Market Rules

Chapter 7 System Operations and Physical Markets - Appendices

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Appendix 7.1 – Energy Offer, Schedule or Forecast Information

1.1 Within the IESO Control Area

1.1.1 Unique plant identifier (by *generation unit* or *generation units* that have been aggregated with the approval of the *IESO*).

1.1.2 Contact information.

1.1.3 Hour(s) for which *offer*, schedule or forecast applies.

1.1.4 [Intentionally left blank – section deleted]

1.1.5 For a *dispatchable generation facility*, two to twenty *price-quantity pairs* for each *dispatch hour*, the final of which represents the maximum quantity of the *offer*. If the *generator* has specified *forbidden regions*, the submitted *offer price-quantity pairs* must include a quantity equal to each of the lower and upper limits of each *forbidden region*.

1.1.6 For a *dispatchable generation facility*, one to five sets of ramp quantity and ramp up/ramp down values for each *dispatch hour* applicable to the entire range of generator output contained in the *offer*.

1.1.7 Daily *energy* limit (if applicable).

1.1.8 [Intentionally left blank – section deleted]

1.1.9 [Intentionally left blank – section deleted]

1.1.10 Is this a standing *offer*, schedule or forecast? Yes/No. If Yes, Date To: ________ For which day(s) of the week? ____________________

1.2 Offers Outside the IESO Control Area

1.2.1 Unique *boundary entity* identifier (by *boundary entity* resource as created by the *IESO*).

1.2.2 Contact information.

1.2.3 Hour(s) for which *offer* applies.

1.2.4 [Intentionally left blank]

1.2.5 Two to twenty *price-quantity pairs* for each *dispatch hour*, the final of which represents the maximum quantity of the *offer*.

1.2.6 Daily *energy* limit (if applicable).

1.2.7 [Intentionally left blank]

1.2.8 Is this a standing *offer*? – Yes/No. If Yes, Date To: _____ For which day(s) of the week? __________

1.2.9 Source *control area* (determined by selecting appropriate *boundary entity* resource).

1.2.10 [Intentionally left blank]

1.2.10A *NERC* transaction tag identification.

1.2.11 *NERC* transaction tags shall be submitted within the times outlined in the *IESO* interchange tagging procedures and in accordance with the following:

1.2.11.1 all resources shall be designated as firm for the Ontario flowgates and the Ontario portion of the *intertie* flowgates;

1.2.11.2 each *registered market participant* shall submit its transaction tag to the *IESO* through the electronic information system sanctioned by the relevant *standards authority* or, when not available, by such alternative means as may be specified by the *IESO* consistent with the policies of the relevant *standards authority*; and

1.2.11.3 interchange scheduling defaults specified by the relevant *standards authority* shall be used unless otherwise approved by the *IESO*. Transactions shall be one hour in duration, in accordance with agreements between *control areas* along the path. Transactions shall ramp in/out over the hour and shall respect a ten-minute ramp period.

1.3 [Intentionally left blank – section deleted]

1.3.1 [Intentionally left blank – section deleted]

1.3.2 [Intentionally left blank – section deleted]

1.3.3 [Intentionally left blank – section deleted]

1.3.4 [Intentionally left blank – section deleted]

Appendix 7.2 – Energy Bid Information

1.1 Within the IESO Control Area

1.1.1 Unique load identifier.

1.1.2 Contact information.

1.1.3 Hours for which *bid* applies.

1.1.4 [Intentionally left blank]

1.1.5 Two to twenty *price-quantity pairs* for each *dispatch hour*, the final of which represents the maximum quantity of the *bid*.

1.1.6 One to five ramp sets of ramp quantity and ramp up/ramp down values for each *dispatch hour* applicable to the entire range of load contained in the *bid*.

1.1.7 [Intentionally left blank]

1.1.8 [Intentionally left blank]

1.1.9 Is this a standing *bid*? Yes/No. If Yes, Date To:_________ For which day(s) of the week? __________________

1.2 Bids Outside the IESO Control Area

1.2.1 Unique *boundary entity* identifier (by *boundary entity* resource as created by the *IESO*).

1.2.2 Contact information.

1.2.3 Hour(s) for which *bid* applies.

1.2.4 [Intentionally left blank]

1.2.5 Two to twenty *price-quantity pairs* for each *dispatch hour*, the final of which represents the maximum quantity of the *bid*.

1.2.6 [Intentionally left blank]

1.2.7 [Intentionally left blank]

1.2.8 Is this a standing *bid*? – Yes/No. If Yes, Date To: ________ For which day(s) of the week? ______

1.2.9 Sink *control area* (determined by selecting appropriate *boundary entity* resource).

1.2.10 [Intentionally left blank]

1.2.10A *NERC* transaction tag identification.

1.2.11 *NERC* transaction tags shall be submitted within the times outlined in the *IESO* interchange tagging procedures and in accordance with the following:

1.2.11.1 all resources shall be designated as firm for the Ontario flowgates and the Ontario portion of the *intertie* flowgates;

1.2.11.2 each *registered market participant* shall submit its transaction tag to the *IESO* through the electronic information system sanctioned by the relevant *standards authority* or, when not available, by such alternative means as may be specified by the *IESO* consistent with the policies of the relevant *standards authority*; and

1.2.11.3 interchange scheduling defaults specified by the relevant *standards authority* shall be used unless otherwise approved by the *IESO*. Transactions shall be one hour in duration, in accordance with agreements between *control areas* along the path. Transactions shall ramp in/out over the hour and shall respect a ten-minute ramp period.

Appendix 7.3 – Operating Reserve Offer Information

1.1 Generators Within the IESO Control Area

1.1.1 Unique plant identifier (by *generation unit* or *IESO*-approved aggregated *generation units*).

1.1.2 Contact information.

1.1.3 Hour(s) for which *offer* applies.

1.1.4 Minimum MW level of *generator* output at which the *generation unit* can offer its maximum level of *ten-minute operating reserve* that is synchronized with the *IESO-controlled grid*.

1.1.5 Minimum MW level of generator output at which the *generation unit* can offer its maximum level of *thirty-minute operating reserve*.

1.1.6 Two to five *price-quantity pairs* for each *dispatch hour* for each category of *operating reserve* being offered, the final of which represents the maximum quantity of the *offer*.

1.1.7 One ramping rate applicable for all categories of *operating reserve* being offered.

1.1.8 [Intentionally left blank]

1.1.9 [Intentionally left blank]

1.1.10 [Intentionally left blank]

1.1.11 Is this a standing *offer*? Yes/No. If Yes, Date To: _________ For which day(s) of the week? _________

1.2 Offers Outside the IESO Control Area

1.2.1 Unique *boundary entity* identifier (by *boundary entity* resource as created by the *IESO*).

1.2.2 Contact information.

1.2.3 Hour(s) for which *offer* applies.

1.2.4 Two to five *price-quantity pairs* for each *dispatch hour* for each category of *operating reserve* being offered, the final of which represents the maximum quantity of the *offer*.

1.2.5 [Intentionally left blank]

1.2.6 Is this a standing *offer*? – Yes/No. If Yes, Date To: _____ For which day(s) of the week?______

1.2.7 Source *control area* (determined by selecting appropriate *boundary entity* resource).

1.2.7A *NERC* transaction tag identification.

1.2.8 *NERC* transaction tags shall be submitted within the times outlined in the *IESO* interchange tagging procedures and in accordance with the following:

1.2.8.1 all resources shall be designated as firm for the Ontario flowgates and the Ontario portion of the *intertie* flowgates; and

1.2.8.2 each *registered market participant* shall submit its transaction tag to the *IESO* through the electronic information system sanctioned by the relevant *standards authority* or, when not available, by such alternative means as may be specified by the *IESO* consistent with the policies of the relevant *standards authority*.

1.3 Load Within the IESO Control Area

1.3.1 Unique load identifier.

1.3.2 Contact information.

1.3.3 Hour(s) for which *offer* applies.

1.3.4 [Intentionally left blank]

1.3.5 Two to five *price-quantity pairs* for each *dispatch hour* for each category of *operating reserve* being offered, the final of which represents the maximum quantity of the *offer*.

1.3.6 One ramping rate applicable for all categories of *operating reserve* being offered.

1.3.7 [Intentionally left blank]

1.3.8 [Intentionally left blank]

1.3.9 Is this a standing *offer*? Yes/No. If Yes, Date To: _______ For which day(s) of the week? __________

1.4 Loads Outside the IESO Control Area

1.4.1 Unique *boundary entity* identifier (by *boundary entity* resource as created by the *IESO*).

1.4.2 Contact information.

1.4.3 Hour(s) for which *offer* applies.

1.4.4 Two to five *price-quantity pairs* for each *dispatch hour* for each category of *operating reserve* being offered, the final of which represents the maximum quantity of the *offer*.

1.4.5 [Intentionally left blank]

1.4.6 Is this a standing *offer* – Yes/No. If Yes, Date To: _________ For which day(s) of the week? _____

1.4.7 Sink *control area* (determined by selecting appropriate *boundary entity* resource).

1.4.7A *NERC* transaction tag identification.

1.4.8 *NERC* transaction tags shall be submitted within the times outlined in the *IESO* interchange tagging procedures and in accordance with the following:

1.4.8.1 all resources shall be designated as firm for the Ontario flowgates and the Ontario portion of the *intertie* flowgates; and

1.4.8.2 each *registered market participant* shall submit its transaction tag to the *IESO* through the electronic information system sanctioned by the relevant *standards authority* or, when not available, by such alternative means as may be specified by the *IESO* consistent with the policies of the relevant *standards authority*.

Appendix 7.4 – Transmission Information Required for Scheduling and Dispatching

1.1 Transmission Information Required for Scheduling and Dispatching

1.1.1 Full *connection-related reliability information* and transmission system data is required to be provided and updated to the *IESO* in accordance with Section 2.2.5 of Chapter 7 and Appendix 4.16 of Chapter 4.

1.1.2 Advance outage information is required to be provided to the *IESO* in terms of Chapter 5.

1.1.3 The following information is required to be advised to the *IESO* for scheduling and *dispatch* purposes:

1.1.3.1 any change to the maximum thermal rating of any transmission branch as advised by the *IESO* to be included in the scheduling *dispatch* and pricing algorithm; and

1.1.3.2 any change to the proposed *outage* plan as advised to and approved by the *IESO*.

~~Appendix 7.5 – The Market Clearing and Pricing Process~~

Note: The existing Appendix 7.5- The Market Clearing and Pricing Process has been deleted in its entirety and replaced with the new Appendix 7.5- The Day-Ahead Market Calculation Process

~~Appendix 7.5A – The DACP Calculation Engine Process~~

Note: The existing Appendix 7.5A- The DACP Calculation Engine Process has been deleted in its entirety and replaced with the new Appendix 7.5A- The Pre-Dispatch Calculation Engine Process

~~Appendix 7.6 – Local Market Power~~

Note: The existing Appendix 7.6- Local Market Power has been deleted in its entirety and replaced with the new Appendix 7.6- The Real-Time Calculation Engine Process

Appendix 7.5 – The Day-Ahead Market Calculation Engine Process

1.1 Purpose

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

2 Day-Ahead Market Calculation Engine

2.1 Passes of the Day-Ahead Market Calculation Engine

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

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

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

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

3 Information Used by the Day-Ahead Market Calculation Engine

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

4 Sets, Indices and Parameters Used in the Day-Ahead Market Calculation Engine

4.1 Fundamental Sets and Indices

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

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

4.1.3 $B^{PRL} \subseteq B$ designates the set of buses identifying *price responsive loads*;

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

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

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

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

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

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

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

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

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

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

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

4.1.15 $B_{up}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all upstream *dispatchable* hydroelectric *generation resources* with a registered *forebay* that are linked via *time lag* and *MWh ratio dispatch data* with downstream *dispatchable* hydroelectric *generation resources* with a registered *forebay*;

4.1.16 $B_{dn}^{HE} \subseteq \wp(B^{HE})$ designates the set of buses identifying all downstream *dispatchable* hydroelectric *generation resources* with a registered *forebay* that are linked via *time lag* and *MWh ratio dispatch data* with upstream *dispatchable* hydroelectric *generation resources* with a registered *forebay*;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.1.49 $K'^{LTMLP}_{h,b}$ designates the set of *reference level value* laminations for *energy* quantities up to the *minimum loading point reference level* for a *non-quick start resource* at bus $b \in B^{NQS}$ in hour $h \in \{1,..,24\}$;

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

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

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

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

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

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

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

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

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

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

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

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

4.1.62 BCA designates the set of broad constrained areas;

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

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

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

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

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

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

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

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

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

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

4.2 Market Participant Data Parameters

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

4.2.1.1 $QNDG_{h,b,k}$ designates the maximum incremental quantity of *energy* that may be scheduled in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^E_{h,b}$; and

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

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

4.2.2.1 $MinQDG_b$ designates the *minimum loading point*;

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

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

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

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

4.2.2.6 $Q10NDG_{h,b,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K_{h,b}^{10N}$;

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

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

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

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

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

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

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

4.2.2.14 $DRRDG_{h,b,w}$ for $w \in \{1,..,NumRRDG_{i,b}\}$ designates the ramp rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies in hour $h \in \{1,..,24\}$ while operating in the range between $RmpRngMaxDG_{h,b,w-1}$ and $RmpRngMaxDG_{h,b,w}$, where $RmpRngMaxDG_{h,b,0}$ shall be equal to zero;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2.7.2 $Lag_{b_1,b_2} \in \{0, . . , 23\}$ designates the *time lag* in hours between upstream *dispatchable* hydroelectric *generation resources* $b_1 \in B^{HE}_{up}$ and downstream *dispatchable* hydroelectric *generation resources* $b_2 \in B^{HE}_{dn}$ for $(b_1,b_2) \in LNK$; and

4.2.7.3 $MWhRatio_{b_1,b_2}$ designates the MWh ratio between upstream *dispatchable* hydroelectric *generation resources* $b_1 \in B^{HE}_{up}$ and downstream *dispatchable* hydroelectric *generation resources* $b_2 \in B^{HE}_{dn}$ for $(b_1,b_2) \in LNK$.

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

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

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

4.2.8.3 $RampCT_{b,w}$ designates the quantity of *energy* injected w hours before the *pseudo-unit* reaches its *minimum loading point* that is attributed to the combustion turbine for $w \in \{1 , . . , RampHrs_b\}$; and

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

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

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

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

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

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

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

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

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

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

4.2.9.9 $ORRDL_b$ designates the *operating reserve* ramp rate in MW per minute for reductions in load consumption;

4.2.9.10 $NumRRDL_{h,b}$ designates the number of ramp rates provided in hour $h \in \{1,..,24\}$;

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

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

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

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

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

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

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

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

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

4.2.11 With respect to a *price responsive load* identified by bus $b \in B^{PRL}$:

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

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

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

4.2.12 With respect to a *virtual transaction:*

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

4.2.12.2 $PVB_{h,v,j}$ designates the price for the maximum incremental quantity of *energy* in hour $h \in \{1,..,24\}$ from a *virtual zonal resource* $v \in VB$ in association with *bid* lamination $j \in J^E_{h,v}$;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2.15 With respect to a wheeling through transaction:

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

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

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

4.3.2 Variable Generation Tie-Breaking

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

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

4.3.3 Operating Reserve Requirements

4.3.8.1 $TOT10S_h$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.8.2 $TOT10R_h$ designates the total *ten-minute operating reserve* requirement;

4.3.8.3 $TOT30R_h$ designates the *thirty-minute operating reserve* requirement;

4.3.8.4 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.8.5 $REGMin10R_{h,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$;

4.3.8.86 $REGMin30R_{h,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$;

4.3.8.7 $REGMax10R_{h,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$; and

4.3.8.8 $REGMax30R_{h,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in hour $h \in \{1, . . ,24\}$.

4.3.4 Intertie Limits

4.3.4.1 $EnCoeff_{a,z}$ designates the coefficient for calculating the contribution of scheduled *energy* flows and *operating reserve* inflows for *intertie zone* $a \in A$, which is part of *intertie* limit constraint $z \in Z_{Sch}$. A coefficient of $+1$ shall describe flows into Ontario while a coefficient of -1 shall describe flows out of Ontario;

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

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

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

4.3.5 Resource Minimum and Maximum Constraints

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

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

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

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

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

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

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

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

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

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

4.3.6 Constraint Violation Penalties

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

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

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

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

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

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

4.3.6.7 $(P10RViolSch_{h,i}, Q10RViolSch_{h,i})$ for $i \in \{1, . . , N_{10RViol_h}\}$ designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

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

4.3.6.9 $(P30RViolSch_{h,i}, Q30RViolSch_{h,i})$ for $i \in \{1, . . ,N_{30RViol_h}\}$ designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.10 $(P30RViolPrc_{h,i}, Q30RViolPrc_{h,i})$ for $i \in \{1, . . ,N_{30RViol_h}\}$ designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.11 $(PREG10RViolSch_{h,i}, QREG10RViolSch_{h,i})$ for $i \in \{1,..,N_{REG10RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.12 $(PREG10RViolPrc_{h,i}, QREG10RViolPrc_{h,i})$ for $i \in \{1,..,N_{REG10RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.13 $(PREG30RViolSch_{h,i}, QREG30RViolSch_{h,i})$ for $i \in \{1,..,N_{REG30RViol_h}\}$ designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.14 $(PREG30RViolPrc_{h,i}, QREG30RViolPrc_{h,i})$ for $i \in \{1,..,N_{REG30RViol_h}\}$ designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.15 $(PXREG10RViolSch_{h,i}, QXREG10RViolSch_{h,i})$ for $i \in \{1,..,N_{XREG10RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.16 $(PXREG10RViolPrc_{h,i}, QXREG10RViolPrc_{h,i})$ for $i \in \{1,..,N_{XREG10RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

4.3.6.17 $(PXREG30RViolSch_{h,i}, QXREG30RViolSch_{h,i})$ for $i \in \{1,..,N_{XREG30RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

4.3.6.18 $(PXREG30RViolPrc_{h,i}, QXREG30RViolPrc_{h,i})$ for $i \in \{1,..,N_{XREG30RViol_h}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the As-Offered Pricing algorithm in section 9, Reference Level Pricing algorithm in section 13, Mitigated Pricing algorithm in section 16, and DAM Pricing algorithm in section 21;

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

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

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

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

4.3.6.23 $(PPreXTLViolSch_{z,h,i}, QPreXTLViolSch_{z,h,i})$ for $i \in \{1,..,N_{PreXTLViol_{z,h}}\}$ designate the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used by the As-Offered Scheduling algorithm in section 8, Reference Level Scheduling algorithm in section 12, Mitigated Scheduling algorithm in section 15, Reliability Scheduling algorithm in section 18, and DAM Scheduling algorithm in section 20;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3.7 Price Bounds

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

4.3.7.2 *EngyPrcFlr* designates and is equal to the *settlement floor price*;

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

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

4.3.8 Ex-ante Market Power Mitigation

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3.8.14 $CTEnThresh1^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 50%;

4.3.8.15 $CTEnThresh2^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.8.16 $CTSUThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.8.17 $CTSNLThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference* *level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

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

4.3.8.19 $CTEnThresh2^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.8.20 $CTSUThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.8.21 $CTSNLThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.8.22 $CTEnThresh1^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

4.3.8.23 $CTEnThresh2^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $100/MWh;

4.3.8.24 $CTSUThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 100%;

4.3.8.25 $CTSNLThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 100%;

4.3.8.26 $CTEnThresh1^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

4.3.8.27 $CTEnThresh2^{GMP}$ designates the global market power conduct threshold for a *resource* as a $/MWh increase above the *reference* *level value* of the *energy offer* for the *resource* and is equal to $100 MW/h;

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

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

4.3.8.30 *CTORThresh*1^{ORL} designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to 10%;

4.3.8.31 *CTORThresh*2^{ORL} designates the local market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.8.32 *CTEnThresh*1^{ORL} designates the local market power conduct threshold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 10%;

4.3.8.33 *CTEnThresh*2^{ORL} designates the local maket power conduct threshold for *energy* to *minimum loading point* conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *energy* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

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

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

4.3.8.36 *CTORThresh*1^{ORG} designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level* *value* of the *operating reserve offer* for the *resource* and is equal to 50%;

4.3.8.37 $CTORThresh2^{ORG}$ designates the global market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.8.38 $CTEnThresh1^{ORG}$ designates the global market power conduct threshold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 50%;

4.3.8.39 $CTEnThresh2^{ORG}$ designates the global market power conduct threshold for *energy* to *minimum loading point* for a *resource* as a $/MW increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

4.3.8.40 $CTSUThresh^{ORG}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.8.41 $CTSNLThresh^{ORG}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

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

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

4.3.8.44 $ITThresh1^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.8.45 $ITThresh2^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a $/MWh increase in the *energy* *locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $25/MWh;

4.3.8.46 $ITThresh1^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.8.47 $ITThresh2^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $25/MWh;

4.3.8.48 $ITThresh1^{BCA}$ designates the price impact threshold for a *resource* in a broad constrained area as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.8.49 $ITThresh2^{BCA}$ designates the price impact threshold for a *resource* in a broad constrained area as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to$50/MWh;

4.3.8.50 $ITThresh1^{GMP}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.8.51 $ITThresh2^{GMP}$ designates the global market power price impact threshold for a *resource* as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $50/MWh;

4.3.8.52 $ITThresh1^{ORG}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *operating reserve locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to 50%; and

4.3.8.53 $ITThresh2^{ORG}$ designates the global market power price impact threshold for a *resource* as a $/MW increase in the *operating reserve* *locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to $25/MW.

4.3.9 Weighting Factors for Zonal Prices

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

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

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

4.4 Other Data Parameters

4.3.1 Non-Dispatchable Demand Forecast

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

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

4.3.2 Variable Generation

4.3.2.1 $AFG_{h,b}$ designates the alternative forecast for a *variable generation resource* identified by bus $b \in B^{VG}$ in hour $h \in \{1,...,24\}$, which is either the *registered market participant*-submitted forecast or the *IESO*'s centralized forecast.

4.3.3 Internal Transmission Constraints

4.3.3.1 $PreConSF_{h,f,b}$ designates the pre-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during hour h under pre-contingency conditions;

4.3.3.2 $VPreConSF_{h,f,m}$ designates the pre-contingency sensitivity factor for *virtual transaction zone* $m \in M$ indicating the effect of scheduled *energy* at m to flows on *facility* $f \in F_h$ in hour h under pre-contingency conditions. It shall be determined as the weighted average of the pre-contingency sensitivity factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF^{VIRT}_{h,m,b}$ for *virtual transactions*;

4.3.3.3 $AdjNormMaxFlow_{h,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in hour h under pre-contingency conditions;

4.3.3.4 $SF_{h,c,f,b}$ designates the post-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during hour h under post-contingency conditions for contingency c;

4.3.3.5 $VSF_{h,c,f,m}$ designates the post-contingency sensitivity factor for *virtual transaction zone* $m \in M$ indicating the effect of scheduled *energy* at m to flows on *facility* $f \in F_{h,c}$ in hour h under post-contingency conditions for contingency c. It shall be determined as the weighted average of the post-contingency sensitivity factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF^{VIRT}_{h,m,b}$ for *virtual transactions*; and

4.3.3.6 $AdjEmMaxFlow_{h,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in hour h under post-contingency conditions for contingency c.

4.3.4 Transmission Losses

4.3.4.1 $LossAdj_h$ designates any adjustment needed for hour $h \in \{1, . . , 24\}$ to correct for any discrepancy between Ontario total system losses calculated using a base case power flow from the *security* assessment function and linearized losses that would be calculated using the marginal loss factors.

4.3.4.2 $MglLoss_{h,b}$ designates the marginal loss factor and represent the marginal impact on transmission losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at *resource* bus $b \in B \cup D$ in hour $h \in \{1, . . , 24\}$; and

4.3.4.3 $VMglLoss_{h,m}$ designates the marginal loss factor for *virtual transaction zone* $m \in M$ in hour $h \in \{1,..,24\}$. It shall be determined as the weighted average of the marginal loss factors for *non-dispatchable loads*, *dispatchable loads*, *hourly demand response resources*, and *price responsive loads* within the *virtual transaction zone* using the weighting factors $WF^{VIRT}_{h,m,b}$ for *virtual transactions*.

5 Initialization

5.1 Purpose

5.1.1 The initialization processes set out in this section 5 shall occur prior to the execution of the *day-ahead market calculation engine* described in section 2.1.1 above.

5.2 Reference Bus

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

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

5.3 Islanding Conditions

5.3.1 In the event of a network split, the *day-ahead market calculation engine* shall:

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

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

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

5.4 Variable Generation Tie-Breaking

5.4.1 For each hour $h \in \{1,..,24\}$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K^{E}_{h,b}$, the *offer* price $PDG_{h,b,k}$ shall be modified to $PDG_{h,b,k} - \left(\frac{TBM_b}{NumVG}\right)\rho$, where ρ is a small nominal value of order 10^{-4}.

5.5 Pseudo-Unit Constraints

5.5.1 Constraints for *pseudo-units* corresponding to minimum and maximum constraints on physical *resources* shall be determined in accordance with section 22.

5.6 Initial Scheduling Assumptions

5.6.1 Initial Schedules

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

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

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

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

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

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

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

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

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

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

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

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

5.6.3 Initial Net Interchange Schedule

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

6 Security Assessment Function

6.1 Interaction between the Security Assessment Function and Optimization Functions

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

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

6.1.3 All three passes of the *day-ahead market calculation engine* shall use the *security* assessment function.

6.1.4 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudo-units*.

6.2 Inputs into the Security Assessment Function

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

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

6.1.3 All three passes of the *day-ahead market calculation engine* shall use the *security* assessment function.

6.1.4 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudo-units*.

6.3 Security Assessment Function Processing

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

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

6.3.1.2 determine AFL_h by adding the forecast MW quantities determined for each *non-dispatchable load,* including forecast MW losses in the *demand* forecast areas.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.3.4.10 The As-Offered Pricing, Reference Level Pricing, Mitigated Pricing, and DAM Pricing algorithms described in sections 9, 13, 16 and 21, respectively, shall use the marginal loss factors used in the last iteration of the optimization function in the corresponding scheduling algorithm.

6.4 Outputs from the Security Assessment Function

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

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

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

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

6.4.1.4 loss adjustment quantity for each hour.

7 Pass 1: Market Commitment and Market Power Mitigation Pass

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

- the As-Offered Scheduling algorithm described in section 8;
- the As-Offered Pricing algorithm described in section 9;
- the Constrained Area Conditions Test described in section 10;
- the Conduct Test described in section 11;
- the Reference Level Scheduling algorithm described in section 12;
- the Reference Level Pricing algorithm described in section 13;
- the Price Impact Test described in section 14;
- the Mitigated Scheduling algorithm described in section 15; and
- the Mitigated Pricing algorithm described in section 16.

8 As-Offered Scheduling

8.1 Purpose

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

8.2 Information, Sets, Indices and Parameters

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

8.3 Variables and Objective Function

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

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

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

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

8.3.1.4 $S10NDL_{h,b,j}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in hour $h \in \{1,..,24\}$ in association with lamination $j \in J_{h,b}^{10N}$;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8.3.1.23 $IHE_{h,b,i}$, which 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 $i \in \{1, . . , NStartMW_b\}$;

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

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

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

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

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

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

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

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

Where

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

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

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

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

$$ObjXL_h = \sum_{d \in DX} \left(\sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \cdot PXL_{h,d,j} - \sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \cdot P10NXL_{h,d,j} - \sum_{j \in J_{h,d}^{30R}} S30RXL_{h,d,j} \cdot P30RXL_{h,d,j} \right)$$

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

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

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

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

8.3.2.1 The tie-breaking term (TB_h) shall sum a term for each *bid* or *offer* lamination. For each lamination, this term shall be the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost shall be calculated by multiplying a base penalty cost of $TBPen$ by the amount of the lamination scheduled and then dividing by the maximum amount thzat could have been scheduled. That is:

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

Where:

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

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

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

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

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

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

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

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

and

$$TBIG_h = \sum_{d \in \mathrm{DI}} \left(\sum_{k \in K^E_{h,d}} \left(\frac{\left(SIG_{h,d,k}\right)^2 \cdot TBPen}{QIG_{h,d,k}} \right) + \sum_{k \in K^{10N}_{h,d}} \left(\frac{\left(S10NIG_{h,d,k}\right)^2 \cdot TBPen}{Q10NIG_{h,d,k}} \right) + \sum_{k \in K^{30R}_{h,d}} \left(\frac{\left(S30RIG_{h,d,k}\right)^2 \cdot TBPen}{Q30RIG_{h,d,k}} \right) \right).$$

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

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

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

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

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

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

8.3.2.2.6 $SREG10RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{REG10RViol_h}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.7 $SREG30RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{REG30RViol_h}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{XREG10RViol_h}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.9 $SXREG30RViol_{r,h,i}$, which designates the violation variable associated with segment $i \in \{1,..,N_{XREG30RViol_h}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.10 $SPreITLViol_{f,h,i}$, which 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* $f \in F$;

8.3.2.2.11 $SITLViol_{c,f,h,i}$, which 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 $c \in C$;

8.3.2.2.12 $SPreXTLViol_{z,h,i}$, which 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 $z \in Z_{Sch}$;

8.3.2.2.13 $SNIUViol_{h,i}$, which 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;

8.3.2.2.14 $SNIDViol_{h,i}$, which 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;

8.3.2.2.15 $SMaxDelViol_{h,b,i}$, which 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 $b \in B^{ELR}$;

8.3.2.2.16 $SMinDelViol_{h,b,i}$, which 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 $b \in B^{HE}$;

8.3.2.2.17 $SSMaxDelViol_{h,s,i}$, which 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 $s \in SHE$;

8.3.2.2.18 $SSMinDelViol_{h,s,i}$, which 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 *dispathable* hydroelectric *generation resources* in set $s \in SHE$;

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

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

8.3.2.3 $ViolCost_h$ shall be calculated as follows:

$$ViolCost_h = \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} \cdot PLdViolSch_{h,i} - \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} \cdot PGenViolSch_{h,i} + \sum_{i=1..N_{10SViol_h}} S10SViol_{h,i} \cdot P10SViolSch_{h,i} + \sum_{i=1..N_{10RViol_h}} S10RViol_{h,i} \cdot P10RViolSch_{h,i} + \sum_{i=1..N_{30RViol_h}} S30RViol_{h,i} \cdot P30RViolSch_{h,i} + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_h}} SREG10RViol_{r,h,i} \cdot PREG10RViolSch_{h,i} \right)$$

$$+\sum_{r\in ORREG}\left(\sum_{i=1..N_{REG30RViol_h}} SREG30RViol_{r,h,i} \cdot PREG30RViolSch_{h,i}\right)$$

$$+\sum_{r\in ORREG}\left(\sum_{i=1..N_{XREG10RViol_h}} SXREG10RViol_{r,h,i} \cdot PXREG10RViolSch_{h,i}\right)$$

$$+\sum_{r\in ORREG}\left(\sum_{i=1..N_{XREG30RViol_h}} SXREG30RViol_{r,h,i} \cdot PXREG30RViolSch_{h,i}\right)$$

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

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

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

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

$$\cdot PPreXTLViolSch_{z,h,i}\Bigg)$$

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

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

$$+ \sum_{b \in B^{ELR}} \Bigg(\sum_{i=1..N_{MaxDelViol_h}} SMaxDelViol_{h,b,i}$$

$$\cdot PMaxDelViolSch_{h,i}\Bigg)$$

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

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

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

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

$$\cdot POGenLnkViolSch_{h,i}\Bigg)$$

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

$$\cdot PUGenLnkViolSch_{h,i}\Bigg).$$

8.4 Constraints

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

8.5 Dispatch Data Constraints Applying to Individual Hours

8.5.1 Scheduling Variable Bounds

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

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

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

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

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

8.5.1.5 If the *dispatchable generation resource* at bus $b \in B^{DG}$ is considered committed according to the requirements in sections 8.5.1.2, 8.5.1.3, and 8.5.1.4 in hour $h \in \{1, . . , 24\}$, then:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8.5.2 Resource Minimums and Maximums for Energy

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

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

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

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

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

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

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

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

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

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

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

and

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

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

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

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

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

8.5.3 Off-Market Transactions

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

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

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

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

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

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

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

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

8.5.4 Operating Reserve Requirements

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

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

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

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

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

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

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

and

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

8.5.4.2 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide shall not exceed the amount by which the *dispatchable load* can decrease its load over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all buses $b \in B^{DL}$:

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

8.5.4.3 The total non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled for an hour shall not exceed total scheduled exports. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all *intertie zone* export buses $d \in DX$:

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

8.5.4.4 The total *operating reserve* scheduled from a committed *dispatchable generation resource* shall not exceed that *resource*'s: (i) ramp capability over 30 minutes; (ii) remaining capacity; and (iii) unscheduled capacity. These restrictions shall be enforced by the following constraints for all hours $h \in \{1, . . . , 24\}$ and all buses $b \in B^{DG}$:

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

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

and

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

8.5.4.5 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall not exceed the amount by which the *resource* can increase its output over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all buses $b \in B^{DG}$:

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

8.5.4.6 The amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* may be scheduled to provide shall be limited by its *reserve loading point* for synchronized *ten-minute operating reserve*. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all buses $b \in B^{DG}$ with $RLP10S_{h,b} > 0$:

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

8.5.4.7 The amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for *thirty-minute operating reserve*. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all buses $b \in B^{DG}$ with $RLP30R_{h,b} > 0$:

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

8.5.4.8 The total non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled for an hour shall not exceed the remaining maximum import *offers* minus scheduled *energy* imports. This restriction shall be enforced by the following constraint for all hours $h \in \{1, . . . , 24\}$ and all *intertie zone* import buses $d \in DI$:

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

8.5.5 Pseudo-Units

8.5.5.1 A constraint shall be required to calculate physical *generation resource* schedules from *pseudo-unit* schedules using the steam turbine shares in the operating regions of the *pseudo-unit* determined in section 22. For all hours $h \in \{1, . . , 24\}$ and *pseudo-unit* buses $b \in B^{PSU}$:

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

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

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

8.5.5.2 Maximum constraints shall be enforced on the operating region to which they apply for both *energy* and *operating reserve* schedules. For all hours $h \in \{1, . . , 24\}$ and *pseudo-unit* buses $b \in B^{PSU}$:

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

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

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

and

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

8.5.5.3 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, constraints shall limit the *pseudo-unit* from being scheduled in its duct firing region whenever the *pseudo-unit* is scheduled for *ten-minute operating reserve*. For all hours $h \in \{1,...,24\}$ and *pseudo-unit* buses $b \in B^{NO10DF}$:

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

and

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

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

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

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

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

8.5.5.6 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the combustion turbine schedule for the *pseudo-unit* at bus $b \in B^{PSU}$ in hour $h \in \{1,...,24\}$ shall be equal to:

8.5.1.1.1 $SCT_{h,b}$ if the pseudo-unit is scheduled at or above minimum loading point,

8.5.1.1.2 $RampCT_{b,w}$ if the *pseudo-unit* is scheduled to reach *minimum loading point* in hour $(h + w)$ for $w \in \{1,..,RampHrs_b\}$, or

8.5.1.1.3 0 otherwise.

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

8.5.6 Dispatchable Hydroelectric Generation Resources

8.5.6.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled to at least its *hourly must run* quantity. For all hours $h \in \{1,..,24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

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

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

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

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

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

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

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

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

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

and

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

8.5.7 Wheeling Through Transactions

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

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

8.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

8.6.1 Energy Ramping

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

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

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

8.6.1.4 In all ramping constraints, the schedules for hour 0 are obtained from the initial scheduling assumptions in section 5.6. For all hours $h \in \{1, . . , 24\}$ the ramping rates in all ramping constraints must be adjusted to allow the applicable *resource* to:

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

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

8.6.1.5 *Energy* schedules for *dispatchable loads* cannot vary by more than an hour's ramping capability for the applicable *resource*. This constraint shall be enforced by the following for all hours $h \in \{1, . . , 24\}$ and buses $b \in B^{DL}$:

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

8.6.1.6 *Energy* schedules for *hourly demand response resources* cannot vary by more than an hour's ramping capability for the applicable *resource*. This constraint shall be enforced by the following for all hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{HDR}$:

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

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

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

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

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

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

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

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

8.6.1.8 The constraints in sections 8.6.1.6.1 and 8.6.1.6.3 do not apply to a *quick start resource*.

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

8.6.2 Operating Reserve Ramping

8.6.2.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from *dispatchable loads* shall not exceed their ramp capability to decrease load consumption and for all hours $h \in \{1,..,24\}$ and all buses $b \in B^{DL}$:

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

8.6.2.2 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from a committed *dispatchable generation resource* shall not exceed its ramp capability to increase generation and for all hours $h \in \{1, .., 24\}$ and all buses $b \in B^{DG}$:

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

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

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

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

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

8.6.3 Non-Quick Start Resources

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

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

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

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

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

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

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

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

8.6.3.6 A Boolean variable, $IDG_{h,b}$ indicates that the *non-quick start resource* at bus $b \in B^{NQS}$ is scheduled to reach its *minimum loading point* in hour $h \in \{1,..,24\}$ after being scheduled below its *minimum loading point* in the preceding hour. A value of zero shall indicate that a *resource* is not scheduled to reach its *minimum loading point*, while a value of one indicates that it is scheduled to reach its *minimum loading point*. For all hours $h \in \{1,..,24\}$ and all buses $b \in B^{NQS}$:

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

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

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

8.6.4 Energy Limited Resources

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

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

8.6.4.1.2 *energy* in amounts that would preclude such *resource* from providing *operating reserve* when activated, for all buses $b \in B^{ELR}$ where an *energy limited resource* is located and all hours $H \in \{1,..,24\}$:

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

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

8.6.5 Dispatchable Hydroelectric Generation Resources

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

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

8.6.5.2 A Boolean variable, $IHE_{h,b,i}$ shall indicate that a start for the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ was counted in hour $h \in \{1, . . 24\}$ as a result of the *resource* schedule increasing from below its i-th *start indication value* to at or above its i-th *start indication value* for $i \in \{1, . . . , NStartMW_b\}$. A value of zero shall indicate that a start was not counted, while a value of one indicates that a start was counted.

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

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

8.6.5.3 *Dispatchable* hydroelectric *generation resources* shall not be scheduled to be started more times than permitted by their *maximum number of starts per day*. The following constraint shall apply for all buses $b \in B^{HE}$:

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

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

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

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{H,b}^{10S}}S10SDG_{H,b,k}\right.\right.$$

$$\left.+\sum_{k\in K_{H,b}^{10N}}S10NDG_{H,b,k}\right)$$

$$\left.\left.+30ORConv\left(\sum_{k\in K_{H,b}^{30R}}S30RDG_{H,b,k}\right)\right)\right)$$

$$-\sum_{i=1..N_{SMaxDelViol_H}}SSMaxDelViol_{H,s,i}$$

$$\leq MaxSDEL_s$$

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

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

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

$$\left.+\sum_{i=1..N_{SMinDelViol_h}}SSMinDelViol_{h,s,i}\right)$$

$$\geq MinSDEL_s$$

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

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

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

8.7 Constraints for Reliability Requirements

8.7.1 Energy Balance

8.7.1.1 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in hour $h \in \{1, . . . , 24\}$, $With_{h,b}$ shall be:

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

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

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

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

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

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

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

where

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

and

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

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

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

8.7.1.6 Injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor calculated by the *security* assessment function to reflect the losses or reduction in losses that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other after taking into account the adjustment for any discrepancy between total and marginal losses. Load or generation reduction associated with the *demand* constraint violation shall be subtracted from the total load or generation for the *day-ahead market calculation engine* to produce a solution. For hour $h \in \{1, \ldots, 24\}$, the *energy* balance shall be:

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

8.7.2 Operating Reserve Requirements

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

8.7.2.2 Constraint violation penalty curves shall be used to impose a penalty cost for not meeting the *IESO*'s system-wide *operating reserve* requirements, not meeting a regional minimum requirement, or not adhering to a regional maximum restriction. Full *operating reserve* requirements shall be scheduled unless the cost of doing so would be higher than the applicable penalty cost.

For each hour $h \in \{1, .. 24\}$:

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

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

and

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

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

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

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

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

and

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

8.7.3 IESO Internal Transmission Limits

8.7.3.1 A set of *energy* schedules shall be produced that do not violate any *security limits* in the pre-contingency state and the post-contingency state subject to the remainder of this section 8.7.3. The total amount of *energy* scheduled to be injected and withdrawn at each bus used by the *energy* balance constraint in section 8.7.1.6, shall be used to produce these schedules.

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

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

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

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

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

8.7.4 Intertie Limits

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

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

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

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

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

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

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

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

8.7.5 Penalty Price Variable Bounds

8.7.5.1 Penalty price variables shall be restricted to the ranges determined by the constraint violation penalty curves for the As-Offered Scheduling algorithm and for all hours $h \in \{1, \ldots, 24\}$:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

8.8 Outputs

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

9 As-Offered Pricing

9.1 Purpose

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

9.2 Information, Sets, Indices and Parameters

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

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

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

9.2.1.3 $S10SDG^{AOS}_{h,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, . . . , 24\}$ in association with lamination $k \in K^{10S}_{h,b}$;

9.2.1.4 $S10NDG^{AOS}_{h,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, . . . , 24\}$ in association with lamination $k \in K^{10N}_{h,b}$;

9.2.1.5 $S30RDG^{AOS}_{h,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, . . . , 24\}$ in association with lamination $k \in K^{30R}_{h,b}$; and

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

9.3 Variables and Objective Function

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

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

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

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

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

9.3.1.5 $SOGenLnkViol_{h,(b_1,b_2),i}$ for $(b_1, b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, hour $h \in \{1, . . . , 24\}$ and $i \in \{1, . . . , N_{OGenLnkViol_h}\}$ shall not appear in the formulation; and

9.3.1.6 $SUGenLnkViol_{h,(b_1,b_2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, hour $h \in \{1, . . . , 24\}$ and $i \in \{1, . . . , N_{UGenLnkViol_h}\}$ shall not appear in the formulation.

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

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

where:

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

$$ObjDL_h = \sum_{b \in B^{DL}} \left(\begin{array}{c} \sum_{j \in J_{h,b}^{E}} SDL_{h,b,j} \cdot PDL_{h,b,j} - \sum_{j \in J_{h,b}^{10S}} S10SDL_{h,b,j} \cdot P10SDL_{h,b,j} - \\ \sum_{j \in J_{h,b}^{10N}} S10NDL_{h,b,j} \cdot P10NDL_{h,b,j} - \sum_{j \in J_{h,b}^{30R}} S30RDL_{h,b,j} \cdot P30RDL_{h,b,j} \end{array} \right)$$

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

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

$$ObjXL_h = \sum_{d \in DX} \left(\begin{array}{c} \sum_{j \in J_{h,d}^{E}} SXL_{h,d,j} \cdot PXL_{h,d,j} - \sum_{j \in J_{h,d}^{10N}} S10NXL_{h,d,j} \cdot P10NXL_{h,d,j} \\ - \sum_{j \in J_{h,d}^{30R}} S30RXL_{h,d,j} \cdot P30RXL_{h,d,j} \end{array} \right)$$

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

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

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

$$ObjIG_h = \sum_{d \in DI} \left(\begin{array}{c} \sum_{k \in K_{h,d}^{E}} SIG_{h,d,k} \cdot PIG_{h,d,k} + \sum_{k \in K_{h,d}^{10N}} S10NIG_{h,d,k} \cdot P10NIG_{h,d,k} \\ + \sum_{k \in K_{h,d}^{30R}} S30IG_{h,d,k} \cdot P30RIG_{h,d,k} \end{array} \right)$$

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

9.3.2.2 $ViolCost_h$ shall be calculated as follows:

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

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

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

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

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

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

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

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

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

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

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

9.4 Constraints

9.4.1 The constraints described in sections 9.5, 9.6, 9.7 and 9.8 apply to the optimization function in the As-Offered Pricing algorithm.

9.5 Dispatch Data Constraints Applying to Individual Hours

9.5.1 Scheduling Variable Bounds

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

where

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

9.5.2 Resource Minimums and Maximums

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

9.5.3 Off-Market Transactions

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

9.5.3.2 In the case of emergency energy transactions, subject to section 9.5.3.3, the constraints in sections 8.5.3.3 and 8.5.3.4 shall apply in As-Offered Pricing algorithm.

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

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

9.5.4 Operating Reserve Requirements

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

9.5.5 Pseudo-Units

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

9.5.6 Dispatchable Hydroelectric Generation Resources

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

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

9.5.6.1.2 *minimum hourly output* constraints shall be replaced by the constraints in section 9.8; and

9.5.6.1.3 a *dispatchable* hydroelectric *generation resource's* schedule shall respect its *forbidden regions* and may only set prices within the operating range determined by the adjacent *forbidden regions* between which the *resource* was scheduled.

9.5.7 Wheeling Through Transactions

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

9.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

9.6.1 Energy Ramping

9.6.1.1 The constraints in section 8.6.1 shall apply in the As-Offered Pricing algorithm.

9.6.2 Operating Reserve Ramping

9.6.2.1 The constraints in section 8.6.2 shall apply in the As-Offered Pricing algorithm.

9.6.3 Energy Limited Resources

9.6.3.1 The constraints in section 8.6.4 shall apply to *energy limited resources*. If the *maximum daily energy limit* is binding, then the constraints in section 9.8 shall apply.

9.6.4 Dispatchable Hydroelectric Generation Resources

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

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

9.6.4.2 The constraints in section 9.8.3.3 shall apply to a *dispatchable* hydroelectric *generation resource* with a binding *minimum daily energy limit* in the As-Offered Scheduling algorithm in section 8.

9.6.4.3 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *maximum daily energy limits*. Violation variables for scheduling *resources* above the *maximum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all sets $s \in SHE$ and all hours $H \in \{1,...,24\}$:

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

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

9.6.4.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not violate shared *minimum daily energy limits*. Violation variables for scheduling *resources* below the *minimum daily energy limit* may be used to allow the *day-ahead market calculation engine* to find a solution. For all sets $s \in SHE$:

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

9.7 Constraints for Reliability Requirements

9.7.1 Energy Balance

9.7.1.1 The constraint in section 8.7.1 shall apply in the As-Offered Pricing algorithm, except the marginal loss factors used in the *energy* balance constraint in the As-Offered Pricing algorithm shall be fixed to the marginal loss factors used in the last optimization function iteration of the As-Offered Scheduling algorithm.

9.7.2 Operating Reserve Requirements

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

9.7.3 IESO Internal Transmission Limits

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

9.7.4 Intertie Limits

9.7.4.1 The constraints in section 8.7.4 shall apply in the As-Offered Pricing algorithm.

9.7.5 Penalty Price Variable Bounds

9.7.5.1 The following constraints shall restrict the penalty price variables to the ranges determined by the constraint violation penalty curves for the pricing algorithm. For all $h \in \{1, . . , 24\}$:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

9.8 Constraints to Ensure the Price Setting Eligibility Reflect Offer/Bid Laminations

9.8.1 Commitment Status Variables

9.8.1.1 Commitment decisions shall be fixed to the commitment statuses of *resources* calculated by the As-Offered Scheduling algorithm in section 8. For all hours $h \in \{1, . . , 24\}$ and all buses $b \in B^{DG}$:

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

9.8.2 Energy Limited Resources

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

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

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

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

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

where ϵ is a small positive constant.

9.8.3 Dispatchable Hydroelectric Generation Resources

9.8.3.1 If a *dispatchable* hydroelectric *generation resource* is scheduled to provide *energy* at or above its *minimum hourly output* in the As-Offered Scheduling algorithm in section 8, such *resource* shall also be scheduled at or above its *minimum hourly output* in the As-Offered Pricing algorithm. The *energy offer* laminations corresponding to the *minimum hourly output* amount shall be ineligible to set prices. If a *dispatchable* hydroelectric *generation resource* with a *minimum hourly output* amount receives a zero schedule in the As-Offered Scheduling algorithm, the *resource* shall also receive a zero schedule in the As-Offered Pricing algorithm and shall be ineligible to set prices in the *energy market*. For all hours $h \in \{1, .., 24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

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

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

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

9.8.3.2 For a *dispatchable* hydroelectric *generation resource* with a limited number of starts, such *resource* shall be scheduled such that it is limited to set prices within an operating range consistent with the number of starts utilized by the *resource's* schedule determined by the As-Offered Scheduling algorithm in section 8. The *resource's* schedule shall be between the same *start indication value*s as determined in the As-Offered Scheduling algorithm. For all hydroelectric buses $b \in B^{HE}$ and all hours $h \in \{1, . . . , 24\}$:

If $0 \leq ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} < StartMW_{b,1}$,

then

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

If $StartMW_{b,i} \leq ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} < StartMW_{b,i+1}$ for i ∈ {1, . . , ($NStartMW_b - 1$)},

then

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

If $ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} \geq StartMW_{b,NStartMW_b}$,

then

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

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

$$\sum_{h=1..24} \left(ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} \right) \leq MinDEL_b$$

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

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

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

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

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

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

9.8.3.5 For a *dispatchable* hydroelectric *generation resource* with a binding *maximum daily energy limit* in the As-Offered Scheduling algorithm in section 8, the schedules calculated in the As-Offered Scheduling algorithm shall determine the price-setting eligibility of the *resource's energy* and *operating reserve offer* laminations as described in section 9.8.2.

9.8.3.6 For a *dispatchable* hydroelectric *generation resource* with with a shared *maximum daily energy limit* that was binding in the As-Offered Scheduling algorithm in section 8, the schedules calculated in the As-Offered Scheduling algorithm shall determine the price-setting eligibility of the *resource's offer* laminations for *energy* and *operating reserve*. In each hour, the sum of *energy* schedules calculated in As-Offered Scheduling algorithm for all *resources* in each set $s\in SHE$ will be eligible to set prices. For each set $s\in SHE$, if there exists $H\in\{1,..,24\}$ such that:

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

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{H,b}^{10S}}S10SDG_{H,b,k}^{AOS}\right.\right.$$

$$\left.+\sum_{k\in K_{H,b}^{10N}}S10NDG_{H,b,k}^{AOS}\right)$$

$$\left.+30ORConv\left(\sum_{k\in K_{H,b}^{30R}}S30RDG_{H,b,k}^{AOS}\right)\right)$$

$$=MaxSDEL_s$$

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

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

$$\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{h,b}^{E}}SDG_{h,b,k}+\sum_{k\in K_{h,b}^{10S}}S10SDG_{h,b,k}+\sum_{k\in K_{h,b}^{10N}}S10NDG_{h,b,k}\right.$$

$$\left.+\sum_{k\in K_{h,b}^{30R}}S30RDG_{h,b,k}\right)$$

$$\leq MaxSDEL_s-\sum_{b\in B_s^{HE}}\sum_{\tau=2}^{h-1}\sum_{k\in K_{h,b}^{E}}SDG_{\tau,b,k}^{AOS}.$$

where ϵ is a small positive constant.

9.8.3.7 For a *dispatchable* hydroelectric *generation resource* for which a *MWh ratio* was respected in the As-Offered Scheduling algorithm in section 8, such *resource* shall be scheduled between its As-Offered Scheduling algorithm schedule plus or minus a tolerance Δ specified by the *IESO*. The *resource* schedule shall continue to be limited by its *offer* quantity bounds, in section 9.5.1, and any applicable *resource* minimum or maximum constraints, in section 9.5.2. For all hours $h \in \{1, \ldots, 24\}$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such $b \in \{b_1, b_2\}$ where $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$ for some $(b_1,b_2) \in LNK$ with $h + Lag_{b_1,b_2} \leq 24$:

$$\max\left(0\,, ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} - \Delta\,, AdjMinDG_{h,b}\right)$$
$$\leq ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG_{h,b,k}$$
$$\leq \min\left(\begin{matrix} MinQDG_b + \sum_{k \in K^E_{h,b}} QDG_{h,b,k}\,, \quad ODG^{AOS}_{h,b} \cdot MinQDG_b + \sum_{k \in K^E_{h,b}} SDG^{AOS}_{h,b,k} + \Delta\,, \\ AdjMaxDG_{h,b} \end{matrix}\right)$$

9.9 Outputs

9.9.1 Outputs for the As-Offered Pricing algorithm include the following:

9.9.1.1 shadow prices;

9.9.1.2 *locational marginal prices* and their components; and

9.9.1.3 sensitivity factors.

10 Constrained Area Conditions Test

10.1 Purpose

10.1.1 The Constrained Area Conditions Test shall:

10.1.1.1 identify when and where competition is restricted; and

10.1.12 determine which *resources* shall have their *financial dispatch data parameters* be subject to the Conduct Test in section 11 and the thresholds above the *reference levels* that shall be used in the Conduct Test.

10.2 Information, Sets, Indices and Parameters

10.2.1 The sets and parameters associated with *narrow constrained areas* and *dynamic constrained areas* shall be identified in accordance with Appendix 7.8 and used by the Constrained Area Conditions Test.

10.2.2 Information, sets, indices and parameters for the Constrained Area Conditions Test are described in sections 3 and 4. In addition, the following prices produced by the As-Offered Pricing algorithm shall be used by the Constrained Area Conditions Test:

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

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

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

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

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

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

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

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

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

10.2.2.10 $L30RP^{AOP}_{h,b}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$;

10.2.2.11 $L10NP^{AOP}_{h,b}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$; and

10.2.2.12 $L10SP^{AOP}_{h,b}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$.

10.3 Variables

10.3.1 The *day-ahead market calculation engine* shall use the constrained area conditions in sections 10.4 and 10.5 to identify the *resources* that are part of the following data sets:

10.3.1.1 $BCond^{NCA}_{h}$, which designates the *resources* in a *narrow constrained area* that must be checked for local market power for *energy* in hour $h \in \{1,..,24\}$;

10.3.1.2 $BCond^{DCA}_{h}$, which designates the *resources* in a *dynamic constrained area* that must be checked for local market power for *energy* in hour $h \in \{1,..,24\}$;

10.3.1.3 $BCond^{BCA}_{h}$, which designates the *resources* in a broad constrained area that must be checked for local market power for *energy* in hour $h \in \{1,..,24\}$;

10.3.1.4 $BCond^{GMP}_{h}$, which designates the *resources* that must be checked for global market power for *energy* in hour $h \in \{1,..,24\}$;

10.3.1.5 $BCond_h^{10S}$, which designates the *resources* that must be checked for local market power for synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$;

10.3.1.6 $BCond_h^{10N}$, which designates the *resources* that must be checked for local market power for non-synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$;

10.3.1.7 $BCond_h^{30R}$, which designates the *resources* that must be checked for local market power for *thirty-minute operating reserve* in hour $h \in \{1,..,24\}$;

10.3.1.8 $BCond_h^{GMP10S}$, which designates the *resources* that must be checked for global market power for synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$;

10.3.1.9 $BCond_h^{GMP10N}$, which designates the *resources* that must be checked for global market power for non-synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$; and

10.3.1.10 $BCond_h^{GMP30R}$, which designates the *resources* that must be checked for global market power for *thirty minute operating reserve* in hour $h \in \{1,..,24\}$.

10.4 Constrained Area Conditions Test for Local Market Power (Energy)

10.4.1 Constrained Area Conditions Test for Narrow Constrained Areas and Dynamic Constrained Areas

10.4.1.1 If at least one transmission constraint for a *narrow constrained area* or *dynamic constrained area* is binding in the As-Offered Pricing algorithm, then all *resources* identified within the *narrow constrained area* or *dynamic constrained area* area shall undergo the applicable Conduct Test in section 11 and:

10.4.1.1.1 For each $n \in NCA$ and hour $h \in \{1, . . , 24\}$: For each transmission *facility* that transmits flow into n, $f \in F_n^{NCA}$, check if $SPNormT_{h,f}^{AOP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit, the *day-ahead market calculation engine* will place n in the set $NCA_h{}'$ and assign the *resources* in n to the set $BCond_h^{NCA}$; and

10.4.1.1.2 For each $d \in DCA$ and hour $h \in \{1, . . , 24\}$: For each transmission *facility* that transmits flow into d, $f \in F_d^{DCA}$, check if $SPNormT_{h,f}^{AOP} \neq 0$ or $SPEmT_{h,c,f}^{AOP} \neq 0$ for the inbound flow limit, *the day-ahead market calculation engine* will place d in the set $DCA_h{}'$ and assign the *resources* in d to the set $BCond_h^{DCA}$.

10.4.1.2 Each *narrow constrained area* and *dynamic constrained area* that meets the criteria in section 10.4.1.1 shall be assigned to one of the following subsets, as appropriate:

10.4.1.2.1 $NCA_h{}'$ designates the *narrow constrained areas* that qualify for market power mitigation for *energy* in hour $h \in \{1, . . , 24\}$; and

10.4.1.2.2 $DCA_h{}'$ designates the *dynamic constrained areas* that qualify for market power mitigation for *energy* in hour h $\in \{1,..,24\}$.

10.4.2 Constrained Area Conditions Test for Broad Constrained Areas

10.4.2.1 If the congestion component of the *locational marginal price* for a *resource* is greater than $BCACondThresh$, and the *resource* is not part of a *narrow constrained area* or *dynamic constrained area* that has a binding transmission constraint, then the *resource* shall be tested for Conduct Test under the broad constrained area thresholds. For each hour $h \in \{1, . . , 24\}$ and bus $b \in B^{DG}$ such that $b \notin BCond_h^{NCA} \cup BCond_h^{DCA}$, if $PCong_{h,b}^{AOP} > BCACondThresh$, *the day-ahead market calculation engine* will place *resource* b in the set $BCond_h^{BCA}$.

10.5 Constrained Area Conditions Test for Global Market Power (Energy)

10.5.1 The *day-ahead market calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, subject to 10.5.2, if:

10.5.1.1 the *intertie border prices* at the *global market power reference intertie zones* are greater than the specified threshold value, indicated in hour $h \in \{1, . . , 24\}$ by $IntLMP_{h,d}^{AOP} > IBPThresh$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; and

10.5.1.2 at least one of the following conditions is met:

10.5.1.2.1 import congestion, represented by a negative *intertie* congestion component, is present on all of the *global market power reference interties*, indicated in hour $h \in \{1, . . . , 24\}$ by: $PExtCong_{h,d}^{AOP} < 0$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; or

10.5.1.2.2 the net interchange schedule limit is binding for imports, represented by a non-zero net interchange schedule limit shadow price for incremental imports, indicated in hour $h \in \{1, . . . , 24\}$ by: $SPNIUExtBwdT_h^{AOP} \neq 0$.

10.5.2 If the conditions in sections 10.5.1 are met, then the *day-ahead market calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, for each hour $h \in \{1, . . , 24\}$, place all $b \in B^{DG}$ in the set $BCond_h^{GMP}$, unless they are excluded because one of the following two conditions:

10.5.2.1 the *resources* in any zone have congestion components at least $1/MWh below the internal congestion component at all of the *global market power reference intertie zones:*

10.5.2.1.1 if $PCong_{h,b}^{AOP} < PIntCong_{h,d}^{AOP} - \$1/\text{MWh}$ where $d \in D^{GMPRef}$ is true for all global market power reference intertie zones; or

10.5.2.2 the *resources* can not meet the incremental load because a binding transmission constraint:

10.5.2.2.1 if resources can not meet incremental load because of any binding transmission *facility* where $SPNormT_{h,f}^{AOP} \neq 0$ *or* $SPEmT_{h,c,f}^{AOP} \neq 0$.

10.6 Constrained Area Conditions Test for Local Market Power (Operating Reserve)

10.6.1 Subject to section 10.6.1.3 for a regional minimum requirement of greater than zero for a specific class of *operating reserve*, then all *resources* within the region with *offers* for classes of *operating reserve* that can satisfy the requirements of the specific class of *operating reserve* shall be tested for local market power:

10.6.1.1 A *resource* shall not qualify for local market power mitigation test for *operating reserve* if the *resource* is located in a region with a binding maximum constraint and for each *resource* $b \in B^{DG} \cup B^{DL}$ and hour $h \in \{1, . . , 24\}$:

10.6.1.2 subject to section 10.6.1.3, if b is in a region with a non-zero minimum requirement, then b is subject to the Conduct Test and is placed in the set $BCond_h^{10S}$, $BCond_h^{10N}$, or $BCond_h^{30R}$; and

10.6.1.3 if b is in a region with a binding maximum restriction constraint, then b is exempt from the Conduct Test.

10.7 Constrained Area Conditions Test for Global Market Power (Operating Reserve)

10.7.1 A *resource* shall be subject to global market power mitigation testing for *operating reserve* if its *offers* for a class of *operating reserve* where the *locational marginal price* for that class of *operating reserve* is greater than $ORGCondThresh$.

10.7.2 Subject to section 10.7.3, if the condition in section 10.7.1 has been met for a class of *operating reserve*, then all *resources* with *offers* for classes of *operating reserve* that can satisfy the requirements of that class of *operating reserve* shall be tested and for each $b \in B^{DG} \cup B^{DL}$ and hour $h \in \{1, . . , 24\}$:

10.7.2.1 if $\mathrm{L10SP}_{t,b}^{\mathrm{PDP}} > \mathrm{ORGCondThresh}$, the *day-ahead market* calculation engine shall add resource b to $\mathrm{BCond}_t^{\mathrm{GMP10S}}$;

10.7.2.2 if $L10NP_{t,b}^{PDP} > ORGCondThresh$, the *day-ahead market calculation engine* shall add *resource* b to $BCond_t^{GMP10N}$; and

10.7.2.3 if $L30RP_{t,b}^{PDP} > ORGCondThresh$, the *day-ahead market calculation engine* shall add *resource* b to $BCond_t^{GMP30R}$.

10.7.3 If b is in a region with a binding maximum constraint, then b shall be exempt from the Conduct Test.

10.7.3.1 If a *resource* is located in a region with a binding regional maximum constraint, then the *resource* shall not qualify for global market power mitigation testing for *operating reserve*.

10.8 Outputs

10.8.1 Outputs of the Constrained Area Conditions Test include the list of *resources* that will be subject to the Conduct Test in section 11 and the thresholds that will be used in the Conduct Test for those *resources*.

11 Conduct Test

11.1 Purpose

11.1.1 The Conduct Test shall verify whether the *financial dispatch data parameter* values submitted by *registered market participants* for *resources* identified in section 10.8.1 are within the applicable threshold level of the corresponding *reference level values* for those *resources*.

11.2 Information, Sets, Indices and Parameters

11.2.1 Information, sets, indices and parameters used by the Conduct Test in section 11 are described in section 3. In addition, the list of *resources* produced pursuant to section 10.8.1 shall also be used by the Conduct Test.

11.3 Variables

11.3.1 The *day-ahead market calculation engine* shall apply the Conduct Test set out in sections 11.4 and 11.5 to the *resources* identified by the Constrained Area Conditions Test in accordance with section 10.8, to identify the following data sets:

11.3.1.1 The sets of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter*, where:

11.3.1.1.1 BCT_h^{NCA} designates the *resources* in a *narrow constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in hour $h \in \{1, . . , 24\}$;

11.3.1.1.2 BCT_h^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in hour $h \in \{1, . . , 24\}$;

11.3.1.1.3 BCT_h^{BCA} designates the *resources* in a broad constrained area that failed the Conduct Test for at least one *financial dispatch data parameter* in hour $h \in \{1,..,24\}$;

11.3.1.1.4 BCT_h^{GMP} designates the *resources* that failed the global market power for *energy* Conduct Test for at least one *financial dispatch data parameter* in hour $h \in \{1,..,24\}$;

11.3.1.1.5 BCT_h^{ORL} designates the *resources* that failed the local market power for *operating reserve* Conduct Test for at least one *financial dispatch data parameter* in hour $h \in \{1,..,24\}$; and

11.3.1.1.6 BCT_h^{ORG} designates the *resources* that failed the global market power Conduct Test for *operating reserve* for at least one *financial dispatch data parameter* in hour $h \in \{1,..,24\}$;

11.3.1.2 The following *financial dispatch data parameters* for all hours $h \in \{1,..,24\}$:

11.3.1.2.1 $PARAME_{h,b}$ designates the set of *dispatch data* parameters that failed the *energy* Conduct Test at bus $b \in BCT_h^{NCA} \cup BCT_h^{DCA} \cup BCT_h^{BCA} \cup BCT_h^{GMP}$ in hour h, and may include the following dispatch data parameters:

11.3.1.2.1.1 $EnergyOffer_k$ designates the non-zero quantity of *energy* above the *minimum loading point* in association with *offer* lamination $k \in K_{h,b}^{E}$ failed the Conduct Test;

11.3.1.2.2 For all hours prior to and including the last hour where conditions are met for the *energy* Conduct Test:

11.3.1.2.2.1 $EnergyToMLP_k$ designates the non-zero quantity of *energy* up to the *minimum loading point* in association with *offer* lamination $k \in K_{h,b}^{LTMLP}$ failed the Conduct Test;

11.3.1.2.2.2 $SUOffer$ designates the *start-up offer* failed the Conduct Test; and

11.3.1.2.2.3 $SNLOffer$ designates the *speed no-load offer* failed the Conduct Test;

11.3.1.2.3 $PARAMOR_{h,b}$ designates the set of *dispatch data* parameters that failed the *operating reserve* Conduct Test at bus $b \in$

$BCT_h^{ORL} \cup BCT_h^{ORG}$ in hour h, and may include the following *dispatch data* parameters:

11.3.1.2.3 $OR10SOffer_k$ designates the non-zero quantity of synchronized *ten-minute operating reserve* in association with *offer* lamination $k \in K_{h,b}^{10S}$ failed the Conduct Test;

11.3.1.2.3 $OR10NOffer_k$ designates the non-zero quantity of non-synchronized *ten-minute operating reserve* in association with *offer* lamination $k \in K_{h,b}^{10N}$ failed the Conduct Test;

11.3.1.2.3 $OR30ROffer_k$ designates the non-zero quantity of *thirty-minute operating reserve* in association with *offer* lamination $k \in K_{h,b}^{30R}$ failed the Conduct Test; and

11.3.1.2.4 For all hours prior to and including the last hour where conditions are met for the *operating reserve* Conduct Test:

11.3.1.2.4.1 $SUOffer$ designates the *start-up offer* failed the Conduct Test;

11.3.1.2.4.2 $SNLOffer$ designates the *speed no-load offer* failed the Conduct Test; and

11.3.1.2.4.3 $EnergyToMLP_k$ designates the non-zero quantity of *energy* up to the *minimum loading point* in association with *offer* lamination $k \in K_{h,b}^{E}$ failed the Conduct Test.

11.4 Conduct Test for Energy

11.4.1 The *day-ahead market calculation engine* shall perform the Conduct Test for *energy* for *resources* in a *narrow constrained area* that were identified pursuant to section 10.8.1 as follows, subject to sections 11.4.2 and 11.4.3. For each hour $h \in \{1, .., 24\}$ and $b \in BCond_h^{NCA}$, the *day-ahead market calculation engine* shall:

11.4.1.1 Evaluate *offers* for *energy* above the *minimum loading point*: For all $k \in K_{h,b}^{E}$, if $PDG_{h,b,k} > CTEnMinOffer$ and $PDG_{h,b,k} > min(PDGRef_{h,b,k'}*(1 + CTEnThresh1^{NCA}), PDGRef_{h,b,k'} + CTEnThresh2^{NCA})$, where $k' \in K_{h,b}^{\prime E}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $EnergyOffer_k$ to $PARAME_{h,b}$;

11.4.1.2 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all hours prior to and including the hour that qualified to be tested under the Constrained Area Conditions Test, for all $k \in K_{h,b}^{LTMLP}$, if $PLTMLP_{h,b,k} > CTEnMinOffer$ and $PLTMLP_{h,b,k} > min(PLTMLPRef_{h,b,k'} * (1 + CTEnThresh1^{NCA}), PLTMLPRef_{h,b,k'} + CTEnThresh2^{NCA})$, where $k' \in K_{h,b}^{'E}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $EnergyToMLP_k$ to $PARAME_{h,b}$ and $PARAMOR_{h,b}$;

11.4.1.3 Evaluate *start-up offers*: For all hours prior to and including the hour where conditions are met for the Constrained Area Conditions Test in section 10 , if $SUDG_{h,b} > SUDGRef_{h,b} * (1 + CTSUThresh^{NCA})$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $SUOffer$ to $PARAME_{h,b}$ and $PARAMOR_{h,b}$; and

11.4.1.4 Evaluate *speed no-load offers*: For all hours prior to and including the hour that meets the conditions test, if $SNL_{h,b} > SNLRef_{h,b} * (1 + CTSNLThresh^{NCA})$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{NCA} and add $SNLOffer$ to $PARAME_{h,b}$ and $PARAMOR_{h,b}$.

11.4.2 For *resources* identified pursuant to section 10.8.1 in a *dynamic constrained area* or broad constrained area, the *day-ahead market calculation engine* shall use the steps in section 11.4.1 , using *resources* in $BCond_h^{DCA}$ or $BCond_h^{BCA}$, as the case may be, in place of $BCond_h^{NCA}$ and using the applicable Conduct Test thresholds $CTEnThresh1^{DCA}$, $CTEnThresh2^{DCA}$, $CTEnThresh1^{BCA}$, $CTEnThresh2^{BCA}$, $CTSUThresh^{DCA}$, $CTSUThresh^{BCA}$, $CTSNLThresh^{DCA}$, $CTSNLThresh^{BCA}$. If any of the *financial dispatch data parameters* of a *resource* fail the Conduct Test, the *resource* shall be assigned to subset BCT_h^{DCA} or BCT_h^{BCA}, as the case may be.

11.4.3 For *resources* identified pursuant to section 10.8.1 that were selected for global market power mitigation testing for *energy*, the *day-ahead market calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond_h^{GMP}$ in place of $BCond_h^{NCA}$ and the applicable global market power Conduct Test thresholds $CTEnThresh1^{GMP}$, $CTEnThresh2^{GMP}$, $CTSUThresh^{GMP}$, $CTSNLThresh^{GMP}$. If any of the applicable *financial dispatch data parameters* of a *resource* fails the Conduct Test, the *resource* shall be assigned to subset BCT_h^{GMP}.

11.4.4 If a *resource* is assigned to more than one of the sets, $BCond_h^{NCA}$, $BCond_h^{DCA}$, $BCond_h^{BCA}$, and $BCond_h^{GMP}$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.5 Conduct Test for Operating Reserve

11.5.1 The *day-ahead market calculation engine* shall perform the Conduct Test for local market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1, as follows, subject to 11.5.3. For each hour $h \in \{1, .., 24\}$ and $b \in BCond_h^{10S} \cup BCond_h^{10N} \cup BCond_h^{30R}$, the *day-ahead market calculation engine* shall:

11.5.1.1 Evaluate *offers* for *operating* reserve as follows:

11.5.1.1.1 for all $k \in K_{h,b}^{10S}$ if $P10SDG_{h,b,k} > CTORMinOffer$ and $P10SDG_{h,b,k} > min\left(P10SDGRef_{h,b,k`} * (1 + CTORThresh1^{ORL}), P10SDGRef_{h,b,k`} + CTORThresh2^{ORL}\right)$, where $k' \in K_{h,b}^{\prime 10S}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.2 for all $k \in K_{h,b}^{10N}$ if $P10NDG_{h,b,k} > CTORMinOffer$ and $P10NDG_{h,b,k} > min\,(P10NDGRef_{h,b,k`}*(1 + CTORThresh1^{ORL}), P10NDGRef_{h,b,k`} + CTORThresh2^{ORL})$, where $k' \in K_{h,b}^{\prime 10N}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{h,b}$; and

11.5.1.1.3 for all $k \in K_{h,b}^{30R}$ if $P30RDG_{h,b,k} > CTORMinOffer$ and $P30RDG_{h,b,k} > min(P30RDGRef_{h,b,k`} * (1 + CTORThresh1^{ORL}), P30RDGRef_{h,b,k`} + CTORThresh2^{ORL})$, where $k' \in K_{h,b}^{\prime 30R}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.4 for all $j \in J_{h,b}^{10S}$ if $P10SDL_{h,b,j} > CTORMinOffer$ and $P10SDL_{h,b,j} > min\,(P10SDLRef_{h,b,j`}* (1 + CTORThresh1^{ORL}),$

$P10SDLRef_{h,b,j'}$+$CTORThresh2^{ORL}$), where $j' \in J'^{10S}_{h,b}$, then the Conduct Test was failed for the *dispatchable load* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{h,b}$;

11.5.1.1.5 for all $j \in J^{10N}_{h,b}$ if $P10NDL_{h,b,j} > CTORMinOffer$ and $P10NDG_{h,b,j} > min\,(P10NDLRef_{h,b,j'}*(1 + CTORThresh1^{ORL}), P10NDLRef_{h,b,j'} + CTORThresh2^{ORL})$, where $j' \in J'^{10N}_{h,b}$, then the Conduct Test was failed for the *dispatchable load* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{h,b}$; and

11.5.1.1.6 for all $j \in J^{30R}_{h,b}$ if $P30RDL_{h,b,j} > CTORMinOffer$ and $\text{P30RDL}_{h,b,j} > min\,(P30RDLRef_{h,b,j'}*(1 + CTORThresh1^{ORL}), P30RDLRef_{h,b,j'} + CTORThresh2^{ORL})$, where $j' \in J'^{30R}_{h,b}$, then the Conduct Test was failed for the dispatchable load at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{h,b}$;

11.5.1.2 Evaluate *start-up offers*: For all hours prior to and including the hour that meets the Constrained Area Conditions Test, if $SUDG_{h,b} > SUDGRef_{h,b}*(1 + CTSUThresh^{ORL})$, then the Conduct Test was failed for the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $SUOffer$ to $PARAMOR_{h,b}$ and $PARAME_{h,b}$;

11.5.1.3 Evaluate *speed no-load offers*: For all hours prior to and including the hour that meets the conditions test, if $SNL_{h,b} > SNLRef_{h,b} * (1 + CTSNLThresh^{ORL})$, then the Conduct Test was failed for the *resource* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $SNLOffer$ to $PARAMOR_{h,b}$ and $PARAME_{h,b}$; and

11.5.1.4 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all hours prior to and including the hour that meets the conditions test, for all $k \in K^{LTMLP}_{h,b}$, if

$PLTMLP_{h,b,k} > CTEnMinOffer$ and $PLTMLP_{h,b,k} > min(PLTMLPRef_{h,b,k'}*(1 + CTEnThresh1^{ORL}), PLTMLPRef_{h,b,k'} + CTEnThresh2^{ORL})$, where $k' \in K'^{E}_{h,b}$, then the Conduct Test was failed for the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_h^{ORL} and add $EnergyToMLP_k$ to $PARAMOR_{h,b}$ and $PARAME_{h,b}$.

