,b}^{E}$, where:

$PRucNDG_{h,b,k} = min(n, PNDG_{h,b,k})$;

18.2.3.6 $PRucDG_{h,b,k}$ designates the *energy* price for incremental generation in hour *h* ∈ {1, . . , 24} at *dispatchable generation resource* bus b ∈ B^{DG} *in* association with *offer* lamination k ∈ $K_{h,b}^{E}$, where:

$PRucDG_{h,b,k} = min(n, PDG_{h,b,k})$;

18.2.3.7 $PRuc10SDG_{h,b,k}$ designates the price of being scheduled to provide synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable generation resource* bus b ∈ B_{DG} in association with *offer* lamination $k \in K_{h,b}^{10S}$, where:

$PRuc10SDG_{h,b,k} = min(n, P10SDG_{h,b,k})$;

18.2.3.8 $PRuc10NDG_{h,b,k}$ designates the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable generation resource* bus b ∈ B_{DG} in association with *offer* lamination $k \in K_{h,b}^{10N}$, where:

$PRuc10NDG_{h,b,k} = min(n, P10NDG_{h,b,k})$;

18.2.3.9 $PRuc30RDG_{h,b,k}$ designates the price of being scheduled to provide *thirty-minute operating reserve* in hour h ∈ {1, . . , 24} at *dispatchable* generation bus $b \in BDG$ in association with *offer* lamination $k \in K_{h,b}^{30R}$,

where:

$PRuc30RDG_{h,b,k} = min(n, P30RDG_{h,b,k})$;

where:

n = $0.10/MWh;

18.2.4 For the set of *resources* identified in the buses in section 18.2.1.2, incremental quantities of *energy* at or above *minimum loading point* shall be evaluated in the Reliability Scheduling algorithm as follows:

18.2.4.1 $Q1DG_{h,b,k}$ designates an incremental quantity of *energy* that a *resource* may be scheduled to provide in hour h ∈ {1, . . , 24} in association with *offer* lamination k ∈ $K_{h,b}$ E and corresponding to the Pass 1 scheduled portion of the lamination, where:

$Q1DG_{h,b,k} = SDG_{h,b,k}^{1}$;

18.2.4.2 $P1DG_{h,b,k}$ designates the price for the incremental quantity of *energy* that a *resource* may be scheduled to provide in hour h ∈ {1, . . ,24} in association with *offer* lamination k ∈ $K_{h,b}$ E and corresponding to the Pass 1 scheduled portion of the lamination, where:

$P1DG_{h,b,k} = min(PDG_{h,b,k}, -LMP_{h,b}^{1})$;

18.2.4.3 $Q2DG_{h,b,k}$ designates an incremental quantity of *energy* that a *resource* may be scheduled to provide in hour h ∈ {1, . . , 24} in association with *offer* lamination $k \in K_{h,b}^{E}$ and corresponding to the Pass 1 unscheduled portion of the lamination, where:

$Q2DG_{h,b,k} = QDG_{h,b,k} - SDG_{h,b,k}^{1}$; *and*

18.2.4.4 $P2DGh,b,k$ designates the price for the incremental quantity of *energy* that a *resource* may be scheduled to provide in hour h ∈ {1, . , 24} in association with *offer* lamination $k \in K_{h,b}^{E}$ and corresponding to the Pass 1 unscheduled portion of the lamination, where:

$$P2DG_{h,b,k} = \begin{cases} max(n, PDG_{h,b,k} - LMP_{h,b}^{1}) & if\ b \in B^{BND} \\ min(n, PDG_{h,b,k}) & otherwise \end{cases}.$$

18.3 Variable and Objective Function

18.3.1 The *day-ahead market calculation engine* shall solve for the variables listed in section 8.3.1.

18.3.2 The objective function for the Reliability Scheduling algorithm shall be the same as the objective function in section 8.3.2, with the following exceptions:

18.3.2.1 The *day-ahead market calculation engine* shall remove the variables for *price responsive loads* ($SPRL_{h,b,j}$), *virtual transaction bids* ($PVB_{h,v,j}$, $QVB_{h,v,j}$), and *virtual transaction offers* ($PVO_{h,v,k}$, $QVO_{h,v,k}$) from the objective function;

18.3.2.2 The *day-ahead market calculation engine* shall add the following variables to the objective function:

18.3.2.2.1 $S1DG_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus b ∈ B^{LIM} in hour $h \in \{1, . . , 24\}$ in association with lamination k ∈ $K_{h,b}{}^{E}$ corresponding to the Pass 1 scheduled portion of the lamination; and

18.3.2.2.2 $S2DG_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{LIM}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $k \in K_{h,b}{}^{E}$ corresponding to the Pass 1 unscheduled portion of the lamination

18.3.2.3 The objective function coefficients for *dispatchable loads*, *non-dispatchable generation resources* and *dispatchable generation resources* shall be modified to reflect the price of incremental *energy* from such *resources* as specified in section 18.2.3; and

18.3.2.4 The objective function coefficients for single *energy limited resources* and multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall be modified to reflect the pricing of the Pass 1 scheduled and unscheduled portions as specified in section 18.2.4.

18.3.3 The objective function for the Reliability Scheduling algorithm shall minimize the cost of additional commitments by maximizing the following expression:

$$\sum_{h\,=\,1,..,24} \begin{pmatrix} ObjDL_h - ObjHDR_h + ObjXL_h - \ ObjNDG_h \\ - \ ObjDG_h - ObjIG_h \ - TB_h - \ ViolCost_h \end{pmatrix}$$

where:

$$ObjDL_h = \sum_{b \in B^{DL}} \left(\begin{array}{c} \sum_{j \in J_{h,b}^{E}} SDL_{h,b,j} \cdot PRucDL_{h,b,j} - \sum_{j \in J_{h,b}^{10S}} S10SDL_{h,b,j} \cdot PRuc10SDL_{h,b,j} - \\ \sum_{j \in J_{h,b}^{10N}} S10NDL_{h,b,j} \cdot PRuc10NDL_{h,b,j} - \sum_{j \in J_{h,b}^{30R}} S30RDL_{h,b,j} \cdot PRuc30RDL_{h,b,j} \end{array} \right)$$

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

$$ObjXL_h = \sum_{d \in DX} \left(\begin{array}{c} \sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \cdot PXL_{h,d,j} - \sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \cdot P10NXL_{h,d,j} \\ - \sum_{j \in J_{h,d}^{30R}} S30RXL_{h,d,j} \cdot P30RXL_{h,d,j} \end{array} \right)$$

$$ObjNDG_h = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{h,b}^{E}} SNDG_{h,b,k} \cdot PRucNDG_{h,b,k} \right)$$

$$\begin{aligned} ObjDG_h &= \sum_{b \in B^{DG},\ b \notin B^{LIM}} \left(\sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} \cdot PRucDG_{h,b,k} \right) \\ &+ \sum_{b \in B^{LIM}} \left(\sum_{k \in K_{h,b}^{E}} \left(S1DG_{h,b,k} \cdot P1DG_{h,b,k} + S2DG_{h,b,k} \cdot P2DG_{h,b,k} \right) \right) \\ &+ \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K_{h,b}^{10S}} S10SDG_{h,b,k} \cdot PRuc10SDG_{h,b,k} + \\ \sum_{k \in K_{h,b}^{10N}} S10NDG_{h,b,k} \cdot PRuc10NDG_{h,b,k} + \sum_{k \in K_{h,b}^{30R}} S30RDG_{h,b,k} \cdot PRuc30RDG_{h,b,k} \end{array} \right) \\ &+ \sum_{b \in B^{NQS}} \left(ODG_{h,b} \cdot MGODG_{h,b} + IDG_{h,b} \cdot SUDG_{h,b} \right) \end{aligned}$$

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

18.3.3.1 The tie-breaking (TB_h) and the violation cost ($ViolCost_h$) terms used shall be the ones defined in sections 8.3.1 and 8.3.2.

18.4 Constraints

18.4.1 The Reliability Scheduling algorithm optimization shall apply the constraints described in sections 18.5 through 18.7 and 18.8.

18.5 Dispatch Data Constraints Applying to Individual Hours

18.5.1 Scheduling Variable Bounds and Commitment Status Variables

18.5.1.1 The constraints shall be the same as in section 8.5.1 with the following exceptions:

18.5.1.1.1 the constraints applying to *price responsive loads* in section 8.5.1.6 shall be removed; and

18.5.1.1.2 the constraints applying to *virtual transaction bids* and *offers* in section 8.5.1.6 shall be removed.

18.5.2 Resource Minimums and Maximums

18.5.2.1 The constraints in section 8.5.2 shall apply for *dispatchable loads*, *non-dispatchable generation resources* and inadvertent payback transactions.

