Market Rule Amendment Proposal Form

Part 1 - Market Rule Information

Identification No.:	MR-00454-R03
Subject:	Market Renewal Program – Market and System Operations
Title:	Market Renewal Program – Market and System Operations
Nature of Proposal:	☐ Alteration ☐ Deletion ☒ Addition
Chapter:	Chapter 7
Appendix:	
Sections:	Chapter 7, Appendix 7.8
Sub-sections proposed for amending:	
Current Market Rules Baseline:	

Part 2 - Proposal History

Version	Reason for Issuing	Version Date
1.0	Draft for Stakeholder Review	July 14, 2023
2.0	Draft for Technical Panel Review	March 26, 2024

Approved Amendment Publication Date:

Approved Amendment Effective Date:

Part 3 - Explanation for Proposed Amendment

Provide a brief description that includes some or all of the following points:

- The reason for the proposed amendment and the impact on the *IESO-administered markets* if the amendment is not made.
- Alternative solutions considered.
- The proposed amendment, how the amendment addresses the above reason and impact of the proposed amendment on the *IESO-administered markets*.

Summary

The IESO proposes to amend the market rules to codify the Market Renewal Program's (MRP) market and system operations framework.

New Appendix 7.8 of Chapter 7: Economic Operating Point defines the variables and calculations used for economic operating point, describing the process used to determine the following:

- Section 2 – Day-Ahead Market Lost Cost Economic Operating Point;
- Section 3 – Real-Time Market Lost Cost Economic Operation Point; and
- Section 4 – Real-Time Market Lost Opportunity Cost Economic Operating Point.

This proposal is based on input from various stakeholder engagement initiatives for the Market Renewal Program (MRP).

Further information on MRP can be found on the IESO's Market Renewal webpage.

Background

The IESO provided stakeholders with an in-depth overview of the Economic Operating Point design at an April 21, 2022 MRP engagement session. That presentation can be found here, Market Renewal - Energy Project: Overview of Economic Operating Point Design.

Economic operating point serves as the reference point from which make-whole payments for lost cost and lost opportunity scenarios are established. Lost cost scenarios occur when the locational marginal price implies the resource should have been scheduled lower. Lost opportunity scenarios occur when the locational marginal price implies the resource should have been schedule higher.

Therefore, a lost cost make-whole payment is designed to compensate a resource when its market schedule results in unrecovered costs relative to its economic operating point. The lost opportunity make-whole payment is designed to compensate a resource when its market schedule results in unrealized profits relative to its economic operating point.

Discussion

The accompanying "Summary of Market and System Operations" readers guide provides a summary of the market rule amendments to Chapter 7 of the market rules.

Part 4 - Proposed Amendment

Appendix 7.8 – Economic Operating Point

1. Introduction

1.1 Purpose

1.1.1 This appendix describes the processes used to determine the economic operating points for lost cost in the *day-ahead market* and *real-time market*, and for lost opportunity in the *real-time market.*

2. Day-Ahead Market Lost Cost Economic Operating Point

2.1 Purpose

2.1.1 This section describes the process used to determine the lost cost economic operating point for eligible *resources* in the *day-ahead market* (DAM LC EOP).

2.2 Sets, Indices and Parameters used in the DAM LC EOP Calculation

Fundamental Sets and Indices

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

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

2.2.3 $B^{DG} \subseteq B$ designates the set of buses identifying *dispatchable generation resources*;

2.2.4 $B^{DL} \subseteq B$ designates the set of buses identifying *dispatchable loads*;

2.2.5 $B^{HE} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources*;

2.2.6 $B^{HE}_{s} \subseteq B^{HE}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources* in set s ∈ SHE;

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

2.2.8 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone* $a \in A$;

2.2.9 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

2.2.10 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone* $a \in A$;

2.2.11 $DX \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids*;

2.2.12 $DX_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone* $a \in A$;

2.2.13 $J^{E}_{h,b}$ designates the set of *bid* laminations for *energy* at bus $b \in B^{DL} \cup DX$ for hour $h \in \{1,..,24\}$;

2.2.14 $J^{10S}_{h,b}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DL}$ for hour $h \in \{1,..,24\}$;

2.2.15 $J^{10N}_{h,b}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B^{DL} \cup DX$ for hour $h \in \{1,..,24\}$;

2.2.16 $J^{30R}_{h,b}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at $b \in B^{DL} \cup DX$ for hour $h \in \{1,..,24\}$;

2.2.17 $K_{h,b}^{E}$ designates the set of *offer* laminations for *energy* at bus $b \in B \cup DI$ for hour $h \in \{1,..,24\}$;

2.2.18 $K_{h,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $\mathrm{b} \in B^{DG} \cup DI$ for hour $\mathrm{h} \in \{1,..,24\}$;

2.2.19 $K_{h,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $\mathrm{b} \in B^{DG} \cup DI$ for hour $\mathrm{h} \in \{1,..,24\}$;

2.2.20 $K_{h,b}^{30R}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DG} \cup DI$ for hour $\mathrm{h} \in \{1,..,24\}$;

2.2.21 $\wp(B^{HE})$ designates the set of all subsets of the set B^{HE};

2.2.22 $B_{up}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all upstream *dispatchable* hydroelectric *generation resources* with a *linked forebay*;

2.2.23 $B_{dn}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all downstream *dispatchable* hydroelectric *generation resources* with a *linked forebay*;

Market Participant Data Parameters

2.2.24 With respect to all *resources*:

2.2.24.1 $Derate_{h,b}$ designates the maximum amount of *energy and operating reserve* that can be scheduled for a *resource* in a *dispatch hour* $h \in \{1, . . , 24\}$.

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

2.2.25.1 $MinQDG_b$ designates the *minimum loading point*;

2.2.25.2 $ORRDG_b$ designates the maximum *operating reserve* ramp rate in MW per minute;

2.2.25.3 $PDG_{h,b,k}$ designates the price for the maximum incremental quantity of *energy* for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $\mathrm{k} \in K_{h,b}^{E}$;

2.2.25.4 $P10SDG_{h,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $\mathrm{k} \in K_{h,b}^{10S}$;

2.2.25.4 $P10NDG_{h,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{10N}_{h,b}$;

2.2.25.6 $P30RDG_{h,b,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{30R}_{h,b}$;

2.2.25.7 $QDG_{h,b,k}$ designates the maximum incremental quantity of *energy* above the *minimum loading point* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,b}$;

2.2.25.8 $Q10SDG_{h,b,k}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{10S}_{h,b}$;

2.2.25.9 $Q10NDG_{h,b,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{10N}_{h,b}$;

2.2.25.10 $Q30RDG_{h,b,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{30R}_{h,b}$;

2.2.25.11 $RLP10S_{h,b}$ designates the *reserve loading point* for synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$;

2.2.25.12 $RLP30R_{h,b}$ designates the *reserve loading point* for *thirty-minute operating reserve* for hour $h \in \{1,..,24\}$; and

2.2.25.13 $QDLFIRM_{h,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in hour $h \in \{1,..,24\}$;

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

2.2.26.1 $ForL_{b,i}, ForU_{b,i}$ shall designate the lower and upper limits, respectively, of the *resource's forbidden regions* indicating that the *resource* cannot be scheduled between $ForLb,i$ and $ForU_{b,i}$ for all $i \in \{1,..,N_{Forb}\}$;

2.2.26.2 $MaxStartsHE_b$ designates the *maximum number of starts per day* for the *resource*;

2.2.26.3 $MaxDEL_b$ designates the *maximum daily energy limit* for a single *resource* with or without a *linked forebay*;

2.2.26.4 $MinDEL_b$ designates the *minimum daily energy limit* for a single *resource* with or without a *linked forebay*;

2.2.26.5 $MinHMR_{h,b}$ designates the *hourly must-run* quantity for the *resource* for hour $h \in \{1,..,24\}$;

2.2.26.6 $MinHO_{h,b}$ designates the *minimum hourly output* quantity for the *resource* for hour $h \in \{1,..,24\}$; and

2.2.26.7 $StartMW_{b,i}$ for $i \in \{1,.., NStartMW_b\}$ designates the *start indication value* for measuring *maximum number of starts per day*;

2.2.27 With respect to *dispatchable* hydroelectric *generation resources* with a *linked forebay*:

2.2.27.1 $MaxSDEL_s$ designates the *maximum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$; and

2.2.27.2 $MinSDEL_s$ designates the *minimum daily energy limit* shared by all *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

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

2.2.28.1 $LNK \subseteq B_{up}^{HE} \times B_{dn}^{HE}$ designates the set of linked *dispatchable* hydroelectric *generation resources*, where LNK is a set with elements of the form $(\mathrm{b}_1, \mathrm{b}_2)$ and $\mathrm{b}_1 \in \mathrm{B}_{\mathrm{up}}^{\mathrm{HE}}$ and $\mathrm{b}_2 \in \mathrm{B}_{\mathrm{dn}}^{\mathrm{HE}}$;

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

2.2.29.1 $CTShareMLP_b$ designates the combustion turbine share of the *minimum loading point* region;

2.2.29.2 $CTShareDR_b$ designates the combustion turbine share of the *dispatchable* region;

2.2.29.3 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region; and

2.2.29.4 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region;

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

2.2.30.1 $PDL_{h,b,j}$ designates the price for the maximum incremental quantity of *energy* for hour $h \in \{1,..,24\}$ in association with *bid* lamination $j \in J_{h,b}^{E}$;

2.2.30.2 $P10SDL_{h,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{10S}$;

2.2.30.3 $P10NDL_{h,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{10N}$;

2.2.30.4 $P30RDL_{h,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{30R}$;

2.2.30.5 $QDL_{h,b}$ shall designate the maximum *bid* quantity for *energy* at $b \in B^{DL}$ for hour $h \in \{1,..,24\}$ in association with *bid* lamination $j \in J_{h,b}^{E}$;

2.2.30.6 $QDLFIRM_{h,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* at $b \in B^{DL}$ for hour $h \in \{1,..,2\}$;

2.2.30.7 $Q10SDL_{h,b}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{10S}$;

2.2.30.8 $Q10NDL_{h,b}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{10N}$; and

2.2.30.9 $Q30RDL_{h,b}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,b}^{30R}$;

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

2.2.31.1 $PIG_{h,d,k}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to import in hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{h,b}^{E}$;

2.2.31.2 $P10NIG_{h,d,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{h,d}^{10N}$;

2.2.31.3 $P30RIG_{h,d,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{h,d}^{30R}$;

2.2.31.4 $QIG_{h,d,k}$ designates the maximum incremental quantity of *energy* for hour $\mathrm{h} \in \{1,..,24\}$ that may be scheduled in association with *offer* lamination $k \in K_{h,d}^{E}$;

2.2.31.5 $Q10NIG_{h,d,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{h,d}^{10N}$;

2.2.31.6 $Q30RIG_{h,d,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled for hour $\mathrm{h} \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{d,b}^{30R}$;

2.2.32 With respect to a *boundary entity resource* export at *intertie zone* bus $d \in DX$, where the *locational marginal price* represents the price at the *intertie metering point*;

2.2.32.1 $PXL_{h,d,j}$ 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 $j \in J_{h,d}^{E}$;

2.2.32.2 $P10NXL_{h,d,j}$ 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 $j \in J_{h,d}^{10N}$;

2.2.32.3 $P30RXL_{h,d,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,d}^{30R}$;

2.2.32.4 $QXL_{h,d,j}$ designates the maximum quantity of *energy* for hour $h \in \{1,..,24\}$ may be scheduled in association with *bid* lamination $j \in J_{h,d}^{E}$;

2.2.32.5 $Q10NXL_{h,d,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,d}^{10N}$;

2.2.32.6 $Q30RXL_{h,d,j}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J_{h,d}^{30R}$;

IESO Data Parameters

2.2.33 $ASDG_{h,b}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide by the *day-ahead market calculation engine* at bus b for hour $h \in \{1,..,24\}$;