11.5.2 The *day-ahead market calculation engine* shall perform the Conduct Test for global market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1. The *day-ahead market calculation engine* shall use the steps set out in section 11.5.1 using *resources* in $BCond_h^{GMP10S}$, $BCond_h^{GMP10N}$, and $BCond_h^{GMP30R}$ in place of $BCond_h^{10S}$, $BCond_h^{10N}$, and $BCond_h^{30R}$, respectively, and the applicable Conduct Test thresholds $CTORThresh1^{ORG}$, $CTORThresh2^{ORG}$, $CTSUThresh^{ORG}$, $CTSNLThresh^{ORG}$, $CTEnThresh1^{ORG}$, $CTEnThresh2^{ORG}$. The *resources* shall be assigned to the subset BCT_h^{ORG}.

11.5.3 If a *resource* is assigned to more than one of $BCond_h^{GMP10S}$, $BCond_h^{GMP10N}$, and $BCond_h^{GMP30R}$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.6 Outputs

11.6.1 Subject to section 11.6.2, the outputs of the Conduct Test shall include the following for each hour $h \in \{1, \ldots, 24\}$:

11.6.1.1 The set of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter* by condition type;

11.6.1.2 The *financial dispatch data parameters* that failed the Conduct Test for the *resource* at bus b; and

11.6.1.3 A revised set of *financial dispatch data parameters* for *resources* that failed a Conduct Test with *dispatch data* parameters that failed the Conduct Test replaced with *reference level values*. For *offers* for *energy* and *operating reserve* with multiple laminations:

11.6.1.3.1 if the *offer* lamination for *energy* that corresponds to the *minimum loading point* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *energy* up to the *minimum loading point*;

11.6.1.3.2 if one or more *offer* laminations for *energy* above the *minimum loading point* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *energy* up to and above the *minimum loading point*; and

11.6.1.3.3 if one or more *offer* laminations for *operating reserve* fails the Conduct Test, the *day-ahead market calculation engine* shall replace all *offer* laminations for *operating reserve*.

11.6.2 The *day-ahead market calculation engine* shall not replace the *financial dispatch data parameter* for a *resource* with that *resource's* applicable *reference level value* if the *financial dispatch data parameter* is less than the corresponding *reference level value*.

12 Reference Level Scheduling

12.1 Purpose

12.1.1 The *day-ahead market calculation engine* shall perform the Reference Level Scheduling algorithm where at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test in section 11.

12.1.2 The Reference Level Scheduling algorithm shall perform a *security*-constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, including *reference level value* for *resources* subject to section 12.2.2, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*.

12.2 Information, Sets, Indices and Parameters

12.2.1 Information, sets, indices and parameters used by the Reference Level Scheduling algorithm are described in section 3 and 4. In addition, the list of *resources* that failed the Conduct Test from section 11.6.1.1 and a revised set of *financial dispatch data parameters* from section 11.6.1.3, for those *resources* shall be used by the Reference Level Scheduling algorithm.

12.2.2 The Reference Level Scheduling algorithm shall use the *reference level value* that corresponds to any *financial dispatch data parameter* submitted for a *resource* that failed the Conduct Test.

12.3 Variables and Objective Function

12.3.1 The *day-ahead market calculation engine* shall solve for the variables listed in section 8.3.1.

12.3.2 The objective function for the Reference Level Scheduling algorithm shall be the same as the objective function in section 8.3.2, subject to section 12.4.

12.4 Constraints

12.4.1 The constraints in sections 8.4 through 8.7 apply in the Reference Level Scheduling algorithm, except that the sensitivities and limits considered for *IESO* internal transmission limits shall be those provided by the most recent *security* assessment function iteration of the Reference Level Scheduling algorithm.

12.5 Outputs

12.5.1 Outputs of the Reference Level Scheduling algorithm include *resource* schedules and commitments.

13 Reference Level Pricing

13.1 Purpose

13.1.1 The *day-ahead market calculation engine* shall perform the Reference Level Pricing algorithm whenever the Reference Level Scheduling algorithm has been performed.

13.1.2 The Reference Level Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, reference level values* for *resources* subject to section 13.2.2, and *resource* schedules and commitments produced by the Reference Level Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*.

13.2 Information, Sets, Indices and Parameters

13.2.1 Information, sets, indices and parameters used by the Reference Level Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedule and commitments from the Reference Level Scheduling algorithm shall be used by the Reference Level Pricing algorithm:

13.2.1.1 $SDG^{RLS}_{h,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K^{E}_{h,b}$;

13.2.1.2 $ODG^{RLS}_{h,b}$ designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1, .., 24\}$;

13.2.1.3 $S10SDG^{RLS}_{h,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K^{10S}_{h,b}$;

13.2.1.4 $S10NDG^{RLS}_{h,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K^{10N}_{h,b}$;

13.2.1.5 $S30RDG^{RLS}_{h,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, .., 24\}$ in association with lamination $k \in K^{30R}_{h,b}$; and

13.2.1.6 $OHO^{RLS}_{h,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour $h \in \{1, .., 24\}$.

13.2.2 The Reference Level Pricing algorithm shall use a *resource's reference level value* for any *financial dispatch data parameters* submitted by *registered market participants* that failed the Conduct Test.

13.3 Variables and Objective Function

13.3.1 The *day-ahead market calculation engine* shall solve for the variables set out in section 9.3.1.

13.3.2 The objective function used in the Reference Level Pricing algorithm shall be the same as the objective function set out in section 9.3.2, subject to section 13.4.

13.4 Constraints

13.4.1 The constraints that apply in the Reference Level Pricing algorithm shall be the same as the constraints in sections 9.4 through 9.8, with the following exceptions:

13.4.1.1 the marginal loss factors used in the *energy* balance constraint in section 9.7.1 shall be fixed to the marginal loss factors used in the last optimization function iteration of the Reference Level Scheduling alogorithm;

13.4.1.2 the sensitivities and limits in section 9.7.3 shall be replaced with the most recent *security* assessment function iteration of the Reference Level Pricing algorithm; and

13.4.1.3 for the constraints in section 9.8, the outputs from the As-Offered Scheduling algorithm shall be replaced with the outputs from the Reference Level Scheduling algorithm as follows:

13.4.1.3.1 $SDG_{h,b,k}^{AOS}$ shall be replaced by $SDG_{h,b,k}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{E}$;

13.4.1.3.2 $ODG_{h,b}^{AOS}$ shall be replaced by $ODG_{h,b}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{DG}$;

13.4.1.3.3 $S10SDG_{h,b,k}^{AOS}$ shall be replaced by $S10SDG_{h,b,k}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10S}$;

13.4.1.3.4 $S10NDG_{h,b,k}^{AOS}$ shall be replaced by $S10NDG_{h,b,k}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10N}$;

13.4.1.3.5 $S30RDG_{h,b,k}^{AOS}$ shall be replaced by $S30RDG_{h,b,k}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{30R}$; and

13.4.1.3.6 $OHO_{h,b}^{AOS}$ shall be replaced by $OHO_{h,b}^{RLS}$ for all $h \in \{1, . . , 24\}, b \in B^{HE}$.

13.5 Outputs

13.5.1 Outputs of the Reference Level Pricing algorithm include the following:

13.5.1.1 shadow prices; and

13.5.1.2 *locational marginal prices* and their components.

14 Price Impact Test

14.1 Purpose

14.1.1 The *day-ahead market calculation engine* shall perform the Price Impact Test whenever at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test.

14.1.2 The Price Impact Test shall:

14.1.2.1 compare the *locational marginal prices* for *energy* or *operating reserve* produced by the As-Offered Pricing algorithm with those produced by the Reference Level Pricing algorithm; and

14.1.2.2 consider the corresponding *offer* parameters to have failed the Price Impact Test if the difference in price in section 14.1.2.1 is greater than the applicable impact threshold in section 4.3.8.

14.2 Information, Sets, Indices and Parameters

14.2.1 Information, sets, indices and parameters for the Price Impact Test are described in sections 3 and 4. In addition, the following *locational marginal prices* from the As-Offered Pricing algorithm and the Reference Level Pricing algorithm shall be used by the Price Impact Test:

14.2.1.1 $LMP_{h,b}^{AOP}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the As-Offered Pricing algorithm;

14.2.1.2 $L30RP_{h,b}^{AOP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the As-Offered Pricing algorithm;

14.2.1.3 $L10NP_{h,b}^{AOP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the As-Offered Pricing algorithm;

14.2.1.4 $L10SP^{AOP}_{h,b}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the As-Offered Pricing algorithm;

14.2.1.5 $LMP^{RLP}_{h,b}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the Reference Level Pricing algorithm;

14.2.1.6 $L30RP^{RLP}_{h,b}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the Reference Level Pricing algorithm;

14.2.1.7 $L10NP^{RLP}_{h,b}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the Reference Level Pricing algorithm; and

14.2.1.8 $L10SP^{RLP}_{h,b}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in hour $h \in \{1,..,24\}$ from the Reference Level Pricing algorithm.

14.3 Variables

14.3.1 The *day-ahead market calculation engine* shall apply the Price Impact Test as set out in sections 14.4 and 14.5 for the *resources* identified in accordance with section 10.3.1, to identify:

14.3.1.1 A set of *resources* that failed the Price Impact Test for each condition for all hours $h \in \{1,..,24\}$, where:

14.3.1.1.1 BIT^{NCA}_{h} designates the *resources* in a *narrow constrained area* that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.2 BIT^{DCA}_{h} designates the *resources* in a *dynamic constrained area* that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.3 BIT^{BCA}_{h} designates the *resources* in a broad constrained area that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.4 BIT_h^{GMP} designates the *resources* that failed the global market power (*energy*) Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.5 BIT_h^{ORL} designates the *resources* that failed the local market power (*operating reserve*) Price Impact Test for at least one type of *locational marginal price* for *operating reserve*;

14.3.1.1.6 BIT_h^{ORG} designates the *resources* that failed the global market power (*operating reserve*) Price Impact Test for at least one type of *locational marginal price* for *operating reserve*; and

14.3.1.1.7 $LMPIT_{h,b}$ designates the locational marginal price that failed the Price Impact Test for bus $b \in BIT_h^{NCA} \cup BIT_h^{DCA} \cup BIT_h^{BCA} \cup BIT_h^{GMP} \cup BIT_h^{ORL} \cup BIT_h^{ORG}$ in hour h; and

14.3.1.2 *Locational marginal prices* for *energy* and *operating reserve* for each *resource* at bus $b \in B^{DG} \cup B^{DL}$ that failed the Price Impact Test, where:

14.3.1.2.1 $EnergyLMP$ designates that the *locational marginal price* for *energy* failed the Price Impact Test;

14.3.1.2.2 $OR10SLMP$ designates that the *locational marginal price* for synchronized *ten-minute operating reserve* failed the Price Impact Test;

14.3.1.2.3 $OR10NLMP$ designates that the *locational marginal price* for non-synchronized *ten-minute operating reserve* failed the Price Impact Test; and

14.3.1.2.4 $OR30RLMP$ designates that the *locational marginal price* for *thirty-minute operating reserve* failed the Price Impact Test.

14.4 Price Impact Test for Energy

14.4.1 The *day-ahead market calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *energy* in section 11.6.1.1, as follows:

14.4.1.1 For local market power for *energy*:

14.4.1.1.1 For each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{NCA}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} * (1 + ITThresh1^{NCA}), LMP_{h,b}^{RLP} +$

$ITThresh2^{NCA}$), the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{NCA} and add $EnergyLMP$ to $LMPIT_{h,b}$;

14.4.1.1.2 For each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{DCA}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} * (1 + ITThresh1^{DCA}), LMP_{h,b}^{RLP} + ITThresh2^{DCA})$, the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{DCA} and add $EnergyLMP$ to $LMPIT_{h,b}$; and

14.4.1.1.3 For each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{BCA}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} * (1 + ITThresh1^{BCA}), LMP_{h,b}^{RLP} + ITThresh2^{BCA})$, the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{BCA} and add $EnergyLMP$ to $LMPIT_{h,b}$.

14.4.1.2 For global market power for *energy*:

14.4.1.2.1 For each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{GMP}$, if $LMP_{h,b}^{AOP} > min(LMP_{h,b}^{RLP} * (1 + ITThresh1^{GMP}), LMP_{h,b}^{RLP} + ITThresh2^{GMP})$, the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{GMP} and add $EnergyLMP$ to $LMPIT_{h,b}$.

14.5 Price Impact Test for Operating Reserve

14.5.1 The *day-ahead market calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *operating reserve* in section 11.6.1.1, as follows:

14.5.1.1 For local market power for *operating reserve*, for each hour $h \in \{1, . . , 24\}$ and $b \in BCT_h^{ORL}$:

14.5.1.1.1 If $L30RP_{h,b}^{AOP} > L30RP_{h,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{ORL} and add $OR30RLMP$ to $LMPIT_{h,b}$;

14.5.1.1.2 If $L10NP_{h,b}^{AOP} > L10NP_{h,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{ORL} and add $OR10NLMP$ to $LMPIT_{h,b}$; and

14.5.1.1.3 If $L10SP_{h,b}^{AOP} > L10SP_{h,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{ORL} and add $OR10SLMP$ to $LMPIT_{h,b}$.

14.5.1.2 For global market power for *operating reserve*, for each hour $h \in \{1,..,24\}$ and $b \in BCT_h^{ORG}$:

14.5.1.2.1 If $L30RP_{h,b}^{AOP} > min(L30RP_{h,b}^{RLP} * (1 + ITThresh1^{ORG}), L30RP_{h,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{ORG} and add $OR30RLMP$ to $LMPIT_{h,b}$;

14.5.1.2.2 If $L10NP_{h,b}^{AOP} > min(L10NP_{h,b}^{RLP} * (1 + ITThresh1^{ORG}), L10NP_{h,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* to subset BIT_h^{ORG} and add $OR10NLMP$ to $LMPIT_{h,b}$; and

14.5.1.2.3 If $L10SP_{h,b}^{AOP} > min(L10SP_{h,b}^{RLP} * (1 + ITThresh1^{ORG}), L10SP_{h,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus b and the *day-ahead market calculation engine* shall assign the *resource* BIT_h^{ORG} and add $OR10SLMP$ to $LMPIT_{h,b}$.

14.6 Revised Financial Dispatch Data Parameter Determination

14.6.1.1 A *resource* that fails the Price Impact Test shall have its *financial dispatch data parameters* revised as follows:

14.6.1.1 If the *resource* has failed a Price Impact Test for *energy* and is in BIT_h^{NCA}, BIT_h^{DCA}, BIT_h^{BCA}, or BIT_h^{GMP}, the *dispatch data* parameters in $PARAME_{h,b}$ shall be used to determine the *dispatch data* parameters that shall be replaced.

14.6.1.2 If the *resource* has failed a Price Impact Test for *operating reserve* and is in BIT_h^{ORL} or BIT_h^{ORG}, the *dispatch data* parameters in $PARAMOR_{h,b}$ shall be used to determine the *dispatch data* parameters that shall be replaced.

14.6.1.3 If a *non-quick-start resource* has failed a Price Impact Test in any hour, the *commitment cost parameters* that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that hour. For any hours prior, any *commitment cost parameters* for that *resource* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level values* in those hours. This is expressed as:

14.6.1.3.1 For each hour $h \in \{1, . . , 24\}$ and all $b \in B^{NQS}$ such that $b \in BIT_h^{NCA} \cup BIT_h^{DCA} \cup BIT_h^{BCA} \cup BIT_h^{GMP}$, for hours prior to and including the hour that failed the Price Impact Test, $H \in \{1, . . , h\}$, if $b \in BCT_H^{NCA} \cup BCT_H^{DCA} \cup BCT_H^{BCA} \cup BCT_H^{GMP}$ and $PARAME_{H,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, these parameters shall be replaced with *reference levels*.

14.6.1.4 Section 14.6.1.3 shall apply to the tests for local market power and global market power for *operating reserve*, except $PARAMOR_{H,b}$ shall be checked in place of $PARAME_{H,b}$.

14.6.1.5 If a *resource* is in a *narrow constrained area* or a *dynamic constrained area* and has failed a Price Impact Test, each *resource* in the same *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its *offer* data replaced with its applicable *reference level value* for that hour. For each hour $h \in \{1, . . , 24\}$:

14.6.1.5.1.1 if BIT_h^{NCA} includes one or more *resource* in a *narrow constrained area*, n, each *resource* $b \in BCT_h^{NCA}$ for the *narrow constrained area*, n, shall have the parameters in $PARAME_{h,b}$ replaced with its *reference level values*; and

14.6.1.5.1.2 if BIT_h^{DCA} includes one or more *resources* in a *dynamic constrained area*, d, each *resource* $b \in BCT_h^{DCA}$ for *dynamic constrained area*, d, shall have the parameters in $\text{PARAME}_{h,b}$ replaced with its *reference level values*.

14.6.1.6 If a *non-quick-start resource* in a *narrow constrained area* or a *dynamic constrained area* has failed a Price Impact Test, each *non-quick start resource* in the *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its commitment cost parameters replaced with its applicable *reference level value* for that hour. For any hours prior, if a *non-quick-start resource* in that *narrow constrained area* or *dynamic constrained area* has a commitment cost parameter that failed the Conduct Test, that commitment cost parameter shall be replaced with the *resource's* applicable *reference level value* in those hours. This is expressed as:

14.6.1.6.1 For all hours up to the hour in which a *resource* failed the Price Impact Test for a *narrow constrained area*, for all $b \in BCT_h^{NCA}$, if $PARAME_{h,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.6.1.6.2 For all hours up to the hour in which a *resource* failed the Price Impact Test for a *dynamic constrained area*, for all $b \in BCT_h^{DCA}$, if $PARAME_{h,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.6.1.7 If a *resource* fails the local market power for *operating reserve* Price Impact Test, all *resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test for at least one parameter shall have the parameter that failed the Conduct Test replaced with the *resource's* applicable *reference level value* for that hour. This is expressed as:

14.6.1.7.1 For each hour $h \in \{1, .., 24\}$, if BIT_h^{ORL} includes one or more *resources* in *operating reserve* region, r, all *resources*, $b \in BIT_h^{ORL}$ for *operating reserve* region, r, shall have the parameters in $PARAMOR_{h,b}$ replaced with *reference level values*.

14.6.1.8 If a *non-quick start resource* fails the local market power for *operating reserve* Price Impact Test in any hour, the *commitment cost parameters* for all *non-quick start resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that hour. For any hours prior, any *commitment cost parameters* of *non-*

quick start resources that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level value* in those hours. This is expressed as:

14.6.1.8.1 For all hours up to the hour in which a *resource* failed the Price Impact Test for r, for all $b \in BCT_h^{ORL}$, if $PARAME_{h,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.7 Outputs

14.7.1 The *day-ahead market calculation engine* shall prepare the following outputs for each hour $h \in \{1, \ldots, 24\}$:

14.7.1.1 The set of *resources* that failed the Price Impact Test, by condition, in accordance to sections 14.4 and 14.5;

14.7.1.2 The *locational marginal prices* for *energy* and *operating reserve* that failed the Price Impact Test for each *resource* at bus b in accordance to sections 14.4 and 14.5; and

14.7.1.3 A revised set of *offer* data for *resources* that failed the Price Impact Test, replacing *offer* data that failed the Conduct Test with the applicable *reference level values*, in accordance with section 14.6.

14.7.2 The *day-ahead market calculation engine* shall not replace *financial dispatch data parameters* for a *resource* with that *resource's* applicable *reference level value* if the *dispatch data* is less than the *reference level value*.

15 Mitigated Scheduling

15.1 Purpose

15.1.1 The *day-ahead market calculation engine* shall perform the Mitigated Scheduling algorithm if at least one *resource* failed the Price Impact Test in section 14.

15.1.2 The Mitigated Scheduling algorithm shall perform a *security*-constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, including *resource reference level values* subject to section 15.2.2, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

15.2 Information, Sets, Indices and Parameters

15.2.1 Information, sets, indices and parameters used by the Mitigated Scheduling algorithm are described in section 3 and 4. In addition, the Mitigated Scheduling algorithm shall use the list of *resources* that failed the Price Impact Test and a revised set of *financial dispatch data parameters* for those *resources*.

15.2.2 For *resources* identified in section 14.7.1, the Mitigated Scheduling algorithm shall use *reference level value* for any *financial dispatch data parameters* that failed the Conduct Test.

15.3 Variables, Objective Function and Constraints

15.3.1 The *day-ahead market calculation engine* shall solve for the variables set out in section 8.3.1.

15.3.2 The objective function for the Mitigated Scheduling algorithm shall be the same as the objective function in section 8.3.2, subject to the constraints in sections 8.4 through 8.7. The sensitivities and limits used in section 8.7.3 shall be replaced with those provided by the most recent *security* assessment function iteration in the Mitigated Scheduling algorithm.

15.4 Outputs

15.4.1 Outputs of the Mitigated Scheduling algorithm include *resource* schedules and commitments.

16 Mitigated Pricing

16.1 Purpose

16.1.1 The *day-ahead market calculation engine* shall perform the Mitigated Pricing algorithm if the *day-ahead market calculation engine* performs the Mitigated Scheduling algorithm.

16.1.2 The Mitigated Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, resource reference level value* subject to section

16.2.2, and *resource* schedules and commitments produced by the Mitigated Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

16.2 Information, Sets, Indices and Parameters

16.2.1 Information, sets, indices and parameters used by the Mitigated Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedules and commitments from the Mitigated Scheduling algorithm shall be used by the Mitigated Pricing algorithm:

16.2.1.1 $SDG^{MS}_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{E}_{h,b}$;

16.2.1.2 $ODG^{MS}_{h,b}$ designates whether a *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1,..,24\}$;

16.2.1.3 $S10SDG^{MS}_{h,b,k}$ designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10S}_{h,b}$;

16.2.1.4 $S10NDG^{MS}_{h,b,k}$ designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10N}_{h,b}$;

16.2.1.5 $S30RDG^{MS}_{h,b,k}$ designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{30R}_{h,b}$; and

16.2.1.6 $OHO^{MS}_{h,b}$ designates whether a *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour $h \in \{1,..,24\}$.

16.2.2 For each *resource* identified in section 14.7.1, the Mitigated Pricing algorithm shall use such *resource's reference level value* for any *financial dispatch data parameters* that failed the Conduct Test.

16.3 Variables and Objective Function

16.3.1 The *day-ahead market calculation engine* shall solve for the variables listed in section 9.3.1.

16.3.2 The objective function for the Mitigated Pricing algorithm shall be the same as the objective function in section 9.3.2, subject to section 16.4.

16.4 Constraints

16.4.1 The constraints that apply in the Mitigated Pricing algorithm shall be the same as the constraints in sections 9.4 through 9.8, with the following exceptions:

16.4.1.1 The marginal loss factors used in the *energy* balance constraint in section 9.7.1 shall be fixed to the marginal loss factors used in the last iteration of the optimization function in the Mitigated Scheduling algorithm.

16.4.1.2 The sensitivities and limits used in section 9.7.3 shall be replaced with those provided by the most recent *security* assessment function iteration in the Mitigated Pricing algorithm.

16.4.1.3 For the constraints in section 9.8, the outputs from the As-Offered Scheduling algorithm shall be replaced with the outputs from the Mitigated Scheduling algorithm as follows:

16.4.1.3.1 $SDG_{h,b,k}^{AOS}$ shall be replaced by $SDG_{h,b,k}^{MS}$ for all $h \in \{1, \ldots, 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{E}$;

16.4.1.3.2 $ODG_{h,b}^{AOS}$ shall be replaced by $ODG_{h,b}^{MS}$ for all $h \in \{1, \ldots, 24\}, b \in B^{DG}$;

16.4.1.3.3 $S10SDG_{h,b,k}^{AOS}$ shall be replaced by $S10SDG_{h,b,k}^{MS}$ for all $h \in \{1, \ldots, 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10S}$;

16.4.1.3.4 $S10NDG_{h,b,k}^{AOS}$ shall be replaced by $S10NDG_{h,b,k}^{MS}$ for all $h \in \{1, \ldots, 24\}, b \in B^{ELR} \cup B^{HE}, k \in K_{h,b}^{10N}$;

16.4.1.3.5 $S30RDG^{AOS}_{h,b,k}$ shall be replaced by $S30RDG^{MS}_{h,b,k}$ for all $h \in \{1, \ldots, 24\}, b \in B^{ELR} \cup B^{HE}, k \in K^{30R}_{h,b}$; and

16.4.1.3.6 $OHO^{AOS}_{h,b}$ shall be replaced by $OHO^{MS}_{h,b}$ for all $h \in \{1, \ldots, 24\}, b \in B^{HE}$.

16.5 Outputs

16.5.1 Outputs of the Mitigated Pricing algorithm include the following:

16.5.1.1 Shadow prices; and

16.5.1.2 *Locational marginal prices* and their components.

17 Pass 2: Reliability Scheduling and Commitment

17.1 Purpose

17.1.1 Pass 2 shall use *market participant* and *IESO* inputs along with *resource* and system constraints to determine a set of *resource* schedules and commitments. Pass 2 shall consist of the Reliability Scheduling algorithm described in section 18.

18 Reliabilty Scheduling

18.1 Purpose

18.1.1 The Reliability Scheduling algorithm shall use *dispatch data* submitted by *registered market participants* and perform a *security*-constrained unit commitment and economic *dispatch* to meet the *IESO's* peak province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next day to minimize the cost of additional commitments.

18.2 Information, Sets, Indices and Parameters

18.2.1 Information sets, indices and parameters used by the Reliability Scheduling algorithm are described in sections 3 and 4. The Reliability Scheduling algorithm shall also use the following:

18.2.1.1 *resource* schedules, commitments, and *locational marginal prices* from Pass 1, where:

18.2.1.1.1 $SXL^{1}_{h,d,j}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to export at *intertie zone* bus $d \in DX$ in hour $h \in \{1,..,24\}$ in association with lamination $j \in J^{E}_{h,d}$;

18.2.1.1.2 $SDG^{1}_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_{b}$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{E}_{h,b}$;

18.2.1.1.3 $ODG^{1}_{h,b}$ designates whether a *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1,..,24\}$;

18.2.1.1.4 $S10SDG^{1}_{h,b,k}$ designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10S}_{h,b}$;

18.2.1.1.8 $S10NDG^{1}_{h,b,k}$ designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10N}_{h,b}$;

18.2.1.1.6 $S30RDG^{1}_{h,b,k}$ designates the amount of *thirty-minute operating reserve* that a qualified *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{30R}_{h,b}$;

18.2.1.1.7 $SIG^{1}_{h,d,k}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to import at *intertie zone* bus $d \in DI$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{E}_{h,d}$; and

18.2.1.1.8 $LMP^{1}_{h,b}$ designates the *locational marginal price* in hour $h \in \{1,..,24\}$ at bus $b \in B^{ELR} \cup B^{HE}$; and

18.2.1.2 the buses identifying either single *energy limited resources* or multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay*, and the subset of *resources* with a binding *maximum daily energy limit* constraint from Pass 1:

18.2.1.2.1 $B^{LIM} = B^{ELR} \cup \{B^{HE}_{s}$ for all $s \in SHE\}$ designates the set of buses identifying either *energy limited resources* or *dispatchable* hydroelectric *generation resources* sharing a *maximum daily energy limit*; and

18.2.1.2.2 $B^{BND} \subseteq B^{LIM}$ designates the subset of buses identifying either *energy limited resources*, or *dispatchable* hydroelectric *generation resources* sharing a *maximum daily energy limit*, with a binding *maximum daily energy limit* constraint from Pass 1, where:

a *maximum daily energy limit* shall be considered binding if the criteria in sections 9.8.2 and 9.8.3.6 are met using $ODG^{1}_{h,b}$, $SDG^{1}_{h,b,k}$, $S10SDG^{1}_{h,b,k}$, $S10NDG^{1}_{h,b,k}$ and $S30RDG^{1}_{h,b,k}$.

18.2.2 The Reliability Scheduling algorithm shall use *reference level value* for any *financial dispatch data parameters* that failed the Conduct Test associated with *resources* identified in section 14.7.

18.2.3 *Dispatchable loads*, *non-dispatchable generation resources*, and the *energy* offered above *minimum loading point* for *dispatchable generation resources* shall be evaluated in the Reliability Scheduling algorithm as follows:

18.2.3.1 $PRucDL_{h,b,j}$ designates the *energy* price for incremental *energy* consumption in hour $h \in \{1,..,24\}$ at *dispatchable load* bus $b \in B^{DL}$ in association with *bid* lamination $j \in J^{E}_{h,b}$, where:

$$PRucDL_{h,b,j} = min(n, PDL_{h,b,j});$$

18.2.3.2 $PRuc10SDL_{h,b,j}$ designates the price of being scheduled to provide synchronized *ten-minute operating reserve* in hour $h \in \{1,..,24\}$ at *dispatchable load* bus $b \in B^{DL}$ in association with *offer* lamination $j \in J^{10S}_{h,b}$, where:

$$PRuc10SDL_{h,b,j} = min(n, P10SDL_{h,b,j});$$

18.2.3.3 $PRuc10NDL_{h,b,j}$ designates the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in hour $h \in \{1, . . , 24\}$ at *dispatchable load* bus $b \in B^{DL}$ in association with *offer* lamination $j \in J^{10N}_{h,b}$, where:

$$PRuc10NDL_{h,b,j} = min(n,P10NDL_{h,b,j});$$

18.2.3.4 $PRuc30RDL_{h,b,j}$ designates the price of being scheduled to provide *thirty-minute operating reserve* in hour $h \in \{1, . . , 24\}$ at *dispatchable load* bus $b \in B^{DL}$ in association with *offer* lamination $j \in J^{30R}_{h,b}$, where:

$$PRuc30RDL_{h,b,j} = min(n, P30RDL_{h,b,j});$$

18.2.3.5 $PRucNDG_{h,b,k}$ designates the *energy* price for incremental generation in hour $h \in \{1, . . , 24\}$ at *non-dispatchable generation resource* bus $b \in B^{NDG}$ in association with *offer* lamination $k \in K^{E}_{h,b}$, where:

$$PRucNDG_{h,b,k} = min(n, PNDG_{h,b,k});$$

18.2.3.6 $PRucDG_{h,b,k}$ designates the *energy* price for incremental generation in hour $h \in \{1, . . , 24\}$ at *dispatchable generation resource* bus $b \in B^{DG}$ in association with *offer* lamination $k \in K^{E}_{h,b}$, where:

$$PRucDG_{h,b,k} = min(n, PDG_{h,b,k});$$

18.2.3.7 $PRuc10SDG_{h,b,k}$ designates the price of being scheduled to provide synchronized *ten-minute operating reserve* in hour $h \in \{1, . . , 24\}$ at *dispatchable generation resource* bus $b \in B^{DG}$ in association with *offer* lamination $k \in K^{10S}_{h,b}$, where:

$$PRuc10SDG_{h,b,k} = min(n, P10SDG_{h,b,k});$$

18.2.3.8 $PRuc10NDG_{h,b,k}$ designates the price of being scheduled to provide non-synchronized *ten-minute operating reserve* in hour $h \in \{1, . . , 24\}$ at *dispatchable generation resource* bus $b \in B^{DG}$ in association with *offer* lamination $k \in K^{10N}_{h,b}$, where:

$$PRuc10NDG_{h,b,k} = min(n, P10NDG_{h,b,k});$$

18.2.3.9 $PRuc30RDG_{h,b,k}$ designates the price of being scheduled to provide *thirty-minute operating reserve* in hour $h \in \{1, . . , 24\}$ at *dispatchable* generation bus $b \in B^{DG}$ in association with *offer* lamination $k \in K^{30R}_{h,b}$, where:

$$PRuc30RDG_{h,b,k} = min(n, P30RDG_{h,b,k});$$

where:

n = \$0.10/MWh;

18.2.4 For the set of *resources* identified in the buses in section 18.2.1.2, incremental quantities of *energy* at or above *minimum loading point* shall be evaluated in the Reliability Scheduling algorithm as follows:

18.2.4.1 $Q1DG_{h,b,k}$ designates an incremental quantity of *energy* that a *resource* may be scheduled to provide in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^E_{h,b}$ and corresponding to the Pass 1 scheduled portion of the lamination, where:

$$Q1DG_{h,b,k} = SDG^1_{h,b,k};$$

18.2.4.2 $P1DG_{h,b,k}$ designates the price for the incremental quantity of *energy* that a *resource* may be scheduled to provide in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^E_{h,b}$ and corresponding to the Pass 1 scheduled portion of the lamination, where:

$$P1DG_{h,b,k} = min\left(PDG_{h,b,k}, -LMP^1_{h,b}\right);$$

18.2.4.3 $Q2DG_{h,b,k}$ designates an incremental quantity of *energy* that a *resource* may be scheduled to provide in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^E_{h,b}$ and corresponding to the Pass 1 unscheduled portion of the lamination, where:

$$Q2DG_{h,b,k} = QDG_{h,b,k} - SDG^1_{h,b,k};$$ and

18.2.4.4 $P2DG_{h,b,k}$ designates the price for the incremental quantity of *energy* that a *resource* may be scheduled to provide in hour $h \in \{1,..,24\}$ in association with *offer* lamination $k \in K^E_{h,b}$ and corresponding to the Pass 1 unscheduled portion of the lamination, where:

$$P2DG_{h,b,k} = \begin{cases} max(n, PDG_{h,b,k} - LMP^1_{h,b}) & if\ b \in B^{BND} \\ min(n, PDG_{h,b,k}) & otherwise \end{cases}.$$

18.3 Variable and Objective Function

18.3.1 The *day-ahead market calculation engine* shall solve for the variables listed in section 8.3.1.

18.3.2 The objective function for the Reliability Scheduling algorithm shall be the same as the objective function in section 8.3.2, with the following exceptions:

18.3.2.1 The *day-ahead market calculation engine* shall remove the variables for *price responsive loads* ($SPRL_{h,b,j}$), *virtual transaction bids* ($PVB_{h,v,j}$, $QVB_{h,v,j}$), and *virtual transaction offers* ($PVO_{h,v,k}$, $QVO_{h,v,k}$) from the objective function;

18.3.2.2 The *day-ahead market calculation engine* shall add the following variables to the objective function:

18.3.2.2.1 $S1DG_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{LIM}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{E}_{h,b}$ corresponding to the Pass 1 scheduled portion of the lamination; and

18.3.2.2.2 $S2DG_{h,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{LIM}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{E}_{h,b}$ corresponding to the Pass 1 unscheduled portion of the lamination;

18.3.2.3 The objective function coefficients for *dispatchable loads*, *non-dispatchable generation resources* and *dispatchable generation resources* shall be modified to reflect the price of incremental *energy* from such *resources* as specified in section 18.2.3; and

18.3.2.4 The objective function coefficients for single *energy limited resources* and multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall be modified to reflect the pricing of the Pass 1 scheduled and unscheduled portions as specified in section 18.2.4.

18.3.3 The objective function for the Reliability Scheduling algorithm shall minimize the cost of additional commitments by maximizing the following expression:

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

where:

$$ObjDL_h = \sum_{b \in B^{DL}} \left(\begin{array}{c} \sum_{j \in J^{E}_{h,b}} SDL_{h,b,j} \cdot PRucDL_{h,b,j} - \sum_{j \in J^{10S}_{h,b}} S10SDL_{h,b,j} \cdot PRuc10SDL_{h,b,j} - \\ \sum_{j \in J^{10N}_{h,b}} S10NDL_{h,b,j} \cdot PRuc10NDL_{h,b,j} - \sum_{j \in J^{30R}_{h,b}} S30RDL_{h,b,j} \cdot PRuc30RDL_{h,b,j} \end{array} \right)$$

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

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

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

$$\begin{aligned} ObjDG_h &= \sum_{b \in B^{DG},\ b \notin B^{LIM}} \left(\sum_{k \in K^{E}_{h,b}} SDG_{h,b,k} \cdot PRucDG_{h,b,k} \right) \\ &+ \sum_{b \in B^{LIM}} \left(\sum_{k \in K^{E}_{h,b}} \left(S1DG_{h,b,k} \cdot P1DG_{h,b,k} + S2DG_{h,b,k} \cdot P2DG_{h,b,k} \right) \right) \\ &+ \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K^{10S}_{h,b}} S10SDG_{h,b,k} \cdot PRuc10SDG_{h,b,k} + \\ \sum_{k \in K^{10N}_{h,b}} S10NDG_{h,b,k} \cdot PRuc10NDG_{h,b,k} + \sum_{k \in K^{30R}_{h,b}} S30RDG_{h,b,k} \cdot PRuc30RDG_{h,b,k} \end{array} \right) \\ &+ \sum_{b \in B^{NQS}} \left(ODG_{h,b} \cdot MGODG_{h,b} + IDG_{h,b} \cdot SUDG_{h,b} \right) \end{aligned}$$

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

18.3.3.1 The tie-breaking (TB_h) and the violation cost ($ViolCost_h$) terms used shall be the ones defined in sections 8.3.1 and 8.3.2.

18.4 Constraints

18.4.1 The Reliability Scheduling algorithm optimization shall apply the constraints described in sections 18.5 through 18.7 and 18.8.

18.5 Dispatch Data Constraints Applying to Individual Hours

18.5.1 Scheduling Variable Bounds and Commitment Status Variables

18.5.1.1 The constraints shall be the same as in section 8.5.1 with the following exceptions:

18.5.1.1.1 the constraints applying to *price responsive loads* in section 8.5.1.6 shall be removed; and

18.5.1.1.2 the constraints applying to *virtual transaction bids* and *offers* in section 8.5.1.6 shall be removed.

18.5.2 Resource Minimums and Maximums

18.5.2.1 The constraints in section 8.5.2 shall apply for *dispatchable loads*, *non-dispatchable generation resources* and inadvertent payback transactions.

18.5.2.2 The constraints in section 8.5.2 shall apply for *dispatchable generation resources*, except the alternative forecast ($AFG_{h,b}$) is replaced with the *IESO*'s centralized forecast ($FG_{h,b}$). That is:

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

and

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

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

$$AdjMinDG_{h,b} \leq MinQDG_b \cdot ODG_{h,b} + \sum_{k \in K^E_{h,b}} SDG_{h,b,k} \leq AdjMaxDG_{h,b}$$

18.5.3 Operating Reserve Requirements

18.5.3.1 The constraints in section 8.5.4 shall apply for *operating reserve* requirements.

18.5.4 Pseudo-Units

18.5.4.1 The constraints in section 8.5.5 shall apply for *pseudo-units*.

18.5.5 Dispatchable Hydroelectric Generation Resources

18.5.5.1 The constraints in section 8.5.6 shall apply for *dispatchable* hydroelectric *generation resources*.

18.5.6 Wheeling Through Transactions

18.5.6.1 The constraints in section 8.5.7 shall apply for wheeling through transactions.

18.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

18.6.1 Energy Ramping

18.6.1.1 The constraints in section 8.6.1 shall apply for *energy* ramping.

18.6.2 Operating Reserve Ramping

18.6.2.1 The constraints in section 8.6.2 shall apply for *operating reserve* ramping.

18.6.3 Non-Quick-start Resources

18.6.3.1 The constraints in section 8.6.3 shall apply for *non-quick start resources*.

18.6.4 Energy Limited Resources

18.6.4.1 The constraints in section 8.6.4 shall apply for *energy limited resources*.

18.6.5 Dispatchable Hydroelectric Generation Resources

18.6.5.1 The constraints in section 8.6.5 shall apply for *dispatchable* hydroelectric *generation resources*.

18.7 Constraints for Reliability Requirements

18.7.1 Energy Balance

18.7.1.1 The constraint in section 8.7.1 shall apply in the Reliability Scheduling algorithm, with the following exceptions:

18.7.1.1.1 *price responsive loads* shall be removed from the total amount of scheduled *energy* withdrawals, $With_{h,b}$, in section 8.7.1.1;

18.7.1.1.2 the net withdrawal for *virtual transaction zones*, $VWith_{h,m}$, in sections 8.7.1.2 and 8.7.1.6 shall be removed; and

18.7.1.1.3 the Reliability Scheduling algorithm shall use the *IESO's* peak province-wide non-*dispatchable demand* forecast (PFL_h), in place of the *IESO's* average province-wide non-*dispatchable* demand forecast (AFL_h).

18.7.1.2 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in hour $h \in \{1,..,24\}$, $With_{h,b}$, shall be:

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

18.7.1.3 The total amount of *energy* withdrawals scheduled at *intertie zone* bus $d \in DX$ in hour $h \in \{1,..,24\}$, $With_{h,d}$, shall be:

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

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

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

where:

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

and

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

18.7.1.5 The total amount of *energy* injections scheduled at *intertie zone* bus $d \in DI$ in hour $h \in \{1,..,24\}$, $Inj_{h,d}$, shall be:

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

18.7.1.6 *Energy* injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor from the *security* assessment function to reflect the losses or reduction in losses that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted *energy* injections and withdrawals must then be equal to each other, after taking into account the adjustment for any discrepancy between total and marginal losses. Load or generation reduction associated with the *demand* constraint violation shall be subtracted from the total load or generation to allow the *day-ahead market calculation engine* to produce a solution. For hour $h \in \{1,..,24\}$:

$$PFL_h + \sum_{b \in B^{DL} \cup B^{HDR}} (1 + MglLoss_{h,b}) \cdot With_{h,b} + \sum_{d \in DX} (1 + MglLoss_{h,d}) \cdot With_{h,d} - \sum_{i=1..N_{LdViol_h}} SLdViol_{h,i} = \sum_{b \in B^{NDG} \cup B^{DG}} \left(1 + MglLoss_{h,b}\right) \cdot Inj_{h,b} + \sum_{d \in DI} \left(1 + MglLoss_{h,d}\right) \cdot Inj_{h,d} - \sum_{i=1..N_{GenViol_h}} SGenViol_{h,i} + LossAdj_h.$$

18.7.2 Operating Reserve Requirements

18.7.2.1 The constraints in section 8.7.2 shall apply for *operating reserve*.

18.7.3 IESO Internal Transmission Limits

18.7.3.1 The constraints in section 8.7.3 shall apply for *IESO* internal transmission limits. The sensitivities and limits applied shall be provided by the most recent *security* assessment function iteration of the Reliability Scheduling algorithm, with the following exceptions:

18.7.3.2 The terms for *price responsive loads* in sections 8.7.3.3 and 8.7.3.4 shall be removed; and

18.7.3.3 The terms for *bids* and *offers* for *virtual transactions* in sections 8.7.3.3 and 8.7.3.4 shall be removed.

18.7.4 Intertie Limits

18.7.4.1 The constraints in section 8.7.4 shall apply for *intertie* limits.

18.7.5 Penalty Price Variable Bounds

18.7.5.1 The constraints in section 8.7.5 shall apply for penalty price variable bounds.

18.8 Constraints to Respect Pass 1 Decisions

18.8.1 The Reliability Scheduling algorithm shall not schedule *energy* import schedules for *boundary entity resources* below those import schedules determined in Pass 1. For all hours $h \in \{1,..,24\}$ and *intertie zone* buses $d \in DI$ that are not part of a wheeling through transaction:

$$\sum_{k \in K^E_{h,d}} SIG_{h,d,k} \geq \sum_{k \in K^E_{h,d}} SIG^1_{h,d,k}$$

18.8.2 The Reliability Scheduling algorithm shall not schedule *energy* export schedules for *boundary entity resources* above those export schedules determined in Pass 1. For all hours $h \in \{1,..,24\}$ and *intertie zone* buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J^E_{h,d}} SXL_{h,d,j} \leq \sum_{j \in J^E_{h,d}} SXL^1_{h,d,j}$$

18.8.3 The Reliability Scheduling algorithm shall not de-commit *dispatchable generation resources* committed in Pass 1. For all hours $h \in \{1,..,24\}$ and buses $b \in B^{DG}$:

$$ODG_{h,b} \geq ODG^1_{h,b}$$

18.8.4 For single *energy limited resources* and multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay*, the Reliability Scheduling algorithm shall ensure the schedule for each *offer* lamination is equal to the schedules corresponding to the Pass 1 scheduled and unscheduled portions. For all buses $b \in B^{LIM}$, hours $h \in \{1,..,24\}$ and *offer* laminations $k \in K^E_{h,b}$:

$$SDG_{h,b,k} = S1DG_{h,b,k} + S2DG_{h,b,k}$$

18.8.5 The *generation resource* schedules for the Pass 1 scheduled and unscheduled portions of the lamination shall respect the incremental quantity of *energy* beyond the *minimum loading point* that may be scheduled. For all buses $b \in B^{LIM}$, hours $h \in \{1,..,24\}$ and *offer* laminations $k \in K^E_{h,b}$:

$$0 \leq S1DG_{h,b,k} \leq Q1DG_{h,b,k}$$

and

$$0 \leq S2DG_{h,b,k} \leq Q2DG_{h,b,k}$$

18.9 Outputs

18.9.1 Outputs of the Reliability Scheduling algorithm shall include *resource* schedules and commitments.

19 Pass 3: DAM Scheduling and Pricing

19.1 Purpose

19.1.1 Pass 3 shall use *market participant* and *IESO* inputs along with *resource* and system constraints to determine a set of *resource* schedules, commitments, and shadow prices, as well as a set of schedules and *locational marginal prices* that shall be used for *settlement*. Pass 3 consists of the DAM Scheduling algorithm described in section 20 and the DAM Pricing algorithm described in section 21.

20 DAM Scheduling

20.1 Purpose

20.1.1 The DAM Scheduling algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, reference level values* for *resources* subject to section 20.2.2, and *resource* schedules and commitments from the Reliability Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day*

20.2 Information, Sets, Indices and Parameters

20.2.1 Information, sets, indices and parameters for the DAM Scheduling algorithm are described in sections 3 and 4. In addition, the following *resource* schedules and commitments from Pass 2 shall be used by the DAM Scheduling algorithm:

20.2.1.1 $SXL^2_{h,d,j}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to export at *intertie zone* bus $d \in DX$ in hour $h \in \{1,..,24\}$ in association with lamination $j \in J^E_{h,d}$;

20.2.1.2 $ODG^2_{h,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1,..,24\}$; and

20.2.1.3 $SIG^2_{h,d,k}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import at *intertie zone* bus $d \in DI$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^E_{h,d}$.

20.2.2 The DAM Scheduling algorithm shall use *reference level value* for any *financial dispatch data parameters* that failed the Conduct Test associated with *resources* identified in section 14.7.

20.3 Variables and Objective Function

20.3.1 The *day-ahead market calculation engine* shall solve for the variables set out in section 8.3.1.

20.3.2 The objective function for the DAM Scheduling algorithm shall be the same as the objective function in section 8.3.2, with the following exceptions:

20.3.2.1 the variables for unit commitment decisions ($ODG_{h,b}$) shall be fixed within the optimization function; and

20.3.2.2 the *start-up offer* ($SUDG_{h,b}$) and the *offer* price to operate at *minimum loading point* ($MGODG_{h,b}$) shall be removed from the objective function.

20.3.3 The optimization function in the DAM Scheduling algorithm shall be subject to the constraints described in section 20.4.

20.4 Constraints

20.4.1 The DAM Scheduling algorithm optimization function shall apply the constraints described in sections 20.5– 20.8.

20.5 Dispatch Data Constraints Applying to Individual Hours

20.5.1 The constraints in section 8.5 shall apply in the DAM Scheduling algorithm.

20.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

20.6.1 The constraints in section 8.6 shall apply in the DAM Scheduling algorithm, with the exception that the constraints for *non-quick start resources* in section 8.6.3 shall be removed.

20.7 Constraints to Ensure Schedules Do Not Violate *Reliability* Requirements

20.7.1 The constraints are the same as in section 8.7. The sensitivities and limits used in section 8.7.3 are those provided by the most recent *security* assessment function iteration of the DAM Scheduling algorithm.

20.8 Constraints to Respect Pass 2 Decisions

20.8.1 The DAM Scheduling algorithm shall not decrease import schedules from the values produced in Pass 2 and may schedule additional imports of *energy* in Pass 3. For all hours $h \in \{1, . . , 24\}$ and *intertie zone* buses $d \in DI$ that are not part of a wheeling through transaction:

$$\sum_{k \in K^E_{h,d}} SIG_{h,d,k} \geq \sum_{k \in K^E_{h,d}} SIG^2_{h,d,k}$$

20.8.2 The DAM Scheduling algorithm shall not increase export schedules in Pass 3 from the values produced in Pass 2. For all hours $h \in \{1, . . , 24\}$ and *intertie zone* buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J^E_{h,d}} SXL_{h,d,j} \leq \sum_{j \in J^E_{h,d}} SXL^2_{h,d,j}$$

20.8.3 The DAM Scheduling algorithm shall not change commitments statuses in Pass 3 for *resources* as determined in Pass 2. For all hours $h \in \{1, . . , 24\}$ and buses $b \in B^{DG}$:

$$ODG_{h,b} = ODG^2_{h,b}$$

20.9 Outputs

20.9.1 Outputs for the DAM Scheduling algorithm shall include *resource* schedules and commitments.

21 DAM Pricing

21.1 Purpose

21.1.1 The DAM Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants, reference level values* for *resources* subject to section 21.2.2, and *resource* schedules and commitments produced by the DAM Scheduling algorithm, to meet the *IESO's* average province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the next *dispatch day.*

21.2 Information, Sets, Indices and Parameters

21.2.1 Information, sets, indices and parameters for the DAM Pricing algorithm are described in sections 3 and 4. In addition, DAM Pricing algorithm shall use the following *resource* schedules and commitments from the DAM Scheduling algorithm in section 20:

21.2.1.1 $SDG^3_{h,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDG_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^E_{h,b}$.;

21.2.1.2 $ODG^3_{h,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in hour $h \in \{1,..,24\}$. Note that $ODG^3_{h,b} = ODG^2_{h,b}$ for all hours $h \in \{1,..,24\}$ and buses $b \in B^{DG}$;

21.2.1.3 $S10SDG^3_{h,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10S}_{h,b}$;

21.2.1.4 $S10NDG^3_{h,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1,..,24\}$ in association with lamination $k \in K^{10N}_{h,b}$;

21.2.1.5 $S30RDG^{3}_{h,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in hour $h \in \{1, . . , 24\}$ in association with lamination $k \in K^{30R}_{h,b}$; and

21.2.1.6 $OHO^{3}_{h,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{h,b}$ in hour $h \in \{1, . . , 24\}$.

21.2.2 The *resource* schedules from Pass 2:

21.2.2.1 $SXL^{2}_{h,d,j}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to export at bus $d \in DX$ in hour $h \in \{1, . . , 24\}$ in association with lamination $j \in J^{E}_{h,d}$; and

21.2.2.2 $SIG^{2}_{h,d,k}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import at bus $d \in DI$ in hour $h \in \{1, . . , 24\}$ in association with lamination $k \in K^{E}_{h,d}$.

21.2.2.3 The DAM Pricing algorithm shall use *reference level values* for any *financial dispatch data parameters* that failed the Conduct Test associated with *resources* identified in section 14.7.

21.3 Variables and Objective Function

21.3.1 The DAM Pricing algorithm shall solve for the variables listed in section 9.3.1.

21.3.2 The objective function for the DAM Pricing algorithm shall be the same as the objective function in section 9.3.2, subject to section 21.4.

21.4 Constraints

21.4.1 The constraints in sections 9.4 through 9.8 shall apply in the DAM Pricing algorithm, with the following exceptions:

21.4.1.1 The marginal loss factors used in the *energy* balance constraint in section 9.7.1 shall be fixed to the marginal loss factors used in the last optimization function iteration of the DAM Scheduling alogorithm in section 20.

21.4.1.2 The sensitivities and limits used in section 9.7.3 shall be provided by the most recent *security* assessment function iteration of the DAM Pricing algorithm.

21.4.1.3 For the constraints in section 9.8, the outputs from the As-Offered Scheduling algorithm in section 8 shall be replaced with the outputs from the DAM Scheduling algorithm in section 20, as follows:

21.4.1.3.1 $SDG^{AOS}_{h,b,k}$ shall be replaced by $SDG^{3}_{h,b,k}$ for all $h \in \{1,...,24\}, b \in B^{ELR} \cup B^{HE}, k \in K^{E}_{h,b}$;

21.4.1.3.2 $ODG^{AOS}_{h,b}$ shall be replaced by $ODG^{3}_{h,b}$ for all $h \in \{1,...,24\}, b \in B^{DG}$;

21.4.1.3.3 $S10SDG^{AOS}_{h,b,k}$ shall be replaced by $S10SDG^{3}_{h,b,k}$ for all $h \in \{1,...,24\}, b \in B^{ELR} \cup B^{HE}, k \in K^{10S}_{h,b}$;

21.4.1.3.4 $S10NDG^{AOS}_{h,b,k}$ shall be replaced by $S10NDG^{3}_{h,b,k}$ for all $h \in \{1,...,24\}, b \in B^{ELR} \cup B^{HE}, k \in K^{10N}_{h,b}$;

21.4.1.3.5 $S30RDG^{AOS}_{h,b,k}$ shall be replaced by $S30RDG^{3}_{h,b,k}$ for all $h \in \{1,...,24\}, b \in B^{ELR} \cup B^{HE}, k \in K^{30R}_{h,b}$; and

21.4.1.3.6 $OHO^{AOS}_{h,b}$ shall be replaced by $OHO^{3}_{h,b}$ for all $h \in \{1,...,24\}, b \in B^{HE}$.

21.4.1.4 The constraints imposed for *boundary entity resource* schedules in section 20.8 shall apply to *boundary entity resource* schedules in the DAM Pricing algorithm, with a tolerance Δ specified by the *IESO* and:

21.4.1.4.1 For all hours $h \in \{1,...,24\}$ and *boundary entity resource* import buses $d \in DI$ that are not part of a wheeling through transaction:

$$\sum_{k \in K^{E}_{h,d}} SIG_{h,d,k} \geq \sum_{k \in K^{E}_{h,d}} SIG^{2}_{h,d,k} - \Delta$$

21.4.1.4.2 For all hours $h \in \{1,...,24\}$ and *boundary entity resource* export buses $d \in DX$ that are not part of a wheeling through transaction:

$$\sum_{j \in J^E_{h,d}} SXL_{h,d,j} \leq \sum_{j \in J^E_{h,d}} SXL^2_{h,d,j} + \Delta$$

21.5 Outputs

21.5.1 Outputs of the DAM Pricing algorithm include shadow prices and *locational marginal prices* for *energy* and *operating reserve*.

22 Pseudo-Unit Modelling

22.1 Pseudo-Unit Model Parameters

22.1.1 The *day-ahead market calculation engine* shall use the following registration and daily *dispatch data* to determine the underlying relationship between a *pseudo-unit* and the associated physical *resources* for a combined cycle *facility* with K combustion turbines and one steam turbine:

22.1.1.1 $CMCR_k$ designates the registered *maximum continuous rating* of combustion turbine $k \in \{1,..,K\}$ in MW;

22.1.1.2 $CMLP_k$ designates the *minimum loading point* of combustion turbine $k \in \{1,..,K\}$ in MW;

22.1.1.3 $SMCR$ designates the registered *maximum continuous rating* of the steam turbine in MW;

22.1.1.4 $SMLP$ designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

22.1.1.5 SDF designates the amount of duct firing capacity available on the steam turbine in MW;

22.1.1.6 $STPortion_k$ designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

22.1.1.7 $CSCM_k \in \{0,1\}$ designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in single cycle mode for the day.

22.1.2 The *day-ahead market calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..K\}$:

22.1.2.1 $MMCR_k$ designates the *maximum continuous rating* of *pseudo-unit* k and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

22.1.2.2 $MMLP_k$ designates the *minimum loading point* of *pseudo-unit* k and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

22.1.2.3 MDF_k designates the duct firing capacity of *pseudo-unit* k and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

22.1.2.4 MDR_k designates the *dispatchable* capacity of *pseudo-unit* k and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

22.1.3 The *day-ahead market calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

22.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

22.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and $MMLP_k + MDR_k$; and

22.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

22.1.4 The *day-ahead market calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

22.1.4.1 For the minimum loading point region:

22.1.4.1.1 Steam turbine share: $STShareMLP_k = \frac{SMLP \cdot (1 - CSCM_k)}{MMLP_k}$; and

22.1.4.1.2 Combustion turbine share: $CTShareMLP_k = \frac{CMLP_k}{MMLP_k}$;

22.1.4.2 For the *dispatchable* region:

22.1.4.2.1 Steam turbine share:

$$STShareDR_k = \frac{(1-CSCM_k)(SMCR \cdot STPortion_k - SMLP - SDF_k \cdot STPortion_k)}{MDR_k};$$

and

22.1.4.2.2 Combustion turbine share: $CTShareDR_k = \frac{CMCR_k - CMLP_k}{MDR_k}$; and

22.1.4.3 For the duct firing region:

22.1.4.3.1 Steam turbine share shall be equal to 1; and

22.1.4.3.2 Combustion turbine share shall be equal to 0.

22.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

22.2.1 The *day-ahead market calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

22.2.1.1 $CTCap_{h,k}$ designates the capacity of combustion turbine $k \in \{1,..,K\}$ in hour h as determined by submitted deratings;

22.2.1.2 $STCap_h$ designates the capacity of the steam turbine in hour h as determined by submitted deratings; and

22.2.1.3 $TotalQ_{h,k}$ designates the total *offered* quantity of *energy* for *pseudo-unit* $k \in \{1,..,K\}$ in hour h.

22.2.2 The *day-ahead market calculation engine* shall solve for the following operating region parameters for hour $h \in [1,..,24]$ for each *pseudo-unit* $k \in \{1,..,K\}$:

22.2.2.1 $MLP_{h,k}$ designates the *minimum loading point* of *pseudo-unit* k in hour h;

22.2.2.2 $DR_{h,k}$ designates the *dispatchable* region capacity of *pseudo-unit* k in hour h; and

22.2.2.3 $DF_{h,k}$ designates the duct firing region capacity of *pseudo-unit* k in hour h.

22.2.3 Pre-processing of De-rates

22.2.3.1 The *day-ahead market calculation engine* shall perform the following pre-processing steps to determine the available operating regions for a *pseudo-unit* based on the combustion turbine and steam turbine share and the application of the *pseudo-unit* deratings. For *pseudo-unit* $k \in \{1,..,K\}$ for hour $h \in \{1,..,24\}$:

22.2.3.1.1 Step 1: Calculate the amount of *offered energy* attributed to each combustion turbine ($CTAmt_{h,k}$) and steam turbine portion ($STAmt_{h,k}$):

If $TotalQ_{h,k} < MMLP_k$ then:

$CTAmt_{h,k} = 0$; and

$STAmt_{h,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{h,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{h,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{h,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{h,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{h,k} = CTAmtMLP + CTAmtDR$; and

$STAmt_{h,k} = STAmtMLP + STAmtDR + STAmtDF$.

22.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$$PRSTCap_{h,k} = \left(\frac{STAmt_{h,k}}{\sum_{w \in \{1,..,K\}} STAmt_{h,w}}\right) \cdot STCap_h$$

22.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{h,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $STAmt_{h,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{h,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $PRSTCap_{h,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

22.2.3.1.4 Step 4: Initialize the operating region parameters for hour $h \in \{1, . . , 24\}$ to the model parameter values:

Set $MLP_{h,k} = MMLP_k$.

Set $DR_{h,k} = MDR_k$.

Set $DF_{h,k} = MDF_k$.

22.2.3.1.5 Step 5: Apply the derating on the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k = CTCap_{h,k}$; and

Set $DR_{h,k} = min(DR_{h,k}, P \cdot MDR_k)$.

22.2.3.1.6 Step 6: Apply the derating on the steam turbine to the duct firing and *dispatchable* regions for *pseudo-units* not operating in *single cycle mode*:

Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{h,k}$.

If $R \leq 1$, set $DF_{h,k} = 0$, and $DR_{h,k} = min(DR_{h,k}, R \cdot MDR_k)$.

If $R > 1$, set $DF_{h,k} = min(DF_{h,k}, PRSTCap_{h,k} - SMLP - STShareDR_k \cdot MDR_k)$.

22.2.4 Available Energy Laminations

22.2.4.1 The *day-ahead market calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for hour $h \in \{1, .., 24\}$ for each *pseudo-unit* $k \in \{1, .., K\}$, subject to section 22.2.4.2, where:

22.2.4.1.1 $QMLP_{h,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

22.2.4.1.2 $QDR_{h,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

22.2.4.1.3 $QDF_{h,k}$ designates the total quantity that may be scheduled in the duct firing region.

22.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$$0 \leq QMLP_{h,k} \leq MLP_{h,k};$$

$$0 \leq QDR_{h,k} \leq DR_{h,k};$$

$$0 \leq QDF_{h,k} \leq DF_{h,k};$$

if $QMLP_{h,k} < MLP_{h,k}$, then the *pseudo-unit* is unavailable and $QDR_{h,k} = QDF_{h,k} = 0$; and

if $QDR_{h,k} < DR_{t,k}$, then $QDF_{h,k} = 0$.

22.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

22.3.1 The *day-ahead market calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

22.3.1.1 $PSUMin^q_{h,k}$ designates the minimum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a minimum limitation on *pseudo-unit* k, then $PSUMin^q_{h,k}$ shall be set equal to 0;

22.3.1.2 $PSUMax^q_{h,k}$ designates the maximum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a maximum limitation on *pseudo-unit* k, then $PSUMax^q_{h,k}$ shall be set equal to $MLP_{h,k}+DR_{h,k}+DF_{h,k}$; and

22.3.1.3 $CTCmtd_{h,k} \in \{0,1\}$ designates whether combustion turbine $k \in \{1,..K\}$ is considered committed in hour $h \in \{1,..,24\}$.

22.3.2 The *day-ahead market calculation engine* shall calculate the minimum and maximum limitations, subject to section 22.3.3.1, as follows:

22.3.2.1 Minimum limitation: $MinDG_{h,k} = max_{q \in \{1,..Q\}} PSUMin^q_{h,k}$; and

22.3.2.2 Maximum limitation: $MaxDG_{h,k} = min_{q \in \{1,..Q\}} PSUMax^q_{h,k}$.

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *day-ahead market calculation engine*.

22.3.3 Pseudo-unit Minimum and Maximum Constraints

22.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

22.3.3.1.1 $PSUMin_{h,k} = PMin$, where $PMin$ shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for hour $h \in \{1,..,24\}$; and

22.3.3.1.2 $PSUMax_{h,k} = PMax$, where $PMax$ shall be a maximum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for hour $h \in \{1,..,24\}$.

22.3.4 Combustion Turbine Minimum and Maximum Constraints

22.3.4.1 If a *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMin < MLP_{h,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right); \text{ and}$$

$$STMinDR = 0$$

Otherwise, if $CTMin \geq MLP_{h,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{h,k} \cdot STShareMLP_k \text{ ; and}$$

$$STMinDR = \left(CTMin - MLP_{h,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMin_{h,k} = CTMin + STMinMLP + STMinDR$$

22.3.4.2 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMin_{h,k} = CTMin$$

22.3.4.3 If a *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMax < MLP_{h,k} \cdot CTShareMLP_k$, then $PSUMax_{h,k} = 0$

Otherwise, calculate the effect of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions: :

$$STMaxMLP = MLP_{h,k} \cdot STShareMLP_k$$

$$STMaxDR = \left(CTMax - MLP_{h,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{h,k} = CTMax + STMaxMLP + STMaxDR$$

22.3.4.4 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMax_{h,k} = CTMax$$

22.3.5 Steam Turbine Minimum and Maximum Constraints

22.3.5.1.1 The *day-ahead market calculation engine* shall convert a steam turbine minimum constraint to a *pseudo-unit* constraint as follows:

22.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which shall indicate the set of *pseudo-units* to which the constraint may be allocated where *pseudo-unit* $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k$=0 and $CTCmtd_{h,k} = 1$. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

22.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity of *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{h,k} \cdot STShareMLP_k + QDR_{h,k} \cdot STShareDR_k + QDF_{h,k}$$

22.3.5.1.3 Step 3: Allocate the $STMin$ constraint to each *pseudo-unit* $k \in A$, where $STMin$ constraint shall be allocated equally to each *pseudo-unit* $k \in A$ and $STPMin_k$ is limited by $STCap_k$.

22.3.5.1.4 Step 4: The steam turbine portion minimum constraint shall be converted to a *pseudo-unit* constraint, where for each *pseudo-unit* $k \in A$:

If $STPMin_k < MLP_{h,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = \mathrm{STPMin_k} \cdot \left(\frac{\mathrm{CTShareMLP_k}}{\mathrm{STShareMLP_k}}\right); \text{ and}$$

$$CTMinDR_k = 0$$

Otherwise, if $STPMin_k \geq MLP_{h,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = MLP_{h,k} \cdot CTShareMLP_k; \text{ and}$$

$$CTMinDR_k = \left(STPMin_k - MLP_{h,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right)$$

Therefore:

$$PSUMin_{h,k} = STPMin_k + CTMinMLP_k + CTMinDR_k$$

22.3.5.2 If *pseudo-units* with sufficient steam turbine capacity are not committed, then the *day-ahead market calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudo-unit* constraints.

22.3.5.3 The steam turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PRSTMax_{h,k} = \left(\frac{STAmt_{h,k}}{\sum_{w \in \{1,..,K\}} STAmt_{h,w}} \right) \cdot STMax$$

If the prorated steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{h,k} = 0$$

Otherwise, calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTMax_{h,k}$

If $R \leq 1$, set $PSUMax_{h,k} = MLP_{h,k} + min(DR_{h,k}, R \cdot MDR_k)$

If $R > 1$, set $PSUMax_{h,k} = MLP_{h,k} + DR_{h,k} + PRSTMax_{h,k} - SMLP - STShareDR_k \cdot MDR_k$

22.3.5.4 If the steam turbine minimum and maximum constraints are equal but do not convert to equal *pseudo-unit* minimum and maximum constraints, then the steam turbine minimum constraint conversion in section 22.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

22.4 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

22.4.1 For a combined cycle *facility* with K combustion turbines and one steam turbine, the *day-ahead market calculation engine* shall compute the following *energy* and *operating reserve* schedules for hours $h \in \{1, . . , 24\}$:

22.4.1.1 $CTE_{h,k}$ designates the *energy* schedule for combustion turbine $k \in \{1, . . , K\}$;

22.4.1.2 $STPE_{h,k}$ designates the *energy* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1, . . , K\}$;

22.4.1.3 STE_h designates the *energy* schedule for the steam turbine;

22.4.1.4 $CT10S_{h,k}$ designates the synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1, . . ,K\}$;

22.4.1.5 $STP10S_{h,k}$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1, . . ,K\}$;

22.4.1.6 $ST10S_h$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine;

22.4.1.7 $CT10N_{h,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1, . . ,K\}$;

22.4.1.8 $STP10N_{h,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1, . . ,K\}$;

22.4.1.9 $ST10N_h$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine;

22.4.1.10 $CT30R_{h,k}$ designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1, . . ,K\}$;

22.4.1.11 $STP30R_{h,k}$ designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1, . . ,K\}$; and

22.4.1.12 $ST30R_h$ designates the *thirty-minute operating reserve* schedule for the steam turbine.

22.4.2 The *day-ahead market calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo-unit* $k \in \{1, . . ,K\}$ in hour $h \in \{1, . . , 24\}$:

22.4.2.1 $SE_{h,k}$ designates the total amount of *energy* scheduled and $SE_{h,k} = SEMLP_{h,k} + SEDR_{h,k} + SEDF_{h,k}$ where:

22.4.2.1.1 $SEMLP_{h,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \leq SEMLP_{h,k} \leq QMLP_{h,k}$;

22.4.2.1.2 $SEDR_{h,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \leq SEDR_{h,k} \leq QDR_{h,k}$ and $SEDR_{h,k} > 0$ only if $SEMLP_{h,k} = QMLP_{h,k}$; and

22.4.2.1.3 $SEDF_{h,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \leq SEDF_{h,k} \leq QDF_{h,k}$ and $SEDF_{h,k} > 0$ only if $SEDR_{h,k} = QDR_{h,k}$;

22.4.2.2 $S10S_{h,k}$ designates the total amount of synchronized *ten-minute operating reserve* scheduled;

22.4.2.3 $S10N_{h,k}$ designates the total amount of non-synchronized *ten-minute operating reserve* scheduled. If the *pseudo-unit* cannot provide *operating reserve* from its duct firing region then $0 \leq SE_{h,k} + S10S_{h,k} + S10N_{h,k} \leq QMLP_{h,k} + QDR_{h,k}$; and

22.4.2.4 $S30R_{h,k}$ designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{h,k} + S10S_{h,k} + S10N_{h,k} + S30R_{h,k} \leq QMLP_{h,k} + QDR_{h,k} + QDF_{h,k}$.

22.4.3 The *day-ahead market calculation engine* shall convert *pseudo-unit* schedules to physical *generation resource* schedules for *energy* and *operating reserve*, as follows:

22.4.3.1 If $SE_{h,k} \geq MLP_{h,k}$, then:

$$CTE_{h,k} = SEMLP_{h,k} \cdot CTShareMLP_k + SEDR_{h,k} \cdot CTShareDR_k;$$

$$STPE_{h,k} = SEMLP_{h,k} \cdot STShareMLP_k + SEDR_{h,k} \cdot STShareDR_k + SEDF_{h,k};$$

$$RoomDR_{h,k} = QDR_{h,k} - SEDR_{h,k};$$

$$10SDR_{h,k} = min(RoomDR_{h,k}, S10S_{h,k});$$

$$10NDR_{h,k} = min(RoomDR_{h,k} - 10SDR_{h,k}, S10N_{h,k});$$

$$30RDR_{h,k} = min(RoomDR_{h,k} - 10SDR_{h,k} - 10NDR_{h,k}, S30R_{h,k});$$

$$CT10S_{h,k} = 10SDR_{h,k} \cdot CTShareDR_k;$$

$$STP10S_{h,k} = 10SDR_{h,k} \cdot STShareDR_k + (S10S_{h,k} - 10SDR_{h,k});$$

$$CT10N_{h,k} = 10NDR_{h,k} \cdot CTShareDR_k;$$

$$STP10N_{h,k} = 10NDR_{h,k} \cdot STShareDR_k + (S10N_{h,k} - 10NDR_{h,k});$$

$$CT30R_{h,k} = 30RDR_{h,k} \cdot CTShareDR_k\text{; and}$$

$$STP30R_{h,k} = 30RDR_{h,k} \cdot STShareDR_k + (S30R_{h,k} - 30RDR_{h,k}).$$

22.4.3.2 If $SE_{h,k} < MLP_{h,k}$ and is ramping to *minimum loading point*, then the conversion shall be determined by the *ramp up energy to minimum loading point*.