18.5.2.2 The constraints in section 8.5.2 shall apply for *dispatchable generation resources*, except the alternative forecast $(AFG_{h,b})$ is replaced with the *IESO*'s centralized forecast $(FG_{h,b})$. That is:

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

and

$$AdjMinDG_{h,b} = min(MinDG_{h,b}, AdjMaxDG_{h,b})$$

Then, for all hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$:

$$AdjMinDG_{h,b} \le MinQDG_b \cdot ODG_{h,b} + \sum_{k \in K_{h,b}^{E}} SDG_{h,b,k} \le AdjMaxDG_{h,b}$$

18.5.3 Operating Reserve Requirements

18.5.3.1 The constraints in section 8.5.4 shall apply for *operating reserve* requirements.

18.5.4 Pseudo-Units

18.5.4.1 The constraints in section 8.5.5 shall apply for *pseudo-units*.

18.5.5 Dispatchable Hydroelectric Generation Resources

18.5.5.1 The constraints in section 8.5.6 shall apply for *dispatchable* hydroelectric *generation resources*.

18.5.6 Wheeling Through Transactions

18.5.6.1 The constraints in section 8.5.7 shall apply for wheeling through transactions.

18.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

18.6.1 Energy Ramping

18.6.1.1 The constraints in section 8.6.1 shall apply for *energy* ramping.

18.6.2 Operating Reserve Ramping

18.6.2.1 The constraints in section 8.6.1.1 shall apply for *operating reserve* ramping.

18.6.3 Non-Quick-start Resources

18.6.3.1 The constraints in section 8.6.3 shall apply for *non-quick start resources*.

18.6.4 Energy Limited Resources

18.6.4.1 The constraints in section 8.6.4 shall apply for *energy limited resources*.

18.6.5 Dispatchable Hydroelectric Generation Resources

18.6.5.1 The constraints in section 8.6.5 shall apply for *dispatchable* hydroelectric *generation resources*.

18.7 Constraints for Reliability Requirements

18.7.1 Energy Balance

18.7.1.1 The constraint in section 8.7.1 shall apply in the Reliability Scheduling algorithm, with the following exceptions:

18.7.1.1.1 *price responsive loads* shall be removed from the total amount of scheduled *energy* withdrawals, $With_{h,b}$, in section 8.7.1.1;

18.7.1.1.2 the net withdrawal for *virtual transaction zones*, $VWith_{h,m}$, in sections 8.7.1.2 and 8.7.1.6 shall be removed; and

18.7.1.1.3 the Reliability Scheduling algorithm shall use the *IESO's* peak province-wide non-*dispatchable demand* forecast (PFL_h), in place of the *IESO's* average province-wide non-*dispatchable* demand forecast (AFL_h).

18.7.1.2 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in hour $h \in \{1, .., 24\}$, $With_{h,b}$, shall be:

$$With_{h,b} = \begin{cases} \sum_{j \in J^E_{h,b}} SDL_{h,b,j} & if\ b \in B^{DL} \\ \sum_{j \in J^E_{h,b}} (QHDR_{h,b,j} - SHDR_{h,b,j}) & if\ b \in B^{HDR} \end{cases}$$

18.7.1.3 The total amount of *energy* withdrawals scheduled at *intertie zone* bus $d \in DX$ in hour $h \in \{1, .., 24\}$, $With_{h,d}$, shall be:

$$With_{h,d} = \sum_{j \in J^E_{h,d}} SXL_{h,d,j}$$

18.7.1.4 The total amount of *energy* injections scheduled at internal bus $b \in B$ in hour $h \in \{1, .., 24\}$, $Inj_{h,b}$, shall be:

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

where:

$$OfferInj_{h,b} = \begin{cases} \sum_{k \in K^E_{h,b}} SNDG_{h,b,k} & if\ b \in B^{NDG} \\ ODG_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG_{h,b,k} & if\ b \in B^{DG} \end{cases}$$

and

$$RampInj_{h,b} = \begin{cases} \sum_{w=1..min(RampHrs_b, 24-h)} RampE_{b,w} \cdot IDG_{h+w,b} & if\ b \in B^{NQS} \\ 0 & otherwise \end{cases}$$

18.7.1.5 The total amount of *energy* injections scheduled at *intertie zone* bus $d \in DI$ in hour $h \in \{1, . . , 24\}$, $Inj_{h,d}$, shall be:

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

18.7.1.6 *Energy* injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor from 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 *energy* 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 to allow the *day-ahead market calculation engine* to produce a solution. For hour $h \in \{1, . . , 24\}$:

$$\begin{aligned} PFL_h + \sum_{b \in B^{DL} \cup B^{HDR}} (1 + MglLoss_{h,b}) \cdot With_{h,b} \\ + \sum_{d \in DX} (1 + MglLoss_{h,d}) \cdot With_{h,d} \\ - \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} \\ = \sum_{b \in B^{NDG} \cup B^{DG}} \left(1 + MglLoss_{h,b}\right) \cdot Inj_{h,b} \\ + \sum_{d \in DI} \left(1 + MglLoss_{h,d}\right) \cdot Inj_{h,d} \\ - \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} + LossAdj_h. \end{aligned}$$

18.7.2 Operating Reserve Requirements

18.7.2.1 The constraints in section 8.7.2 shall apply for *operating reserve*.

18.7.3 IESO Internal Transmission Limits

18.7.3.1 The constraints in section 8.7.3 shall apply for *IESO* internal transmission limits. The sensitivities and limits applied shall be provided by the most recent *security* assessment function iteration of the Reliability Scheduling algorithm, with the following exceptions:

18.7.3.2 The terms for *price responsive loads* in sections 8.7.3.3 and 8.7.3.4 shall be removed; and

18.7.3.3 The terms for *bids* and *offers* for *virtual transactions* in sections 8.7.3.3 and 8.7.3.4 shall be removed.

18.7.4 Intertie Limits

18.7.4.1 The constraints in section 8.7.4 shall apply for *intertie* limits.

18.7.5 Penalty Price Variable Bounds

18.7.5.1 The constraints in section 8.7.5 shall apply for penalty price variable bounds.

18.8 Constraints to Respect Pass 1 Decisions

18.8.1 The Reliability Scheduling algorithm shall not schedule *energy* import schedules for *boundary entity resources* below those import schedules determined in Pass 1. For all hours $h \in \{1, . . , 24\}$ and *intertie zone* buses $d \in DI$ that are not part of a wheeling through transaction:

$$\sum_{k \in K_{h,d}^{E}} SIG_{h,d,k} \geq \sum_{k \in K_{h,d}^{E}} SIG_{h,d,k}^{1}$$

18.8.2 The Reliability Scheduling algorithm shall not schedule *energy* export schedules for *boundary entity resources* above those export schedules determined in Pass 1. For all hours $h \in \{1, . . , 24\}$ and *intertie zone* buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \leq \sum_{j \in J_{h,d}^{E}} SXL_{h,d,j}^{1}$$

18.8.3 The Reliability Scheduling algorithm shall not de-commit *dispatchable generation resources* committed in Pass 1. For all hours h ∈ $\{1, . . , 24\}$ and buses $b \in B^{DG}$:

$$ODG_{h,b} \geq ODG_{h,b}^{1}$$

18.8.4 For single *energy limited resources* and multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay*, the Reliability Scheduling algorithm shall ensure the schedule for each *offer* lamination is equal to the schedules corresponding to the Pass 1 scheduled and unscheduled portions. For all buses $b \in B^{LIM}$, hours $h \in \{1, . . , 24\}$ and *offer* laminations $k \in K_{h,b}^{E}$:

$$SDG_{h,b,k} = S1DG_{h,b,k} + S2DG_{h,b,k}$$

18.8.5 The *generation resource* schedules for the Pass 1 scheduled and unscheduled portions of the lamination shall respect the incremental quantity of *energy* beyond the *minimum loading point* that may be scheduled. For all buses $b \in B^{LIM}$, hours $h \in \{1, . . , 24\}$ and *offer* laminations $k \in K_{h,b}^{E}$:

$$0 \leq S1DG_{h,b,k} \leq Q1DG_{h,b,k}$$

and

$$0 \leq S2DG_{h,b,k} \leq Q2DG_{h,b,k}$$

18.9 Outputs

18.9.1 Outputs of the Reliability Scheduling algorithm shall include *resource* schedules and commitments.

19 Pass 3: DAM Scheduling and Pricing

19.1 Purpose

19.1.1 Pass 3 shall use *market participant* and *IESO* inputs along with *resource* and system constraints to determine a set of *resource* schedules, commitments, and shadow prices, as well as a set of schedules and *locational marginal prices* that shall be used for *settlement*. Pass 3 consists of the DAM Scheduling algorithm described in section 20 and the DAM Pricing algorithm described in section 21.

20 DAM Scheduling

20.1 Purpose

20.1.1 The DAM Scheduling algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, reference level values* for *resources* subject to section 20.2.2, and *resource* schedules and commitments from the Reliability Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*

20.2 Information, Sets, Indices and Parameters

20.2.1 Information, sets, indices and parameters for the DAM Scheduling algorithm are described in sections 3 and 4. In addition, the following *resource* schedules and commitments from Pass 2 shall be used by the DAM Scheduling algorithm:

20.2.1.1 $SXL_{h,d,j}^2$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to export at *intertie zone* bus d ∈ DX in hour h ∈ {1, . . , 24} in association with lamination j ∈ $J_{h,d}^E$;

20.2.1.2 $ODG_{h,b}^2$, which designates whether the *dispatchable generation resource* at bus b ∈ B_{DG} was scheduled at or above its *minimum loading point* in hour h ∈ {1, . . , 24}; and

20.2.1.3 $SIG_{h,d,k}^2$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import at *intertie zone* bus d ∈ DI in hour h ∈ {1, . . , 24} in association with lamination $k \in K_{h,d}^E$.