2.2.34 $COMCYCMW_{h,b}$ designates the MWh constraint placed onto a *resource* that is not modelled as a *pseudo unit* at bus b for hour $h \in \{1,..,24\}$ to reflect that *resource's energy* capability in combined cycle mode;

2.2.35 $ExtLMP_{h,d}^{3}$ designates the *locational marginal price* for *energy* for hour $h \in \{1,..,24\}$ as determined by Pass 3 of the *day-ahead market calculation engine* for *intertie zone* bus $d \in D$;

2.2.36 $ExtL10NP_{h,d}^{3}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* for the *dispatch hour* $h \in \{1,..,24\}$ as calculated by Pass 3 of the *day-ahead market calculation engine* for *intertie zone* bus $d \in D$;

2.2.37 $ExtL30RP_{h,d}^{3}$ designates the *locational marginal price* for *thirty-minute operating reserve* for the *dispatch hour* $h \in \{1,..,24\}$ as calculated by Pass 3 of the *day-ahead market calculation engine* for *intertie zone* bus $d \in D$;

2.2.38 $FG_{h,b}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus $b \in B^{VG}$ for hour $h \in \{1,..,24\}$;

2.2.39 $GridConnected_{h,b}$ designates whether the *resource* is connected to the *IESO-controlled grid* at bus b for hour $h \in \{1,..,24\}$;

2.2.40 $IHE_{h,b,i}$, designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ registered a start between hours $(h-1)$ and $h \in \{1,..,24\}$ as a result of its schedule increasing from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$;

2.2.41 $LMP_{h,b}^{3}$ designates the *locational marginal price* for *energy* for hour $h \in \{1,..,24\}$ as determined by Pass 3 of the *day-ahead market calculation engine*;

2.2.42 $L10SP^{3}_{h,b}$ designates the *locational marginal price* for synchronized *ten-minute operating reserve* for hour $h \in \{1,..,24\}$ as determined by Pass 3 of the *day-ahead market calculation engine*;

2.2.43 $L10NP^{3}_{h,b}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* for hour $h \in \{1, . . . , 24\}$ as determined by Pass 3 of the *day-ahead market calculation engine*;

2.2.44 $L30RP^{3}_{h,b}$ designates the *locational marginal price* for *thirty-minute operating reserve* for hour h ∈ {1, . . . , 24} as determined by Pass 3 of the *day-ahead market calculation engine*;

2.2.47 $REGULATIONMW_{h,b}$ designates the MWh constraint placed onto a *resource* at bus b for hour $h \in \{1,..,24\}$ for *regulation*;

2.2.48 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 *linked forebay*; and

2.2.49 $SEALMW_{h,b}$ designates the MWh constraint placed onto a *resource* at bus b for hour $h \in \{1,..,24\}$ for actions taken to ensure the safety of any person, prevent the damage of equipment, or prevent the violation of any *applicable law*;

Constraint Violation Variables

2.2.50 $SLdViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{LdViol_h}\}$ of the penalty curve for the *energy* balance constraint allowing under-generation;

2.2.51 $SGenViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{GenViol_h}\}$ of the penalty curve for the *energy* balance constraint allowing over-generation;

2.2.52 $S10SViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{10SViol_h}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;

2.2.53 $S10RViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{10RViol_h}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;

2.2.54 $S30RViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{30RViol_h}\}$ of the penalty curve for the *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;

2.2.55 $SREG10RViol_{r,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{REG10RViol_h}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

2.2.56 $SREG30RViol_{r,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{REG30RViol_h}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

2.2.57 $SXREG10RViol_{r,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{XREG10RViol_h}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

2.2.58 $SXREG30RViol_{r,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{XREG30RViol_h}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

2.2.59 $SPreITLViol_{f,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{PreITLViol_{f,h}}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$;

2.2.60 $SITLViol_{c,f,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{ITLViol_{c,f,h}}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$;

2.2.61 $SPreXTLViol_{z,h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{PreXTLViol_{z,h}}\}$ of the penalty curve for violating the import/export limit associated with *intertie* limit constraint $z \in Z_{Sch}$;

2.2.62 $SNIUViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{NIUViol_h}\}$ of the penalty curve for exceeding the net interchange increase limit between hours $(h-1)$ and h;

2.2.63 $SNIDViol_{h,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{NIDViol_h}\}$ of the penalty curve for exceeding the net interchange decrease limit between hours $(h-1)$ and h;

2.2.64 $SMaxDelViol_{h,b,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{MaxDelViol_h}\}$ of the penalty curve for exceeding the *maximum daily energy limit* constraint for a *resource* at bus $b \in B^{ELR}$;

2.2.65 $SMinDelViol_{h,b,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{MinDelViol_h}\}$ of the penalty curve for violating the *minimum daily energy limit* constraint for a *resource* at bus $b \in B^{HE}$;

2.2.66 $SSMaxDelViol_{h,s,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{SMaxDelViol_h}\}$ of the penalty curve for exceeding the shared *maximum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

2.2.67 $SSMinDelViol_{h,s,i}$ designates the violation variable associated with segment $i \in \{1,..,N_{SMinDelViol_h}\}$ of the penalty curve for violating the shared *minimum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

2.2.68 $SOGenLnkViol_{h,(b_1,b_2),i}$ designates the violation variable associated with segment $i \in \{1,..,N_{OGenLnkViol_h}\}$ of the penalty curve for violating the *linked forebay* constraint for *dispatchable* hydroelectric *generation resources* by over-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$; and

2.2.69 $SUGenLnkViol_{h,(b_1,b_2),i}$ designates the violation variable associated with segment $i \in \{1,..,N_{UGenLnkViol_h}\}$ of the penalty curve for violating the *linked forebay* constraint for *dispatchable* hydroelectric *generation resources* by under-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$.

2.3 Objective Functions

2.3.1 The objective functions for the DAM LC EOP calculation shall solve for the following variables:

2.3.1.1 $ESDG_{h,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,b}$;

2.3.1.2 $ES10SDG_{h,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{10S}_{h,b}$;

2.3.1.3 $ES10NDG_{h,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{10N}_{h,b}$;

2.3.1.4 $ES30RDG_{h,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{30R}_{h,b}$;

2.3.1.5 $ESIG_{h,d,k}$ which designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* bus $d \in DI$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,d}$;

2.3.1.6 $ES10NIG_{h,d,k}$ which designates the amount of non-synchronized *ten-minute operating reserve* that an import *boundary entity resource* is scheduled to provide from *intertie zone* bus $d \in DI$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,d}$;

2.3.1.7 $ES30RIG_{h,d,k}$ which designates the amount of *thirty-minute operating reserve* that an import *boundary entity resource* is scheduled to provide at bus $d \in DI$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,d}$;

2.3.1.8 $ESDL_{h,b,j}$, which designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$ for hour $h \in \{1,..,24\}$ in association with *bid* lamination $j \in J^{E}_{h,b}$;

2.3.1.9 $ES10SDL_{h,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J^{10S}_{h,b}$;

2.3.1.10 $ES10NDL_{h,b,j}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J^{10N}_{h,b}$;

2.3.1.11 $ES30RDL_{h,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $j \in J^{30R}_{h,b}$;

2.3.1.12 $ESXL_{h,d,k}$ which designates the amount of *energy* a *boundary entity resource* is scheduled to export at *intertie zone* at bus $d \in DX$ for hour $h \in \{1,..,24\}$ in association with *bid* lamination $k \in K^{E}_{h,d}$;

2.3.1.13 $ES10NXL_{h,d,k}$ which designates the amount of non-synchronized *ten-minute operating reserve* that an export *boundary entity resource* is scheduled to provide at *intertie zone* bus $d \in DX$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,d}$;

2.3.1.14 $ES30RXL_{h,d,k}$ which designates the amount of *thirty-minute operating reserve* that an export *boundary entity resource* is scheduled to provide at *intertie zone* bus $d \in DX$ for hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^{E}_{h,d}$;

2.3.2 For each of the following *resource* types, the objective function for determining a DAM LC EOP shall maximize the value of the following expressions:

2.3.2.1 For *dispatchable generation resources*:

$$ObjSDG_h = \sum_{k \in K^{E}_{h,b}} ESDG_{h,b,k} \cdot \left(LMP^{3}_{h,b} - PDG_{h,b,k}\right)$$

$$Obj10SDG_h = \sum_{k \in K^{10S}_{h,b}} ES10SDG_{h,b,k} \cdot \left(L10SP^{3}_{h,b} - P10SDG_{h,b,k}\right)$$

$$Obj10NDG_h = \sum_{k \in K^{10N}_{h,b}} ES10NDG_{h,b,k} \cdot \left(L10NP^{3}_{h,b} - P10NDG_{h,b,k}\right)$$

$$Obj30RDG_h = \sum_{k \in K^{30R}_{h,b}} ES30RDG_{h,b,k} \cdot \left(L30RP^{3}_{h,b} - P30RDG_{h,b,k}\right)$$

2.3.2.2 For *dispatchable loads*:

$$ObjSDL_h = \sum_{j \in J^E_{h,b}} ESDL_{h,b,j} \cdot \left(PDL_{h,b,j} - LMP^3_{h,b}\right)$$

$$Obj10SDL_h = \sum_{j \in J^{10S}_{h,b}} ES10SDL_{h,b,j} \cdot \left(L10SP^3_{h,b} - P10SDL_{h,b,j}\right)$$

$$Obj10NDL_h = \sum_{j \in J^{10N}_{h,b}} ES10NDL_{h,b,j} \cdot \left(L10NP^3_{h,b} - P10NDL_{h,b,j}\right)$$

$$Obj30RDL_h = \sum_{j \in J^{30R}_{h,b}} ES30RDL_{h,b,j} \cdot \left(L30RP^3_{h,b} - P30RDL_{h,b,j}\right)$$

2.3.2.3 For import transactions associated with *boundary entity resources*:

$$ObjSIG_h = \sum_{k \in K^E_{h,d}} ESIG_{h,d,k} \cdot \left(ExtLMP^3_{h,d} - PIG_{h,d,k}\right)$$

$$Obj10NIG_h = \sum_{k \in K^{10N}_{h,d}} ES10NIG_{h,d,k} \cdot \left(ExtL10NP^3_{h,d} - P10NIG_{h,d,k}\right)$$

$$Obj30RIG_h = \sum_{k \in K^{30R}_{h,d}} ES30RIG_{h,d,k} \cdot \left(ExtL30RP^3_{h,d} - P30RIG_{h,d,k}\right)$$

2.3.2.4 For export transactions associated with *boundary entity resources*

$$ObjSXL_h = \sum_{j \in J^E_{h,b}} ESXL_{h,d,j} \cdot \left(PXL_{h,d,j} - \mathrm{ExtLMP}^3_{\mathrm{h,d}}\right)$$

$$Obj10NXL_h = \sum_{j \in J^{10N}_{h,b}} ES10NXL_{h,d,j} \cdot \left(\mathrm{ExtL10NP}^3_{\mathrm{h,d}} - P10NXL_{h,d,j}\right)$$

$$Obj30RXL_h = \sum_{j \in J^{30R}_{h,b}} ES30RXL_{h,d,j} \cdot \left(\mathrm{ExtL30RP}^3_{\mathrm{h,d}} - P30RXL_{h,d,j}\right)$$

2.4 Constraints

2.4.1 The constraints described in this section 2.4 shall apply to the objective functions used for the DAM LC EOP calculation.