22.4.3.3 The steam turbines portion schedules from section 22.4.3.1 shall be summed to obtain the steam turbine schedule as follows:

$$STE_h = \sum_{k=1,..,K} STPE_{h,k};$$

$$ST10S_h = \sum_{k=1,..,K} STP10S_{h,k};$$

$$ST10N_h = \sum_{k=1,..,K} STP10N_{h,k}\text{; and}$$

$$ST30R_h = \sum_{k=1,..,K} STP30R_{h,k}.$$

23 Pricing Formulas

23.1 Purpose

23.1.1 The *day-ahead market calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

23.2 Sets, Indices and Parameters

23.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Passes 1 and 3 shall be used:

23.2.1.1 $SPEmT^p_{h,c,f}$ designates the Pass p shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in hour h;

23.2.1.2 $SPExtT^p_{h,z}$ designates the Pass p shadow price for the import or export limit constraint $z \in Z_{Sch}$ in hour h;

23.2.1.3 SPL^p_h designates the Pass p shadow price for the *energy* balance constraint in hour h;

23.2.1.4 $SPNIUExtBwdT^p_h$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting increases in net imports between hour $(h-1)$ and hour h;

23.2.1.5 $SPNIDExtBwdT^p_h$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between hour $(h-1)$ and hour h;

23.2.1.6 $SPNIUExtFwdT^p_h$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting increases in net imports between hour h and hour $(h+1)$;

23.2.1.7 $SPNIDExtFwdT^p_h$ designates the Pass p shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between hour h and hour $(h+1)$;

23.2.1.8 $SPNormT^{p}_{h,f}$ designates the Pass p shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in hour h;

23.2.1.9 $SP10S^{p}_{h}$ designates the Pass p shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in hour h;

23.2.1.10 $SP10R^{p}_{h}$ designates the Pass p shadow price for the total *ten-minute operating reserve* requirement constraint in hour h;

23.2.1.11 $SP30R^{p}_{h}$ designates the Pass p shadow price for the total *thirty-minute operating reserve* requirement constraint in hour h;

23.2.1.12 $SPREGMin10R^{p}_{h,r}$ designates the Pass p shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in hour h;

23.2.1.13 $SPREGMin30R^{p}_{h,r}$ designates the Pass p shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in hour h;

23.2.1.14 $SPREGMax10R^{p}_{h,r}$ designates the Pass p shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in hour h; and

23.2.1.15 $SPREGMax30R^{p}_{h,r}$ designates the Pass p shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in hour h.

23.3 Locational Marginal Prices for Energy

23.3.1 Energy Locational Marginal Prices for Delivery Points

23.3.1.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass $p \in \{1,3\}$ and hour $h \in \{1,..,24\}$ for every bus $b \in L$ where a non-*dispatchable* or *dispatchable generation resource*, a *dispatchable load*, a *price responsive load*, an *hourly demand response resource*, or a *non-dispatchable load* is sited and:

23.3.1.1.1 $LMP^{p}_{h,b}$ designates the Pass p hour h *locational marginal price* for *energy*;

23.3.1.1.2 $PRef_h^p$ designates the Pass p hour h energy locational marginal price for energy at the reference bus;

23.3.1.1.3 $PLoss_{h,b}^p$ designates the Pass p hour h loss component; and

23.3.1.1.4 $PCong_{h,b}^p$ designates the Pass p hour h congestion component.

23.3.1.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass $p \in \{1,3\}$ at bus $b \in L$ in hour $h \in \{1, .., 24\}$, as follows:

$$InitLMP_{h,b}^p = InitPRef_h^p + InitPLoss_{h,b}^p + InitPCong_{h,b}^p$$

where

$$InitPRef_h^p = SPL_h^p;$$

$$InitPLoss_{h,b}^p = MglLoss_{h,b}^p \cdot SPL_h^p;$$

and

$$InitPCong_{h,b}^p = \sum_{f \in F_h} PreConSF_{h,f,b} \cdot SPNormT_{h,f}^p + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,b} \cdot SPEmT_{h,c,f}^p$$

23.3.1.3 If the initial *locational marginal price* for *energy* at the *reference bus* ($InitPRef_h^p$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy* at the *reference bus* as follows:

If $InitPRef_h^p > EngyPrcCeil$, $PRef_h^p = EngyPrcCeil$

If $InitPRef_h^p < EngyPrcFlr$, $PRef_h^p = EngyPrcFlr$

Otherwise, $PRef_h^p = InitPRef_h^p$

23.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP_{h,b}^p$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP^p_{h,b} > EngyPrcCeil$, $LMP^p_{h,b} = EngyPrcCeil$

If $InitLMP^p_{h,b} < EngyPrcFlr$, $LMP^p_{h,b} = EngyPrcFlr$

Otherwise, $LMP^p_{h,b} = InitLMP^p_{h,b}$

23.3.1.5 The *day-ahead market calculation engine* shall modify the loss component as follows:

If $PRef^p_h \neq InitPRef^p_h$, then $PLoss^p_{h,b} = MglLoss^p_{h,b} \cdot PRef^p_h$

Otherwise, $PLoss^p_{h,b} = InitPLoss^p_{h,b}$

23.3.1.6 The *day-ahead market calculation engine* shall modify the congestion component as follows:

If $LMP^p_{h,b} - PRef^p_h - PLoss^p_{h,b}$ and $InitPCong^p_{h,b}$ have the same mathematical sign, then $PCong^p_{h,b} = LMP^p_{h,b} - PRef^p_h - PLoss^p_{h,b}$

Otherwise, $PCong^p_{h,b} = 0$ and $PLoss^p_{h,b} = LMP^p_{h,b} - PRef^p_h$

23.3.2 Energy Locational Marginal Prices for Intertie Metering Points

23.3.2.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass $p \in \{1,3\}$ and hour $h \in \{1,..,24\}$ for *intertie zone* bus $d \in D$, where:

23.3.2.1.1 $\mathrm{ExtLMP}^p_{h,d}$ designates the Pass p hour h locational marginal price for energy;

23.3.2.1.2 $IntLMP^p_{h,d}$ designates the Pass p hour h *intertie border price* for *energy*;

23.3.2.1.3 $ICP^p_{h,d}$ designates the Pass p hour h *intertie congestion price*;

23.3.2.1.4 $PRef^p_h$ designates the Pass p hour h *locational marginal price* for *energy* at the reference bus;

23.3.2.1.5 $PLoss^p_{h,d}$ designates the Pass p hour h loss component;

23.3.2.1.6 $PIntCong^p_{h,d}$ designates the Pass p hour h internal congestion component for *energy*;

23.3.2.1.7 $PExtCong^p_{h,d}$ designates the Pass p hour h external congestion component for the *intertie congestion price*; and

23.3.2.1.8 $PNISL^p_{h,d}$ designates the Pass p hour h net interchange scheduling limit congestion component for the *intertie congestion price*.

23.3.2.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss component and a congestion component for *energy* for Pass p at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in hour $h \in \{1,...,24\}$, subject to section 23.3.2.8 and 23.3.2.9, as follows:

$$InitExtLMP^p_{h,d} = InitIntLMP^p_{h,d} + InitICP^p_{h,d}$$

where

$$InitPRef^p_h = SPL^p_h ;$$

$$InitPLoss^p_{h,d} = MglLoss^p_{h,d} \cdot SPL^p_h ;$$

$$InitPIntCong^p_{h,d} = \sum_{f \in F_h} PreConSF_{h,f,d} \cdot SPNormT^p_{h,f} + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,d} \cdot SPEmT^p_{h,c,f} ;$$

$$InitIntLMP^p_{h,d} = InitPRef^p_h + InitPLoss^p_{h,d} + InitPIntCong^p_{h,d};$$

$$InitICP^p_{h,d} = InitPExtCong^p_{h,d} + InitPNISL^p_{h,d};$$

$$InitPExtCong^p_{h,d} = \sum_{z \in Z_{sch}} EnCoeff_{a,z} \cdot SPExtT^p_{h,z} ;$$

and

$$InitPNISL^p_{h,d} = SPNIUExtBwdT^p_h - SPNIUExtFwdT^p_h - SPNIDExtBwdT^p_h + SPNIDExtFwdT^p_h$$

23.3.2.3 If the initial *locational marginal price* for *energy* ($InitExtLMP^{p}_{h,d}$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *day-ahead market calculation engine* shall modify the *intertie border price* for *energy*, and its components, as follows:

23.3.2.3.1 The initial *locational marginal price* for the *reference bus* ($InitPRef^{p}_{h}$) shall be modified per section 23.3.1.3;

23.3.2.3.2 The initial *intertie border price* ($InitIntLMP^{p}_{h,d}$) shall be modified per section 23.3.1.4, where $InitLMP^{p}_{h,b} = InitIntLMP^{p}_{h,d}$;

23.3.2.3.3 The initial loss component ($InitPLoss^{p}_{h,b}$) shall be modified per section 23.3.1.5; and

23.3.2.3.4 The initial congestion component ($InitPCong^{p}_{h,b}$) shall be modified per section 23.3.1.6.

23.3.2.4 If the initial *locational marginal price* for *energy* ($InitExtLMP^{p}_{h,d}$) is not within the *settlement* bounds ($EngyPrcFlr, EngyPrcCeil$), then the *day-ahead market calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $InitExtLMP^{p}_{h,d} > EngyPrcCeil$, set $ExtLMP^{p}_{h,d} = EngyPrcCeil$

If $InitExtLMP^{p}_{h,d} < EngyPrcFlr$, set $ExtLMP^{p}_{h,d} = EngyPrcFlr$

Otherwise, set $ExtLMP^{p}_{h,d} = InitExtLMP^{p}_{h,d}$

23.3.2.5 If the modified *locational marginal price* for *energy* ($ExtLMP^{p}_{h,d}$) is equal to the *intertie border price* for *energy* ($IntLMP^{p}_{h,d}$), then the *day-ahead market calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion components for the *intertie congestion price*, as follows:

If $ExtLMP^{p}_{h,d} = IntLMP^{p}_{h,d}$, set $PExtCong^{p}_{h,d} = 0$ and $PNISL^{p}_{h,d} = 0$

23.3.2.6 If the modified *locational marginal price* for *energy* ($ExtLMP^{p}_{h,d}$) is not equal to the *intertie border price* for *energy* ($IntLMP^{p}_{h,d}$), then the *day-ahead market calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion components for the *intertie congestion price*, as follows:

If $ExtLMP_{h,d}^{p} \neq IntLMP_{h,d}^{p}$, set

$$PNISL_{h,d}^{p} = (ExtLMP_{h,d}^{p} - IntLMP_{h,d}^{p}) \cdot \left(\frac{InitPNISL_{h,d}^{p}}{InitPNISL_{h,d}^{p} + InitPExtCong_{h,d}^{p}} \right)$$

If $PNISL_{h,d}^{p} > NISLPen$, $PNISL_{h,d}^{p} = NISLPen$

If $PNISL_{h,d}^{p} < (-1) \cdot NISLPen$, $PNISL_{h,d}^{p} = (-1) \cdot NISLPen$

Then $PExtCong_{h,d}^{p} = ExtLMP_{h,d}^{p} - IntLMP_{h,d}^{p} - PNISL_{h,d}^{p}$

23.3.2.7 The day-ahead market calculation engine shall calculate the intertie congestion price as follows:

$$ICP_{h,d}^{p} = PExtCong_{h,d}^{p} + PNISL_{h,d}^{p}$$

23.3.2.8 The *locational marginal price* for *energy* calculated by the *day-ahead market calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. *Intertie* transactions associated with the same *boundary entity resource* bus, but specified as occurring at different *intertie zones*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these transactions shall utilize shadow prices associated with the internal transmission constraints, *intertie* limits and transmission losses applicable to the path associated to the relevant *intertie zone*.

23.3.2.9 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all import and export *boundary entity resources* for that *intertie zone* will receive a zero schedule and the *locational marginal price* for *energy* shall be set to the *intertie border price* for *energy*.

23.3.3 Zonal Prices for Energy

23.3.3.1 The *day-ahead market calculation engine* shall calculate the zonal price for *energy* and its components for each Pass $p \in \{1,3\}$ and hour $h \in \{1,..,24\}$ for each *virtual transaction zone* $m \in M$, as follows:

$$VZonalP_{h,m}^{p} = PRef_{h}^{p} + VZonalPLoss_{h,m}^{p} + VZonalPCong_{h,m}^{p}$$

where

$$VZonalPLoss_{h,m}^{p} = \sum_{b \in L_{m}^{VIRT}} WF_{h,m,b}^{VIRT} \cdot PLoss_{h,b}^{p}$$

and

$$VZonalPCong_{h,m}^{p} = \sum_{b \in L_{m}^{VIRT}} WF_{h,m,b}^{VIRT} \cdot PCong_{h,b}^{p}$$

23.3.3.2 The *day-ahead market calculation engine* shall calculate the zonal price for *energy* and its components for each Pass $p \in \{1,3\}$ and hour $h \in \{1,..,24\}$ for *non-dispatchable load* zone, $y \in Y$ as follows:

$$ZonalP_{h,y}^{p} = PRef_{h}^{p} + ZonalPLoss_{h,y}^{p} + ZonalPCong_{h,y}^{p}$$

where

$$ZonalPLoss_{h,y}^{p} = \sum_{b \in L_{y}^{NDL}} WF_{h,y,b}^{NDL} \cdot PLoss_{h,b}^{p}$$

and

$$ZonalPCong_{h,y}^{p} = \sum_{b \in L_{y}^{NDL}} WF_{h,y,b}^{NDL} \cdot PCong_{h,b}^{p}$$

23.3.4 Pseudo-Unit Pricing

23.3.4.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *energy* for each Pass $p \in \{1,3\}$ and hour $h \in \{1,..,24\}$ for every *pseudo-unit* $k \in \{1,..,K\}$ where:

23.3.4.1.1 $CTMglLoss_{h,k}^{p}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit* k for hour h in Pass p;

23.3.4.1.2 $STMglLoss^{p}_{h,k}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit* k for hour h in Pass p;

23.3.4.1.3 $CTPreConSF_{h,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during hour h under pre-contingency conditions;

23.3.4.1.4 $STPreConSF_{h,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during hour h under pre-contingency conditions;

23.3.4.1.5 $CTSF_{h,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during hour h under post-contigency conditions for contingency c; and

23.3.4.1.6 $STSF_{h,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during hour h under post-contingency conditions for contingency c.

23.3.4.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass $p \in \{1,3\}$ for every *pseudo-unit* $k \in \{1,..,K\}$ in hour $h \in \{1,..,24\}$, as follows:

$$InitLMP^{p}_{h,k} = InitPRef^{p}_{h} + InitPLoss^{p}_{h,k} + InitPCong^{p}_{h,k}$$

where

$$InitPRef^{p}_{h} = SPL^{p}_{h};$$

$$InitPLoss^{p}_{h,k} = MglLoss^{p}_{h,k} \cdot SPL^{p}_{h};$$

and

$$InitPCong^{p}_{h,k} = \sum_{f \in F_h} PreConSF_{h,f,k} \cdot SPNormT^{p}_{h,f} + \sum_{c \in C} \sum_{f \in F_{h,c}} SF_{h,c,f,k} \cdot SPEmT^{p}_{h,c,f}$$

23.3.4.3 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its Minimum Loading Point range or not scheduled at all, its marginal loss and sensitivity factors shall be:

$$MglLoss^{p}_{h,k} = CTShareMLP_{k} \cdot CTMglLoss^{p}_{h,k} + STShareMLP_{k} \cdot STMglLoss^{p}_{h,k}$$

$$PreConSF_{h,f.k} = CTShareMLP_{k} \cdot CTPreConSF_{h,f,k} + STShareMLP_{k} \cdot STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = CTShareMLP_{k} \cdot CTSF_{h,c,f,k} + STShareMLP_{k} \cdot STSF_{h,c,f,k}$$

23.3.4.4 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{p}_{h,k} = CTShareDR_{k} \cdot CTMglLoss^{p}_{h,k} + STShareDR_{k} \cdot STMglLoss^{p}_{h,k}$$

$$PreConSF_{h,f,k} = CTShareDR_{k} \cdot CTPreConSF_{h,f,k} + STShareDR_{k} \cdot STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = CTShareDR_{k} \cdot CTSF_{h,c,f,k} + STShareDR_{k} \cdot STSF_{h,c,f,k}$$

23.3.4.5 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{p}_{h,k} = STMglLoss^{p}_{h,k}$$

$$PreConSF_{h,f,k} = STPreConSF_{h,f,k}$$

$$SF_{h,c,f,k} = STSF_{h,c,f,k}$$

23.4 Locational Marginal Prices for Operating Reserve

23.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

23.4.1.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for each Pass $p \in \{1,3\}$ and hour $h \in \{1,...,24\}$ for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$, where:

23.4.1.1.1 $L30RP^{p}_{h,b}$ designates the Pass p hour h *locational marignal price* for *thirty-minute operating reserve*;

23.4.1.1.2 $P30RRef^{p}_{h}$ designates the Pass p hour h *locational marignal price* for *thirty-minute operating reserve* at the *reference bus*;

23.4.1.1.3 $P30RCong^{p}_{h,b}$ designates the Pass p hour h congestion component for *thirty-minute operating reserve*;

23.4.1.1.4 $L10NP^{p}_{h,b}$ designates the Pass p hour h *locational marignal price* for non-synchronized *ten-minute operating reserve*;

23.4.1.1.5 $P10NRef^{p}_{h}$ designates the Pass p hour h *locational marignal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.1.1.6 $P10NCong^{p}_{h,b}$ designates the Pass p hour h congestion component for non-synchronized *ten-minute operating reserve*;

23.4.1.1.7 $L10SP^{p}_{h,b}$ designates the Pass p hour h *locational marignal price* for synchronized *ten-minute operating reserve*;

23.4.1.1.8 $P10SRef^{p}_{h}$ designates the Pass p hour h *locational marignal price* for synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.1.1.9 $P10SCong^{p}_{h,b}$ designates the Pass p hour h congestion component for synchronized *ten-minute operating reserve*; and

23.4.1.1.10 $ORREG_b \subseteq ORREG$ designates the subset of $ORREG$ consisting of regions that include bus b.

23.4.1.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass p for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus $b \in B$ in hour $h \in \{1, .., 24\}$, for each class of *operating reserve*, as follows:

$$InitL30RP_{h,b}^{p} = InitP30RRef_{h}^{p} + InitP30RCong_{h,b}^{p}$$

where

$$InitP30RRef_{h}^{p} = SP30R_{h}^{p}$$

and

$$InitP30RCong_{h,b}^{p} = \sum_{r \in ORREG_b} SPREGMin30R_{h,r}^{p} - \sum_{r \in ORREG_b} SPREGMax30R_{h,r}^{p}$$

$$InitL10NP_{h,b}^{p} = InitP10NRef_{h}^{p} + InitP10NCong_{h,b}^{p}$$

where

$$InitP10NRef_{h}^{p} = SP10R_{h}^{p} + SP30R_{h}^{p}$$

and

$$InitP10NCong_{h,b}^{p} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

$$InitL10SP_{h,b}^{p} = InitP10SRef_{h}^{p} + InitP10SCong_{h,b}^{p}$$

where

$$InitP10SRef_{h}^{p} = SP10S_{h}^{p} + SP10R_{h}^{p} + SP30R_{h}^{p}$$

and

$$InitP10SCong_{h,b}^{p} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

23.4.1.3 If the initial *locational marginal price* at the *reference bus* ($InitP30RRef_{h}^{p}$, $InitP10NRef_{h}^{p}$, or $InitP10SRef_{h}^{p}$) is not within the *settlement* bounds (*ORPrcFlr*, *ORPrcCeil*), then the *day-ahead market* *calculation engine* shall modify the initial *locational marginal prices* at the *reference bus* for each class of *operating reserve* as follows:

If $IInitP30RRef_h^p > ORPrcCeil$, $P30RRef_h^p = ORPrcCeil$;

If $InitP30RRef_h^p < ORPrcFlr$, $P30RRef_h^p = ORPrcFlr$;
Otherwise, $P30RRef_h^p = InitP30RRef_h^p$.

If $InitP10NRef_h^p > ORPrcCeil$, $P10NRef_h^p = ORPrcCeil$;

If $InitP10NRef_h^p < ORPrcFlr$, $P10NRef_h^p = ORPrcFlr$;
Otherwise, $P10NRef_h^p = InitP10NRef_h^p$.

If $InitP10SRef_h^p > ORPrcCeil$, $P10SRef_h^p = ORPrcCeil$;

If $InitP10SRef_h^p < ORPrcFlr$, $P10SRef_h^p = ORPrcFlr$;
Otherwise, $P10SRef_h^p = InitP10SRef_h^p$

23.4.1.4 If the initial *locational marginal price* ($InitL30RP_{h,b}^p$, $InitL10NP_{h,b}^p$, or $InitL10SP_{h,b}^p$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *day-ahead market calculation engine* shall modify the initial *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{h,b}^p > ORPrcCeil$, $L30RP_{h,b}^p = ORPrcCeil$;

If $InitL30RP_{h,b}^p < ORPrcFlr$, $L30RP_{h,b}^p = ORPrcFlr$;
Otherwise, $L30RP_{h,b}^p = InitL30RP_{h,b}^p$.

If $InitL10NP_{h,b}^p > ORPrcCeil$, $L10NP_{h,b}^p = ORPrcCeil$;

If $InitL10NP_{h,b}^p < ORPrcFlr$, $L10NP_{h,b}^p = ORPrcFlr$;
Otherwise, $L10NP_{h,b}^p = InitL10NP_{h,b}^p$.

If $InitL10SP_{h,b}^p > ORPrcCeil$, $L10SP_{h,b}^p = ORPrcCeil$;

If $InitL10SP_{h,b}^p < ORPrcFlr$, $L10SP_{h,b}^p = ORPrcFlr$;
Otherwise, $L10SP_{h,b}^p = InitL10SP_{h,b}^p$

23.4.1.5 If the initial *locational marginal price* ($InitL30RP^p_{h,b}$, $InitL10NP^p_{h,b}$, or $InitL10SP^p_{h,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *day-ahead market calculation engine* shall modify the congestion component for each class of *operating reserve*, as follows:

Set $P30RCong^p_{h,b} = L30RP^p_{h,b} - P30RRef^p_h$;

Set $P10NCong^p_{h,b} = L10NP^p_{h,b} - P10NRef^p_h$; and

Set $P10SCong^p_{h,b} = L10SP^p_{h,b} - P10SRef^p_h$.

23.4.2 Operating Reserve Locational Marginal Prices for Intertie Metering Points

23.4.2.1 The *day-ahead market calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for each Pass $p \in \{1,3\}$ and hour $h \in \{1,...,24\}$ for *intertie zone* bus $d \in D$, where:

23.4.2.1.1 $ExtL30RP^p_{h,d}$ designates the Pass p hour h *locational marginal price* for *thirty-minute operating reserve*;

23.4.2.1.2 $P30RRef^p_h$ designates the Pass p hour h *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

23.4.2.1.3 $P30RIntCong^p_{h,d}$ designates the Pass p hour h internal congestion component for *thirty-minute operating reserve*;

23.4.2.1.4 $P30RExtCong^p_{h,d}$ designates the Pass p hour h *intertie* congestion component for *thirty-minute operating reserve*;

23.4.2.1.5 $ExtL10NP^p_{h,d}$ designates the Pass p hour h non-synchronized *ten-minute operating reserve* price;

23.4.2.1.6 $P10NRef^p_h$ designates the Pass p hour h *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

23.4.2.1.7 $P10NIntCong^p_{h,d}$ designates the Pass p hour h internal congestion component for non-synchronized *ten-minute operating reserve*;

23.4.2.1.8 $P10NExtCong_{h,d}^{p}$ designates the Pass p hour h *intertie* congestion component for non-synchronized *ten-minute operating reserve*; and

23.4.2.1.9 $ORREG_d \subseteq ORREG$ designates the subset of $ORREG$ consisting of regions that include bus d.

23.4.2.2 The *day-ahead market calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, an internal congestion component and an *intertie* congestion component for Pass p at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in hour $h \in \{1, . . , 24\}$, for each class of *operating reserve*, subject to sections 23.4.2.5 and 23.4.2.6, as follows:

$$InitExtL30RP_{h,d}^{p} = InitP30RRef_{h}^{p} + InitP30RIntCong_{h,d}^{p} + InitP30RExtCong_{h,d}^{p}$$

where

$$InitP30RRef_{h}^{p} = SP30R_{h}^{p};$$

$$InitP30RIntCong_{h,d}^{p} = \sum_{r \in ORREG_d} SPREGMin30R_{h,r}^{p} - \sum_{r \in ORREG_d} SPREGMax30R_{h,r}^{p};$$

$$InitP30RExtCong_{h,d}^{p} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT_{h,z}^{p}$$

$$InitExtL10NP_{h,d}^{p} = InitP10NRef_{h}^{p} + InitP10NIntCong_{h,d}^{p} + InitP10NExtCong_{h,d}^{p}$$

where

$$InitP10NRef_{h}^{p} = SP10R_{h}^{p} + SP30R_{h}^{p};$$

$$InitP10NIntCong_{h,d}^{p} = \sum_{r \in ORREG_d} \left(SPREGMin10R_{h,r}^{p} + SPREGMin30R_{h,r}^{p}\right) - \sum_{r \in ORREG_d} \left(SPREGMax10R_{h,r}^{p} + SPREGMax30R_{h,r}^{p}\right)$$

and

$$InitP10NExtCong_{h,d}^{p} = -\sum_{z \in Z_{Sch}} 0.5 \cdot \left(EnCoeff_{a,z} + 1\right) \cdot SPExtT_{h,z}^{p}$$

23.4.2.3 If the initial *locational marginal price* ($InitExtL30RP_{h,b}^{p}$) is not within the *settlement* bounds ($ORPrcFlr, ORPrcCeil$), then the *day-ahead market calculation engine* shall modify the initial *locational marginal price*, the *locational marginal price* at the *reference bus*, and the external congestion component for *thirty-minute operating reserve* as follows:

$$IntL30R = InitP30RRef_{h}^{p} + InitP30RIntCong_{h,d}^{p}$$

If $InitP30RRef_{h}^{p} > ORPrcCeil$, $P30RRef_{h}^{p} = ORPrcCeil$;

If $InitP30RRef_{h}^{p} < ORPrcFlr$, $P30RRef_{h}^{p} = ORPrcFlr$;
Otherwise, $P30RRef_{h}^{p} = InitP30RRef_{h}^{p}$;

Set $P30RIntCong_{h,d}^{p} = ExtL30RP_{h,d}^{p} - P30RRef_{h}^{p}$

If $InitExtL30RP_{h,b}^{p} > ORPrcCeil$, $ExtL30RP_{h,b}^{p} = ORPrcCeil$;

If $InitExtL30RP_{h,b}^{p} < ORPrcFlr$, $ExtL30RP_{h,b}^{p} = ORPrcFlr$;
Otherwise, $ExtL30RP_{h,b}^{p} = InitExtL30RP_{h,b}^{p}$; and

Set $P30RExtCong_{h,d}^{p} = ExtL30RP_{h,b}^{p} - P30RRef_{h}^{p} - P30RIntCong_{h,d}^{p}$

23.4.2.4 If the initial *locational marginal price* ($InitExtL10NP_{h,b}^{p}$) is not within the *settlement* bounds ($ORPrcFlr, ORPrcCeil$), then the *day-ahead market calculation engine* shall modify the initial *locational* *marginal price*, *locational marginal price* at the *reference bus*, and the external congestion component for *ten-minute operating reserve* as follows:

$$IntL10N = InitP10NRef_h^p + InitP10NIntCong_{h,d}^p$$

If $InitP10NRef_h^p > ORPrcCeil$, $P10NRef_h^p = ORPrcCeil$;

If $InitP10NRef_h^p < ORPrcFlr$, $P10NRef_h^p = ORPrcFlr$;
Otherwise, $P10NRef_h^p = InitP10NRef_h^p$;

Set $P10NCong_{h,b}^p = L10NP_{h,b}^p - P10NRef_h^p$

If $InitExtL10NP_{h,b}^p > ORPrcCeil$, $ExtL10NP_{h,b}^p = ORPrcCeil$;

If $InitExtL10NP_{h,b}^p < ORPrcFlr$, $ExtL10NP_{h,b}^p = ORPrcFlr$;
Otherwise, $ExtL10NP_{h,b}^p = InitExtL10NP_{h,b}^p$; and

Set $P10NExtCong_{h,d}^p = ExtL10NP_{h,b}^p - P10NRef_h^p - P10NIntCong_{h,d}^p$

23.4.2.5 The *locational marginal price* calculated by the *day-ahead market calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. Reserve imports associated with the same *boundary entity resource* bus, but specified as occurring at a different *intertie zone*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these reserve imports shall utilize shadow prices associated with *intertie* limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

23.4.2.6 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all *boundary entity resources* for that *intertie zone* will receive a zero schedule for *energy and operating reserve* and the *intertie operating reserve* prices shall be set equal to the *locational marginal price* for the *reference bus* for that class of *operating reserve* plus the applicable shadow prices associated with regional minimum and maximum *operating reserve* requirements.

23.5 Pricing for Islanded Nodes

23.5.1 For *non-quick start resources* that are not connected to the *main island*, the *day-ahead market calculation engine* may use the following reconnection logic where enabled by the *IESO* in the order set out below to calculate the *locational marginal prices* for *energy*:

23.5.1.1 Determine the connection paths over open switches that connect the *non-quick start resource* to the *main island*;

23.5.1.2 Determine the priority rating for each connection path identified based on a weighted sum of the base voltage over all open switches used by the reconnection path and the MW ratings of the newly connected branches; and

23.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

23.5.2 For all (i) *resources* other than those specified in section 23.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 23.5.1; the *day-ahead market calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices*, using a node-level and *facility*-level substitution list determined by the *IESO*:

23.5.2.1 Use the *locational marginal price* for *energy* at a node in the node-level substitution list where defined and enabled by the *IESO*, provided such node is connected to the *main island*;

23.5.2.2 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes at the same voltage level within the same *facility* that are connected to the *main island*;

23.5.2.3 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes within the same *facility* that are connected to the *main island*;

23.5.2.4 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes from another *facility* that is connected to the *main island*, as determined by the *facility*-level substitution list where defined and enabled by the *IESO*; and

23.5.2.5 If a price is unable to be determined in accordance with sections 23.5.2.1 through 23.5.2.4, use the *locational marginal price* for *energy* for the *reference bus*.

Appendix 7.5A – The Pre-Dispatch Calculation Engine Process

1.1 Purpose

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

2 Pre-Dispatch Calculation Engine

2.1 Pre-Dispatch Look-Ahead Period

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

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

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

2.2 Pre-Dispatch Calculation Engine Pass

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

3 Information Used by the Pre-Dispatch

Calculation Engine

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

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

4.1 Fundamental Sets and Indices

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.1.4 7$K^{E}_{t,b}$ designates the set of *offer* laminations for *energy* at bus $b \in B \cup DI$ for time-step $t \in TS$;

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

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

4.1.50 $K_{t,b}^{\prime LTMLP}$ designates the set of *reference level value* laminations for *energy* quantities up to the *minimum loading point reference level* for a *non-quick start resource* at bus $b \in B^{NQS}$ for time-step $t \in TS$;

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

4.1.52 $K_{t,b}^{\prime 10S}$ designates the set of *reference level value* laminations for synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

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

4.1.54 $K_{t,b}^{\prime 10N}$ designates the set of *reference level value* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B$ for time-step $t \in TS$;

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

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

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

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

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

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

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

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

4.1.63 BCA designates the set of broad constrained areas;

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

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

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

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

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

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

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

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

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

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

4.2 Market Participant Data Parameters

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

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

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

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

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

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

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

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

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

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

4.2.2.7 $P10NDG_{t,b,k}$ 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 $k \in K^{10N}_{t,b}$;

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

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

4.2.2.10 $ORRDG_{b}$ designates the maximum *operating reserve* ramp rate in MW per minute;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2.3.7 $\mathrm{MGBDTDG}_{q,b}^{COLD}$ designates the minimum generation block down-time for a cold thermal state in dispatch day $q \in DAYS$;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4.2.8 With respect to a *pseudo-unit* identified by bus $b \in B^{PSU}$:

4.2.8.1 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region;

4.2.8.2 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region;

4.2.8.3 $RampCT_{q,b,w}^{m}$ designates the quantity of *energy* injected w hours before the *pseudo-unit* reaches its *minimum loading point* in *dispatch day* $q \in DAYS$ and *thermal state* $m \in THERM$ that is attributed to the combustion turbine for $w \in \{1,..,RampHrs_{q,b}^{m}\}$; and

4.2.8.4 $RampST_{q,b,w}^{m}$ designates the quantity of *energy* injected w hours before the *pseudo-unit* reaches its *minimum loading point* in *dispatch day* $q \in DAYS$ for *thermal state* $m \in THERM$ that is attributed to the steam turbine for $w \in \{1,..,RampHrs_{q,b}^{m}\}$.

4.2.9 With respect to a *dispatchable load* identified by bus $b \in B^{DL}$:

4.2.9.1 $QDL_{t,b,j}$ designates the maximum incremental quantity of *energy* that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$;

4.2.9.2 $PDL_{t,b,j}$ designates the price for the maximum incremental quantity of *energy* in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$;

4.2.9.3 $Q10SDL_{t,b,j}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10S}_{t,b}$;

4.2.9.4 $P10SDL_{t,b,j}$ designates the price for the maximum incremental quanitity of synchronized *ten-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10S}_{t,b}$;

4.2.9.5 $Q10NDL_{t,b,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10N}_{t,b}$;

4.2.9.6 $P10NDL_{t,b,j}$ 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 $j \in J^{10N}_{t,b}$;

4.2.9.7 $Q30RDL_{t,b,j}$ designates the maximum increamental quantity of *thirty-minute operating reserve* that may be scheduled in time-step $t \in TS$ in association with *offer* lamination $j \in J^{30R}_{t,b}$;

4.2.9.8 $P30RDL_{t,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J^{30R}_{t,b}$;

4.2.9.9 $ORRDL_{b}$ designates the *operating reserve* ramp rate in MW per minute for reductions in load consumption;

4.2.9.10 $NumRRDL_{t,b}$ designates the number of ramp rates provided in time-step $t \in TS$;

4.2.9.11 $RmpRngMaxDL_{t,b,w}$ for $w \in \{1,..,NumRRDL_{t,b}\}$ designates the w[th] ramp rate break point in time-step $t \in TS$;

4.2.9.12 $URRDL_{t,b,w}$ for $w \in \{1,..,NumRRDL_{t,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption in time-step $t \in TS$ while operating in the range between $RmpRngMaxDL_{t,b,w-1}$ and $RmpRngMaxDL_{t,b,w}$, where $RmpRngMaxDL_{t,b,0}$ shall be equal to zero;

4.2.9.13 $DRRDL_{t,b,w}$ for $w \in \{1,..,NumRRDL_{t,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption in time-step $t \in TS$ while operating in the range between $RmpRngMaxDL_{t,b,w-1}$ and $RmpRngMaxDL_{t,b,w}$, where $RmpRngMaxDL_{t,b,0}$ shall be equal to zero; and

4.2.9.14 $QDLFIRM_{t,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in time-step $t \in TS$.

4.2.10 With respect to an *hourly demand response resource* identified by bus $b \in B^{HDR}$:

4.2.10.1 $QHDR_{t,b,j}$ designates an maximum incremental quantity of reduction in *energy* consumption that may be scheduled in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$;

4.2.10.2 $PHDR_{t,b,j}$ designates the price for the maximum incremental quantity of reduction in *energy* consumption for time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,b}$;

4.2.10.3 $URRHDR_{b}$ designates the maximum rate in MW per minute at which the *hourly demand response resource* can decrease its amount of *energy* consumption; and

4.2.10.4 $DRRHDR_{b}$ designates the maximum rate in MW per minute at which the *hourly demand response resource* can increase its amount of *energy* consumption.

4.2.11 With respect to a *boundary entity resource* import from *intertie zone* bus $d \in DI$, where the *locational marginal price* represents the price for the *intertie metering point*:

4.2.11.1 $QIG_{t,d,k}$ designates the maximum incremental quantity of *energy* that may be scheduled to import in time-step $t \in TS$ in association with *offer* lamination $k \in K^{E}_{t,d}$;

4.2.11.2 $PIG_{t,d,k}$ designates the price for the maximum incremental quantity of *energy* may be scheduled to import in time-step $t \in TS$ in association with *offer* lamination $k \in K^{E}_{t,d}$;

4.2.11.3 $Q10NIG_{t,d,k}$ 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 $k \in K^{10N}_{t,d}$;

4.2.11.4 $P10NIG_{t,d,k}$ 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 $k \in K^{10N}_{t,d}$;

4.2.11.5 $Q30RIG_{t,d,k}$ 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 $k \in K^{30R}_{t,d}$; and

4.2.11.6 $P30RIG_{t,d,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $k \in K^{30R}_{t,d}$.

4.2.12 With respect to a *boundary entity resource* export to *intertie zone* sink bus $d \in DX$, where the *locational marginal price* represents the price for the *intertie metering point*:

4.2.12.1 $QXL_{t,d,j}$ designates the maximum incremental quantity of *energy* that may be scheduled to export in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,d}$;

4.2.12.2 $PXL_{t,d,j}$ designates the price for the maximum incremental quantity of *energy* that may be scheduled to export in time-step $t \in TS$ in association with *bid* lamination $j \in J^{E}_{t,d}$;

4.2.12.3 $Q10NXL_{t,d,j}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* that may be scheduled to provide in time-step $t \in TS$ in association with *offer* lamination $j \in J^{10N}_{t,d}$;

4.2.12.4 $P10NXL_{t,d,j}$ 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 $j \in J^{10N}_{t,d}$;

4.2.12.5 $Q30RXL_{t,d,j}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled to provide in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$; and

4.2.12.6 $P30RXL_{t,d,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in time-step $t \in TS$ in association with *offer* lamination $j \in J_{t,d}^{30R}$.

4.2.13 With respect to a wheeling through transaction:

4.2.13.1 $L_t \subseteq DX \times DI$ designates the set of linked *boundary entity resource* import and export buses corresponding to *wheeling through transactions*, where L_t is a set with elements of the form *(dx, di)* where $dx \in DX$ and $di \in DI$.

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

4.3.1.1 $FG_{t,b}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus $b \in B^{VG}$ in time-step $t \in TS$.

4.3.2 Variable Generation Tie-Breaking

4.3.2.1 $NumVG_t$ designates the number of *variable generation resources* in the daily *dispatch* order for time-step $t \in TS$; and

4.3.2.2 $TBM_{t,b} \in \{1,..,NumVG_t\}$ designates the tie-breaking modifier for the *variable generation resource* at bus $b \in B^{VG}$ for time-step $t \in TS$.

4.3.3 Intertie Curtailments

4.3.3.1 $ICMaxXL_{t,d}$ designates the maximum limit on the quantity of *energy* scheduled for export to *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.2 $ICMinXL_{t,d}$ designates the minimum limit on the quantity of *energy* scheduled for export to *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.3 $ICMaxIG_{t,d}$ designates the maximum limit on the quantity of *energy* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.4 $ICMax10NIG_{t,d}$ designates the maximum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.5 $ICMax30RIG_{t,d}$ designates the maximum limit on the quantity of *thirty-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.6 $ICMinIG_{t,d}$ designates the minimum limit on the quantity of *energy* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment;

4.3.3.7 $ICMin10NIG_{t,d}$ designates the minimum limit on the quantity of non-synchronized *ten-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment; and

4.3.3.8 $ICMin30RIG_{t,d}$ designates the minimum limit on the quantity of *thirty-minute operating reserve* scheduled for import from *intertie zone* source bus $d \in DI$ and time-step $t \in TS$ as the result of an *intertie* curtailment.

4.3.4 Operating Reserve Requirements

4.3.4.1 $TOT10S_t$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.4.2 $TOT10R_t$ designates the total *ten-minute operating reserve* requirement;

4.3.4.3 $TOT30R_t$ designates the *thirty-minute operating reserve* requirement;

4.3.4.4 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.4.5 $REGMin10R_{t,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;

4.3.4.6 $REGMin30R_{t,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region $r \in ORREG$ in time-step $t \in TS$;

4.3.4.7 $REGMax10R_{t,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in time-step $t \in TS$; and

4.3.4.8 $REGMax30R_{t,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in time-step $t \in TS$.

4.3.5 Intertie Limits

4.3.5.1 $EnCoeff_{a,z}$ designates the coefficient for calculating the contribution of scheduled *energy* flows and *operating reserve* inflows for *intertie* zone $a \in A$, which is part of *intertie* limit constraint $z \in Z_{Sch}$. A coefficient of $+1$ shall describe flows into Ontario while a coefficient of -1 shall describe flows out of Ontario;

4.3.5.2 $MaxExtSch_{t,z}$ designates the maximum flow limit for *intertie* flow constraint $z \in Z_{Sch}$ in time-step $t \in TS$;

4.3.5.3 $ExtDSC_t$ designates the net interchange scheduling limit for when the net flows over all *interties* from time-step $(t-1)$ to time-step t decrease; and

4.3.5.4 $ExtUSC_t$ designates the net interchange scheduling limit for when the net flows over all *interties* from time-step $(t-1)$ to time-step t increase.

4.3.6 Resource Minimum and Maximum Constraints

4.3.6.1 Where applicable the minimum or maximum output of a *dispatchable generation resource* or a *non-dispatchable generation resource*, minimum or maximum consumption of a *dispatchable load*, and minimum and maximum reduction of an *hourly demand response resource* may be limited due to *reliability* constraints, applicable *contracted ancillary services*, day-ahead operational commitments, previous pre-dispatch operational commitments, *outages*, derates, activation/non-activation of *hourly demand response resources* and other constraints, such that:

4.3.6.1.1 $MinDL_{t,b}$ designates the most restrictive minimum consumption limit for the *dispatchable load* at bus $b \in B^{DL}$;

4.3.6.1.2 $MaxDL_{t,b}$ designates the most restrictive maximum consumption limit for the *dispatchable load* at bus $b \in B^{DL}$;

4.3.6.1.3 $MinNDG_{t,b}$ designates the most restrictive minimum output limitfor the *non-dispatchable generation resource* at bus $b \in B^{NDG}$;

4.3.6.1.4 $MaxNDG_{t,b}$ designates the most restrictive maximum output limitfor the *non-dispatchable generation resource* at bus $b \in B^{NDG}$;

4.3.6.1.5 $MinDG_{t,b}$ designates the most restrictive minimum output limit for the *dispatchable generation resource* at bus $b \in B^{DG}$;

4.3.6.1.6 $MaxDG_{t,b}$ designates the most restrictive maximum output limit for the *dispatchable generation resource* at bus $b \in B^{DG}$;

4.3.6.1.7 $MaxMLP_{t,b}$ designates the maximum output limit in time-step t for the *minimum loading point* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.8 $MaxDR_{t,b}$ designates the maximum output limit in time-step t for the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.9 $MaxDF_{t,b}$ designates the maximum output limit in time-step t for the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.6.1.10 $MinHDR_{t,b}$ designates the minimum load reduction level that may be scheduled for the *hourly demand response resource* at bus $b \in B^{HDR}$; and

4.3.6.1.11 $MaxHDR_{t,b}$ designates the maximum load reduction level that may be scheduled for the *hourly demand response resource* at bus $b \in B^{HDR}$.

4.3.7 Constraint violation penalties for time step $t \in TS$:

4.3.7.1 $(PLdViolSch_{st,i}, QLdViolSch_{t,i})$ for $i \in \{1,..,N_{LdViol_t}\}$ designates the price-quantity segments of the penalty curve for under generation used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.2 $(PLdViolPrc_{t,i}, QLdViolPrc_{t,i})$ for $i \in \{1,..,N_{LdViol_t}\}$ designates the price-quantity segments of the penalty curve for under generation used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.3 $(PGenViolSch_{t,i}, QGenViolSch_{t,i})$ for $i \in \{1,..,N_{GenViol_t}\}$ designates the price-quantity segments of the penalty curve for over generation used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.4 $(PGenViolPrc_{t,i}, QGenViolPrc_{t,i})$ for $i \in \{1,..,N_{GenViol_t}\}$ designates the price-quantity segments of the penalty curve for over generation used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.5 $(P10SViolSch_{t,i}, Q10SViolSch_{t,i})$ for $i \in \{1,..,N_{10SViol_t}\}$ designates the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.6 $(P10SViolPrc_{t,i}, Q10SViolPrc_{t,i})$ for $i \in \{1,..,N_{10SViol_t}\}$ designates the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.7 $(P10RViolSch_{t,i}, Q10RViolSch_{t,i})$ for $i \in \{1,..,N_{10RViol_t}\}$ designates the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.8 $(P10RViolPrc_{t,i}, Q10RViolPrc_{t,i})$ for $i \in \{1,..,N_{10RViol_t}\}$ designates the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.9 $(P30RViolSch_{t,i}, Q30RViolSch_{t,i})$ for $i \in \{1,..,N_{30RViol_t}\}$ designates the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.10 $(P30RViolPrc_{t,i}, Q30RViolPrc_{t,i})$ for $i \in \{1,..,N_{30RViol_t}\}$ designates the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.11 $(PREG10RViolSch_{t,i}, QREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{REG10RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.12 $(PREG10RViolPrc_{t,i}, QREG10RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG10RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.13 $(PREG30RViolSch_{t,i}, QREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{REG30RViol_t}\}$ designates the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.14 $(PREG30RViolPrc_{t,i}, QREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{REG30RViol_t}\}$ designates the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.15 $(PXREG10RViolSch_{t,i}, QXREG10RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG10RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.16 $(PXREG10RViolPrc_{t,i}, QXREG10RViolPrc_{t,i})$ for $i \in \{1,..,N_{XREG10RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.17 $(PXREG30RViolSch_{t,i}, QXREG30RViolSch_{t,i})$ for $i \in \{1,..,N_{XREG30RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.18 $(PXREG30RViolPrc_{t,i}, QXREG30RViolPrc_{t,i})$ for $i \in \{1,..,N_{XREG30RViol_t}\}$ designates the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.19 $(PPreITLViolSch_{f,t,i}, QPreITLViolSch_{f,t,i})$ for $i \in \{1,..,N_{PreITLViol_{f,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.20 $(PPreITLViolPrc_{f,t,i}, QPreITLViolPrc_{f,t,i})$ for $i \in \{1,..,N_{PreITLViol_{f,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.21 $(PITLViolSch_{c,f,t,i}, QITLViolSch_{c,f,t,i})$ for $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.22 $(PITLViolPrc_{c,f,t,i}, QITLViolPrc_{c,f,t,i})$ for $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.23 $(PPreXTLViolSch_{z,t,i}, QPreXTLViolSch_{z,t,i})$ for $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.24 $(PPreXTLViolPrc_{z,t,i}, QPreXTLViolPrc_{z,t,i})$ for $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ designates the price-quantity segments of the penalty curve for exceeding the flow limit specified by $z \in Z_{Sch}$ used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.25 $(PNIUViolSch_{t,i}, QNIUViolSch_{t,i})$ for $i \in \{1,..,N_{NIUViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding the time-step t net interchange increase constraint between time-steps $(t$-1) and t used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.26 $(PNIUViolPrc_{t,i}, QNIUViolPrc_{t,i})$ for $i \in \{1,..,N_{NIUViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding the time-step t net interchange increase constraint between time-steps $(t$-1) and t used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.27 $(PNIDViolSch_{t,i}, QNIDViolSch_{t,i})$ for $i \in \{1,..,N_{NIDViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding the time-step t net interchange decrease constraint between time-steps $(t$-1) and t used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.28 $(PNIDViolPrc_{t,i}, QNIDViolPrc_{t,i})$ for $i \in \{1,..,N_{NIDViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding the time-step t net interchange decrease constraint between time-steps $(t$-1) and t used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.29 $(PMaxDelViolSch_{t,i}, QMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.30 $(PMaxDelViolPrc_{t,i}, QMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ designates the price-quantity segments of the penalty curve for exceeding a *resource's maximum daily energy limit* used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.31 $(PMinDelViolSch_{t,i}, QMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{MinDelViol_t}\}$ designates the price-quantity segments of the penalty curve for under-scheduling a *resource's minimum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.32 $(PMinDelViolPrc_{t,i}, QMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MinDelViol_t}\}$ designates the price-quantity segments of the penalty curve for under-scheduling a *resource's minimum daily energy limit* used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.33 $(PSMaxDelViolSch_{t,i}, QSMaxDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMaxDelViol_t}\}$ designate the price-quantity segments of the penalty curve for exceeding a shared *maximum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.34 $(PSMaxDelViolPrc_{t,i}, QSMaxDelViolPrc_{t,i})$ for $i \in \{1,..,N_{MaxDelViol_t}\}$ designate the price-quantity segments of the penalty curve for exceeding a shared *maximum daily energy limit* used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.35 $(PSMinDelViolSch_{t,i}, QSMinDelViolSch_{t,i})$ for $i \in \{1,..,N_{SMinDelViol_t}\}$ designate the price-quantity segments of the penalty curve for under-scheduling a shared *minimum daily energy limit* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.36 $(PSMinDelViolPrc_{t,i}, QSMinDelViolPrc_{t,i})$ for $i \in \{1,..,N_{SMinDelViol_t}\}$ designate the price-quantity segments of the penalty curve for under-scheduling a shared *minimum daily energy limit* used by the Pre-Dispatch Pricing algorithm in section 9 and Reference Level Pricing algorithm in section 13;

4.3.7.37 $(POGenLnkViolSch_{t,i}, QOGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{OGenLnkViol_t}\}$ designate the price-quantity segments of the penalty curve for over generation on a downstream *resource* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12;

4.3.7.38 $(PUGenLnkViolSch_{t,i}, QUGenLnkViolSch_{t,i})$ for $i \in \{1,..,N_{UGenLnkViol_t}\}$ designate the price-quantity segments of the penalty curve for under generation on a downstream *resource* used by the Pre-Dispatch Scheduling algorithm in section 8 and the Reference Level Scheduling algorithm in section 12; and

4.3.7.39 $NISLPen$ designates the net interchange scheduling limit constraint violation penalty price for *locational marginal pricing*.

4.3.8 Price Bounds

4.3.8.1 $EngyPrcCeil$ designates and is equal to the *maximum market clearing price* for *energy*;

4.3.8.2 $EngyPrcFlr$ designates and is equal to the *settlement floor price* for *energy*;

4.3.8.3 $ORPrcCeil$ designates and is equal to the *maximum operating reserve price* for all classes of *operating reserve*; and

4.3.8.4 $ORPrcFlr$ designates the minimum price for all classes of *operating reserve* and is equal to $0.

4.3.9 Ex-Ante Market Power Mitigation

4.3.9.1 $BCACondThresh$ designates the threshold for the congestion component of a *resource's locational marginal price* for *energy*, above which the *resource* will meet the broad constrained area condition, and is equal to $25/MWh;

4.3.9.2 $IBPThresh$ designates the *intertie border price* threshold for *energy* and is equal to $100/MWh;

4.3.9.3 $ORGCondThresh$ designates the global market power condition threshold for a *resource's locational marginal price* for *operating reserve* and is equal to $15/MW;

4.3.9.4 $PDGRef_{t,b,k'}$ designates the *reference level value* for *energy* lamination $k' \in K^{E}_{t,b}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.5 $P10SDGRef_{t,b,k'}$ designates the *reference level value* for synchronized *ten-minute operating reserve* lamination $k' \in K'^{10S}_{t,b}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.6 $P10NDGRef_{t,b,k'}$ designates the *reference level value* for non-synchronized *ten-minute operating reserve* lamination $k' \in K'^{10N}_{t,b}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.7 $P30RDGRef_{t,b,k'}$ designates the *reference level value* for *thirty-minute operating reserve* lamination $k' \in K^{30R}_{t,b}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.8 $P10SDLRef_{t,b,j'}$ designates the *reference level value* for synchronized *ten-minute operating reserve* lamination $j' \in J'^{10S}_{t,b}$ for the *resource* at bus $b \in B^{DL}$ in time-step $t \in TS$;

4.3.9.9 $P10NDLRef_{t,b,j'}$ designates the *reference level value* for non-synchronized *ten-minute operating reserve* lamination $j' \in J'^{10N}_{t,b}$ for the *resource* at bus $b \in B^{DL}$ in time-step $t \in TS$;

4.3.9.10 $P30RDLRef_{t,b,j'}$ designates the *reference level value* for *thirty-minute operating reserve* lamination $j' \in J^{30R}_{t,b}$ for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$

4.3.9.11 $SUDGRef_{t,b}$ designates the *reference level value* for the *start-up offer* for the *resource* at bus $b \in B^{NQS}$ in time-step $t \in TS$;

4.3.9.12 $SNLRef_{t,b}$ designates the *reference level value* for the *speed no-load offer* for the *resource* at bus $b \in B^{NQS}$ in time-step $t \in TS$;

4.3.9.12 $PLTMLPRef_{t,b,k'}$ designates the *reference level value* for the *energy* up to the *minimum loading point reference level* lamination $k' \in K'^{LTMLP}_{h,b}$ of the *offer* for the *resource* at bus $b \in B^{DG}$ in time-step $t \in TS$;

4.3.9.14 $CTEnThresh1^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 50%;

4.3.9.15 $CTEnThresh2^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.9.16 $CTSUThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.17 $CTSNLThresh^{NCA}$ designates the conduct threshold for a *resource* in a *narrow constrained area* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.18 $CTEnThresh1^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 50%;

4.3.9.19 $CTEnThresh2^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $25/MWh;

4.3.9.20 $CTSUThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.21 $CTSNLThresh^{DCA}$ designates the conduct threshold for a *resource* in a *dynamic constrained area* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.22 $CTEnThresh1^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

4.3.9.23 $CTEnThresh2^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $100/MWh;

4.3.9.24 $CTSUThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 100%;

4.3.9.25 $CTSNLThresh^{BCA}$ designates the conduct threshold for a *resource* in a broad constrained area as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 100%;

4.3.9.26 $CTEnThresh1^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *energy offer* for the *resource* and is equal to 300%;

4.3.9.27 $CTEnThresh2^{GMP}$ designates the global market power conduct threshold for a *resource* as a $/MWh increase above the *reference level value* of the *energy offer* for the *resource* and is equal to $100 MW/h;

4.3.9.28 $CTSUThresh^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 100%;

4.3.9.29 $CTSNLThresh^{GMP}$ designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 100%;

4.3.9.30 $CTORThresh1^{ORL}$ designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to 10%;

4.3.9.31 $CTORThresh2^{ORL}$ designates the local market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.9.32 $CTEnThresh1^{ORL}$ designates the local marker power conduct thershold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 10%;

4.3.9.33 $CTEnThresh2^{ORL}$ designates the local maket power conduct threshold for *energy* to *minimum loading point* conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *energy* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

4.3.9.34 *CTSUThresh*^{ORL} designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 10%;

4.3.9.35 *CTSNLThresh*^{ORL} designates the local market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 10%;

4.3.9.36 *CTORThresh*1^{ORG} designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to 50%;

4.3.9.37 *CTORThresh*2^{ORG} designates the global market power conduct threshold for a *resource* as a $/MW increase above the *reference level value* of the *operating reserve offer* for the *resource* and is equal to $25/MW;

4.3.9.38 *CTEnThresh*1^{ORG} designates the global market power conduct thershold for *energy* to *minimum loading point* for a *resource* as a percent increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to 50%;

4.3.9.39 *CTEnThresh*2^{ORG} designates the global market power conduct thershold for *energy* to *minimum loading point* for a *resource* as a $/MW increase above the *reference level value* of the *offer* for *energy* up to the *minimum loading point* for the *resource* and is equal to $25/MW;

4.3.9.40 *CTSUThresh*^{ORG} designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *start-up offer* for the *resource* and is equal to 25%;

4.3.9.41 *CTSNLThresh*^{ORG} designates the global market power conduct threshold for a *resource* as a percent increase above the *reference level value* of the *speed no-load offer* for the *resource* and is equal to 25%;

4.3.9.42 *CTEnMinOffer* designates the minimum price for the *offer* lamination for *energy* to be included in the Conduct Test. *Offer* laminations for *energy* below this value are excluded from the Conduct Test and is equal to $25/MWh;

4.3.9.43 *CTORMinOffer* designates the minimum price for the *offer* lamination for *operating reserve* to be included in the Conduct Test. *Offer* laminations for *operating reserve* below this value are excluded from the Conduct Test and is equal to $5/MW;

4.3.9.44 $ITThresh1^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.9.45 $ITThresh2^{NCA}$ designates the price impact threshold for a *resource* in a *narrow constrained area* as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $25/MWh;

4.3.9.46 $ITThresh1^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 50%;

4.3.9.47 $ITThresh2^{DCA}$ designates the price impact threshold for a *resource* in a *dynamic constrained area* as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $25/MWh;

4.3.9.48 $ITThresh1^{BCA}$ designates the price impact threshold for a *resource* in a broad constrained area as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.9.49 $ITThresh2^{BCA}$ designates the price impact threshold for a *resource* in a broad constrained area as a $/MWh increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to$50/MWh;

4.3.9.50 $ITThresh1^{GMP}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *energy locational marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to 100%;

4.3.9.51 $ITThresh2^{GMP}$ designates the global market power price impact threshold for a *resource* as a $/MWh increase in the *energy locational* *marginal price* output from section 9 above the *energy locational marginal price* output from section 13 and is equal to $50/MWh;

4.3.9.52 $ITThresh1^{ORG}$ designates the global market power price impact threshold for a *resource* as a percent increase in the *operating reserve locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to 50%; and

4.3.9.53 $ITThresh2^{ORG}$ designates the global market power price impact threshold for a *resource* as a $/MW increase in the *operating reserve locational marginal price* output from section 9 above the *operating reserve locational marginal price* output from section 13 and is equal to $25/MW.

4.3.10 Weighting Factors for Zonal Prices

4.3.10.1 $WF^{VIRT}_{t,m,b}$ designates the weighting factor for bus $b \in L^{VIRT}_{m}$ used to calculate the price for *virtual transaction zone* $m \in M$ for time-step $t \in TS$ and is equal to the weighting factor used in the *day-ahead market* for the applicable hour;

4.3.10.2 $WF^{NDL}_{h,y,b}$ designates the weighting factor for bus $b \in L^{NDL}_{y}$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for time-step $t \in TS$. The weighting factors shall be obtained by renormalizing the load distribution factors so that for a given time-step the sum of weighting factors for a *non-dispatchable load* zone is equal to one.

4.3.11 Day-Ahead Market Scheduled Intertie Transactions

4.3.11.1 $SIGT^{DAM}_{t,d}$ designates the *day-ahead market* scheduled quantity of import *energy* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.2 $S10NIGT^{DAM}_{t,d}$ designates the *day-ahead market* scheduled quantity of non-synchronized *ten-minute operating reserve* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.3 $S30RIGT^{DAM}_{t,d}$ designates the *day-ahead market* scheduled quantity of *thirty-minute operating reserve* for *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.4 $SXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of export *energy* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$;

4.3.11.5 $S10NXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of non-synchronized *ten-minute operating reserve* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$; and

4.3.11.6 $S30RXLT_{t,d}^{DAM}$ designates the *day-ahead market* scheduled quantity of *thirty-minute operating reserve* for *intertie zone* sink bus $d \in DX$ in time-step $t \in \{4,..,n_{LAP}\}$.

4.3.12 Import Offers Without a Day-Ahead Market Schedule

4.3.12.1 $SIGT_{t,d}^{EXTRA}$ designates the extra quantity of *energy* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*;

4.3.12.2 $S10NIGT_{t,d}^{EXTRA}$ designates the extra quantity of non-synchronized *ten-minute operating reserve* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*; and

4.3.12.3 $S30RIGT_{t,d}^{EXTRA}$ designates the extra quantity of *thirty-minute operating reserve* for import from *intertie zone* source bus $d \in DI$ in time-step $t \in \{4,..,n_{LAP}\}$ that may be considered for the purpose of *reliability*.

4.4 Other Data Parameters

4.4.1 Non-Dispatchable Demand Forecast

4.4.1.1 FL_t designates the total province-wide non-*dispatchable demand* forecast for time-step $t \in TS$ calculated by the *security* assessment function.

4.4.2 Internal Transmission Constraints

4.4.2.1 $PreConSF_{t,f,b}$ designates the pre-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during time-step t under pre-contingency conditions;

4.4.2.12 $AdjNormMaxFlow_{t,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in time-step t under pre-contingency conditions;

4.4.2.13 $SF_{t,c,f,b}$ designates the post-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during time-step t under post-contingency conditions for contingency c; and

4.4.2.4 $AdjEmMaxFlow_{t,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in time-step t under post-contingency conditions for contingency c.

4.4.3 Transmission Losses

4.4.3.1 $MglLoss_{t,b}$ designates the marginal loss factor and represents the marginal impact on transmission losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at *resource* bus $b \in B \cup D$ in time-step $t \in TS$; and

4.4.3.2 $LossAdj_t$ designates any adjustment needed for time-step $t \in TS$ to correct for any discrepancy between Ontario total system losses calculated using a base case power flow from the *security* assessment function and linearized losses that would be calculated using the marginal loss factors.

5 Initialization

5.1 Purpose

5.1.1 The initialization processes set out in this section 5 shall occur prior to the execution of the *pre-dispatch calculation engine* described in section 2.2.1 above.

5.2 Reference Bus

5.2.1 The *IESO* shall use Richview Transformer Station as the *pre-dispatch calculation engine's* default *reference bus* for the calculation of *locational marginal prices.*

5.2.2 If the default *reference bus* is out of service, another in-service bus shall be selected.

5.3 Islanding Conditions

5.3.1 In the event of a network split, the *pre-dispatch calculation engine* shall:

5.3.1.1 only evaluate *resources* that are within the *main island*;

5.3.1.2 use only forecasts of *demand* forecast areas in the *main island*; and

5.3.1.3 use a bus within the *main island* in place of the *reference bus* if the *reference bus* does not fall within the *main island*.

5.4 Variable Generation Tie-Breaking

5.4.1 For each time-step $t \in TS$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K^{E}_{t,b}$, the *offer* price $PDG_{t,b,k}$ shall be modified to $PDG_{t,b,k} - \left(\frac{TBM_{t,b}}{NumVG_t}\right)\rho$, where ρ is a small nominal value of order 10^{-4}.

5.5 Pseudo-Unit Constraints

5.5.1 Constraints for *pseudo-units* corresponding to minimum and maximum constraints on physical *resources* shall be determined in accordance with section 15.

5.6 Dispatch Data Across Two Dispatch Days

5.6.1 If the pre-dispatch look-ahead period spans two *dispatch days*, then the *pre-dispatch calculation engine* shall set the parameters below as follows:

5.6.1.1 $LNKC$, which designates the linked *dispatchable* hydroelectric *generation resources* and is defined by:

$$LNKC = \begin{cases} LNK_{tod} & if\ DAYS = \{tod\} \\ LNK_{tom} & if\ DAYS = \{tod, tom\} \end{cases}.$$

5.6.1.2 $LagC_{b_1,b_2}$, which designates the *time lag* between *dispatchable* hydroelectric *generation resources* $(b_1,b_2) \in LNKC$ and is defined by:

$$LagC_{b_1,b_2} = \begin{cases} Lag_{tod,b_1,b_2} & if\ DAYS = \{tod\} \\ Lag_{tom,b_1,b_2} & if\ DAYS = \{tod, tom\} \end{cases}.$$

5.6.1.3 $MWhRatioC_{b_1,b_2}$, which designates the *MWh ratio* for *dispatchable* hydroelectric *generation resources* $(b_1,b_2) \in LNKC$ and is defined by:

$$MWhRatioC_{b_1,b_2} = \begin{cases} MWhRatio_{tod,b_1,b_2} & if\ DAYS = \{tod\} \\ MWhRatio_{tom,b_1,b_2} & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.4 $MinQDGC_b$, which designates the *minimum loading point* for *dispatchable generation resource* $b \in B^{DG}$ and, subject to section 5.6.2, is defined by:

$$MinQDGC_b = \begin{cases} MinQDG_{tod,b} & if\ DAYS = \{tod\} \\ MinQDG_{tom,b} & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.5 $MGBRTDGC_b$, which designates the *minimum generation block run time* for *non-quick start resource* $b \in B^{NQS}$ and, subject to section 5.6.2, is defined by:

$$MGBRTDGC_b = \begin{cases} MGBRTDG_{tod,b} & if\ DAYS = \{tod\} \\ MGBRTDG_{tom,b} & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.6 $MGBDTDGC_b^m$, which designates the *minimum generation block down time* for *non-quick start resource* $b \in B^{NQS}$ for *thermal state* $m \in THERM$ and is defined by:

$$MGBDTDGC_b^m = \begin{cases} MGBDTDG_{tod,b}^m & if\ DAYS = \{tod\} \\ MGBDTDG_{tom,b}^m & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.7 LTC_b^m, which designates the *lead time* for *non-quick start resource* $b \in B^{NQS}$ for *thermal state* $m \in THERM$ and is defined by

$$LTC_b^m = \begin{cases} LT_{tod,b}^m & if\ DAYS = \{tod\} \\ LT_{tom,b}^m & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.8 $RampHrsC_b^m$, which designates the *ramp hours to minimum loading point* for a *non-quick start resource* $b \in B^{NQS}$ for *thermal state* $m \in THERM$ and is defined by:

$$RampHrsC_b^m = \begin{cases} RampHrs_{tod,b}^m & if\ DAYS = \{tod\} \\ RampHrs_{tom,b}^m & if\ DAYS = \{tod,tom\} \end{cases}.$$

5.6.1.9 $\mathrm{RampEC}_{b,w}^m$ for $w \in \{1,..,\mathrm{RampHrsC}_b^m\}$, which designates the ramp up energy to minimum loading point for a non-quick start resource $b \in B^{NQS}$ for thermal state $m \in THERM$ and is defined by:

$$RampEC_{b,w}^{m} = \begin{cases} RampE_{tod,b,w}^{m} & if\ DAYS = \{tod\} \\ RampE_{tom,b,w}^{m} & if\ DAYS = \{tod, tom\} \end{cases}.$$

5.6.1.10 $RampCTC_{b,w}^{m}$ for $w \in \{1,..,RampHrsC_{b}^{m}\}$, which designates the *ramp up energy to minimum loading point* for the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ for *thermal state* $m \in THERM$ and is defined by:

$$RampCTC_{b,w}^{m} = \begin{cases} RampCT_{tod,b,w}^{m} & if\ DAYS = \{tod\} \\ RampCT_{tom,b,w}^{m} & if\ DAYS = \{tod, tom\} \end{cases}.$$

5.6.1.11 $RampSTC_{b,w}^{m}$ for $w \in \{1,..,RampHrsC_{b}^{m}\}$, which designates the *ramp up energy to minimum loading point* for the steam turbine portion of the *pseudo-unit* at bus $b \in B^{PSU}$ for *thermal state* $m \in THERM$ and is defined by:

$$RampSTC_{b,w}^{m} = \begin{cases} RampST_{tod,b,w}^{m} & if\ DAYS = \{tod\} \\ RampST_{tom,b,w}^{m} & if\ DAYS = \{tod, tom\} \end{cases}.$$

5.6.2 If a *non-quick start resource* receives a commitment prior to the 20:00 EST *pre-dispatch calculation engine* run but that commitment is not yet complete, then:

5.6.2.1 $MinQDG_{tod,b}$ and $MGBRTDG_{tod,b}$ shall continue to be applied until the commitment is complete; and

5.6.2.2 $MinQDG_{tom,b}$ and $MGBRTDG_{tom,b}$ shall be applied for any new commitments made in the 20:00 EST *pre-dispatch calculation engine run* or later.

5.6.3 For all other daily *dispatch data*, except the single-cycle mode flag determined in section 15.5, the current day value shall be used for all *dispatch hours* in the current *dispatch day* and the next day value shall be used for all *dispatch hours* in the next *dispatch day*.

5.7 Start-Up Offers for Non-Quick Start Resource Advancements

5.7.1 The *pre-dispatch calculation engine* shall use *start-up offers* for *non-quick start resources* with a day-ahead operational commitment as follows:

5.7.1.1 If the time-step t in the set of hours preceding the start-up time $t_{DAM} \in TSC_{b}$ of a day-ahead operational commitment in day $q \in DAYS$ are such that $t \in \{max(t_{DAM}$-$(MGBRTDG_{q,b} + MGBDTDG_{q,b}^{HOT}), 2),...,t_{DAM}\}$, then:

If $SUDG_{t,b}^{m} \geq SUDG_{t,b}^{DAM}$, then set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{m}$

If $SUDG_{t,b}^{m} < SUDG_{t,b}^{DAM}$, then set $SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{DAM}$

5.7.1.2 If the time-step t in the set of hours preceding the start-up time $t_{DAM} \in TSC_b$ of a day-ahead operational commitment in day $q \in DAYS$ are *offer*such that $t \notin \{max(t_{DAM}$-$(MGBRTDG_{q,b} + MGBDTDG_{q,b}^{HOT}), 2),...,t_{DAM}\}$, then:

$$SUAdjDG_{t,b}^{m} = SUDG_{t,b}^{m}$$

5.8 Non-Quick Start Resource First Time-Step Available to Start

5.8.1 The *pre-dispatch calculation engine* shall determine the first time-step a *non-quick start resource* can be scheduled to its *minimum loading point* as follows:

5.8.1.1 For a *non-quick start resource* at bus $b \in B^{NQS}$ that has not been scheduled at or above its *minimum loading point* for $InitDownHrs_b$ hours:

5.8.1.1.1 If $0 \leq InitDownHrs_b + t - 1 \leq MGBDTDGC_b^{HOT}$, then the *resource* cannot be scheduled to reach *minimum loading point* in time-step $t \in TS$;

5.8.1.1.2 If $InitDownHrs_b + LTC_b^{HOT} + 1 \leq MGBDTDGC_b^{WARM}$, then a *lead time* of LTC_b^{HOT} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_b^{HOT} + 2$;

5.8.1.1.3 If $InitDownHrs_b + LTC_b^{WARM} + 1 \leq MGBDTDGC_b^{COLD}$, then a *lead time* of LTC_b^{WARM} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_b^{WARM} + 2$; and

5.8.1.1.4 If a *lead time* of LTC_b^{COLD} will be applied and the *resource* can be scheduled to its *minimum loading point* in time-step $t \in TS$ only if $t \geq LTC_b^{COLD} + 2$.

5.9 Initial Scheduling Assumptions

5.9.1 Initial Schedules

5.9.1.1 The following parameters designate the initial *energy* schedules used for time-step 1 of the pre-dispatch look-ahead period and shall be based on the values determined by the *IESO's energy* management system for internal *resources* and the most recent *interchange schedules* for time-step 1 for *boundary entity resources*:

5.9.1.1.1 $SDL_{1,b,j}$ designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$;

5.9.1.1.2 $SHDR_{1,b,j}$ designates the amount of *energy* an *hourly demand response resource* is scheduled to reduce consumption at bus $b \in B^{HDR}$;

5.9.1.1.3 $SXL_{1,d,j}$ designates the amount of *energy* a *bounday entity resource* is scheduled to export at bus $d \in DX$;

5.9.1.1.4 $SDG_{1,b,k}$ designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$;

5.9.1.1.5 $SCT_{1,b}$ designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$;

5.9.1.1.6 $SST_{1,p}$ designates the schedule of steam turbine $p \in PST$;

5.9.1.1.7 $SIG_{1,d,k}$ designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* source bus $d \in DI$;

5.9.1.2 The initial schedules for *non-quick start resources* shall be determined to align with the commitment status logic described in section 5.9.2.

5.9.2 The following parameters designate initial commitment status, number of hours in operation and number of hours down for time-step 1 of the pre-dispatch look-ahead period:

5.9.2.1 $ODG_{1,b}$ designates whether the *dispatchable generation resource* at bus $b \in B^{NQS}$ has been scheduled at or above its *minimum loading point* in time-step 1, where $ODG_{1,b}$ shall be set to $ODG_{2,b}$ from the previous *pre-dispatch calculation engine run* unless the *real-time* *calculation engine* has kept such *resource* at or above its *minimum loading point* to respect a *reliability* constraint. In such cases, $ODG_{1,b}$ shall be determined by the *real-time calculation engine* advisory schedule;

5.9.2.2 $InitOperHrs_b$ designates the number of consecutive hours at the end of time-step 1 for which the *resource* at bus $b \in B^{NQS}$ has been, and is anticipated to be, operating at or above its *minimum loading point*. For *resources* with $ODG_{1,b} = 0$, $InitOperHrs_b$ shall be set to zero; and

5.9.2.3 $InitDownHrs_b$ designates the number of consecutive hours at the end of time-step 1 for which the *resource* at bus $b \in B^{NQS}$ has not been, and is not anticipated to be, operating at or above its *minimum loading point*. For *resources* with $ODG_{1,b} = 1$, $InitDownHrs_b$ shall be set to zero.