20.2.2 The DAM Scheduling algorithm shall use *reference level value* for any financial dispatch data parameters that failed the Conduct Test associated with resources identified in section 14.7.

20.3 Variables and Objective Function

20.3.1 The *day-ahead market calculation engine* shall solve for the variables set out in section 8.3.1.

20.3.2 The objective function for the DAM Scheduling algorithm shall be the same as the objective function in section 8.3.2, with the following exceptions:

20.3.2.1 the variables for unit commitment decisions ($ODG_{h,b}$) shall be fixed within the optimization function; and

20.3.2.2 the *start-up offer* ($SUG_{h,b}$) and the *offer* price to operate at *minimum loading point* ($MGODG_{h,b}$) shall be removed from the objective function.

20.3.3 The optimization function in the DAM Scheduling algorithm shall be subject to the constraints described in section 20.4.

20.4 Constraints

20.4.1 The DAM Scheduling algorithm optimization function shall apply the constraints described in sections 20.5– 20.8.

20.5 Dispatch Data Constraints Applying to Individual Hours

20.5.1 The constraints in section 8.5 shall apply in the DAM Scheduling algorithm.

20.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

20.6.1 The constraints in section 8.6 shall apply in the DAM Scheduling algorithm, with the exception that the constraints for *non-quick start resources* in section 8.6.3 shall be removed.

20.7 Constraints to Ensure Schedules Do Not Violate *Reliability* Requirements

20.7.1 The constraints are the same as in section 8.7. The sensitivities and limits used in section 8.7.3 are those provided by the most recent *security* assessment function iteration of the DAM Scheduling algorithm.

20.8 Constraints to Respect Pass 2 Decisions

20.8.1 The DAM Scheduling algorithm shall not decrease import schedules from the values produced in Pass 2 and may schedule additional imports of *energy* in Pass 3. For all hours h $\in \{1,..,24\}$ and *intertie zone* buses d $\in$ DI that are not part of a wheeling through transaction:

$$\sum_{k \in K_{h,d}^{E}} SIG_{h,d,k} \geq \sum_{k \in K_{h,d}^{E}} SIG_{h,d,k}^{2}$$

20.8.2 The DAM Scheduling algorithm shall not increase export schedules in Pass 3 from the values produced in Pass 2. For all hours $h \in \{1, . . , 24\}$ and *intertie zone* buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \leq \sum_{j \in J_{h,d}^{E}} SXL_{h,d,j}^{2}$$

20.8.3 The DAM Scheduling algorithm shall not change commitments statuses in Pass 3 for *resources* as determined in Pass 2. For all hours $h \in \{1, . . , 24\}$ and buses $b \in B^{DG}$:

$$ODG_{h,b} = ODG_{h,b}^{2}$$

20.9 Outputs

20.9.1 Outputs for the DAM Scheduling algorithm shall include *resource* schedules and commitments.

21 DAM Pricing

21.1 Purpose

21.1.1 The DAM Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, reference level values* for *resources* subject to section 21.2.2.3, and *resource* schedules and commitments produced by the DAM Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

21.2 Information, Sets, Indices and Parameters

21.2.1 Information, sets, indices and parameters for the DAM Pricing algorithm are described in sections 3 and 4. In addition, DAM Pricing algorithm shall use the following *resource* schedules and commitments from the DAM Scheduling algorithm in section 20:

21.2.1.1 $SDG_{h,b,k}{}^{3}$ which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus b $\in B^{ELR} \cup B^{HE}$ in hour h $\in \{1,..,24\}$ in association with lamination k $\in K_{hb}{}^{E}$

21.2.1.2 $ODG_{h,b}{}^{3}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour h $\in \{1,..,24\}$. Note that $ODG_{h,b}{}^{3} = ODG_{h,b}{}^{2}$ for all hours $h \in \{1,...,24\}$ and buses $b \in B^{DG}$;

21.2.1.3 $S10SDG_{h,b,k}{}^{3}$, 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 hour $h \in \{1,..,24\}$ in association with lamination $k \in K_{h,b}{}^{10S}$;

21.2.1.4 $S10NDG_{h,b,k}{}^{3}$, 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 hour h $\in \{1,..,24\}$ in association with lamination $k \in K_{h,b}{}^{10N}$;

21.2.1.5 $S30RDG_{h,b,k}{}^{3}$, 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 hour h $\in \{1,..,24\}$in association with lamination $k \in K_{h,b}{}^{30R}$; and

21.2.1.6 $OHO_{h,b}{}^{3}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus b $\in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour h $\in \{1,..,24\}$.

21.2.2 *The resource schedules from Pass 2:*

21.2.2.1 $SXL_{h,d,j}{}^{2}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to export at bus d $\in DX$ in hour h $\in \{1,..,24\}$ in association with lamination $j \in J_{h,d}{}^{E}$; and

21.2.2.2 $SIG_{h,d,k}{}^{2}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import at *bus* $d \in DI$ in hour h $\in \{1,..24\}$ in association with lamination $k \in K_{h,d}{}^{E}$.

21.2.2.3 The DAM Pricing algorithm shall use *reference level values* for any *financial dispatch data parameters* that failed the Conduct Test associated with *resources* identified in section 14.7.

21.3 Variables and Objective Function

21.3.1 The DAM Pricing algorithm shall solve for the variables listed in section 9.3.1.

21.3.2 The objective function for the DAM Pricing algorithm shall be the same as the objective function in section 9.3.2, subject to section 21.4.

21.4 Constraints

21.4.1 The constraints in sections 9.4 through 9.8 shall apply in the DAM Pricing algorithm, with the following exceptions:

21.4.1.1 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 DAM Scheduling algorithm in section 20.

21.4.1.2 The sensitivities and limits used in section 9.7.3 shall be provided by the most recent *security* assessment function iteration of the DAM Pricing algorithm.

21.4.1.3 For the constraints in section 9.8, the outputs from the As-Offered Scheduling algorithm in section 8 shall be replaced with the outputs from the DAM Scheduling algorithm in section 20, as follows:

21.4.1.3.1 $SDG_{h,b,k}^{AOS}$ shall be replaced by $SDG_{h,b,k}^{3}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{E}$;

21.4.1.3.2 $ODG_{h,b}^{AOS}$ shall be replaced by $ODG_{h,b}^{3}$ for all $h \in \{1,..,24\}$, $b \in B^{DG}$;

21.4.1.3.3 $S10SDG_{h,b,k}^{AOS}$ shall be replaced by $S10SDG_{h,b,k}^{3}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{10S}$;

21.4.1.3.4 $S10NDG_{h,b,k}^{AOS}$ shall be replaced by $S10NDG_{h,b,k}^{3}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{10N}$;

21.4.1.3.5 $S30RDG_{h,b,k}^{AOS}$ shall be replaced by $S30RDG_{h,b,k}$ for all $h \in \{1,..,24\}$, $b \in B^{ELR} \cup B^{HE}$, $k \in K_{h,b}^{30R}$; and

21.4.1.3.6 $OHO_{h,b}^{AOS}$ shall be replaced by $OHO_{h,b}^{3}$ for all $h \in \{1,..,24\}$, $b \in B^{HE}$.

21.4.1.4 The constraints imposed for *boundary entity resource* schedules in section 20.8 shall apply to *boundary entity resource* schedules in the DAM Pricing algorithm, with a tolerance Δ specified by the *IESO* and:

21.4.1.4.1 For all hours h ∈ {1, . . , 24} and *boundary entity resource* import buses $d \in DI$ that are not part of a wheeling through transaction:

$$\sum_{k \in K_{h,d}^{E}} SIG_{h,d,k} \geq \sum_{k \in K_{h,d}^{E}} SIG_{h,d,k}^{2} - \Delta$$

21.4.1.4.2 For all hours h ∈ {1, . . , 24} and *boundary entity resource* export buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \leq \sum_{j \in J_{h,d}^{E}} SXL_{h,d,j}^{2} + \Delta$$

21.5 Outputs

21.5.1 Outputs of the DAM Pricing algorithm include shadow prices and *locational marginal prices* for *energy* and *operating reserve*.

22 Pseudo-Unit Modelling

22.1 Pseudo-Unit Model Parameters

22.1.1 The *day-ahead market 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 L combustion turbines and one steam turbine:

22.1.1.1 $CMCR_k$ designates the registered *maximum continuous rating* of combustion turbine $k \in \{1, . . ,K\}$ in MW;

22.1.1.2 $CMLP_k$ designates the *minimum loading point* of combustion turbine $k \in \{1, . . ,K\}$ in MW;

22.1.1.3 *SMCR* designates the registered *maximum continuous rating* of the steam turbine in MW;

22.1.1.4 *SMLP* designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

22.1.1.5 *SDF* designates the amount of duct firing capacity available on the steam turbine in MW;

22.1.1.6 $STPortion_k$ designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

22.1.1.7 $CSCM_k \in \{0,1\}$ designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in single cycle mode for the day.