Scheduling Variable Bounds

2.4.2 No DAM LC EOP shall be negative, nor shall any DAM LC EOP exceed the *offer* or *bid* quantity for *energy* or the *offer* quantity for *operating reserve*. Therefore, for all hours $h \in \{1,..,24\}$:

$0 \leq ESDL_{h,b,j} \leq QDL_{h,b,j}$	for all $b \in B^{DL}, j \in J_{h,b}^{E}$;
$0 \leq ES10SDL_{h,b,j} \leq Q10SDL_{h,b,j}$	for all $b \in B^{DL}, j \in J_{h,b}^{10S}$;
$0 \leq ES10NDL_{h,b,j} \leq Q10NDL_{h,b,j}$	for all $b \in B^{DL}, j \in J_{h,b}^{10N}$;
$0 \leq ES30RDL_{h,b,j} \leq Q30RDL_{h,b,j}$	for all $b \in B^{DL}, j \in J_{h,b}^{30R}$;
$0 \leq ESDG_{h,b,k} \leq QDG_{h,b,k}$	for all $b \in B^{DG}, k \in K_{h,b}^{E}$;
$0 \leq ES10SDG_{h,b,k} \leq Q10SDG_{h,b,k}$	for all $b \in B^{DG}, k \in K_{h,b}^{10S}$;
$0 \leq ES10NDG_{h,b,k} \leq Q10NDG_{h,b,k}$	for all $b \in B^{DG}, k \in K_{h,b}^{10N}$;
$0 \leq ES30RDG_{h,b,k} \leq Q30RDG_{h,b,k}$	for all $b \in B^{DG}, k \in K_{h,b}^{30R}$;
$0 \leq ESXL_{h,d,j} \leq QXL_{h,d,j}$	for all $b \in DX, j \in J_{h,d}^{E}$;
$0 \leq ES10NXL_{h,d,j} \leq Q10NXL_{h,d,j}$	for all $b \in DX, j \in J_{h,d}^{10N}$;
$0 \leq ES30RXL_{h,d,j} \leq Q30RXL_{h,d,j}$	for all $b \in DX, j \in J_{h,d}^{30R}$;
$0 \leq ESIG_{h,d,k} \leq QIG_{h,d,k}$	for all $b \in DI, k \in K_{h,d}^{E}$;
$0 \leq ES10NIG_{h,d,k} \leq Q10NIG_{h,d,k}$	for all $b \in DI, k \in K_{h,d}^{10N}$;
$0 \leq ES30RIG_{h,d,k} \leq Q30RIG_{h,d,k}$	for all $b \in DI, k \in K_{h,d}^{30R}$;

2.4.3 For a *dispatchable load*, its DAM LC EOP for each class of *operating reserve* shall not exceed its DAM LC EOP for *energy*:

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j}$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j}$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j}$$

2.4.4 For a *dispatchable generation resource* for a *dispatch hour* $h \in \{1,..,24\}$:

For all $b \in B^{VG}$:

$$VGForecast_{h,b} = \begin{Bmatrix} AFG_{h,b} & if\ provided \\ FG_{h,b} & otherwise \end{Bmatrix}$$

For all $b \in B^{DG}$:

$$AdjMaxDG_{h,b} = \begin{Bmatrix} min\left(\sum_{k \in K_{h,b}^{E}} QDG_{h,b,k}, Derate_{h,b}, VGForecast_{h,b}\right) & if\ b \in B^{VG} \\ min\left(\sum_{k \in K_{h,b}^{E}} QDG_{h,b,k}, Derate_{h,b}\right) & otherwise \end{Bmatrix}$$

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} \leq AdjMaxDG_{h,b}$$

$$\sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k} \leq AdjMaxDG_{h,b}$$

$$\sum_{k \in K_{h,b}^{10N}} ES10NDG_{h,b,k} \leq AdjMaxDG_{h,b}$$

$$\sum_{k \in K_{h,b}^{30R}} ES30RDG_{h,b,k} \leq AdjMaxDG_{h,b}$$

2.4.5 Subject to section 2.4.6, the DAM LC EOP for a *non-quick start resource* shall be greater than or equal to its *minimum loading point*:

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} \geq MinQDG_{b}$$

2.4.6 For a *non-quick start resource* that is scheduled below its *minimum loading point*, its DAM LC EOP shall be equal to its *day-ahead schedule*:

If $\sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k} < MinQDG_b$ for $b \in B^{NQS}$ then:

$$\sum_{k\in K_{h,b}^{E}E} ESDG_{h,b,k} = ASDG_{h,b}$$

Constraints for Regulation Requirements

2.4.7 For a *dispatchable generation resource,* its DAM LC EOP for *energy* shall be greater than or equal to any *regulation* constraint that is applied for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k\in K_{h,b}^{E}} ESDG_{h,b,k} \geq REGULATIONMW_{h,b}$$

2.4.8 For a *dispatchable generation resource,* its DAM LC EOP for *energy* and each class of *operating reserve* shall not exceed the maximum available capacity the *resource* has less the *regulation constraint* that is applied for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k\in K_{h,b}^{E}} ESDG_{h,b,k} \leq AdjMaxDG_{h,b} - REGULATIONMW_{h,b}$$

$$\sum_{k\in K_{h,b}^{10S}} ES10SDG_{h,b,k} \leq AdjMaxDG_{h,b} - REGULATIONMW_{h,b}$$

$$\sum_{k\in K_{h,b}^{10N}} ES10NDG_{h,b,k} \leq AdjMaxDG_{h,b} - REGULATIONMW_{h,b}$$

$$\sum_{k\in K_{h,b}^{30R}} ES30RDG_{h,b,k} \leq AdjMaxDG_{h,b} - REGULATIONMW_{h,b}$$

Constraints for Market Participant Requirements

2.4.9 For a *dispatchable generation resource,* its DAM LC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{h,b}$ constraint that is applied for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} \geq SEALMW_{h,b}$$

2.4.10 For a *dispatchable load,* its DAM LC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{h,b}$constraint that is applied and for each class of *operating reserve*, the DAM LC EOP shall be less than or equal to the DAM LC EOP for *energy* for that *resource* less any minimum $SEALMW_{h,b}$ constraint that is applied for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} \geq SEALMW_{h,b}$$

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{h,b,k} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} \; - \; SEALMW_{h,b}$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{h,b,k} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} \; - \; SEALMW_{h,b}$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{h,b,k} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} \; - \; SEALMW_{h,b}$$

2.4.11 For a *dispatchable generation resource,* its DAM LC EOP for *energy* shall be less than or equal to any maximum $SEALMW_{h,b}$ constraint that is applied for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} \leq SEALMW_{h,b}$$

2.4.12 For a *dispatchable load,* its DAM LC EOP for *energy* shall be less than or equal to any maximum $SEALMW_{h,b}$constraint that is applied for hour $h \in \{1,..,24\}$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} \leq SEALMW_{h,b}$$

2.4.13 For a *dispatchable generation resource,* its DAM LC EOP for *energy* shall be equal to any fixed $SEALMW_{h,b}$constraint that is applied for hour $h \in \{1,..,24\}$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} = SEALMW_{h,b}$$

2.4.14 For a *dispatchable load,* its DAM LC EOP for *energy* shall be equal to any fixed $SEALMW_{h,b}$constraint that is applied and equal to zero for each class of *operating reserve* for hour $h \in \{1,..,24\}$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} = SEALMW_{h,b}$$

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{h,b,j} = 0$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{h,b,j} = 0$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{h,b,j} = 0$$

2.4.15 For a *dispatchable load,* its DAM LC EOP for *energy* shall be greater than or equal to the *bid* quantity for *energy* priced at the *maximum market clearing price*:

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

2.4.16 For a *dispatchable load,* its DAM LC EOP for *operating reserve* shall be less than or equal its DAM LC EOP for *energy* less the *bid* quantity for *energy* priced at the *maximum market clearing price*:

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} - QDLFIRM_{h,b}$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} - QDLFIRM_{h,b}$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{h,b,j} \leq \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j} - QDLFIRM_{h,b}$$

Constraints for Operating Reserve Ramping

2.4.18 For a *dispatchable generation resource* with $RLP10S_{h,b} > 0$, its DAM LC EOP for *ten-minute operating reserve* shall be less than or equal to its *reserve loading point* for *ten-minute operating reserve* for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k} \leq \left(\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} \right) \cdot \left(\frac{1}{RLP10S_{h,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_{b}, \sum_{k \in K_{h,b}^{10S}} Q10SDG_{h,b,k} \right\} \right)$$

2.4.19 For a *dispatchable generation resource* with $RLP30R_{h,b} > 0$, its DAM LC EOP for *thirty-minute operating reserve* shall be less than or equal to its *reserve loading point* for *thirty-minute operating reserve* for hour $h \in \{1, .., 24\}$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{h,b}^{30R}} ES30RDG_{h,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} ESDG_{h,b,k} \right) \cdot \left(\frac{1}{RLP30R_{h,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_{b}, \sum_{k \in K_{h,b}^{30R}} Q30RDG_{h,b,k} \right\} \right)$$

Constraints for Pseudo-Units

2.4.20 For a *pseudo-unit,* its DAM LC EOP for *energy* for the *dispatchable* region and duct firing region shall be less than or equal to the respective maximum capabilities for those regions for hour $h \in \{1,..,24\}$ and bus $b \in B^{PSU}$:

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

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

2.4.21 For a *pseudo-unit,* its DAM LC EOP for each class of *operating reserve* shall be less than or equal to the sum of the maximum capabilities for its *dispatchable* region and duct firing region for hour $h \in \{1,..,24\}$ and bus $b \in B^{PSU}$:

$$\sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k} \leq MaxDR_{h,b} + MaxDF_{h,b}$$

$$\sum_{k \in K_{h,b}^{10N}} ES10NDG_{h,b,k} \leq MaxDR_{h,b} + MaxDF_{h,b}$$

$$\sum_{k \in K_{h,b}^{30R}} ES30RDG_{h,b,k} \leq MaxDR_{h,b} + MaxDF_{h,b}$$

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2.4.22 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, the following constraint shall apply:

$$\sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k} + \sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k} + \sum_{k \in K_{h,b}^{10N}} ES10NDG_{h,b,k} \leq MINQDG_b + QDR_{h,k}$$

Constraints for Resources with Linked Forebays

2.4.23 For all *dispatchable* hydroelectric *generation resources* with a *linked forebay*, the DAM LC EOP for *energy* at the upstream *resources* in one hour shall result in a proportional DAM LC EOP for *energy* at the downstream *resources* in the hour determined by the *time lag*.

For all *dispatchable* hydroelectric *generation resources* with a *linked forebay* between upstream *resources* $b_1 \in B_{up}^{HE}$ and downstream *resources* $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNK$ and hours $h \in \{1, . . . , 24\}$ such that $h + Lag_{b_1,b_2} \leq 24$:

$$\sum_{b_2 \in B_{dn}^{HE}} \left(\sum_{k \in K_{b_2,h+Lag_{b_1,b_2}}^{E}} ESDG_{k,h+Lag_{b_1,b_2},b_2} \right) = MWhRatio_{b_1,b_2} \cdot \sum_{b_1 \in B_{up}^{HE}} \left(\sum_{k \in K_{b_1,h}^{E}} ESDG_{k,h,b_1} \right)$$

2.5 Calculation of DAM LC EOP for Resources with a Linked Forebay Under Certain Conditions

2.4.24 For *dispatchable* hydroelectric *resources* with a *linked forebay,* the DAM LC EOP shall be equal to the *resource's day-ahead schedule* if the conditions in sections 2.4.24.1 and 2.4.24.2 are both satisfied:

2.4.24.1 The following constraint violation prices were non-binding in Pass 1 or Pass 3 of the *day-ahead market calculation engine* run for any *dispatch hour* in the *dispatch day*:

$$\sum_{i=1:N_{MaxDelViol_h}} SMaxDelViol_{h,b,i} = 0$$

$$\sum_{i=1:N_{MinDelViol_h}} SMinDelViol_{h,b,i} = 0$$

$$\sum_{i=1:N_{SMaxDelViol_h}} SSMaxDelViol_{h,s,i} = 0$$

$$\sum_{i=1:N_{SMinDelViol_h}} SSMinDelViol_{h,s,i} = 0$$; or

$$\sum_{i=1:N_{LdViol_h}} SLdViol_{h,i} = 0$$

$$\sum_{i=1:N_{GenViol_h}} SGenViol_{h,i} = 0$$

$$\sum_{i=1:N_{10SViol_h}} S10SViol_{h,i} = 0$$

$$\sum_{i=1:N_{10RViol_h}} S10RViol_{h,i} = 0$$

$$\sum_{i=1:N_{30RViol_h}} S30RViol_{h,i} = 0$$

$$\sum_{i=1:N_{REG10RViol_h}} SREG10RViol_{r,h,i} = 0$$

$$\sum_{i=1:N_{REG30RViol_h}} SREG30RViol_{r,h,i} = 0$$

$$\sum_{i=1:N_{XREG10RViol_h}} SXREG10RViol_{r,h,i} = 0$$

$$\sum_{i=1:N_{XREG30RViol_h}} SXREG30RViol_{r,h,i} = 0$$

$$\sum_{i=1:N_{PreITLViol_{f,h}}} SPreITLViol_{f,h,i} = 0$$

$$\sum_{i=1:N_{ITLViol_{c,f,h}}} SITLViol_{c,f,h,i} = 0$$

$$\sum_{i=1:N_{PreXTLViol_{z,h}}} SPreXTLViol_{z,h,i} = 0$$

$$\sum_{i=1:N_{NIUViol_h}} SNIUViol_{h,i} = 0$$

$$\sum_{i=1:N_{NIDViol_h}} SNIDViol_{h,i} = 0$$

$$\sum_{i=1:N_{OGenLnkViol_h}} SOGenLnkViol_{h,(b1,b2),i} = 0$$

$\sum_{i=1:N_{UGenLnkViol_h}} SUGenLnkViol_{h,(b1,b2),i} = 0$, and

2.4.24.2 At least one of the conditions set out in sections 2.4.24.2.1-2.4.24.2.4 is met:

2.4.24.2.1 At least one *resource* with a *linked forebay* has a *day-ahead schedule* that satisfies any one of the following conditions for a *dispatch hour* in which the *time lag* was evaluated:

a. $\sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k} \leq MinHMR_{h,b}$;
b. $\sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k} \leq MinHO_{h,b}$; or
c. $ForL_{b,i} \leq \sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k} \leq ForU_{b,i}$;

2.4.24.2.2 For all *resources* with a *linked forebay* where at least one of the following daily constraints are binding for at least one *dispatch hour* in a *dispatch day*:

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

$$\sum_{h=1..H}\left(\sum_{b\in B_S^{HE}}\left(\sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k}\right)\right) + \sum_{b\in B_S^{HE}}\left(10ORConv\left(\sum_{k\in K_{H,b}^{10S}} S10SDG_{H,b,k} + \sum_{k\in K_{H,b}^{10N}} S10NDG_{H,b,k}\right) + 30ORConv\left(\sum_{k\in K_{H,b}^{30R}} S30RDG_{H,b,k}\right)\right) \geq MaxSDEL_s$$

$\sum_{h=1..24}\left(\sum_{b\in B_S^{HE}}\left(\sum_{k\in K_{h,b}^{E}} ASDG_{h,b,k}\right)\right) \leq MinSDEL_s$;

2.4.24.2.3 For all *resources* with a *linked forebay* that do not have a binding *reliability* constraint applied for a *dispatch hour* in which the *time lag* was evaluated:

$$\sum_{k \in K_{h,b}^{E}} ASDG_{h,b,k} \neq RELIABILITYMW_{h,b} \quad where\ b \in B^{HE}$$

2.4.24.2.4 For all *resources* with a *linked forebay* that have at least one binding $SEALMW_{h,b}$constraint for a *dispatch hour* in which the *time lag* was evaluated, at least one of the following conditions was met:

a. For a *resource* that has a fixed $SEALMW_{h,b}$constraint applied for hour $h \in \{1,..,24\}$ and bus $b \in B^{HE}$:

$$\sum_{k \in K_{h,b}^{E}} ASDG_{h,b,k} = SEALMW_{h,b}$$

For a *resource* that has a minimum $SEALMW_{h,b}$constraint applied for hour $h \in \{1,..,24\}$ and bus $b \in B^{HE}$:

$$\sum_{k \in K_{h,b}^{E}} ASDG_{h,b,k} \leq SEALMW_{h,b}$$

For a *resource* that has a maximum $SEALMW_{h,b}$constraint applied for hour $h \in \{1,..,24\}$ and bus $b \in B^{HE}$:

$$\sum_{k \in K_{h,b}^{E}} ASDG_{h,b,k} \geq SEALMW_{h,b}$$

2.6 Outputs

2.5.1 The DAM LC EOPs used for *settlement* for *energy* and *operating reserve* for all *resources* except *pseudo-units* for each hour of the *dispatch day* shall be the sum of each DAM LC EOP variable determined by the objective function in section 2.3 for that *resource*, subject to constraints in section 2.4 applicable for that *resource* determined as follows:

$$DGEnergyEOP_{h,b} = \sum_{k \in K_{h,b}^{E}} ESDG_{h,b,k}$$

$$DG10SEOP_{h,b} = \sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k}$$

$$DG10NEOP_{h,b} = \sum_{k \in K_{h,b}^{10N}} ES10NDG_{h,b,k}$$

$$DG30REOP_{h,b} = \sum_{k \in K_{h,b}^{30R}} ES30RDG_{h,b,k}$$

$$DLEnergyEOP_{h,b} = \sum_{j \in J_{h,b}^{E}} ESDL_{h,b,j}$$

$$DL10SEOP_{h,b} = \sum_{j \in J_{h,b}^{10S}} ES10SDL_{h,b,j}$$

$$DL10NEOP_{h,b} = \sum_{j \in J_{h,b}^{10N}} ES10NDL_{h,b,j}$$

$$DL30REOP_{h,b} = \sum_{j \in J_{h,b}^{30R}} ES30RDL_{h,b,j}$$

$$DIEnergyEOP_{h,b} = \sum_{k \in K_{h,b}^{E}} ESIG_{h,b,k}$$

$$DI10NEOP_{h,b} = \sum_{k \in K_{h,b}^{10N}} ES10NIG_{h,b,k}$$

$$DI30REOP_{h,b} = \sum_{k \in K_{h,b}^{30R}} ES30RIG_{h,b,k}$$

$$DXEnergyEOP_{h,b} = \sum_{j \in J_{h,b}^{E}} ESXL_{h,b,j}$$

$$DX10NEOP_{h,b} = \sum_{j \in J_{h,b}^{10N}} ES10NXL_{h,b,j}$$

$$DX30REOP_{h,b} = \sum_{j \in J_{h,b}^{30R}} ES30RXL_{h,b,j}$$

2.5.2 The DAM LC EOPs for *energy* and *operating reserve* for a *pseudo-unit* for each hour of the *dispatch day,* which will be used for converting the DAM LC EOPs to physical *resource* equivalents in accordance with sections 2.5.3 to 2.5.4, shall be determined as follows:

$$PSUMLPEnergyEOP_{h,k} = \sum_{k \in K_{h,b}^{MLP}} ESDG_{h,b,k}$$

$$PSUDREnergyEOP_{h,k} = \sum_{k \in K_{h,b}^{DR}} ESDG_{h,b,k}$$

$$PSUDFEnergyEOP_{h,k} = \sum_{k \in K_{h,b}^{DF}} ESDG_{h,b,k}$$

$$PSU10SEOP_{h,k} = \sum_{k \in K_{h,b}^{10S}} ES10SDG_{h,b,k}$$

$$PSU10NEOP_{h,k} = \sum_{k \in K_{h,b}^{10N}} ES10NDG_{h,b,k}$$

$$PSU30REOP_{h,k} = \sum_{k \in K_{h,b}^{30R}} ES30RDG_{h,b,k}$$

Conversion of DAM LC EOPs for Pseudo-Units to Physical Resource Equivalents

2.6.3 The DAM LC EOP used for *settlement* for *energy* for a combustion turbine and a steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in hour h shall be determined as follows:

$$CTEnergyEOP_{h,k} = PSUMLPEnergyEOP_{h,k} \cdot CTShareMLP_{h,k} + PSUDREnergyEOP_{h,k} \cdot CTShareDR_{h,k}$$

$$STEnergyEOP_{h,k} = PSUMLPEnergyEOP_{h,k} \cdot STShareMLP_{k} + PSUDREnergyEOP_{h,k} \cdot STShareDR_{k} + PSUDFEnergyEOP_{h,k}$$

2.6.4 The DAM LC EOPs used for *settlement* for *operating reserve* for a combustion turbine and a steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in hour h shall be determined as follows and in the following order for each class of *operating reserve*:

$$10SDR_{h,k} = \min\left(QDR_{h,k}, PSU10SEOP_{h,k}\right)$$

$$10NDR_{h,k} = \min\left(QDR_{h,k} - 10SDR_{h,k}, PSU10NEOP_{h,k}\right)$$

$$30RDR_{h,k} = \min\left(QDR_{h,k} - 10SDR_{h,k} - 10NDR_{h,k}, PSU30REOP_{h,k}\right)$$

$$CT10SEOP_{h,k} = 10SDR_{h,k} \cdot CTShareDR_k$$
$$ST10SEOP_{h,k} = 10SDR_{h,k} \cdot STShareDR_k + (PSU10SEOP_{h,k} - 10SDR_{h,k})$$

$$CT10NEOP_{h,k} = 10NDR_k \cdot CTShareDR_{h,k}$$
$$ST10NEOP_{h,k} = 10NDR_{h,k} \cdot STShareDR_k + (PSU10NEOP_{h,k} - 10NDR_{h,k})$$

$$CT30REOP_{h,k} = 30RDR_k \cdot CTShareDR_{h,k}$$
$$ST30REOP_{h,k} = 30RDR_{h,k} \cdot STShareDR_k + (PSU30REOP_{h,k} - 30RDR_{h,k})$$

3. Real-Time Market Lost Cost Economic Operating Point

3.1 Purpose

3.1.1 This section describes the process used to determine lost cost economic operating point (RT LC EOP) for eligible *resources* in the *real-time market*.

3.2 Sets, Indices and Parameters used by the Real-Time Lost Cost Economic Operating Point Calculation

Fundamental Sets and Indices

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

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

3.2.3 $B^{DG} \subseteq B$ designates the set of buses identifying *dispatchable generation resources*;

3.2.4 $B^{DL} \subseteq B$ designates the set of buses identifying *dispatchable loads*;

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

3.2.6 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone a* ∈ *A*;

3.2.7 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

3.2.8 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone a* ∈ *A*;

3.2.9 $DX \subseteq B^{DL}$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

3.2.10 $DX_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone a* ∈ *A*;

3.2.11 $ExtLMP^{PD}_{i,d}$ designates the *locational marginal price* for *energy* for the *dispatch hour* in which interval $i \in I$ falls as determined by Pass 1 of the *pre-dispatch calculation engine*;

3.2.12 I = {1,..,n_I} designates the set of all intervals, where n_I designates the number of five-minute intervals considered within the real-time look-ahead period;

3.2.13 $J^{E}_{i,b}$ designates the set of *bid* laminations for *energy* at $b \in B^{DL} \cup DX$ for interval $i \in I$;

3.2.14 $J^{10S}_{i,b}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at $b \in B^{DL}$ for interval $i \in I$;

3.2.15 $J^{10N}_{i,b}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at $b \in B^{DL} \cup DX$ for interval $i \in I$;

3.2.16 $J^{30R}_{i,b}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at $b \in B^{DL} \cup DX$ for interval $i \in I$;

3.2.17 $J^{E}_{t,d}$ designates the set of *bid* laminations for *energy* at *intertie zone* bus $d \in DX$ for time-step $t \in TS$;

3.2.18 $J^{10N}_{t,d}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at $d \in DX$ for time-step $t \in TS$;

3.2.19 $J^{30R}_{t,d}$ shall designate the set of *offer* laminations for *thirty-minute operating reserve* at $d \in DX$ for time-step $t \in TS$;