5.9.3 Initial Net Interchange Schedule

5.9.3.1 The initial net *interchange schedule* value shall be the difference between all imports to Ontario and all exports from Ontario for time-step 1. By default, this value will be based on fixed schedules for imports and exports from the *real-time calculation engine*.

5.9.4 Number of Starts for Non-Quick Start Resources

5.9.4.1 $NumStarts_b$ designates the number of starts the *resource* at bus $b \in B^{NQS}$ has incurred in the current *dispatch* day, plus any anticipated starts in time-step 1.

5.9.5 Number of Starts for Hydroelectric Resources

5.9.5.1 $NumStartsHE_b$ designates the number of starts the *resource* at bus $b \in B^{HE}$ has incurred in the current *dispatch day*, plus any anticipated starts in time-step 1.

5.9.6 Cumulative Energy Production for Energy Limited Resources and Dispatchable Hydroelectric Resources

5.9.6.1 $EngyUsed_b$ designates the *energy* already provided by the *resource* at bus $b \in B^{ELR} \cup B^{HE}$ in the current *dispatch day*, plus the *energy* scheduled in time-step 1; and

5.9.6.2 $EngyUsedSHE_s$ designates the *energy* already provided in the current *dispatch day* by all *resources* sharing a *maximum daily energy limit* or *minimum daily energy limit* in set $s \in SHE$ plus the *energy* scheduled in time-step 1.

5.9.7 Past Hourly Production for Linked Hydroelectric Resources

5.9.7.1 For linked hydroelectric *resources*, the past hourly *energy* production of upstream *resources* shall be used to schedule downstream *resources* for time-steps in the pre-dispatch look-ahead period within the *time lag*. These past hourly production schedules shall be equal to the output determined by the *IESO's energy* management system based on real-time telemetry less any production scheduled as part of an *operating reserve* activation. For all linked hydroelectric *resources* $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t \leq LagC_{b_1,b_2}$, $PastMWh_{t,b_1}$ designates the total *energy* produced by *resource* b_1 exactly $LagC_{b_1,b_2}$ hours prior to time-step t.

5.9.7.2 The schedules of downstream *resources* linked to time-step 1 upstream *resource* schedules shall be pre-determined based on the average value of the upstream *resource* advisory schedules from the last *real-time calculation engine* run that successfully completed before the *pre-dispatch calculation engine* run commenced. If the advisory schedule reflects an *operating reserve* activation for an upstream *resource*, then the schedule determined by the *real-time calculation engine* run prior to the *operating reserve* activation shall be used. For all linked hydroelectric *resources* $(b_1,b_2) \in LNKC$ and all time-steps $t \in TS$ such that $t = LagC_{b_1,b_2}+1$, $PastMWh_{t,b_1}$ designates the total *energy* determined for *resource* b_1 for time-step 1 to be used for scheduling downstream *resources* in time-step t.

6 Security Assessment Function in the Pre-Dispatch Calculation Engine

6.1 Interaction between the Security Assessment Function and Optimization Functions

6.1.1 The scheduling and pricing algorithms of the *pre-dispatch calculation engine* shall perform multiple iterations of the optimization functions and the *security* assessment function to check for violations of monitored thermal limits and operating *security limits* using the schedules produced by the optimization functions.

6.1.2 As multiple iterations are performed, the transmission constraints produced by the *security* assessment function shall be used by the optimization functions.

6.1.3 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudo-units*.

6.2 Inputs into the Security Assessment Function

6.2.1 The *security* assessment function shall use the following inputs:

6.2.1.1 the *IESO demand* forecasts; and

6.2.1.2 applicable *IESO-controlled grid* information pursuant to section 3A.1 of Chapter 7.

6.2.2 The *security* assessment function shall also use the following outputs of the optimization functions:

6.2.2.1 the schedules for *dispatchable loads* and *hourly demand response resources*;

6.2.2.2 the schedules for *non-dispatchable generation resources* and *dispatchable generation resources*; and

6.2.2.3 the schedules for *boundary entity resources* at each *intertie zone*.

6.3 Security Assessment Function Processing

6.3.1 The *security* assessment function shall determine the province-wide non-*dispatchable demand* forecast for time-step t, FL_t, as follows:

6.3.1.1 determine forecast MW quantities for all *load resources* and losses using the *IESO demand* forecasts for *demand* forecast areas, load distribution factors, and the total of the *bid* quantities submitted for virtual *hourly demand response resources* and physical *hourly demand response resources*; and

6.3.1.2 determine FL_t by adding the forecast MW quantities determined for each *non-dispatchable load*, each *price responsive load*, and each *dispatchable load* with no *bid*, including forecast MW losses in the *demand* forecast areas.

6.3.2 The *security* assessment function shall perform the following calculations and analyses:

6.3.2.1 A base case solution function shall prepare a power flow solution for each time-step. The base case solution function shall select the power system model state applicable to the forecast of conditions for the time-step and input schedules.

6.3.2.2 The base case solution function shall use an AC power flow analysis. If the AC power flow analysis fails to converge, the base case solution function shall use a non-linear DC power flow analysis. If the non-linear DC power flow analysis fails to converge, the base case solution function shall use a linear DC power flow analysis.

6.3.2.3 If the AC or non-linear DC power flow analysis converges, continuous thermal limits for all monitored equipment and operating *security limits* shall be monitored to check for pre-contingency limit violations.

6.3.2.4 Violated pre-contingency limits shall be linearized using pre-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.5 If the linear DC power flow analysis is used, the pre-contingency *security* assessment may develop linear constraints to facilitate the convergence of the AC or non-linear DC power flow analysisin the subsequent iterations.

6.3.2.6 A linear power flow analysis shall be used to simulate contingencies, calculate post-contingency flows and check all monitored equipment for limited-time thermal limit violations.

6.3.2.7 Violated post-contingency limits shall be linearized using post-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.8 The base case solution shall be used to calculate Ontario *transmission system* losses, marginal loss factors and loss adjustment for each time-step. The impact of losses on branches between the *resource* bus and the *resource connection point* to the *IESO-controlled grid* and losses on branches outside Ontario shall be excluded when determining marginal loss factors.

6.3.2.9 The Pre-Dispatch Scheduling and the Reference Level Scheduling algorithms described in sections 8 and 12, respectively, shall use the marginal loss factors for each time step calculated by the *security* assessment function.

6.3.2.10 The Pre-Dispatch Pricing and Reference Level Pricing algoritms described in sections 9 and 13, respectively, shall use the marginal loss factors used in the last iteration of the optimization function in the corresponding scheduling algorithm.

6.4 Outputs from the Security Assessment Function

6.4.1 The outputs of the *security* assessment function used in the optimization functions include the following:

6.4.1.1 a set of linearized constraints for all violated pre-contingency and post-contingency limits for each time-step. The sensitivities and limits associated with the constraints shall be those provided by the most recent *security* assessment function iteration;

6.4.12 pre-contingency and post-contingency sensitivity factors for each time step;

6.4.1.3 the marginal loss factors as described in sections 6.3.2.8 - 6.3.2.10; and

6.4.1.4 loss adjustment quantity for each time-step.

7 Pass 1: Pre-Dispatch Scheduling Process

7.1.1 Pass 1 shall use *market participant* and *IESO* inputs and *resource* and system constraints to determine a set of *resource* schedules, commitments and *locational marginal prices*. Pass 1 shall consist of the following algorithms and tests:

- the Pre-Dispatch Scheduling algorithm described in section 8;
- the Pre-Dispatch Pricing algorithm described in section 9;
- the Constrained Area Conditions Test described in section 10;
- the Conduct Test described in section 11;
- the Reference Level Scheduling algorithm described in section 12;
- the Reference Level Pricing algorithm described in section 13; and

- the Price Impact Test described in section 14.

8 Pre-Dispatch Scheduling

8.1 Purpose

8.1.1 The Pre-Dispatch Scheduling algorithm shall perform a *security*-constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants,* subject to section 14.7.1.3, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

8.2 Information, Sets, Indices and Parameters

8.2.1 Information, sets, indices and parameters used by the Pre-Dispatch Scheduling algorithm are described in sections 3 and 4.

8.3 Variables and Objective Function

8.3.1 The Pre-Dispatch Scheduling algorithm shall solve for the following variables:

8.3.1.1 $SDL_{t,b,j}$, which designates the amount of *energy* that a *dispatchable load* is scheduled to consume at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,b}$;

8.3.1.2 $S10SDL_{t,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{10S}_{t,b}$;

8.3.1.3 $S10NDL_{t,b,j}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{10N}_{t,b}$;

8.3.1.4 $S30RDL_{t,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in time-step $t \in TS$ in association with lamination $j \in J^{30R}_{t,b}$;

8.3.1.5 $SHDR_{t,b,j}$, which designates the amount of *energy* reduction scheduled for an *hourly demand response resource* at bus $b \in B^{HDR}$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,b}$;

8.3.1.6 $SXL_{t,d,j}$, which designates the amount of *energy* a *boundary entity resource* is scheduled to export at bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{E}_{t,d}$;

8.3.1.7 $S10NXL_{t,d,j}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *boundary entity resource* is scheduled to provide at bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{10N}_{t,d}$;

8.3.1.8 $S30RXL_{t,d,j}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide bus $d \in DX$ in time-step $t \in TS$ in association with lamination $j \in J^{30R}_{t,d}$;

8.3.1.9 $SNDG_{t,b,k}$, which designates the amount of *energy* that a *non-dispatchable generation resource* is scheduled to provide at bus $b \in B^{NDG}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$;

8.3.1.10 $SDG_{t,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$;

8.3.1.11 $ODG_{t,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled at or above its *minimum loading point* in time-step $t \in TS$;

8.3.1.12 $IDG_{t,b}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ has been scheduled to reach its *minimum loading point* in time-step $t \in TS$;

8.3.1.13 $S10SDG_{t,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K^{10S}_{t,b}$;

8.3.1.14 $S10NDG_{t,b,k}$, 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 time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$;

8.3.1.15 $S30RDG_{t,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{30R}$;

8.3.1.16 $SCT_{t,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ in time-step $t \in TS$;

8.3.1.17 $SST_{t,p}$, which designates the schedule of steam turbine $p \in PST$ in time-step $t \in TS$;

8.3.1.18 $O10R_{t,b}$, which designates whether the *pseudo-unit* at bus $b \in B^{NO10DF}$ has been scheduled for *ten-minute operating reserve* in time-step $t \in TS$;

8.3.1.19 $OHO_{t,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$;

8.3.1.20 $OFR_{t,b,i}$ for $i \in \{1,..,NFor_{q,b}\}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or below $ForL_{q,b,i}$, or, at or above $ForU_{q,b,i}$ in time-step $t \in TS$;

8.3.1.21 $IHE_{t,b,i}$, which designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ registered a start between time-step $(t-1)$ and t as a result of its schedule increasing from below $StartMW_{b,i}$ to at or above $StartMW_{b,i}$ for $i \in \{1,..,NStartMW_b\}$;

8.3.1.22 $SIG_{t,d,k}$, which designates the amount of *energy* that a *boundary entity resource* is scheduled to import from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{E}$;

8.3.1.23 $S10NIG_{t,d,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K_{t,d}^{10N}$;

8.3.1.24 $S30RIG_{t,d,k}$, which designates the amount of *thirty-minute operating reserve* that a *boundary entity resource* is scheduled to provide from *intertie zone* source bus $d \in DI$ in time-step $t \in TS$ in association with lamination $k \in K^{30R}_{t,d}$;

8.3.1.25 TB_t, which designates any adjustment to the objective function to facilitate pro-rata tie-breaking in time-step $t \in TS$, as described in section 8.3.2.1; and

8.3.1.26 $ViolCost_t$, which designates the cost incurred in order to avoid having the schedules violate constraints in time-step $t \in TS$, as described in section 8.3.2.3.

8.3.2 The objective function for the Pre-Dispatch Scheduling algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{t \in TS} \begin{pmatrix} ObjDL_t - ObjHDR_t + ObjXL_t - ObjNDG_t \\ - ObjDG_t - ObjIG_t - TB_t - ViolCost_t \end{pmatrix}$$

where:

$$ObjDL_t = \sum_{b \in B^{DL}} \begin{pmatrix} \sum_{j \in J^E_{t,b}} SDL_{t,b,j} \cdot PDL_{t,b,j} - \sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} \cdot P10SDL_{t,b,j} - \\ \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} \cdot P10NDL_{t,b,j} - \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \cdot P30RDL_{t,b,j} \end{pmatrix};$$

$$ObjHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J^E_{t,b}} SHDR_{t,b,j} \cdot PHDR_{t,b,j} \right);$$

$$ObjXL_t = \sum_{d \in DX} \begin{pmatrix} \sum_{j \in J^E_{t,d}} SXL_{t,d,j} \cdot PXL_{t,d,j} - \sum_{j \in J^{10N}_{t,d}} S10NXL_{t,d,j} \cdot P10NXL_{t,d,j} \\ - \sum_{j \in J^{30R}_{t,d}} S30RXL_{t,d,j} \cdot P30RXL_{t,d,j} \end{pmatrix};$$

$$ObjNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{t,b}^{E}} SNDG_{t,b,k} \cdot PNDG_{t,b,k} \right);$$

$$ObjDG_t = \sum_{b \in B^{DG}} \left(\begin{array}{l} \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \cdot PDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \cdot P10SDG_{t,b,k} + \\ \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \cdot P10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \cdot P30RDG_{t,b,k} \end{array} \right) + \sum_{b \in B^{NQS}} \left(ODG_{t,b} \cdot MGODG_{t,b} + IDG_{t,b} \cdot SUAdjDG_{t,b}^{T_{t,b}} \right);$$

and

$$ObjIG_t = \sum_{d \in DI} \left(\begin{array}{l} \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} \cdot PIG_{t,d,k} + \sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \cdot P10NIG_{t,d,k} \\ + \sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \cdot P30RIG_{t,d,k} \end{array} \right).$$

8.3.2.1 The tie-breaking term TB_t shall sum a term for each *bid* or *offer* lamination. For each lamination, this term shall be the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost shall be calculated by multiplying a base penalty cost of *TBPen* by the amount of the lamination scheduled and then dividing by the maximum amount that could have been scheduled. That is:

$$TB_t = TBDL_t + TBHDR_t + TBXL_t + TBNDG_t + TBDG_t + TBIG_t$$

Where

$$TBDL_t = \sum_{b \in B^{DL}} \left(\sum_{j \in J^E_{t,b}} \left(\frac{(SDL_{t,b,j})^2 \cdot TBPen}{QDL_{t,b,j}} \right) + \sum_{j \in J^{10S}_{t,b}} \left(\frac{(S10SDL_{t,b,j})^2 \cdot TBPen}{Q10SDL_{t,b,j}} \right) + \sum_{j \in J^{10N}_{t,b}} \left(\frac{(S10NDL_{t,b,j})^2 \cdot TBPen}{Q10NDL_{t,b,j}} \right) + \sum_{j \in J^{30R}_{t,b}} \left(\frac{(S30RDL_{t,b,j})^2 \cdot TBPen}{Q30RDL_{t,b,j}} \right) \right);$$

$$TBHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J^E_{t,b}} \frac{(SHDR_{t,b,j})^2 \cdot TBPen}{QHDR_{t,b,j}} \right);$$

$$TBXL_t = \sum_{d \in DX} \left(\sum_{j \in J^E_{t,d}} \left(\frac{(SXL_{t,d,j})^2 \cdot TBPen}{QXL_{t,d,j}} \right) + \sum_{j \in J^{10N}_{t,d}} \left(\frac{(S10NXL_{t,d,j})^2 \cdot TBPen}{Q10NXL_{t,d,j}} \right) + \sum_{j \in J^{30R}_{t,d}} \left(\frac{(S30RXL_{t,d,j})^2 \cdot TBPen}{Q30RXL_{t,d,j}} \right) \right);$$

$$TBNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K^E_{t,b}} \left(\frac{(SNDG_{t,b,k})^2 \cdot TBPen}{QNDG_{t,b,k}} \right) \right);$$

$$TBDG_t = \sum_{b \in B^{DG}} \left(\sum_{k \in K^E_{t,b}} \left(\frac{(SDG_{t,b,k})^2 \cdot TBPen}{QDG_{t,b,k}} \right) + \sum_{k \in K^{10S}_{t,b}} \left(\frac{(S10SDG_{t,b,k})^2 \cdot TBPen}{Q10SDG_{t,b,k}} \right) + \sum_{k \in K^{10N}_{t,b}} \left(\frac{(S10NDG_{t,b,k})^2 \cdot TBPen}{Q10NDG_{t,b,k}} \right) + \sum_{k \in K^{30R}_{t,b}} \left(\frac{(S30RDG_{t,b,k})^2 \cdot TBPen}{Q30RDG_{t,b,k}} \right) \right);$$

and

$$TBIG_t = \sum_{d \in DI} \left(\sum_{k \in K^E_{t,d}} \left(\frac{(SIG_{t,d,k})^2 \cdot TBPen}{QIG_{t,d,k}} \right) + \sum_{k \in K^{10N}_{t,d}} \left(\frac{(S10NIG_{t,d,k})^2 \cdot TBPen}{Q10NIG_{t,d,k}} \right) + \sum_{k \in K^{30R}_{t,d}} \left(\frac{(S30RIG_{t,d,k})^2 \cdot TBPen}{Q30RIG_{t,d,k}} \right) \right).$$

8.3.2.2 $ViolCost_t$ shall be calculated for time-step $t \in TS$ using the following variables:

8.3.2.2.1 $SLdViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{LdViol_t}\}$ of the penalty curve for the *energy* balance constraint allowing under-generation;

8.3.2.2.2 $SGenViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{GenViol_t}\}$ of the penalty curve for the *energy* balance constraint allowing over-generation;

8.3.2.2.3 $S10SViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{10SViol_t}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;

8.3.2.2.4 $S10RViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{10RViol_t}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;

8.3.2.2.5 $S30RViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{30RViol_t}\}$ of the penalty curve for the *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;

8.3.2.2.6 $SREG10RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{REG10RViol_t}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.7 $SREG30RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{REG30RViol_t}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{XREG10RViol_t}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.9 $SXREG30RViol_{r,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{XREG30RViol_t}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.10 $SPreITLViol_{f,t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{PreITLViol_{f,t}}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$;

8.3.2.2.11 $SITLViol_{c,f,t,i}$, which designates the violation variable affiliated with segment $I \in \{1,..,N_{ITLViol_{c,f,t}}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$;

8.3.2.2.12 $SPreXTLViol_{z,t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$ of the penalty curve for violating the import/export limit affiliated with *intertie* limit constraint $z \in Z_{Sch}$;

8.3.2.2.13 $SNIUViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{NIUViol_t}\}$ of the penalty curve for exceeding the net interchange increase limit between time-steps $(t\text{-}1)$ and t;

8.3.2.2.14 $SNIDViol_{t,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{NIDViol_t}\}$ of the penalty curve for exceeding the net interchange decrease limit between time-steps $(t\text{-}1)$ and t;

8.3.2.2.15 $SMaxDelViol_{t,b,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{MaxDelViol_t}\}$ of the penalty curve for exceeding the *maximum daily energy limit* constraint for a *resource* at bus $b \in B^{ELR}$;

8.3.2.2.16 $SMinDelViol_{t,b,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{MinDelViol_t}\}$ of the penalty curve for violating the *minimum daily energy limit* constraint for a *resource* at bus $b \in B^{HE}$;

8.3.2.2.17 $SSMaxDelViol_{t,s,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{SMaxDelViol_t}\}$ of the penalty curve for exceeding the shared *maximum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

8.3.2.2.18 $SSMinDelViol_{t,s,i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{SMinDelViol_t}\}$ of the penalty curve for violating the shared *minimum daily energy limit* constraint for *dispatchable* hydroelectric *generation resources* in set $s \in SHE$;

8.3.2.2.19 $SOGenLnkViol_{t,(b_1,b_2),i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{OGenLnkViol_t}\}$ of the penalty curve for violating the linked *dispatchable* hydroelectric *generation resources* constraint by over-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$; and

8.3.2.2.20 $SUGenLnkViol_{t,(b_1,b_2),i}$, which designates the violation variable affiliated with segment $i \in \{1,..,N_{UGenLnkViol_t}\}$ of the penalty curve for violating the linked *dispatchable* hydroelectric *generation resources* constraint by under-generating the downstream *resource*, for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$.

8.3.2.3 $ViolCost_t$ shall be calculated as follows:

$$
\begin{aligned}
&ViolCost_t = \\
&\sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} \cdot PLdViolSch_{t,i} \text{ -} \\
&\sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} \cdot PGenViolSch_{t,i} + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \cdot P10SViolSch_{t,i} + \\
&\sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \cdot P10RViolSch_{t,i} + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \cdot P30RViolSch_{t,i} + \\
&\sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \cdot PREG10RViolSch_{t,i} \right) + \\
&\sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \cdot PREG30RViolSch_{t,i} \right) + \\
&\sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \cdot PXREG10RViolSch_{t,i} \right) + \\
&\sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i} \cdot PXREG30RViolSch_{t,i} \right) \\
&\quad ..... \\
&+ \sum_{f \in F_t} \left(\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \cdot PPreITLViolSch_{f,t,i} \right) \\
&+ \sum_{c \in C} \sum_{f \in F_{t,c}} \left(\sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i} \cdot PITLViolSch_{c,f,t,i} \right) \\
&+ \sum_{z \in Z_{Sch}} \left(\sum_{i=1..N_{PreXTLViol_{z,t}}} SPreXTLViol_{z,t,i} \cdot PPreXTLViolSch_{z,t,i} \right) \\
&+ \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i} \cdot PNIUViolSch_{t,i} + \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i} \cdot PNIDViolSch_{t,i}
\end{aligned}
$$

$$+\sum_{b\in B^{ELR}}\left(\sum_{i=1..N_{MaxDelViol_t}} SMaxDelViol_{t,b,i}\cdot PMaxDelViolSch_{t,b,i}\right)$$

$$+\sum_{b\in B^{HE}}\left(\sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i}\cdot PMinDelViolSch_{t,b,i}\right)$$

$$+\sum_{s\in SHE}\left(\sum_{i=1..N_{SMaxDelViol_t}} SSMaxDelViol_{t,s,i}\cdot PSMaxDelViolSch_{t,s,i}\right)$$

$$+\sum_{s\in SHE}\left(\sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i}\cdot PSMinDelViolSch_{t,s,i}\right)$$

$$+\sum_{(b_1,b_2)\in LNK}\left(\sum_{i=1..N_t} SOGenLnkViol_{t,(b_1,b_2),i}\cdot POGenLnkViolSch_{t,i}\right)/$$

$$+\sum_{(b_1,b_2)\in LNK}\left(\sum_{i=1..N_t} SUGenLnkViol_{t,(b_1,b_2),i}\cdot PUGenLnkViolSch_{t,i}\right).$$

8.4 Constraints

8.4.1 The constraints described in sections 8.5 – 8.7 apply to the optimization function in the Pre-Dispatch Scheduling algorithm.

8.5 Dispatch Data Constraints Applying to Individual Hours

8.5.1 Scheduling Variable Bounds

8.5.1.1 A Boolean variable $ODG_{t,b}$ indicates whether the *resource* at bus $b\in B^{DG}$ is committed in time-step $t\in TS$. A value of zero indicates that a *resource* is not committed, while a value of one indicates that it is committed. Therefore:

$$ODG_{t,b}\in\{0,1\} \text{ for all time-steps } t\in TS \text{ and all buses } b\in B^{DG}.$$

8.5.1.2 *Reliability must-run resources* are considered committed for all must-run hours.

8.5.1.3 *Resources* providing *regulation* are considered committed for all the hours that they are regulating.

8.5.1.4 *Dispatchable generation resources* that have *minimum loading points*, *start-up offers*, *speed no-load offers*, *minimum generation block run-times* and *minimum generation block down times* equal to zero shall be considered committed for all hours.

8.5.1.5 If the *dispatchable generation resource* at bus $b \in B^{DG}$ is considered committed according to the requirements in sections 8.5.1.2, 8.5.1.3, and 8.5.1.4 in time-step $t \in TS$ then:

$$ODG_{t,b} = 1$$

8.5.1.6 No schedule shall be negative, nor shall any schedule exceed the quantity *offered* for the respective *energy* and *operating reserve* market. Therefore:

$$0 \leq SDL_{t,b,j} \leq QDL_{t,b,j} \qquad \text{for all } b \in B^{DL}, j \in J^{E}_{t,b};$$

$$0 \leq S10SDL_{t,b,j} \leq Q10SDL_{t,b,j} \qquad \text{for all } b \in B^{DL}, j \in J^{10S}_{t,b};$$

$$0 \leq S10NDL_{t,b,j} \leq Q10NDL_{t,b,j} \qquad \text{for all } b \in B^{DL}, j \in J^{10N}_{t,b};$$

$$0 \leq S30RDL_{t,b,j} \leq Q30RDL_{t,b,j} \qquad \text{for all } b \in B^{DL}, j \in J^{30R}_{t,b};$$

$$0 \leq SHDR_{t,b,j} \leq QHDR_{t,b,j} \qquad \text{for all } b \in B^{HDR}, j \in J^{E}_{t,b};$$

$$0 \leq SXL_{t,d,j} \leq QXL_{t,d,j} \qquad \text{for all } d \in DX, j \in J^{E}_{t,d};$$

$$0 \leq S10NXL_{t,d,j} \leq Q10NXL_{t,d,j} \qquad \text{for all } d \in DX, j \in J^{10N}_{t,d};$$

$$0 \leq S30RXL_{t,d,j} \leq Q30RXL_{t,d,j} \qquad \text{for all } d \in DX, j \in J^{30R}_{t,d};$$

$$0 \leq SNDG_{t,b,k} \leq QNDG_{t,b,k} \qquad \text{for all } b \in B^{NDG}, k \in K^{E}_{t,b};$$

$$0 \leq SIG_{t,d,k} \leq QIG_{t,d,k} \qquad \text{for all } d \in DI, k \in K^{E}_{t,d};$$

$$0 \leq S10NIG_{t,d,k} \leq Q10NIG_{t,d,k} \qquad \text{for all } d \in DI, k \in K^{10N}_{t,d}; \text{ and}$$

$$0 \leq S30RIG_{t,d,k} \leq Q30RIG_{t,d,k} \qquad \text{for all } d \in DI, k \in K^{30R}_{t,d}$$

for all time-steps $t \in TS$.

8.5.1.7 *Generation resources* may be scheduled for *energy* and/or *operating reserve* only if their commitment status is equal to 1. Therefore, for all time-steps $t \in TS$:

$$0 \leq SDG_{t,b,k} \leq ODG_{t,b} \cdot QDG_{t,b,k} \qquad \text{for all } b \in B^{DG},\ k \in K^{E}_{t,b};$$

$$0 \leq S10SDG_{t,b,k} \leq ODG_{t,b} \cdot Q10SDG_{t,b,k} \qquad \text{for all } b \in B^{DG},\ k \in K^{10S}_{t,b};$$

$$0 \leq S10NDG_{t,b,k} \leq ODG_{t,b} \cdot Q10NDG_{t,b,k} \qquad \text{for all } b \in B^{DG},\ k \in K^{10N}_{t,b};$$

and

$$0 \leq S30RDG_{t,b,k} \leq ODG_{t,b} \cdot Q30RDG_{t,b,k} \qquad \text{for all } b \in B^{DG},\ k \in K^{30R}_{t,b}.$$

8.5.2 Resource Minimums and Maximums for Energy

8.5.2.1 A constraint shall limit schedules for *dispatchable loads* within their minimum and maximum consumption for a time-step. For all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$MinDL_{t,b} \leq \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} \leq MaxDL_{t,b}.$$

8.5.2.2 The non-*dispatchable* portion of a *dispatchable load* shall always be scheduled. For all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} \geq QDLFIRM_{t,b}.$$

8.5.2.3 A constraint shall limit schedules for *non-dispatchable generation resources* within their minimum and maximum output for a time-step. For all time-steps $t \in TS$ and all buses $b \in B^{NDG}$:

$$MinNDG_{t,b} \leq \sum_{k \in K^{E}_{t,b}} SNDG_{t,b,k} \leq MaxNDG_{t,b}.$$

8.5.2.4 A constraint shall limit schedules for *dispatchable generation resources* within their minimum and maximum output for a time-step.For a *dispatchable variable generation resource*, the maximum schedule shall be limited by its forecast. That is:

For all time-steps $t \in TS$ and all buses $b \in B^{DG}$,

$$AdjMaxDG_{t,b} = \begin{cases} Min(MaxDG_{t,b}, FG_{t,b}) & if\ b \in B^{VG} \\ MaxDG_{t,b} & \text{otherwise} \end{cases}$$

and

$$AdjMinDG_{t,b} = Min(MinDG_{t,b}, AdjMaxDG_{t,b}).$$

For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$AdjMinDG_{t,b} \leq MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq AdjMaxDG_{t,b}.$$

8.5.2.5 If the commitment status, $ODG_{t,b}$, of a *dispatchable generation resource* is equal to 1 and if this status is inconsistent with the adjusted minimum and maximum constraints, $MinQDGC_b > AdjMaxDG_{t,b}$, then the commitment status value, $ODG_{t,b}$, shall be changed to a value between 0 and 1.

8.5.2.6 If the total *offered* quantity does not exceed the minimum, $MinQDGC_b + \sum_{k \in K^E_{t,b}} QDG_{t,b,k} < AdjMinDG_{t,b}$, then the *resource* shall receive a schedule of zero.

8.5.2.7 Minimum and maximum limits placed on *hourly demand response resource* schedules for the purposes of reflecting activation/non-activation decisions shall be respected. For all time-steps $t \in TS$ and all buses $b \in B^{HDR}$:

$$MinHDR_{t,b} \leq \sum_{j \in J^E_{t,b}} SHDR_{t,b,j} \leq MaxHDR_{t,b}.$$

8.5.3 Off-Market Transactions

8.5.3.1 For all time-steps $t \in TS$ and all *intertie zone* buses corresponding to an inadvertent *energy* payback export transaction $d \in DX^{INP}_t$:

$$\sum_{j \in J^E_{t,d}} SXL_{t,d,j} = \sum_{j \in J^E_{t,d}} QXL_{t,d,j}.$$

8.5.3.2 For all time-steps $t \in TS$ and all *intertie zone* buses corresponding to an inadvertent *energy* payback import transaction $d \in DI_t^{INP}$:

$$\sum_{k \in K_{t,d}^E} SIG_{t,d,k} = \sum_{k \in K_{t,d}^E} QIG_{t,d,k}.$$

8.5.3.3 For all time-steps $t \in TS$ and all *intertie zone* buses corresponding to an *emergency energy* export $d \in DX_t^{EM}$:

$$\sum_{j \in J_{t,d}^E} SXL_{t,d,j} = \sum_{j \in J_{t,d}^E} QXL_{t,d,j}.$$

8.5.3.4 For all time-steps $t \in TS$ and all *intertie zone* buses corresponding to *emergency energy* import $d \in DI_t^{EM}$:

$$\sum_{k \in K_{t,d}^E} SIG_{t,d,k} = \sum_{k \in K_{t,d}^E} QIG_{t,d,k}.$$

8.5.4 Intertie Minimum and Maximum Constraints

8.5.4.1 A constraint shall limit export schedules beyond the first two forecast hours of the pre-dispatch look-ahead period to the corresponding *day-ahead market* schedules for export transactions, subject to Chapter 7, section 5.2.2. For time-step $t \in \{4,..,n_{LAP}\}$ and *intertie zone* sink bus d ∈ DX such that $d \notin DX_t^{CAPEX} \cup DX_t^{EM} \cup DX_t^{INP}$:

$$\sum_{j \in J_{t,d}^E} SXL_{t,d,j} \le SXLT_{t,d}^{DAM};$$

$$\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \le S10NXLT_{t,d}^{DAM};$$

and

$$\sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \le S30RXLT_{t,d}^{DAM}.$$

8.5.4.2 Import *offers* with no *day-ahead market* schedule may be evaluated beyond the first two forecast hours of the look-ahead period for the purpose of *reliability*.

8.5.4.3 A constraint shall limit import schedules beyond the first two forecast hours of the pre-dispatch look-ahead period to the corresponding *day-ahead market* schedules for import transactions plus any additional *offered* quantities permitted for *reliability* reasons, with the exception of transactions flagged as capacity imports or off-market transactions, subject to Chapter 7, section 5.2.2. For time-step $t \in \{4,..,n_{LAP}\}$ and *intertie zone* source bus $d \in DI$ such that $d \notin DI_t^{CAPEX} \cup DI_t^{EM} \cup DI_t^{INP}$:

$$\sum_{k \in K_{t,d}^E} SIG_{t,d,k} \leq SIGT_{t,d}^{DAM} + SIGT_{t,d}^{EXTRA};$$

$$\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \leq S10NIGT_{t,d}^{DAM} + S10NIGT_{t,d}^{EXTRA};$$

and

$$\sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \leq S30RIGT_{t,d}^{DAM} + S30RIGT_{t,d}^{EXTRA}.$$

8.5.4.4 A constraint shall limit *intertie* schedules as a result of *intertie* curtailments. For *intertie zone* sink bus $d \in DX$ and time-step $t \in TS$:

$$ICMinXL_{t,d} \leq \sum_{j \in J_{t,d}^E} SXL_{t,d,j} \leq ICMaxXL_{t,d}.$$

8.5.4.4.1 For *intertie zone* source bus $d \in DI$ and time-step $t \in TS$:

$$ICMinIG_{t,d} \leq \sum_{k \in K^{E}_{t,d}} SIG_{t,d,k} \leq ICMaxIG_{t,d};$$

$$ICMin10NIG_{t,d} \leq \sum_{k \in K^{10N}_{t,d}} S10NIG_{t,d,k} \leq ICMax10NIG_{t,d};$$

and

$$ICMin30RIG_{t,d} \leq \sum_{k \in K^{30R}_{t,d}} S30RIG_{t,d,k} \leq ICMax30RIG_{t,d}.$$

8.5.5 Operating Reserve Requirements

8.5.5.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled from a *dispatchable load* shall not exceed:

8.5.5.1.1 the *dispatchable* load's ramp capability over 30 minutes;

8.5.5.1.2 the total scheduled load less the non-*dispatchable* portion; and

8.5.5.1.3 the remaining portion of its capacity that is *dispatchable* after considering minimum load consumption constraints.

8.5.5.1.4 These restrictions shall be enforced by the following constraints for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} + \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} + \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \leq 30 \cdot ORRDL_{b};$$

$$\sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} + \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} + \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \leq \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} - QDLFIRM_{t,b};$$

and

$$\sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} + \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} + \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \leq \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} - MinDL_{t,b}.$$

8.5.5.2 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide shall not exceed the amount by which the *dispatchable load* can decrease its load over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} + \sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \leq 10 \cdot ORRDL_b.$$

8.5.5.3 The total non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled for an hour shall not exceed total scheduled exports. This restriction shall be enforced by the following constraint for all all time-steps $t \in TS$ and all *intertie zone* sink buses $d \in DX$:

$$\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} + \sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \leq \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j}.$$

8.5.5.4 The total *operating reserve* scheduled from a committed *dispatchable generation resource* shall not exceed that *resource*'s: (i) ramp capability over 30 minutes; (ii) remaining capacity; and (iii) unscheduled capacity. These restrictions shall be enforced by the following constraints for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq 30 \cdot ORRDG_b;$$

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \sum_{k \in K_{t,b}^{E}} (QDG_{t,b,k} - SDG_{t,b,k});$$

and

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq AdjMaxDG_{t,b} - \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} - MinQDGC_b.$$

8.5.5.5 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall not exceed the amount by which the *resource* can increase its output over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \leq 10 \cdot ORRDG_b.$$

8.5.5.6 The amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point for* synchronized *ten-minute operating reserve*. This restriction shall be enforced by the following constraint for all time-steps $t \in TS$ and all buses $b \in B^{DG}$ with $RLP10S_{t,b} > 0$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \leq \left(MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) \cdot \left(\frac{1}{RLP10S_{t,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_b, \sum_{k \in K_{t,b}^{10S}} Q10SDG_{t,b,k} \right\} \right).$$

8.5.5.7 The amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for *thirty-minute operating reserve*. This restriction shall be enforced by the following constraint for all all time-steps $t \in TS$ and all buses $b \in B^{DG}$ with $RLP30R_{t,b} > 0$:

$$\sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \left(MinQDGC_b \cdot ODG_{t,b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) \cdot \left(\frac{1}{RLP30R_{t,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_b, \sum_{k \in K_{t,b}^{30R}} Q30RDG_{t,b,k} \right\} \right).$$

8.5.5.8 The total non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled for an hour shall not exceed the remaining maximum import *offers* minus scheduled *energy* imports. This restriction shall be enforced by the following constraint for all time-steps $t \in TS$ and all *intertie zone* source buses $d \in DI$:

$$\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} + \sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \leq \sum_{k \in K_{t,d}^{E}} (QIG_{t,d,k} - SIG_{t,d,k}).$$

8.5.6 Pseudo-Units

8.5.6.1 A constraint shall be required to calculate physical *generation resource* schedules from *pseudo-unit* schedules using the steam turbine shares in the operating regions of the *pseudo-unit* determined in section 15. For all time-steps $t \in TS$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$SCT_{t,b} = (1 - STShareMLP_b) \cdot MinQDGC_b \cdot ODG_{t,b} + (1 - STShareDR_b) \cdot \left(\sum_{k \in K_{t,b}^{DR}} SDG_{t,b,k} \right),$$

and for all time-steps $t \in TS$ and steam turbines $p \in PST$:

$$SST_{t,p} = \sum_{b \in B_p^{ST}} \left(\begin{array}{c} STShareMLP_b \cdot MinQDGC_b \cdot ODG_{t,b} + \\ STShareDR_b \cdot \left(\sum_{k \in K_{t,b}^{DR}} SDG_{t,b,k} \right) + \sum_{k \in K_{t,b}^{DF}} SDG_{t,b,k} \end{array} \right).$$

8.5.6.2 Maximum constraints shall be enforced on the operating region to which they apply for both *energy* and *operating reserve* schedules. For all time-steps $t \in TS$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$MinQDGC_b \cdot ODG_{t,b} \leq MaxMLP_{t,b},$$

$$\sum_{k \in K_{t,b}^{DR}} SDG_{t,b,k} \leq MaxDR_{t,b},$$

$$\sum_{k \in K_{t,b}^{DF}} SDG_{t,b,k} \leq MaxDF_{t,b},$$

and

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq MaxDR_{t,b} + MaxDF_{t,b}.$$

8.5.6.3 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, constraints shall limit the *pseudo-unit* from being scheduled in its duct firing region whenever the *pseudo-unit* is scheduled for *ten-minute operating reserve.* For all all time-steps $t \in TS$ and *pseudo-unit* buses $b \in B^{NO10DF}$:

$$O10R_{t,b} \in \{0,1\},$$

and

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \leq MaxDR_{t,b} + (1 - O10R_{t,b}) \cdot MaxDF_{t,b}$$

8.5.6.3.1 For all time-steps $t \in TS$, *pseudo-unit* buses $b \in B^{NO10DF}$, and laminations $k \in K_{t,b}^{10S}$:

$$S10SDG_{t,b,k} \leq O10R_{t,b} \cdot Q10SDG_{t,b,k}.$$

8.5.6.3.2 For all time-steps $t \in TS$, *pseudo-unit* buses $b \in B^{NO10DF}$, and laminations $k \in K_{t,b}^{10N}$:

$$S10NDG_{t,b,k} \leq O10R_{t,b} \cdot Q10NDG_{t,b,k}.$$

8.5.6.4 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the combustion turbine schedule for the *pseudo-unit* at bus $b \in B^{PSU}$ in in time-step $t \in TS$ will be equal to:

8.5.6.4.1 $SCT_{t,b}$ if the *pseudo-unit* is scheduled at or above *minimum loading point*;

8.5.6.4.2 $RampCTC^{m}_{b,w}$ if the *pseudo-unit* is scheduled to reach *minimum loading point* in *thermal state* $m \in THERM$ in time-step $t+w$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$; or

8.5.6.4.3 0 otherwise.

8.5.6.5 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the steam turbine schedule for $p \in PST$ shall be equal to $SST_{h,p}$ plus any contribution from *pseudo-unit* $b \in B^{ST}_{p}$ ramping to *minimum loading point* as given by $RampSTC^{m}_{b,w}$ for a *pseudo-unit* scheduled to reach *minimum loading point* in *thermal state* $m \in THERM$ in time-step $(t+w)$ for $w \in \{1,..,RampHrsC^{m}_{b}\}$.

8.5.7 Dispatchable Hydroelectric Generation Resources

8.5.7.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled to at least its *hourly must-run* quantity. For all time-steps $t \in TS$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$ODG_{t,b} \cdot MinQDGC_{b} + \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \geq MinHMR_{t,b}.$$

8.5.7.2 A *dispatchable* hydroelectric *generation resource* shall either be scheduled to 0 or to at least its *minimum hourly output*. For all time-steps $t \in TS$ and all hydroelectric *generation resource* buses $b \in B^{HE}$:

$$OHO_{t,b} \in \{0,1\};$$

$$ODG_{t,b} \cdot MinQDGC_{b} + \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \geq MinHO_{t,b} \cdot OHO_{t,b};$$

and for all $k \in K^{E}_{t,b}$:

$$0 \leq SDG_{t,b,k} \leq OHO_{t,b} \cdot QDG_{t,b,k}.$$

8.5.7.3 A *dispatchable* hydroelectric *generation resource* shall not be scheduled within its *forbidden regions*. For *dispatch days* $q \in DAYS$, all time-steps $t \in TS$ in *dispatch day* q, all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ and all $i \in \{1,..,NFor_{q,b}\}$:

$$OFR_{t,b,i} \in \{0,1\};$$

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq OFR_{t,b,i} \cdot ForL_{q,b,i} + (1 - OFR_{t,b,i}) \cdot \left(MinQDGC_b + \sum_{k \in K^E_{t,b}} QDG_{t,b,k} \right);$$

and

$$ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \geq (1 - OFR_{t,b,i}) \cdot ForU_{q,b,i}.$$

8.5.8 Wheeling Through Transactions

8.5.8.1 The amount of scheduled export *energy* must be equal to the amount of scheduled import *energy* for *wheeling through transactions*. For all time-steps $t \in TS$ and all linked *boundary entity resource* buses $(dx,di) \in L_t$:

$$\sum_{j \in J^E_{t,dx}} SXL_{t,dx,j} = \sum_{k \in K^E_{t,di}} SIG_{t,di,k}.$$

8.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

8.6.1 Energy Ramping

8.6.1.1 For *disptachable loads*, the constraints in section 8.6.1.5 and section 8.6.2.1 use $URRDL_b$ to represent a ramp up rate selected from $URRDL_{t,b,w}$ and uses $DRRDL_b$ to represent a ramp down rate selected from $DRRDL_{t,b,w}$.

8.6.1.2 For *disptachable generation resources*, the constraints in section 8.6.1.7 and section 8.6.2.2 use $URRDG_b$ to represent a ramp up rate selected from $URRDG_{t,b,w}$ and uses $DRRDG_b$ to represent a ramp down rate selected from $DRRDG_{t,b,w}$.

8.6.1.3 The *pre-dispatch calculation engine* shall respect the ramping restrictions determined by the up to five *offered* MW quantity, ramp up rate and ramp down rate value sets.

8.6.1.4 In all ramping constraints, the schedules for time-step 1 are obtained from the initial scheduling assumptions in section 5.9. For all time-steps $t \in TS$ the ramping rates in all ramping constraints shall be adjusted to allow the applicable *resource* to:

8.6.1.3.1 ramp down from its lower limit in time-step $(t-1)$ to its upper limit in time-step t; and

8.6.1.3.2 ramp up from its upper limit in time-step $(t-1)$ to its lower limit in time-step t.

8.6.1.5 *Energy* schedules for *dispatchable loads* cannot vary by more than an hour's ramping capability for the applicable *resource*. This constraint shall be enforced by the following for all time-steps $t \in TS$ and buses $b \in B^{DL}$:

$$\sum_{j \in J^E_{t-1,b}} SDL_{t-1,b,j} - 60 \cdot DRRDL_b \leq \sum_{j \in J^E_{t,b}} SDL_{t,b,j} \leq \sum_{j \in J^E_{t-1,b}} SDL_{t-1,b,j} + 60 \cdot URRDL_b.$$

8.6.1.6 *Energy* schedules for *hourly demand response resources* cannot vary by more than an hour's ramping capability for the applicable *resource*. This constraint shall be enforced by the following for all time-steps $t \in TS$ and all buses $b \in B^{HDR}$:

$$\sum_{j \in J^E_{t-1,b}} (QHDR_{t-1,b,j} - SHDR_{t-1,b,j}) - 60 \cdot URRHDR_b \leq \sum_{j \in J^E_{t,b}} (QHDR_{t,b,j} - SHDR_{t,b,j}) \leq \sum_{j \in J^E_{t-1,b}} (QHDR_{t-1,b,j} - SHDR_{t-1,b,j}) + 60 \cdot DRRHDR_b.$$

8.6.1.7 *Energy* schedules for a *dispatchable generation resource* that is committed cannot vary by more than an hour's ramping capability for the applicable *resource*. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

8.6.1.7.1 For the first hour a *resource* reaches its *minimum loading point*, where $ODG_{t,b} = 1$, $ODG_{t-1,b} = 0$, the following constraint shall be applied:

$$0 \leq \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq 30 \cdot URRDG_b$$

8.6.1.7.2 If the *resource* stays on at or above *minimum loading point* and $ODG_{t,b} = 1$, $ODG_{t-1,b} = 1$, the following constraint shall be applied:

$$\sum_{k \in K^E_{t-1,b}} SDG_{t-1,b,k} - 60 \cdot DRRDG_b \leq \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq \sum_{k \in K^E_{t-1,b}} SDG_{t-1,b,k} + 60 \cdot URRDG_b$$

8.6.1.7.3 For the last hour the *resource* is scheduled at or above *minimum loading point* before being scheduled off, where $ODG_{t,b} = 1$, $ODG_{t+1,b} = 0$, the following constraint shall be applied:

$$0 \leq \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \leq 30 \cdot DRRDG_b$$

8.6.1.8 The first and third constraint in section 8.6.1.6 do not apply to a *quick start resource*.

8.6.1.9 For time-steps where *non-quick start resources* are ramping up to *minimum loading point*, *energy* shall be scheduled for these *resources* using the submitted *ramp up energy to minimum loading point*.

8.6.2 Operating Reserve Ramping

8.6.2.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from *dispatchable loads* shall not exceed the their ramp capability to decrease load consumption and for all time-steps $t \in TS$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} + \sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} + \sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \leq \sum_{j \in J_{t,b}^{E}} SDL_{t,b,j} - \sum_{j \in J_{t-1,b}^{E}} SDL_{t-1,b,j} + 60 \cdot DRRDL_b.$$

8.6.2.2 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* from a committed *dispatchable generation resource* shall not exceed its ramp capability to increase generation and for all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq \sum_{k \in K_{t-1,b}^{E}} SDG_{t-1,b,k} - \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + 60 \cdot URRDG_b;$$

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq [(t-n) \cdot 60 + 30] \cdot URRDG_b \cdot ODG_{t,b}$$

where n is the time-step of the last start before or in time-step t, and

$$\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{h,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq [(m-t) \cdot 60 + 30] \cdot DRRDG_b \cdot ODG_{t,b}$$

where m is the time-step of the last shutdown in or after time-step t.

8.6.3 Non-Quick Start Resources

8.6.3.1 Schedules for a *non-quick start resource* shall not violate such *resource's minimum generation block run-times*, *minimum generation block down times* and *maximum number of starts per day*.

8.6.3.2 In the first forecast hour of the pre-dispatch look-ahead period, a *resource's* current hours on shall determine any remaining *minimum generation block run-time* to enforce. If $0 < InitOperHrs_b < MGBRTDG_{tod,b}$, then the *resource* at bus $b \in B^{NQS}$ has yet to complete its *minimum generation block run-time*, and:

$$ODG_{2,b}, ODG_{3,b}, \ldots, ODG_{min(n_{LAP}, MGBRTDG_{tod,b} - InitOperHrs_b + 1),b} = 1.$$

8.6.3.3 In the first forecast hour of the pre-dispatch look-ahead period (i.e. time-step 2), the number of hours a *resource* has been down shall determine any remaining *minimum generation block down time* to enforce and shall respect the *minimum generation block down time* for a hot *thermal state*. If $0 < InitDownHrs_b < MGBDTDG^{HOT}_{tod,b}$, then the *resource* at bus $b \in B^{NQS}$ has yet to complete its *minimum generation block down time*, and:

$$ODG_{2,b}, ODG_{3,b}, \ldots, ODG_{min(n_{LAP}, MGBDTDG^{HOT}_{tod,b} - InitDownHrs_b + 1),b} = 0.$$

8.6.3.4 If $ODG_{t-1,b} = 0$ and $ODG_{t,b} = 1$ for time-step $t \in TS$, then the *resource* at bus $b \in B^{NQS}$ has been scheduled to start up during time-step t and shall be scheduled to remain in operation until it has completed its *minimum generation block run-time* or to the end of the pre-dispatch look-ahead period. Therefore:

$$ODG_{t+1,b}, ODG_{t+2,b}, \ldots, ODG_{min(n_{LAP}, t + MGBRTDGC_b - 1),b} = 1.$$

8.6.3.5 If $ODG_{t-1,b} = 1$ and $ODG_{t,b} = 0$ for time-step $t \in TS$, then the *resource* at bus $b \in B^{NQS}$ has been scheduled to shut down during time-step t and shall be scheduled to remain off until it has completed its hot *minimum generation block down time* or to the end of the pre-dispatch look-ahead period. Therefore:

$$ODG_{t+1,b}, ODG_{t+2,b}, \ldots, ODG_{min(n_{LAP}, t + MGBDTDGC^{HOT}_b - 1),b} = 0.$$

8.6.3.6 A Boolean variable $IDG_{t,b}$ indicates that the *non-quick start resource* at bus $b \in B^{NQS}$ is scheduled to reach its *minimum loading point* in time-step $t \in TS$ after being scheduled below its *minimum loading point* in the preceding time-step. A value of zero indicates that a *resource* is not scheduled to reach its *minimum loading point*, while a value of one indicates that it is scheduled to reach its *minimum loading point*. Therefore, for all time-steps $t \in TS$ and all buses $b \in B^{NQS}$:

$$IDG_{t,b} = \begin{cases} 1 & if\ ODG_{t\text{-}1,b} = 0\ and\ ODG_{t,b} = 1 \\ 0 & otherwise. \end{cases}$$

8.6.3.7 A *non-quick start resource* shall not be scheduled more than its *maximum number of starts per day*. For all buses $b \in B^{NQS}$:

$$\sum_{t \in TS_{tod}} IDG_{t,b} \le MaxStartsDG_{tod,b} - NumStarts_{tod,b}.$$

8.6.3.7.1 and if the pre-dispatch look-ahead period spans two *dispatch days* then:

$$\sum_{t \in TS_{tom}} IDG_{t,b} \le MaxStartsDG_{tom,b}.$$

8.6.3.8 For a *non-quick start resource* at bus $b \in B^{NQS}$ that has been offline $InitDownHrs_b$ hours, and for future *minimum loading point* time-step $t \in \{2,....,n_{LAP}\}$, the *pre-dispatch calcluation* engine shall assign a *start-up offer* and ramp *energy* to *minimum loading point* profile as follows:

8.6.3.8.1 If $0 \le InitDownHrs_b + t - 1 \le MGBDTDGC_b^{HOT}$, then the *resource* cannot be scheduled in time-step t;

8.6.3.8.2 If $MGBDTDGC_b^{HOT} < InitDownHrs_b + t - 1 \le MGBDTDGC_b^{WARM}$, then the *resource* will be assigned a "HOT" *thermal state* for time-step t and the *start-up offer* $SUDG_{t,b}^{HOT}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $\mathrm{RampEC}_{b,w}^{HOT}$ for $w \in \{1,..,RampHrsC_b^m\}$;

8.6.3.8.3 If $MGBDTDGC_b^{WARM} < InitDownHrs_b + t - 1 \le MGBDTDGC_b^{COLD}$, then the *resource* will be assigned a "WARM" *thermal state* for time-step t and the *start-up offer* $SUDG_{t,b}^{WARM}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $RampEC_{b,w}^{WARM}$ for $w \in \{1,..,RampHrsC_b^m\}$; and

8.6.3.8.4 If $MGBDTDGC_b^{COLD} < InitDownHrs_b + t - 1$ then the *resource* will be assigned a "COLD" *thermal state* for time-step t and the *start-up offer* $SUDG_{t,b}^{COLD}$ shall apply. The *ramp up energy to minimum loading point* profile shall be $RampEC_{b,w}^{COLD}$ for $w \in \{1,..,RampHrsC_b^m\}$.

8.6.3.9 For a *non-quick start resource* at bus $b \in B^{NQS}$ that is in-service as determined by its initial condition, the *pre-dispatch calculation engine* shall assign a *start-up offer* and *ramp up energy to minimum loading point* profile associated with the future *thermal state* as specified in section 8.6.3.8.

8.6.4 Energy Limited Resources

8.6.4.1 An *energy limited resource* shall not be scheduled to provide:

8.6.4.1.1 more *energy* than the *maximum daily energy limit* specified for such *resource*; or

8.6.4.1.2 *energy* in amounts that would preclude such *resource* from providing *operating reserve* when activated;

8.6.4.1.3 for all buses $b \in B^{ELR}$ where an *energy limited resource* is located and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T}\left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}\right) + 10ORConv\left(\sum_{k \in K_{T,b}^{10S}} S10SDG_{T,b,k} + \sum_{k \in K_{T,b}^{10N}} S10NDG_{T,b,k}\right) + 30ORConv\left(\sum_{k \in K_{T,b}^{30R}} S30RDG_{T,b,k}\right) - \sum_{i=1..N_{MaxDelViol_T}} SMaxDelViol_{T,b,i} \leq MaxDEL_{tod,b} - EngyUsed_b.$$

8.6.4.2 If the pre-dispatch look-ahead period spans two *dispatch days*, the constraints in section 8.6.4.1 shall apply to an *energy limited resource* for each *dispatch day*, and shall consider the amount of *energy* already provided by the *resource* for the current *dispatch day*. Therefore, for all buses $b \in B^{ELR}$ where an *energy limited resource* is located and all time-steps $T \in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(ODG_{t,b}\cdot MinQDGC_b + \sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}\right) + 10ORConv\left(\sum_{k\in K_{T,b}^{10S}} S10SDG_{T,b,k} + \sum_{k\in K_{T,b}^{10N}} S10NDG_{T,b,k}\right) + 30ORConv\left(\sum_{k\in K_{T,b}^{30R}} S30RDG_{T,b,k}\right) - \sum_{i=1..N_{MaxDelViol_T}} SMaxDelViol_{T,b,i} \le MaxDEL_{tom,b}.$$

where the factors $10\ ORConv$ and $30\ ORConv$ are applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* for *energy limited resources* to convert MW into MWh. Violation variables for over-scheduling a *resource's maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution.

8.6.5 Dispatchable Hydroelectric Generation Resources

8.6.5.1 *Dispatchable* hydroelectric *generation resources* shall be scheduled for at least their *minimum daily energy limit*. If the pre-dispatch look-ahead period spans two *dispatch days*, the constraint shall be applied for both days. Violation variables for under-scheduling a *resource's minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tod,b} - EngyUsed_b.$$

8.6.5.1.1 and if the pre-dispatch look-ahead period spans two *dispatch days*, for all hydroelectric *resource* buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tom,b}.$$

8.6.5.2 A Boolean variable $IHE_{t,b,i}$ indicates that a start for the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ was counted in time-step $t \in TS$ as a result of the *resource* schedule increasing from below its i-th *start indication value* to at or above its i-th start indication for $i \in \{1,..,NStartMW_b\}$. A value of zero indicates that a start was not counted, while a value of one indicates that a start was counted. Therefore, for all time-steps $t \in TS$, buses $b \in B^{HE}$ and *start indication values* $i \in \{1,..,NStartMW_b\}$:

$$IHE_{t,b,i} = \begin{cases} 1 \quad if \left(ODG_{t-1,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t-1,b}} SDG_{t-1,b,k} < StartMW_{b,i} \right) \\ \quad and \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K^E_{t,b}} SDG_{t,b,k} \geq StartMW_{b,i} \right) \\ 0 \quad otherwise. \end{cases}$$

8.6.5.3 *Dispatchable* hydroelectric *generation resources* shall not be scheduled to be started more times than permitted by their *maximum number of starts per day*. If the pre-dispatch look-ahead period spans two *dispatch days*, this constraint shall be applied for both days. The following constraint shall apply for all buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tod}} \left(\sum_{i=1..NStartMW_b} IHE_{t,b,i} \right) \leq MaxStartsHE_{tod,b} - NumStartsHE_b.$$

8.6.5.3.1 and if the pre-dispatch look-ahead period spans two *dispatch days*, for buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tom}} \left(\sum_{i=1..NStartMW_b} IHE_{t,b,i} \right) \leq MaxStartsHE_{tom,b}.$$

8.6.5.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not exceed shared *maximum daily energy limits*. If the pre-dispatch look-ahead period spans two *dispatch days*, the constraint shall be applied for both days, where the constraint for today shall consider the amount of *energy* already provided by *resources* with a registered *forebay*. Violation variables for over-scheduling the *maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s \in SHE$ and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \right) \right)$$
$$+ \sum_{b \in B_s^{HE}} \left(10ORConv \left(\sum_{k \in K_{T,b}^{10S}} S10SDG_{T,b,k} + \sum_{k \in K_{T,b}^{10N}} S10NDG_{T,b,k} \right) \right.$$
$$\left. + 30ORConv \left(\sum_{k \in K_{T,b}^{30R}} S30RDG_{T,b,k} \right) \right)$$
$$- \sum_{i=1..N_{SMaxDelViol_T}} SSMaxDelViol_{T,s,i} \leq MaxSDEL_{tod,s} - EngyUsedSHE_s$$

8.6.5.4.1 and if the look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$ and all time-steps $T \in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_S^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$

$$+\sum_{b\in B_S^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$

$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)$$

$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}\leq MaxSDEL_{tom,s}$$

where the factors $10\ ORConv$ and $30\ ORConv$ shall be applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* to convert MW into MWh.

8.6.5.5 Schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *minimum daily energy limits*. If the pre-dispatch look-ahead period spans two *dispatch days*, the constraint shall be applied for both days, where the constraint for today shall consider the amount of *energy* already provided by *resources* with a registered *forebay*. Violation variables for under-scheduling the *minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s \in SHE$:

$$\sum_{t\in TS_{tod}}\left(\sum_{b\in B_S^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right.$$

$$\left.+\sum_{i=1..N_{SMinDelViol_t}}SSMinDelViol_{t,s,i}\right)\geq MinSDEL_{tod,s}-EngyUsedSHE_s$$

8.6.5.5.1 and if the pre-dispatch look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$:

$$\sum_{t\in TS_{tom}}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^E}SDG_{t,b,k}\right)+\sum_{i=1..N_{SMinDelViol_t}}SSMinDelViol_{t,s,i}\right)\geq MinSDEL_{tom,s}.$$

8.6.5.6 For linked *dispatchable* hydroelectric *generation resources* with a registered *forebay*, *energy* scheduled at the upstream *resource* in one time-step shall result in a proportional amount of *energy* being scheduled at the linked downstream *resource* in the time-step determined by the *time lag*.

8.6.5.7 For linked *dispatchable* hydroelectric *generation resources*, time-steps in which the upstream *resources* schedule is not determined in the *pre-dispatch calculation engine* optimization, the constraint shall link either the historical or time-step 1 anticipated production for the upstream *resources* to the schedule for the downstream *resources*.

8.6.5.8 For all linked *dispatchable* hydroelectric *generation resources* between upstream *resources* $b_1 \in B_{up}^{HE}$ and downstream *resources* $b_2 \in B_{dn}^{HE}$ for $(b_1,b_2) \in LNKC$ and all time-steps $t\in TS$ such that $t \leq LagC_{b_1,b_2}+1$:

$$\sum_{b_2\in B_{dn}^{HE}}\left(ODG_{t,b_2}\cdot MinQDGC_{b_2}+\sum_{k\in K_{t,b_2}^E}SDG_{t,b_2,k}\right)-\sum_{i=1..N_{OGenLnkViol_t}}SOGenLnkViol_{t,(b_1,b_2),i}+\sum_{i=1..N_{UGenLnkViol_t}}SUGenLnkViol_{t,(b_1,b_2),i}=MWhRatioC_{b_1,b_2}\cdot PastMWh_{t,b_1}.$$

8.6.5.9 For linked *dispatchable* hydroelectric *generation resources*, time-steps in which both the upstream and downstream *resource* schedules are determined in the *pre-dispatch calculation engine* optimization, the constraint will link the scheduling variables for both the upstream and downstream *resources*.

8.6.5.10 For all linked *dispatchable* hydroelectric *generation resources* between upstream *resources* $b_1 \in B^{HE}_{up}$ and downstream *resources* $b_2 \in B^{HE}_{dn}$ for $(b_1,b_2) \in LNKC$ and time-steps $t \in TS$ such that $t + LagC_{b_1,b_2} \le n_{LAP}$:

$$\sum_{b_2 \in B^{HE}_{dn}} \left(ODG_{t+LagC_{b_1,b_2},b_2} \cdot MinQDGC_{b_2} + \sum_{k \in K^{E}_{t+LagC_{b_1,b_2},b_2}} SDG_{t+LagC_{b_1,b_2},b_2,k} \right) - \sum_{i=1..N_{OGenLnkViol_{t+Lag_{b_1,b_2}}}} SOGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i} + \sum_{i=1..N_{UGenLnkViol_{t+Lag_{b_1,b_2}}}} SUGenLnkViol_{t+Lag_{b_1,b_2},(b_1,b_2),i} = MWhRatioC_{b_1,b_2} \cdot \sum_{b_1 \in B^{HE}_{up}} \left(ODG_{t,b_1} \cdot MinQDGC_{b_1} + \sum_{k \in K^{E}_{t,b_1}} SDG_{t,b_1,k} \right)$$

8.7 Constraints for Reliability Requirements

8.7.1 Energy Balance

8.7.1.1 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in time-step $t \in TS$, $With_{t,b}$ shall be represented by:

$$With_{t,b} = \begin{cases} \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} & if\ b \in B^{DL} \\ \sum_{j \in J^{E}_{t,b}} (QHDR_{t,b,j} - SHDR_{t,b,j}) & if\ b \in B^{HDR} \end{cases}.$$

8.7.1.1 The total amount of export *energy* scheduled at *intertie zone* bus $d \in DX$ in time-step $t \in TS$, $With_{t,d}$, as the exports from Ontario to the *intertie zone* bus shall be represented by:

$$With_{t,d} = \sum_{j \in J^{E}_{t,d}} SXL_{t,d,j}.$$

8.7.1.1 The total amount of injections scheduled at internal bus $b \in B$ in time-step $t \in TS$, $Inj_{t,b}$, shall be represented by:

$$Inj_{t,b} = OfferInj_{t,b} + RampInj_{t,b}$$

where:

$$OfferInj_{t,b} = \begin{cases} \sum_{k \in K_{t,b}^{E}} SNDG_{t,b,k} & if\ b \in B^{NDG} \\ ODG_{t,b} \cdot MinQDGC_{b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} & if\ b \in B^{DG} \end{cases}$$

and

$$RampInj_{t,b} = \begin{cases} \sum_{w=1..min(RampHrsC_{b}^{m}, n_{LAP}-t)} RampEC_{b,w}^{m} \cdot IDG_{t+w,b} & if\ b \in B^{NQS} \\ 0 & otherwise \end{cases}.$$

8.7.1.1 The total amount of import *energy* scheduled at *intertie zone* bus $d \in DI$ in time-step $t \in TS$, $Inj_{t,d}$, as the imports into Ontario from that *intertie zone* bus shall be represented by:

$$Inj_{t,d} = \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k}.$$

8.7.1.1 Injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor calculated by the *security* assessment function to reflect the losses or reduction in losses that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other after taking into account the adjustment for any discrepancy between total and marginal losses. Load or generation reduction associated with the *demand* constraint violation shall be subtracted from the total load or generation for the *pre-dispatch calculation engine* to produce a solution. For time-step $t \in TS$, the *energy* balance shall be:

$$FL_t + \sum_{b \in B^{DL} \cup B^{HDR}} (1 + MglLoss_{t,b}) \cdot With_{t,b} + \sum_{d \in DX} (1 + MglLoss_{t,d}) \cdot With_{t,d} - \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} = \sum_{b \in B^{NDG} \cup B^{DG}} (1 + MglLoss_{t,b}) \cdot Inj_{t,b} + \sum_{d \in DI} (1 + MglLoss_{t,d}) \cdot Inj_{t,d} - \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} + LossAdj_t.$$

8.7.2 Operating Reserve Requirements

8.7.2.1 *Operating reserve* shall be scheduled to meet system-wide requirements for synchronized *ten-minute operating reserve*, total *ten-minute operating reserve,* and *thirty-minute operating reserve* while respecting all applicable regional minimum requirements and regional maximum restrictions for *operating reserve*.

8.7.2.2 Constraint violation penalty curves may be used to impose a penalty cost for not meeting the *IESO*'s system-wide *operating reserve* requirements, not meeting a regional minimum requirement, or not adhering to a regional maximum restriction. Full *operating reserve* requirements shall be scheduled unless the cost of doing so would be higher than the applicable penalty cost. For each time-step $t \in TS$:

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \geq TOT10S_t;$$

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) + \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \geq TOT10R_t;$$

and

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \right) + \sum_{d \in DX} \left(\sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \right) + \sum_{d \in DI} \left(\sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \right) + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \geq TOT30R_t.$$

8.7.2.3 The following constraints shall be applied for each time-step $t \in TS$ and each region $r \in ORREG$:

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) + \sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \geq REGMin10R_{t,r};$$

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) - \sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \leq REGMax10R_{t,r};$$

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10S}} S10SDL_{t,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{10N}} S10NDL_{t,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{t,d}^{10N}} S10NXL_{t,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{t,d}^{10N}} S10NIG_{t,d,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{t,b}^{30R}} S30RDL_{t,b,j} \right) + \sum_{d \in D_r^{REG} \cap DX} \left(\sum_{j \in J_{t,d}^{30R}} S30RXL_{t,d,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \right) + \sum_{d \in D_r^{REG} \cap DI} \left(\sum_{k \in K_{t,d}^{30R}} S30RIG_{t,d,k} \right) + \sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \geq REGMin30R_{t,r};$$

and

$$
\begin{aligned}
&+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10N}} S10NDL_{t,b,j}\right)\\
&\qquad+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{10N}} S10NXL_{t,d,j}\right)\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{10S}} S10SDL_{t,b,j}\right)\\
&\qquad+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k}\right)\\
&\qquad+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{10N}} S10NIG_{t,d,k}\right)+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{t,b}^{30R}} S30RDL_{t,b,k}\right)\\
&\qquad+\sum_{d\in D_r^{REG}\cap DX}\left(\sum_{j\in J_{t,d}^{30R}} S30RXL_{t,d,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right)\\
&\qquad+\sum_{d\in D_r^{REG}\cap DI}\left(\sum_{k\in K_{t,d}^{30R}} S30RIG_{t,d,k}\right)-\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i}\\
&\qquad\le REGMax30R_{t,r}.
\end{aligned}
$$

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8.7.3 IESO Internal Transmission Limits

8.7.3.1 The Pre-Dispatch Scheduling algorithm shall produce a set of *energy* schedules that do not violate any *security limits* in the pre-contingency state and the post-contingency state subject to the remainder of this section 8.7.3. The total amount of *energy* scheduled to be injected and withdrawn at each bus used by the *energy* balance constraint in section 8.7.1.5, shall be used to produce these schedules.

8.7.3.2 Pre-contigency, $SPreITLViol_{f,t,i}$, and post-contingency, $SITLViol_{c,f,t,i}$, transmission limit violation variables shall allow the *pre-dispatch calculation engine* to find a solution.

8.7.3.3 For all time-steps $t \in TS$ and *facilities* $f \in F_t$, the linearized constraints for violated pre-contingency limits obtained from the *security* assesment function shall take the form:

$$\sum_{b\in B^{NDG}\cup B^{DG}} PreConSF_{t,f,b}\cdot Inj_{t,b} - \sum_{b\in B^{DL}\cup B^{HDR}} PreConSF_{t,f,b}\cdot With_{t,b} + \sum_{d\in DI} PreConSF_{t,f,d}\cdot Inj_{t,d} - \sum_{d\in DX} PreConSF_{t,f,d}\cdot With_{t,d} - \sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i} \le AdjNormMaxFlow_{t,f}.$$

8.7.3.4 For all time-steps $t\in TS$, contingencies $c\in C$, and *facilities* $f\in F_{t,c}$, the linearized constraints for violated post-contingency limits obtained from the *security* assesment function shall take the form:

$$\sum_{b\in B^{NDG}\cup B^{DG}} SF_{t,c,f,b}\cdot Inj_{t,b} - \sum_{b\in B^{DL}\cup B^{HDR}} SF_{t,c,f,b}\cdot With_{t,b} + \sum_{d\in DI} SF_{t,c,f,d}\cdot Inj_{t,d} - \sum_{d\in DX} SF_{t,c,f,d}\cdot With_{t,d} - \sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i} \le AdjEmMaxFlow_{t,c,f}.$$

8.7.4 Intertie Limits

8.7.4.1 The Pre-Dispatch Scheduling algorithm shall produce a set of *energy* and *operating reserve* schedules that respect any *security limits* associated with *interties* between Ontario and *intertie zones*. For all time-steps $t\in TS$ and all constraints $z\in Z_{Sch}$:

$$\sum_{a\in A:\, EnCoeff_{a,z}\neq 0}\left[EnCoeff_{a,z}\left(\sum_{d\in DI_a}\sum_{k\in K^{E}_{t,d}} SIG_{t,d,k} - \sum_{d\in DX_a}\sum_{j\in J^{E}_{t,d}} SXL_{t,d,j}\right) + 0.5\cdot(EnCoeff_{a,z}+1)\left(\sum_{d\in DI_a}\left(\sum_{k\in K^{10N}_{t,d}} S10NIG_{t,d,k} + \sum_{k\in K^{30R}_{t,d}} S30RIG_{t,d,k}\right) + \sum_{d\in DX_a}\left(\sum_{j\in J^{10N}_{t,d}} S10NXL_{t,d,j} + \sum_{j\in J^{30R}_{t,d}} S30RXL_{t,d,j}\right)\right)\right] - \sum_{i=1..N_{PreConXTLViol_{z,t}}} SPreXTLViol_{z,t,i} \le MaxExtSch_{t,z}.$$

where for out-of-service *intertie zones*, the *intertie* limits shall be set to zero and all *boundary entity resources* shall receive a zero schedule for *energy* and *operating reserve*.

8.7.4.2 Changes in the hour-to-hour net *energy* schedule over all *interties* shall not exceed the net interchange scheduling limit. The net import schedule shall be summed over all *intertie zones* for a given time-step to obtain the net *interchange schedule* for the time-step, and shall not:

8.7.4.2.1 exceed the net *interchange schedule* for the previous time-step plus the net interchange scheduling limit; and

8.7.4.2.2 be less than the net *interchange schedule* for the previous time-step minus the net interchange scheduling limit.