22.1.2 The *day-ahead market calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..K\}$:

22.1.2.1 $MMCR_k$ designates the *maximum continuous rating* of *pseudo-unitPP* and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

22.1.2.2 $MMLP_k$ designates the *minimum loading point* of *pseudo-unitPP* and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

22.1.2.3 MDF_k designates the duct firing capacity of *pseudo-unitPP* and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

22.1.2.4 MDR_k designates the *dispatchable* capacity of *pseudo-unitPP* and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

22.1.3 The *day-ahead market calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

22.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

22.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and $MMLP_k + MDR_k$; and

22.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

22.1.4 The *day-ahead market calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* k ∈ {1,..K}, as follows:

22.1.4.1 For the minimum loading point region:

22.1. 4.1.1 Steam turbine share: $STShareMLP_k = SMLP \cdot (1 - CSCMk) / MMLPk$; and

22.1. 4.1.2 Combustion turbine share: $CTShareMLP_k = CMLP_k / MMLP_k$;

22.1.4.2 For the *dispatchable* region:

22.1.4.2.1 Steam turbine share:

$STShareDRk =$

$(1 - CSCM_k)(SMCR \cdot STPortion_k - SMLP - SDF_k \cdot STPortion_k) / MDR_k$; and

22.1.4.2.2 Combustion turbine share: $CTShareDR_k = (CMCR_k - CMLP_k) / MDR_k$

22.1.4.3 For the duct firing region:

22.1.4.3.1 Steam turbine share shall be equal to 1; and

22.1.4.3.2 Combustion turbine share shall be equal to 0.

22.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

22.2.1 The *day-ahead market calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

22.2.1.1 $CTCap_{h,k}$ designates the capacity of combustion turbine k ∈ {1, . . ,K}in hour h as determined by submitted deratings;

22.2.1.2 $STCap_h$ designates the capacity of the steam turbine in hour h as determined by submitted deratings; and

22.2.1.3 $TotalQ_{h,k}$ designates the total *offered* quantity of *energy* for *pseudo-unit* k ∈ {1, . . ,K} in hour h.

22.2.2 The *day-ahead market calculation engine* shall solve for the following operating region parameters for hour $h \in [1, . . ,24\}$ for each *pseudo-unit* $k \in \{1, . . ,K\}$:

22.2.2.1 $MLP_{h,k}$ designates the *minimum loading point* of *pseudo-unit* k in hour h;

22.2.2.2 $DR_{h,k}$ designates the *dispatchable* region capacity of *pseudo-unit* k in hour h; and

22.2.2.3 $DF_{h,k}$ designates the duct firing region capacity of *pseudo-unitPP* in hour h.

22.2.3 Pre-processing of De-rates

22.2.3.1 The *day-ahead market calculation engine* shall perform the following pre-processing 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 hour $h \in \{1, . . , 24\}$:

22.2.3.1.1 Step 1: Calculate the amount of *offered energy* attributed to each combustion turbine ($CTAmt_{h,k}$) and steam turbine portion ($STAmt_{h,k}$):

If $TotalQ_{h,k} < MMLP_k$ then:

$CTAmt_{h,k} = 0$; and

$STAmt_{h,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{h,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{h,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{h,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{h,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{h,k} = CTAmtMLP + CTAmtDR; and$

$STAmt_{h,k} = STAmtMLP + STAmtDR + STAmtDF.$

22.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$PRSTCap_{h,k}= (STAmt_{h,k} / \sum_{w \in \{1,..,K\}} STAmt_{h,w}) \cdot STCap_h$

22.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{h.k} < CMLP_k$, then the *pseudo-unit* is unavailable.
If $STAmt_{h,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{h,k} < CMLP_k$, then the *pseudo-unit* is unavailable. If $PRSTCap_{h,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

22.2.3.1.4 Step 4: Initialize the operating region parameters for hour h ∈ {1, . . , 24} to the model parameter values:

Set $MLP_{h,k} = MMLP_k.$

Set $DR_{h,k} = MDR_k.$

Set $DF_{h,k} = MDF_k.$

22.2.3.1.5 Step 5: Apply the deratingon the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k = CTCap_{h,k;}$ and

Set $DR_{h,k} = min(DR_{h,k} , P \cdot MDR_k).$

22.2.3.1.6 Step 6: Apply the deratingon the steam turbine to the duct firing and *dispatchable* regions for *pseudo-unit*s not operating in *single cycle mode*:

Calculate NN so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{h,k.}$

If R ≤ 1, set $DF_{h,k} = 0$, and $DR_{h,k} = min(DR_{h,k} , R \cdot MDR_k).$

If R > 1, set $DF_{h,k} = min(DF_{h,k}, PRSTCap_{h,k} - SMLP - STShareDR_k \cdot MDR_k).$

22.2.4 Available Energy Laminations

22.2.4.1 The *day-ahead market calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for hour h $\in \{1, . . , 24\}$ for each *pseudo-unit* $k \in \{1, . . ,K\}$, subject to section 22.2.4.2, where:

22.2.4.1.1 $QMLP_{h,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

22.2.4.1.2 $QDR_{h,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

22.2.4.1.3 $QDF_{h,k}$ designates the total quantity that may be scheduled in the duct firing region.

22.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$0 \leq QMLP_{h,k} \leq MLP_{h,k}$;

$0 \leq QDR_{h,k} \leq DR_{h,k}$;

$0 \leq QDF_{h,k} \leq DF_{h,k}$;

if $QMLP_{h,k} < MLP_{h,k}$, then the *pseudo-unit* is unavailable and $QDR_{h,k} = QDF_{h,k} = 0$; and

if $QDR_{h,k} < DR_{t,k}$, then $QDF_{h,k} = 0$.

22.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

22.3.1 The *day-ahead market calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

22.3.1.1 $PSUMin_{h,k}\ q$ designates the minimum limitation on *pseudo-unit* P determined by translating constraint q. When constraint qq does not provide a minimum limitation on *pseudo-unit* P, then $PSUMin_{h,k\ q}$ shall be set equal to 0;

22.3.1.2 $PSUMax_{h,k}{}^{q}$ 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 $PSUMax_{h,k}{}^{q}$ shall be set equal to $MLP_{h,k}+DR_{h,k}+DF_{h,k}$; and

22.3.1.3 $CTCmtd_{h,k} \in \{0,1\}$ designates whether combustion turbine k $\in \{1,..K\}$ is considered committed in hour $h \in \{1,..,24\}$.

The *day-ahead market calculation engine* shall calculate the minimum and maximum limitations, subject to section 22.3.3.1, as follows:

22.3.2.1 Minimum limitation: $MinDG_{h,k} = max_{q \in \{1,..Q\}} PSUMin_{h,k}{}^{q}$; and

22.3.2.2 Maximum limitation: $MaxDG_{h,k} = min_{q \in \{1,..Q\}} PSUMax_{h,k}{}^{q}$.

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *day-ahead market calculation engine*.

22.3.3 Pseudo-unit Minimum and Maximum Constraints

22.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

22.3.3.1.1 $PSUMin_{h,k}$ = PMin, where PMin shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for hour $h \in \{1,..,24\}$; and

22.3.3.1.2 $PSUMax_{h,k}$ = PMax, where PMax shall be a maximum constraint provided on *pseudo-unit* k $\in \{1,..,K\}$ for hour $h \in \{1,..,24\}$.

22.3.4 Combustion Turbine Minimum and Maximum Constraints

22.3.4.1 If a *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 $CTMin < MLP_{h,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right); \text{ and}$$

$$STMinDR = 0$$

Otherwise, if $CTMin \geq MLP_{h,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{h,k} \cdot STShareMLP_k \text{ ; and}$$

$$STMinDR = \left(CTMin - MLP_{h,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMin_{h,k} = CTMin + STMinMLP + STMinDR$$

22.3.4.2 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:

$$PSUMin_{h,k}=CTMin$$

22.3.4.3 If a *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 $CTMax < MLP_{h,k} \cdot CTShareMLP_k$, then $PSUMax_{h,k} = 0$

Otherwise, calculate the effect of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions:

$$STMaxMLP = MLP_{h,k} \cdot STShareMLP_k$$

$$STMaxDR = \left(CTMax - MLP_{h,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{h,k} = CTMax + STMaxMLP + STMaxDR$$

:

22.3.4.4 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:

$$PSUMax_{h,k}=CTMax$$

22.3.5 Steam Turbine Minimum and Maximum Constraints

22.3.5.1 The *day-ahead market calculation engine* shall convert a steam turbine minimum constraint to a *pseudo-unit* constraint as follows:

22.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which shall indicate 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 $CTCmtd_{h,k}$ = 1. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

22.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity of *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{h,k} \cdot STShareMLP_k + QDR_{h,k} \cdot STShareDR_k + QDF_{h,k}$$

22.3.5.1.3 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 $STPMin_k$ is limited by $STCap_k$.

22.3.5.1.4 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 $STPMin_k < MLP_{h,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = \mathrm{STPMin_k} \cdot \left(\frac{\mathrm{CTShareMLP_k}}{\mathrm{STShareMLP_k}}\right); \text{ and}$$

$$CTMinDR_k = 0$$

Otherwise, if $STPMin_k \geq MLP_{h,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = MLP_{h,k} \cdot CTShareMLP_k; \text{ and}$$

$$CTMinDR_k = \left(STPMin_k - MLP_{h,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right)$$

Therefore:

$$PSUMin_{h,k} = STPMin_k + CTMinMLP_k + CTMinDR_k$$

22.3.5.2 If *pseudo-units* with sufficient steam turbine capacity are not committed, then the *day-ahead market calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudo-unit* constraints.