3.2.20 $K^{E}_{i,b}$ designates the set of *offer* laminations for *energy* at $b \in B^{DG} \cup DI$ for interval $i \in I$;

3.2.21 $K^{10S}_{i,b}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DG}$ for interval $i \in I$;

3.2.22 $K^{10N}_{i,b}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B^{DG} \cup DI$ for interval $i \in I$;

3.2.23 $K^{30R}_{i,b}$ designates the set of *offer* laminations for non-synchronized *thirty-minute operating reserve* at bus $b \in B^{DG} \cup DI$ for interval $i \in I$;

3.2.24 $K^{E}_{t,d}$ designates the set of *offer* laminations for energy at $d \in DI$ for time-step $t \in TS$;

3.2.25 $K_{t,d}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $d \in DI$ for time-step $t \in TS$;

3.2.26 $K_{t,d}^{30R}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $d \in DI$for time-step $t \in TS$; and

3.2.27 $TS = \{2, \dots, n_{LAP}\}$ designates the set of all time-steps in the look-ahead period that are included in the *pre-dispatch calculation engine* optimization, where n_{LAP} designates the number of time-steps in the pre-dispatch look-ahead period;

Market Participant Data Parameters

3.2.28 With respect to all *resources*:

3.2.28.1 $Derate_{i,b}$ designates the maximum amount of *energy* and *operating reserve* that can be scheduled for a *resource* in a *dispatch interval*;

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

3.2.29.1 $MinQDG_{i,b}$ designates the *minimum loading point* indicating the minimum output at which a *resource* must be scheduled to except for times when the *resource* is starting up or shutting down at $b \in B^{DG}$ for interval i;

3.2.29.2 $ORRDG_b$ designates the maximum *operating reserve* ramp rate in MW per minute for the *resource* at $b \in B^{DG}$;

3.2.29.3 $PDG_{i,b,k}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{E}$;

3.2.29.4 $P10SDG_{i,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10S}$;

3.2.30.5 $P10NDG_{i,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10N}$;

3.2.30.6 $P30RDG_{i,b,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{30R}$;

3.2.30.7 $QDG_{i,b,k}$ designates the maximum incremental quantity of *energy* above the *minimum loading point* that may be scheduled in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$;

3.2.30.8 $Q10SDG_{i,b,k}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{10S}_{i,b}$;

3.2.30.9 $Q10NDG_{i,b,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{10N}_{i,b}$; and

3.2.30.10 $Q30RDG_{i,b,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{30R}_{i,b}$;

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

3.2.31.1 $PDL_{i,b,j}$ designates the price for the maximum incremental quantity of *energy* for interval $i \in I$ in association with *bid* lamination $j \in J^{E}_{i,b}$;

3.2.31.2 $P10SDL_{i,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J^{10S}_{i,b}$;

3.2.31.3 $P10NDL_{i,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J^{10N}_{i,b}$;

3.2.31.4 $P30RDL_{i,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J^{30R}_{i,b}$;

3.2.31.5 $QDL_{i,b}$ designates the maximum *bid* quantity for *energy* at $b \in B^{DL}$ for interval $i \in I$ in association with *bid* lamination $j \in J^{E}_{i,b}$;

3.2.31.6 $QDLFIRM_{i,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* at $b \in B^{DL}$ in interval $i \in I$;

3.2.31.7 $Q10SDL_{i,b}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

3.2.31.8 $Q10NDL_{i,b}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

3.2.31.9 $Q30RDL_{i,b}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

3.2.31.10 $RLP10S_{i,b}$ designates the *reserve loading point* for synchronized *ten-minute operating reserve* in interval $i \in I$; and

3.2.31.11 $RLP30R_{i,b}$ designates the *reserve loading point* for *thirty-minute operating reserve* in interval $i \in I$;

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

3.2.32.1 $CTShareMLP_b$ designates the combustion turbine share of the *minimum loading point* region;

3.2.32.2 $CTShareDR_b$ designates the combustion turbine share of the *dispatchable* region;

3.2.32.3 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region; and

3.2.32.4 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region;

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

3.2.33.1 $PIG_{t,d,k}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to import in time-step $t \in TS$ in association with *offer* lamination $k \in$;

3.2.33.2 $P10NIG_{t,d,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{10N}$;

3.2.33.3 $P30RIG_{t,d,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{30R}$;

3.2.33.4 $QIG_{t,d,k}$ designates the maximum quantity of *energy* for which an import at bus $d \in DI$ in time-step $t \in TS$ may be scheduled in association with *offer* lamination $k \in K_{t,d}^{E}$;

3.2.33.5 $Q10NIG_{t,d,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{10N}$; and

3.2.33.6 $Q30RIG_{t,d,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* quantity that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $k \in K_{t,d}^{30R}$;

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

3.2.34.1 $PXL_{t,d,j}$ designates the price of the exporter at bus *d* for an incremental quantity of *energy* in time-step $t \in TS$ in association with *bid* lamination $j \in J_{t,d}^{E}$;

3.2.34.2 $P10NXL_{t,d,j}$ designates the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{10N}$;

3.2.34.3 $P30RXL_{t,d,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$;

3.2.34.4 $QXL_{t,d,j}$ designates the maximum quantity of *energy* for which the export at bus *b* in time-step $t \in TS$ may be scheduled in association with *bid* lamination $j \in J_{t,d}^{E}$;

3.2.34.5 $Q10NXL_{t,d,j}$ designates the quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{10N}$; and

3.2.34.6 $Q30RXL_{t,d,j}$ designates the quantity of *thirty-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$;

IESO Data Parameters

3.2.35 $ASDG_{i,b}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide by the *real-time calculation engine* at bus b for interval $i \in I$;

3.2.36 $COMCYCMW_{i,b}$ designates the MWh constraint placed onto a *resource* that is not modelled as a *pseudo-unit* at bus b for interval $i \in I$ to reflect that *resource's energy* capability in combined cycle mode;

3.2.37 $ExtL10NP_{i,d}^{PD}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* for the *dispatch hour* in which interval $i \in I$ falls as calculated by Pass 1 of the *pre-dispatch calculation engine*;

3.2.38 $ExtL30RP_{i,d}^{PD}$ designates the *locational marginal price* for *thirty-minute operating reserve* for the *dispatch hour* in which interval $i \in I$ falls as calculated by Pass 1 of the *pre-dispatch calculation engine*;

3.2.39 $FG_{i,b}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus b for interval $i \in I$;

3.2.40 $LMP_{i,b}^{1}$ designates the *locational marginal price* for *energy* in interval $i \in I$ as determined by Pass 1 of the *real-time calculation engine*;

3.2.41 $L10SP_{i,b}^{1}$ designates the *locational marginal price* for synchronized *ten-minute operating reserve* in interval $i \in I$ as determined by Pass 1 of the *real-time calculation engine*;

3.2.42 $L10NP_{i,b}^{1}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* in interval $i \in I$ as determined by Pass 1 of the *real-time calculation engine*;

3.2.43 $L30RP_{i,b}^{1}$ designates the *locational marginal price* for *thirty-minute operating reserve* in interval $i \in I$ as determined by Pass 1 of the *real-time calculation engine*;

3.2.44 $REGULATIONMW_{h,b}$ designates the MWh constraint placed onto a *resource* at bus b for interval $i \in I$ for *regulation*; and

3.2.45 $SEALMW_{i,b}$ designates the MWh constraint placed onto a *resource* at bus b for interval $i \in I$ for actions taken to ensure the safety of any person, prevent the damage of equipment, or prevent the violation of any *applicable law*.

3.3 Objective Functions

3.3.1 The objective functions for the Real-Time Market Lost Cost Economic Operating Point calculation shall solve for the following variables:

3.3.1.1 $ESDG_{i,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$;

3.3.1.2 $ES10SDG_{i,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{10S}_{i,b}$;

3.3.1.3 $ES10NDG_{i,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{10N}_{i,b}$;

3.3.1.4 $ES30RDG_{i,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{30R}_{i,b}$;

3.3.1.5 $ESIG_{i,d,k}$, which designates the amount of *dispatchable* imports scheduled at bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$;

3.3.1.6 $ES10NIG_{i,d,k}$ which designates the amount of non-synchronized *ten-minute operating reserve* scheduled at bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$;

3.3.1.7 $ES30RIG_{i,d,k}$ which designates the amount of *thirty-minute operating reserve* scheduled at bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$;

3.3.1.8 $ESDL_{i,b,j}$, which designates the amount of *energy* that a *dispatchable load* scheduled at bus $b \in B^{DL}$ in interval $i \in I$ in association with *offer* lamination $j \in J^{E}_{i,b}$;

3.3.1.9 $ES10SDL_{i,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with *offer* lamination $j \in J^{10S}_{i,b}$;

3.3.1.10 $ES10NDL_{i,b,j}$, 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 interval $i \in I$ in association with *offer* lamination $j \in J^{10N}_{i,b}$;

3.3.1.11 $ES30RDL_{i,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with *offer* lamination $j \in J^{30R}_{i,b}$;

3.3.1.12 $ESXL_{i,d,k}$ which designates the amount of *dispatchable* imports scheduled at bus $d \in DX$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$;

3.3.1.13 $ES10NXL_{i,d,k}$ which designates the amount of non-synchronized *ten-minute operating reserve* scheduled at bus $d \in DX$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$; and

3.3.1.14 $ES30RXL_{i,d,k}$ which designates the amount of *thirty-minute operating reserve* scheduled at bus $d \in DX$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$.

3.3.2 For each of the following *resource* types, the objective function for determining an RT LC EOP will maximize the value of the following expressions:

3.3.2.1 For *dispatchable generation resources*:

$$ObjSDG = \sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \cdot \left(LMP_{i,b}^{1} - PDG_{i,b,k}\right)$$

$$Obj10SDG = \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \cdot \left(L10SP_{i,b}^{1} - P10SDG_{i,b,k}\right)$$

$$Obj10NDG = \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \cdot \left(L10NP_{i,b}^{1} - P10NDG_{i,b,k}\right)$$

$$Obj30RDG = \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \cdot \left(L30RP_{i,b}^{1} - P30RDG_{i,b,k}\right)$$

3.3.2.2 For *dispatchable loads*:

$$ObjSDL_{i} = \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \cdot \left(PDL_{i,b,j} - LMP_{i,b}^{1}\right)$$

$$Obj10SDL_{i} = \sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} \cdot \left(P10SDL_{i,b,j} - L10SP_{i,b}^{1}\right)$$

$$Obj10NDL_{i} = \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} \cdot \left(P10NDL_{i,b,j} - L10NP_{i,b}^{1}\right)$$

$$Obj30RDL_{i} = \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \cdot \left(P30RDL_{i,b,j} - L30RP_{i,b}^{1}\right)$$

3.3.2.3 For import transactions associated with *boundary entity resources*:

$$ObjSIG_i = \sum_{k \in K_{i,d}^{E}} ESIG_{i,d,k} \cdot \left(ExtLMP_{i,d}^{PD} - PIG_{t,d,k}\right)$$

$$Obj10NIG_i = \sum_{k \in K_{i,d}^{10N}} ES10NIG_{i,d,k} \cdot \left(ExtL10NP_{i,d}^{PD} - P10NIG_{t,d,k}\right)$$

$$Obj30RIG_i = \sum_{k \in K_{i,d}^{30R}} ES30RIG_{i,d,k} \cdot \left(ExtL30RP_{i,d}^{PD} - P30RIG_{t,d,k}\right)$$

3.3.2.4 For export transactions associated with *boundary entity resources*:

$$ObjSXL_i = \sum_{j \in J_{i,d}^{E}} ESXL_{i,d,j} \cdot \left(PXL_{t,d,j} - ExtLMP_{i,d}^{PD}\right)$$

$$Obj10NXL_i = \sum_{j \in J_{i,d}^{10N}} ES10NXL_{i,d,j} \cdot \left(P10NXL_{t,d,j} - ExtL10NP_{i,d}^{PD}\right)$$

$$Obj30RXL_i = \sum_{j \in J_{i,d}^{30R}} ES30RXL_{i,d,j} \cdot \left(P30RXL_{t,d,j} - ExtL30RP_{i,d}^{PD}\right)$$

3.4 Constraints

3.4.1 The constraints described in this section 3.4 shall apply to the objective functions used for the RT LC EOP calculation.