8.7.4.3 Violation variables shall be provided for both the up and down ramp limits to allow the *pre-dispatch calculation engine* to find a solution and for all time-steps $t \in TS$:

$$\sum_{d \in DI} \sum_{k \in K_{t-1,d}^{E}} SIG_{t-1,d,k} - \sum_{d \in DX} \sum_{j \in J_{t-1,d}^{E}} SXL_{t-1,d,j} - ExtDSC_t - \sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i}$$
$$\leq \sum_{d \in DI} \sum_{k \in K_{t,d}^{E}} SIG_{t,d,k} - \sum_{d \in DX} \sum_{j \in J_{t,d}^{E}} SXL_{t,d,j}$$
$$\leq \sum_{d \in DI} \sum_{k \in K_{t-1,d}^{E}} SIG_{t-1,d,k} - \sum_{d \in DX} \sum_{j \in J_{t-1,d}^{E}} SXL_{t-1,d,j} + ExtUSC_t$$
$$+ \sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i}.$$

8.7.5 Penalty Price Variable Bounds

8.7.5.1 Penalty price variables shall be restricted to the ranges determined by the constraint violation penalty curves for the Pre-Dispatch Scheduling algorithm and for time-steps $t \in TS$:

$0 \leq SLdViol_{t,i} \leq QLdViolSch_{t,i}$ for all $i \in \{1,..,N_{LdViol_t}\}$;

$0 \leq SGenViol_{t,i} \leq QGenViolSch_{t,i}$ for all $i \in \{1,..,N_{GenViol_t}\}$;

$0 \leq S10SViol_{t,i} \leq Q10SViolSch_{t,i}$ for all $i \in \{1,..,N_{10SViol_t}\}$;

$0 \leq S10RViol_{t,i} \leq Q10RViolSch_{t,i}$ for all $i \in \{1,..,N_{10RViol_t}\}$;

$0 \leq S30RViol_{t,i} \leq Q30RViolSch_{t,i}$ for all $i \in \{1,..,N_{30RViol_t}\}$;

$0 \leq SREG10RViol_{r,t,i} \leq QREG10RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG10RViol_t}\}$;

$0 \leq SREG30RViol_{r,t,i} \leq QREG30RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG30RViol_t}\}$;

$0 \leq SXREG10RViol_{r,t,i} \leq QXREG10RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG10RViol_t}\}$;

$0 \leq SXREG30RViol_{r,t,i} \leq QXREG30RViolSch_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG30RViol_t}\}$;

$0 \leq SPreITLViol_{f,t,i} \leq QPreITLViolSch_{f,t,i}$ for all $f \in F_t$, $i \in \{1,..,N_{PreITLViol_{f,t}}\}$;

$0 \leq SITLViol_{c,f,t,i} \leq QITLViolSch_{c,f,t,i}$ for all $c \in C$, $f \in F_{t,c}$, $i \in \{1,..,N_{ITLViol_{c,f,t}}\}$;

$0 \leq SPreXTLViol_{z,t,i} \leq QPreXTLViolSch_{z,t,i}$ for all $z \in Z_{Sch}$, $i \in \{1,..,N_{PreXTLViol_{z,t}}\}$;

$0 \leq SNIUViol_{t,i} \leq QNIUViolSch_{t,i}$ for all $i \in \{1,..,N_{NIUViol_t}\}$;

$0 \leq SNIDViol_{t,i} \leq QNIDViolSch_{t,i}$ for all $i \in \{1,..,N_{NIDViol_t}\}$;

$0 \leq SMaxDelViol_{t,b,i} \leq QMaxDelViolSch_{t,b,i}$ for all $b \in B^{ELR}$, $i \in \{1,..,N_{MaxDelViol_t}\}$;

$0 \leq SMinDelViol_{t,b,i} \leq QMinDelViolSch_{t,b,i}$ for all $b \in B^{HE}$, $i \in \{1,..,N_{MinDelViol_t}\}$;

$0 \leq SSMaxDelViol_{t,s,i} \leq QSMaxDelViolSch_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMaxDelViol_t}\}$;

$0 \leq SSMinDelViol_{t,s,i} \leq QSMinDelViolSch_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMinDelViol_t}\}$;

$0 \leq SOGenLnkViol_{t(b_1,b_2),i} \leq QOGenLnkViol_{t(b_1,b_2),i}$ for all $(b_1,b_2) \in LNK$, $i \in \{1,..,N_{OGenLnkViol_t}\}$;

and

$0 \leq SUGenLnkViol_{t(b_1,b_2),i} \leq QUGenLnkViol_{t(b_1,b_2),i}$ for all $(b_1,b_2) \in LNK$, $i \in \{1,..,N_{UGenLnkViol_t}\}$.

8.8 Outputs

8.8.1 Outputs for the Pre-Dispatch Scheduling algorithm include *resource* schedules and commitments.

9 Pre-Dispatch Pricing

9.1 Purpose

9.1.1 The Pre-Dispatch Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, subject to section 14.7.1.3, and *resource* schedules and commitments produced by the Pre-Dispatch Scheduling algorithm to meet the *IESO's* province-wide non-dispatchable *demand* forecast and IESO-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

9.2 Information, Sets, Indices and Parameters

9.2.1 Information, sets, indices and parameters used by the Pre-Dispatch Pricing algorithm are described in section 3. In addition, the following *resource* schedules and commitments determined by the Pre-Dispatch Scheduling algorithm shall be used by the Pre-Dispatch Pricing algorithm:

9.2.1.1 $SDG_{t,b,k}^{PDS}$ designates the amount of *energy* that the *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{E}$;

9.2.1.2 $ODG_{t,b}^{PDS}$ designates whether the *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$;

9.2.1.3 $S10SDG_{t,b,k}^{PDS}$ designates the amount of synchronized *ten-minute operating reserve* that the *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10S}$;

9.2.1.4 $S10NDG_{t,b,k}^{PDS}$ designates the amount of non-synchronized *ten-minute operating reserve* that the *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K_{t,b}^{10N}$;

9.2.1.5 $S30RDG_{t,b,k}^{PDS}$ designates the amount of *thirty-minute operating reserve* that the *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K^{30R}_{t,b}$; and

9.2.1.6 $OHO^{PDS}_{t,b}$ designates whether the *dispatchable* hydroelectric *generation resource* at bus $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

9.3 Variables and Objective Function

9.3.1 The Pre-Dispatch Pricing algorithm shall solve for the same variables as in the Pre-Dispatch Scheduling algorithm, section 8.3.1, with the following exceptions:

9.3.1.1 $IDG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ shall not appear in the formulation;

9.3.1.2 $ODG_{t,b}$ for bus $b \in B^{DG}$ and time-step $t \in TS$ will be fixed to a constant value, as determined by the Pre-Dispatch Scheduling algorithm;

9.3.1.3 $OHO_{t,b}$ for bus $b \in B^{HE}$ and time-step $t \in TS$ will be fixed to a constant value, as determined by the Pre-Dispatch Scheduling algorithm;

9.3.1.4 $IHE_{t,b,i}$ for $b \in B^{HE}$, time-step $t \in TS$ and *start indication value* $i \in \{1,..,NStartMW_b\}$ shall not appear in the formulation;

9.3.1.5 $SOGenLnkViol_{t,(b_1,b_2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, time-step $t \in TS$ and $i \in \{1,..,N_{OGenLnkViol_t}\}$ shall not appear in the formulation; and

9.3.1.6 $SUGenLnkViol_{t,(b_1,b_2),i}$ for $(b_1,b_2) \in LNK$ such that $b_1 \in B^{HE}_{up}$ and $b_2 \in B^{HE}_{dn}$, time-step $t \in TS$ and $i \in \{1,..,N_{UGenLnkViol_t}\}$ shall not appear in the formulation.

9.3.2 The objective function for the Pre-Dispatch Pricing algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{t \in TS} \begin{pmatrix} ObjDL_t - ObjHDR_t + ObjXL_t - ObjNDG_t \\ - ObjDG_t - ObjIG_t - TB_t - ViolCost_t \end{pmatrix}$$

where:

$$ObjDL_t = \sum_{b \in B^{DL}} \begin{pmatrix} \sum_{j \in J^{E}_{t,b}} SDL_{t,b,j} \cdot PDL_{t,b,j} - \sum_{j \in J^{10S}_{t,b}} S10SDL_{t,b,j} \cdot P10SDL_{t,b,j} - \\ \sum_{j \in J^{10N}_{t,b}} S10NDL_{t,b,j} \cdot P10NDL_{t,b,j} - \sum_{j \in J^{30R}_{t,b}} S30RDL_{t,b,j} \cdot P30RDL_{t,b,j} \end{pmatrix};$$

$$ObjHDR_t = \sum_{b \in B^{HDR}} \left(\sum_{j \in J^{E}_{t,b}} SHDR_{t,b,j} \cdot PHDR_{t,b,j} \right);$$

$$ObjXL_t = \sum_{d \in DX} \begin{pmatrix} \sum_{j \in J^{E}_{t,d}} SXL_{t,d,j} \cdot PXL_{t,d,j} - \sum_{j \in J^{10N}_{t,d}} S10NXL_{t,d,j} \cdot P10NXL_{t,d,j} \\ - \sum_{j \in J^{30R}_{t,d}} S30RXL_{t,d,j} \cdot P30RXL_{t,d,j} \end{pmatrix};$$

$$ObjNDG_t = \sum_{b \in B^{NDG}} \left(\sum_{k \in K^{E}_{t,b}} SNDG_{t,b,k} \cdot PNDG_{t,b,k} \right);$$

$$ObjDG_t = \sum_{b \in B^{DG}} \begin{pmatrix} \sum_{k \in K^{E}_{t,b}} SDG_{t,b,k} \cdot PDG_{t,b,k} + \sum_{k \in K^{10S}_{t,b}} S10SDG_{t,b,k} \cdot P10SDG_{t,b,k} + \\ \sum_{k \in K^{10N}_{t,b}} S10NDG_{t,b,k} \cdot P10NDG_{t,b,k} + \sum_{k \in K^{30R}_{t,b}} S30RDG_{t,b,k} \cdot P30RDG_{t,b,k} \end{pmatrix};$$

$$ObjIG_t = \sum_{d \in DI} \begin{pmatrix} \sum_{k \in K^{E}_{t,d}} SIG_{t,d,k} \cdot PIG_{t,d,k} + \sum_{k \in K^{10N}_{t,d}} S10NIG_{t,d,k} \cdot P10NIG_{t,d,k} \\ + \sum_{k \in K^{30R}_{t,d}} S30RIG_{t,d,k} \cdot P30RIG_{t,d,k} \end{pmatrix}.$$

9.3.2.1 The tie-breaking term, TB_t, shall be the same term described in section 8.3.2.1.

9.3.2.2 $ViolCost_t$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_t = & \sum_{i=1..N_{LdViol_t}} SLdViol_{t,i} \cdot PLdViolPrc_{t,i} \\
& - \sum_{i=1..N_{GenViol_t}} SGenViol_{t,i} \cdot PGenViolPrc_{t,i} \\
& + \sum_{i=1..N_{10SViol_t}} S10SViol_{t,i} \cdot P10SViolPrc_{t,i} \\
& + \sum_{i=1..N_{10RViol_t}} S10RViol_{t,i} \cdot P10RViolPrc_{t,i} \\
& + \sum_{i=1..N_{30RViol_t}} S30RViol_{t,i} \cdot P30RViolPrc_{t,i} \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG10RViol_t}} SREG10RViol_{r,t,i} \cdot PREG10RViolPrc_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{REG30RViol_t}} SREG30RViol_{r,t,i} \cdot PREG30RViolPrc_{t,i} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{i=1..N_{XREG10RViol_t}} SXREG10RViol_{r,t,i} \cdot PXREG10RViolPrc_{t,i} \right)
\end{aligned}
$$

$$+\sum_{r\in ORREG}\left(\sum_{i=1..N_{XREG30RViol_t}} SXREG30RViol_{r,t,i}\cdot PXREG30RViolPrc_{t,i}\right)$$

$$+\sum_{f\in F_t}\left(\sum_{i=1..N_{PreITLViol_{f,t}}} SPreITLViol_{f,t,i}\cdot PPreITLViolPrc_{f,t,i}\right)$$

$$+\sum_{c\in C}\sum_{f\in F_{t,c}}\left(\sum_{i=1..N_{ITLViol_{c,f,t}}} SITLViol_{c,f,t,i}\cdot PITLViolPrc_{c,f,t,i}\right)$$

$$+\sum_{z\in Z_{Sch}}\left(\sum_{i=1..N_{PreXTLViol_t}} SPreXTLViol_{z,t,i}\cdot PPreXTLViolPrc_{z,t,i}\right)$$

$$+\sum_{i=1..N_{NIUViol_t}} SNIUViol_{t,i}\cdot PNIUViolPrc_{t,i}$$

$$+\sum_{i=1..N_{NIDViol_t}} SNIDViol_{t,i}\cdot PNIDViolPrc_{t,i}$$

$$+\sum_{b\in B^{ELR}}\left(\sum_{i=1..N_{MaxDelViol_t}} SMaxDelViol_{t,b,i}\cdot PMaxDelViolPrc_{t,b,i}\right)$$

$$+\sum_{b\in B^{HE}}\left(\sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i}\cdot PMinDelViolPrc_{t,b,i}\right)$$

$$+\sum_{s\in SHE}\left(\sum_{i=1..N_{SMaxDelViol_t}} SSMaxDelViol_{t,s,i}\cdot PSMaxDelViolPrc_{t,s,i}\right)$$

$$+\sum_{s\in SHE}\left(\sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i}\cdot PSMinDelViolPrc_{t,s,i}\right)$$

9.3.2.3 The objective function of the Pre-Dispatch Pricing algorithm in section 9.3.2 shall be subject to the constraints described in sections 9.4 - 9.8.

9.4 Constraints

9.4.1 The constraints described in sections 9.5, 9.6, 9.7 and 9.8 apply to the optimization function in the Pre-Dispatch Pricing algorithm.

9.5 Dispatch Data Constraints Applying to Individual Hours

9.5.1 Scheduling Variable Bounds

9.5.1.1 *Energy* and *operating reserve* schedules shall not be negative and shall not exceed the quantity respectively offered for *energy* and *operating reserve*. For all time-steps $t \in TS$:

$$0 \leq SDL_{t,b,j} \leq QDL_{t,b,j} \quad \text{for all } b \in B^{DL}, j \in J^{E}_{t,b};$$

$$0 \leq S10SDL_{t,b,j} \leq Q10SDL_{t,b,j} \quad \text{for all } b \in B^{DL}, j \in J^{10S}_{t,b};$$

$$0 \leq S10NDL_{t,b,j} \leq Q10NDL_{t,b,j} \quad \text{for all } b \in B^{DL}, j \in J^{10N}_{t,b};$$

$$0 \leq S30RDL_{t,b,j} \leq Q30RDL_{t,b,j} \quad \text{for all } b \in B^{DL}, j \in J^{30R}_{t,b};$$

$$0 \leq SHDR_{t,b,j} \leq QHDR_{t,b,j} \quad \text{for all } b \in B^{HDR}, j \in J^{E}_{t,b};$$

$$0 \leq SXL_{t,d,j} \leq QXL_{t,d,j} \quad \text{for all } d \in DX, j \in J^{E}_{t,d};$$

$$0 \leq S10NXL_{t,d,j} \leq Q10NXL_{t,d,j} \quad \text{for all } d \in DX, j \in J^{10N}_{t,d};$$

$$0 \leq S30RXL_{t,d,j} \leq Q30RXL_{t,d,j} \quad \text{for all } d \in DX, j \in J^{30R}_{t,d};$$

$$0 \leq SNDG_{t,b,k} \leq QNDG_{t,b,k} \quad \text{for all } b \in B^{NDG}, k \in K^{E}_{t,b};$$

$$0 \leq SIG_{t,d,k} \leq QIG_{t,d,k} \quad \text{for all } d \in DI, k \in K^{E}_{t,d};$$

$$0 \leq S10NIG_{t,d,k} \leq Q10NIG_{t,d,k} \quad \text{for all } d \in DI, k \in K^{10N}_{t,d}; \text{ and}$$

$$0 \leq S30RIG_{t,d,k} \leq Q30RIG_{t,d,k} \quad \text{for all } d \in DI, k \in K^{30R}_{t,d}.$$

9.5.1.2 A *dispatchable generation resource* may be scheduled for *energy* and *operating reserve* only if its commitment status variable, as determined by the Pre-Dispatch Scheduling algorithm, is equal to 1. For all time-steps $t \in TS$:

$$0 \leq SDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot QDG_{t,b,k} \quad \text{for all } b \in B^{DG}, \; k \in K^{E}_{t,b};$$

$$0 \leq S10SDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q10SDG_{t,b,k} \quad \text{for all } b \in B^{DG}, \; k \in K^{10S}_{t,b};$$

$$0 \leq S10NDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q10NDG_{t,b,k} \quad \text{for all } b \in B^{DG}, \; k \in K^{10N}_{t,b}; \text{and}$$

$$0 \leq S30RDG_{t,b,k} \leq ODG^{PDS}_{t,b} \cdot Q30RDG_{t,b,k} \quad \text{for all } b \in B^{DG}, \; k \in K^{30R}_{t,b}.$$

where

$ODG^{PDS}_{t,b}$ is a fixed constant in the above constraints, per section 9.8.1.1.

9.5.2 Resource Minimums and Maximums

9.5.2.1 The constraints in section 8.5.2 shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3 Off-Market Transactions

9.5.3.1 The constraints in sections 8.5.3.1 and 8.5.3.2 for inadvertent payback transactions shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3.2 In the case of *emergency energy* transactions, subject to section 9.5.3.3, the constraints in sections 8.5.3.3 and 8.5.3.4 shall apply in the Pre-Dispatch Pricing algorithm.

9.5.3.3 For all time-steps $t \in TS$ and all *boundary entity resources* scheduled to import *emergency energy* that does not support an export $d \in DI^{EMNS}_{t}$:

$$\sum_{k \in K^{E}_{t,d}} SIG_{t,d,k} = 0.$$

9.5.4 Intertie Minimum and Maximum Constraints

9.5.4.1 The constraints in section 8.5.4 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.5 Operating Reserve Scheduling

9.5.5.1 The constraints in section 8.5.5 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.6 Pseudo-Units

9.5.6.1 The constraints in section 8.5.6 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.5.7 Dispatchable Hydroelectric Generation Resources

9.5.7.1 The constraints in section 8.5.7 shall apply in the Pre-Dispatch Pricing algorithm as well, with the following exceptions:

9.5.7.1.1 *energy offer* laminations corresponding to the *hourly must-run* amount shall be ineligible to set prices;

9.5.7.1.2 *minimum hourly output* constraints shall be replaced by the constraints in section 9.8; and

9.5.7.1.3 a *dispatchable* hydroelectric *generation resource's* schedule shall respect its *forbidden regions* and may only set prices within the operating range determined by the adjacent *forbidden regions* between which the *resource* was scheduled.

9.5.8 Wheeling Through Transactions

9.5.8.1 The constraints in section 8.5.8 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6 Dispatch Data Inter-Hour/Multi-Hour Constraints

9.6.1 Energy Ramping

9.6.1.1 The constraints in section 8.6.1 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6.2 Operating Reserve Ramping

9.6.2.1 The constraints in section 8.6.2 shall apply in the Pre-Dispatch Pricing algorithm as well.

9.6.3 Energy Limited Resources

9.6.3.1 The constraints in section 8.6.4 shall apply to *energy limited resources*. If a *resource's maximum daily energy limit* is binding, then the constraints in section 9.8 shall also apply.

9.6.4 Dispatchable Hydroelectric Generation Resources

9.6.4.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled for *energy* to at least its *minimum daily energy limit*. Violation variables for under-scheduling a *resource's minimum daily energy limit* shall be provided to allow the *pre-dispatch calculation engine* to find a solution. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tod,b} - EngyUsed_b.$$

9.6.4.1.1 If the pre-dispatch look-ahead period spans two *dispatch days*, for all hydroelectric *resource* buses $b \in B^{HE}$:

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{i=1..N_{MinDelViol_t}} SMinDelViol_{t,b,i} \right) \geq MinDEL_{tom,b}.$$

9.6.4.2 The constraints in section 9.8.3.3 shall apply to a *dispatchable* hydroelectric *generation resource* with a binding *minimum daily energy limit* in the Pre-Dispatch Scheduling algorithm.

9.6.4.3 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall respect shared *maximum daily energy limits*. Violation variables for scheduling *resources* above the *maximum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s \in SHE$ and all time-steps $T \in TS_{tod}$:

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$

$$\left.\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)\right)$$

$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}\le MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

9.6.4.3.1 If the look-ahead period spans two *dispatch days*, then for all sets $s\in SHE$ and all time-steps $T\in TS_{tom}$:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^{E}}SDG_{t,b,k}\right)\right)$$

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}\right)\right.$$

$$\left.\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}\right)\right)\right)$$

$$-\sum_{i=1..N_{SMaxDelViol_T}}SSMaxDelViol_{T,s,i}\le MaxSDEL_{tom,s}$$

where the factors 10 $ORConv$ and 30 $ORConv$ shall be applied to scheduled *ten-minute operating reserve* and *thirty-minute operating reserve* to convert MW into MWh.

9.6.4.4 The schedules for multiple *dispatchable* hydroelectric *generation resources* with a registered *forebay* shall not violate shared *minimum daily energy limits*. Violation variables for scheduling *resources* below the *minimum daily energy limit* may be used to allow the *pre-dispatch calculation engine* to find a solution. For all sets $s\in SHE_{tod}$ and all time-steps $t\in TS_{tod}$:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tod,s} - EngyUsedSHE_s.$$

9.6.4.4.1 If the look-ahead period spans two *dispatch days*, then for all sets $s \in SHE$ and all time-steps $t \in TS_{tom}$:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) + \sum_{i=1..N_{SMinDelViol_t}} SSMinDelViol_{t,s,i} \right) \geq MinSDEL_{tom,s}.$$

9.7 Constraints for Reliability Requirements

9.7.1 Energy Balance

9.7.1.1 The constraint in section 8.7.1 shall also apply in the Pre-Dispatch Pricing algorithm, except the marginal loss factors used in the *energy* balance constraint in the Pre-Dispatch Pricing algorithm shall be fixed to the marginal loss factors used in the last optimization function iteration of the Pre-Dispatch Scheduling algorithm.

9.7.2 Operating Reserve Requirements

9.7.2.1 The constraints in section 8.7.2 shall also apply in the Pre-Dispatch Pricing algorithm.

9.7.3 IESO Internal Transmission Limits

9.7.3.1 The constraints in section 8.7.3 shall also apply in the Pre-Dispatch Pricing algorithm, except the sensitivities and limits considered shall be those provided by the most recent *security* assessment function iteration of the Pre-Dispatch Pricing algorithm.

9.7.4 Intertie Limits

9.7.4.1 The constraints in section 8.7.4 shall also apply in the Pre-Dispatch Pricing algorithm.

9.7.5 Penalty Price Variable Bounds

9.7.5.1 The following constraints shall restrict the penalty price variables to the ranges determined by the constraint violation penalty curves for the pricing algorithm. For all time-steps $t \in TS$:

$0 \le SLdViol_{t,i} \le QLdViolPrc_{t,i}$ for all $i \in \{1,..,N_{LdViol_t}\}$;

$0 \le SGenViol_{t,i} \le QGenViolPrc_{t,i}$ for all $i \in \{1,..,N_{GenViol_t}\}$;

$0 \le S10SViol_{t,i} \le Q10SViolPrc_{t,i}$ for all $i \in \{1,..,N_{10SViol_t}\}$;

$0 \le S10RViol_{t,i} \le Q10RViolPrc_{t,i}$ for all $i \in \{1,..,N_{10RPrc_t}\}$;

$0 \le S30RViol_{t,i} \le Q30RViolPrc_{t,i}$ for all $i \in \{1,..,N_{30RPrc_t}\}$;

$0 \le SREG10RViol_{r,t,i} \le QREG10RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG10RPrc_t}\}$;

$0 \le SREG30RViol_{r,t,i} \le QREG30RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{REG30RPrc_t}\}$;

$0 \le SXREG10RViol_{r,t,i} \le QXREG10RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG10RPrc_t}\}$;

$0 \le SXREG30RViol_{r,t,i} \le QXREG30RViolPrc_{t,i}$ for all $r \in ORREG$, $i \in \{1,..,N_{XREG30RPrc_t}\}$;

$0 \le SPreITLViol_{f,t,i} \le QPreITLViolPrc_{f,t,i}$ for all $f \in F_t$, $i \in \{1,..,N_{PreITLPrc_{f,t}}\}$;

$0 \le SITLViol_{f,c,t,i} \le QITLViolPrc_{f,c,t,i}$ for all $c \in C$, $f \in F_{c,t}$, $i \in \{1,..,N_{PITLPrc_{c,f,t}}\}$;

$0 \le SPreXTLViol_{z,t,i} \le QPreXTLViolPrc_{z,t,i}$ for all $z \in Z_{Sch}$, $i \in \{1,..,N_{PreXTLPrc_{z,t}}\}$;

$0 \le SNIUViol_{t,i} \le QNIUViolPrc_{t,i}$ for all $i \in \{1,..,N_{NIUPrc_t}\}$;

$0 \le SNIDViol_{t,i} \le QNIDViolPrc_{t,i}$ for all $i \in \{1,..,N_{NIDPrc_t}\}$;

$0 \le SMaxDelViol_{t,b,i} \le QMaxDelViolPrc_{t,b,i}$ for all $b \in B^{ELR}$, $i \in \{1,..,N_{MaxDelViol_t}\}$;

$0 \le SMinDelViol_{t,b,i} \le QMinDelViolPrc_{t,b,i}$ for all $b \in B^{HE}$, $i \in \{1,..,N_{MinDelViol_t}\}$;

$0 \le SSMaxDelViol_{t,s,i} \le QSMaxDelViolPrc_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMaxDelViol_t}\}$; and

$0 \le SSMinDelViol_{t,s,i} \le QSMinDelViolPrc_{t,s,i}$ for all $s \in SHE$, $i \in \{1,..,N_{SMinDelViol_t}\}$.

9.8 Constraints to Ensure the Price Setting Eligibility of Offer/Bid Laminations

9.8.1 Commitment Status Variables

9.8.1.1 Commitment decisions shall be fixed to the commitment statuses of *resources* calculated by the Pre-Dispatch Scheduling algorithm in section 8. For all time-steps $t \in TS$ and all buses $b \in B^{DG}$:

$$ODG_{t,b} = ODG_{t,b}^{PDS}.$$

9.8.2 Energy Limited Resources

9.8.2.1 For an *energy limited resource* with a *maximum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the schedules calculated by the Pre-Dispatch Scheduling algorithm shall determine the price-setting eligibility of the *resource's energy* and *operating reserve offer* laminations. In each time-step, *energy* or *operating reserve* laminations up to the total amount of *energy* and *operating reserve* scheduled in the Pre-Dispatch Scheduling algorithm shall be eligible to set prices. For bus $b \in B^{ELR}$, if there exists a time-step $T \in TS_{tod}$ such that:

$$\sum_{t=2..T}\left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS}\right) + 10ORConv\left(\sum_{k \in K_{T,b}^{10S}} S10SDG_{T,b,k}^{PDS} + \sum_{k \in K_{T,b}^{10N}} S10NDG_{T,b,k}^{PDS}\right) + 30ORConv\left(\sum_{k \in K_{T,b}^{30R}} S30RDG_{T,b,k}^{PDS}\right) = MaxDEL_{tod,b} - EngyUsed_b$$

9.8.2.1.1 then the *maximum daily energy limit* constraint shall be considered binding in the Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints must hold for bus $b \in B^{ELR}$ for all time-steps $t \in TS_{tod}$:

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq MaxDEL_{tod,b} - EngyUsed_{b} - \sum_{\tau=2}^{t-1} \sum_{k \in K_{t,b}^{E}} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.2.2 If the pre-dispatch look-ahead period spans two *dispatch days*, then for bus $b \in B^{ELR}$, if there exists a time-step $T \in TS_{tom}$ such that:

$$\sum_{t=t_{tom}..T} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_{b} + \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} \right) + 10ORConv \left(\sum_{k \in K_{T,b}^{10S}} S10SDG_{T,b,k}^{PDS} + \sum_{k \in K_{T,b}^{10N}} S10NDG_{T,b,k}^{PDS} \right) + 30ORConv \left(\sum_{k \in K_{T,b}^{30R}} S30RDG_{T,b,k}^{PDS} \right) = MaxDEL_{tom,b}$$

9.8.2.2.1 then the *maximum daily energy limit* constraint is considered to be binding for the next *dispatch day* in Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints must hold for bus $b \in B^{ELR}$ for all time-steps $t \in TS_{tom}$:

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{k \in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{k \in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k \in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k \in K_{t,b}^{30R}} S30RDG_{t,b,k} \leq MaxDEL_{tom,b} - \sum_{\tau=tom}^{t-1} \sum_{k \in K_{t,b}^{E}} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3 Dispatchable Hydroelectric Generation Resources

9.8.3.1 If a *dispatchable* hydroelectric *generation resource* is scheduled to provide *energy* at or above its *minimum hourly output* in the Pre-Dispatch Scheduling algorithm, such *resource* shall also be scheduled at or above its *minimum hourly output* in the Pre-Dispatch Pricing algorithm. The *energy offer* laminations corresponding to the *minimum hourly output* amount shall be ineligible to set prices. If a *dispatchable* hydroelectric *generation resource* with a *minimum hourly output* amount receives a zero schedule in the Pre-Dispatch Scheduling algorithm, the *resource* shall also receive a zero schedule in the Pre-Dispatch Pricing algorithm and shall be ineligible to set prices in the *energy* market. For all time-steps $t \in TS$ and *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$:

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq MinHO_{t,b} \cdot OHO_{t,b}^{PDS}$$

and for all $k \in K_{t,b}^E$:

$$0 \leq SDG_{t,b,k} \leq OHO_{t,b}^{PDS} \cdot QDG_{t,b,k}.$$

9.8.3.2 For a *dispatchable* hydroelectric *generation resource* with a limited number of starts, such *resource* shall be scheduled such that it is limited to set prices within an operating range consistent with the number of starts utilized by the *resource's* schedule determined by the Pre-Dispatch Scheduling algorithm. The *resource's* schedule shall be between the same *start indication values* as determined in the Pre-Dispatch Scheduling algorithm. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ and all time-steps $t \in TS$:

If $0 \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} < StartMW_{b,1}$,

then

$$0 \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq StartMW_{b,1} - 0.1$$

If $StartMW_{b,i} \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} < StartMW_{b,i+1}$ for $i \in \{1,...,(NStartMW_b\text{-}1)\}$,

then

$$StartMW_{b,i} \leq ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \leq StartMW_{b,i+1} - 0.1$$

If $ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \geq StartMW_{b,NStartMW_b}$,

then

$$ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \geq StartMW_{b,NStartMW_b}.$$

9.8.3.3 For a *dispatchable* hydroelectric *generation resource* with a *minimum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the *offer* laminations corresponding to the *energy* schedules calculated in the Pre-Dispatch Scheduling algorithm shall be ineligible to set prices. For all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such that $MinDEL_{tod,b} > 0$ and

$$\sum_{t \in TS_{tod}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tod,b} - EngyUsed_b,$$

9.8.3.3.1 the following constraints must hold for all time-steps $t \in TS_{tod}$ and *offer* laminations $k \in K_{t,b}^E$:

$$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}.$$

9.8.3.3.2 If the pre-dispatch look-ahead period spans two *dispatch days*, for all *dispatchable* hydroelectric *generation resource* buses $b \in B^{HE}$ such that $MinDEL_{tom,b} > 0$ and

$$\sum_{t \in TS_{tom}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \leq MinDEL_{tom,b},$$

9.8.3.3.3 the following constraints must hold for all time-steps $t \in TS_{tom}$ and *offer* laminations $k \in K_{t,b}^E$:

$$SDG_{t,b,k} \geq SDG_{t,b,k}^{PDS}.$$

9.8.3.4 For a *dispatchable* hydroelectric *generation resource* with a shared *minimum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, the *offer* laminations corresponding to the *energy* schedules calculated for all *resources* in the set $s \in SHE$ in the Pre-Dispatch Scheduling algorithm shall be ineligible to set prices. Thus, for each set $s \in SHE$:

$$\sum_{t \in TS_{tod}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tod,s} - EngyUsedSHE_s,$$

9.8.3.4.1 the following constraints must hold for all time-steps $t \in TS_{tod}$ $\in$:

$$\sum_{b \in B_s^{HE}} \left(ODG_{t,b} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k} \right) \geq \sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right).$$

9.8.3.4.2 If the pre-dispatch look-ahead period spans two *dispatch days*, then for each set $s \in SHE$:

$$\sum_{t \in TS_{tom}} \left(\sum_{b \in B_s^{HE}} \left(ODG_{t,b}^{PDS} \cdot MinQDGC_b + \sum_{k \in K_{t,b}^E} SDG_{t,b,k}^{PDS} \right) \right) \leq MinSDEL_{tom,s}$$

9.8.3.4.3 the following constraints must hold for all time-steps $t \in TS_{tom}$:

$$\sum_{b\in B_s^{HE}}\left(ODG_{t,b}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^E}SDG_{t,b,k}\right)$$

$$\geq\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^E}SDG_{t,b,k}^{PDS}\right).$$

9.8.3.5 For a *dispatchable* hydroelectric *generation resource* with a binding *maximum daily energy limit* in the Pre-Dispatch Scheduling algorithm, the schedules calculated in the Pre-Dispatch Scheduling algorithm shall determine the price-setting eligibility of the *resource's energy* and *operating reserve offer* laminations as described in section 9.8.2.

9.8.3.6 For a *dispatchable* hydroelectric *generation resource* with a shared *maximum daily energy limit* that was binding in the Pre-Dispatch Scheduling algorithm, in each hour, the *offer* laminations up to the sum of *energy* and *operating reserve* schedules calculated in Pre-Dispatch Scheduling algorithm for all *resources* in each set $s\in SHE$ will be eligible to set prices. For each set $s\in SHE$, if there exists $T\in TS_{tod}$ such that:

$$\sum_{t=2..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b+\sum_{k\in K_{t,b}^E}SDG_{t,b,k}^{PDS}\right)\right)$$

$$+\sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}}S10SDG_{T,b,k}^{PDS}+\sum_{k\in K_{T,b}^{10N}}S10NDG_{T,b,k}^{PDS}\right)\right.$$

$$\left.+30ORConv\left(\sum_{k\in K_{T,b}^{30R}}S30RDG_{T,b,k}^{PDS}\right)\right)=MaxSDEL_{tod,s}-EngyUsedSHE_s.$$

9.8.3.6.1 then the *maximum daily energy limit* constraint is considered to be binding for the current *dispatch day* in the Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints shall apply for all time-steps $t\in TS_{tod}$:

$$\sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right) \leq MaxSDEL_{tod,s} - EngyUsedSHE_s - \sum_{b\in B_s^{HE}}\sum_{\tau=2}^{t-1}\sum_{k\in K_{t,b}^{E}} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3.6.2 If the pre-dispatch look-ahead period spans two *dispatch days*, if there exists a time-step $T \in TS_{tom}$ such that:

$$\sum_{t=t_{tom}..T}\left(\sum_{b\in B_s^{HE}}\left(ODG_{t,b}^{PDS}\cdot MinQDGC_b + \sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}^{PDS}\right)\right) + \sum_{b\in B_s^{HE}}\left(10ORConv\left(\sum_{k\in K_{T,b}^{10S}} S10SDG_{T,b,k}^{PDS} + \sum_{k\in K_{T,b}^{10N}} S10NDG_{T,b,k}^{PDS}\right) + 30ORConv\left(\sum_{k\in K_{T,b}^{30R}} S30RDG_{T,b,k}^{PDS}\right)\right) = MaxSDEL_{tom,s},$$

9.8.3.6.3 then the *maximum daily energy limit* constraint is considered to be binding for the next *dispatch day* in the Pre-Dispatch Scheduling algorithm. In such circumstances, the following constraints shall apply for all time-steps $t \in TS_{tom}$:

$$\sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} \leq \sum_{b\in B_s^{HE}}\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k}^{PDS} + \epsilon,$$

$$\sum_{b\in B_s^{HE}}\left(\sum_{k\in K_{t,b}^{E}} SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10S}} S10SDG_{t,b,k} + \sum_{k\in K_{t,b}^{10N}} S10NDG_{t,b,k} + \sum_{k\in K_{t,b}^{30R}} S30RDG_{t,b,k}\right) \leq MaxSDEL_{tom,s} - \sum_{b\in B_s^{HE}}\sum_{\tau=tom}^{t-1}\sum_{k\in K_{t,b}^{E}} SDG_{\tau,b,k}^{PDS}.$$

where ϵ is a small positive constant.

9.8.3.7 For a *dispatchable* hydroelectric *generation resource* for which a *MWh ratio* was respected in the Pre-Dispatch Scheduling algorithm, such *resource* shall be scheduled between its Pre-Dispatch Scheduling algorithm schedule plus or minus a tolerance Δ specified by the *IESO*. The *resource* schedule shall be limited by its *offer* quantity bounds, in section 9.5.1, and any applicable *resource* minimum or maximum constraints, in section 9.5.2. For all linked downstream *dispatchable* hydroelectric *generation resources* b_2 such that $(b_1,b_2) \in LNKC$ where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$ and all time-steps $t \in TS$:

$$ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k}^{PDS} - \Delta \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k} \leq ODG_{t,b_2}^{PDS} \cdot MinQDGC_{b_2} + \sum_{k \in K_{t,b_2}^{E}} SDG_{t,b_2,k}^{PDS} + \Delta.$$

9.8.3.7.1 For all linked *dispatchable* hydroelectric *generation resources* b_1 such that $(b_1,b_2) \in LNKC$ where $b_1 \in B_{up}^{HE}$ and $b_2 \in B_{dn}^{HE}$ and all time-steps $t \in TS$ such that $t + LagC_{b_1,b_2} \leq n_{LAP}$:

$$ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k}^{PDS} - \Delta \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k} \leq ODG_{t,b_1}^{PDS} \cdot MinQDGC_{b_1} + \sum_{k \in K_{t,b_1}^{E}} SDG_{t,b_1,k}^{PDS} + \Delta.$$

9.9 Outputs

9.9.1 Outputs for the Pre-Dispatch Pricing algorithm include the following:

9.9.1.1 shadow prices;

9.9.1.2 *locational marginal prices* and their components; and

9.9.1.3 sensitivity factors.

10 Constrained Area Conditions Test

10.1 Purpose

10.1.1 The Constrained Area Conditions Test shall:

10.1.1.1 identify when and where competition is restricted; and

10.1.1.2 determine which *resources* shall have their *financial dispatch data parameters* be subject to the Conduct Test in section 11 and the thresholds above the *reference levels* that shall be used in the Conduct Test.

10.2 Information, Sets, Indices and Parameters

10.2.1 The *narrow constrained areas* and *dynamic constrained areas* and the information published therein in accordance with section 22 of Chapter 7 shall be inputs for the Constrained Area Conditions Test.

10.2.2 Information, sets, indices and parameters for the Constrained Area Conditions Test are described in sections 3 and 4. In addition, the following prices produced by the Pre-Dispatch Pricing algorithm shall be used by the Constrained Area Conditions Test:

10.2.2.1 $LMP_{t,b}^{PDP}$, which designates the *locational marginal price* for bus $b \in B$ in time-step $t \in TS$;

10.2.2.2 $PCong_{t,b}^{PDP}$, which designates the congestion component of the *locational marginal price* for bus $b \in B$ in time-step $t \in TS$;

10.2.2.3 $ExtLMP_{t,d}^{PDP}$, which designates the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.4 $PExtCong_{t,d}^{PDP}$, which designates the *intertie* congestion component of the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.5 $PIntCong_{t,d}^{PDP}$, which designates the internal congestion component of the *locational marginal price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.6 $IntLMP_{t,d}^{PDP}$, which designates the *intertie border price* for *intertie* bus $d \in D$ in time-step $t \in TS$;

10.2.2.7 $SPNormT_{t,f}^{PDP}$, which designates the shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in time-step $t \in TS$;

10.2.2.8 $SPEmT_{h,c,f}^{PDP}$, which designates the shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step $t \in TS$;

10.2.2.9 $SPNIUExtBwdT_{t}^{PDP}$, which designates the shadow price for the net *interchange schedule* limit constraint limiting increases in net imports between time-step $(t - 1)$ and time-step t;

10.2.2.10 $L30RP_{t,b}^{PDP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$;

10.2.2.11 $L10NP_{t,b}^{PDP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$; and

10.2.2.12 $L10SP_{t,b}^{PDP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$.

10.3 Variables

10.3.1 The *pre-dispatch calculation engine* shall use the constrained area conditions tests in sections 10.4 and 10.5 to identify the *resources* that are part of the following data sets:

10.3.1.1 $BCond_{t}^{NCA}$, which designates the *resources* in a *narrow constrained area* that must be checked for local market power for *energy* in time-step $t \in TS$;

10.3.1.2 $BCond_{t}^{DCA}$, which designates the *resources* in a *dynamic constrained area* that must be checked for local market power for *energy* in time-step $t \in TS$;

10.3.1.3 $BCond_{t}^{BCA}$, which designates the *resources* in a broad constrained area to be checked for local market power for *energy* in time-step $t \in TS$;

10.3.1.4 $BCond_{t}^{GMP}$, which designates the *resources* to be checked for global market power for *energy* in time-step $t \in TS$;

10.3.1.5 $BCond_t^{10S}$, which designates that *resources* to be checked for local market power for synchronized *ten-minute operating reserve* in time-step $t \in TS$;

10.3.1.6 $BCond_t^{10N}$, which designates that *resources* to be checked for local market power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$;

10.3.1.7 $BCond_t^{30R}$, which designates that *resources* to be checked for local market power for *thirty-minute operating reserve* in time-step $t \in TS$;

10.3.1.8 $BCond_t^{GMP10S}$, which designates that *resources* to be checked for global market power for synchronized *ten-minute operating reserve* in time-step $t \in TS$;

10.3.1.9 $BCond_t^{GMP10N}$, which designates that *resources* to be checked for global market power for non-synchronized *ten-minute operating reserve* in time-step $t \in TS$; and

10.3.1.10 $BCond_t^{GMP30R}$, which designates that *resources* to be checked for global market power for *thirty-minute operating reserve* in time-step $t \in TS$.

10.4 Constrained Area Conditions Test for Local Market Power (Energy)

10.4.1 Constrained Area Conditions Test for *narrow constrained areas* and *dynamic constrained area*

10.4.1.1 If at least one transmission constraint for a *narrow constrained area* or *dynamic constrained area* is binding in the Pre-Dispatch Pricing algorithm, then all *resources* identified within the *narrow constrained area* or *dynamic constrained area* shall undergo the applicable Conduct Test in section 11 and:

10.4.1.1.1 For each $n \in NCA$ and time-step $t \in TS$: For each transmission *facility* that transmits flow into n, $f \in F_n^{NCA}$, if $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{t,c,f}^{PDP} \neq 0$ for the inbound flow limit, the *pre-dispatch calculation engine* will place n in the set NCA_t' and assign the *resources* in n to the set $BCond_t^{NCA}$; and

10.4.1.1.2 For each $d \in DCA$ and time-step $t \in TS$: For each transmission *facility* that transmits flow into d, $f \in F_d^{DCA}$, if $SPNormT_{t,f}^{PDP} \neq 0$

or $SPEmT_{t,c,f}^{PDP} \neq 0$ for the inbound flow limit, the *pre-dispatch calculation engine* will place d in the set DCA_t' and assign the *resources* in n to the set $BCond_t^{DCA}$.

10.4.1.2 Each *narrow constrained area* and *dynamic constrained area* that meets the criteria in section 10.4.1.1 shall be assigned to one of the following subsets, as appropriate:

10.4.1.2.1 NCA_t', which designates the *narrow constrained areas* that qualify for market power mitigation for *energy* in time-step $t \in TS$; and

10.4.1.2.2 DCA_t', which designates the *dynamic constrained areas* that qualify for market power mitigation for *energy* in time-step $t \in TS$.

10.4.2 Constrained Area Conditions Test for the Broad Constrained Area

10.4.2.1 If the congestion component of the *locational marginal price* of a *resource* is greater than $BCACondThresh$ and the *resource* is not part of a *narrow constrained area* or *dynamic constrained area* that has a binding transmission constraint, then the *resource* shall be tested using the broad constrained area thresholds. For each time-step $t \in TS$ and bus $b \in B^{DG}$ such that $b \notin BCond_t^{NCA} \cup BCond_t^{DCA}$, if $PCong_{t,b}^{PDP} > BCACondThresh$, the *pre-dispatch calculation engine* will then place *resource* b in the set $BCond_t^{BCA}$.

10.5 Constrained Area Conditions Test for Global Market Power (Energy)

10.5.1 The *pre-dispatch calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, subject to section 10.5.2, if:

10.5.1.1 the *intertie border prices* at the *global market power reference intertie zones* are greater than the $IBPThresh$ threshold value, indicated in time-step $t \in TS$ by:

10.5.1.1.1 $IntLMP_{t,d}^{PDP} > IBPThresh$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zones*; and

10.5.1.2 at least one of the following conditions is met:

10.5.1.2.1 import congestion, represented by a negative *intertie* congestion component, is present on all of the *global market power reference intertie zones*, indicated in time-steps $t = \{2,3\}$ by:

10.5.1.2.1.1 $PExtCong_{t,d}^{PDP} < 0$ for *bids* and *offers*, $d \in D^{GMPRef}$, corresponding to the *boundary entity resource* bus for the *global market power reference intertie zone*; or

10.5.1.2.1 the net *interchange schedule* limit is binding for imports, represented by a non-zero net *interchange schedule* limit shadow price for incremental imports, indicated in time-steps $t = \{2,3\}$ by:

$$SPNIUExtBwdT_t^{PDP} \neq 0$$

10.5.2 If the conditions in sections 10.5.1 are met, then the *pre-dispatch calculation engine* shall test *resources* that can meet incremental load within Ontario for global market power, for each time-step $t \in TS$, place all $b \in B^{DG}$ in the set $BCond_t^{GMP}$, unless they are excluded because one of the following two conditions:

10.5.2.1 the *resources* in any zone have congestion components at least \$1/MWh below the internal congestion component at all of the *global market power reference intertie zones*:

10.5.2.1.1 if $PCong_{t,b}^{PDP} < PIntCong_{t,d}^{PDP} - \$1/MWh$ where $d \in D^{GMPRef}$ is true for all *global market power reference intertie zones*; or

10.5.2.2 the resources can not meet the incremental load because a binding transmission constraint:

10.5.2.2.1 if resources can not meet incremental load because of any binding transmission *facility* where $SPNormT_{t,f}^{PDP} \neq 0$ or $SPEmT_{t,c,f}^{PDP} \neq 0$.

10.6 Constrained Area Conditions Test for Local Market Power (Operating Reserve)

10.6.1 Subject to section 10.6.2, for a regional minimum requirement of greater than zero for a specific class of *operating reserve*, then all *resources* within the region with *offers* for classes of *operating reserve* that can satisfy the requirements of the specific class of *operating reserve* shall be tested for local market power:

10.6.1.1 if b is in a region with a non-zero minimum requirement, then b is subject to the Conduct Test and is placed in the set $BCond_t^{10S}$, $BCond_t^{10N}$, or $BCond_t^{30R}$

10.6.2 A *resource* shall not qualify for local market power mitigation testing for *operating reserve* if the *resource* is located in a region with a binding maximum constraint and for each *resource* $b \in B^{DG} \cup B^{DL}$ and time-step $t \in TS$:

10.6.2.1 if b is in a region with a binding maximum restriction constraint, then b is exempt from the Conduct Test.

10.7 Constrained Area Conditions Test for Global Market Power (Operating Reserve)

10.7.1 A *resource* shall be subject to global market power mitigation testing for *operating reserve* if its offers for a class of *operating reserve* where the *locational marginal price* for that class of *operating reserve* is greater than $ORGCondThresh$.

10.7.2 Subject to section 10.7.3, if the condition in section 10.7.1 has been met for a class of *operating reserve*, then all *resources* with offers for classes of *operating reserve* that can satisfy the requirements of that class of *operating reserve* shall be tested and for each $b \in B^{DG} \cup B^{DL}$ and time-step $t \in TS$:

10.7.2.1 if $L10SP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond_t^{GMP10S}$;

10.7.2.2 if $L10NP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond_t^{GMP10N}$; and

10.7.2.2 if $L30RP_{t,b}^{PDP} > ORGCondThresh$, the *pre-dispatch calculation engine* shall add *resource* b to $BCond_t^{GMP30R}$.

10.7.3 If a *resource* is located in a region with a binding regional maximum constraint, then the *resource* shall not qualify for global market power mitigation testing for *operating reserve*:

10.7.3.1 if b is in a region with a binding maximum constraint, then b shall be exempt from the Conduct Test.

10.8 Outputs

10.8.1 Outputs of the Constrained Area Conditions Test include the list of *resources* that will be subject to the Conduct Test in section 11 and the thresholds that will be used in the Conduct Test for those *resources*.

11 Conduct Test

11.1 Purpose

11.1.1 The Conduct Test shall verify whether the *financial dispatch data parameter* values submitted by *registered market participants* for *resources* identified in section 10.8.1 are within the applicable threshold level of the *reference level values* for those *resources*.

11.2 Information, Sets, Indices and Parameters

11.2.1 Information, sets, indices and parameters for the Conduct Test are described in sections 3 and 4. In addition, the list of *resources* produced pursuant to section 10.8.1 shall be used by the Conduct Test.

11.3 Variables

11.3.1 The *pre-dispatch calculation engine* shall apply the Conduct Test set out in sections 11.4 and 11.5 to the *resources* identified by the Constrained Area Conditions Test in accordance with section 10.8, to identify the following data sets:

11.3.1.1 The sets of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter*, where:

11.3.1.1.1 BCT_t^{NCA} designates the *resources* in a *narrow constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.2 BCT_t^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.3 BCT_t^{BCA} designates the *resources* in a broad constrained area that failed the Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.1.4 BCT_t^{GMP} designates the *resources* that failed the global market power for *energy* Conduct Test for at least one *financial dispatch data parameter* in time-step $t \in TS$;

11.3.1.5 BCT_t^{ORL} designates the *resources* that failed the local market power for *operating reserve* Conduct Test for at least one *dispatch data* parameter in time-step $t \in TS$; and

11.3.1.1.6 BCT_t^{ORG} designates the *resources* that failed the global market power Conduct Test for *operating reserve* for at least one *financial dispatch data parameter* in time-step $t \in TS$.

11.3.1.2 The following *financial dispatch data parameters* for all time-steps $t \in TS$:

11.3.1.2.1 $PARAME_{t,b}$, which designates the set of *dispatch data* parameters that failed the *energy* Conduct Test at bus $b \in \{BCT_t^{NCA} \cup BCT_t^{DCA} \cup BCT_t^{BCA} \cup BCT_t^{GMP}\}$ in time-step *t*, and may include the following *financial dispatch data parameters*:

11.3.1.2.1.1 $EnergyOffer_k$, which designates a non-zero quantity of *energy* above the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{E}$ failed the Conduct Test;

11.3.1.2.2 For all hours prior to and including the last hour where conditions are met for the *energy* Conduct Test:

11.3.1.2.2.1 $EnergyToMLP_k$, which designates the non-zero quantity of *energy* up to the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{LTMLP}$ failed the Conduct Test;

11.3.1.2.2.2 *SUOffer*, which designates the *start-up offer* failed the Conduct Test; and

11.3.1.2.2.3 *SNLOffer*, which designates the *speed no-load offer* failed the Conduct Test.

11.3.1.2.3 $PARAMOR_{t,b}$ designates the set of *financial dispatch data parameter* that failed the *operating reserve* Conduct Test for bus $b \in \{BCT_t^{ORL} \cup BCT_t^{ORG}\}$ in time-step t, and may include the following *financial dispatch data parameter*:

11.3.1.2.3.1 $OR10SOffer_k$, which designates the non-zero quantity of synchronized *ten-minute operating reserve* in association with *offer* lamination $k \in K_{t,b}^{10S}$ failed the Conduct Test;

11.3.1.2.3.2 $OR10NOffer_k$, which designates the non-zero quantity of non-synchronized *ten-minute operating reserve* in associciation with *offer* lamination $k \in K_{t,b}^{10N}$ failed the Conduct Test; and

11.3.1.2.3.3 $OR30ROffer_k$, which designates the non-zero quantity of *thirty-minute operating reserve* in association with *offer* lamination $k \in K_{t,b}^{30R}$ failed the Conduct Test;

11.3.1.2.4 For all hours prior to and including the last hour where conditions are met for the *operating reserve* Conduct Test:

11.3.1.2.4.1 *SUOffer*, which designates the *start-up offer* failed the Conduct Test;

11.3.1.2.4.2 *SNLOffer*, which designates the *speed no-load offer* failed the Conduct Test; and

11.3.1.2.4.3 $EnergyToMLP_k$, which designates the non-zero quantity of up to the *minimum loading point* in association with *offer* lamination $k \in K_{t,b}^{E}$ failed the Conduct Test.

11.4 Conduct Test for Energy

11.4.1 The *pre-dispatch calculation engine* shall perform the Conduct Test for *energy* for *resources* in a *narrow constrained area* that were identified pursuant to section 10.8.1 as follows, subject to sections 11.4.2 and 11.4.3. For each time-step $t \in TS$ and $b \in BCond_t^{NCA}$, the *pre-dispatch calculation engine* shall:

11.4.1.1 Evaluate energy offers above *minimum loading point*: For all $k \in K_{t,b}^{E}$, if $PDG_{t,b,k} > CTEnMinOffer$ and $PDG_{t,b,k} > min\,(PDGRef_{t,b,k'} * (1 + CTEnThresh1^{NCA}), PDGRef_{t,b,k'} + CTEnThresh2^{NCA})$, where $k' \in K_{t,b}^{\prime E}$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $EnergyOffer_k$ to $PARAME_{t,b}$;

11.4.1.2 Evaluate *offers* for *energy* for the range of production up to *minimum loading point*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, for all $k \in K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > min\ (PLTMLPRef_{t,b,k`} * (1 + CTEnThresh1^{NCA}), PLTMLPRef_{t,b,k`} + CTEnThresh2^{NCA}$, where $k' \in K_{t,b}^{'E}$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $EnergyToMLP_k$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$;

11.4.1.3 Evaluate *start-up offers*: For all time-steps prior to and including the last time-step t where conditions are met for the Constrained Area Conditions Test in section 10, if $SUDG_{t,b} > SUDGRef_{t,b} * (1 + CTSUThresh^{NCA})$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $SUOffer$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$; and

11.4.1.4 Evaluate *speed no-load offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SNL_{t,b} > SNLRef_{t,b} * (1 + CTSNLThresh^{NCA})$, then the Conduct Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{NCA} and add $SNLOffer$ to $PARAME_{t,b}$ and $PARAMOR_{t,b}$.

11.4.2 For *resources* identified pursuant to section 10.8.1 in a *dynamic constrained area* or broad constrained area, the *pre-dispatch calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond_t^{DCA}$ or $BCond_t^{BCA}$, as the case may be, in place of $BCond_t^{NCA}$ and using the applicable Conduct Test thresholds $CTEnThresh1^{DCA}$, $CTEnThresh2^{DCA}$, $CTEnThresh1^{BCA}$, $CTEnThresh2^{BCA}$, $CTSUThresh^{DCA}$, $CTSUThresh^{BCA}$, $CTSNLThresh^{DCA}$, $CTSNLThresh^{BCA}$. If any of the *financial dispatch data parameters* of *a resource* fail the Conduct Test, the *resource* shall be assigned to subset BCT_h^{DCA} or BCT_h^{BCA}, as the case may be.

11.4.3 For *resources* identified pursuant to section 10.8.1 that were selected for global market power mitigation testing for *energy*, the *pre-dispatch calculation engine* shall use the steps in section 11.4.1, using *resources* in $BCond_t^{GMP}$ in place of $BCond_t^{NCA}$ and the applicable global market power Conduct Test thresholds

$CTEnThresh1^{GMP}$, $CTEnThresh2^{GMP}$, $CTSUThresh^{GMP}$, $CTSNLThresh^{GMP}$. If any of the applicable *financial dispatch data parameters* of a *resource* fails the Conduct Test, the *resource* shall be assigned to subset BCT_h^{GMP}.

11.4.4 If a *resource* is assigned to more than one of the sets, $BCond_t^{NCA}$, $BCond_t^{DCA}$, $BCond_t^{BCA}$, and $BCond_t^{GMP}$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.5 Conduct Test for Operating Reserve

11.5.1 The *pre-dispatch calculation engine* shall perform the Conduct Test for local market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1, as follows, subject to 11.5.3. For each time-step $t \in TS$ and $b \in BCond_t^{10S} \cup BCond_t^{10N} \cup BCond_t^{30R}$, the pre-dispatch calculation engine shall:

11.5.1.1 Evaluate *offers* for *operating reserve* as follows:

11.5.1.1.1 for all $k \in K_{t,b}^{10S}$ such that $P10SDG_{t,b,k} > CTORMinOffer$ and $P10SDG_{t,b,k} > min\,(P10SDGRef_{t,b,k'}*(1 + CTORThresh1^{ORL}), P10SDGRef_{t,b,k'} + CTORThresh2^{ORL})$, where $k' \in K_{h,b}^{'10S}$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.2 such that $P10NDG_{t,b,k} > CTORMinOffer$ and $P10NDG_{t,b,k} > min\,(P10NDGRef_{t,b,k'}*(1 + CTORThresh1^{ORL}), P10NDGRef_{t,b,k'} + CTORThresh2^{ORL})$, where $k' \in K_{h,b}^{'10N}$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.3 for all $k \in K_{t,b}^{30R}$ such that $P30RDG_{t,b,k} > CTORMinOffer$ and $P30RDG_{t,b,k} > min\,(P30RDGRef_{t,b,k'}*(1 + CTORThresh1^{ORL}), P30RDGRef_{t,b,k'} + CTORThresh2^{ORL})$, where $k' \in K_{h,b}^{'30R}$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.4 for all $j \in J_{t,b}^{10S}$ if $P10SDL_{t,b,j} > CTORMinOffer$ and $P10SDL_{t,b,j} > min\,(P10SDLRef_{t,b,j'}*(1+CTORThresh1^{ORL}), P10SDLRef_{t,b,j'}+CTORThresh2^{ORL})$, where $j' \in J_{t,b}^{'10S}$, then the Conduct Test was failed for the *dispatchable load* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10SOffer_k$ to $PARAMOR_{t,b}$;

11.5.1.1.5 for all $j \in J_{t,b}^{10N}$ if $P10NDL_{t,b,j} > CTORMinOffer$ and $P10NDG_{t,b,j} > min\,(P10NDLRef_{t,b,j'}*(1+CTORThresh1^{ORL}), P10NDLRef_{t,b,j'}+CTORThresh2^{ORL})$, where $j' \in J_{t,b}^{'10N}$, then the Conduct Test was failed for the *dispatchable load* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR10NOffer_k$ to $PARAMOR_{t,b}$; and

11.5.1.1.6 for all $j \in J_{t,b}^{30R}$ if $P30RDL_{t,b,j} > CTORMinOffer$ and $P30RDL_{t,b,j} > min\,(P30RDLRef_{t,b,j'}*(1+CTORThresh1^{ORL}), P30RDLRef_{t,b,j'}+ CTORThresh2^{ORL}$, where $j' \in J_{t,b}^{'30R}$, then the Conduct Test was failed for the *dispatchable load* at bus *b* and the *day-ahead market calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $OR30ROffer_k$ to $PARAMOR_{t,b}$;

11.5.1.2 Evaluate *start-up offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SUDG_{t,b} > SUDGRef_{t,b} *(1 + CTSUThresh^{ORL})$, then the Conduct Test failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $SUOffer$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$;

11.5.1.3 Evaluate *speed no-load offers*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, if $SNL_{t,b} > SNLRef_{t,b} *(1 + CTSNLThresh^{ORL})$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $SNLOffer$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$; and

11.5.1.4 Evaluate *offers* for *energy* for the range of production up to the *minimum loading point*: For all time-steps prior to and including the last time-step where conditions are met for the Constrained Area Conditions Test, for all $k \in K_{t,b}^{LTMLP}$, if $PLTMLP_{t,b,k} > CTEnMinOffer$ and $PLTMLP_{t,b,k} > min\,(PLTMLPRef_{t,b,k`} * (1 + CTEnThresh1^{ORL}), PLTMLPRef_{t,b,k`} + CTEnThresh2^{ORL})$, where $k' \in K_{t,b}^{\prime E}$, then the Conduct Test was failed for the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BCT_t^{ORL} and add $EnergyToMLP_k$ to $PARAMOR_{t,b}$ and $PARAME_{t,b}$.

11.5.2 The *pre-dispatch calculation engine* shall perform the Conduct Test for global market power for *operating reserve* for *resources* that were identified pursuant to section 10.8.1. The *pre-dispatch calculation engine* shall use the steps set out in section 11.5.1 using *resources* in $BCond_t^{GMP10S}$, $BCond_t^{GMP10N}$, and $BCond_t^{GMP30R}$ in place of $BCond_t^{10S}$, $BCond_t^{10N}$, and $BCond_t^{30R}$, respectively, and the applicable Conduct Test thresholds ($CTORThresh1^{ORG}$, $CTORThresh2^{ORG}$, $CTSUThresh^{ORG}$, $CTSNLThresh^{ORG}$, $CTEnThresh1^{ORG}$, $CTEnThresh2^{ORG}$). The *resources* shall be assigned to the subset BCT_h^{ORG}.

11.5.3 If a *resource* is assigned to more than one of $BCond_t^{GMP10S}$, $BCond_t^{GMP10N}$, and $BCond_t^{GMP30R}$, only the Conduct Test with the most restrictive threshold levels shall be performed for that *resource*.

11.6 Outputs

11.6.1 Subject to section 11.6.2, the outputs of the Conduct Test shall include the following for each time-step $t \in TS$:

11.6.1.1 The set of *resources* that failed the Conduct Test for at least one *financial dispatch data parameter* by condition type;

11.6.1.2 The *financial dispatch data parameters* that failed the Conduct Test for the *resource* at bus *b*; and

11.6.1.3 A revised set of *financial dispatch data parameters* replaced with *reference level values* for *resources* that:

11.6.1.3.1 has one or more *financial dispatch data parameters* that failed a Conduct Test for the current *pre-dispatch calculation engine* run; and

11.6.13.2 has one or more *financial dispatch data parameter*s that failed both the Conduct Test and failed the Price Impact Test in previous *pre-dispatch calculation engine* runs.

11.6.1.4 For *offers* for *energy* and *operating reserve* with multiple laminations:

11.6.1.4.1 if the *offer* lamination for *energy* that corresponds to the *minimum loading point* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *energy* up to the *minimum loading point*;

11.6.1.4.2 if one or more offer laminations for *energy* above the *minimum loading point* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *energy* up to and above the *minimum loading point*; and

11.6.1.4.3 if one or more *offer* laminations for *operating reserve* fails the Conduct Test, the *pre-dispatch calculation engine* shall replace all *offer* laminations for *operating reserve.*

11.6.1.5 For a *non-quick start resource* whose *start-up offer* failed the Conduct Test, identified in section 11.6.1.1, the *pre-dispatch calculation engine* shall use the *start-up offer reference level value* to evaluate any advancements pursuant to section 5.7.

11.6.2 The pre-dispatch calculation engine shall not replace the financial dispatch data parameter for a resource with that resource's applicable reference level value if the financial dispatch data parameter is less than the corresponding reference level value.

12 Reference Level Scheduling

12.1 Purpose

12.1.1 The *pre-dispatch calculation engine* shall perform the Reference Level Scheduling algorithm where at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test in section 11.

12.1.2 The Reference Level Scheduling algorithm shall perform a *security*-constrained unit commitment and economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, including *reference level value* for *resources* subject to 14.7.1.3 and 12.2.2, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

12.2 Information, Sets, Indices and Parameters

12.2.1 Information, sets, indices and parameters used by the Reference Level Scheduling algorithm are described in section 3 and section 4. In addition, the list of *resources* that failed the Conduct Test from section 11.6.1.1 and a revised set of *financial dispatch data parameters* from section 11.6.1.3, for those *resources* shall be used by the Reference Level Scheduling algorithm

12.2.2 The Reference Level Scheduling algorithm shall use the *reference level value* that corresponds to any *financial dispatch data parameter* submitted for a *resource* that failed the Conduct Test.

12.3 Variables and Objective Function

12.3.1 The *pre-dispatch calculation engine* shall solve for the variables listed in section 8.3.1.

12.3.2 The objective function for the Reference Level Scheduling algorithm shall be the same as the objective function in section 8.3.2, subject to section 12.4.

12.4 Constraints

12.4.1 The constraints in sections 8.4 through 8.7 apply in the Reference Level Scheduling algorithm, except that the sensitivities and limits considered for IESO internal transmission limits shall be those provided by the most recent *security* assessment function iteration of the Reference Level Scheduling algorithm.

12.5 Outputs

12.5.1 Outputs of the Reference Level Scheduling algorithm include *resource* schedules and commitments.

13 Reference Level Pricing

13.1 Purpose

13.1.1 The *pre-dispatch calculation engine* shall perform the Reference Level Pricing algorithm whenever the Reference Level Scheduling algorithm has been performed.

13.1.2 The Reference Level Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants*, *reference level value* for *resources* subject to 14.7.1.3 and 13.2.2, and *resource* schedules and commitments produced by the Reference Level Scheduling algorithm, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each hour of the pre-dispatch look-ahead period.

13.2 Information, Sets, Indices and Parameters

13.2.1 Information, sets, indices and parameters used by the Reference Level Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedule and commitments from the Reference Level Scheduling algorithm shall be used by the Reference Level Pricing algorithm:

13.2.1.1 $SDG^{RLS}_{t,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled to provide above $MinQDGC_b$ at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K^{E}_{t,b}$;

13.2.1.2 $ODG^{RLS}_{t,b}$, which designates whether a *dispatchable generation resource* at bus $b \in B^{DG}$ was scheduled at or above its *minimum loading point* in time-step $t \in TS$;

13.2.1.3 $S10SDG^{RLS}_{t,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K^{10S}_{t,b}$;

13.2.1.4 $S10NDG^{RLS}_{t,b,k}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable* generation *resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K^{10N}_{t,b}$;

13.2.1.5 $S30RDG^{RLS}_{t,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable* generation *resource* is scheduled to provide at bus $b \in B^{ELR} \cup B^{HE}$ in time-step $t \in TS$ in association with lamination $k \in K^{30R}_{t,b}$; and

13.2.1.6 $OHO^{RLS}_{t,b}$, which designates whether the *dispatchable* hydroelectric *generation resource* at but $b \in B^{HE}$ has been scheduled at or above $MinHO_{t,b}$ in time-step $t \in TS$.

13.2.2 The Reference Level Pricing algorithm shall use *a resource's reference level value* for any *financial dispatch data parameters* submitted by *registered market participants* that failed the Conduct Test in Section 11.

13.3 Variables and Objective Function

13.3.1 The *pre-dispatch calculation engine* shall solve for the variables set out in section 9.3.1.

13.3.2 The objective function used in the Reference Level Pricing algorithm shall be the same as the objective function set out in section 9.3.2, subject to section 13.4.

13.4 Constraints

13.4.1 The constraints that apply in the Reference Level Pricing algorithm shall be the same as the constraints in sections 9.4 through 9.8, with the following exceptions:

13.4.1.1 the marginal loss factors used in the *energy* balance constraint in section 9.7.1 shall be fixed to the marginal loss factors used in the last optimization function iteration of the Reference Level Scheduling alogorithm;

13.4.1.2 the sensitivities and limits in section 9.7.3 shall be replaced with the most recent *security* assessment function iteration of the Reference Level Pricing algorithm; and

13.4.1.3 for the constraints in section 9.8, the outputs from the Pre-Dispatch Scheduling algorithm shall be replaced with the outputs from the Reference Level Scheduling algorithm as follows:

13.4.1.3.1 $SDG^{PDS}_{t,b,k}$ shall be replaced by $SDG^{RLS}_{t,b,k}$ for all $t \in TS$, $b \in B^{ELR} \cup B^{HE}$, $k \in K^{E}_{t,d}$;

13.4.1.3.2 $ODG^{PDS}_{t,b}$ shall be replaced by $ODG^{RLS}_{t,b}$ for all $t \in TS$, $b \in B^{DG}$;

13.4.1.3.3 $IDG^{PDS}_{t,b}$ shall be replaced by $IDG^{RLS}_{t,b}$ for all $t \in TS$, $b \in B^{DG}$;

13.4.1.3.4 $S10SDG^{PDS}_{t,b,k}$ shall be replaced by $S10SDG^{RLS}_{t,b,k}$ for all $t \in TS$, $b \in B^{ELR} \cup B^{HE}$, $k \in K^{10S}_{t,b}$;

13.4.1.3.5 $S10NDG^{PDS}_{t,b,k}$ shall be replaced by $S10NDG^{RLS}_{t,b,k}$ for all $t \in TS$, $b \in B^{ELR} \cup B^{HE}$, $k \in K^{10N}_{t,b}$;

13.4.1.3.1 $S30RDG^{PDS}_{t,b,k}$ shall be replaced by $S30RDG^{RLS}_{t,b,k}$ for all $t \in TS$, $b \in B^{ELR} \cup B^{HE}$, $k \in K^{30R}_{t,b}$; and

13.4.1.3.1 $OHO^{PDS}_{t,b}$ shall be replaced by $OHO^{RLS}_{t,b}$ for all $t \in TS$, $b \in B^{HE}$.

13.5 Outputs

13.5.1 Outputs of the Reference Level Pricing algorithm include the following:

13.5.1.1 shadow prices; and

13.5.1.2 *locational marginal prices* and their components.

14 Price Impact Test

14.1 Purpose

14.1.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test whenever at least one *financial dispatch data parameter* for a *resource* failed the Conduct Test.

14.1.2 The Price Impact Test shall:

14.1.2.1 compare the *locational marginal prices* for *energy* or *operating reserve* produced by the Pre-Dispatch Pricing algorithm with those produced by the Reference Level Pricing algorithm; and

14.1.2.2 consider the corresponding *offer* parameters to have failed the price impact test if the difference in price in section 14.1.2.1 is greater than the applicable impact threshold in section 4.3.9.

14.2 Information, Sets, Indices and Parameters

14.2.1 Information, sets, indices and parameters for the Price Impact Test are described in sections 3 and 4. In addition, the following *locational marginal prices* from the Pre-Dispatch Pricing algorithm and the Reference Level Pricing algorithm shall be used:

14.2.1.1 $LMP_{t,b}^{PDP}$, which designates the *locational marginal price* for *energy* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.2 $L30RP_{t,b}^{PDP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.3 $L10NP_{t,b}^{PDP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.4 $L10SP_{t,b}^{PDP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Pre-Dispatch Pricing algorithm;

14.2.1.5 $LMP_{t,b}^{RLP}$, which designates the *locational marginal price* for energy at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm;

14.2.1.6 $L30RP_{t,b}^{RLP}$, which designates the *locational marginal price* for *thirty-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm;

14.2.1.7 $L10NP_{t,b}^{RLP}$, which designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm; and

14.2.1.8 $L10SP_{t,b}^{RLP}$, which designates the *locational marginal price* for synchronized *ten-minute operating reserve* at bus $b \in B$ in time-step $t \in TS$ from the Reference Level Pricing algorithm.

14.3 Variables

14.3.1 The *pre-dispatch calculation engine* shall apply the Price Impact Test as set out in sections 14.4 and 14.5 for the *resources* identified in accordance with section 10.3.1, to identify:

14.3.1.1 A set of *resources* that failed the Price Impact Test for each condition for all time-steps $t \in TS$, where:

14.3.1.1.1 BIT_t^{NCA} designates the *resources* in a *narrow constrained area* that failed the Price Impact Test for the *locational marginal price* for *energy*;

14.3.1.1.2 BIT_t^{DCA} designates the *resources* in a *dynamic constrained area* that failed the Price Impact Test for *energy locational marginal price*;

14.3.1.1.3 BIT_t^{BCA} designates the *resources* in a broad constrained area that failed Price Impact Test for *energy locational marginal price*;

14.3.1.1.4 BIT_t^{GMP} designates the *resources* that failed the Global Market Power (*energy*) Price Impact Test for *energy locational marginal price*;

14.3.1.1.5 BIT_t^{ORL} designates the *resources* that failed the Local Market Power (*operating reserve*) Price Impact Test for at least one type of *operating reserve locational marginal price*;

14.3.1.1.6 BIT_t^{ORG} designates the *resources* that failed the Global Market Power (*operating reserve*) Price Impact Test for at least one type of *operating reserve locational marginal price*; and

14.3.1.1.7 $LMPIT_{t,b}$ designates the *locational marginal price* that failed the Price Impact Test for bus $b \in BIT_t^{NCA} \cup BIT_t^{DCA} \cup BIT_t^{BCA} \cup BIT_t^{GMP} \cup BIT_t^{ORL} \cup BIT_t^{ORG}$ in time-step $t \in TS$ and

14.3.1.2 *Locational marginal prices* for *energy* and *operating reserve* for each *resource* at bus $b \in B^{DG} \cup B^{DL}$ that failed the Price Impact Test, where:

14.3.1.2.1 *EnergyLMP* designates that the *locational marginal price* for *energy* failed the Price Impact Test;

14.3.1.2.2 $OR10SLMP$ designates that the synchronized *ten-minute operating reserve locational marginal price* failed the Price Impact Test;

14.3.1.2.3 $OR10NLMP$ designates that the non-synchronized *ten-minute operating reserve locational marginal price* failed the Price Impact Test; and

14.3.1.2.4 $OR30RLMP$ designates that the *thirty-minute operating reserve locational marginal price* failed the Price Impact Test.