22.3.5.3 The steam turbine maximum constraint shall be converted to a *pseudo unit* constraint as follows:

$$PRSTMax_{h,k} = \left(\frac{STAmt_{h,k}}{\sum_{w\in\{1,..,K\}} STAmt_{h,w}}\right) \cdot STMax$$

If the prorated steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{h,k} = 0$$

Otherwise, calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTMax_{h,k}$

If $R \leq 1$, set $PSUMax_{h,k} = MLP_{h,k} + min(DR_{h,k}, R \cdot MDR_k)$

If $R > 1$, set $PSUMax_{h,k} = MLP_{h,k} + DR_{h,k} + PRSTMax_{h,k} - SMLP - STShareDR_k \cdot MDR_k$

22.3.5.4 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 22.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

22.4 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

22.4.1 For a combined cycle *facility* with ▯ combustion turbines and one steam turbine, the *day-ahead market calculation engine* shall compute the following *energy* and *operating reserve* schedules for hours $h \in \{1, .., 24\}$:

22.4.1.1 $CTE_{h,k}$ designates the *energy* schedule *fo*r combustion turbine $k \in \{1, .., K\}$;

22.4.1.2 $STPE_{h,k}$ designates the energy schedule for the steam turbine portion of pseudo-unit $k \in \{1, .., K\}$;

22.4.1.3 STE_h designates the energy schedule for the steam turbine;

22.4.1.4 $CT10S_{h,k}$ designates the synchronized ten-minute operating reserve schedule for combustion turbine $k \in \{1, . ., K\}$;

22.4.1.5 $STP10S_{h,k}$ designates the synchronized ten-minute operating reserve schedule for the steam turbine portion of pseudo-unit $k \in \{1, . ., K\}$;

22.4.1.6 $ST10S_h$ designates the synchronized ten-minute operating reserve schedule for the steam turbine;

22.4.1.7 $CT10N_{h,k}$ designates the non-synchronized ten-minute operating reserve schedule for combustion turbine $k \in \{1, . ., K\}$;

22.4.1.8 $STP10N_{h,k}$ designates the non-synchronized ten-minute operating reserve schedule for the steam turbine portion of pseudo-unit $k \in \{1, . . ,K\}$;

22.4.1.9 $ST10N_h$ designates the non-synchronized ten-minute operating reserve schedule for the steam turbine;

22.4.1.10 $CT30R_{h,k}$ designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1, . . ,K\}$;

22.4.1.11 $STP30R_{h,k}$ designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1, . . ,K\}$; and

22.4.1.12 $ST30R_h$ designates the *thirty-minute operating reserve* schedule for the steam turbine.

22.4.2 The *day-ahead market calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo-unit* $k \in \{1, . . ,K\}$ in hour $h \in \{1, . . , 24\}$:

22.4.2.1 $SE_{h,k}$ designates the total amount of *energy* scheduled and $SE_{h,k} = SEMLP_{h,k} + SEDR_{h,k} + SEDF_{h,k}$ where:

22.4.2.1.1 $SEMLP_{h,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \le SEMLP_{h,k} \le QMLP_{h,k}$;

22.4.2.1.2 $SEDR_{h,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \le SEDR_{h,k} \le QDR_{h,k}$ and $SEDR_{h,k} > 0$ only if $SEMLP_{h,k} = QMLP_{h,k}$; and

22.4.2.1.3 $SEDF_{h,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \le SEDF_{h,k} \le QDF_{h,k}$ and $SEDF_{h,k} > 0$ only if $SEDR_{h,k} = QDR_{h,k}$;

22.4.2.2 $S10S_{h,k}$ designates the total amount of synchronized *ten-minute operating reserve* scheduled;

22.4.2.3 $S10N_{h,k}$ 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 $0 \leq SE_{h,k} + S10S_{h,k} + S10N_{h,k} \leq QMLP_{h,k} + QDR_{h,k}$; and

22.4.2.4 $S30R_{h,k}$ designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{h,k} + S10S_{h,k} + S10N_{h,k} + S30R_{h,k} \leq QMLP_{h,k} + QDR_{h,k} + QDF_{h,k}$.

22.4.3 The *day-ahead market calculation engine* shall convert *pseudo-unit* schedules to physical *generation resource* schedules for *energy* and *operating reserve*, as follows:

22.4.3.1 If $SE_{h,k} \geq MLP_{h,k}$, then:

$$CTE_{h,k} = SEMLP_{h,k} \cdot CTShareMLP_k + SEDR_{h,k} \cdot CTShareDR_k;$$

$$STPE_{h,k} = SEMLP_{h,k} \cdot STShareMLP_k + SEDR_{h,k} \cdot STShareDR_k + SEDF_{h,k};$$

$$RoomDR_{h,k} = QDR_{h,k} - SEDR_{h,k};$$

$$10SDR_{h,k} = min(RoomDR_{h,k}, S10S_{h,k});$$

$$10NDR_{h,k} = min(RoomDR_{h,k} - 10SDR_{h,k}, S10N_{h,k});$$

$$30RDR_{h,k} = min(RoomDR_{h,k} - 10SDR_{h,k} - 10NDR_{h,k}, S30R_{h,k});$$

$$CT10S_{h,k} = 10SDR_{h,k} \cdot CTShareDR_k;$$

$$STP10S_{h,k} = 10SDR_{h,k} \cdot STShareDR_k + (S10S_{h,k} - 10SDR_{h,k});$$

$$CT10N_{h,k} = 10NDR_{h,k} \cdot CTShareDR_k;$$

$$STP10N_{h,k} = 10NDR_{h,k} \cdot STShareDR_k + (S10N_{h,k} - 10NDR_{h,k});$$

$$CT30R_{h,k} = 30RDR_{h,k} \cdot CTShareDR_k; \text{ and}$$

$$STP30R_{h,k} = 30RDR_{h,k} \cdot STShareDR_k + (S30R_{h,k} - 30RDR_{h,k}).$$

22.4.3.2 If $SE_{h,k} < MLP_{h,k}$ and is ramping to *minimum loading point*, then the conversion shall be determined by the *ramp up energy to minimum loading point*.

22.4.3.3 The steam turbines portion schedules from section 22.4.3.1 shall be summed to obtain the steam turbine schedule as follows:

$STE_h = \sum_{k=1,...,K} STPE_{h,k}$;

$ST10S_h = \sum_{k=1,...,K} STP10S_{h,k}$;

$ST10N_h = \sum_{k=1,...,K} STP10N_{h,k}$; and

$ST30R_h = \sum_{k=1,...,K} STP30R_{h,k}$.

23 Pricing Formulas

23.1 Purpose

23.1.1 The *day-ahead market calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

23.2 Sets, Indices and Parameters

23.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Passes 1 and 3 shall be used:

23.2.1.1 $SPEmT_{h,c,f}^{p}$ designates the Pass p shadow price for the post-contingency transmission constraint for *facility* f ∈ F in contingency c ∈ C in hour h;

23.2.1.2 $SPExtT_{h,z}^{p}$ designates the Pass p shadow price for the import or export limit constraint $z \in Z_{Sch}$ in hour h;

23.2.1.3 SPL_h^{p} designates the Pass p shadow price for the *energy* balance constraint in hour h;

23.2.1.4 $SPNIUExtBwdT_h^{p}$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting increases in net imports between hour $(h - 1)$ and hour h;

23.2.1.5 $SPNIDExtBwdT_h^{p}$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between hour $(h - 1)$ and hour h;

23.2.1.6 $SPNIUExtFwdT_h^p$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting increases in net imports imports between hour h and hour $(h + 1)$;

23.2.1.7 $SPNIDExtFwdT_h^p$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between hour h and hour $(h + 1)$;

23.2.1.8 $SPNormT_{h,f}^p$ designates the Pass p shadow price for the pre-contingency transmission constraint for *facility* f ∈ F in hour h;

23.2.1.9 $SP10S_h^p$ designates the Pass p shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in hour h;

23.2.1.10 $SP10R_h^p$ designates the Pass p shadow price for the total *ten-minute operating reserve* requirement constraint in hour h;

23.2.1.11 $SP30R_h^p$ designates the Pass p shadow price for the total *thirty- minute operating reserve* requirement constraint in hour h;

23.2.1.12 $SPREGMin10R_{h,r}^p$ designates the Pass p shadow price for the minimum *ten-minute operating reserve* constraint for region r ∈ ORREG in hour h;

23.2.1.13 $SPREGMin30R_{h,r}^p$ designates the Pass p shadow price for the minimum *thirty-minute operating reserve* constraint for region r ∈ *ORREG* in hour h;

23.2.1.14 $SPREGMax10R_{h,r}^p$ designates the Pass p shadow price for the maximum *ten-minute operating reserve* constraint for region r ∈ORREG in hour h; and

23.2.1.15 $SPREGMax30R_{h,r}^p$ designates the Pass P shadow price for the maximum *thirty-minute operating reserve* constraint for region r ∈ORREG in hour h.