Scheduling Variable Bounds

3.4.2 No RT LC EOP shall be negative, nor shall any RT LC EOP exceed the *offer* or *bid* quantity for *energy* or the *offer* quantity for *operating reserve.* For all intervals $i \in I$:

$0 \leq ESDL_{i,b,j} \leq QDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{E}$;

$0 \leq ES10SDL_{i,b,j} \leq Q10SDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{10S}$;

$0 \leq ES10NDL_{i,b,j} \leq Q10NDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{10N}$;

$0 \leq ES30RDL_{i,b,j} \leq Q30RDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{30R}$;

$0 \leq ESDG_{i,b,k} \leq QDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{E}$;

$0 \leq ES10SDG_{i,b,k} \leq Q10SDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{10S}$;

$0 \leq ES10NDG_{i,b,k} \leq Q10NDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{10N}$;

$0 \leq ES30RDG_{i,b,k} \leq Q30RDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{30R}$;

$0 \leq ESDX_{i,d,j} \leq QXL_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{E}$;

$0 \leq ES10NXL_{i,d,j} \leq Q10NXL_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{10N}$;

$0 \leq ES30RXL_{i,d,j} \leq Q30RXL_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{30R}$;

$0 \leq ESIG_{i,d,k} \leq QIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{E}$;

$0 \leq ES10NIG_{i,d,k} \leq Q10NIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{10N}$;

$0 \leq ES30RIG_{i,d,k} \leq Q30RIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{30R}$;

3.4.3 Subject to section 3.4.4, the RT LC EOP for a *non-quick start resource* shall be greater than or equal to its *minimum loading point* for interval i ∈ I and bus $b \in B^{NQS}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq MinQDG_b$$

3.4.4 The RT LC EOP for a *non-quick start resource* shall be equal to its *real-time schedule* when it is scheduled below its *minimum loading point* for interval $i \in I$ and bus $b \in B^{NQS}$:

If $\sum_{k \in K_{i,b}^{E}} ASDG_{i,b,k} < MinQDG_b$ for $b \in B^{NQS}$ then:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} = ASDG_{i,b}$$

Constraints for Regulation Requirements

3.4.5 For a *dispatchable generation resource,* its RT LC EOP for *energy* shall be greater than or equal to any *regulation* constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq REGULATIONMW_{i,b}$$

3.4.6 For a *dispatchable generation resource,* its RT LC EOP for *energy* and each class of *operating reserve* shall not exceed the maximum available capacity the *resource* has less the *regulation* constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \leq AdjMaxDG_{i,b} - REGULATIONMW_{i,b}$$

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \leq AdjMaxDG_{i,b} - REGULATIONMW_{i,b}$$

$$\sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \leq AdjMaxDG_{i,b} - REGULATIONMW_{i,b}$$

$$\sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq AdjMaxDG_{i,b} - REGULATIONMW_{i,b}$$

Constraints for Market Participant Requirements

3.4.7 For a *dispatchable generation resource,* its RT LC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq SEALMW_{i,b}$$

3.4.8 For a *dispatchable load,* its RT LC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{i,b}$constraint that is applied and for each class of *operating reserve*, the RT LC EOP shall be less than or equal to the RT LC EOP for *energy* for that *resource* less any minimum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \geq SEALMW_{i,b}$$

$$\sum_{j\in J_{i,b}^{10S}} ES10SDL_{i,b,j} \le \sum_{j\in J_{i,b}^{E}} ESDL_{i,b,j} - SEALMW_{i,b}$$

$$\sum_{j\in J_{i,b}^{10N}} ES10NDL_{i,b,j} \le \sum_{j\in J_{i,b}^{E}} ESDL_{i,b,j} - SEALMW_{i,b}$$

$$\sum_{j\in J_{i,b}^{30R}} ES30RDL_{i,b,j} \le \sum_{j\in J_{i,b}^{E}} ESDL_{i,b,j} - SEALMW_{i,b}$$

3.4.9 For a *dispatchable generation resource,* its RT LC EOP for *energy* shall be less than or equal to any maximum $SEALMW_{i,b}$constraint applied for all intervals $i \in I$ and buses $b \in B^{DG}$:

$$\sum_{k\in K_{i,b}^{E}} ESDG_{i,b,k} \le SEALMW_{i,b}$$

3.4.10 For a *dispatchable load,* its RT LC EOP for *energy* shall be less than or equal to any maximum $SEALMW_{i,b}$constraint applied for all intervals $i \in I$ and buses $b \in B^{DG}$:

$$\sum_{j\in J_{i,b}^{E}} ESDL_{i,b,j} \le SEALMW_{i,b}$$

3.4.11 For a *dispatchable generation resource,* its RT LC EOP for *energy* shall be equal to any fixed $SEALMW_{i,b}$constraint applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k\in K_{i,b}^{E}} ESDG_{i,b,k} = SEALMW_{i,b}$$

3.4.12 For a *dispatchable load,* its RT LC EOP for *energy* shall be equal to any fixed $SEALMW_{h,b}$constraint that is applied and equal to zero for each class of *operating reserve* for interval i ∈ I and buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} = SEALMW_{i,b}$$

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{i,b,k} = 0$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{i,b,k} = 0$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{i,b,k} = 0$$

3.4.13 For a *dispatchable load,* its RT LC EOP for *energy* shall be greater than or equal to the *bid* quantity for *energy* priced at the *maximum market clearing price*:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \geq QDLFIRM_{i,b}$$

3.4.14 For a *dispatchable load,* its RT LC EOP for *operating reserve* shall be less than or equal its RT LC EOP for *energy* less the *bid* quantity for *energy* priced at the *maximum market clearing price*:

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} - QDLFIRM_{i,b}$$

$$\sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} - QDLFIRM_{i,b}$$

$$\sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} - QDLFIRM_{i,b}$$

Constraints for Operating Reserve Ramping

3.4.15 For a *dispatchable generation resource* with $RLP10S_{h,b} > 0$, the amount of *ten-minute operating reserve* that the *resource* is scheduled to provide shall be less than or equal to its *reserve loading point* for *ten-minute operating reserve* and , the following constraint shall apply for all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP10S_{i,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_{i,b}, \sum_{k \in K_{i,b}^{10S}} Q10SDG_{i,b,k} \right\} \right)$$

3.4.16 For a *dispatchable generation resource* with $RLP30R_{h,b} > 0$, the amount of *thirty-minute operating reserve* that the *resource* is scheduled to provide shall be less than or equal to its *reserve loading point* for *thirty-minute operating reserve* and the following constraint shall apply for all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP30R_{i,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_{i,b}, \sum_{k \in K_{i,b}^{30R}} Q30RDG_{i,b,k} \right\} \right)$$

Constraints for Pseudo-units

3.4.17 For a *pseudo-unit,* its RT LC EOP for *energy* for the *dispatchable* region and duct firing region shall be less than or equal to the respective maximum capabilities for those regions for interval $i \in \mathrm{I}$ and bus $b \in B^{PSU}$:

$$\sum_{k \in K_{i,b}^{DR}} ESDG_{i,b,k} \leq MaxDR_{i,b}$$

$$\sum_{k \in K_{i,b}^{DF}} ESDG_{i,b,k} \leq MaxDF_{i,b}$$

3.4.18 For a *pseudo-unit,* its RT LC EOP for each class of *operating reserve* shall be less than or equal to the sum of the maximum capabilities for its *dispatchable* region and duct firing region for hour $i \in \mathrm{I}$ and bus $b \in B^{PSU}$:

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}$$

$$\sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}$$

$$\sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}$$

3.4.19 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, the following constraint shall apply:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \leq MINQDG_{b} + QDR_{i,k}$$

3.5 Outputs

3.5.1 The RT LC EOP s used for *settlement* for *energy* and *operating reserve* for all *resources* except *pseudo-unit resources* for each interval of the *dispatch hour* shall be the sum of each RT LC EOP variable determined by the objective function in section 3.3 for that *resource*, subject to constraints in section 3.4 applicable for that *resource* determined as follows:

$$DGEnergyEOP_{i,b}^{LC} = \sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \qquad DG10SEOP_{i,b}^{LC} = \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k}$$

$$DG10NEOP_{i,b}^{LC} = \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k}$$

$$DG30REOP_{i,b}{}_{i,b}^{LC} = \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k}$$

$$DLEnergyEOP_{i,b}^{LC} = \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j}$$

$$DL10SEOP_{i,b}{}_{i,b}^{LC} = \sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j}$$

$$DL10NEOP_{i,b}^{LC} = \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j}$$

$$DL30REOP_{i,b}{}_{i,b}^{LC} = \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j}$$

$$DIEnergyEOP_{i,b}^{LC} = \sum_{k \in K_{i,b}^{E}} ESIG_{i,b,k}$$

$$DI10NEOP_{i,b}^{LC} = \sum_{k \in K_{i,b}^{10N}} ES10NIG_{i,b,k}$$

$$DI30REOP_{i,b}{}_{i,b}^{LC} = \sum_{k \in K_{i,b}^{30R}} ES30RIG_{i,b,k}$$

$$DXEnergyEOP_{i,b}^{LC} = \sum_{j \in J_{i,b}^{E}} ESXL_{i,b,j}$$

$$DX10NEOP_{i,b}^{LC} = \sum_{j \in J_{i,b}^{10N}} ES10NXL_{i,b,j}$$

$$DX30REOP_{i,b}^{LC} = \sum_{j \in J_{i,b}^{30R}} ES30RXL_{i,b,j}$$

3.5.2 The RT LC EOPs for *energy* and *operating reserve* for a *pseudo-unit* for each interval of the *dispatch hour,* which will be used for converting the RT LC EOPs to physical *resource* equivalents in accordance with sections 3.5.3 to 3.5.4, shall be determined as follows:

$$PSUMLPEnergyEOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{MLP}} ESDG_{i,b,k}$$

$$PSUDREnergyEOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{DR}} ESDG_{i,b,k}$$

$$PSUDFEnergyEOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{DF}} ESDG_{i,b,k}$$

$$PSU10SEOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k}$$

$$PSU10NEOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k}$$

$$PSU30REOP_{i,k}^{LC} = \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k}$$

Conversion of RT LC EOPs for Pseudo-Units to Physical Resource Equivalents

3.5.3 The RT LC EOP used for *settlement* for *energy* for a combustion turbine and a steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in interval i shall be determined as follows:

$$CTEnergyEOP_{i,k} = PSUMLPEnergyEOP_{i,k}^{LC} \cdot CTShareMLP_{i,k} + PSUDREnergyEOP_{i,k}^{LC} \cdot CTShareDR_{i,k}$$

$$STEnergyEOP_{i,k} = PSUMLPEnergyEOP_{i,k}^{LC} \cdot STShareMLP_{k} + PSUDREnergyEOP_{i,k}^{LC} \cdot STShareDR_{k} + PSUDFEnergyEOP_{i,k}^{LC}$$

3.5.4 The RT LC EOPs used for *settlement* for *operating reserve* for a combustion turbine and a steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in interval i shall be determined as follows and in the following order for each class of *operating reserve*:

$$10SDR_{i,k} = \min\left(QDR_{i,k}, PSU10SEOP_{i,k}^{LC}\right)$$
$$10NDR_{i,k} = \min\left(QDR_{i,k} - 10SDR_{i,k}, PSU10NEOP_{i,k}^{LC}\right)$$
$$30RDR_{i,k} = \min\left(QDR_{i,k} - 10SDR_{i,k} - 10NDR_{i,k}, PSU30REOP_{i,k}^{LC}\right)$$

$$CT10SEOP_{i,k} = 10SDR_{i,k} \cdot CTShareDR_k$$
$$ST10SEOP_{i,k} = 10SDR_{i,k} \cdot STShareDR_k + (PSU10SEOP_{i,k}^{LC} - 10SDR_{i,k})$$

$$CT10NEOP_{i,k} = 10NDR_k \cdot CTShareDR_{i,k}$$
$$ST10NEOP_{i,k} = 10NDR_{i,k} \cdot STShareDR_k + (PSU10NEOP_{i,k}^{LC} - 10NDR_{i,k})$$

$$CT30REOP_{i,k} = 30RDR_k \cdot CTShareDR_{i,k}$$

$$ST30REOP_{i,k} = 30RDR_{i,k} \cdot STShareDR_k + (PSU30REOP_{i,k}^{LC} - 30RDR_{i,k})$$

4. Real-Time Market Lost Opportunity Cost Economic Operating Point

4.1 Purpose

4.1.1 This section describes the process used to determine the lost opportunity cost economic operating point for eligible *resources* in the *real-time market* (RT LOC EOP).