14.4 Price Impact Test for Energy

14.4.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *energy* in section 11.6.1.1, as follows:

14.4.1.1 For local market power for *energy*:

14.4.1.1.1 For each time-step $t \in TS$ and $b \in BCT_t^{NCA}$, if $LMP_{t,b}^{PDP} > min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{NCA}), LMP_{t,b}^{RLP} + ITThresh2^{NCA})$, the Price Impact Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{NCA} and add $EnergyLMP$ to $LMPIT_{t,b}$;

14.4.1.1.2 For each time-step $t \in TS$ and $b \in BCT_t^{DCA}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{DCA}), LMP_{t,b}^{RLP} + ITThresh2^{DCA})$, the Price Impact Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{DCA} and add $EnergyLMP$ to $LMPIT_{t,b}$; and

14.4.1.1.3 For each time-step $t \in TS$ and $b \in BCT_t^{BCA}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{BCA}), LMP_{t,b}^{RLP} + ITThresh2^{BCA})$, the Price Impact Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{BCA} and add $EnergyLMP$ to $LMPIT_{t,b}$; and

14.4.1.2 For global market power for *energy*:

14.4.1.2.1 For each time-step $t \in TS$ and $b \in BCT_t^{GMP}$, if $LMP_{t,b}^{PDP} > Min(LMP_{t,b}^{RLP} * (1 + ITThresh1^{GMP}), LMP_{t,b}^{RLP} + ITThresh2^{GMP})$, the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{GMP} and add $EnergyLMP$ to $LMPIT_{t,b}$.

14.5 Price Impact Test for Operating Reserve

14.5.1 The *pre-dispatch calculation engine* shall perform the Price Impact Test for *resources* that were identified in the corresponding Conduct Test for *operating reserve* in section 11.6.1.1, as follows:

14.5.1.1 For local market power for *operating reserve*, for each time-step $t \in TS$ and $b \in BCT_t^{ORL}$:

14.5.1.1.1 If $L30RP_{t,b}^{PDP} > L30RP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR30RLMP$ to $LMPIT_{t,b}$;

14.5.1.1.2 If $L10NP_{t,b}^{PDP} > L10NP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR10NLMP$ to $LMPIT_{t,b}$; and

14.5.1.1.3 If $L10SP_{t,b}^{PDP} > L10SP_{t,b}^{RLP}$, then the Price Impact Test was failed by the *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORL} and add $OR10SLMP$ to $LMPIT_{t,b}$; and

14.5.1.2 For global market power for *operating reserve*, for each time-step $t \in TS$ and $b \in BCT_t^{ORG}$:

14.5.1.2.1 If $L30RP_{t,b}^{PDP} > min(L30RP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L30RP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by *resource* at bus *b* and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORG} and add $OR30RLMP$ to $LMPIT_{t,b}$;

14.5.1.2.2 If $L10NP_{t,b}^{PDP} > min(L10NP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L10NP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign the *resource* to subset BIT_t^{ORG} and add $OR10NLMP$ to $LMPIT_{t,b}$; and

14.5.1.2.3 If $L10SP_{t,b}^{PDP} > min(L10SP_{t,b}^{RLP} * (1 + ITThresh1^{ORG}), L10SP_{t,b}^{RLP} + ITThresh2^{ORG})$, then the Price Impact Test was failed by the *resource* at bus b and the *pre-dispatch calculation engine* shall assign *resource* to subset BIT_t^{ORG} and add $OR10SLMP$ to $LMPIT_{t,b}$.

14.6 Revised Financial Dispatch Data Parameter Determination

14.6.1 A *resource* that fails the Price Impact Test in a time-step (t) shall have its *financial dispatch data parameters* revised as follows:

14.6.1.1 If the *resource* has failed a Price Impact Test for *energy* and is in BIT_t^{NCA}, BIT_t^{DCA}, BIT_t^{BCA}, BIT_t^{GMP}, the *financial dispatch data parameters* in $PARAME_{t,b}$ shall be used to determine the *financial dispatch data parameters* that shall be replaced with the *resource's* applicable *reference level value.*

14.6.1.2 If the *resource* has failed a Price Impact Test for *operating reserve* and is in BIT_t^{ORL} or BIT_t^{ORG}, the *financial dispatch data parameters* in $PARAMOR_{t,b}$ shall be used to determine the *financial dispatch data parameters* that shall be replaced with the *resource's* applicable *reference level value.*

14.6.1.3 If a non-*quick-start resource* has failed a Price Impact Test in any time-step, the *commitment cost parameters* (*start-up offer*, *speed-no-load offer*, or *energy offer* associated with the *minimum loading point*) that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that time-step. For any time-steps prior, any *commitment cost parameters* for that *resource* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level value* in those time-steps. This is expressed as:

14.6.1.3.1 For each time-step $t \in TS$ and all $b \in B^{NQS} \cap (BIT_t^{NCA} \cup BIT_t^{DCA} \cup BIT_t^{BCA} \cup BIT_t^{GMP})$, for hours prior to and including the hour that failed the Price Impact Test, $T \in \{1,..,t\}$, if $b \in BCT_T^{NCA} \cup BCT_T^{DCA} \cup BCT_T^{BCA} \cup BCT_T^{GMP}$ and $PARAME_{T,b}$ contains any of the *commitment cost parameters* *SUOffer*, *SNLOffer*, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.6.1.4 Section 14.6.1.3 shall apply to the tests for local market power and global market power for *operating reserve*, except $PARAMOR_{T,b}$ shall be checked in place of $PARAME_{T,b}$.

14.6.1.5 If a *resource* is in a *narrow constrained area* or a *dynamic constrained area* and has failed a Price Impact Test, each *resource* in the same *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its *offer* data replaced with its applicable *reference level value* for that hour. For each time-step $t \in TS$:

14.6.1.5.1 if BIT_t^{NCA} includes one or more *resources* in a *narrow constrained area, n*, each *resource* $b \in BCT_t^{NCA}$ for *narrow constrained area, n*, shall have the parameters in $PARAME_{t,b}$ replaced with its *reference level values*; and

14.6.1.5.2 if BIT_t^{DCA} includes one or more *resources* in a *dynamic constrained area, d*, each *resource* $b \in BCT_t^{DCA}$ for *dynamic constrained area, d*, shall have the parameters in $PARAME_{t,b}$ replaced with its *reference level values*.

14.6.1.6 If a *non-quick-start resource* in a *narrow constrained area* or a *dynamic constrained area* has failed a Price Impact Test, each *non-quick-start resource* in the *narrow constrained area* or *dynamic constrained area* that also failed the corresponding Conduct Test shall have its commitment cost parameters replaced with its applicable *reference level value* for that time-step. For any time-steps prior, if a *non-quick-start resource* in that *narrow constrained area* or *dynamic constrained area* has a commitment cost parameter that failed the Conduct Test, that commitment cost parameter shall be replaced with the *resource's* applicable *reference level* value in those time-steps. This is expressed as:

14.6.1.6.1 For all time-steps up to the time-step in which a *resource* failed the Price Impact Test for a *narrow constrained area* , for all $b \in BCT_t^{NCA}$, if $PARAME_{t,b}$ contains any of the *commitment* *cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.6.1.6.2 For all time-stepsup to the time-step in which a *resource* failed the Price Impact Test for a *dynamic constrained area*, for all $b \in BCT_t^{DCA}$, if $PARAME_{t,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.6.1.7 If a *resource* fails the local market power for *operating reserve* Price Impact Test, all *resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test for at least one parameter shall have the parameter that failed the Conduct Test replaced with the *resource's* applicable *reference level value* for that hour. This is expressed as:

14.6.1.7.1 For each time-step $t \in TS$, if BIT_t^{ORL} includes one or more *resource* in *operating reserve* region, r, all *resources*, $b \in BIT_t^{ORL}$ for *operating reserve* region r, shall have the parameters in $PARAMOR_{t,b}$ replaced with *reference level values*.

14.6.1.8 If a *non-quick-start resource* fails the local market power for *operating reserve* Price Impact Test in any time-step, the *commitment cost parameters* for all *non-quick-start resources* in the same *operating reserve* region with a non-zero *operating reserve* minimum requirement that failed the corresponding Conduct Test shall be replaced with the *resource's* applicable *reference level value* for that time-step. For any time-steps prior, any *commitment cost parameters* of *non-quick-start resources* that failed the Conduct Test shall be replaced with the *resource's* applicable *reference level value* in those time-steps. This is expressed as:

14.6.1.8.1 For all time-steps up to the time-step in which a *resource* failed the Price Impact Test for r, for all $b \in BCT_t^{ORL}$, if $PARAME_{t,b}$ contains any of the *commitment cost parameters* $SUOffer$, $SNLOffer$, or $EnergyToMLP_k$, replace these parameters with *reference level values*.

14.7 Outputs

14.7 The *pre-dispatch calculation engine* shall prepare the following outputs, subject to section 14.7.2, for each time-step $t \in TS$:

14.7.1.1 The set of *resources* that failed the Price Impact Test for all time-steps in the pre-dispatch look ahead period, by condition, in acordance to sections 14.4 and 14.5. Those *resources* shall be added to the accumulated set of *resources* from previous *pre-dispatch calculation engine* runs which failed the Price Impact Test in the current time-step $t \in TS$;

14.7.1.2 The *locational marginal prices* for *energy* and *operating reserve* that failed the Price Impact Test for each *resource* at bus b in acordance to sections 14.4 and 14.5;

14.7.1.3 A revised set of *offer* data to be used by the next *pre-dispatch calculation engine* run and next real-time hour. The revised set of offer data will be for the *resources* that failed the Price Impact Test:

14.7.1.3.1 in current *pre-dispatch calculation engine* run replacing *offer* data that failed the Conduct Test with the applicable *reference level values*, in accordance with section 14.6; and

14.7.1.3.2 in previous *pre-dispatch calculation engine* runs with *financial dispatch data parameters* that were decided to be mitigated in previous *pre-dispatch calculation engine* runs replaced with *reference level values*.

14.7.2 The *pre-dispatch calculation engine* shall not replace *financial dispatch data parameters* from a *resource* with that *resource's* applicable *reference level value* if the *financial dispatch data parameters* is less than the *reference level value*.

15 Pseudo-Unit Modelling

15.1 Pseudo-Unit Model Parameters

15.1.1 The *pre-dispatch calculation engine* shall use the following registration and daily *dispatch data* to determine the underlying relationship between a *pseudo-unit* and the associated physical *resources* for a combined cycle *facility* with K combustion turbines and one steam turbine:

15.1.1.1 $CMCR_k$ designates the registered *maximum continuous rating* of combustion turbine $k \in \{1,..,K\}$ in MW;

15.1.1.2 $CMLP_k$ designates the *minimum loading point* of combustion turbine $k \in \{1,..,K\}$ in MW;

15.1.1.3 *SMCR* designates the registered *maximum continuous rating* of the steam turbine in MW;

15.1.1.4 *SMLP* designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

15.1.1.5 *SDF* designates the amount of duct firing capacity available on the steam turbine in MW;

15.1.1.6 $STPortion_k$ designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

15.1.1.7 $CSCM_k \in \{0,1\}$ designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in *single cycle mode*, subject to section 15.5.

15.1.2 The *pre-dispatch calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..K\}$:

15.1.2.1 $MMCR_k$ designates the maximum continuous rating of *pseudo-unit* k and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

15.1.2.2 $MMLP_k$ designates the *minimum loading point* of *pseudo-unit* k and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

15.1.2.3 MDF_k designates the duct firing capacity of *pseudo-unit* k and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

15.1.2.4 MDR_k designates the *dispatchable* capacity of *pseudo-unit* k and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

15.1.3 The *pre-dispatch calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

15.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

15.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and $MMLP_k + MDR_k$;

15.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

15.1.4 The *pre-dispatch calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

15.1.4.1 For the *minimum loading point* region:

15.1.4.1.1 Steam turbine share: $STShareMLP_k = \frac{SMLP \cdot (1\text{-}CSCM_k)}{MMLP_k}$;

15.1.4.1,2 Combustion turbine share: $CTShareMLP_k = \frac{CMLP_k}{MMLP_k}$; and

15.1.4.2 For the *dispatchable* region:

15.1.4.2.1 Steam turbine share:

$$STShareDR_k = \frac{(1\text{-}CSCM_k)(SMCR \cdot STPortion_k\text{-}SMLP\text{-}SDF \cdot STPortion_k)}{MDR_k}; \text{ and}$$

15.1.4.2.2 Combustion turbine share: $CTShareDR_k = \frac{CMCR_k\text{-}CMLP_k}{MDR_k}$; and

15.1.4.3 For the duct firing region:

15.1.4.3.1 Steam turbine share shall be equal to 1; and

15.1.4.3.2 Combustion turbine share shall be equal to 0.

15.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

15.2.1 The *pre-dispatch calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

15.2.1.1 $CTCap_{t,k}$ designates the capacity of combustion turbine $k \in \{1,..,K\}$ in time-step t as determined by submitted deratings;

15.2.1.2 $STCap_t$ designates the capacity of the steam turbine in time-step t as determined by submitted deratings; and

15.2.1.3 $TotalQ_{t,k}$ designates the total quantity of *energy* for *pseudo-unit* $k \in \{1,..,K\}$ in time-step t.

15.2.2 The *pre-dispatch calculation engine* shall solve for the following operating region parameters for each *pseudo-unit* $k \in \{1,..,K\}$:

15.2.2.1 $MLP_{t,k}$, which designates the *minimum loading point* of *pseudo-unit* k in time-step t;

15.2.2.2 $DR_{t,k}$, which designates the *dispatchable* region capacity of *pseudo-unit* k in time-step t; and

15.2.2.3 $DF_{t,k}$, which designates the duct firing region capacity of *pseudo-unit* k in time-step t.

15.2.3 Pre-Processing of De-rates

15.2.3.1 The *pre-dispatch calculation engine* shall perform the following pre-processing steps to determine the available operating regions for a *pseudo-unit* based on the combustion turbine and steam turbine share and the application of the *pseudo-unit* deratings. For *pseudo-unit* $k \in \{1,..,K\}$ for time-step $t \in TS$:

15.2.3.1.1 Step 1: Calculate the amount of *offered energy* attributed to each combustion turbine ($CTAmt_{t,k}$) and steam turbine portion ($STAmt_{t,k}$):

If $TotalQ_{t,k} < MMLP_k$ then:

Calculate $CTAmt_{t,k} = 0$; and

Calculate $STAmt_{t,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{t,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{t,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{t,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{t,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{t,k} = CTAmtMLP + CTAmtDR$; and

$STAmt_{t,k} = STAmtMLP + STAmtDR + STAmtDF$.

15.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$$PRSTCap_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}} \right) \cdot STCap_t$$

15.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{t,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $STAmt_{t,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{t,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $PRSTCap_{t,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

15.2.3.1.4 Step 4: Initialize the operating region parameters for time-step $t \in TS$ to the model parameter values:

Set $MLP_{t,k} = MMLP_k$.

Set $DR_{t,k} = MDR_k$.

Set $DF_{t,k} = MDF_k$.

15.2.3.1.5 Step 5: Apply the derating on the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k = CTCap_{t,k}$; and

Set $DR_{t,k} = min(DR_{t,k}, P \cdot MDR_k)$.

15.2.3.1.6 Step 6: Apply the derating on the steam turbine to the duct firing and *dispatchable* regions for *pseudo-units* not operating in *single-cycle mode*:

Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{t,k}$.

If $R \leq 1$, update $DF_{t,k} = 0$, and $DR_{t,k} = min(DR_{t,k}, R \cdot MDR_k)$.

If $R > 1$, update $DF_{t,k} = min(DF_{t,k}, PRSTCap_{t,k} - SMLP - STShareDR_k \cdot MDR_k)$.

15.2.4 Available Energy Laminations

15.2.4.1 The *pre-dispatch calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for time-step $t \in TS$ for each *pseudo-unit* $k \in \{1,..,K\}$, subject to section 15.2.4.2, where:

15.2.4.1.1 $QMLP_{t,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

15.2.4.1.2 $QDR_{t,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

15.2.4.1.3 $QDF_{t,k}$ designates the total quantity that may be scheduled in the duct firing region.

15.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$0 \leq QMLP_{t,k} \leq MLP_{t,k}$;

$0 \leq QDR_{t,k} \leq DR_{t,k}$;

$0 \leq QDF_{t,k} \leq DF_{t,k}$;

if $QMLP_{t,k} < MLP_{t,k}$, then the *pseudo-unit* is unavailable and $QDR_{t,k} = QDF_{t,k} = 0$; and

if $QDR_{t,k} < DR_{t,k}$, then $QDF_{t,k} = 0$.

15.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

15.3.1 The *pre-dispatch calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

15.3.1.1 $PSUMin^{q}_{t,k}$ designates the minimum limitation on *pseudo-unit* k determined by translating constraint *q*. When constraint *q* does not provide a minimum limitation on *pseudo-unit* *k*, then $PSUMin^{q}_{t,k}$ shall be set equal to 0;

15.3.1.2 $PSUMax^{q}_{t,k}$ designates the maximum limitation on *pseudo-unit* *k* determined by translating constraint *q*. When constraint *q* does not provide a maximum limitation on *pseudo-unit* k, then $PSUMax^{q}_{t,k}$ shall be set equal to $MLP_{t,k} + DR_{t,k} + DF_{t,k}$;

15.3.1.3 $CTCmtd_{t,k} \in \{0,1\}$ designates whether combustion turbine $k \in \{1,..K\}$ is considered committed in time-step $t \in TS$.

15.3.2 The *pre-dispatch calculation engine* shall calculate the minimum and maximum limitations, subject to section 15.3.3.1, as follows:

15.3.2.1 Minimum limitation: $MinDG_{t,k} = max_{q \in \{1,..Q\}} PSUMin^{q}_{t,k}$

15.3.2.2 Maximum limitation: $MaxDG_{t,k} = min_{q \in \{1,..Q\}} PSUMax^{q}_{t,k}$

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *pre-dispatch calculation engine*.

15.3.3 Pseudo-Unit Minimum and Maximum Constraints

15.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

15.3.3.1.1 $PSUMin_{t,k} = PMin$, where $PMin$ shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,...,K\}$ for time-step $t \in TS$; and

15.3.3.1.2 $PSUMax_{t,k} = PMax$, $PMax$ shall be a maximum constraint provided on *pseudo-unit* $k \in \{1,...,K\}$ for time-step $t \in TS$.

15.3.4 Combustion Turbine Minimum and Maximum Constraints

15.3.4.1 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMin < MLP_{t,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right);$$ and

$$STMinDR = 0.$$

Otherwise, if $CTMin \geq MLP_{t,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{t,k} \cdot STShareMLP_k;$$ and

$$STMinDR = \left(CTMin\text{-}MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

Therefore:

$$PSUMin_{t,k} = CTMin + STMinMLP + STMinDR.$$

15.3.4.2 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMin_{t,k} = CTMin.$$

15.3.4.3 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMax < MLP_{t,k} \cdot CTShareMLP_k$, then the *pseudo-unit* is unavailable (i.e. $PSUMax_{t,k} = 0$).

Otherwise, calculate the effect of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions:

$$STMaxMLP = MLP_{t,k} \cdot STShareMLP_k$$

$$STMaxDR = \left(CTMax\text{-}MLP_{t,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{t,k} = CTMax + STMaxMLP + STMaxDR$$

15.3.4.4 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMax_{t,k} = CTMax.$$

15.3.5 Steam Turbine Minimum and Maximum Constraints

15.3.5.1 The *pre-dispatch calculation engine* shall convert a stream turbine minimum constraint to a *pseudo-unit* constraints as follows:

15.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which designates the set of *pseudo-units* to which the constraint may be allocated where *pseudo-unit* $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k = 0$ and $CTCmtd_{t,k} = 1$. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

15.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity of *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{t,k} \cdot STShareMLP_k + QDR_{t,k} \cdot STShareDR_k + QDF_{t,k}.$$

15.3.5.1.3 Step 3: Allocate the $STMin$ constraint to each *pseudo-unit* $k \in A$, where $STMin$ constraint shall be allocated equally to each *pseudo-unit* $k \in A$ and and $STPMin_k$ is limited by $STCap_k$.

15.3.5.1.4 Step 4: The steam turbine portion minimum constraint shall be converted to a *pseudo-unit* constraint ,where for each *pseudo-unit* $k \in A$:

If $STPMin_k < MLP_{t,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = STPMin_k \cdot \left(\frac{CTShareMLP_k}{STShareMLP_k}\right); \text{ and}$$

$$CTMinDR_k = 0.$$

Otherwise, if $STPMin_k \geq MLP_{t,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = MLP_{t,k} \cdot CTShareMLP_k; \text{ and}$$

$$CTMinDR_k = \left(STPMin_k - MLP_{t,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right).$$

Therefore:

$$PSUMin_{t,k} = STPMin_k + CTMinMLP_k + CTMinDR_k.$$

15.3.5.2 If *pseudo-units* with sufficient steam turbine capacity are not commited, then the *pre-dispatch calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudo-unit* constraints.

15.3.5.3 The steam turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PRSTMax_{t,k} = \left(\frac{STAmt_{t,k}}{\sum_{w \in \{1,..,K\}} STAmt_{t,w}}\right) \cdot STMax.$$

15.3.5.3.1 If the converted steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{t,k} = 0.$$

15.3.5.3.2 Otherwise, calculate R so that SMLP + R·STShareDR$_k$·MDR$_k$ = PRSTMax$_{t,k}$:

If $R \leq 1$, set $PSUMax_{t,k} = MLP_{t,k} + min(DR_{t,k}, R \cdot MDR_k)$.

If $R > 1$, set $PSUMax_{t,k} = MLP_{t,k} + DR_{t,k} + PRSTMax_{t,k} - SMLP - STShareDR_k \cdot MDR_k$.

15.3.5.4 If the steam turbine minimum and maximum constraints are equal but do not convert to equal *pseudo-unit* minimum and maximum constraints, then the steam turbine minimum constraint conversion in section 15.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

15.4 Steam Turbine Forced Outages

15.4.1 If the steam turbine experiences a *forced outage*, the *pre-dispatch calculation engine* shall evaluate the corresponding *pseudo-units* as *resources* being offered in *single cycle mode.*

15.5 Single-Cycle Mode Flag Across Two Dispatch Days

15.5.1 If the pre-dispatch look-ahead period spans two *dispatch days* and the *single cycle mode* flag across the two *dispatch days* differs, then the *pre-dispatch calculation engine* shall apply the following:

15.5.1.1 If there are no future minimum constraints for the *pseudo-unit* before the end of the first *dispatch day* and if the *IESO's energy* management system indicates that the combustion turbine associated with the *pseudo-unit* is not online, then the *pre-dispatch calculation engine* shall use the *single cycle mode* flag of the second *dispatch day* for the entire pre-dispatch look-ahead period.

15.5.1.2 If there are no minimum *reliability* or commitment constraints on the *pseudo-unit* which cross into the next *dispatch day* and either there is a future minimum *reliability* or commitment constraint on the *pseudo-unit* that ends before the end of the first *dispatch day* or if the *IESO's energy* management system indicates that the combustion turbine associated with the *pseudo-unit* is online, then the *pre-dispatch calculation engine* shall:

15.5.1.2.1 use the *single cycle mode* flag of the first *dispatch day* for the pre-dispatch look-ahead period in the first *dispatch day* and use the *single cycle mode* flag of the second *dispatch* day for the pre-dispatch look-ahead period in the second *dispatch* day; and

15.5.1.2.2 schedule the *pseudo-unit* to 0 MW in the first hour of the second *dispatch day.*

15.5.1.3 If there is a minimum *reliability* or commitment constraint on the *pseudo-unit* that crosses into the next *dispatch day*, then *the pre-dispatch calculation engine* shall:

15.5.1.3.1 use the *single cycle mode* flag of the first *dispatch day* for the pre-dispatch look-ahead period in the first *dispatch day* and the beginning hours of the second *dispatch day* to meet such constraint;

15.5.1.3.2 use the *single cycle mode* flag of the second *dispatch day* for pre-dispatch look-ahead period in the second *disptch day* after such constraint for the *pseudo-unit* has completed; and

15.5.1.3.3 schedule the *pseudo-unit* to 0 MW in the first hour for which no *reliability* or commitment constraint applies in the second *dispatch day*.

15.6 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

15.6.1 For a combined cycle *facility* with K combustion turbines and one steam turbine, the *pre-dispatch calculation engine* shall compute the following *energy* and *operating reserve* schedules for time-step $t \in TS$:

15.6.1.1 $CTE_{t,k}$, which designates the *energy* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.2 $STPE_{t,k}$, which designates the *energy* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.3 STE_t, which designates the *energy* schedule for the steam turbine;

15.6.1.4 $CT10S_{t,k}$, which designates the synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.5 $STP10S_{t,k}$, which designates the synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.6 $ST10S_t$, which designates the synchronized *ten-minute operating reserve* schedule for the steam turbine;

15.6.1.7 $CT10N_{t,k}$, which designates the non-synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.8 $STP10N_{t,k}$, which designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

15.6.1.9 $ST10N_t$, which designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine;

15.6.1.10 $CT30R_{t,k}$, which designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

15.6.1.11 $STP30R_{t,k}$, which designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$; and

15.6.1.12 $ST30R_t$, which designates the *thirty-minute operating reserve* schedule for the steam turbine.

15.6.2 The *pre-dispatch calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo*-unit $k \in \{1,..,K\}$ in time-step $t \in TS$:

15.6.2.1 $SE_{t,k}$, which designates the total amount of *energy* scheduled and $SE_{t,k} = SEMLP_{t,k} + SEDR_{t,k} + SEDF_{t,k}$ where:

15.6.2.1.1 $SEMLP_{t,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \leq SEMLP_{t,k} \leq QMLP_{t,k}$;

15.6.2.1.2 $SEDR_{t,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \leq SEDR_{t,k} \leq QDR_{t,k}$ and $SEDR_{t,k} > 0$ only if $SEMLP_{t,k} = QMLP_{t,k}$;

15.6.2.1.3 $SEDF_{t,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \leq SEDF_{t,k} \leq QDF_{t,k}$ and $SEDF_{t,k} > 0$ only if $SEDR_{t,k} = QDR_{t,k}$;

15.6.2.2 $S10S_{t,k}$, which designates the total amount of synchronized *ten-minute operating reserve* scheduled;

15.6.2.3 $S10N_{t,k}$, which designates the total amount of non-synchronized *ten-minute operating reserve* scheduled. If the *pseudo-unit* cannot provide *operating reserve* from its duct firing region, then $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} \leq QMLP_{t,k} + QDR_{t,k}$; and

15.6.2.4 $S30R_{t,k}$, which designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{t,k} + S10S_{t,k} + S10N_{t,k} + S30R_{t,k} \leq QMLP_{t,k} + QDR_{t,k} + QDF_{t,k}$.

15.6.3 The *pre-dispatch calculation engine* shall convert *pseudo-unit* schedules to physical generation *resource* schedules for *energy* and *operating reserve*, as follows:

15.6.3.1 If $SE_{h,k} \geq MLP_{h,k}$, then:

$$CTE_{t,k} = SEMLP_{t,k} \cdot CTShareMLP_k + SEDR_{h,k} \cdot CTShareDR_k;$$

$$STPE_{t,k} = SEMLP_{t,k} \cdot STShareMLP_k + SEDR_{t,k} \cdot STShareDR_k + SEDF_{t,k};$$

$$RoomDR_{t,k} = QDR_{t,k} - SEDR_{t,k};$$

$$10SDR_{t,k} = min(RoomDR_{t,k}, S10S_{t,k});$$

$$10NDR_{t,k} = min(RoomDR_{t,k} - 10SDR_{t,k}, S10N_{t,k});$$

$$30RDR_{t,k} = min(RoomDR_{t,k} - 10SDR_{t,k} - 10NDR_{t,k}, S30R_{t,k});$$

$$CT10S_{t,k} = 10SDR_{t,k} \cdot CTShareDR_k;$$

$$STP10S_{t,k} = 10SDR_{t,k} \cdot STShareDR_k + (S10S_{t,k} - 10SDR_{t,k});$$

$$CT10N_{t,k} = 10NDR_{t,k} \cdot CTShareDR_k;$$

$$STP10N_{t,k} = 10NDR_{t,k} \cdot STShareDR_k + (S10N_{t,k} - 10NDR_{t,k});$$

$$CT30R_{t,k} = 30RDR_{t,k} \cdot CTShareDR_k; \text{ and}$$

$$STP30R_{t,k} = 30RDR_{t,k} \cdot STShareDR_k + (S30R_{t,k} - 30RDR_{t,k})$$

15.6.3.2 If $SE_{t,k} < MLP_{t,k}$ and is ramping to *minimum loading point*, then the conversion shall be determined by the *ramp up energy to minimum loading point*.

15.6.3.3 The steam turbines portion schedules from section 15.6.3.1 shall be summed to obtain the steam turbine schedule as follows:

$$STE_t = \sum_{k=1,..,K} STPE_{t,k};$$

$$ST10S_t = \sum_{k=1,..,K} STP10S_{t,k};$$

$$ST10N_t = \sum_{k=1,..,K} STP10N_{t,k}; \text{ and}$$

$$ST30R_t = \sum_{k=1,..,K} STP30R_{t,k}.$$

16 Pricing Formulas

16.1 Purpose

16.1.1 The *pre-dispatch calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

16.2 Sets, Indices and Parameters

16.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Pass 1 shall be used:

16.2.1.1 $SPEmT^1_{t,c,f}$, which designates the Pass 1 shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in time-step t;

16.2.1.2 $SPExtT^1_{t,z}$, which designates the Pass 1 shadow price for the import or export limit constraint $z \in Z_{Sch}$ in time-step t;

16.2.1.3 SPL^1_t, which designates the Pass 1 shadow price for the energy balance constraint in time-step t;

16.2.1.4 $SPNIUExtBwdT^1_t$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step $(t-1)$ and time-step t;

16.2.1.5 $SPNIDExtBwdT^1_t$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step $(t-1)$ and time-step t;

16.2.1.6 $SPNIUExtFwdT^1_t$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting increases in net imports between time-step t and time-step $(t+1)$;

16.2.1.7 $SPNIDExtFwdT_t^1$, which designates the Pass 1 shadow price for the net interchange scheduling limit constraint limiting decreases in net imports between time-step *t* and time-step $(t+1)$;

16.2.1.8 $SPNormT_{t,f}^1$, which designates the Pass 1 shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in time-step *t*;

16.2.1.9 $SP10S_t^1$, which designates the Pass 1 shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.10 $SP10R_t^1$, which designates the Pass 1 shadow price for the total *ten-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.11 $SP30R_t^1$, which designates the Pass 1 shadow price for the total *thirty-minute operating reserve* requirement constraint in time-step *t*;

16.2.1.12 $SPREGMin10R_{r,t}^1$, which designates the Pass 1 shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*;

16.2.1.13 $SPREGMin30R_{r,t}^1$, which designates the Pass 1 shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*;

16.2.1.14 $SPREGMax10R_{r,t}^1$, which designates the Pass 1 shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*; and

16.2.1.15 $SPREGMax30R_{r,t}^1$, which designates the Pass 1 shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in time-step *t*.

16.3 Locational Marginal Prices for Energy

16.3.1 Energy Locational Marginal Prices for Delivery Points

16.3.1.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each time-step $t \in TS$ for every bus $b \in L$ where a non-dispatchable or *dispatchable generation resource*, a *dispatchable load*, an *hourly demand response resource*, or a *non-dispatchable load* is sited and:

16.3.1.1.1 $LMP^{1}_{t,b}$ designates the Pass 1 time-step t *locational marginal price* for *energy*;

16.3.1.1.2 $PRef^{1}_{t}$ designates the Pass 1 time-step t *locational marginal price* for *energy* at the *reference bus*;

16.3.1.1.3 $PLoss^{1}_{t,b}$ designates the Pass 1 time-step t loss component; and

16.3.1.1.4 $PCong^{1}_{t,b}$ designates the Pass 1 time-step t congestion component.

16.3.1.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 at bus $b \in L$ in time-step $t \in TS$, as follows:

$$InitLMP^{1}_{t,b} = InitPRef^{1}_{t} + InitPLoss^{1}_{t,b} + InitPCong^{1}_{t,b}$$

where:

$$InitPRef^{1}_{t} = SPL^{1}_{t};$$

$$InitPLoss^{1}_{t,b} = MglLoss^{1}_{t,b} \cdot SPL^{1}_{t};$$

and

$$InitPCong^{1}_{t,b} = \sum_{f \in F_t} PreConSF_{t,f,b} \cdot SPNormT^{1}_{t,f} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,b} \cdot SPEmT^{1}_{t,c,f}.$$

16.3.1.3 If the initial *locational marginal price* for *energy* at the *reference bus* ($InitPRef^{1}_{t}$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for *energy* at the *reference bus* as follows:

If $InitPRef^{1}_{t} > EngyPrcCeil$, set $PRef^{1}_{t} = EngyPrcCeil$

If $InitPRef^{1}_{t} < EngyPrcFlr$, set $PRef^{1}_{t} = EngyPrcFlr$

Otherwise, set $PRef^{1}_{t} = InitPRef^{1}_{t}$

16.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP^{1}_{t,b}$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *pre-*

dispatch calculation engine shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP^1_{t,b} > EngyPrcCeil$, set $LMP^1_{t,b} = EngyPrcCeil$

If $InitLMP^1_{t,b} < EngyPrcFlr$, set $LMP^1_{t,b} = EngyPrcFlr$

Otherwise, set $LMP^1_{t,b} = InitLMP^1_{t,b}$

16.3.1.5 The *pre-dispatch calculation engine* shall modify the loss component as follows:

If $PRef^1_t \neq InitPRef^1_t$, set $PLoss^1_{t,b} = MglLoss^1_{t,b} \cdot PRef^1_t$

Otherwise, set $PLoss^1_{t,b} = InitPLoss^1_{t,b}$

16.3.1.6 The *pre-dispatch calculation engine* shall modify the congestion component as follows:

If $LMP^1_{t,b}$ -$PRef^1_t$ -$PLoss^1_{t,b}$ and $InitPCong^1_{t,b}$ have the same mathematical sign, then set $PCong^1_{t,b} = LMP^1_{t,b}$ -$PRef^1_t$ -$PLoss^1_{t,b}$

Otherwise, set $PCong^1_{t,b} = 0$ and set $PLoss^1_{t,b} = LMP^1_{t,b}$-$PRef^1_t$

16.3.2 Energy Locational Marginal Prices for Intertie Metering Points

16.3.2.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each time-step $t \in TS$ for *intertie zone* bus $d \in D$, where:

16.3.2.1.1 $ExtLMP^1_{t,d}$ designates the Pass 1 time-step t *locational marginal price* for *energy*;

16.3.2.1.2 $IntLMP^1_{t,d}$ designates the Pass 1 time-step t *intertie border price* for *energy*;

16.3.2.1.3 $ICP^1_{t,d}$ designates the Pass 1 time-step t *intertie congestion price*;

16.3.2.1.4 $PRef^1_t$ designates the Pass 1 time-step t *locational marginal price* for *energy* at the *reference bus*;

16.3.2.1.5 $PLoss^{1}_{t,d}$ designates the Pass 1 time-step t loss component;

16.3.2.1.6 $PIntCong^{1}_{t,d}$ designates the Pass 1 time-step t internal congestion component for *energy;*

16.3.2.1.7 $PExtCong^{1}_{t,d}$ designates the Pass 1 time-step t external congestion component for the *intertie congestion price*; and

16.3.2.1.8 $PNISL^{1}_{t,d}$ designates the Pass 1 time-step t net interchange scheduling limit congestion component for the *intertie congestion price.*

16.3.2.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss components and a congestion components for *energy* for Pass 1 at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in time-step t, subject to sections 16.3.2.8 and 16.3.2.9, as follows:

$$InitExtLMP^{1}_{t,d} = InitIntLMP^{1}_{t,d} + InitICP^{1}_{t,d}$$

where:

$$InitPRef^{1}_{t} = SPL^{1}_{t};$$

$$InitPLoss^{1}_{t,d} = MglLoss^{1}_{t,d} \cdot SPL^{1}_{t};$$

$$InitPIntCong^{1}_{t,d} = \sum_{f \in F_t} PreConSF_{t,f,d} \cdot SPNormT^{1}_{t,f} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,d} \cdot SPEmT^{1}_{t,c,f};$$

$$InitIntLMP^{1}_{t,d} = InitPRef^{1}_{t} + InitPLoss^{1}_{t,d} + InitPIntCong^{1}_{t,d};$$

$$InitPExtCong^{1}_{t,d} = \sum_{z \in Z_{sch}} EnCoeff_{a,z} \cdot SPExtT^{1}_{t,z};$$

and

$$InitPNISL^{1}_{t,d} = SPNIUExtBwdT^{1}_{t} - SPNIUExtFwdT^{1}_{t} - SPNIDExtBwdT^{1}_{t} + SPNIDExtFwdT^{1}_{t};$$

$$InitICP^{1}_{t,d} = InitPExtCong^{1}_{t,d} + InitPNISL^{1}_{t,d}$$

16.3.2.3 If the initial *locational marginal price* for *energy* ($InitExtLMP^{1}_{t,d}$) is not within the *settlement* bounds (*EngyPrcFlr, EngyPrcCeil*), then the *pre-*

dispatch calculation engine shall modify the *intertie border price* for *energy*, and its components, as follows:

16.3.2.3.1 The initial *locational marginal price* for the *reference bus* ($InitPRef_t^1$) shall be modified as per section 16.3.1.3;

16.3.2.3.2 The initial *intertie border price* ($InitIntLMP_{t,d}^1$) shall be modified as per section 16.3.1.4, where $InitLMP_{t,b}^1 = InitIntLMP_{t,d}^1$;

16.3.2.3.3 The initial loss component ($InitPLoss_{t,d}^1$) shall be modified as per section 16.3.1.5; and

16.3.2.3.4 The initial internal congestion component ($InitPIntCong_{t,d}^1$) shall be modified as per section 16.3.1.6, where $InitPCong_{t,b}^1 = InitPIntCong_{t,d}^1$.

16.3.2.4 If the initial *locational marginal price* for *energy* ($InitExtLMP_{t,d}^1$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $InitExtLMP_{t,d}^1 > EngyPrcCeil$, set $ExtLMP_{t,d}^1 = EngyPrcCeil$

If $InitExtLMP_{t,d}^1 < EngyPrcFlr$, set $ExtLMP_{t,d}^1 = EngyPrcFlr$

Otherwise, set $ExtLMP_{t,d}^1 = InitExtLMP_{t,d}^1$

16.3.2.5 If the modified *locational marginal price* for *energy* ($ExtLMP_{t,d}^1$) is equal to the *intertie border price* for *energy* ($IntLMP_{t,d}^1$), then the *pre-dispatch calculation engine* shall modify the external congestion component for the *intertie* congestion price and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{t,d}^1 = IntLMP_{t,d}^1$, set $PExtCong_{t,d}^1 = 0$ and $PNISL_{t,d}^1 = 0$

16.3.2.6 If the modified *locational marginal price* for *energy* ($ExtLMP_{t,d}^1$) is not equal to the *intertie border price* for *energy* ($IntLMP_{t,d}^1$), then the *pre-dispatch calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP^{1}_{t,d} \neq IntLMP^{1}_{t,d}$, set

$$PNISL^{1}_{t,d} = (ExtLMP^{1}_{t,d} - IntLMP^{1}_{t,d}) \cdot \left(\frac{InitPNISL^{1}_{h,d}}{InitPNISL^{1}_{t,d} + InitPExtCong^{1}_{t,d}} \right).$$

If $PNISL^{1}_{t,d} > NISLPen$, set $PNISL^{1}_{t,d} = NISLPen$

If $PNISL^{1}_{t,d} < (-1) \cdot NISLPen$, set $PNISL^{1}_{t,d} = (-1) \cdot NISLPen$

Then $PExtCong^{1}_{t,d} = ExtLMP^{1}_{t,d} - IntLMP^{1}_{t,d} - PNISL^{1}_{t,d}$

16.3.2.7 The *pre-dispatch calculation engine* shall calculate the *intertie* congestion price as follows:

$$ICP^{1}_{t,d} = PExtCong^{1}_{t,d} + PNISL^{1}_{t,d}$$

16.3.2.8 The *locational marginal price* for *energy* calculated by the *pre-dispatch calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. *Intertie* transactions associated with the same *boundary entity resource* bus, but specified as occurring at different *intertie zones*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these transactions shall utilize shadow prices associated with the internal transmission constraints, *intertie* limits and transmission losses applicable to the path associated to the relevant *intertie* zone.

16.3.2.9 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all import and export *boundary entity resources* for that *intertie zone* will receive a zero schedule and the *locational marginal price* for *energy* shall be set to the *intertie border price* for *energy*.

16.3.3 Zonal Prices for Energy

16.3.3.1 The *pre-dispatch calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each time-step t for each *virtual transaction zone* $m \in M$, as follows:

$$VZonalP_{t,m}^{1} = PRef_{t}^{1} + VZonalPLoss_{t,m}^{1} + VZonalPCong_{t,m}^{1}$$

where

$$VZonalPLoss_{t,m}^{1} = \sum_{b \in L_{m}^{VIRT}} WF_{t,m,b}^{VIRT} \cdot PLoss_{t,b}^{1}$$

and

$$VZonalPCong_{t,m}^{1} = \sum_{b \in L_{m}^{VIRT}} WF_{t,m,b}^{VIRT} \cdot PCong_{t,b}^{1}$$

16.3.3.2 The *pre-dispatch calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each time-step t for each *non-dispatchable load* zone $y \in Y$, as follows:

$$ZonalP_{t,y}^{1} = PRef_{t}^{1} + ZonalPLoss_{t,y}^{1} + ZonalPCong_{t,y}^{1}$$

where:

$$ZonalPLoss_{t,y}^{1} = \sum_{b \in L_{y}^{NDL}} WF_{t,y,b}^{NDL} \cdot PLoss_{t,b}^{1}$$

and

$$ZonalPCong_{t,y}^{1} = \sum_{b \in L_{y}^{NDL}} WF_{t,y,b}^{NDL} \cdot PCong_{t,b}^{1}$$

16.3.3.3 The *Ontario zonal price* is calculated per section 16.3.3.2 where the *non-dispatchable load* zone is comprised of all *non-dispatchable loads* within Ontario.

16.3.4 Pseudo-Unit Pricing

16.3.4.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each time-step *t* for every *pseudo-unit* $k \in \{1,..,K\}$, where:

16.3.4.1.1 $CTMglLoss^{1}_{t,k}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit* k for time-step t in Pass 1;

16.3.4.1.2 $STMglLoss^{p}_{t,k}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit* k for time-step t in Pass 1;

16.3.4.1.3 $CTPreConSF_{t,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during time-step t under pre-contingency conditions;

16.3.4.1.4 $STPreConSF_{t,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during time-step t under pre-contingency conditions;

16.3.4.1.5 $CTSF_{t,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during time-step t under post-contingency conditions for contingency c; and

16.3.4.1.6 $STSF_{t,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during time-step t under post-contingency conditions for contingency c.

16.3.4.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 and each time-step t for every *pseudo-unit* $k \in \{1,..,K\}$, as follows:

$$InitLMP^{1}_{t,k} = InitPRef^{1}_{t} + InitPLoss^{1}_{t,k} + InitPCong^{1}_{t,k}$$

where:

$$InitPRef^{1}_{t} = SPL^{1}_{t};$$

$$InitPLoss^{1}_{t,k} = MglLoss^{1}_{t,k} \cdot SPL^{1}_{t};$$

and

$$InitPCong^{1}_{t,k} = \sum_{f \in F_t} PreConSF_{t,f,k} \cdot SPNormT^{1}_{t,f} + \sum_{c \in C} \sum_{f \in F_{t,c}} SF_{t,c,f,k} \cdot SPEmT^{1}_{t,c,f}$$

16.3.4.3 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *minimum loading point range* or not scheduled at all, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = CTShareMLP_k \cdot CTMglLoss^{1}_{t,k} + STShareMLP_k \cdot STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = CTShareMLP_k \cdot CTPreConSF_{t,f,k} + STShareMLP_k \cdot STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = CTShareMLP_k \cdot CTSF_{t,c,f,k} + STShareMLP_k \cdot STSF_{t,c,f,k}$$

16.3.4.4 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = CTShareDR_k \cdot CTMglLoss^{1}_{t,k} + STShareDR_k \cdot STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = CTShareDR_k \cdot CTPreConSF_{t,f,k} + STShareDR_k \cdot STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = CTShareDR_k \cdot CTSF_{t,c,f,k} + STShareDR_k \cdot STSF_{t,c,f,k}$$

16.3.4.5 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss^{1}_{t,k} = STMglLoss^{1}_{t,k}$$

$$PreConSF_{t,f,k} = STPreConSF_{t,f,k}$$

$$SF_{t,c,f,k} = STSF_{t,c,f,k}$$

16.4 Locational Marginal Prices for Operating Reserve

16.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

16.4.1.1 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for Pass 1 and each time-step t for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus b ∈ B, where:

16.4.1.1.1 $L30RP^{1}_{t,b}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve*;

16.4.1.1.2 $P30RRef_t^1$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

16.4.1.1.3 $P30RCong_{t,b}^1$ designates the Pass 1 time-step t congestion component for *thirty-minute operating reserve*;

16.4.1.1.4 $L10NP_{t,b}^1$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve*;

16.4.1.1.5 $P10NRef_t^1$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.1.6 $P10NCong_{t,b}^1$ designates the Pass 1 time-step t congestion component for non-synchronized *ten-minute operating reserve*;

16.4.1.1.7 $L10SP_{t,b}^1$ designates the Pass 1 time-step t *locational marginal price* for synchronized *ten-minute operating reserve*;

16.4.1.1.8 $P10SRef_t^1$ designates the Pass 1 time-step t *locational marginal prices* for synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.1.9 $P10SCong_{t,b}^1$ designates the Pass 1 time-step t congestion component for synchronized *ten-minute operating reserve*; and

16.4.1.1.10 $ORREG_b \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus b.

16.4.1.2 The *pre-dispatch calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass 1 for a *delivery point* associated with the *dispatchable generation resource* and *dispatchable load* at bus b ∈ B in time-step t ∈ TS, for each class of *operating reserve*, as follows:

$$InitL30RP_{t,b}^1 = InitP30RRef_t^1 + InitP30RCong_{t,b}^1$$

where

$$InitP30RRef_t^1 = SP30R_t^1$$

and

$$InitP30RCong_{t,b}^{1} = \sum_{r \in ORREG_b} SPREGMin30R_{t,r}^{1} - \sum_{r \in ORREG_b} SPREGMax30R_{t,r}^{1}$$

$$InitL10NP_{t,b}^{1} = InitP10NRef_t^1 + InitP10NCong_{t,b}^{1}$$

where

$$InitP10NRef_t^1 = SP10R_t^1 + SP30R_t^1$$

and

$$InitP10NCong_{t,b}^{1} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{r,t}^{1} + SPREGMin30R_{r,t}^{1}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{r,t}^{1} + SPREGMax30R_{r,t}^{1}\right)$$

$$InitL10SP_{t,b}^{1} = InitP10SRef_t^1 + InitP10SCong_{t,b}^{1}$$

where

$$InitP10SRef_t^1 = SP10S_t^1 + SP10R_t^1 + SP30R_t^1$$

and

$$InitP10SCong_{t,b}^{1} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{r,t}^{1} + SPREGMin30R_{r,t}^{1}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{r,t}^{1} + SPREGMax30R_{r,t}^{1}\right)$$

16.4.1.3 If the initial *locational marginal price* at the *reference bus* ($InitP30RRef_t^1$, $InitP10NRef_t^1$, or $InitP10SRef_t^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* at the *reference bus* for each class of *operating reserve* as follows:

If $InitP30RRef_t^1 > ORPrcCeil$, set $P30RRef_t^1 = ORPrcCeil$;

If $InitP30RRef_t^1 < ORPrcFlr$, set $P30RRef_t^1 = ORPrcFlr$;

Otherwise, set $P30RRef_t^1 = InitP30RRef_t^1$.

If $InitP10NRef_t^1 > ORPrcCeil$, set $P10NRef_t^1 = ORPrcCeil$

If $InitP10NRef_t^1 < ORPrcFlr$, set $P10NRef_t^1 = ORPrcFlr$

Otherwise, set $P10NRef_t^1 = InitP10NRef_t^1$

If $InitP10SRef_t^1, ORPrcFlr > ORPrcCeil$, set $10SRef_t^1 = ORPrcCeil$

If $InitP10SRef_t^1, ORPrcFlr < ORPrcFlr$, set $10SRef_t^1 = ORPrcFlr$

Otherwise, set $10SRef_t^1 = InitP10SRef_t^1$

16.4.1.4 If the initial *locational marginal price* ($InitL30RP_{t,b}^1$, $InitL10NP_{t,b}^1$, or $InitL10SP_{t,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{t,b}^1 > ORPrcCeil$, set $L30RP_{t,b}^1 = ORPrcCeil$;

If $InitL30RP_{t,b}^1 < ORPrcFlr$, set $L30RP_{t,b}^1 = ORPrcFlr$;

Otherwise, set $L30RP_{t,b}^1 = InitL30RP_{t,b}^1$.

If $InitL10NP_{t,b}^1 > ORPrcCeil$, set $L10NP_{t,b}^1 = ORPrcCeil$;

If $InitL10NP_{t,b}^1 < ORPrcFlr$, set $L10NP_{t,b}^1 = ORPrcFlr$;

Otherwise, set $L10NP_{t,b}^1 = InitL10NP_{t,b}^1$.

If $InitL10SP_{t,b}^1 > ORPrcCeil$, set $L10SP_{t,b}^1 = ORPrcCeil$;

If $InitL10SP_{t,b}^1 < ORPrcFlr$, set $L10SP_{t,b}^1 = ORPrcFlr$;

Otherwise, set $L10SP_{t,b}^1 = InitL10SP_{t,b}^1$.

16.4.1.5 If the initial *locational marginal price* ($InitL30RP^{1}_{t,b}$, $InitL10NP^{1}_{t,b}$, or $InitL10SP^{1}_{t,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the congestion component for each class of *operating reserve* as follows:

Set $P30RCong^{1}_{t,b} = L30RP^{1}_{t,b} - P30RRef^{1}_{t}$;

Set $P10NCong^{1}_{t,b} = L10NP^{1}_{t,b} - P10NRef^{1}_{t}$; and

Set $P10SCong^{1}_{t,b} = L10SP^{1}_{t,b} - P10SRef^{1}_{t}$.

16.4.1.6 Operating Reserve Locational Marginal Prices for Intertie Metering Points

16.4.1.7 The *pre-dispatch calculation engine* shall calculate a *locational marginal price* and components for *operating reserve* for Pass 1 and each time-step t ∈ TS for *intertie zone* bus d ∈ D, where:

16.4.1.7.1 $ExtL30RP^{1}_{t,d}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve*;

16.4.1.7.2 $P30RRef^{1}_{t}$ designates the Pass 1 time-step t *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

16.4.1.7.3 $P30RIntCong^{1}_{t,d}$ designates the Pass 1 time-step t internal congestion component *for thirty-minute operating reserve*;

16.4.1.7.4 $P30RExtCong^{1}_{t,d}$ designates the Pass 1 time-step t *intertie* congestion component *thirty-minute operating reserve*;

16.4.1.7.5 $ExtL10NP^{1}_{t,d}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve*;

16.4.1.7.6 $P10NRef^{1}_{t}$ designates the Pass 1 time-step t *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

16.4.1.7.7 $P10NIntCong^1_{t,d}$ designates the Pass 1 time-step t internal congestion component for non-synchronized *ten-minute operating reserve*;

16.4.1.7.8 $P10NExtCong^1_{t,d}$ designates the Pass 1 time-step t external congestion component for non-synchronized *ten-minute operating reserve*; and

16.4.1.7.9 $ORREG_d \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus d.

16.4.1.8 The *pre-dispatch calculation engine* shall calculate initial *locational marginal price*, *locational marginal price* at the *reference bus*, internal congestion component and external congestion component for Pass 1 at *intertie zone bus* $d \in D_a$ in *intertie zone* $a \in A$ in time-step $t \in TS$, for each class of *operating reserve*, subject to sections 16.4.1.11 and 16.4.1.12, as follows:

$$InitExtL30RP^1_{t,d} = InitP30RRef^1_t + InitP30RIntCong^1_{t,d} + InitP30RExtCong^1_{t,d}$$

where:

$$InitP30RRef^1_t = SP30R^1_t;$$

$$InitP30RIntCong^1_{t,d} = \sum_{r \in ORREG_d} SPREGMin30R^1_{t,r} - \sum_{r \in ORREG_d} SPREGMax30R^1_{t,r};$$

and

$$InitP30RExtCong^1_{t,d} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT^1_{t,z}.$$

$$InitExtL10NP^1_{t,d} = InitP10NRef^1_t + InitP10NIntCong^1_{t,d} + InitP10NExtCong^1_{t,d}$$

where:

$$InitP10NRef^1_t = SP10R^1_t + SP30R^1_t;$$

$$InitP10NIntCong^1_{t,d} = \sum_{r \in ORREG_d}(SPREGMin10R^1_{r,t} + SPREGMin30R^1_{r,t}) - \sum_{r \in ORREG_d}(SPREGMax10R^1_{r,t} + SPREGMax30R^1_{r,t});$$

and

$$InitP10NExtCong^1_{t,d} = -\sum_{z \in Z_{Sch}} 0.5 \cdot (EnCoeff_{a,z} + 1) \cdot SPExtT^1_{t,z}$$

-

16.4.1.9 If the initial *locational marginal price* ($InitExtL30RP^1_{t,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the external congestion component for *thirty-minute operating reserve* as follows:

$$IntL30R = InitP30RRef^1_t + InitP30RIntCong^1_{t,d};$$

If $InitP30RRef^1_t > ORPrcCeil$, set $P30RRef^1_t = ORPrcCeil$;

If $InitP30RRef^1_t < ORPrcFlr$, set $P30RRef^1_t = ORPrcFlr$;

Otherwise, set $P30RRef^1_t = InitP30RRef^1_t$;

Set $P30RIntCong^1_{t,d} = ExtL30RP^1_{t,b} - P30RRef^1_t$;

If $InitExtL30RP^1_{t,b} > ORPrcCeil$, set $ExtL30RP^1_{t,b} = ORPrcCeil$;

If $InitExtL30RP^1_{t,b} < ORPrcFlr$, set $ExtL30RP^1_{t,b} = ORPrcFlr$;

Otherwise, $ExtL30RP^1_{t,b} = InitExtL30RP^1_{t,b}$; and

Set $P30RExtCong^1_{t,d} = ExtL30RP^1_{t,b} - P30RRef^1_t - P30RIntCong^1_{t,d}$

16.4.1.10 If the initial *locational marginal price* ($InitExtL10NP^1_{t,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *pre-dispatch calculation engine* shall modify the initial *locational marginal price*, *locational marginal price* at the *reference bus*, and the external congestion component for *ten-minute operating reserve* as follows:

$$IntL10N = InitP10NRef^1_t + InitP10NIntCong^1_{t,d};$$

If $InitP10NRef^1_t > ORPrcCeil$, set $P10NRef^1_t = ORPrcCeil$;

If $InitP10NRef_t^1 < ORPrcFlr$, set $P10NRef_t^1 = ORPrcFlr$;

Otherwise, $P10NRef_t^1 = InitP10NRef_t^1$; and

Set $P10NIntCong_{t,d}^1 = L10NP_{t,b}^1 - P10NRef_t^1$;

If $InitExtL10NP_{t,b}^1 > ORPrcCeil$, set $ExtL10NP_{t,b}^1 = ORPrcCeil$;

If $InitExtL10NP_{t,b}^1 < ORPrcFlr$, set $ExtL10NP_{t,b}^1 = ORPrcFlr$;

Otherwise, $ExtL30RP_{t,b}^1 = InitExtL10NP_{t,b}^1$; and

Set $P10NExtCong_{t,d}^1 = ExtL10NP_{t,b}^1 - P10NRef_t^1 - P10NIntCong_{t,d}^1$

16.4.1.11 The *locational marginal price* calculated by the *pre-dispatch calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. Reserve imports associated with the same *boundary entity resource* bus, but specified as ocurring at a different *intertie zone*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these reserve imports shall utilize shadow prices associated with *intertie* limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

16.4.1.12 When an *intertie zone* is out-of-service, the *intertie* limits for that *intertie zone* will be set to zero and all *boundary entity resources* for that *intertie zone* will receive a zero schedule for *energy* and *operating reserve* and the *intertie operating reserve* prices shall be set equal to the *locational marginal price* for the *reference bus* for that class of *operating reserve* plus the applicable shadow prices associated with regional minimum and maximum *operating reserve* requirements.

16.5 Pricing for Islanded Nodes

16.5.1 For *non-quick start resources* that are not connected to the *main island*, the *pre-dispatch calculation engine* may use the following reconnection logic where enabled by the *IESO* in the order set out below to calculate the *locational marginal prices* for *energy*:

16.5.1.1 Determine the connection paths over open switches that connect the *non-quick start resource* to the *main island*;

16.5.1.2 Determine the priority rating for each connection path identified based on a weighted sum of the base voltage over all open switches used by the reconnection path and the MW ratings of the newly connected branches; and

16.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

16.5.2 For all (i) *resources* other than those specified in section 16.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 16.5.1; the *pre-dispatch calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices* for *energy*, using a node-level and *facility*-level substitution list determined by the *IESO*:

16.5.2.1 Use the *locational marginal price* for *energy* at a node in the node-level substitution list where defined and enabled by the *IESO*, provided such node is connected to the *main island*;

16.5.2.2 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes at the same voltage level within the same *facility* that are connected to the *main island*;

16.5.2.3 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes within the same *facility* that are connected to the *main island*;

16.5.2.4 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes from another *facility* that is connected to the *main island*, as determined by the *facility*-level substitution list where defined and enabled by the *IESO*; and

16.5.2.5 If a price is unable to be determined in accordance with sections 16.5.2.2 through 16.5.2.4, use the *locational marginal price* for *energy* for the *reference bus*.

Appendix 7.6A – The Real-Time Calculation Engine Process

1.1 Purpose

1.1.1 This appendix describes the process used by the *real-time calculation engine* to determine schedules and prices for the *real-time market* and real-time look-ahead period.

2 Real-Time Calculation Engine

2.1 Real-Time Look-Ahead Period

2.11 The real-time look-ahead period is the time horizon of the multi-interval optimization that includes the *dispatch interval* and the subsequent ten five-minute intervals.

2.2 Real-Time Calculation Engine Pass

2.2.1 The *real-time calculation engine* shall execute one pass, Pass 1, the Real-Time Scheduling and Pricing Pass in accordance with section 7, to produce *real-time schedules* and *locational marginal prices*.

3 Information Used by the Real-Time Calculation Engine

3.1.1 The *real-time calculation engine* shall use the information in section 3A.1 of Chapter 7.

4 Sets, Indices and Parameters Used by the Real-Time Calculation Engine

4.1 Fundamental Sets and Indices

4.1.1 A designates the set of all *intertie zones*;

4.1.2 B designates the set of buses identifying all *dispatchable* and non-*dispatchable resources* within Ontario;

4.1.3 $B^{DG} \subseteq B$ designates the set of buses identifying *dispatchable generation resources*;

4.1.4 $B^{DL} \subseteq B$ designates the set of buses identifying *dispatchable loads*;

4.1.5 $B^{HDR} \subseteq B$ designates the set of buses identifying *hourly demand response resources*;

4.1.6 $B^{HE} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable* hydroelectric *generation resources*;

4.1.7 $B^{NDG} \subseteq B$ designates the set of buses identifying *non-dispatchable generation resources*;

4.1.8 $B^{NoBid} \subseteq B$ designates the set of buses identifying *dispatchable loads* with no *bid* for *energy*;

4.1.9 $B^{NoOffer} \subseteq B$ designates the set of buses identifying *generation resources* with no *offer* for *energy*;

4.1.10 $B^{NO10DF} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* that cannot provide *ten-minute operating reserve* from the duct firing region;

4.1.11 $B^{NQS} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable non-quick start resources*;

4.1.12 $B^{PSU} \subseteq B^{NQS}$ designates the subset of buses identifying *pseudo-units*;

4.1.13 $B_r^{REG} \subseteq B$ designates the set of internal buses in *operating reserve* region $r \in ORREG$;

4.1.14 $B_p^{ST} \subseteq B^{PSU}$ designates the subset of buses identifying *pseudo-units* with a share of steam turbine $p \in PST$;

4.1.15 $B^{VG} \subseteq B^{DG}$ designates the subset of buses identifying *dispatchable variable generation resources*;

4.1.16 C designates the set of contingencies that shall be considered in the *security* assessment function;

4.1.17 D designates the set of buses outside Ontario, corresponding to imports and exports at *intertie zones*;

4.1.18 $D_r^{REG} \subseteq D$ designates the set of *intertie zone* buses identifying *boundary entity resources* in *operating reserve* region $r \in ORREG$;

4.1.19 $D_a \subseteq D$ designates the set of all buses identifying *boundary entity resources* in *intertie zone* $a \in A$;

4.1.20 $DI \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers*;

4.1.21 $DI_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to import *offers* in *intertie zone* $a \in A$;

4.1.22 $DX \subseteq D$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids*;

4.1.23 $DX_a \subseteq D_a$ designates the subset of *intertie zone* buses identifying *boundary entity resources* that correspond to export *bids* in *intertie zone* $a \in A$;

4.1.24 F designates the set of *facilities* and groups of *facilities* for which transmission constraints may be identified;

4.1.25 $F_i \subseteq F$ designates the set of *facilities* whose pre-contingency limit was violated in interval i as determined by a preceding *security* assessment function iteration;

4.1.26 $F_{i,c} \subseteq F$ designates the set of *facilities* whose post-contingency limit for contingency c is violated in interval i as determined by a preceding *security* assessment function iteration;

4.1.27 $I = \{1,..,n_I\}$ designates the set of all intervals, where n_I designates the number of five-minute intervals considered within the real-time look-ahead period;

4.1.28 $J_{i,b}^E$ designates the set of *bid* laminations for *energy* at $b \in B^{DL}$ for interval $i \in I$;

4.1.29 $J_{i,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DL}$ for interval $i \in I$;

4.1.30 $J_{i,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B^{DL}$ for interval $i \in I$;

4.1.31 $J_{i,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus $b \in B^{DL}$ for interval $i \in I$;

4.1.32 $K_{i,b}^{DF} \subseteq K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$;

4.1.33 $K_{i,b}^{DR} \subseteq K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$;

4.1.34 $K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* at $b \in B^{NDG} \cup B^{DG}$ for interval $i \in I$;

4.1.35 $K_{i,b}^{MLP} \subseteq K_{i,b}^{E}$ designates the set of *offer* laminations for *energy* corresponding to the *minimum loading point* region of a *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$;

4.1.36 $K_{i,b}^{10S}$ designates the set of *offer* laminations for synchronized *ten-minute operating reserve* at bus $b \in B^{DG}$ for interval $i \in I$;

4.1.37 $K_{i,b}^{10N}$ designates the set of *offer* laminations for non-synchronized *ten-minute operating reserve* at bus $b \in B^{DG}$ for interval $i \in I$;

4.1.38 $K_{i,b}^{30R}$ designates the set of *offer* laminations for *thirty-minute operating reserve* at bus $b \in B^{DG}$ for interval $i \in I$;

4.1.39 L designates the set of buses where the *locational marginal prices* represent prices for *delivery points* associated with non-*dispatchable* and *dispatchable generation resources*, *dispatchable loads*, *hourly demand response resources*, *price responsive loads* and *non-dispatchable loads;*

4.1.40 $L_m^{VIRT} \subseteq L$ designates the buses contributing to the *virtual zonal price* for *virtual transaction zone* $m \in M$;

4.1.41 $L_y^{NDL} \subseteq L$ designates the buses contributing to the zonal price for *non-dispatchable load* zone $y \in Y$;

4.1.42 M designates the set of *virtual transaction zones*;

4.1.43 PST designates the set of steam turbines *offered* as part of a *pseudo-unit*;

4.1.44 Y designates the *non-dispatchable load* zones in Ontario.

4.2 Market Participant Data Parameters

4.2.1 With respect to a non-dispatchable generation resource identified by bus $b \in B^{NDG}$:

4.2.1.1 $FNDG_{i,b}$ designates the fixed quantity of *energy* scheduled for interval $i \in I$;

4.2.1.2 $PNDG_{i,b,k}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$; and

4.2.1.3 $QNDG_{i,b,k}$ designates the maximum incremental quantity of *energy* that may be scheduled in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$.

4.2.2 With respect to a *dispatchable generation resource* identified by bus $b \in B^{DG}$:

4.2.2.1 $DRRDG_{i,b,w}$ for $w \in \{1,...,NumRRDG_{i,b}\}$ designates the ramp rate in MW per minute at which the *resource* can decrease the amount of *energy* it supplies in interval $i \in I$ while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$;

4.2.2.2 $NumRRDG_{i,b}$ designates the number of ramp rates provided for interval $i \in I$;

4.2.2.3 $ORRDG_{b}$ designates the maximum *operating reserve* ramp rate in MW per minute;

4.2.2.4 $PDG_{i,b,k}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *offer* lamination $k \in K^{E}_{i,b}$;

4.2.2.5 $P10SDG_{i,b,k}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K^{10S}_{i,b}$;

4.2.2.6 $P10NDG_{i,b,k}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10N}$;

4.2.2.7 $P30RDG_{i,b,k}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{30R}$;

4.2.2.8 $QDG_{i,b,k}$ designates the maximum incremental quantity of *energy* above the *minimum loading point* that may be scheduled in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{E}$;

4.2.2.9 $Q10SDG_{i,b,k}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10S}$;

4.2.2.10 $Q10NDG_{i,b,k}$ designates the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{10N}$;

4.2.2.11 $Q30RDG_{i,b,k}$ designates the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $k \in K_{i,b}^{30R}$;

4.2.2.12 $RLP30R_{i,b}$ designates the *reserve loading point* for *thirty-minute operating reserve* in interval $i \in I$;

4.2.2.13 $RLP10S_{i,b}$ designates the *reserve loading point* for synchronized *ten-minute operating reserve* in interval $i \in I$;

4.2.2.14 $RmpRngMaxDG_{i,b,w}$ for $w \in \{1,..,NumRRDG_{i,b}\}$ designates the w^th ramp rate break point for interval $i \in I$;

4.2.2.15 $URRDG_{i,b,w}$ for $w \in \{1,..,NumRRDG_{i,b}\}$ designates the ramp rate in MW per minute at which the *resource* can increase the amount of *energy* it supplies in interval $i \in I$ while operating in the range between $RmpRngMaxDG_{i,b,w-1}$ and $RmpRngMaxDG_{i,b,w}$, where $RmpRngMaxDG_{i,b,0}$ shall be equal to zero.

4.2.3 With respect to a *dispatchable non-quick start resource* identified by bus $b \in B^{NQS}$:

4.2.3.1 $MinQDG_b$ designates the *minimum loading point* indicating the minimum output at which the *resource* must be scheduled except for times when the *resource* is starting up or shutting down.

4.2.4 With respect to a *dispatchable* hydroelectric *generation resource* identified by bus $b \in B^{HE}$:

4.2.4.1 -($ForL_{i,b,w}$,$ForU_{i,b,w}$) for $w \in \{1,..,NFor_{i,b}\}$ designate the lower and upper limits of the *forbidden regions* in interval $i \in I$ and indicate that the *resource* cannot be scheduled between $ForL_{i,b,w}$ and $ForU_{i,b,w}$ for all $w \in \{1,..,NFor_{i,b}\}$.

4.2.5 With respect to a *pseudo-unit* identified by bus $b \in B^{PSU}$:

4.2.5.1 $STShareMLP_b$ designates the steam turbine share of the *minimum loading point* region; and

4.2.5.2 $STShareDR_b$ designates the steam turbine share of the *dispatchable* region.

4.2.6 With respect to a *generation resource* with no *offer* for *energy* identified by bus $b \in B^{NoOffer}$:

4.2.6.1 $FNOG_{i,b}$ designates the fixed quantity of *energy* scheduled for injection for interval $i \in I$ determined by the *IESO*'s *energy* management system.

4.2.7 With respect to a *dispatchable load* identified by bus $b \in B^{DL}$:

4.2.7.1 $DRRDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can decrease its amount of *energy* consumption in interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$;

4.2.7.2 $NumRRDL_{i,b}$ designates the number of ramp rates provided for interval $i \in I$;

4.2.7.3 $ORRDL_b$ designates the *operating reserve* ramp rate in MW per minute for reductions in load consumption;

4.2.7.4 $PDL_{i,b,j}$ designates the price for the maximum incremental quantity of *energy* in interval $i \in I$ in association with *bid* lamination $j \in J^E_{i,b}$;

4.2.7.5 $P10NDL_{i,b,j}$ designates the price for the maximum incremental quantity of non-synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

4.2.7.6 $P10SDL_{i,b,j}$ designates the price for the maximum incremental quantity of synchronized *ten-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

4.2.7.7 $P30RDL_{i,b,j}$ designates the price for the maximum incremental quantity of *thirty-minute operating reserve* in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

4.2.7.8 $QDL_{i,b,j}$ designates the maximum incremental quantity of *energy* that may be scheduled in interval $i \in I$ in association with *bid* lamination $j \in J_{i,b}^{E}$;

4.2.7.9 $QDLFIRM_{i,b}$ designates the quantity of *energy* that is *bid* at the *maximum market clearing price* in interval $i \in I$;

4.2.7.10 $Q10NDL_{i,b,j}$ designates the maximum incremental quanity of non-synchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10N}$;

4.2.7.11 $Q10SDL_{i,b,j}$ designates the maximum incremental quantity of synchronized *ten-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{10S}$;

4.2.7.12 $Q30RDL_{i,b,j}$ designates the maximum incremental quantity of *thirty-minute operating reserve* that may be scheduled in interval $i \in I$ in association with *offer* lamination $j \in J_{i,b}^{30R}$;

4.2.7.13 $RmpRngMaxDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the w[th] ramp rate break point for interval $i \in I$;

4.2.7.14 $URRDL_{i,b,w}$ for $w \in \{1,..,NumRRDL_{i,b}\}$ designates the ramp rate in MW per minute at which the *dispatchable load* can increase its amount of *energy* consumption in interval $i \in I$ while operating in the range between $RmpRngMaxDL_{i,b,w-1}$ and $RmpRngMaxDL_{i,b,w}$, where $RmpRngMaxDL_{i,b,0}$ shall be equal to zero.

4.2.8 With respect to an *hourly demand response resource* identified by bus $b \in B^{HDR}$:

4.2.8.1 $FHDR_{i,b}$ designates the fixed schedule of *energy* consumption for interval $i \in I$ determined by the activation of the *hourly demand response resource*.

4.2.9 With respect to a *dispatchable load* with no *bid* for *energy* at bus $b \in B^{NoBid}$:

4.2.9.1 $FNBL_{i,b}$ designates the fixed quantity of *energy* scheduled for consumption for interval $i \in I$ determined by the *IESO*'s *energy management system.*

.4.2.10 With respect to a *boundary entity resource* import at *intertie zone* bus $d \in DI$, where the *locational marginal price* represents the price for the *intertie metering point* and its fixed schedules are the most recent *interchange schedules*:

4.2.10.1 $FIGPrc_{i,d}$ designates the fixed quantity of *energy* scheduled to import for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.10.2 $FIGSch_{i,d}$ designates the fixed quantity of *energy* scheduled to import for interval $i \in I$ and used for determining schedules;

4.2.10.3 $F10NIGPrc_{i,d}$ designates the fixed quantity of non-synchronized *ten-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational market prices*;

4.2.10.4 $F10NIGSch_{i,d}$ designates the fixed quantity of non-synchronized *ten-minute operating reserve* scheduled for in interval $i \in I$ and used for determining schedules;

4.2.10.5 $F30RIGPrc_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*; and

4.2.10.6 $F30RIGSch_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules.