23.3 Locational Marginal Prices for Energy

23.3.1 Energy Locational Marginal Prices for Delivery Points

23.3.1.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass p ∈ {1,3} and hour $h \in \{1, .., 24\}$ for every bus $b \in L$ where a non-*dispatchable* or *dispatchable generation resource*, a *dispatchable load*, a *price responsive load*, an *hourly demand response resource*, or a *non-dispatchable load* is sited and:

23.3.1.1.1 $LMP_{h,b}^p$ designates the Pass p hour h *locational marginal price* for *energy*;

23.3.1.1.2 $PRef_h^p$ designates the Pass p hour h *energy locational marginal price* for *energy* at the *reference bus*;

23.3.1.1.3 $PLoss_{h,b}^p$ designates the Pass p hour h loss component; and

23.3.1.1.4 $PCong_{h,b}^p$ designates the Pass p hour h congestion component.

23.3.1.2 The *day-ahead market 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 $p \in \{1,3\}$ at bus $b \in L$ in hour $h \in \{1,..24\}$,as follows:

$$InitLMP_{h,b}^{p} = InitPRef_{h}^{p} + InitPLoss_{h,b}^{p} + InitPCong_{h,b}^{p}$$

where

$$InitPRef_{h}^{p} = SPL_{h}^{p};$$

$$InitPLoss_{h,b}^{p} = MglLoss_{h,b}^{p} \cdot SPL_{h}^{p};$$

and

$$InitPCong_{h,b}^{p} = \sum_{f \in F_h} PreConSF_{h,f,b} \cdot SPNormT_{h,f}^{p} + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,b} \cdot SPEmT_{h,c,f}^{p}$$

23.3.1.3 If the initial *locational marginal price* for *energy* at the reference bus *($InitPRef_h^p$)* is not within the *settlement* bounds *(EngyPrcFlr, EngyPrcCeil)*, then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy* at the reference bus as follows:

If $InitPRef_h^p > EngyPrcCeil$, $PRef_h^p = EngyPrcCeil$

If $InitPRef_h^p < EngyPrcFlr$, $PRef_h^p = EngyPrcFlr$

Otherwise, $PRef_h^p = InitPRef_h^p$

23.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP_{h,b}^p$) is not within the *settlement* bounds *(EngyPrcFlr, EngyPrcCeil),* then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP_{h,b}^p > EngyPrcCeil$, $LMP_{h,b}^p = EngyPrcCeil$

If $InitLMP_{h,b}^{p} < EngyPrcFlr$, $LMP_{h,b}^{p} = EngyPrcFlr$

Otherwise, $LMP_{h,b}^{p} = InitLMP_{h,b}^{p}$

23.3.1.5 The *day-ahead market calculation engine* shall modify the loss component as follows:

If $PRef_{h}^{p} \neq InitPRef_{h}^{p}$, then $PLoss_{h,b}^{p} = MglLoss_{h,b}^{p} \cdot PRef_{h}^{p}$

Otherwise, $PLoss_{h,b}^{p} = InitPLoss_{h,b}^{p}$

23.3.1.6 The *day-ahead market calculation engine* shall modify the congestion component as follows:

If $LMP_{h,b}^{p} - PRef_{h}^{p} - PLoss_{h,b}^{p}$ and $InitPCong_{h,b}^{p}$ have the same mathematical sign, then $PCong_{h,b}^{p} = LMP_{h,b}^{p} - PRef_{h}^{p} - PLoss_{h,b}^{p}$

Otherwise, $PCong_{h,b}^{p} = 0$ and $PLoss_{h,b}^{p} = LMP_{h,b}^{p} - PRef_{h}^{p}$

23.3.2 Energy Locational Marginal Prices for Intertie Metering Points

23.3.2.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass p ∈ {1,3} and hour h ∈ {1, . . , 24} for *intertie zone* bus d ∈ D, where:

23.3.2.1.1 $ExtLMP_{h,d}^{p}$ designates the Pass *RR* hour *h locational marginal price* for *energy*;

23.3.2.1.2 $IntLMP_{h,d}^{p}$ designates the Pass *RR* hour *h intertie border price* for *energy*;

23.3.2.1.3 $ICP_{h,d}^{p}$ designates the Pass *RR* hour *h intertie congestion price*;

23.3.2.1.4 $PRef_{h}^{p}$ designates the Pass *RR* hour *h locational marginal price* for *energy* at the reference bus;

23.3.2.1.5 $PLoss_{h,d}^{p}$ designates the Pass *RR* hour *h* loss component;

23.3.2.1.6 $PIntCong_{h,d}^{p}$ designates the Pass *RR* hour *h* internal congestion component for *energy*;

23.3.2.1.7 $PExtCong_{h,d}^{p}$ designates the Pass *RR* hour *h* external congestion component for the *intertie congestion price*; and

23.3.2.1.8 $PNISL_{h,d}^{p}$ designates the Pass *RR* hour *h* net interchange scheduling limit congestion component for the *intertie congestion price*.

23.3.2.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price for energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss component and a congestion component for *energy* for Pass p at *intertie zone* bus $d \in Da$ in *intertie zone* a ∈ A in hour h ∈ {1, . . , 24}, subject to section 23.3.2.8 and 23.3.2.9, as follows:

$$InitExtLMP_{h,d}^{p} = InitIntLMP_{h,d}^{p} + InitICP_{h,d}^{p}$$

where

$$InitPRef_{h}^{p} = SPL_{h}^{p} ;$$

$$InitPLoss_{h,d}^{p} = MglLoss_{h,d}^{p} \cdot SPL_{h}^{p} ;$$

$$InitPIntCong_{h,d}^{p} = \sum_{f \in F_h} PreConSF_{h,f,d} \cdot SPNormT_{h,f}^{p} + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,d} \cdot SPEmT_{h,c,f}^{p} ;$$

$$InitIntLMP_{h,d}^{p} = InitPRef_{h}^{p} + InitPLoss_{h,d}^{p} + InitPIntCong_{h,d}^{p};$$

$$InitICP_{h,d}^{p} = InitPExtCong_{h,d}^{p} + InitPNISL_{h,d}^{p};$$

$$InitPExtCong_{h,d}^{p} = \sum_{z \in Z_{sch}} EnCoeff_{a,z} \cdot SPExtT_{h,z}^{p} ;$$

and

$$InitPNISL_{h,d}^{p} = SPNIUExtBwdT_{h}^{p} - SPNIUExtFwdT_{h}^{p} - SPNIDExtBwdT_{h}^{p} + SPNIDExtFwdT_{h}^{p}$$

23.3.2.3 If the initial *locational marginal price* for *energy* ($InitExtLMP_{h,d}^{p}$) is not within the *settlement* bounds *(EngyPrcFlr, EngyPrcCeil)*, then the *day-ahead market calculation engine* shall modify the *intertie border price* for *energy*, and its components, as follows:

23.3.2.3.1 The initial *locational marginal price* for the *reference bus* ($InitPRef_{h}^{p}$) shall be modified per section 23.3.1.3;

23.3.2.3.2 The initial *intertie border price* ($InitIntLMP_{h,d}^{p}$) shall be modified per section 23.3.1.4, where $\text{InitLMP}_{h,\square}^{p} = InitIntL\text{MP}_{h,d}^{p}$;

23.3.2.3.3 The initial loss component ($InitPLoss_{h,b}^{p}$) shall be modified per section 23.3.1.5; and

23.3.2.3.4 The initial congestion component ($InitPCong_{h,b}^{p}$) shall be modified per section 23.3.1.6.

23.3.2.4 If the initial *locational marginal price* for *energy* ($InitExtLMP_{h,d}^{p}$) is not within the *settlement* bounds (*EngyPrcFlr, EngyPrcCeil*), then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $\text{InitExtLM}P_{h,d}^{p} > \text{EngyPrcCeil}$, set $\text{ExtLMP}_{h,d}^{p} = \text{EngyPrcCeil}$

If $\text{InitExtLMP}_{h,d}^{p} < \text{EngyPrcFlr}$, set $\text{ExtLMP}_{h,d}^{p} = \text{EngyPrcFlr}$

Otherwise, set $\text{ExtLMP}_{h,d}^{p} = \text{InitExtLMP}_{h,d}^{P}$

23.3.2.5 If the modified *locational marginal price* for *energy* ($ExtLMP_{h,d}^{p}$) is equal to the *intertie border price* for *energy* ($IntLMP_{h,d}^{p}$), then the *day-ahead market calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion components for the *intertie congestion price*, as follows:

If $ExtLMP_{h,d}^{p} = IntLMP_{h,d}^{p}$, set $PExtCong_{h,d}^{p} = 0$ and $PNISL_{h,d}^{p} = 0$

23.3.2.6 If the modified *locational marginal price* for *energy* ($ExtLMP_{h,d}^{p}$) is not equal to the *intertie border price* for *energy* ($IntLMP_{h,d}^{p}$), then the *day-ahead market calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion components for the *intertie congestion price*, as follows:

If $ExtLMP_{h,d}^{p} \neq IntLMP_{h,d}^{p}$, set

$$PNISL_{h,d}^{p} = (ExtLMP_{h,d}^{p} - IntLMP_{h,d}^{p}) \cdot \left(\frac{InitPNISL_{h,d}^{p}}{InitPNISL_{h,d}^{p} + InitPExtCong_{h,d}^{p}}\right)$$

If $PNISL_{h,d}^{p} > NISLPen$, $PNISL_{h,d}^{p} = NISLPen$

If $PNISL_{h,d}^{p} < (-1) \cdot NISLPen$, $PNISL_{h,d}^{p} = (-1) \cdot NISLPen$

Then $PExtCong_{h,d}^{p} = ExtLMP_{h,d}^{p} - IntLMP_{h,d}^{p} - PNISL_{h,d}^{p}$

23.3.2.7 The *day-ahead market calculation engine* shall calculate the *intertie congestion price* as follows:

$$ICP_{h,d}^{p} = PExtCong_{h,d}^{p} + PNISL_{h,d}^{P}$$

23.3.2.8 The *locational marginal price* for *energy* calculated by the *day-ahead market 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*.