4.2 Sets, Indices and Parameters Used by the Real-Time Market Lost Opportunity Cost Economic Operating Point

Fundamental Sets and Indices

4.2.1 The fundamental inputs used to calculate RT LOC EOP are described in section 3.2.

Market Participant Data Parameters

4.2.2 In addition to the *market participant* data parameters described in section 3.2, the following parameters are also used to calculate the RT LOC EOP.

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

4.2.3.1 $DRRDG_{i,b,w}$ designates the maximum rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies at $b \in B^{DG}$ for interval i while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$ for $w \in \{1, \dots, NumRRDG_{i,b}\}$;

4.2.3.2 $NumRRDG_{i,b}$ designates the number of ramp rates provided in time-step $i \in I$; and

4.2.3.3 $URRDG_{i,b,w}$ designates the maximum rate in MW per minute at which the *resource* can increase the amount of *energy* it supplies at $b \in B^{DG}$ for interval $i \in I$ while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$ for $w \in \{1, \dots, NumRRDG_{i,b}\}$;

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

4.2.4.1 $DRRDL_{i,b,w}$ designates the maximum rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies at $b \in B^{DL}$ for interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$ for $w \in \{1, \dots, NumRRDG_{i,b}\}$;

4.2.4.2 $NumRRDL_{i,b}$ designates the number of ramp rates provided at $b \in B^{DL}$ for interval $i \in I$;

4.2.4.3 $ORRDL_b$ designates the *operating reserve* ramp rate in MW per minute of reductions in load consumption;

4.2.4.4 $RmpRngMaxDG_{i,b,w}$ designates the w^{th} ramp rate break point provided at $b \in B^{DG}$ for interval $i \in I$ where $w \in \{1, \dots, NumRRDG_{i,b}\}$;

4.2.4.5 $RmpRngMaxDL_{i,b,w}$ designates the w^{th} ramp rate break point provided at $b \in B^{DL}$ for interval $i \in I$ where $w \in \{1, \dots, NumRRDG_{i,b}\}$; and

4.2.4.6 $URRDL_{i,b,w}$ designates the maximum rate in MW per minute at which the *resource* can increase the amount of *energy* it supplies at $b \in B^{DL}$ for interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$ for $w \in \{1, \dots, NumRRDL_{i,b}\}$.

IESO Data Parameters

4.2.5 In addition to the *IESO* data parameters described in section 3.2, the following parameters are also used to the calculate the RT LOC EOP.

4.2.5.1 $GridConnected_{i,b}$ designates if the *resource* is connected to the *IESO-controlled grid* at bus b for interval $i \in I$; and

4.2.5.2 $RELIABILITYMW_{i,b}$ designates the MWh constraint placed onto a *resource* at bus b for interval $i \in I$ for *reliability* purposes.

4.3 Objective Functions

4.3.1 The objective functions for the Real-Time Market Lost Opportunity Cost Economic Operating Point calculation shall solve for the following variables:

4.3.1.1 $ESDG_{i,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$;

4.3.1.2 $ES10SDG_{i,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{10S}_{i,b}$;

4.3.1.3 $ES10NDG_{i,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{10N}_{i,b}$;

4.3.1.4 $ES30RDG_{i,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with *offer* lamination $k \in K^{30R}_{i,b}$;

4.3.1.5 $ESIG_{i,d,k}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,d}$;

4.3.1.6 $ES10NIG_{i,d,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K_{i,d}^{E}$;

4.3.1.7 $ES30RIG_{i,d,k}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide at bus $d \in DI$ in interval $i \in I$ in association with *offer* lamination $k \in K_{i,d}^{E}$;

4.3.1.8 $ESDL_{i,b,j}$, which designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$ in interval $i \in I$ in association with *bid* lamination $j \in J_{i,b}^{E}$;

4.3.1.9 $ES10SDL_{i,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

4.3.1.10 $ES10NDL_{i,b,j}$, 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 interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

4.3.1.11 $ES30RDL_{i,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

4.3.1.12 $ESXL_{i,d,k}$ which designates the amount of *energy* a *boundary entity resource* is scheduled to export at *intertie zone* bus $d \in DX$ in interval $i \in I$ in association with *bid* lamination $k \in K_{i,d}^{E}$;

4.3.1.13 $ES10NXL_{i,d,k}$ which designates the amount of non-synchronized *ten-minute operating reserve* that a *boundary entity resource* is scheduled to provide at *intertie zone* bus $d \in DX$ in interval $i \in I$ in association with *offer* lamination $k \in K_{i,d}^{E}$;

4.3.1.14 $ES30RXL_{i,d,k}$ which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide at *intertie zone* bus $d \in DX$ in interval i in association with *offer* lamination $k \in K_{i,d}^{E}$;

4.3.1.15 $ESDGInitSch_{i,b}$ designates the initial schedule for a *dispatchable generation resource* at bus $b \in B^{DG}$; and

4.3.1.16 $ESDLInitSch_{i,b}$ designates the initial schedule for a *dispatchable load* at bus $b \in B^{DL}$.

4.3.2 For each of the following *resource* types, the objective function for determining an RT LOC EOP shall maximize the value of the following expressions:

4.3.2.1 For *dispatchable generation resources*:

$$ObjDG_i = \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \cdot \left(LMP_{i,b}^{1} - PDG_{i,b,k}\right) + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \cdot \left(L10SP_{i,b}^{1} - P10SDG_{i,b,k}\right) + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \cdot \left(L10NP_{i,b}^{1} - P10NDG_{i,b,k}\right) + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \cdot \left(L30RP_{i,b}^{1} - P30RDG_{i,b,k}\right) \right)$$

4.3.2.2 For *dispatchable loads*:

$$ObjDL_i = \sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \cdot \left(PDL_{i,b,j} - LMP_{i,b}^{1}\right) + \sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} \cdot \left(P10SDL_{i,b,j} - L10SP_{i,b}^{1} - P10SDL_{i,b,j}\right) + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} \cdot \left(L10NP_{i,b}^{1} - P10NDL_{i,b,j} - L10NP_{i,b}^{1}\right) + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \cdot \left(L30RP_{i,b}^{1} - P30RDL_{i,b,j} - L30RP_{i,b}^{1}\right) \right)$$

4.3.2.3 For an import transaction at an *intertie metering point* 'i' associated with a *boundary entity resource*:

$$ObjDI_i = \sum_{d \in DI} \left(\sum_{k \in K_{i,d}^{E}} EDIG_{i,d,k} \cdot \left(ExtLMP_{i,d}^{PD} - PIG_{t,d,k} \right) + \sum_{k \in K_{i,d}^{10N}} ES10NIG_{i,d,k} \cdot \left(ExtL10NP_{i,d}^{PD} - P10NIG_{t,d,k} \right) + \sum_{k \in K_{i,d}^{30R}} ES30RIG_{i,d,k} \cdot \left(ExtL30RP_{i,d}^{PD} - P30RIG_{t,d,k} \right) \right)$$

4.3.2.4 For an export transaction at an *intertie metering point* 'i' associated with a *boundary entity resource*:

$$ObjDX_i = \sum_{d \in DX} \left(\sum_{j \in J_{i,d}^{E}} ESXL_{i,d,j} \cdot \left(PXL_{t,d,j} - ExtLMP_{i,d}^{PD} \right) + \sum_{j \in J_{i,d}^{10N}} ES10NXL_{i,d,j} \cdot \left(ExtL10NP_{i,d}^{PD} - P10NXL_{t,d,j} \right) + \sum_{j \in J_{i,d}^{30R}} ES30RXL_{i,d,j} \cdot \left(ExtL30RP_{i,d}^{PD} - P30RXL_{t,d,j} \right) \right)$$

4.4 Constraints

4.4.1 The constraints described in this section 4.4 shall apply to the objective functions used for the RT LOC EOP calculation.

Scheduling Variable Bounds

4.4.2 No RT LOC EOP shall be negative, nor shall any RT LOC EOP exceed the *offer* or *bid* quantity for *energy* or the *offer* quantity for *operating reserve*. Therefore, for all intervals $i \in I$:

$0 \leq ESDL_{i,b,j} \leq QDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{E}$;

$0 \leq ES10SDL_{i,b,j} \leq Q10SDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{10S}$;

$0 \leq ES10NDL_{i,b,j} \leq Q10NDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{10N}$;

$0 \leq ES30RDL_{i,b,j} \leq Q30RDL_{i,b,j}$ for all $b \in B^{DL}, j \in J_{i,b}^{30R}$;

$0 \leq ESDG_{i,b,k} \leq QDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{E}$;

$0 \leq ES10SDG_{i,b,k} \leq Q10SDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{10S}$;

$0 \leq ES10NDG_{i,b,k} \leq Q10NDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{10N}$;

$0 \leq ES30RDG_{i,b,k} \leq Q30RDG_{i,b,k}$ for all $b \in B^{DG}, k \in K_{i,b}^{30R}$;

$0 \leq ESDX_{i,d,j} \leq QXl_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{E}$;

$0 \leq ES10NXL_{i,d,j} \leq Q10NXL_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{10N}$;

$0 \leq ES30RXL_{i,d,j} \leq Q30RXL_{t,d,j}$ for all $d \in DX, j \in J_{t,d}^{30R}$;

$0 \leq ESDI_{i,d,k} \leq QIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{E}$;

$0 \leq ES10NIG_{i,d,k} \leq Q10NIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{10N}$;

$0 \leq ES30RIG_{i,d,k} \leq Q30RIG_{t,d,k}$ for all $d \in DI, k \in K_{t,d}^{30R}$;

4.4.3 For a *dispatchable generation resource* that is not connected to the *IESO-controlled grid* and is not eligible for *dispatch*, its RT LOC EOP shall be set to zero for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} = 0$$

4.4.4 For a *dispatchable load* that is not connected to the *IESO-controlled grid* and is not eligible for *dispatch*, its RT LOC EOP shall be set to zero for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} + \sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} = 0$$

4.4.5 For a *dispatchable load*, the sum of the RT LOC EOP for all classes of *operating reserve* for the *resource* shall not exceed its RT LOC EOP for *energy* for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j}$$

4.4.6 For a *dispatchable generation resource,* its RT LOC EOP shall not exceed the maximum available capacity for the *resource* for interval $i \in I$ and bus $b \in B^{DG}$:

$$AdjMaxDG_{i,b} = \begin{cases} min\left(\sum_{k \in K_{i,b}^{E}} QDG_{i,b,k}, Derate_{i,b}, FG_{i,b}\right) & if\ b \in B^{VG} \\ min\left(\sum_{k \in K_{i,b}^{E}} QDG_{i,b,k}, Derate_{i,b}\right) & otherwise \end{cases}$$

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq AdjMaxDG_{i,b}$$

4.4.7 Subject to section 4.4.8, the RT LOC EOP for a *non-quick start resource* shall be greater than or equal to its *minimum loading point* f for interval i ∈ I and bus $b \in B^{NQS}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq MinQDG_{b}$$