4.2.11 With respect to a *boundary entity resource* export at *intertie zone* bus $d \in DX$, where the *locational marginal price* represents the price for the *intertie metering point* and its fixed schedules are the most recent *interchange schedules*:

4.2.11.1 $FXLPrc_{i,d}$ designates the fixed quantity of *energy* scheduled to export for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.11.2 $FXLSch_{i,d}$ designates the fixed quantity of *energy* scheduled to export for interval $i \in I$ and used for determining schedules;

4.2.11.3 $F10NXLPrc_{i,d}$ designates the fixed quantity of non-synchronized *ten-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*;

4.2.11.4 $F10NXLSch_{i,d}$ designates the fixed quantity of non-synchronized *ten-minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules;

4.2.11.5 $F30RXLPrc_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for calculating *locational marginal prices*; and

4.2.11.6 $F30RXLSch_{i,d}$ designates the fixed quantity of *thirty-minute operating reserve* scheduled for interval $i \in I$ and used for determining schedules.

4.3 IESO Data Parameters

4.3.1 Variable Generation Forecast

4.3.1.1 $FG_{i,b}$ designates the *IESO's* centralized *variable generation* forecast for a *variable generation resource* identified by bus $b \in B^{VG}$ for interval $i \in I$.

4.3.2 Variable Generation Tie-Breaking

4.3.2.1 $NumVG_i$ designates the number of *variable generation resources* in the daily *dispatch* order for interval $i \in I$; and

4.3.2.2 $TBM_{i,b} \in \{1,..,NumVG_i\}$ designates the tie-breaking modifier for the *variable generation resource* at bus $b \in B^{VG}$ for interval $i \in I$.

4.3.3 Operating Reserve Requirements

4.3.3.1 $ORREG$ designates the set of regions for which regional *operating reserve* limits have been defined;

4.3.3.2 $REGMin10R_{i,r}$ designates the minimum requirement for total *ten-minute operating reserve* in region $r \in ORREG$ in interval $i \in I$;

4.3.3.3 $REGMin30R_{i,r}$ designates the minimum requirement for *thirty-minute operating reserve* in region $r \in ORREG$ in interval $i \in I$;

4.3.3.4 $REGMax10R_{i,r}$ designates the maximum amount of total *ten-minute operating reserve* that may be scheduled in region $r \in ORREG$ in interval $i \in I$;

4.3.3.5 $REGMax30R_{i,r}$ designates the maximum amount of *thirty-minute operating reserve* that may be scheduled in region $r \in ORREG$ in interval $i \in I$;

4.3.3.6 $TOT10S_i$ designates the synchronized *ten-minute operating reserve* requirement;

4.3.3.7 $TOT10R_i$ designates the total *ten-minute operating reserve* requirement; and

4.3.3.8 $TOT30R_i$ designates the *thirty-minute operating reserve* requirement.

4.3.4 Resource Minimums and Maximums

4.3.4.1 Where applicable the minimum or maximum output of a *dispatchable generation resource* and minimum or maximum consumption of a *dispatchable load* may be limited due to *reliability* constraints, applicable *contracted ancillary services*, day-ahead operational commitments, pre-dispatch operational commitments, *outages,* derates, *operating reserve* activation, and other constraints, such that:

4.3.4.1.1 $MaxDF_{i,b}$ designates the maximum output limit in interval i for the duct firing region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.4.1.2 $MaxDG_{i,b}$ designates the most restrictive maximum output limit for the *dispatchable generation resource* in interval i at bus $b \in B^{DG}$;

4.3.4.1.3 $MaxDL_{i,b}$ designates the most restrictive maximum consumption limit for the *dispatchable load* in interval i at bus $b \in B^{DL}$;

4.3.4.1.4 $MaxDR_{i,b}$ designates the maximum output limit in interval i for the *dispatchable* region of a *pseudo-unit* at bus $b \in B^{PSU}$;

4.3.4.1.5 $MinDG_{i,b}$ designates the most restrictive minimum output limit for the *dispatchable generation resource* in interval i at bus $b \in B^{DG}$; and

4.3.4.1.6 $MinDL_{i,b}$ designates the most restrictive minimum consumption limit for the *dispatchable load* in interval i at bus $b \in B^{DL}$.

4.3.5 Control Action Adjustments for Pricing

4.3.5.1 $CAAdj_i$ designates the *demand* adjustment required to calculate *locational marginal prices* appropriately when voltage reduction or load shedding has been implemented.

4.3.6 Constraint Violation Penalties for interval $i \in I$:

4.3.6.1 $(PLdViolSch_{i,w}, QLdViolSch_{i,w})$ for $w \in \{1,..,N_{LdViol_i}\}$ designate the price-quantity segments of the penalty curve for under *generation* used by the Real-Time Scheduling algorithm in section 8;

4.3.6.2 $(PLdViolPrc_{i,w}, QLdViolPrc_{i,w})$ for $w \in \{1,..,N_{LdViol_i}\}$ designate the price-quantity segments of the penalty curve for under *generation* used by the Real-Time Pricing algorithm in section 9;

4.3.6.3 $(PGenViolSch_{i,w}, QGenViolSch_{i,w})$ for $w \in \{1,..,N_{GenViol_i}\}$ designate the price-quantity segments of the penalty curve for over *generation* used by the Real-Time Scheduling algorithm in section 8;

4.3.6.4 $(PGenViolPrc_{i,w}, QGenViolPrc_{i,w})$ for $w \in \{1,..,N_{GenViol_i}\}$ designate the price-quantity segments of the penalty curve for over *generation* used by the Real-Time Pricing algorithm in section 9;

4.3.6.5 $(P10SViolSch_{i,w}, Q10SViolSch_{i,w})$ for $w \in \{1,..,N_{10SViol_i}\}$ designate the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Real-Time Scheduling algorithm in section 8;

4.3.6.6 $(P10SViolPrc_{i,w}, Q10SViolPrc_{i,w})$ for $w \in \{1,..,N_{10SViol_i}\}$ designate the price-quantity segments of the penalty curve for the synchronized *ten-minute operating reserve* requirement used by the Real-Time Pricing algorithm in section 9;

4.3.6.7 $(P10RViolSch_{i,w}, Q10RViolSch_{i,w})$ for $w \in \{1,..,N_{10RViol_i}\}$ designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Real-Time Scheduling algorithm in section 8;

4.3.6.8 $(P10RViolPrc_{i,w}, Q10RViolPrc_{i,w})$ for $w \in \{1,..,N_{10RViol_i}\}$ designate the price-quantity segments of the penalty curve for the total *ten-minute operating reserve* requirement used by the Real-Time Pricing algorithm in section 9;

4.3.6.9 $(P30RViolSch_{i,w}, Q30RViolSch_{i,w})$ for $w \in \{1,..,N_{30RViol_i}\}$ designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the Real-Time Scheduling algorithm in section 8;

4.3.6.10 $(P30RViolPrc_{i,w}, Q30RViolPrc_{i,w})$ for $w \in \{1,..,N_{30RViol_i}\}$ designate the price-quantity segments of the penalty curve for the total *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement used by the Real-Time Pricing algorithm in section 9;

4.3.6.11 $(PREG10RViolSch_{i,w}, QREG10RViolSch_{i,w})$ for $w \in \{1,..,N_{REG10RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Real-Time Scheduling algorithm in section 8;

4.3.6.12 $(PREG10RViolPrc_{i,w}, QREG10RViolPrc_{i,w})$ for $w \in \{1,..,N_{REG10RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* minimum requirements used by the Real-Time Pricing algorithm in section 9;

4.3.6.13 $(PREG30RViolSch_{i,w}, QREG30RViolSch_{i,w})$ for $w \in \{1,..,N_{REG30RViol_i}\}$ designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Real-Time Scheduling algorithm in section 8;

4.3.6.14 $(PREG30RViolPrc_{i,w}, QREG30RViolPrc_{i,w})$ for $w \in \{1,..,N_{REG30RViol_i}\}$ designate the price-quantity segments of the penalty curve for area *thirty-minute operating reserve* minimum requirements used by the Real-Time Pricing algorithm in section 9;

4.3.6.15 $(PXREG10RViolSch_{i,w}, QXREG10RViolSch_{i,w})$ for $w \in \{1,..,N_{XREG10RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Real-Time Scheduling algorithm in section 8;

4.3.6.16 $(PXREG10RViolPrc_{i,w}, QXREG10RViolPrc_{i,w})$ for $w \in \{1,..,N_{XREG10RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *ten-minute operating reserve* maximum restrictions used by the Real-Time Pricing algorithm in section 9;

4.3.6.17 $(PXREG30RViolSch_{i,w}, QXREG30RViolSch_{i,w})$ for $w \in \{1,..,N_{XREG30RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Real-Time Scheduling algorithm in section 8;

4.3.6.18 $(PXREG30RViolPrc_{i,w}, QXREG30RViolPrc_{i,w})$ for $w \in \{1,..,N_{XREG30RViol_i}\}$ designate the price-quantity segments of the penalty curve for area total *thirty-minute operating reserve* maximum restrictions used by the Real-Time Pricing algorithm in section 9;

4.3.6.19 $(PPreITLViolSch_{f,i,w}, QPreITLViolSch_{f,i,w})$ for $w \in \{1,..,N_{PreITLViol_{f,i}}\}$ designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Real-Time Scheduling algorithm in section 8;

4.3.6.20 $(PPreITLViolPrc_{f,i,w}, QPreITLViolPrc_{f,i,w})$ for $w \in \{1,..,N_{PreITLViol_{f,i}}\}$ designate the price-quantity segments of the penalty curve for exceeding the pre-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Real-Time Pricing algorithm in section 9;

4.3.6.21 $(PITLViolSch_{c,f,i,w}, QITLViolSch_{c,f,i,w})$ for $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$ designate the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Real-Time Scheduling algorithm in section 8;

4.3.6.22 $(PITLViolPrc_{c,f,i,w}, QITLViolPrc_{c,f,i,w})$ for $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$ designate the price-quantity segments of the penalty curve for exceeding the contingency $c \in C$ post-contingency limit of the transmission constraint for *facility* $f \in F$ used by the Real-Time Pricing algorithm in section 9; and

4.3.6.23 $NISLPen$ designates the net interchange scheduling limit constraint violation penalty price for *locational marginal pricing*.

4.3.7 Price Bounds

4.3.7.1 *EngyPrcCeil* designates and is equal to the *maximum market clearing price* for *energy*;

4.3.7.2 *EngyPrcFlr* designates and is equal to the *settlement floor price* for *energy*;

4.3.7.3 *ORPrcCeil* designates and is equal to the *maximum operating reserve price* for all classes of *operating reserve*; and

4.3.7.4 *ORPrcFlr* designates the minimum price for all classes of *operating reserve* and is equal to $0/MW.

4.3.8 Weighting Factors for Zonal Prices

4.3.8.1 $WF_{i,m,b}^{VIRT}$ designates the weighting factor for bus $b \in L_m^{VIRT}$ used to calculate the price for *virtual transaction zone* $m \in M$ for interval $i \in I$ and shall be equal to the weighting factor used in the *day-ahead market* for the applicable hour;

4.3.8.2 $WF_{i,y,b}^{NDL}$ designates the weighting factor for bus $b \in L_y^{NDL}$ used to calculate the price for *non-dispatchable load* zone $y \in Y$ for interval $i \in I$ and shall be obtained by renormalizing the load distribution factors so that the sum of weighting factors for a *non-dispatchable load* zone and for a given interval is one.

4.4 Other Data Parameters

4.4.1 Non-Dispatchable Demand Forecast

4.4.1.1 FL_i designates the five-minute province-wide non-*dispatchable demand* forecast for interval $i \in I$ calculated by the *security* assessment function.

4.4.2 Internal Transmission Constraints

4.4.2.1 $PreConSF_{i,f,b}$ designates the pre-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during interval i under pre-contingency conditions;

4.4.2.12 $AdjNormMaxFlow_{i,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in interval i under pre-contingency conditions;

4.4.2.3 $SF_{i,c,f,b}$ designates the post-contingency sensitivity factor for bus $b \in B \cup D$ indicating the fraction of *energy* injected at bus b which flows on *facility* f during interval i under post-contingency conditions for contingency c; and

4.4.2.4 $AdjEmMaxFlow_{i,c,f}$ designates the limit corresponding to the maximum flow allowed on *facility* f in interval i under post-contingency conditions for contingency c.

4.4.3 Transmission Losses

4.4.3.1 $LossAdj_i$ designates any adjustment needed for interval $i \in I$ to correct for any discrepancy between Ontario total system losses calculated using a base case power flow from the *security* assessment function and linearized losses that would be calculated using the marginal loss factors; and

4.4.3.2 $MglLoss_{i,b}$ designates the marginal loss factor and represents the marginal impact on transmission losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at *resource* bus $b \in B \cup D$ in interval $i \in I$.

5 Initialization

5.1 Purpose

5.1.1 The initialization processes set out in this section shall occur prior to the execution of the *real-time calculation engine* described in section 2.2.1 above.

5.2 Reference Bus

5.2.1 The *IESO* shall use Richview Transformer Station as the *real-time calculation engine's* default *reference bus* for the calculation of *locational marginal prices*.

5.2.2 If the default *reference bus* is out of service, another in-service bus shall be selected.

5.3 Islanding Conditions

5.3.1 In the event of a network split, the *real-time calculation engine* shall:

5.3.1.1 only evaluate *resources* that are within the *main island*;

5.3.1.2 use only forecasts of *demand* forecast areas in the *main island*; and

5.3.1.3 use a bus within the *main island* in place of the *reference bus* if the *reference bus* does not fall within the *main island*.

5.4 Variable Generation Tie-Breaking

5.4.1 For each interval $i \in I$, each *variable generation resource* bus $b \in B^{VG}$ and each *offer* lamination $k \in K^{E}_{i,b}$, the *offer* price $PDG_{i,b,k}$ shall be updated to $PDG_{i,b,k} - \left(\frac{TBM_{i,b}}{NumVG_i}\right)\rho$, where ρ is a small nominal value of order 10^{-4}.

5.5 Pseudo-Unit Constraints

5.5.1 Constraints for *pseudo-units* corresponding to the minimum and maximum constraints on physical *resources* shall be determined in accordance with section 10.

5.6 Initial Scheduling Assumptions

5.6.1 Initial Schedules

5.6.1.1 Initial *energy* schedules shall be based on the values deteremined by the *IESO's energy* management system and the schedules from the previous *real-time calculation engine* run, where:

5.6.1.1.1 $RTDLTel_{-1,b}$ designates the *energy* management system MW value for the *dispatchable load* at bus $b \in B^{DL}$;

5.6.1.1.2 $SDLSch^{Prev}_{0,b}$ designates the schedule determined for the *dispatchable load* at bus $b \in B^{DL}$ by the Real-Time Scheduling algorithm in section 8, of the previous *real-time calculation engine* run;

5.6.1.1.3 $RTDGTel_{-1,b}$ designates the *energy* management system MW value for the *dispatchable generation resource* at bus $b \in B^{DG}$;

5.6.1.1.4 $SDGSch^{Prev}_{0,b}$ designates the schedule determined for the *dispatchable generation resource* at bus $b \in B^{DG}$ by the Real-Time Scheduling algorithm in section 8, of the previous *real-time calculation engine* run;

5.6.1.1.5 $SDLPrc_{0,b}^{Prev}$ designates the schedule determined for the *dispatchable load* at bus $b \in B^{DL}$ by the Real-Time Pricing algorithm in section 9, of the previous *real-time calculation engine* run; and

5.6.1.1.6 $SDGPrc_{0,b}^{Prev}$ designates the schedule determined for the *dispatchable generation resource* at bus $b \in B^{DG}$ by the Real-Time Pricing algorithm in section 9, of the previous *real-time calculation engine* run.

5.6.1.2 For the *dispatchable load* at bus *b*, the intitial schedule, $SDLInitSch_{0,b}$, for the Real-Time Scheduling algorithm in section 8, shall be determined as follows:

5.6.1.2.1 Step 1: Calculate $TelUp_{0,b}$ using the submitted up ramp rates and break points to determine the maximum consumption level the *dispatchable load* can achieve in five minutes from $RTDLTel_{-1,b}$;

5.6.1.2.2 Step 2: Calculate $TelDown_{0,b}$ using the submitted down ramp rates and break points to determine the minimum consumption level the *dispatchable load* can achieve in five minutes from $RTDLTel_{-1,b}$; and

5.6.1.2.3 Step 3: If the schedule from the previous *real-time calculation engine* run is achievable by ramping from the $RTDLTel_{-1,b}$, then set the initial schedule to the schedule from the previous *real-time calculation engine* run. Otherwise, set the initial schedule to the nearest boundary:

If $TelDown_{0,b} \leq SDLSch_{0,b}^{Prev} \leq TelUp_{0,b}$, then set $SDLInitSch_{0,b} = SDLSch_{0,b}^{Prev}$

If $SDLSch_{0,b}^{Prev} < TelDown_{0,b}$, then set $SDLInitSch_{0,b} = TelDown_{0,b}$

Otherwise, set $SDLInitSch_{0,b} = TelUp_{0,b}$.

5.6.1.3 For the *dispatchable generation resource* at bus *b*, the intitial schedule, $SDGInitSch_{0,b}$, for the Real-Time Scheduling algorithm in section 8, shall be determined as follows:

5.6.1.3.1 Step 1: Calculate $TelUp_{0,b}$ using the submitted up ramp rates and break points to determine the maximum production level the *resource* can achieve in five minutes from $RTDGTel_{-1,b}$;

5.6.1.3.2 Step 2: Calculate $TelDown_{0,b}$ using the submitted down ramp rates and break points to determine the minimum production level the *resource* can achieve in five minutes from $RTDGTel_{-1,b}$; and

5.6.1.3.3 Step 3: If the schedule from the previous *real-time calculation engine* run is achievable by ramping from the $RTDGTel_{-1,b}$, then set the initial schedule to the schedule from the previous *real-time calculation engine* run. Otherwise, set the initial schedule to the nearest boundary:

If $TelDown_{0,b} \leq SDGSch_{0,b}^{Prev} \leq TelUp_{0,b}$ then set $SDGInitSch_{0,b} = SDGSch_{0,b}^{Prev}$

If $SDGSch_{0,b}^{Prev} < TelDown_{0,b}$ then set $SDGInitSch_{0,b} = TelDown_{0,b}$

Otherwise, set $SDGInitSch_{0,b} = TelUp_{0,b}$.

5.6.1.4 For the *dispatchable load* at bus b, the intitial schedule, $SDLInitPrc_{0,b}$, for the Real-Time Pricing algorithm in section 9, shall be determined as follows:

If $SDLSch_{0,b}^{Prev} \leq SDLPrc_{0,b}^{Prev} \leq SDLInitSch_{0,b}$ or $SDLInitSch_{0,b} \leq SDLPrc_{0,b}^{Prev} \leq SDLSch_{0,b}^{Prev}$, then set $SDLInitPrc_{0,b} = SDLInitSch_{0,b}$;

Otherwise set $SDLInitPrc_{0,b} = SDLPrc_{0,b}^{Prev}$.

5.6.1.5 For the *dispatchable generation* at bus b, the intitial schedule $SDGInitPrc_{0,b}$, for the Real-Time Pricing algorithm in section 9, designates the initial schedule for the *dispatchable generation resource* at bus b and is determined as follows:

If $SDGSch_{0,b}^{Prev} \leq SDGPrc_{0,b}^{Prev} \leq SDGInitSch_{0,b}$ or $SDGInitSch_{0,b} \leq SDGPrc_{0,b}^{Prev} \leq SDGSch_{0,b}^{Prev}$ then set $SDGInitPrc_{0,b} = SDGInitSch_{0,b}$;

Otherwise set $SDGInitPrc_{0,b} = SDGPrc_{0,b}^{Prev}$.

5.6.2 Start-up and Shutdown for Non-Quick Start Resources

5.6.2.1 The start-up and shutdown for *non-quick start resources* at bus $b \in B^{NQS}$ and interval $i \in I$ shall be based on the following parameters that are determined based on observed *resource* operation as well as confirmed start-up and shutdown times:

5.6.2.1.1 $AtZero_{i,b} \in \{0,1\}$, which designates that the *resource* is scheduled to be offline;

5.6.2.1.2 $SU_{i,b} \in \{0,1\}$, which designates that the *resource* must be scheduled on its start-up trajectory. This input may indicate an upcoming confirmed start-up or that the *resource* has started ramping up already;

5.6.2.1.3 $AtMLP_{i,b} \in \{0,1\}$, which designates that the *resource* is scheduled to operate at or above its *minimum loading point* due to a minimum generation constraint or the *resource* shutdown has yet to be confirmed by the *IESO*;

5.6.2.1.4 $EvalSD_{i,b} \in \{0,1\}$, which designates that the *resource* has been de-committed by the *pre-dispatch calculation engine*, such de-commitment has been confirmed by the *IESO*, and the *resource* can be evaluated for *energy* schedules below its *minimum loading point* but can still be scheduled at or above its *minimum loading point*; and

5.6.2.1.5 $SD_{i,b} \in \{0,1\}$, which designates that the *resource* must be scheduled on its shutdown trajectory. This input may indicate an upcoming mandatory shutdown or that the *resource* has already started ramping down.

5.6.2.2 For all parameters in section 5.6.2.1:

$$AtZero_{i,b} + SU_{i,b} + AtMLP_{i,b} + EvalSD_{i,b} + SD_{i,b} = 1.$$

6 Security Assessment Function in the Real-Time Calculation Engine

6.1 Interaction between the Security Assessment Function and Optimization Functions

6.1.1 The scheduling and pricing algorithms of the *real-time calculation engine* pass shall perform multiple iterations of the optimization functions and the *security* assessment function to check for violations of monitored thermal limits and operating *security limits* using the schedules produced by the optimization functions.

6.1.2 As multiple iterations are performed, the transmission constraints produced by the *security* assessment function shall be used by the optimization functions.

6.1.3 The *security* assessment function shall use the physical *resource* representation of combined cycle *facilities* that are registered as *pseudo-units*.

6.2 Inputs into the Security Assessment Function

6.2.1 The *security* assessment function shall use the following inputs:

6.2.1.1 the *IESO demand* forecasts; and

6.2.1.2 applicable *IESO-controlled grid* information pursuant to section 3A.1 of Chapter 7.

6.2.2 The *security* assessment function shall also use the following outputs of the optimization functions:

6.2.2.1 the schedules for *dispatchable loads* and *hourly demand response resources*;

6.2.2.2 the schedules for *non-dispatchable generation resources* and *dispatchable generation resources*; and

6.2.2.3 the schedules for *boundary entity resources* at each *intertie zone*.

Security Assessment Function Processing

6.3.1 The *security* assessment function shall determine the province-wide non-*dispatchable demand* forecast quantity, FL_i, using *demand* forecasts for *demand* forecast areas, the *IESO's energy* management system MW quantities and the scheduled quantities from the previous *real-time calculation engine* run as follows:

6.3.1.1 sum the *IESO* five-minute *demand* forecasts for *demand* forecast areas;

6.3.1.2 subtract the expected consumption of all physical *hourly demand response resources*;

6.3.1.3 subtract the expected consumption of all virtual *hourly demand response resources*; and

6.3.1.4 subtract the expected consumption of all *dispatchable loads*.

6.3.2 The *security* assessment function shall perform the following calculations and analyses:

6.3.2.1 A base case solution function shall prepare a power flow solution for each interval in the real-time look-ahead period. The base case solution function shall select the power system model state applicable to the forecast of conditions for the interval and input schedules.

6.3.2.2 The base case solution function shall use an AC power flow analysis. If the AC power flow analysis fails to converge, the base case solution function shall use a non-linear DC power flow analysis. If the non-linear DC power flow analysis fails to converge, the base case solution function shall use a linear DC power flow analysis.

6.3.2.3 If the AC or non-linear DC power flow analysis converges, continuous thermal limits for all monitored equipment and operating *security limits* shall be monitored to check for pre-contingency limit violations.

6.3.2.4 Violated pre-contingency limits shall be linearized using pre-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.5 If the linear DC power flow analysis is used, the pre-contingency *security* assessment may develop linear constraints to facilitate the convergence of the AC or non-linear DC power flow analysis in the subsequent iterations.

6.3.2.6 A linear power flow analysis shall be used to simulate contingencies, calculate post-contingency flows and check all monitored equipment for limited-time thermal limit violations.

6.3.2.7 Violated post-contingency limits shall be linearized using post-contingency sensitivity factors and incorporated as constraints for use by the optimization functions.

6.3.2.8 The base case solution shall be used to calculate Ontario *transmission system* losses, marginal loss factors and loss adjustment for each interval. The impact of losses on branches between the *resource* bus and the *resource connection point* to the *IESO-controlled grid* and losses on branches outside Ontario shall be excluded when determining marginal loss factors.

6.3.2.9 The *real-time calculation engine* shall use a set of fixed marginal loss factors for each *dispatch hour*. The same set of fixed marginal loss factors shall apply to all five-minute intervals that fall in the *dispatch hour.* The set of fixed marginal loss factors for each *dispatch hour* shall be determined based on the marginal loss factors calculated in the previous hour by the Real-Time Scheduling algorithm in section 8 of the *real-time calculation engine*.

6.3.2.10 The marginal loss factors for the advisory intervals that fall in the hour following the *dispatch hour* shall be determined based on the fixed marginal loss factors for the *dispatch hour* described in section 6.3.2.9 and the marginal loss factors calculated by the Real-Time Scheduling algorithm in section 8 of the previous *real-time calculation engine* run.

6.3.2.11 The Real-Time Scheduling and Real-Time Pricing algorithms in sections 8 and 9, respectively, shall use the same set of marginal loss factors.

6.3 Outputs from the Security Assessment Function

6.4.1 The outputs of the *security* assessment function used in the optimization functions include the following:

6.4.1.1 a set of linearized constraints for all violated pre-contingency and post-contingency limits for each interval. The sensitivities and limits associated with the constraints shall be those provided by the most recent *security* assessment function iteration;

6.4.1.2 pre-contingency and post-contingency sensitivity factors for each interval;

6.4.1.3 the marginal loss factors as described in sections 6.3.2.8 – 6.3.2.11; and

6.4.1.4 loss adjustment quantity for each interval.

7 Pass 1: Real-Time Scheduling and Pricing

7.1.1 Pass 1 shall use *market participant* and *IESO* inputs and *resource* and system constraints to determine a set of *resource* schedules and *locational marginal prices*. Pass 1 shall consist of the following algorithms:

- the Real-Time Scheduling algorithm described in section 8;
- the Real-Time Pricing algorithm described in section 9;

8 Real-Time Scheduling

8.1 Purpose

8.1.1 The Real-Time Scheduling algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade using *dispatch data* submitted by *registered market participants* or where applicable, the *reference level values* for *financial dispatch data parameters* mitigated in previous *pre-dispatch calculation engine* runs in accordance with Appendix 7.2A, section 14.7, to meet the *IESO's* province-wide non-*dispatchable demand* forecast and *IESO*-specified *operating reserve* requirements for each interval of the real-time look-ahead period.

8.2 Information, Sets, Indices and Parameters

8.2.1 Information, sets, indices and parameters used by Real-Time Scheduling algorithm are described in sections 3 and 4.

8.3 Variables and Objective Function

8.3.1 The Real-Time Scheduling algorithm shall solve for the following variables:

8.3.1.1 $SDL_{i,b,j}$, which designates the amount of *energy* that a *dispatchable load* scheduled at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J^{E}_{i,b}$;

8.3.1.2 $S10SDL_{i,b,j}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{10S}$;

8.3.1.3 $S10NDL_{i,b,j}$, which designates the amount of non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{10N}$;

8.3.1.4 $S30RDL_{i,b,j}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable load* is scheduled to provide at bus $b \in B^{DL}$ in interval $i \in I$ in association with lamination $j \in J_{i,b}^{30R}$;

8.3.1.5 $SNDG_{i,b,k}$, which designates the amount of *energy* that a *non-dispatchable generation resource* scheduled at bus $b \in B^{NDG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{E}$;

8.3.1.6 $SDG_{i,b,k}$, which designates the amount of *energy* that a *dispatchable generation resource* is scheduled at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{E}$;

8.3.1.7 $S10SDG_{i,b,k}$, which designates the amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{10S}$;

8.3.1.8 $S10NDG_{i,b,k}$, 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 lamination $k \in K_{i,b}^{10N}$;

8.3.1.9 $S30RDG_{i,b,k}$, which designates the amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide at bus $b \in B^{DG}$ in interval $i \in I$ in association with lamination $k \in K_{i,b}^{30R}$;

8.3.1.10 $SCT_{i,b}$, which designates the schedule of the combustion turbine associated with the *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$;

8.3.1.11 $SST_{i,p}$, which designates the schedule of steam turbine $p \in PST$ in interval $i \in I$;

8.3.1.12 TB_i, which designates any adjustment to the objective function to facilitate pro-rata tie-breaking in interval $i \in I$, as described in section 8.3.2.1; and

8.3.1.13 $ViolCost_i$, which designates the cost incurred in order to avoid having the schedules violate constraints for interval $i \in I$, as described in section 8.3.2.3.

8.3.2 The objective function for the Real-Time Scheduling algorithm shall maximize gains from trade by maximizing the following expression:

$$\sum_{i=1..n_I} (ObjDL_i - ObjNDG_i - ObjDG_i - TB_i - ViolCost_i)$$

where:

$$ObjDL_i = \sum_{b \in B^{DL}} \left(\begin{array}{l} \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} \cdot PDL_{i,b,j} - \sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \cdot P10SDL_{i,b,j} - \\ \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \cdot P10NDL_{i,b,j} - \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \cdot P30RDL_{i,b,j} \end{array} \right);$$

$$ObjNDG_i = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{i,b}^{E}} SNDG_{i,b,k} \cdot PNDG_{i,b,k} \right);$$

and

$$ObjDG_i = \sum_{b \in B^{DG}} \left(\begin{array}{l} \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} \cdot PDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \cdot P10SDG_{i,b,k} + \\ \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \cdot P10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \cdot P30RDG_{i,b,k} \end{array} \right).$$

8.3.2.1 The tie-breaking term (TB_i) shall sum a term for each *bid* or *offer* lamination. For each lamination, this term shall be the product of a small penalty cost and the quantity of the lamination scheduled. The penalty cost shall be calculated by multiplying a base penalty cost of *TBPen* by the amount of the lamination scheduled and then dividing by the maximum amount that could have been scheduled. That is:

$$TB_i = TBDL_i + TBNDG_i + TBDG_i$$

where:

$$TBDL_i = \sum_{b \in B^{DL}} \left(\begin{array}{c} \sum_{j \in J_{i,b}^{E}} \left(\frac{(SDL_{i,b,j})^2 \cdot TBPen}{QDL_{i,b,j}} \right) + \sum_{j \in J_{i,b}^{10S}} \left(\frac{(S10SDL_{i,b,j})^2 \cdot TBPen}{Q10SDL_{i,b,j}} \right) + \\ \sum_{j \in J_{i,b}^{10N}} \left(\frac{(S10NDL_{i,b,j})^2 \cdot TBPen}{Q10NDL_{i,b,j}} \right) + \sum_{j \in J_{i,b}^{30R}} \left(\frac{(S30RDL_{i,b,j})^2 \cdot TBPen}{Q30RDL_{i,b,j}} \right) \end{array} \right);$$

$$TBNDG_i = \sum_{b \in B^{NDG}} \left(\sum_{k \in K_{i,b}^{E}} \left(\frac{(SNDG_{i,b,k})^2 \cdot TBPen}{QNDG_{i,b,k}} \right) \right);$$

and

$$TBDG_i = \sum_{b \in B^{DG}} \left(\begin{array}{c} \sum_{k \in K_{i,b}^{E}} \left(\frac{(SDG_{i,b,k})^2 \cdot TBPen}{QDG_{i,b,k}} \right) + \sum_{k \in K_{i,b}^{10S}} \left(\frac{(S10SDG_{i,b,k})^2 \cdot TBPen}{Q10SDG_{i,b,k}} \right) + \\ \sum_{k \in K_{i,b}^{10N}} \left(\frac{(S10NDG_{i,b,k})^2 \cdot TBPen}{Q10NDG_{i,b,k}} \right) + \sum_{k \in K_{i,b}^{30R}} \left(\frac{(S30RDG_{i,b,k})^2 \cdot TBPen}{Q30RDG_{i,b,k}} \right) \end{array} \right).$$

8.3.2.1 $ViolCost_i$ shall be calculated for interval $i \in I$ using the following variables:

8.3.2.2.1 $SLdViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{LdViol_i}\}$ of the penalty curve for the *energy* balance constraint allowing under-generation;

8.3.2.2.2 $SGenViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{GenViol_i}\}$ of the penalty curve for the *energy* balance constraint allowing over-generation;

8.3.2.2.3 $S10SViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{10SViol_i}\}$ of the penalty curve for the synchronized *ten-minute operating reserve* requirement;

8.3.2.2.4 $S10RViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{10RViol_i}\}$ of the penalty curve for the total *ten-minute operating reserve* requirement;

8.3.2.2.5 $S30RViol_{i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{30RViol_i}\}$ of the penalty curve for the *thirty-minute operating reserve* requirement and, when applicable, the flexibility *operating reserve* requirement;

8.3.2.2.6 $SREG10RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{REG10RViol_i}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.7 $SREG30RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{REG30RViol_i}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* minimum requirement in region $r \in ORREG$;

8.3.2.2.8 $SXREG10RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{XREG10RViol_i}\}$ of the penalty curve for violating the area total *ten-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.9 $SXREG30RViol_{r,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{XREG30RViol_i}\}$ of the penalty curve for violating the area *thirty-minute operating reserve* maximum restriction in region $r \in ORREG$;

8.3.2.2.10 $SPreITLViol_{f,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{PreITLViol_{f,i}}\}$ of the penalty curve for violating the pre-contingency transmission limit for *facility* $f \in F$; and

8.3.2.2.11 $SITLViol_{c,f,i,w}$, which designates the violation variable affiliated with segment $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$ of the penalty curve for violating the post-contingency transmission limit for *facility* $f \in F$ and contingency $c \in C$.

8.3.2.2 $ViolCost_i$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_i = & \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \cdot PLdViolSch_{i,w} \\
& - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \cdot PGenViolSch_{i,w} \\
& + \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \cdot P10SViolSch_{i,w} \\
& + \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \cdot P10RViolSch_{i,w} \\
& + \sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \cdot P30RViolSch_{i,w} \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \cdot PREG10RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \cdot PREG30RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \cdot PXREG10RViolSch_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w} \cdot PXREG30RViolSch_{i,w} \right) \\
& + \sum_{f \in F_i} \left(\sum_{w=1..N_{PreITLViol_{f,i}}} SPreITLViol_{f,i,w} \cdot PPreITLViolSch_{f,i,w} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{i,c}} \left(\sum_{w=1..N_{ITLViol_{c,f,i}}} SITLViol_{c,f,i,w} \cdot PITLViolSch_{c,f,i,w} \right).
\end{aligned}
$$

8.4 Constraints

8.4.1 The Real-Time Scheduling algorithm optimization function shall apply the constraints described in sections 8.5 – 8.7.

8.5 Dispatch Data Constraints Applying to Individual Intervals

8.5.1 Scheduling Variable Bounds

8.5.1.1 No schedule shall be negative, nor shall any schedule exceed the quantity *offered* for *energy* and *operating reserve* respectively. Therefore:

$0 \leq SDL_{i,b,j} \leq QDL_{i,b,j}$ for all $b \in B^{DL}$, $j \in J^{E}_{i,b}$;

$0 \leq S10SDL_{i,b,j} \leq Q10SDL_{i,b,j}$ for all $b \in B^{DL}$, $j \in J^{10S}_{i,b}$;

$0 \leq S10NDL_{i,b,j} \leq Q10NDL_{i,b,j}$ for all $b \in B^{DL}$, $j \in J^{10N}_{i,b}$;

$0 \leq S30RDL_{i,b,j} \leq Q30RDL_{i,b,j}$ for all $b \in B^{DL}$, $j \in J^{30R}_{i,b}$;

$0 \leq SNDG_{i,b,k} \leq QNDG_{i,b,k}$ for all $b \in B^{NDG}$, $k \in K^{E}_{i,b}$;

$0 \leq SDG_{i,b,k} \leq QDG_{i,b,k}$ for all $b \in B^{DG}$, $k \in K^{E}_{i,b}$;

$0 \leq S10SDG_{i,b,k} \leq Q10SDG_{i,b,k}$ for all $b \in B^{DG}$, $k \in K^{10S}_{i,b}$;

$0 \leq S10NDG_{i,b,k} \leq Q10NDG_{i,b,k}$ for all $b \in B^{DG}$, $k \in K^{10N}_{i,b}$; and

$0 \leq S30RDG_{i,b,k} \leq Q30RDG_{i,b,k}$ for all $b \in B^{DG}$, $k \in K^{30R}_{I,b}$

for all intervals $i \in I$.

8.5.1.2 A *non-quick start resource* cannot provide *energy* when it is scheduled to be offline. Therefore, for all intervals $i \in I$, *non-quick start resource* buses $b \in B^{NQS}$, and *offer* laminations $k \in K^{E}_{i,b}$:

$$0 \leq SDG_{i,b,k} \leq (1 - AtZero_{i,b}) \cdot QDG_{i,b,k}.$$

8.5.1.3 A *non-quick start resource* cannot provide *operating reserve* unless it is scheduled at or above its *minimum loading point*. Therefore, for all intervals $i \in I$ and *non-quick start resource* buses $b \in B^{NQS}$:

$0 \leq S10SDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q10SDG_{i,b,k}$ for all $k \in K^{10S}_{i,b}$;

$0 \leq S10NDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q10NDG_{i,b,k}$ for all $k \in K^{10N}_{i,b}$; and

$0 \leq S30RDG_{i,b,k} \leq (AtMLP_{i,b} + EvalSD_{i,b}) \cdot Q30RDG_{i,b,k}$ for all $k \in K^{30R}_{i,b}$.

8.5.2 Resource Initial Conditions

8.5.2.1 The initial schedule for a *dispatchable load* at bus $b \in B^{DL}$ shall be fixed to the *resource* initial schedules. For all *dispatchable load* buses $b \in B^{DL}$:

$$\sum_{j \in J_{0,b}^{E}} SDL_{0,b,j} = SDLInitSch_{0,b}$$

8.5.2.2 The initial schedule for a *dispatchable generation resource* at bus $b \in B^{DG}$ shall be fixed to the *resource* initial schedules. For all *dispatchable generation resource* buses $b \in B^{DG}$:

$$\sum_{k \in K_{0,b}^{E}} SDG_{0,b,k} = SDGInitSch_{0,b}$$

8.5.3 Resource Minimums and Maximums for Energy

8.5.3.1 A constraint shall limit schedules for *dispatchable loads* within their minimum and maximum consumption for an interval. For all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$MinDL_{i,b} \leq \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} \leq MaxDL_{i,b}.$$

8.5.3.2 The non-*dispatchable* portion of a *dispatchable load* shall always be scheduled. For all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} \geq QDLFIRM_{i,b}.$$

8.5.3.3 The *non-dispatchable generation resources* shall be scheduled to the fixed quantity determined by their observed output. For all intervals $i \in I$ and all buses $b \in B^{NDG}$:

$$\sum_{k \in K_{i,b}^{E}} SNDG_{i,b,k} = FNDG_{i,b}.$$

8.5.3.4 A constraint shall limit schedules for *dispatchable generation resources* within their minimum and maximum output for an interval. For a *dispatchable variable generation resource*, the maximum schedule shall be limited by its forecast. That is:

8.5.3.4.1 For all intervals $i \in I$ and all buses $b \in B^{DG}$,

$$AdjMaxDG_{i,b} = \begin{cases} min(MaxDG_{i,b}, FG_{i,b}) & if\ b \in B^{VG} \\ MaxDG_{i,b} & otherwise \end{cases}$$

and

$$AdjMinDG_{i,b} = min(MinDG_{i,b}, AdjMaxDG_{i,b}).$$

8.5.3.4.2 For all intervals $i \in I$ and all buses $b \in B^{DG}$:

$$AdjMinDG_{i,b} \leq \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} \leq AdjMaxDG_{i,b}.$$

8.5.3.5 A constraint shall limit the schedule for a *non-quick start resource* at or above its *minimum loading point* when such *resource* is committed or when the *resource* shutdown is yet to be confirmed by the *IESO*. For all *non-quick start resource* buses $b \in B^{NQS}$ and intervals $i \in I$:

$$\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} \geq AtMLP_{i,b} \cdot MinQDG_{b}.$$

8.5.4 Operating Reserve Requirements

8.5.4.1 The total synchronized *ten-minute operating reserve*, non-synchronized *ten-minute operating reserve* and *thirty-minute operating reserve* scheduled from a *dispatchable load* shall not exceed:

8.5.4.1.1 the *dispatchable load's* ramp capability over 30 minutes;

8.5.4.1.2 the total scheduled consumption less the non-*dispatchable* portion; and

8.5.4.1.3 the remaining portion of its capacity that is *dispatchable* after considering minimum load consumption constraints.

8.5.4.2 These restrictions shall be enforced by the following constraints for all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \leq 30 \cdot ORRDL_b;$$

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} - QDLFIRM_{i,b};$$

and

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \leq \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} - MinDL_{i,b}.$$

8.5.4.3 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable load* is scheduled to provide shall not exceed the amount by which the *dispatchable load* can decrease its consumption over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \leq 10 \cdot ORRDL_b.$$

8.5.4.4 The total *operating reserve* scheduled from a *dispatchable generation resource* shall not exceed the *resource*'s ramp capability over 30 minutes, its remaining capacity, and its unscheduled capacity. These restrictions shall be enforced by the following constraints for all intervals $i \in I$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq 30 \cdot ORRDG_b;$$

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq \sum_{k \in K_{i,b}^{E}} (QDG_{i,b,k} - SDG_{i,b,k});$$

and

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq AdjMaxDG_{i,b} - \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k}.$$

8.5.4.5 The amount of both synchronized and non-synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall not exceed the amount by which the *resource* can increase its output over 10 minutes, as limited by its *operating reserve* ramp rate. This restriction shall be enforced by the following constraint for all intervals $i \in I$ and all buses $b \in B^{DG}$:

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \leq 10 \cdot ORRDG_b.$$

8.5.4.6 The amount of synchronized *ten-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for synchronized *ten-minute operating reserve*. This restriction shall be enforced by the following constraint for all intervals $i \in I$ and all buses $b \in B^{DG}$ with $RLP10S_{i,b} > 0$:

$$\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP10S_{i,b}} \right) \cdot \left(min \left\{ 10 \cdot ORRDG_b, \sum_{k \in K_{i,b}^{10S}} Q10SDG_{i,b,k} \right\} \right).$$

8.5.4.7 The amount of *thirty-minute operating reserve* that a *dispatchable generation resource* is scheduled to provide shall be limited by its *reserve loading point* for *thirty-minute operating reserve*. This restriction shall be enforced by the following constraint for all intervals $i \in I$ and all buses $b \in B^{DG}$ with $RLP30R_{i,b} > 0$:

$$\sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq \left(\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} \right) \cdot \left(\frac{1}{RLP30R_{i,b}} \right) \cdot \left(min \left\{ 30 \cdot ORRDG_b, \sum_{k \in K_{i,b}^{30R}} Q30RDG_{i,b,k} \right\} \right).$$

8.5.5 Pseudo-Units

8.5.5.1 A constraint shall be required to calculate physical *generation resource* schedules from *pseudo-unit* schedules using the steam turbine

$$SSTMod_{i,p} = \sum_{b \in B_p^{ST}} \left(\begin{array}{c} STShareMLP_b \cdot \left(\sum_{k \in K_{i,b}^{MLP}} SDG_{i,b,k} \right) + \\ STShareDR_b \cdot \left(\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} \right) + \sum_{k \in K_{i,b}^{DF}} SDG_{i,b,k} \end{array} \right).$$

shares in the operating regions of the *pseudo-unit* determined in section 10. For all intervals $i \in I$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$SCTMod_{i,b} = (1 - STShareMLP_b) \cdot \left(\sum_{k \in K_{i,b}^{MLP}} SDG_{i,b,k} \right) + (1 - STShareDR_b) \cdot \left(\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} \right),$$

8.5.5.1.1 and for all intervals $i \in I$ and steam turbines $p \in PST$;

8.5.5.2 Maximum constraints shall be enforced on the operating region to which they apply for both *energy* and *operating reserve* schedules. For all intervals $i \in I$ and *pseudo-unit* buses $b \in B^{PSU}$:

$$\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} \leq MaxDR_{i,b},$$

$$\sum_{k \in K_{i,b}^{DF}} SDG_{i,b,k} \leq MaxDF_{i,b},$$

and

$$\sum_{k \in K_{i,b}^{DR}} SDG_{i,b,k} + \sum_{k \in K_{i,b}^{DF}} SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \leq MaxDR_{i,b} + MaxDF_{i,b}.$$

8.5.5.3 For a *pseudo-unit* that cannot provide *ten-minute operating reserve* from its duct firing region, constraints shall limit the *pseudo-unit* from being scheduled to provide *ten-minute operating reserve* whenever the *pseudo-unit* is scheduled for *energy* in its duct firing region.

8.5.5.4 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the combustion turbine schedule for the *pseudo-unit* at bus $b \in B^{PSU}$ in interval $i \in I$, $SCT_{i,b}$ shall be equal to:

8.5.5.4.1 $SCTMod_{i,b}$ if the *pseudo-unit* is scheduled at or above *minimum loading point*;

8.5.5.4.2 the portion of $UpTraj_{i,b}$ or $DnTraj_{i,b}$ defined in the section 8.6.2 that was allocated to the combustion turbine in accordance with section 10.6 if the *resource* is ramping to or ramping from its *minimum loading point*; or

8.5.5.4.3 0 otherwise.

8.5.5.5 For the purposes of the *energy* balance constraint in section 8.7.1 and the transmission constraints in section 8.7.3, the steam turbine schedule for $p \in PST$, $SST_{i,p}$ shall be equal to $SSTMod_{i,p}$ where $SST_{i,p}$ will be corrected to account for the contribution from *pseudo-units* $b \in B_p^{ST}$ ramping to or ramping from *minimum loading point* as determined by the allocation of $UpTraj_{i,b}$ or $DnTraj_{i,b}$ in accordance with section 10.6.

8.5.6 Dispatchable Hydroelectric Generation Resources

8.5.6.1 A *dispatchable* hydroelectric *generation resource* shall be scheduled within its *forbidden region* if the *resource* is being ramped through the *forbidden region* at its maximum *offered* ramp capability.

8.6 Dispatch Data Inter-Interval/Multi-Interval Constraints

8.6.1 Energy Ramping

8.6.1.1 For *disptachable loads*, the ramping constraint in section 8.6.1.4 uses $URRDL_b$ to represent a ramp up rate selected from $URRDL_{i,b,w}$ and uses $DRRDL_b$ to represent a ramp down rate selected from $DRRDL_{i,b,w}$.

8.6.1.2 For *disptachable generation resources*, the ramping constraint in section 8.6.1.5 uses $URRDG_b$ to represent a ramp up rate selected from $URRDG_{i,b,w}$ and uses $DRRDG_b$ to represent a ramp down rate selected from $DRRDG_{i,b,w}$.

8.6.1.3 The *real-time calculation engine* shall respect the ramping restrictions determined by the up to five *offered* MW quantity, ramp up rate and ramp down rate value sets.

8.6.1.4 In the case of *dispatchable loads*, *energy* schedules cannot vary by more than an interval's ramping capability for that *resource*. This constraint shall be enforced by the following for all intervals $i \in I$ and buses $b \in B^{DL}$:

$$\sum_{j \in J^E_{i-1,b}} SDL_{i-1,b,j} - 5 \cdot DRRDL_b \leq \sum_{j \in J^E_{i,b}} SDL_{i,b,j} \leq \sum_{j \in J^E_{i-1,b}} SDL_{i-1,b,j} + 5 \cdot URRDL_b.$$

8.6.1.5 *Energy* schedules for a *dispatchable generation resource* cannot vary by more than an interval's ramping capability for that *resource*. This constraint shall be enforced by the following for all intervals $i \in I$ and buses $b \in B^{DG}$:

$$\sum_{k \in K^E_{i-1,b}} SDG_{i-1,b,k} - 5 \cdot DRRDG_b \leq \sum_{k \in K^E_{i,b}} SDG_{i,b,k} \leq \sum_{k \in K^E_{i-1,b}} SDG_{i-1,b,k} + 5 \cdot URRDG_b.$$

8.6.1 Non-Quick Start Resource Start-up and Shutdown

8.6.2.1 For all intervals in the real-time look-ahead period in which a *non-quick start resource* is scheduled to start-up, such *resource* shall be scheduled on a fixed ramp-up trajectory as determined by its *offered* ramp rates. The ramp-up trajectory ($UpTraj_{i,b}$) for interval $i \in I$ such that $SU_{i,b}=1$ is determined as follows:

8.6.2.1.1 If $i = 1$, then $UpTraj_{i,b}$ shall be determined from the *resource* initial schedule and the *offered* ramp up capability;

8.6.2.1.2 If $i > 1$ and $SU_{i-1,b} = 0$, then $UpTraj_{i,b}$ shall be determined from the *offered* ramp up capability from 0; and

8.6.2.1.3 For all intervals $i \in I$ such that $SU_{i,b}=1$:

$$\sum_{k \in K^E_{i,b}} SDG_{i,b,k} = UpTraj_{i,b}.$$

8.6.2.2 For all intervals in the real-time look-ahead period in which a *non-quick start resource* is scheduled to shutdown, such *resource* shall be scheduled on a fixed ramp-down trajectory as determined by its *offered* ramp rates. The ramp-down trajectory ($DnTraj_{i,b}$) for interval $i \in I$ such that $SD_{i,b} = 1$ is determined as follows:

8.6.2.2.1 If $i = 1$, then $DnTraj_{i,b}$ shall be determined from the *resource* initial schedule and the *offered* ramp down capability;

8.6.2.2.2 If $i > 1$ and $SD_{i-1,b} = 0$, then $DnTraj_{i,b}$ shall be $MinQDG_b$; and

8.6.2.2.3 If $i > 1$ and $SD_{i-1,b} = 1$, then $DnTraj_{i,b}$ shall be determined from the *offered* ramp down capability from $DnTraj_{i-1,b}$.

8.6.2.2.4 For all intervals $i \in I$ such that $SD_{i,b} = 1$:

$$\sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} = DnTraj_{i,b}.$$

8.6.3 Operating Reserve Ramping

8.6.3.1 Constraints shall be applied to recognize that interval to interval changes to a *dispatchable load*'s schedule for *energy* may modify the amount of *operating reserve* that the *resource* can provide. For all intervals $i \in I$ and all buses $b \in B^{DL}$:

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} + \sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \le -\sum_{j \in J_{i-1,b}^{E}} SDL_{i-1,b,j} + \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} + 30 \cdot ORRDL_b$$

and

$$\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} + \sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \le -\sum_{j \in J_{i-1,b}^{E}} SDL_{i-1,b,j} + \sum_{j \in J_{i,b}^{E}} SDL_{i,b,j} + 10 \cdot ORRDL_b.$$

8.6.3.2 Constraints shall be applied to recognize that interval to interval changes in a *dispatchable generation resource's* schedule for *energy* may modify the amount of *operating reserve* that the *resource* can provide. For all intervals $i \in I$ and all buses $b \in B^{DG}$:

$$\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k} + \sum_{k\in K_{i,b}^{30R}} S30RDG_{i,b,k} \le \sum_{k\in K_{i-1,b}^{E}} SDG_{i-1,b,k} - \sum_{k\in K_{i,b}^{E}} SDG_{i,b,k} + 30 \cdot ORRDG_b$$

and

$$\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k} + \sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k} \le \sum_{k\in K_{i-1,b}^{E}} SDG_{i-1,b,k} - \sum_{k\in K_{i,b}^{E}} SDG_{i,b,k} + 10 \cdot ORRDG_b.$$

8.7 Constraints for Reliability Requirements

8.7.1 Energy Balance

8.7.1.1 The total amount of *energy* withdrawals scheduled at load bus $b \in B$ in interval $i \in I$, $With_{i,b}$ shall be:

$$With_{i,b} = \begin{cases} \sum_{j\in J_{i,b}^{E}} SDL_{i,b,j} & if\ b \in B^{DL} \\ FHDR_{i,b} & if\ b \in B^{HDR} \\ FNBL_{i,b} & if\ b \in B^{NoBid} \end{cases}$$

8.7.1.2 The total amount of export *energy* scheduled at *intertie zone* bus $d \in DX$ in interval $i \in I$, $With_{i,d}$, as the fixed exports from Ontario to the *intertie zone* export bus shall be:

$$With_{i,d} = FXLSch_{i,d}.$$

8.7.1.3 The total amount of injections scheduled at internal bus $b \in B$, in interval $i \in I$, $Inj_{i,b}$ shall be:

$$Inj_{i,b} = \begin{cases} \sum_{k \in K_{i,b}^{E}} SNDG_{i,b,k} & if\ b \in B^{NDG} \\ \sum_{k \in K_{i,b}^{E}} SDG_{i,b,k} & if\ b \in B^{DG} \\ FNOG_{i,b} & if\ b \in B^{NoOffer} \end{cases}$$

8.7.1.4 The total amount of import *energy* scheduled at *intertie zone* bus $d \in DI$ in interval $i \in I$, $Inj_{i,d}$, as the imports into Ontario from that *intertie zone* bus shall be:

$$Inj_{i,d} = FIGSch_{i,d}.$$

8.7.1.5 Injections and withdrawals at each bus shall be multiplied by one plus the marginal loss factor to reflect the losses or reduction in losses that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other after taking into account the adjustment for any discrepancy between total and marginal losses. Load or generation reduction associated with the demand constraint violation shall be subtracted from the total load or generation for the *real-time calculation engine* to produce a solution.

For interval $i \in I$, the *energy* balance shall be:

$$\begin{aligned} FL_i + \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} (1 + MglLoss_{i,b}) \cdot With_{i,b} \\ + \sum_{d \in DX} (1 + MglLoss_{i,d}) \cdot With_{i,d} - \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \\ = \sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} (1 + MglLoss_{i,b}) \cdot Inj_{i,b} \\ + \sum_{d \in DI} (1 + MglLoss_{i,d}) \cdot Inj_{i,d} - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \\ + LossAdj_i. \end{aligned}$$

8.7.2 Operating Reserve Requirements

8.7.2.1 *Operating reserve* shall be scheduled to meet system-wide requirements for synchronized *ten-minute operating reserve*, total *ten-*

minute operating reserve, and *thirty-minute operating reserve* while respecting all applicable regional minimum requirements and regional maximum restrictions for *operating reserve*.

8.7.2.2 Constraint violation penalty curves shall be used to impose a penalty cost for not meeting the *IESO's* system-wide *operating reserve* requirements, not meeting a regional minimum requirement, or not adhering to a regional maximum restriction. Full *operating reserve* requirements shall be scheduled unless the cost of doing so would be higher than the applicable penalty cost. For each interval $i \in I$:

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \geq TOT10S_i;$$

$$\sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{b \in B^{DL}} \left(\sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \right) + \sum_{b \in B^{DG}} \left(\sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \right) + \sum_{d \in DX} F10NXLSch_{i,d} + \sum_{d \in DI} F10NIGSch_{i,d} + \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \geq TOT10R_i;$$

and

$$\sum_{b\in B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)+\sum_{b\in B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)+\sum_{d\in DX} F10NXLSch_{i,d}+\sum_{d\in DI} F10NIGSch_{i,d}+\sum_{b\in B^{DL}}\left(\sum_{j\in J_{i,b}^{30R}} S30RDL_{i,b,j}\right)+\sum_{b\in B^{DG}}\left(\sum_{k\in K_{i,b}^{30R}} S30RDG_{i,b,k}\right)+\sum_{d\in DX} F30RXLSch_{i,d}+\sum_{d\in DI} F30RIGSch_{i,d}+\sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \geq TOT30R_i.$$

8.7.2.3 The following constraints shall be applied for each interval $i\in I$ and each region $r\in ORREG$:

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right)+\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right)+\sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d}+\sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d}+\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \geq REGMin10R_{i,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right) + \sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right) + \sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d} + \sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d} - \sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \leq REGMax10R_{i,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right) + \sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right) + \sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d} + \sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d} - \sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \leq REGMax10R_{i,r};$$

$$\sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10S}} S10SDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10S}} S10SDG_{i,b,k}\right) + \sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{10N}} S10NDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{10N}} S10NDG_{i,b,k}\right) + \sum_{d\in D_r^{REG}\cap DX} F10NXLSch_{i,d} + \sum_{d\in D_r^{REG}\cap DI} F10NIGSch_{i,d} + \sum_{b\in B_r^{REG}\cap B^{DL}}\left(\sum_{j\in J_{i,b}^{30R}} S30RDL_{i,b,j}\right)+\sum_{b\in B_r^{REG}\cap B^{DG}}\left(\sum_{k\in K_{i,b}^{30R}} S30RDG_{i,b,k}\right) + \sum_{d\in D_r^{REG}\cap DX} F30RXLSch_{i,d} + \sum_{d\in D_r^{REG}\cap DI} F30RIGSch_{i,d} + \sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \geq REGMin30R_{i,r};$$

and

$$\sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{i,b}^{10S}} S10SDL_{i,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{i,b}^{10S}} S10SDG_{i,b,k} \right) + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{i,b}^{10N}} S10NDL_{i,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{i,b}^{10N}} S10NDG_{i,b,k} \right) + \sum_{d \in D_r^{REG} \cap DX} F10NXLSch_{i,d} + \sum_{d \in D_r^{REG} \cap DI} F10NIGSch_{i,d} + \sum_{b \in B_r^{REG} \cap B^{DL}} \left(\sum_{j \in J_{i,b}^{30R}} S30RDL_{i,b,j} \right) + \sum_{b \in B_r^{REG} \cap B^{DG}} \left(\sum_{k \in K_{i,b}^{30R}} S30RDG_{i,b,k} \right) + \sum_{d \in D_r^{REG} \cap DX} F30RXLSch_{i,d} + \sum_{d \in D_r^{REG} \cap DI} F30RIGSch_{i,d} - \sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w} \leq REGMax30R_{i,r}.$$

8.7.3 IESO Internal Transmission Limits

8.7.3.1 A set of *energy* schedules shall be produced that do not violate any *security* limits in the pre-contingency state and the post-contingency state subject to the remainder of this section 8.7.3. The total amount of *energy* scheduled to be injected and withdrawn at each bus used by the *energy* balance constraint in section 8.7.1.5, shall be used to produce these schedules.

8.7.3.2 Pre-contigency, $SPreITLViol_{f,i,w}$, and post-contingency, $SITLViol_{c,f,i,w}$, transmission limit violation variables shall allow the *real-time calculation engine* to find a solution.

8.7.3.3 For all intervals $i \in I$ and *facilities* $f \in F_i$, the linearized constraints for violated pre-contingency limits obtained from the *security* assesment function shall take the form:

$$\sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} PreConSF_{i,f,b} \cdot Inj_{i,b} - \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} PreConSF_{i,f,b} \cdot With_{i,b} + \sum_{d \in DI} PreConSF_{i,f,d} \cdot Inj_{i,d} - \sum_{d \in DX} PreConSF_{i,f,d} \cdot With_{i,d} - \sum_{w=1..N_{PreITLViol_{f,i}}} SPreITLViol_{f,i,w} \leq AdjNormMaxFlow_{i,f}.$$

8.7.3.4 For all intervals $i \in I$, contingencies $c \in C$, and *facilities* $f \in F_{i,c}$, the linearized constraints for violated post-contingency limits obtained from the *security* assesment function shall take the form:

$$\sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} SF_{i,c,f,b} \cdot Inj_{i,b} - \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} SF_{i,c,f,b} \cdot With_{i,b} + \sum_{d \in DI} SF_{i,c,f,d} \cdot Inj_{i,d} - \sum_{d \in DX} SF_{i,c,f,d} \cdot With_{i,d} - \sum_{w=1..N_{ITLViol_{c,f,i}}} SITLViol_{c,f,i,w} \leq AdjEmMaxFlow_{i,c,f}.$$

8.7.4 Penalty Price Variable Bounds

8.7.4.1 Penalty price variables shall be restricted to the ranges determined by the constraint violation penalty curves for the Real-Time Scheduling algorithm and for all intervals $i \in I$:

$0 \leq SLdViol_{i,w} \leq QLdViolSch_{i,w}$ for all $w \in \{1,..,N_{LdViol_i}\}$;

$0 \leq SGenViol_{i,w} \leq QGenViolSch_{i,w}$ for all $w \in \{1,..,N_{GenViol_i}\}$;

$0 \leq S10SViol_{i,w} \leq Q10SViolSch_{i,w}$ for all $w \in \{1,..,N_{10SViol_i}\}$;

$0 \leq S10RViol_{i,w} \leq Q10RViolSch_{i,w}$ for all $w \in \{1,..,N_{10RViol_i}\}$;

$0 \leq S30RViol_{i,w} \leq Q30RViolSch_{i,w}$ for all $w \in \{1,..,N_{30RViol_i}\}$;

$0 \leq SREG10RViol_{r,i,w} \leq QREG10RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG10RViol_i}\}$;

$0 \leq SREG30RViol_{r,i,w} \leq QREG30RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG30RViol_i}\}$;

$0 \leq SXREG10RViol_{r,i,w} \leq QXREG10RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG10RViol_i}\}$;

$0 \leq SXREG30RViol_{r,i,w} \leq QXREG30RViolSch_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG30RViol_i}\}$;

$0 \leq SPreITLViol_{f,i,w} \leq QPreITLViolSch_{f,i,w}$ for all $f \in F_i$, $w \in \{1,..,N_{PreITLViol_{f,i}}\}$;

and

$0 \leq SITLViol_{c,f,i,w} \leq QITLViolSch_{c,f,i,w}$ for all $c \in C, f \in F_{i,c}$, $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$.

8.8 Outputs

8.8.1 Outputs for the Real-Time Scheduling algorithm includes *resource* schedules.

9 Real-Time Pricing

9.1 Purpose

9.1.1 The Real-Time Pricing algorithm shall perform a *security*-constrained economic *dispatch* to maximize gains from trade to meet the *IESO's* province-wide non-*dispatchable demand* forecast and the *IESO*-specified *operating reserve* requirements for each interval of the real-time look-ahead period.

9.2 Information, Sets, Indices and Parameters

9.2.1 Information, sets, indices and parameters used by the Real-Time Pricing algorithm are described in sections 3 and 4. In addition, the following *resource* schedules from the Real-Time Scheduling algorithm in section 8 shall be used in the Real-Time Pricing algorithm:

9.2.1.1 $SD_{i,b}^{RTS} \in \{0,1\}$, which designates whether the *dispatchable generation resource* at bus $b \in B^{NQS}$ was scheduled on a shutdown trajectory in interval $i \in I$ such that $EvalSD_{i,b} = 1$;

9.2.1.2 $SDLInitSch_{0,b}$, which designates the initial schedule for the *dispatchable load* at bus $b \in B^{DL}$ used in the Real-Time Scheduling algorithm in section 8; and

9.2.1.3 $SDGInitSch_{0,b}$, which designates the initial schedule for the *dispatchable generation resource* at bus $b \in B^{DG}$ used in the Real-Time Scheduling algorithm in section 8.

9.3 Variables and Objective Function

9.3.1 The Real-Time Pricing algorithm shall solve for the same variables as the Real-Time Scheduling algorithm in section 8.3.1.

9.3.2 The objective function for the Real-Time Pricing algorithm shall maximize gains from trade by maximizing the expression in section 8.3.2 for the Real-Time Scheduling algorithm.

9.3.3 $ViolCost_i$ shall be calculated as follows:

$$
\begin{aligned}
ViolCost_i = & \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} \cdot PLdViolPrc_{i,w} \\
& - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} \cdot PGenViolPrc_{i,w} \\
& + \sum_{w=1..N_{10SViol_i}} S10SViol_{i,w} \cdot P10SViolPrc_{i,w} \\
& + \sum_{w=1..N_{10RViol_i}} S10RViol_{i,w} \cdot P10RViolPrc_{i,w} \\
& + \sum_{w=1..N_{30RViol_i}} S30RViol_{i,w} \cdot P30RViolPrc_{i,w} \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG10RViol_i}} SREG10RViol_{r,i,w} \cdot PREG10RViolPrc_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{REG30RViol_i}} SREG30RViol_{r,i,w} \cdot PREG30RViolPrc_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG10RViol_i}} SXREG10RViol_{r,i,w} \cdot PXREG10RViolPrc_{i,w} \right) \\
& + \sum_{r \in ORREG} \left(\sum_{w=1..N_{XREG30RViol_i}} SXREG30RViol_{r,i,w} \cdot PXREG30RViolPrc_{i,w} \right) \\
& + \sum_{f \in F_i} \left(\sum_{w=1..N_{PreITLViol_{f,i}}} SPreITLViol_{f,i,w} \cdot PPreITLViolPrc_{f,i,w} \right) \\
& + \sum_{c \in C} \sum_{f \in F_{i,c}} \left(\sum_{w=1..N_{ITLViol_{c,f,i}}} SITLViol_{c,f,i,w} \cdot PITLViolPrc_{c,f,i,w} \right).
\end{aligned}
$$

9.3.3.1 The constraints in section 9.4 shall apply to the Real-Time Pricing algorithm.

9.4 Constraints

9.4.1 The Real-Time Pricing algorithm optimization function shall apply the constraints described in sections 9.5 – 9.8.

9.5 Dispatch Data Constraints Applying to Individual Intervals

9.5.1 Scheduling Variable Bounds

9.5.1.1 The constraints in section 8.5.1 shall apply in the Real-Time Pricing algorithm, with the following exceptions for a *non-quick start resource* bus $b \in B^{NQS}$ and interval $i \in I$, where:

9.5.1.1.1 $AtZero_{i,b}$ shall be replaced by $AtZero_{i,b}^{RTP}$;

9.5.1.1.2 $AtMLP_{i,b}$ shall be replaced by $AtMLP_{i,b}^{RTP}$; and

9.5.1.1.3 $EvalSD_{i,b}$ shall be replaced by $EvalSD_{i,b}^{RTP}$.

9.5.2 Resource Initial Conditions

9.5.2.1 The initial schedule for a *dispatchable load* at bus $b \in B^{DL}$ shall be fixed to the *resource* initial schedules. For all *dispatchable load* buses $b \in B^{DL}$:

$$\sum_{j \in J_{0,b}^{E}} SDL_{0,b,j} = SDLInitPrc_{0,b}$$

9.5.2.2 The initial schedule for a *dispatchable generation resource* at bus $b \in B^{DG}$ shall be fixed to the *resource* initial schedules. For all *dispatchable generation resource* buses $b \in B^{DG}$:

$$\sum_{k \in K_{0,b}^{E}} SDG_{0,b,k} = SDGInitPrc_{0,b}$$

9.5.3 Resource Minimums and Maximums

9.5.3.1 The constraints in section 8.5.3 shall apply in the Real-Time Pricing algorithm, with the following exception:

9.5.3.1.1 $AtMLP_{i,b}$ shall be replaced by $AtMLP_{i,b}^{RTP}$

where $AtMLP_{i,b}^{RTP}$ is determined in accordance with section 9.8.1.

9.5.4 Operating Reserve Requirements

9.5.4.1 The constraints in section 8.5.4 shall apply in the Real-Time Pricing algorithm.

9.5.5 Pseudo-Units

9.5.5.1 The constraints in section 8.5.5 shall apply in the Real-Time Pricing algorithm.

9.5.6 Dispatchable Hydroelectric Generation Resources

9.5.6.1 The constraints in section 8.5.6 shall apply in the Real-Time Pricing algorithm.

9.6 Dispatch Data Inter-Interval/Multi-Interval Constraints

9.6.1 Energy Ramping

9.6.1.1 The constraints in section 8.6.1 shall apply in the Real-Time Pricing algorithm.

9.6.2 Non-Quick Start Resource Start-up and Shutdown

9.6.2.1 The constraints in section 8.6.2 shall apply in the Real-Time Pricing algorithm, with the exception of the *non-quick start resource* start-up and shutdown statuses, which are determined in accordance with section 9.8.1.

9.6.3 Operating Reserve Ramping

9.6.3.1 The constraints in section 8.6.3 shall apply in the Real-Time Pricing algorithm.

9.7 Constraints for Reliability Requirements

9.7.1 Energy Balance

9.7.1.1 The constraint in section 8.7.1 shall apply in the Real-Time Pricing algorithm, with the following exceptions:

9.7.1.1.1 $FXLSch_{i,d}$ shall be replaced by $FXLPrc_{i,d}$ in section 8.7.1.2;

9.7.1.1.2 $FIGSch_{i,d}$ shall be replaced by $FIGPrc_{i,d}$ in section 8.7.1.4; and

9.7.1.1.3 The *energy* balance constraint in section 8.7.1.5 shall be modified to account for the *demand* adjustment required to calculate *locational marginal prices* when a voltage reduction or load shedding has been implemented, as follows:

$$FL_i + CAAdj_i + \sum_{b \in B^{DL} \cup B^{HDR} \cup B^{NoBid}} (1 + MglLoss_{i,b}) \cdot With_{i,b} + \sum_{d \in DX} (1 + MglLoss_{i,d}) \cdot With_{i,d} - \sum_{w=1..N_{LdViol_i}} SLdViol_{i,w} = \sum_{b \in B^{NDG} \cup B^{DG} \cup B^{NoOffer}} (1 + MglLoss_{i,b}) \cdot Inj_{i,b} + \sum_{d \in DI} (1 + MglLoss_{i,d}) \cdot Inj_{i,d} - \sum_{w=1..N_{GenViol_i}} SGenViol_{i,w} + LossAdj_i.$$

9.7.2 Operating Reserve Requirements

9.7.2.1 The constraint in section 8.7.2 shall apply in the Real-Time Pricing algorithm, with the following exceptions:

9.7.2.1.1 $F10NXLSch_{i,d}$ shall be replaced by $F10NXLPrc_{i,d}$ for all $d \in DX$;

9.7.2.1.2 $F10NIGSch_{i,d}$ shall be replaced by $F10NIGPrc_{i,d}$ for all $d \in DI$;

9.7.2.1.3 $F30RXLSch_{i,d}$ shall be replaced by $F30RXLPrc_{i,d}$ for all $d \in DX$; and

9.7.2.1.4 $F30RIGSch_{i,d}$ shall be replaced by $F30RIGPrc_{i,d}$ for all $d \in DI$.

9.7.3 IESO Internal Transmission Limits

9.7.3.1 The constraints in section 8.7.3 shall apply in the Real-Time Pricing algorithm except the sensitivities and limits considered shall be those provided by the most recent *security* assessment function iteration of the Real-Time Pricing algorithm.

9.7.4 Penalty Price Variable Bounds

9.7.4.1 The following constraints shall restrict the penalty price variables to the ranges determined by the constraint violation penalty curves. For all intervals $i \in I$:

$0 \le SLdViol_{i,w} \le QLdViolPrc_{i,w}$ for all $w \in \{1,..,N_{LdViol_i}\}$;

$0 \le SGenViol_{i,w} \le QGenViolPrc_{i,w}$ for all w $\in \{1,..,N_{GenViol_i}\}$;

$0 \le S10SViol_{i,w} \le Q10SViolPrc_{i,w}$ for all $w \in \{1,..,N_{10SViol_i}\}$;

$0 \le S10RViol_{i,w} \le Q10RViolPrc_{i,w}$ for all $w \in \{1,..,N_{10RViol_i}\}$;

$0 \le S30RViol_{i,w} \le Q30RViolPrc_{i,w}$ for all $w \in \{1,..,N_{30RViol_i}\}$;

$0 \le SREG10RViol_{r,i,w} \le QREG10RViolPrc_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG10RViol_i}\}$;

$0 \le SREG30RViol_{r,i,w} \le QREG30RViolPrc_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{REG30RViol_i}\}$;

$0 \le SXREG10RViol_{r,i,w} \le QXREG10RViolPrc_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG10RViol_i}\}$

$0 \le SXREG30RViol_{r,i,w} \le QXREG30RViolPrc_{i,w}$ for all $r \in ORREG$, $w \in \{1,..,N_{XREG30RViol_i}\}$

$0 \le SPreITLViol_{f,i,w} \le QPreITLViolPrc_{f,i,w}$ for all $f \in F_i$, $w \in \{1,..,N_{PreITLViol_{f,i}}\}$; and

$0 \le SITLViol_{c,f,i,w} \le QITLViolPrc_{c,f,i,w}$ for all $c \in C$, $f \in F_{i,c}$, $w \in \{1,..,N_{ITLViol_{c,f,i}}\}$.