23.3.2.9 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*.

23.3.3 Zonal Prices for Energy

23.3.3.1 The *day-ahead market calculation engine* shall calculate the zonal price for *energy* and its components for each Pass p ∈ {1,3} and hour h ∈ {1, . . , 24} for each *virtual transaction zone* $m \in M$, as follows:

$$VZonalP_{h,m}^{p} = PRef_{h}^{p} + VZonalPLoss_{h,m}^{p} + VZonalPCong_{h,m}^{p}$$

where

$$VZonalPLoss_{h,m}^{p} = \sum_{b \in L_{m}^{VIRT}} WF_{h,m,b}^{VIRT} \cdot PLoss_{h,b}^{p}$$

and

$$VZonalPCong_{h,m}^{p} = \sum_{b \in L_{m}^{VIRT}} WF_{h,m,b}^{VIRT} \cdot PCong_{h,b}^{p}$$

23.3.3.2 The *day-ahead market calculation engine* shall calculate the zonal price for *energy* and its components for each Pass $p \in \{1,3\}$ and hour $h \in \{1, . . , 24\}$ for *non-dispatchable load* zone, $y \in Y$ as follows:

$$ZonalP_{h,y}^{p} = PRef_{h}^{p} + ZonalPLoss_{h,y}^{p} + ZonalPCong_{h,y}^{p}$$

where

$$ZonalPLoss_{h,y}^{p} = \sum_{b \in L_{y}^{NDL}} WF_{h,y,b}^{NDL} \cdot PLoss_{h,b}^{p}$$

and

$$ZonalPCong_{h,y}^{p} = \sum_{b \in L_{y}^{NDL}} WF_{h,y,b}^{NDL} \cdot PCong_{h,b}^{p}$$

23.3.4 Pseudo-Unit Pricing

23.3.4.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass $p \in \{1,3\}$ and hour $h \in \{1, . . , 24\}$ for every *pseudo-unit* k $\in \{1, . . , K\}$ where:

23.3.4.1.1 $CTMglLoss_{h,k}^{p}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit* k for hour h in Pass p;

23.3.4.1.2 $STMglLoss_{h,k}^{p}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit* k for hour h in Pass p;

23.3.4.1.3 $\text{CTPreConSF}_{h,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility f* during hour h under pre-contingency conditions;

23.3.4.1.4 $STPreConSF_{h,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility f* during hour h under pre-contingency conditions;

23.3.4.1.5 $CTSF_{h,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility f* during hour h under post-contigency conditions for contingency c; and

23.3.4.1.6 $\text{STS}F_{h,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility f* during hour h under post-contingency conditions for contingency c.

23.3.4.2 The *day-ahead market 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 P $\in \{1,3\}$ for every *pseudo-unit* $k \in \{1, . . , LL\}$ in hour h $\in \{1, . . , 24\}$, as follows:

$$InitLMP_{h,k}^{p} = InitPRef_{h}^{p} + InitPLoss_{h,k}^{p} + InitPCong_{h,k}^{p}$$

where

$$InitPRef_{h}^{p} = SPL_{h}^{p} ;$$

$$InitPLoss_{h,k}^{p} = MglLoss_{h,k}^{p} \cdot SPL_{h}^{p} ;$$

and

$$InitPCong_{h,k}^{p} = \sum_{f \in F_h} PreConSF_{h,f,k} \cdot SPNormT_{h,f}^{p} + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,k} \cdot SPEmT_{h,c,f}^{p}$$

23.3.4.3 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:

$$MglLoss_{h,k}^{p} = CTShareMLP_{k} \cdot CTMglLoss_{h,k}^{p} + STShareMLP_{k} \cdot STMglLoss_{h,k}^{p}$$

$$PreConSF_{h,f,k} = CTShareMLP_{k} \cdot CTPreConSF_{h,f,k} + STShareMLP_{k} \cdot STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = CTShareMLP_{k} \cdot CTSF_{h,c,f,k} + STShareMLP_{k} \cdot STSF_{h,c,f,k}$$

23.3.4.4 If *pseudo-unit* $k \in \{1, . . , K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{p}_{h,k} = CTShareDR_k \cdot CTMglLoss^{p}_{h,k} + STShareDR_k \cdot STMglLoss^{p}_{h,k}$$

$$PreConSF_{h,f,k} = CTShareDR_k \cdot CTPreConSF_{h,f,k} + STShareDR_k \cdot STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = CTShareDR_k \cdot CTSF_{h,c,f,k} + STShareDR_k \cdot STSF_{h,c,f,k}$$

23.3.4.5 If *pseudo-unit* $k \in \{1, . . , K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{p}_{h,k} = STMglLoss^{p}_{h,k}$$

$$PreConSF_{h,f,k} = STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = STSF_{h,c,f,k}$$

23.4 Locational Marginal Prices for Operating Reserve

23.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

23.4.1.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for each Pass $p \in \{1,3\}$ and hour $h \in \{1, . . , 24\}$ for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$, where:

23.4.1.1.1 $L30RP_{h,b}^{p}$ designates the Pass p hour *h locational marginal price* for *thirty-minute operating reserve*;

23.4.1.1.2 $P30RRef_{h}^{p}$ designates the Pass p hour *h locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

23.4.1.1.3 $P30RCong_{h,b}^{p}$ designates the Pass p hour *h* congestion component for *thirty-minute operating reserve*;

23.4.1.1.4 $L10NP_{h,b}^{p}$ designates the Pass p hour *h locational marginal price* for non-synchronized *ten-minute operating reserve*;

23.4.1.1.5 $P10NRef_{h}^{p}$ designates the Pass p hour *h locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.1.1.6 $P10NCong_{h,b}^{p}$ designates the Pass p hour h congestion component for non-synchronized *ten-minute operating reserve*;

23.4.1.1.7. $L10SP_{h,b}^{p}$ designates the Pass RR hour h *locational marginal price* for synchronized *ten-minute operating reserve*;

23.4.1.1.8. $P10SRef_{h}^{p}$ designates the Pass p hour h *locational marignal price* or synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.1.1.9 $P10SCong_{h,b}^{p}$ designates the Pass RR hour h congestion component for synchronized *ten-minute operating reserve*; and

23.4.1.1.10 $ORREG_{b} \subseteq ORREG$ designates the subset of $ORREG$ consisting of regions that include bus b.

23.4.1.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass RR for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$ in hour $h \in \{1, .., 24\}$, for each class of *operating reserve*, as follows:

$$InitL30RP_{h,b}^{p} = InitP30RRef_{h}^{p} + InitP30RCong_{h,b}^{p}$$

where

$$InitP30RRef_{h}^{p} = SP30R_{h}^{p}$$

and

$$InitP30RCong_{h,b}^{p} = \sum_{r \in ORREG_b} SPREGMin30R_{h,r}^{p} - \sum_{r \in ORREG_b} SPREGMax30R_{h,r}^{p}$$

$$InitL10NP_{h,b}^{p} = InitP10NRef_{h}^{p} + InitP10NCong_{h,b}^{p}$$

where

$$InitP10NRef_{h}^{p} = SP10R_{h}^{p} + SP30R_{h}^{p}$$

and

$$InitP10NCong_{h,b}^{p} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

$$InitL10SP_{h,b}^{p} = InitP10SRef_{h}^{p} + InitP10SCong_{h,b}^{p}$$

where

$$InitP10SRef_{h}^{p} = SP10S_{h}^{p} + SP10R_{h}^{p} + SP30R_{h}^{p}$$

and

$$InitP10SCong_{h,b}^{p} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

23.4.1.3 If the initial *locational marginal price* at the reference bus *($InitP30RRef_h^p$, $InitP10NRef_h^p$, or $InitP10SRef_h^p$)* is not within the *settlement* bounds *(ORPrcFlr, ORPrcCeil)*, then the *day-ahead market calculation engine* shall modify the initial *locational marginal prices* at the *reference bus* for each class of *operating reserve* as follows:

If $IInitP30RRef_h^p > ORPrcCeil$, $P30RRef_h^p = ORPrcCeil$;

If $InitP30RRef_h^p < ORPrcFlr$, $P30RRef_h^p = ORPrcFlr$; Otherwise,

$P30RRef_h^p = InitP30RRef_h^p$.

If $InitP10NRef_h^p > ORPrcCeil$, $P10NRef_h^p = ORPrcCeil$;

If $InitP10NRef_h^p < ORPrcFlr$, $P10NRef_h^p = ORPrcFlr$;

Otherwise, $P10NRef_h^p = InitP10NRef_h^p$.