4.4.8 The RT LOC EOP for a *non-quick start resource* shall be equal to its *real-time schedule* when it is scheduled below its *minimum loading point* for interval i ∈ I and bus $b \in B^{NQS}$:

If $\sum_{k \in K_{i,b}^{E}} ASDG_{i,b,k} < MinQDG_{b}$ for $b \in B^{NQS}$, then:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} = ASDG_{i,b}$$

Constraints for Reliability Requirements

4.4.9 For a *dispatchable generation resource,* its RT LOC EOP shall be greater than or equal to any minimum *reliability* constraint that is applied for interval i ∈ I and bus $b \in B^{DG}$

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq RELIABILITYMW_{i,b}$$

4.4.10 For a *dispatchable load* its RT LOC EOP shall be greater than or equal to any minimum *reliability* constraint that is applied for interval $i \in I$ and bus $b \in B^{DL}$

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,k} \geq RELIABILITYMW_{i,b}$$

4.4.11 For a *dispatchable generation resource* its RT LOC EOP for *energy* shall be greater than or equal to any *regulation* constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq REGULATIONMW_{i,b}$$

4.4.12 For a *dispatchable generation resource,* the sum of RT LOC EOP for *energy* and all classes of *operating reserve* shall be less than or equal to its maximum available capacity less the *regulation* constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq AdjMaxDG_{i,b} - REGULATIONMW_{i,b}$$

Constraints for Market Participant Requirements

4.4.13 For a *dispatchable generation resource,* its RT LOC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq SEALMW_{i,b}$$

4.4.14 For a *dispatchable load,* its RT LOC EOP for *energy* shall be greater than or equal to any minimum $SEALMW_{i,b}$ constraint that is applied and the sum of RT LOC EOP for all classes of *operating reserve* shall be less than or equal to the RT LOC EOP for *energy* for that *resource* less the minimum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \geq SEALMW_{i,b}$$

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} - SEALMW_{i,b}$$

4.4.15 For a *dispatchable generation resource,* the sum of its RT LOC EOPs for *energy* shall be less than or equal to any maximum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \leq SEALMW_{i,b}$$

4.4.16 For a *dispatchable load,* its RT LOC EOP for *energy* shall be less than or equal to any maximum $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \leq SEALMW_{i,b}$$

4.4.17 For a *dispatchable generation resource,* its RT LOC EOP for *energy* shall be equal to any fixed $SEALMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} = SEALMW_{i,b}$$

4.4.18 For a *dispatchable load,* its RT LOC EOP for *energy* shall be equal to any fixed $SEALMW_{i,b}$constraint that is applied and equal to zero for each class of *operating reserve* for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} = SEALMW_{i,b}$$

$$\sum_{j \in J_{h,b}^{10S}} ES10SDL_{i,b,k} = 0$$

$$\sum_{j \in J_{h,b}^{10N}} ES10NDL_{i,b,k} = 0$$

$$\sum_{j \in J_{h,b}^{30R}} ES30RDL_{i,b,k} = 0$$

4.4.19 For a *dispatchable non-quick start resource* that is not being modelled as a *pseudo-unit*, its RT LOC EOP for *energy* shall be greater than or equal to the $COMCYCMW_{i,b}$ constraint that is applied for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \geq COMCYCMW_{i,b}$$

4.4.20 For a *dispatchable load,* its RT LOC EOP for *energy* shall be greater than or equal to the *bid* quantity for *energy* priced at the *maximum market clearing price* for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \geq QDLFIRM_{i,b}$$

4.4.21 For a *dispatchable load,* the sum of RT LOC EOPs for all classes of *operating reserve* shall not exceed the RT LOC EOP for *energy* less the *bid* quantity for *energy* priced at the *maximum market clearing price* for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} - QDLFIRM_{i,b}$$

Constraints for Operating Reserve Ramping

4.4.22 For a *dispatchable resource*, the upper bound of the RT LOC EOP for all classes of *operating reserve* shall be less than or equal to it *operating reserve* ramp rates as follows:

4.4.22.1 For a *dispatchable generation resource,* for interval $i \in I$ and bus $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq 30 \cdot ORRDG_b$$

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \leq 10 \cdot ORRDG_b$$

4.4.22.2 For a *dispatchable load,* for interval $i \in I$ and bus $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j} \leq 30 \cdot ORRDL_b$$

$$\sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j} \leq 10 \cdot ORRDL_b$$

4.4.23 For a *dispatchable generation resource* with $RLP10S_{i,b} > 0$, the amount of *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be less than or equal to its *reserve loading point* for *ten-minute operating reserve*:

$$\sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP10S_{i,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_b, \sum_{k \in K_{i,b}^{10S}} Q10SDG_{i,b,k} \right\} \right)$$

4.4.24 For all *dispatchable generation resources* with $RLP30R_{i,b} > 0$, the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be less than or equal to its *reserve loading point* for *thirty-minute operating reserve*:

$$\sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP30R_{i,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_b, \sum_{k \in K_{i,b}^{30R}} Q30RDG_{i,b,k} \right\} \right)$$

Constraints for Energy Ramping

4.4.25 With the exception of the first *interval* of each *dispatch day*, the RT LOC EOP shall use its RT LOC EOP for the prior interval as its initial starting point as follows:

4.4.25.1 For a *dispatchable generation resource,* its RT LOC EOP for *energy* cannot vary by more than five minutes of the *resource's energy* ramping capability for interval $i \in I$ and bus $b \in B^{DG}$:

$$ESDGInitSch_{\mathrm{i},b} - 5 \cdot DRRDG_{i,b,w} \leq \sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} \leq ESDGInitSch_{i,b} + 5 \cdot URRDG_{i,b,w}$$

4.4.25.2 For a *dispatchable load,* its RT LOC EOP for *energy* cannot vary by more than five minutes of the *resource's* energy ramping capability for interval $i \in I$ and bus $b \in B^{DL}$:

$$ESDLInitSch_{i,b} - 5 \cdot DRRDL_{i,b,w} \leq \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j} \leq ESDLInitSch_{i,b} + 5 \cdot URRDL_{i,b,w}$$

Constraints for Pseudo-Units

4.4.26 For a *pseudo-unit,* its RT LOC EOP for *energy* for the *dispatchable* region and duct firing region shall be less than or equal to the respective maximum capabilities for those regions for interval $i \in \mathrm{I}$ and bus $b \in B^{PSU}$:

$$\sum_{k \in K_{i,b}^{DR}} ESDG_{i,b,k} \leq MaxDR_{i,b}$$

$$\sum_{k \in K_{i,b}^{DF}} ESDG_{i,b,k} \leq MaxDF_{i,b}$$

4.4.27 For a *pseudo-unit,* the sum of its RT LOC EOP for *energy* and the RT LOC EOP s for all classes of *operating reserve* shall be less than or equal to the sum of the maximum capabilities for its *dispatchable* region and duct firing region for interval $i \in \mathrm{I}$ and bus $b \in B^{PSU}$

$$\sum_{k \in K_{i,b}^{DR}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{DF}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}$$

4.4.28 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* in from its duct firing region, the following constraint shall apply:

$$\sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k} \leq MINQDG_b + QDR_{i,k}$$

4.5 Outputs

4.5.1 The RT LOC EOP s used for *settlement* for *energy* and *operating reserve* for all *resources* except *pseudo-units* for each hour of the *dispatch day* shall be the sum of each RT LOC EOP variable determined by the objective function in section 4.3 for that *resource*, subject to constraints in section 4.4 applicable for that *resource* determined as follows:

$$DGEnergyEOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{E}} ESDG_{i,b,k}$$

$$DG10SEOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k}$$

$$DG10NEOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k}$$

$$DG30REOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k}$$

$$DLEnergyEOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{E}} ESDL_{i,b,j}$$

$$DL10SEOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{10S}} ES10SDL_{i,b,j}$$

$$DL10NEOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{10N}} ES10NDL_{i,b,j}$$

$$DL30REOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{30R}} ES30RDL_{i,b,j}$$

$$DIEnergyEOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{E}} ESDI_{i,b,k}$$

$$DI10NEOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{10N}} ES10NDI_{i,b,k}$$

$$DI30REOP_{i,b}^{LOC} = \sum_{k \in K_{i,b}^{30R}} ES30RDI_{i,b,k}$$

$$DXEnergyEOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{E}} ESDX_{i,b,j}$$

$$DX10NEOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{10N}} ES10NDX_{i,b,j}$$

$$DX30REOP_{i,b}^{LOC} = \sum_{j \in J_{i,b}^{30R}} ES30RDX_{i,b,j}$$

4.5.2 The RT LOC EOPs for *energy* and *operating reserve* for a *pseudo-unit* for each interval of the *dispatch hour,* which will be used for converting the RT LOC EOPs to physical *resource* equivalents in accordance with sections 4.5.3 to 4.5.4, shall be determined as follows:

$$PSUMLPEnergyEOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{MLP}} ESDG_{i,b,k}$$

$$PSUDREnergyEOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{DR}} ESDG_{i,b,k}$$

$$PSUDFEnergyEOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{DF}} ESDG_{i,b,k}$$

$$PSU10SEOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{10S}} ES10SDG_{i,b,k}$$

$$PSU10NEOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{10N}} ES10NDG_{i,b,k}$$

$$PSU30REOP_{i,k}^{LOC} = \sum_{k \in K_{i,b}^{30R}} ES30RDG_{i,b,k}$$

Conversion of RT LOC EOPs for Pseudo-Units to Physical Resource Equivalents

4.5.3 The RT LOC EOP *energy* and *operating reserve* for a combustion turbine and steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in interval i shall be determined as follows:

$$CTEnergyEOP_{i,k} = PSUMLPEnergyEOP_{i,k}^{LOC} \cdot CTShareMLP_k + PSUDREnergyEOP_{i,k}^{LOC} \cdot CTShareDR_k$$

$$STEnergyEOP_{i,k} = PSUMLPEnergyEOP_{i,k}^{LOC} \cdot STShareMLP_k + PSUDREnergyEOP_{i,k}^{LOC} \cdot STShareDR_k + PSUDFEnergyEOP_{i,k}^{LOC}$$

4.5.4 The RT LOC EOPs used for *settlement* for *operating reserve* for a combustion turbine and a steam turbine that is associated with *pseudo-unit* $k \in \{1, \dots, K\}$ in interval i shall be determined as follows and in the following order for each class of *operating reserve*:

$$RoomDR_{i,k} = QDR_{i,k} - PSUDREnergyEOP_{i,k}^{LOC}$$

$$10SDR_{i,k} = \min\left(RoomDR_{i,k}, PSU10SEOP_{i,k}^{LOC}\right)$$

$$10NDR_{i,k} = \min\left(RoomDR_{i,k} - 10SDR_{i,k}, PSU10NEOP_{i,k}^{LOC}\right)$$

$$30RDR_{i,k} = \min\left(RoomDR_{i,k} - 10SDR_{i,k} - 10NDR_{i,k}, PSU30REOP_{i,k}^{LOC}\right)$$

$$CT10SEOP_{i,k} = 10SDR_{i,k} \cdot CTShareDR_k$$
$$ST10SEOP_{i,k} = 10SDR_{i,k} \cdot STShareDR_k + (PSU10NEOP_{i,k}^{LOC} - 10SDR_{i,k})$$

$$CT10NEOP_{i,k} = 10NDR_k \cdot CTShareDR_{i,k}$$
$$ST10NEOP_{i,k} = 10NDR_{i,k} \cdot STShareDR_k + (PSU10NEOP_{i,k}^{LOC} - 10NDR_{i,k})$$

$$CT30REOP_{i,k} = 30RDR_k \cdot CTShareDR_{i,k}$$
$$ST30REOP_{i,k} = 30RDR_{i,k} \cdot STShareDR_k + (PSU30REOP_{i,k}^{LOC} - 30RDR_{i,k})$$