If $InitP10SRef_h^p > ORPrcCeil$, $P10SRef_h^p = ORPrcCeil$;

If $InitP10SRef_h^p < ORPrcFlr$, $P10SRef_h^p = ORPrcFlr$;

Otherwise, $P10SRef_h^p = InitP10SRef_h^p$

23.4.1.4. If the initial *locational marginal price* *($InitL30RP_{h,b}^p$, $InitL10NP_{h,b}^p$, or $InitL10SP_{h,b}^p$)* is not within the *settlement* bounds *(ORPrcFlr, ORPrcCeil)*, then the *day- ahead market calculation engine* shall modify the initial *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{h,b}^p > ORPrcCeil$, $L30RP_{h,b}^p = ORPrcCeil$;

If $InitL30RP_{h,b}^p < ORPrcFlr$, $L30RP_{h,b}^p = ORPrcFlr$;

Otherwise, $L30RP_{h,b}^p = InitL30RP_{h,b}^p$.

If $InitL10NP_{h,b}^p > ORPrcCeil$, $L10NP_{h,b}^p = ORPrcCeil$;

If $InitL10NP_{h,b}^p < ORPrcFlr$, $L10NP_{h,b}^p = ORPrcFlr$;

Otherwise, $L10NP_{h,b}^p = InitL10NP_{h,b}^p$.

If $InitL10SP_{h,b}^p > ORPrcCeil$, $L10SP_{h,b}^p = ORPrcCeil$;

If $InitL10SP_{h,b}^p < ORPrcFlr$, $L10SP_{h,b}^p = ORPrcFlr$;

Otherwise, $L10SP_{h,b}^p = InitL10SP_{h,b}^p$

23.4.1.5 If the initial *locational marginal price* ($InitL30RP_{h,b}^{p}$,$InitL10NP_{h,b}^{p}$, or $InitL10SP_{h,b}^{p}$) is not within the *settlement* bounds *(ORPrcFlr, ORPrcCeil),* then the *day-ahead market calculation engine* shall modify the congestion component for each class of *operating reserve*, as follows:

Set $P30RCong_{h,b}^{p} = L30RP_{h,b}^{p} - P30RRef_{h}^{p}$;

Set $P10NCong_{h,b}^{p} = L10NP_{h,b}^{p} - P10NRef_{h}^{p}$; and

Set $P10SCong_{h,b}^{p} = L10SP_{h,b}^{p} - P10SRef_{h}^{p}$.

23.4.2 Operating Reserve Locational Marginal Prices for Intertie Metering Points

23.4.2.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for each Pass $p \in \{1,3\}$ and hour $h \in \{1, . . , 24\}$ for *intertie zone* bus $d \in$ D, where:

23.4.2.1.1 $ExtL30RP_{h,d}^{p}$ designates the Pass p hour h *locational marginal price* for *thirty-minute operating reserve*;

23.4.2.1.2. $P30RRef_{h}^{p}$ designates the Pass p hour h *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

23.4.2.1.3 $P30RIntCong_{h,d}^{p}$ designates the Pass p hour h internal congestion component for *thirty-minute operating reserve*;

23.4.2.1.4. $P30RExtCong_{h,d}^{p}$ designates the Pass p hour h *intertie* congestion component for *thirty-minute operating reserve*;

23.4.2.1.5. $ExtL10NP_{h,d}^{p}$ designates the Pass p hour h non-synchronized *ten-minute operating reserve* price;

23.4.2.1.6 $P10NRefh\ p$ designates the Pass p hour h *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.2.1.7 $P10NIntCong_{h,d}^{p}$ designates the Pass p hour h internal congestion component for non-synchronized *ten-minute operating reserve*;

23.4.2.1.8. $P10NExtCong_{h,d}^{p}$ designates the Pass p hour h *intertie* congestion component for non-synchronized *ten-minute operating reserve*; and

23.4.2.1.9. $ORREG_{d} \subseteq ORREG$ designates the subset of $ORREG$ consisting of regions that include bus d.

23.4.2.22 The *day-ahead market 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 p at *intertie zone* bus $d \in D_a$ in *intertie zone* a ∈ A in hour h ∈ {1, . . , 24}, for each class of *operating reserve*, subject to sections 23.4.2.5 and 23.4.2.6,as follows:

$$InitExtL30RP_{h,d}^{p} = InitP30RRef_{h}^{p} + InitP30RIntCong_{h,d}^{p} + InitP30RExtCong_{h,d}^{p}$$

where

$$InitP30RRef_{h}^{p} = SP30R_{h}^{p};$$

$$InitP30RIntCong_{h,d}^{p} = \sum_{r \in ORREG_d} SPREGMin30R_{h,r}^{p} - \sum_{r \in ORREG_d} SPREGMax30R_{h,r}^{p};$$

$$InitP30RExtCong_{h,d}^{p} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT_{h,z}^{p}$$

$$InitExtL10NP_{h,d}^{p} = InitP10NRef_{h}^{p} + InitP10NIntCong_{h,d}^{p} + InitP10NExtCong_{h,d}^{p}$$

where

$$InitP10NRef_{h}^{p} = SP10R_{h}^{p} + SP30R_{h}^{p};$$

$$InitP10NIntCong_{h,d}^{p} = \sum_{r \in ORREG_d} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_d} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

and

$$InitP10NExtCong_{h,d}^{p} = -\sum_{z \in Z_{Sch}} 0.5 \cdot \left(EnCoeff_{a,z} + 1\right) \cdot SPExtT_{h,z}^{p}$$

23.4.2.3 If the initial *locational marginal price* ($InitExtL30RP_{h,b}^{p}$) is not within the *settlement* bounds *(ORPrcFlr,ORPrcCeil)*, then the *day-ahead market calculation engine* shall modify the initial *locational marginal price*, the *locational marginal price* at the *reference bus*, and the external congestion component for *thirty-minute operating reserve* as follows:

$IntL30R = InitP30RRef_{h}^{p} + InitP30RIntCong_{h,d}^{p}$

If $InitP30RRef_{h}^{p} > ORPrcCeil$, $P30RRef_{h}^{p} = ORPrcCeil$;

If $InitP30RRef_{h}^{p} < ORPrcFlr$, $P30RRef_{h}^{p} = ORPrcFlr$;

Otherwise, $P30RRef_{h}^{p} = InitP30RRef_{h}^{p}$;

Set $P30RIntCong_{h,d}^{p} = ExtL30RP_{h,d}^{p} - P30RRef_{h}^{p}$

If $InitExtL30RP_{h,b}^{p} > ORPrcCeil$, $ExtL30RP_{h,b}^{p} = ORPrcCeil$;

If $InitExtL30RP_{h,b}^{p} < ORPrcFlr$, $ExtL30RP_{h,b}^{p} = ORPrcFlr$;

Otherwise, $ExtL30RP_{h,b}^{p} = InitExtL30RP_{h,b}^{p}$; and

Set $P30RExtCong_{h,d}^{p} = ExtL30RP_{h,b}^{p} - P30RRef_{h}^{p} - P30RIntCong_{h,d}^{p}$

23.4.2.4 If the initial *locational marginal price* *(InitExtL10NPℎ,□□)* is not within the *settlement* bounds *(□RPrcFlr, □RPrcCeil)*, then the *day-ahead market 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:

$IntL10N = InitP10NRef_h^p + InitP10NIntCong_{h,d}^p$

$If\ InitP10NRef_h^p > ORPrcCeil\ ,\ P10NRef_h^p = ORPrcCeil\ ;$

$If\ InitP10NRef_h^p < ORPrcFlr,\ P10NRef_h^p = ORPrcFlr;$

$Otherwise,\ P10NRef_h^p = InitP10NRef_h^p;$

$Set\ P10NCong_{h,b}^p = L10NP_{h,b}^p - P10NRef_h^p$

$If\ InitExtL10NP_{h,b}^p > ORPrcCeil\ ,\ ExtL10NP_{h,b}^p = ORPrcCeil;$

$If\ InitExtL10NP_{h,b}^p < ORPrcFlr,\ ExtL10NP_{h,b}^p = ORPrcFlr;$

$Otherwise,\ ExtL10NP_{h,b}^p = InitExtL10NP_{h,b}^p\ ;\ and$

$Set\ P10NExtCong_{h,d}^p = ExtL10NP_{h,b}^p - P10NRef_h^p -$
$P10NIntCong_{h,d}^p$

23.4.2.5 The *locational marginal price* calculated by the *day-ahead market 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 occurring 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*.

23.4.2.6 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 l*ocational 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.

23.5 Pricing for Islanded Nodes

23.5.1 For *non-quick start resources* that are not connected to the *main island*, the *day-ahead market 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*:

23.5.1.1 Determine the connection paths over open switches that connect the *non-quick start resource* to the *main island*;

23.5.1.2 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

23.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

23.5.2 For all (i) *resources* other than those specified in section 23.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 23.5.1; the *day-ahead market calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices*, using a node-level and *facility*-level substitution list determined by the *IESO*:

23.5.2.1 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;*

23.5.2.2 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*;

23.5.2.3 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*;

23.5.2.4 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

23.5.2.5 If a price is unable to be determined in accordance with sections 23.5.2.1 through 23.5.2.4, 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 $h \in \{1, . . , 24\}$ and $b \in BCond_h^{NCA}$, 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 □□ 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 $LMPIT_{h,b}$;