9.8 Constraints to Ensure the Price Setting Eligibility of Offer/Bid Laminations

9.8.1 Non-Quick Start Resources

9.8.1.1 The Real-Time Pricing algorithm shall modify the following start-up and shutdown statuses for a *non-quick start resource* at bus $b \in B^{NQS}$ and interval $i \in I$:

9.8.1.1.1 $AtZero_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* is not scheduled and is calculated as follows:

$$AtZero_{i,b}^{RTP} = AtZero_{i,b}.$$

9.8.1.1.2 $SU_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* must be scheduled for *energy* on its start-up trajectory and is calculated as follows:

$$SU_{i,b}^{RTP} = SU_{i,b}.$$

9.8.1.1.3 $AtMLP_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* is scheduled for *energy* at or above the *minimum loading point* and is calculated as follows:

$$AtMLP_{i,b}^{RTP} = \begin{cases} AtMLP_{i,b} & if\ EvalSD_{i,b} = 0 \\ 1 - SD_{i,b}^{RTS} & if\ EvalSD_{i,b} = 1 \end{cases}$$

9.8.1.1.4 $EvalSD_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* can be scheduled for *energy* below the *minimum loading point* and is calculated as follows:

$$EvalSD_{i,b}^{RTP} = 0.$$

9.8.1.1.5 $SD_{i,b}^{RTP} \in \{0,1\}$, which designates that the *resource* must be scheduled for *energy* on its shutdown trajectory and is calculated as follows:

$$SD_{i,b}^{RTP} = \begin{cases} SD_{i,b} & if\ EvalSD_{i,b} = 0 \\ SD_{i,b}^{RTS} & if\ EvalSD_{i,b} = 1 \end{cases}$$

9.9 Outputs

9.9.1 Outputs for the Real-Time Pricing algorithm include:

9.9.1.1 shadow prices;

9.9.1.2 *locational marginal prices* and their components; and

9.9.1.3 sensitivity factors.

10 Pseudo-Unit Modelling

10.1 Pseudo-Unit Model Parameters

10.1.1 The *real-time calculation engine* shall use the following registration and *dispatch data* to determine the underlying relationship between a *pseudo-unit* and the associated physical *resources* for a combined cycle *facility* with K combustion turbines and one steam turbine:

10.1.1.1 $CMCR_k$, which designates the registered *maximum continuous rating* of combustion turbine $k \in \{1,..,K\}$ in MW;

10.1.1.2 $CMLP_k$, which designates the *minimum loading point* of combustion turbine $k \in \{1,..,K\}$ in MW;

10.1.1.3 $SMCR$, which designates the registered *maximum continuous rating* of the steam turbine in MW;

10.1.1.4 $SMLP$, which designates the *minimum loading point* of the steam turbine in MW for a 1x1 configuration;

10.1.1.5 SDF, which designates the amount of duct firing capacity available on the steam turbine in MW;

10.1.1.6 $STPortion_k$, which designates the percentage of the steam turbine capacity attributed to *pseudo-unit* $k \in \{1,..,K\}$; and

10.1.1.7 $CSCM_k \in \{0,1\}$, which designates whether *pseudo-unit* $k \in \{1,..,K\}$ is flagged to operate in *single cycle mode*.

10.1.2 The *real-time calculation engine* shall calculate the following model parameters for each *pseudo-unit* $k \in \{1,..K\}$:

10.1.2.1 $MMCR_k$, which designates the *maximum continuous rating* of *pseudo-unit* k and is calculated as follows:

$$CMCR_k + SMCR \cdot STPortion_k \cdot (1 - CSCM_k)$$

10.1.2.2 $MMLP_k$, which designates the *minimum loading point* of *pseudo-unit* k and is calculated as follows:

$$CMLP_k + SMLP \cdot (1 - CSCM_k)$$

10.1.2.3 MDF_k, which designates the duct firing capacity of *pseudo-unit* k and is calculated as follows:

$$SDF \cdot STPortion_k \cdot (1 - CSCM_k)$$

10.1.2.4 MDR_k, which designates the *dispatchable* capacity of *pseudo-unit* k and is calculated as follows:

$$MMCR_k - MMLP_k - MDF_k$$

10.1.3 The *real-time calculation engine* shall define three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

10.1.3.1 The *minimum loading point* region shall be the capacity between 0 and $MMLP_k$;

10.1.3.2 The *dispatchable* region shall be the capacity between $MMLP_k$ and $MMLP_k + MDR_k$;

10.1.3.3 The duct firing region shall be the capacity between $MMLP_k + MDR_k$ and $MMCR_k$.

10.1.4 The *real-time calculation engine* shall calculate the associated combustion turbine and steam turbine shares for the three operating regions of *pseudo-unit* $k \in \{1,..K\}$, as follows:

10.1.4.1 For the minimum loading point region:

10.1.4.1.1 Steam turbine share: $STShareMLP_k = \frac{SMLP \cdot (1 - CSCM_k)}{MMLP_k}$;

10.1.4.1.2 Combustion turbine share: $CTShareMLP_k = \frac{CMLP_k}{MMLP_k}$; and

10.1.4.2 For the *dispatchable* region:

10.1.4.2.1 Steam turbine share:

$$STShareDR_k = \frac{(1 - CSCM_k)(SMCR \cdot STPortion_k - SMLP \cdot SDF \cdot STPortion_k)}{MDR_k}$$; and

10.1.4.2.2 Combustion turbine share:

$$CTShareDR_k = \frac{CMCR_k - CMLP_k}{MDR_k}$$; and

10.1.4.3 For the duct firing region:

10.1.4.3.1 Steam turbine share shall be equal to 1; and

10.1.4.3.2 Combustion turbine share shall be equal to 0.

10.2 Application of Physical Resource Deratings to the Pseudo-Unit Model

10.2.1 The *real-time calculation engine* shall apply deratings submitted by *market participants* to the applicable *dispatchable* capacity and duct firing capacity parameters for a *pseudo-unit*, where:

10.2.1.1 $CTCap_{i,k}$ designates the capacity of combustion turbine $k \in \{1,..,K\}$ in interval i as determined by submitted deratings;

10.2.1.2 $STCap_i$ designates the capacity of the steam turbine in interval i as determined by submitted deratings; and

10.2.1.3 $TotalQ_{i,k}$ designates the total *offered* quantity of *energy* for *pseudo-unit* $k \in \{1,..,K\}$ in interval i.

10.2.2 The *real-time calculation engine* shall solve for the following operating region parameters for each *pseudo-unit* $k \in \{1,..,K\}$:

10.2.2.1 $MLP_{i,k}$ designates the *minimum loading point* of *pseudo-unit* k in interval i;

10.2.2.2 $DR_{i,k}$ designates the *dispatchable* capacity region of *pseudo-unit* k in interval i; and

10.2.2.3 $DF_{i,k}$ designates the duct firing capacity region of *pseudo-unit* k in interval i.

10.2.3 Pre-Processing of De-rates

10.2.3.1 The *real-time calculation engine* shall perform the following pre-processing steps to determine the available operating regions for a *pseudo-unit* based on the combustion turbine and steam turbine share and the application of the *pseudo-unit* deratings. For *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$:

10.2.3.1.1 Step 1: Calculate the amount of the *offer* for *energy* that is attributed to each combustion turbine ($CTAmt_{i,k}$) and steam turbine portion ($STAmt_{i,k}$):

If $TotalQ_{i,k} < MMLP_k$, then:

Calculate $CTAmt_{i,k} = 0$; and

Calculate $STAmt_{i,k} = 0$.

Otherwise:

$CTAmtMLP = MMLP_k \cdot CTShareMLP_k$; and

$STAmtMLP = MMLP_k \cdot STShareMLP_k$.

If $TotalQ_{i,k} > MMLP_k + MDR_k$, then:

$CTAmtDR = MDR_k \cdot CTShareDR_k$;

$STAmtDR = MDR_k \cdot STShareDR_k$; and

$STAmtDF = (1 - CSCM_k) \cdot (TotalQ_{i,k} - MMLP_k - MDR_k)$.

Otherwise:

$CTAmtDR = (TotalQ_{i,k} - MMLP_k) \cdot CTShareDR_k$;

$STAmtDR = (TotalQ_{i,k} - MMLP_k) \cdot STShareDR_k$;

$STAmtDF = 0$;

$CTAmt_{i,k} = CTAmtMLP + CTAmtDR$; and

$STAmt_{i,k} = STAmtMLP + STAmtDR + STAmtDF$.

10.2.3.1.2 Step 2: Allocate the steam turbine capacity to each *pseudo-unit*:

$$PRSTCap_{i,k} = \left(\frac{STAmt_{i,k}}{\sum_{w \in \{1,..,K\}} STAmt_{i,w}} \right) \cdot STCap_i$$

10.2.3.1.3 Step 3: Determine if the *pseudo-unit* is available:

If $CTAmt_{i,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $STAmt_{i,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

If $CTCap_{i,k} < CMLP_k$, then the *pseudo-unit* is unavailable.

If $PRSTCap_{i,k} < SMLP \cdot (1 - CSCM_k)$, then the *pseudo-unit* is unavailable.

10.2.3.1.4 Step 4: Initialize the operating region parameters for interval $i \in I$ to the model parameter values:

Set $MLP_{i,k} = MMLP_k$.

Set $DR_{i,k} = MDR_k$.

Set $DF_{i,k} = MDF_k$.

10.2.3.1.5 Step 5: Apply the derating for the combustion turbine to the *dispatchable* region:

Calculate P so that $CMLP_k + P \cdot CTShareDR_k \cdot MDR_k = CTCap_{i,k}$; and

Set $DR_{i,k} = min(DR_{i,k}, P \cdot MDR_k)$.

10.2.3.1.6 Step 6: Apply the derating for the steam turbine to the duct firing and *dispatchable* regions for *pseudo-units* not operating in *single cycle mode*:

Calculate R so that $SMLP + R \cdot STShareDR_k \cdot MDR_k = PRSTCap_{i,k}$.

If $R \leq 1$, update $DF_{i,k} = 0$, and $DR_{i,k} = min(DR_{i,k}, R \cdot MDR_k)$.

If $R > 1$, update $DF_{i,k} = min(DF_{i,k}, PRSTCap_{i,k} - SMLP - STShareDR_k \cdot MDR_k)$.

10.2.4 Available Energy Laminations

10.2.4.1 The *real-time calculation engine* shall determine the *offer* quantity laminations that may be scheduled for *energy* and *operating reserve* in each operating region for interval $i \in I$ for each *pseudo-unit* $k \in \{1,..,K\}$, subject to section 10.2.4.2, where:

10.2.4.1.1 $QMLP_{i,k}$ designates the total quantity that may be scheduled in the *minimum loading point* region;

10.2.4.1.2 $QDR_{i,k}$ designates the total quantity that may be scheduled in the *dispatchable* region; and

10.2.4.1.3 $QDF_{i,k}$ designates the total quantity that may be scheduled in the duct firing region.

10.2.4.2 The available *offered* quantity laminations shall be subject to the following conditions:

$0 \leq QMLP_{i,k} \leq MLP_{i,k}$;

$0 \leq QDR_{i,k} \leq DR_{i,k}$;

$0 \leq QDF_{i,k} \leq DF_{i,k}$;

if $QMLP_{i,k} < MLP_{i,k}$, then the *pseudo-unit* is unavailable and $QDR_{i,k} = QDF_{i,k} = 0$; and

if $QDR_{i,k} < DR_{i,k}$, then $QDF_{i,k} = 0$.

10.3 Convert Physical Resource Constraints to Pseudo-Unit Constraints

10.3.1 The *real-time calculation engine* shall convert physical *resource* constraints to *pseudo-unit* constraints, where:

10.3.1.1 $PSUMin^{q}_{i,k}$ designates the minimum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a minimum limitation on *pseudo-unit* k, then $PSUMin^{q}_{i,k}$ shall be set equal to 0;

10.3.1.2 $PSUMax^{q}_{i,k}$ designates the maximum limitation on *pseudo-unit* k determined by translating constraint q. When constraint q does not provide a maximum limitation on *pseudo-unit* k, then $PSUMax^{q}_{i,k}$ shall be set equal to $MLP_{i,k} + DR_{i,k} + DF_{i,k}$; and

10.3.1.3 $CTCmtd_{i,k} \in \{0,1\}$ designates whether combustion turbine $k \in \{1,..K\}$ is considered committed in interval $i \in I$.

10.3.2 The *real-time calculation engine* shall calculate the minimum and maximum limitations, subject to section 10.3.3.1, as follows:

10.3.2.1 Minimum limitation: $MinDG_{i,k} = max_{q \in \{1,..Q\}} PSUMin^{q}_{i,k}$

10.3.2.2 Maximum limitation: $MaxDG_{i,k} = min_{q \in \{1,..Q\}} PSUMax^{q}_{i,k}$

where Q designates the number of constraints impacting a combined cycle *facility* that have been provided to the *real-time calculation engine*.

10.3.3 Pseudo-Unit Minimum and Maximum Constraints

10.3.3.1 *Pseudo-unit* minimum and maximum constraints shall be calculated as follows:

10.3.3.1.1 $PSUMin_{i,k} = PMin$ where $PMin$ shall be a minimum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$; and

10.3.3.1.2 $PSUMax_{i,k} = PMax$ where $PMax$ shall be a maximum constraint provided on *pseudo-unit* $k \in \{1,..,K\}$ for interval $i \in I$.

10.3.4 Combustion Turbine Minimum and Maximum Constraints

10.3.4.1 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMin < MLP_{i,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = CTMin \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right).$$

$$STMinDR = 0.$$

Otherwise, if $CTMin \geq MLP_{i,k} \cdot CTShareMLP_k$, then set

$$STMinMLP = MLP_{i,k} \cdot STShareMLP_k.$$

$$STMinDR = \left(CTMin - MLP_{i,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

Therefore:

$$PSUMin_{i,k} = CTMin + STMinMLP + STMinDR.$$

10.3.4.2 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine minimum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMin_{i,k} = CTMin.$$

10.3.4.3 If the *pseudo-unit* is not flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

If $CTMax < MLP_{i,k} \cdot CTShareMLP_k$, then $PSUMax_{i,k} = 0$ and the *pseudo-unit* is unavailable.

Otherwise, calculate the value of the constraint on the steam turbine within the *minimum loading point* and *dispatchable* regions:

$$STMaxMLP = MLP_{i,k} \cdot STShareMLP_k$$

$$STMaxDR = \left(CTMax - MLP_{i,k} \cdot CTShareMLP_k\right) \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right)$$

$$PSUMax_{i,k} = CTMax + STMaxMLP + STMaxDR$$

10.3.4.4 If a *pseudo-unit* is flagged to operate in *single cycle mode*, then the combustion turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PSUMax_{i,k} = CTMax.$$

10.3.5 Steam Turbine Minimum and Maximum Constraints

10.3.5.1 The *real-time calculation engine* shall convert a stream turbine minimum constraint to a *pseudo-unit* constraints as follows:

10.3.5.1.1 Step 1: Identify $A \subseteq \{1,..,K\}$, which designates the set of *pseudo-units* to which the constraint may be allocated where *pseudo-unit* $k \in \{1,..,K\}$ is placed in set A if and only if $CSCM_k = 0$ and $CTCmtd_{i,k} = 1$. If the set A is empty, then no further steps are required, otherwise proceed to Step 2.

10.3.5.1.2 10.3.5.1.2 Step 2: Determine the steam turbine portion of the capacity for *pseudo-unit* $k \in A$:

$$STCap_k = QMLP_{i,k} \cdot STShareMLP_k + QDR_{i,k} \cdot STShareDR_k + QDF_{i,k}.$$

10.3.5.1.3 Step 3: Allocate the *STMin* constraint to each *pseudo-unit* $k \in A$, where *STMin* constraint shall be allocated equally to each *pseudo-unit* $k \in A$, where $STPMin_k$ is limited by $STCap_k$.

10.3.5.1.4 Step 4: The steam turbine portion minimum constraint shall be converted to a *pseudo-unit* constraint ,where for each *pseudo-unit* $k \in A$:

If $STPMin_k < MLP_{i,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = STPMin_k \cdot \left(\frac{CTShareMLP_k}{STShareMLP_k}\right); \text{ and}$$

$$CTMinDR_k = 0.$$

Otherwise, if $STPMin_k \geq MLP_{i,k} \cdot STShareMLP_k$, then set

$$CTMinMLP_k = MLP_{i,k} \cdot CTShareMLP_k; \text{ and}$$

$$CTMinDR_k = \left(STPMin_k - MLP_{i,k} \cdot STShareMLP_k\right) \cdot \left(\frac{CTShareDR_k}{STShareDR_k}\right).$$

Therefore:

$$PSUMin_{i,k} = STPMin_k + CTMinMLP_k + CTMinDR_k.$$

10.3.5.1.4 If *pseudo-units* with sufficient steam turbine capacity are not commited, then the *real-time calculation engine* shall not convert the entire quantity of the steam turbine minimum constraint to *pseudo-unit* constraints.

10.3.5.2 The steam turbine maximum constraint shall be converted to a *pseudo-unit* constraint as follows:

$$PRSTMax_{i,k} = \left(\frac{STAmt_{i,k}}{\sum_{w \in \{1,..,K\}} STAmt_{i,w}}\right) \cdot STMax.$$

If the converted steam turbine maximum constraint limits the steam turbine portion to below its *minimum loading point*, then

$$PSUMax_{i,k} = 0.$$

Otherwise, calculate R so that
$SMLP + R{\cdot}STShareDR_k{\cdot}MDR_k = PRSTMax_{i,k}$

If $R \leq 1$, set $PSUMax_{i,k} = MLP_{i,k} + min(DR_{i,k}, R{\cdot}MDR_k)$.

If $R > 1$, set $PSUMax_{i,k} = MLP_{i,k} + DR_{i,k} + PRSTMax_{i,k}\text{-}SMLP\text{-}STShareDR_k{\cdot}MDR_k$.

10.3.5.3 If the steam turbine minimum and maximum constraints are equal but do not convert to equal *pseudo-unit* minimum and maximum constraints, then the steam turbine minimum constraint conversion in section 10.3.5.1 shall be used to determine equal *pseudo-unit* minimum and maximum constraints.

10.4 Steam Turbine Forced Outages

10.4.1 If the steam turbine experiences a *forced outage*, the *real-time calculation engine* shall evaluate the corresponding *pseudo-units* as being *offered* in *single cycle mode.*

10.5 Determination of Energy Management System MW Values for Pseudo-Units

10.5.1 The *real-time calculation engine* shall determine the effective *energy* management system MW value for each *pseudo-unit* from the *IESO's energy* management system MW values for the corresponding physical *resources*, where:

10.5.1.1 $CTTel_k$ designates the *energy* management system MW value for combustion turbine $k \in \{1,..,K\}$;

10.5.1.2 $STTel$ designates the *energy* management system MW value for the steam turbine;

10.5.1.3 $PSUTel_k$ designates the effective *energy* management system MW value for *pseudo-unit* $k \in \{1,..,K\}$;

10.5.1.4 $TMLP_k$ designates the effective *minimim loading point* operating range for the time at which *energy* management system MW value was determined;

10.5.1.5 TDR_k designates the effective *dispatchable* region operating range for the time at which *energy* management system MW value was determined; and

10.5.1.6 TDF_k, designates the effective duct firing region operating range for the time at which *energy* management system MW value was determined.

10.5.2 The *real-time calculation engine* shall determine the effective *energy* management system MW values for *pseudo-units* as follows:

10.5.2.1 Step 1: For all combustion turbines, assign the following *energy* management system MW values to the corresponding *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.1.1 $CTMLPTel_k$, which designates the MW value assigned to the combustion turbine's share of the *minimum loading point* region and is calculated as follows:

$$CTMLPTel_k = min\{CTTel_k, CTShareMLP_k \cdot TMLP_k\}.$$

10.5.2.1.2 $CTDRTel_k$, which designates the MW value assigned to the combustion turbine's share of the *dispatchable* region and is calculated as follows:

If $CTMLPTel_k < CTTel_k$, then set $CTDRTel_k = min\{(CTTel_k - CTMLPTel_k), CTShareDR_k \cdot TDR_k\}$

Otherwise, set $CTDRTel_k = 0$.

10.5.2.2 Step 2: Determine the maximum *energy* management system MW value for the steam turbine that may be assigned to the steam turbine's share of the *pseudo-unit's minimum loading point* and *dispatchable* regions based on the amount assigned to the combustion turbine's share of the *minimum loading point* and *dispatchable* regions. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.2.1 $STMLPMax_k$ designates the maximum MW value that may be assigned to the steam turbine's share of the *minimum loading point* region and is calculated as follows:

$$STMLPMax_k = CTMLPTel_k \cdot \left(\frac{STShareMLP_k}{CTShareMLP_k}\right).$$

10.5.2.2.2 $STDRMax_k$ designates the maximum MW value that may be assigned to the steam turbine's share of the *dispatchable* region and is calculated as follows:

$$STDRMax_k = CTDRTel_k \cdot \left(\frac{STShareDR_k}{CTShareDR_k}\right).$$

10.5.2.3 Step 3: Allocate the *energy* management system MW value for the steam turbine to the *minimum loading point* and *dispatchable* regions of the *pseudo-unit* in proportion to the maximum amount that may be allocated. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.3.1 $STMLPTel_k$ designates the MW value assigned to the steam turbine share of the *minimum loading point* region and is calculated as follows:

$$STMLPTel_k = min\left\{STMLPMax_k, \left(\frac{STMLPMax_k}{\sum_{w=1..K}(STMLPMax_w + STDRMax_w)}\right) \cdot STTel\right\}.$$

10.5.2.3.2 $STDRTel_k$ designates the MW value assigned the steam turbine share of the *dispatchable* region and is calculated as follows

$$STDRTel_k = min\left\{STDRMax_k, \left(\frac{STDRMax_k}{\sum_{w=1..K}(STMLPMax_w + STDRMax_w)}\right) \cdot STTel\right\}.$$

10.5.2.4 Step 4: Determine the remaining portion of the *energy* management system MW value for the steam turbine that is yet to be distributed ($STRemTel$) as follows:

$$STRemTel = STTel - \sum_{k=1..K}(STMLPTel_k + STDRTel_k).$$

10.5.2.5 Step 5: Determine the maximum *energy* management system MW value for the remaining steam turbine that may be assigned to the duct firing region for the *pseudo-unit* based on whether the *pseudo-unit* is fully loaded for its *minimum loading point* and *dispatchable* regions. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.5.1 $STDFMax_k$ designates the maximum MW value that may be assigned to the duct firing region and is calculated as follows:

If $(CTMLPTel_k + CTDRTel_k + STMLPTel_k + STDRTel_k) \geq TMLP_k + TDR_k$, then set $STDFMax_k = TDF_k$

Otherwise, set $STDFMax_k = 0$.

10.5.2.6 Step 6: Distribute the remaining portion of the *energy* management system MW value for the steam turbine to the duct firing regions of the *pseudo-unit* in proportion to the maximum amount that may be allocated. For *pseudo-unit* $k \in \{1,..,K\}$:

10.5.2.6.1 $STDFTel_k$ designates the MW value assigned to the duct firing region and is calculated as follows:

$$STDFTel_k = min\left\{STDFMax_k, \left(\frac{STDFMax_k}{\sum_{w=1..K} STDFMax_w}\right) \cdot STRemTel\right\}.$$

10.5.2.7 Step 7: Determine the effective real-time *energy* management system MW value for the *pseudo-unit* by summing the MW values assigned to operating regions of the *pseudo-unit*. For *pseudo-unit* $k \in \{1,..,K\}$:

$PSUTel_k = CTMLPTel_k + CTDRTel_k + STMLPTel_k + STDRTel_k + STDFTel_k$.

10.6 Conversion of Pseudo-Unit Schedules to Physical Resource Schedules

10.6.1 For a combined cycle *facility* with K combustion turbines and one steam turbine, the *real-time calculation engine* shall compute the following *energy* and *operating reserve* schedules for interval $i \in I$:

10.6.1.1 $CTE_{i,k}$ designates the *energy* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.2 $STPE_{i,k}$ designates the *energy* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

10.6.1.3 STE_i designates the *energy* schedule for the steam turbine;

10.6.1.4 $CT10S_{i,k}$ designates the synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.5 $STP10S_{i,k}$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

10.6.1.6 $ST10S_i$ designates the synchronized *ten-minute operating reserve* schedule for the steam turbine;

10.6.1.7 $CT10N_{i,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.8 $STP10N_{i,k}$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$;

10.6.1.9 $ST10N_i$ designates the non-synchronized *ten-minute operating reserve* schedule for the steam turbine;

10.6.1.10 $CT30R_{i,k}$ designates the *thirty-minute operating reserve* schedule for combustion turbine $k \in \{1,..,K\}$;

10.6.1.11 $STP30R_{i,k}$ designates the *thirty-minute operating reserve* schedule for the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$; and

10.6.1.12 $ST30R_i$ designates the *thirty-minute operating reserve* schedule for the steam turbine.

10.6.2 The *real-time calculation engine* shall determine the following *energy* and *operating reserve* schedules for *pseudo-unit* $k \in \{1,..,K\}$ in interval $i \in I$:

10.6.2.1 $SE_{i,k}$ designates the total amount of *energy* scheduled and $SE_{i,k} = SEMLP_{i,k} + SEDR_{i,k} + SEDF_{i,k}$, where:

10.6.2.1.1 $SEMLP_{i,k}$ designates the portion of the schedule corresponding to the *minimum loading point* region, where $0 \leq SEMLP_{i,k} \leq QMLP_{i,k}$;

10.6.2.1.2 $SEDR_{i,k}$ designates the portion of the schedule corresponding to the *dispatchable* region, where $0 \leq SEDR_{i,k} \leq QDR_{i,k}$ and $SEDR_{i,k} > 0$ only if $SEMLP_{i,k} = QMLP_{i,k}$;

10.6.2.1.3 $SEDF_{i,k}$ designates the portion of the schedule corresponding to the duct firing region, where $0 \leq SEDF_{i,k} \leq QDF_{i,k}$ and $SEDF_{i,k} > 0$ only if $SEDR_{i,k} = QDR_{i,k}$;

10.6.2.2 $S10S_{i,k}$ designates the total amount of synchronized *ten-minute operating reserve* scheduled;

10.6.2.3 $S10N_{i,k}$ designates the total amount of non-synchronized *ten-minute operating reserve* scheduled. If the *pseudo-unit* cannot provide *operating reserve* from its duct firing region, then $0 \leq SE_{i,k} + S10S_{i,k} + S10N_{i,k} \leq QMLP_{i,k} + QDR_{i,k}$; and

10.6.2.4 $S30R_{i,k}$ designates the total amount of *thirty-minute operating reserve* scheduled, where $0 \leq SE_{i,k} + S10S_{i,k} + S10N_{i,k} + S30R_{i,k} \leq QMLP_{i,k} + QDR_{i,k} + QDF_{i,k}$.

10.6.3 The *real-time calculation engine* shall convert *pseudo-unit* schedules to physical *generation resource* schedules for *energy* and *operating reserve*, where:

10.6.3.1 $STOn \in \{0,1\}$ designates whether the steam turbine is currently online;

10.6.3.2 $CTE_{0,k}$ designates the initial *energy* schedule allocated to the combustion turbine $k \in \{1,..,K\}$; and

10.6.3.3 $STPE_{0,k}$ designates the initial *energy* schedule allocated to the steam turbine portion of *pseudo-unit* $k \in \{1,..,K\}$.

10.6.4 The *real-time calculation engine* shall convert *pseudo-unit* schedules to physical *resource* schedules for *energy* and *operating reserve*, as follows:

10.6.4.1 If $SE_{i,k} \geq MLP_{i,k}$, then:

$$CTE_{i,k} = SEMLP_{i,k} \cdot CTShareMLP_k + SEDR_{i,k} \cdot CTShareDR_k;$$

$$STPE_{i,k} = SEMLP_{i,k} \cdot STShareMLP_k + SEDR_{i,k} \cdot STShareDR_k + SEDF_{i,k};$$

$$RoomDR_{i,k} = QDR_{i,k} - SEDR_{i,k};$$

$$10SDR_{i,k} = min(RoomDR_{i,k}, S10S_{i,k});$$

$$10NDR_{i,k} = min(RoomDR_{i,k} - 10SDR_{i,k}, S10N_{i,k});$$

$$30RDR_{i,k} = min(RoomDR_{i,k} - 10SDR_{i,k} - 10NDR_{i,k}, S30R_{i,k});$$

$$CT10S_{i,k} = 10SDR_{i,k} \cdot CTShareDR_k;$$

$$STP10S_{i,k} = 10SDR_{i,k} \cdot STShareDR_k + (S10S_{i,k} - 10SDR_{i,k});$$

$CT10N_{i,k} = 10NDR_{i,k} \cdot CTShareDR_k$;

$STP10N_{i,k} = 10NDR_{i,k} \cdot STShareDR_k + (S10N_{i,k} - 10NDR_{i,k})$;

$CT30R_{i,k} = 30RDR_{i,k} \cdot CTShareDR_k$; and

$STP30R_{i,k} = 30RDR_{i,k} \cdot STShareDR_k + (S30R_{i,k} - 30RDR_{i,k})$.

10.6.4.2 If $SE_{i,k} < MLP_{i,k}$ and is on a ramp up trajectory, then the *energy* schedules for the combustion turbine and steam turbine are determined as follows:

10.6.4.3 If the steam turbine is not online, then the *pseudo-unit* schedule will be assigned to the combustion turbine as follows:

$CTE_{i,k} = SE_{i,k}$; and

$STPE_{i,k} = 0$.

10.6.4.4 If the steam turbine is online, the incremental *pseudo-unit* schedule will be assigned to the steam turbine until the assigned combustion turbine and steam turbine schedules adhere to the *pseudo-unit* model as follows:

If $\left(\frac{STPE_{i-1,k}}{STPE_{i-1,k}+CTE_{i-1,k}}\right) < STShareMLP_k$, then

$CTE_{i,k} = CTE_{i-1,k}$,

$STPE_{i,k} = SE_{i,k} - CTE_{i-1,k}$.

Otherwise:

$CTE_{i,k} = SE_{i,k} \cdot CTShareMLP_k$; and

$STPE_{i,k} = SE_{i,k} \cdot STShareMLP_k$.

10.6.4.5 If $SE_{i,k} < MLP_{i,k}$ and is on a ramp-down trajectory, then the *energy* schedules for the combustion turbine and steam turbine are determined as follows:

10.6.4.6 If the steam turbine is not online, then the *pseudo-unit* schedule will be assigned to the combustion turbine as follows:

$CTE_{i,k} = SE_{i,k}$; and

$STPE_{i,k} = 0$.

10.6.4.7 If the steam turbine is online, the *pseudo-unit* schedule will be assigned according to the *pseudo-unit* model as follows

$CTE_{i,k} = SE_{i,k} \cdot CTShareMLP_k$; and

$STPE_{i,k} = SE_{i,k} \cdot STShareMLP_k$.

10.6.4.8 If $SE_{i,k} < MLP_{i,k}$, then the *operating reserve* schedules for the combustion turbine and steam turbine are as follows:

$S10S_{i,k} = S10N_{i,k} = S30R_{i,k} = 0$;

$CT10S_{i,k} = 0$;

$STP10S_{i,k} = 0$;

$CT10N_{i,k} = 0$;

$STP10N_{i,k} = 0$;

$CT30R_{i,k} = 0$; and

$STP30R_{i,k} = 0$.

10.6.4.9 The steam turbines portion schedules from section 10.6.4.1 through 10.6.4.8 shall be summed to obtain the steam turbine schedule as follows:

$$STE_i = \sum_{k=1,..,K} STPE_{i,k} ;$$

$$ST10S_i = \sum_{k=1,..,K} STP10S_{i,k} ;$$

$$ST10N_i = \sum_{k=1,..,K} STP10N_{i,k} ;$$

and

$$ST30R_i = \sum_{k=1,..,K} STP30R_{i,k} ;$$

11 Pricing Formulas

11.1 Purpose

11.1.1 The *real-time calculation engine* shall calculate *locational marginal prices* using shadow prices, constraint sensitivities and marginal loss factors.

11.2 Sets, Indices and Parameters

11.2.1 The sets, indices and parameters used to calculate *locational marginal prices* are described in section 4. In addition, the following shadow prices from Pass 1 shall be used:

11.2.1.1 $SPEmT^1_{i,c,f}$ designates the Pass 1 shadow price for the post-contingency transmission constraint for *facility* $f \in F$ in contingency $c \in C$ in interval i;

11.2.1.2 SPL^1_i designates the Pass 1 shadow price for the *energy* balance constraint in interval i;

11.2.1.3 $SPNormT^1_{i,f}$ designates the Pass 1 shadow price for the pre-contingency transmission constraint for *facility* $f \in F$ in interval i;

11.2.1.4 $SP10S^1_i$ designates the Pass 1 shadow price for the total synchronized *ten-minute operating reserve* requirement constraint in interval i;

11.2.1.5 $SP10R_i^1$ designates the Pass 1 shadow price for the total *ten-minute operating reserve* requirement constraint in interval i;

11.2.1.6 $SP30R_i^1$ designates the Pass 1 shadow price for the total *thirty-minute operating reserve* requirement constraint in interval i;

11.2.1.7 $SPREGMin10R_{i,r}^1$ designates the Pass 1 shadow price for the minimum *ten-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.8 $SPREGMin30R_{i,r}^1$ designates the Pass 1 shadow price for the minimum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.9 $SPREGMax10R_{i,r}^1$ designates the Pass 1 shadow price for the maximum *ten-minute operating reserve* constraint for region $r \in ORREG$ in interval i;

11.2.1.10 $SPREGMax30R_{i,r}^1$ designates the Pass 1 shadow price for the maximum *thirty-minute operating reserve* constraint for region $r \in ORREG$ in interval i.

11.3 Locational Marginal Prices for Energy

11.3.1 Energy Locational Marginal Prices for Delivery Points

11.3.1.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for every bus $b \in L$ and:

11.3.1.1.1 $LMP_{i,b}^1$ designates the Pass 1 interval i *locational marginal price* for *energy*;

11.3.1.1.2 $PRef_i^1$ designates the Pass 1 interval i *locational marginal price* for *energy* at the *reference bus*;

11.3.1.1.3 $PLoss_{i,b}^1$ designates the Pass 1 interval i loss component; and

11.3.1.1.4 $PCong_{i,b}^1$ designates the Pass 1 interval i congestion component.

11.3.1.2 The *real-time calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 at bus $b \in L$ in interval $i \in I$, as follows:

$$InitLMP_{i,b}^{1} = InitPRef_{i}^{1} + InitPLoss_{i,b}^{1} + InitPCong_{i,b}^{1}$$

where:

$$InitPRef_{i}^{1} = SPL_{i}^{1};$$

$$InitPLoss_{i,b}^{1} = MglLoss_{i,b} \cdot SPL_{i}^{1};$$

and

$$InitPCong_{i,b}^{1} = \sum_{f \in F_i} PreConSF_{i,f,b} \cdot SPNormT_{i,f}^{1} + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,b} \cdot SPEmT_{i,c,f}^{1}.$$

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11.3.1.3 If the initial *locational marginal price* for *energy* at the *reference bus* ($InitPRef_i^1$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* for *energy* at the *reference bus* as follows:

If $InitPRef_i^1 > EngyPrcCeil$, set $PRef_i^1 = EngyPrcCeil$

If $InitPRef_i^1 < EngyPrcFlr$, set $PRef_i^1 = EngyPrcFlr$

Otherwise, set $PRef_i^1 = InitPRef_i^1$

11.3.1.4 If the initial *locational marginal price* for *energy* ($InitLMP_{i,b}^1$) is not within the *settlement* bounds ($EngyPrcFlr$, $EngyPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* for *energy* as follows:

If $InitLMP_{i,b}^1 > EngyPrcCeil$, set $LMP_{i,b}^1 = EngyPrcCeil$.

If $InitLMP_{i,b}^1 < EngyPrcFlr$, set $LMP_{i,b}^1 = EngyPrcFlr$.

Otherwise, set $LMP_{i,b}^1 = InitLMP_{i,b}^1$

11.3.1.5 The *real-time calculation engine* shall modify the loss component as follows:

If $PRef_i^1 \neq InitPRef_i^1$, set $PLoss_{i,b}^1 = MglLoss_{i,b} \cdot PRef_i^1$

Otherwise, set $PLoss_{i,b}^1 = InitPLoss_{i,b}^1$

11.3.1.6 The *real-time calculation engine* shall modify the congestion component as follows:

If $LMP_{i,b}^1 - PRef_i^1 - PLoss_{i,b}^1$ and $InitPCong_{i,b}^1$ have the same mathematical sign, then set $PCong_{i,b}^1 = LMP_{i,b}^1 - PRef_i^1 - PLoss_{i,b}^1$

Otherwise, set $PCong_{i,b}^1 = 0$ and set $PLoss_{i,b}^1 = LMP_{i,b}^1 - PRef_i^1$

11.3.2 Energy Locational Marginal Prices for Intertie Metering Points

11.3.2.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for *intertie zone* bus $d \in D$, where:

11.3.2.1.1 $ExtLMP_{i,d}^{PD}$ designates the *locational marginal price* for *energy* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.2 $ICP_{i,d}^{1}$ designates the Pass 1 interval i *intertie congestion price*;

11.3.2.1.3 $ICP_{i,d}^{PD}$ designates the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.4 $IntLMP_{i,d}^{1}$ designates the Pass 1 interval i *intertie border price* for *energy*;

11.3.2.1.5 $ExtLMP_{i,d}^{1}$ designates the Pass 1 interval i *locational marginal price* for *energy*;

11.3.2.1.6 $PExtCong_{i,d}^{1}$ designates the Pass 1 interval i external congestion component for the *intertie congestion price*;

11.3.2.1.7 $PExtCong^{PD}_{i,d}$ designates the external congestion component for the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.3.2.1.8 $PIntCong^{1}_{i,d}$ designates the Pass 1 interval i internal congestion component for *energy*;

11.3.2.1.9 $PLoss^{1}_{i,d}$ designates the Pass 1 interval i loss component;

11.3.2.1.10 $PNISL^{1}_{i,d}$ designates the Pass 1 interval i net interchange scheduling limit congestion component for the *intertie congestion price*;

11.3.2.1.11 $PNISL^{PD}_{i,d}$ designates the net interchange scheduling limit congestion component for the *intertie congestion price* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*; and

11.3.2.2 The *real-time calculation engine* shall calculate an *intertie border price* for *energy*, a *locational marginal price* for *energy* for the *reference bus*, a loss component and a congestion component for *energy* for Pass 1 at *intertie zone* bus $d \in D_a$ in *intertie zone* $a \in A$ in interval $i \in I$, subject to section 11.3.2.11, as follows:

$$InitIntLMP^{1}_{i,d} = InitPRef^{1}_{i} + InitPLoss^{1}_{i,d} + InitPIntCong^{1}_{i,d}$$

where

$InitPRef^{1}_{i} = SPL^{1}_{i}$;

$InitPLoss^{1}_{i,d} = MglLoss_{i,d} \cdot SPL^{1}_{i}$;

and

$$InitPIntCong^{1}_{i,d} = \sum_{f \in F_i} PreConSF_{i,f,d} \cdot SPNormT^{1}_{i,f} + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,d} \cdot SPEmT^{1}_{i,c,f}$$

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11.3.2.3 If there is import congestion in pre-dispatch such that $ICP_{i,d}^{PD} < 0$, the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$$InitExtLMP_{i,d}^{1} = min\left(InitIntLMP_{i,d}^{1}, ExtLMP_{i,d}^{PD}\right);$$

$$InitICP_{i,d}^{1} = InitExtLMP_{i,d}^{1} - InitIntLMP_{i,d}^{1};$$

where:

If $InitExtLMP_{i,d}^{1} = InitIntLMP_{i,d}^{1}$, then $InitICP_{i,d}^{1} = 0$ and $InitPNISL_{i,d}^{1} = 0$;

and

If $InitExtLMP_{i,d}^{1} = ExtLMP_{i,d}^{PD}$, then $InitICP_{i,d}^{1}$ and $InitPNISL_{i,d}^{1}$ shall be prorated based on their pre-dispatch magnitudes so that their sum equals the effective real-time *intertie congestion price.*

11.3.2.4 If there is export congestion in pre-dispatch such that $ICP_{i,d}^{PD} > 0$, the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$$InitExtLMP_{i,d}^{1} = InitIntLMP_{i,d}^{1} + InitICP_{i,d}^{1}$$

where:

$$InitICP_{i,d}^{1} = InitPExtCong_{i,d}^{1} + InitPNISL_{i,d}^{1};$$

$$InitPExtCong_{i,d}^{1} = PExtCong_{i,d}^{PD};$$

and

$$InitPNISL_{i,d}^{1} = PNISL_{i,d}^{PD}.$$

11.3.2.5 If there is no *intertie* congestion in pre-dispatch such that $ICP_{i,d}^{PD} = 0$ or an *intertie zone* is out-of-service in real-time, then the *real-time calculation engine* shall calculate an initial *locational marginal price*, an *intertie congestion price*, and the net interchange scheduling limit congestion component for the *intertie congestion price* for *energy* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$$InitExtLMP^1_{i,d} = InitIntLMP^1_{i,d} + InitICP^1_{i,d}$$

where

$$InitICP^1_{i,d} = InitPExtCong^1_{i,d} + InitPNISL^1_{i,d} = 0$$

$$InitPExtCong^1_{i,d} = PExtCong^{PD}_{i,d};$$

and

$$InitPNISL^1_{i,d} = PNISL^{PD}_{i,d}.$$

11.3.2.6 If the *intertie border price* for *energy* ($InitIntLMP^1_{i,d}$) is not within the *settlement* bounds (*EngyPrcFlr*, *EngyPrcCeil*), then the *real-time calculation engine* shall modify the *intertie border price* for *energy*, and its components, as follows:

11.3.2.6.1 The initial *locational marginal price* for the *reference bus* ($InitPRef^1_i$) shall be modified as per section 11.3.1.3;

11.3.2.6.2 The initial *intertie border price* ($InitIntLMP^1_{i,d}$) shall be modified as per section 11.3.1.4, where $InitLMP^1_{i,b} = InitIntLMP^1_{i,d}$;

11.3.2.6.3 The initial loss component ($InitPLoss^1_{i,d}$) shall be modified as per section 11.3.1.5; and

11.3.2.6.4 The initial internal congestion component ($InitPIntCong^1_{i,d}$) shall be modified as per section 11.3.1.6, where $InitPCong^1_{i,b} = InitPIntCong^1_{i,d}$.

11.3.2.7 If the initial *locational marginal price* for *energy* ($InitExtLMP^1_{i,d}$) is not within the *settlement* bounds (*EngyPrcFlr*, *EngyPrcCeil*), then the *real-time calculation engine* shall modify the *locational marginal price* for *energy*, as follows:

If $InitExtLMP^1_{i,d} > EngyPrcCeil$, set $ExtLMP^1_{i,d} = EngyPrcCeil$.

If $InitExtLMP^1_{i,d} < EngyPrcFlr$, set $ExtLMP^1_{i,d} = EngyPrcFlr$.

Otherwise, set $ExtLMP_{i,d}^{1} = InitExtLMP_{i,d}^{1}$.

11.3.2.8 If the modified *locational marginal price* for *energy* ($ExtLMP_{i,d}^{1}$) determined in section 11.3.2.7 is equal to the *intertie border price* for *energy* ($IntLMP_{i,d}^{1}$), then the *real-time calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{i,d}^{1} = IntLMP_{i,d}^{1}$, set $PExtCong_{i,d}^{1} = 0$ and $PNISL_{i,d}^{1} = 0$.

11.3.2.9 If the modified *locational marginal price* for *energy* ($ExtLMP_{i,d}^{1}$) determined in section 11.3.2.7 is not equal to the *intertie border price* for *energy* ($IntLMP_{i,d}^{1}$), then the *real-time calculation engine* shall modify the external congestion component for the *intertie congestion price* and net interchange scheduling limit congestion component for the *intertie congestion price*, as follows:

If $ExtLMP_{i,d}^{1} \neq IntLMP_{i,d}^{1}$, then set

$$PNISL_{i,d}^{1} = (ExtLMP_{i,d}^{1} - IntLMP_{i,d}^{1}) \cdot \left(\frac{InitPNISL_{i,d}^{1}}{InitPNISL_{i,d}^{1} + InitPExtCong_{i,d}^{1}}\right).$$

If $PNISL_{i,d}^{1} > NISLPen$, then set $PNISL_{i,d}^{1} = NISLPen$;

If $PNISL_{i,d}^{1} < (-1) \cdot NISLPen$, then set $PNISL_{i,d}^{1} = (-1) \cdot NISLPen$; and

Set $PExtCong_{i,d}^{1} = ExtLMP_{i,d}^{1} - IntLMP_{i,d}^{1} - PNISL_{i,d}^{1}$

11.3.2.10 The *real-time calculation engine* shall calculate the *intertie* congestion price as follows:

$$ICP_{i,d}^{1} = PExtCong_{i,d}^{1} + PNISL_{i,d}^{1}.$$

11.3.2.11 The *locational marginal price* for *energy* calculated by the real-time calculation engine shall be the same for all boundary entity *resource* buses at the same *intertie zone*. *Intertie* transactions associated with the same *boundary entity resource* bus, but specified as occurring at different *intertie zones*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these transactions shall utilize shadow prices associated with the internal transmission constraints, *intertie* limits and transmission losses applicable to the path associated to the relevant *intertie zone.*

11.3.3 Zonal Prices for Energy

11.3.3.1 The *real-time calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each interval $i \in I$, the *energy* price for *virtual transaction zone* $m \in M$, as follows:

$$VZonalP^1_{i,m} = PRef^1_i + VZonalPLoss^1_{i,m} + VZonalPCong^1_{i,m}$$

where:

$$VZonalPLoss^1_{i,m} = \sum_{b \in L^{VIRT}_m} WF^{VIRT}_{i,m,b} \cdot PLoss^1_{i,b}$$

and

$$VZonalPCong^1_{i,m} = \sum_{b \in L^{VIRT}_m} WF^{VIRT}_{i,m,b} \cdot PCong^1_{i,b}$$

11.3.3.2 The *real-time calculation engine* shall calculate the zonal price for *energy* and its components for Pass 1 and each interval $i \in I$ for *non-dispatchable load* zone $y \in Y$, as follows:

$$ZonalP^1_{i,y} = PRef^1_i + ZonalPLoss^1_{i,y} + ZonalPCong^1_{i,y}$$

where:

$$ZonalPLoss^1_{i,y} = \sum_{b \in L^{NDL}_y} WF^{NDL}_{i,y,b} \cdot PLoss^1_{i,b}$$

and

$$ZonalPCong^1_{i,y} = \sum_{b \in L^{NDL}_y} WF^{NDL}_{i,y,b} \cdot PCong^1_{i,b}$$

11.3.3.3 The *Ontario zonal price* is calculated per section 11.3.3.2 where the *non-dispatchable load* zone is comprised of all *non-dispatchable loads* within Ontario.

11.3.4 Pseudo-Unit Pricing

11.3.4.1 The *real-time calculation engine* shall calculate a *locational marginal price* and components for *energy* for Pass 1 and each interval $i \in I$ for every *pseudo-unit* $k \in \{1,..,K\}$, where:

11.3.4.1.1 $CTMglLoss^{1}_{i,k}$ designates the marginal loss factor for the combustion turbine identified by *pseudo-unit* k for each interval i in Pass 1;

11.3.4.1.2 $STMglLoss^{p}_{i,k}$ designates the marginal loss factor for the steam turbine identified by *pseudo-unit* k for each interval i in Pass 1;

11.3.4.1.3 $CTPreConSF_{i,f,k}$ designates the pre-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during interval i under pre-contingency conditions;

11.3.4.1.4 $STPreConSF_{i,f,k}$ designates the pre-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during interval i under pre-contingency conditions;

11.3.4.1.5 $CTSF_{i,c,f,k}$ designates the post-contingency sensitivity factor for the combustion turbine identified by *pseudo-unit* k on *facility* f during interval i under post-contigency conditions for contingency c; and

11.3.4.1.6 $STSF_{i,c,f,k}$ designates the post-contingency sensitivity factor for the steam turbine identified by *pseudo-unit* k on *facility* f during interval i under post-contingency conditions for contingency c.

11.3.4.2 The *real-time calculation engine* shall calculate an initial *locational marginal price* for *energy*, a *locational marginal price* for *energy* at the *reference bus*, a loss component and a congestion component for Pass 1 and each interval i for every *pseudo-unit* $k \in \{1,..,K\}$, as follows:

$$InitLMP^{1}_{i,k} = InitPRef^{1}_{i} + InitPLoss^{1}_{i,k} + InitPCong^{1}_{i,k}$$

where:

$$InitPRef_i^1 = SPL_i^1;$$

$$InitPLoss_{i,k}^1 = MglLoss_{i,k}^1 \cdot SPL_i^1;$$

and

$$InitPCong_{i,k}^1 = \sum_{f \in F_i} PreConSF_{i,f,k} \cdot SPNormT_{i,f}^1 + \sum_{c \in C} \sum_{f \in F_{i,c}} SF_{i,c,f,k} \cdot SPEmT_{i,c,f}^1$$

11.3.4.3 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *minimum loading point* range or not scheduled at all, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^1 = CTShareMLP_k \cdot CTMglLoss_{i,k}^1 + STShareMLP_k \cdot STMglLoss_{i,k}^1$$

$$PreConSF_{i,f,k} = CTShareMLP_k \cdot CTPreConSF_{i,f,k} + STShareMLP_k \cdot STPreConSF_{i,f,k}$$

$$SF_{i,c,f,k} = CTShareMLP_k \cdot CTSF_{i,c,f,k} + STShareMLP_k \cdot STSF_{i,c,f,k}$$

11.3.4.4 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its *dispatchable* region, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^1 = CTShareDR_k \cdot CTMglLoss_{i,k}^1 + STShareDR_k \cdot STMglLoss_{i,k}^1$$

$$PreConSF_{i,f,k} = CTShareDR_k \cdot CTPreConSF_{i,f,k} + STShareDR_k \cdot STPreConSF_{i,f,k}$$

$$SF_{i,c,f,k} = CTShareDR_k \cdot CTSF_{i,c,f,k} + STShareDR_k \cdot STSF_{i,c,f,k}$$

11.3.4.5 If *pseudo-unit* $k \in \{1,..,K\}$ is scheduled within its duct firing region, its marginal loss and sensitivity factors shall be:

$$MglLoss_{i,k}^1 = STMglLoss_{i,k}^1$$

$$PreConSF_{i,f,k} = STPreConSF_{i,f,k}$$

$$SF_{i,c,f,k} = STSF_{i,c,f,k}$$

11.4 Locational Marginal Prices for Operating Reserve

11.4.1 Operating Reserve Locational Marginal Prices for Delivery Points

11.4.1.1 The *real-time calculation engine* shall calculate *locational marginal prices* and components for *operating reserve* for Pass 1 and each interval i for a *delivery point* associated with the *dispatchable generation resource* or *dispatchable load* bus $b \in B$, where:

11.4.1.1.1 $L30RP^{1}_{i,b}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve*;

11.4.1.1.2 $P30RRef^{1}_{i}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

11.4.1.1.3 $P30RCong^{1}_{i,b}$ designates the Pass 1 interval i congestion component for *thirty-minute operating reserve*;

11.4.1.1.4 $L10NP^{1}_{i,b}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve*;

11.4.1.1.5 $P10NRef^{1}_{i}$ designates the Pass 1 interval i *locational marginal price* for non-synchronized *ten-minute operating reserve* at the *reference bus*;

11.4.1.1.6 $P10NCong^{1}_{i,b}$ designates the Pass 1 interval i congestion component for non-synchronized *ten-minute operating reserve*;

11.4.1.1.7 $L10SP^{1}_{i,b}$ designates the Pass 1 interval i *locational marginal price* for synchronized *ten-minute operating reserve*;

11.4.1.1.8 $P10SRef^{1}_{i}$ designates the Pass 1 interval i *locational marginal price* for synchronized *ten-minute operating reserve* at the *reference bus*;

11.4.1.1.9 $P10SCong^{1}_{i,b}$ designates the Pass 1 interval i congestion component for synchronized *ten-minute operating reserve*; and

11.4.1.1.10 $ORREG_b \subseteq ORREG$ as the subset of $ORREG$ consisting of regions that include bus b.

11.4.1.2 The *real-time calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, and congestion components for Pass 1 for a *delivery point* associated with the *dispatchable generation resource* or *dispatchable load* at bus $b \in B$ in interval $i \in I$ for each class of *operating reserve*, as follows:

$$InitL30RP_{i,b}^{1} = InitP30RRef_{i}^{1} + InitP30RCong_{i,b}^{1}$$

where:

$$InitP30RRef_{i}^{1} = SP30R_{i}^{1}$$

and

$$InitP30RCong_{i,b}^{1} = \sum_{r \in ORREG_b} SPREGMin30R_{i,r}^{1} - \sum_{r \in ORREG_b} SPREGMax30R_{i,r}^{1}$$

$$InitL10NP_{i,b}^{1} = InitP10NRef_{i}^{1} + InitP10NCong_{i,b}^{1}$$

where:

$$InitP10NRef_{i}^{1} = SP10R_{i}^{1} + SP30R_{i}^{1}$$

and

$$InitP10NCong_{i,b}^{1} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{i,r}^{1} + SPREGMin30R_{i,r}^{1}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{i,r}^{1} + SPREGMax30R_{i,r}^{1}\right)$$

$$InitL10SP_{i,b}^{1} = InitP10SRef_{i}^{1} + InitP10SCong_{i,b}^{1}$$

where:

$$InitP10SRef_{i}^{1} = SP10S_{i}^{1} + SP10R_{i}^{1} + SP30R_{i}^{1}$$

and

$$InitP10SCong_{i,b}^{1} = \sum_{r \in ORREG_b} \left(SPREGMin10R_{i,r}^{1} + SPREGMin30R_{i,r}^{1}\right) - \sum_{r \in ORREG_b} \left(SPREGMax10R_{i,r}^{1} + SPREGMax30R_{i,r}^{1}\right)$$

11.4.1.3 If the initial *locational marginal price* at the *reference bus* (*$InitP30RRef_i^1$*, *$InitP10NRef_i^1$* or *$InitP10SRef_i^1$*,) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* at the *reference bus* for each class of *operating reserve* as follows:

If $InitP30RRef_i^1 > ORPrcCeil$, set $P30RRef_i^1 = ORPrcCeil$;

If $InitP30RRef_i^1 < ORPrcFlr$, set $P30RRef_i^1 = ORPrcFlr$;

Otherwise, set $P30RRef_t^1 = InitP30RRef_i^1$.

If $InitP10NRef_i^1 > ORPrcCeil$, set $P10NRef_i^1 = ORPrcCeil$

If $InitP10NRef_i^1 < ORPrcFlr$, set $P10NRef_i^1 = ORPrcFlr$

Otherwise, set $P10NRef_i^1 = InitP10NRef_i^1$

If $InitP10SRef_i^1, ORPrcFlr > ORPrcCeil$, set $P10SRef_i^1 = ORPrcCeil$

If $InitP10SRef_i^1, ORPrcFlr < ORPrcFlr$, set $P10SRef_i^1 = ORPrcFlr$

Otherwise, set $P10SRef_i^1 = InitP10SRef_i^1$

11.4.1.4 If the initial *locational marginal price* ($InitL30RP_{i,b}^1$, $InitL10NP_{i,b}^1$, or $InitL10SP_{i,b}^1$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price* for each class of *operating reserve* as follows:

If $InitL30RP_{i,b}^1 > ORPrcCeil$, set $L30RP_{i,b}^1 = ORPrcCeil$;

If $InitL30RP_{i,b}^1 < ORPrcFlr$, set $L30RP_{i,b}^1 = ORPrcFlr$;

Otherwise, set $L30RP_{i,b}^1 = InitL30RP_{i,b}^1$.

If $InitL10NP_{i,b}^1 > ORPrcCeil$, set $L10NP_{i,b}^1 = ORPrcCeil$;

If $InitL10NP_{i,b}^1 < ORPrcFlr$, set $L10NP_{i,b}^1 = ORPrcFlr$;

Otherwise, set $L10NP_{i,b}^1 = InitL10NP_{i,b}^1$.

If $InitL10SP^{1}_{i,b} > ORPrcCeil$, set $L10SP^{1}_{i,b} = ORPrcCeil$;

If $InitL10SP^{1}_{i,b} < ORPrcFlr$, set $L10SP^{1}_{i,b} = ORPrcFlr$;

Otherwise, set $L10SP^{1}_{i,b} = InitL10SP^{1}_{i,b}$.

11.4.1.5 If the initial *locational marginal price* ($InitL30RP^{1}_{i,b}$, $InitL10NP^{1}_{i,b}$, or $InitL10SP^{1}_{i,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the congestion component for each class of *operating reserve* as follows:

Set $P30RCong^{1}_{i,b} = L30RP^{1}_{i,b} - P30RRef^{1}_{i}$;

Set $P10NCong^{1}_{i,b} = L10NP^{1}_{i,b} - P10NRef^{1}_{i}$; and

Set $P10SCong^{1}_{i,b} = L10SP^{1}_{i,b} - P10SRef^{1}_{i}$.

11.4.2 Operating Reserve Locational Marginal Prices for Intertie Metering Points

11.4.2.1 The *real-time calculation engine* shall calculate *locational marginal prices* and components for *operating reserve* for Pass 1 and each interval $i \in I$, for *intertie zone* bus $d \in D$, where:

11.4.2.1.1 $ExtL30RP^{1}_{i,d}$ designates the Pass 1 interval i *locational marginal price* for *thirty-minute operating reserve*;

11.4.2.1.2 $ExtL30RP^{PD}_{i,d}$ designates the *locational marginal price* for *thirty-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.3 $P30RExtCong^{1}_{i,d}$ designates the Pass 1 interval i intertie congestion component for *thirty-minute operating reserve*;

11.4.2.1.4 $P30RExtCong^{PD}_{i,d}$ designates the *intertie* congestion component for *thirty-minute operating reserve* for the *dispatch hour* in which interval i falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.5 $ExtL10NP^{1}_{i,d}$ designates the Pass 1 interval *i* *locational marginal price* for non-synchronized *ten-minute operating reserve*;

11.4.2.1.6 $ExtL10NP^{PD}_{i,d}$ designates the *locational marginal price* for non-synchronized *ten-minute operating reserve* for the *dispatch hour* in which interval *i* falls as calculated by the *pre-dispatch calculation engine*;

11.4.2.1.7 $P30RRef^{1}_{i}$ designates the Pass 1 interval *i* *locational marginal price* for *thirty-minute operating reserve* at the *reference bus*;

11.4.2.1.8 $P30RIntCong^{1}_{i,d}$ designates the Pass 1 interval *i* internal congestion component for *thirty-minute operating reserve*;

11.4.2.1.9 $P10NRef^{1}_{i}$ designates the Pass 1 interval *i* *locational marginal price* for non-synchronized ten-minute operating reserve at the *reference bus*;

11.4.2.1.10 $P10NIntCong^{1}_{i,d}$ designates the Pass 1 interval *i* internal congestion component for non-synchronized *ten-minute operating reserve*;

11.4.2.1.11 $P10NExtCong^{1}_{i,d}$ designates the Pass 1 interval *i* *intertie* congestion component for non-synchronized *ten-minute operating reserve*; and

11.4.2.1.12 $P10NExtCong^{PD}_{i,d}$ designates the *intertie* congestion component for non-synchronized *ten-minute operating reserve* for the *dispatch hour* in which interval *i* falls as calculated by the *pre-dispatch calculation engine*.

11.4.2.2 The *real-time calculation engine* shall calculate an initial *locational marginal price*, a *locational marginal price* at the *reference bus*, an internal congestion component and an *intertie* congestion component for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$, for each class of *operating reserve*, subject to section 11.4.2.8, as follows:

$$InitIntL30RP^{1}_{i,d} = InitP30RRef^{1}_{i} + InitP30RIntCong^{1}_{i,d}$$

where:

$$InitP30RRef^{1}_{i} = SP30R^{1}_{i}$$

and

$$InitP30RIntCong_{i,d}^{1} = \sum_{r \in ORREG_d} SPREGMin30R_{i,r}^{1} - \sum_{r \in ORREG_d} SPREGMax30R_{i,r}^{1}$$

$$InitIntL10NP_{i,d}^{1} = InitP10NRef_i^{1} + InitP10NIntCong_{i,d}^{1}$$

where:

$$InitP10NRef_i^{1} = SP10R_i^{1} + SP30R_i^{1}$$

-

and

$$InitP10NIntCong_{i,d}^{1} = \sum_{r \in ORREG_d} \left(SPREGMin10R_{i,r}^{1} + SPREGMin30R_{i,r}^{1}\right) - \sum_{r \in ORREG_d} \left(SPREGMax10R_{i,r}^{1} + SPREGMax30R_{i,r}^{1}\right)$$

11.4.2.3 The *real-time calculation engine* shall calculate initial *locational marginal prices*, and its components for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ for each class of *operating reserve* as follows:

11.4.2.3.1 If the *intertie* is import congested in pre-dispatch ($P30RExtCong_{i,d}^{PD} < 0$ or $P10NExtCong_{i,d}^{PD} < 0$), then the prices and components are determined in accordance with section 11.4.2.4;

11.4.2.3.2 If the *intertie* is not import congestion in pre-dispatch ($P30RExtCong_{i,d}^{PD} \geq 0$ or $P10NExtCong_{i,d}^{PD} \geq 0$) or if an *intertie zone* is out-of-service, then the prices and components are determined in accordance with section 11.4.2.5.

11.4.2.4 The *real-time calculation engine* shall calculate an initial *locational marginal price* and an external congestion component for the *intertie congestion price* for each class of *operating reserve* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$$InitExtL30RP_{i,d}^{1} = min(InitIntL30RP_{i,d}^{1}, ExtL30RP_{i,d}^{PD});$$

and

$$InitP30RExtCong^1_{i,d} = InitExtL30RP^1_{i,d} - InitIntL30RP^1_{i,d}.$$

$$InitExtL10NP^1_{i,d} = min(InitIntL10NP^1_{i,d}, ExtL10NP^{PD}_{i,d});$$

and

$$InitP10NExtCong^1_{i,d} = InitExtL10NP^1_{i,d} - InitIntL10NP^1_{i,d}.$$

11.4.2.5 The *real-time calculation engine* shall calculate an initial *locational marginal price* and an external congestion component for the *intertie congestion price* for each class of *operating reserve* for Pass 1 at *intertie zone* bus $d \in D$ in interval $i \in I$ as follows:

$$InitExtL30RP^1_{i,d} = InitIntL30RP^1_{i,d};$$

and

$$InitP30RExtCong^1_{i,d} = 0.$$

$$InitExtL10NP^1_{i,d} = InitIntL10NP^1_{i,d};$$

and

$$InitP10NExtCong^1_{i,d} = 0.$$

11.4.2.6 If the initial *locational marginal price* ($InitExtL30RP^1_{i,b}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the congestion components for *thirty-minute operating reserve* as follows:

$$IntL30R = InitP30RRef^1_i + InitP30RIntCong^1_{i,d}$$

If $InitP30RRef^1_i > ORPrcCeil$, set $P30RRef^1_i = ORPrcCeil$;

If $InitP30RRef^1_i < ORPrcFlr$, set $P30RRef^1_i = ORPrcFlr$;

Otherwise, set $P30RRef^1_i = InitP30RRef^1_i$;

Set $P30RIntCong^1_{i,d} = ExtL30RP^1_{i,b} - P30RRef^1_i$;

If $InitExtL30RP^1_{i,b} > ORPrcCeil$, set $ExtL30RP^1_{i,b} = ORPrcCeil$;

If $InitExtL30RP^{1}_{i,b} < ORPrcFlr$, set $ExtL30RP^{1}_{i,b} = ORPrcFlr$;

Otherwise, $ExtL30RP^{1}_{i,b} = InitExtL30RP^{1}_{i,b}$; and

Set $P30RExtCong^{1}_{i,d} = ExtL30RP^{1}_{i,b} - P30RRef^{1}_{i} - P30RIntCong^{1}_{i,d}$

11.4.2.7 If the initial *locational marginal price* ($InitExtL10NP^{1}_{i,d}$) is not within the *settlement* bounds ($ORPrcFlr$, $ORPrcCeil$), then the *real-time calculation engine* shall modify the *locational marginal price*, the *locational marginal price* at the *reference bus*, and the congestion components for *ten-minute operating reserve* as follows:

$$IntL10N = InitP10NRef^{1}_{i} + InitP10NIntCong^{1}_{i,d}$$

If $InitP10NRef^{1}_{i} > ORPrcCeil$, set $P10NRef^{1}_{i} = ORPrcCeil$;

If $InitP10NRef^{1}_{i} < ORPrcFlr$, set $P10NRef^{1}_{i} = ORPrcFlr$;

Otherwise, $P10NRef^{1}_{i} = InitP10NRef^{1}_{i}$; and

Set $P10NIntCong^{1}_{i,d} = L10NP^{1}_{i,b} - P10NRef^{1}_{i}$

If $InitExtL10NP^{1}_{i,b} > ORPrcCeil$, set $ExtL10NP^{1}_{i,b} = ORPrcCeil$;

If $InitExtL10NP^{1}_{i,b} < ORPrcFlr$, set $ExtL10NP^{1}_{i,b} = ORPrcFlr$;

Otherwise, $ExtL30RP^{1}_{i,b} = InitExtL10NP^{1}_{i,b}$; and

Set $P10NExtCong^{1}_{i,d} = ExtL10NP^{1}_{i,b} - P10NRef^{1}_{i} - P10NIntCong^{1}_{i,d}$

11.4.2.8 The *locational marginal price* calculated by the *real-time calculation engine* shall be the same for all *boundary entity resource* buses at the same *intertie zone*. Reserve imports associated with the same *boundary entity resource* bus, but specified as ocurring at a different *intertie zone*, subject to phase shifter operation, shall be modelled as flowing across independent paths. Pricing of these reserve imports shall utilize shadow prices associated with *intertie* limits and regional minimum and maximum *operating reserve* requirements applicable to the path associated to the relevant *intertie zone*.

11.5 Pricing for Islanded Nodes

11.5.1 For *non-quick start resources* that are not connected to the *main island*, the *real-time calculation engine* shall use the following reconnection logic where enabled by the *IESO* in the order set out below to calculate the *locational marginal prices* for *energy*:

11.5.1.1 Determine the connection paths over open switches that connect the *non-quick start resource* to the *main island*;

11.5.1.2 Determine the priority rating for each connection path identified based on a weighted sum of the base voltage over all open switches used by the reconnection path and the MW ratings of the newly connected branches; and

11.5.1.3 Select the reconnection path with the highest priority rating, breaking ties arbitrarily.

11.5.2 For all (i) *resources* other than those specified in section 11.5.1 not connected to the *main island*; (ii) *non-quick start resources* where a price was not able to be determined in accordance with section 11.5.1; the *real-time calculation engine* shall use the following logic in the order set out below to calculate *locational marginal prices* for *energy*, using a node-level and *facility*-level substitution list determined by the *IESO*:

11.5.2.1 Use the *locational marginal price* for *energy* at a node in the node-level substitution list where defined and enabled by the *IESO*, provided such node is connected to the *main island*;

11.5.2.2 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes at the same voltage level within the same *facility* that are connected to the *main island*;

11.5.2.3 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes within the same *facility* that are connected to the *main island*;

11.5.2.4 If no such nodes are identified, use the average *locational marginal price* for *energy* of all nodes from another *facility* that is connected to the *main island*, as determined by the *facility*-

level substitution list where defined and enabled by the *IESO*; and

11.5.2.5 If a price is unable to be determined in accordance with sections 11.5.2.1 through 11.5.2.4, use the locational margi*nal price* for *energy* for the *reference bus*.

Appendix 7.7 – Radial Intertie Transactions

1.1 Applicable Configurations

1.1.1 A *registered facility* that is a *generation facility* that is connected electrically over a *radial intertie* to a neighbouring *control area* may only provide electricity or any *physical service* for delivery out of the *integrated power system* if it is, with the approval of the *IESO,* operating such *registered facility* in a *segregated mode of operation.*

1.2 Dispatch Data

1.2.1 A *market participant* that intends for a *registered facility* to operate in a segregated mode of operation shall maintain *dispatch data* that was submitted for that *registered facility* for each *dispatch hour* during which a *registered facility* will or is intended to operate in segregated mode of operation. The *market participant* may revise the applicable *dispatch data* in accordance with the timelines for submission of revised *dispatch data* specified in section 3.3 of Chapter 7.

1.2.2 Notwithstanding the provisions of section 3.3 of Chapter 7, if the *IESO*:

1.2.2.1 denies a Request for Segregation; or

1.2.2.2 revokes its approval to operate a *registered facility* in a *segregated mode of operation* or terminates the operation of a *registered facility* in a *segregated mode of operation* in accordance with section 1.3.6,

the *IESO* shall permit new or revised *dispatch data* to be submitted to the *IESO* in respect of the *registered facility* for the *dispatch hours* to which such denied request pertains.

1.3 Scheduling & Scheduling Approval

1.3.1 A registered *market participant* shall, within the time required by section 1.3.3, submit a *Request for Segregation* to the *IESO* for approval to operate its *registered facility* in a *segregated mode of operation* and shall submit an *outage* request, in accordance with the provisions specified in section 6.4 of Chapter 5 and the applicable *market manual*, to the *IESO* for the *registered facilities* intended to operate in a *segregated mode of operation.* The *registered market participant* shall make such a *Request for Segregation* in accordance with the applicable *market manual* and the information contained in such *Request for Segregation* shall include, but not be limited to:

1.3.1.1 the time at which operation in a *segregated mode of operation* is intended to commence;

1.3.1.2 the length of time that the applicable *registered facilities* are intended to operate in a *segregated mode of operation*; and

1.3.1.3 a list of the *registered facilities* that are intended to operate in a *segregated mode of operation*.

1.3.2 If a *registered market participant* wishes to revise the contents of a *Request for Segregation* it shall submit a new *Request for Segregation* and shall submit a new *outage* request to the *IESO* in accordance with section 1.3.1.

1.3.3 A *Request for Segregation* shall be made no earlier than 12:00 EST on the pre-dispatch day and no later than 2 hours prior to the start of the first *dispatch hour* to which such request pertains, unless otherwise agreed by the *IESO*. When the *Request for Segregation* is for the operation of a *registered facility* in a *segregated mode of operation* for more than one day the *IESO* may approve such operation for up to two *business days*.

1.3.4 Upon receipt of the *Request for Segregation* the *IESO* shall make a decision regarding a *Request for Segregation* as soon as practicable but no later than such time that allows the *transmitter*, referred to in section 1.3.5, a minimum of 90 minutes or such lesser time as agreed to by the *transmitter* to switch any applicable equipment or *facilities* required to permit implementation of the *segregated mode of operation* prior to the time set out in section 1.3.1.1, and shall notify the *registered market participant* of such decision. The *IESO*:

1.3.4.1 shall deny such *Request for Segregation* if:

a. such *Request for Segregation* pertains to a *registered facility* located in the province of Ontario and would threaten the reliability of the *IESO-controlled grid*; or

b. the *metering installation* for the *registered facility* to which such *Request for Segregation* relates does not comply with section 4.1A.1 of Chapter 6; or

c. such *Request for Segregation* pertains to a *registered facility* located outside the province of Ontario and would threaten the *security* of the *IESO-controlled grid*; and

1.3.4.2 may deny such *Request for Segregation* if the *metered market participant* for the *metering installation* for the *registered facility* to which such *Request for Segregation* relates has previously failed to comply with section 1.2.1.7 of Appendix 6.1 of Chapter 6 for a period in which such *registered facility* operated in a *segregated mode of operation.*

1.3.5 If the *IESO* approves a *Request for Segregation,* it shall direct the relevant *transmitter* to:

1.3.5.1 switch any applicable equipment or *facilities* required to permit implementation of the *segregated mode of operation* at the time referred to in section 1.3.1.1;

1.3.5.2 switch any applicable equipment or *facilities* required to cease implementation of the *segregated mode of operation* at the expiry of the time referred to in section 1.3.1.2.

1.3.6 The *IESO* may at any time revoke its approval to operate a *registered facility* in a *segregated mode of operation* or terminate the operation of a *registered facility* in a *segregated mode of operation,* as the case may be, for the reason described in section 1.3.4.1(b), where the *metered market participant* is failing to comply with section 1.2.1.7 of Appendix 6.1 of Chapter 6 in respect of the *metering installation* for such *registered facility* or where, in the *IESO's* opinion, such approval or such continued operation would threaten the *reliability* of a *local area* which forms part of the *IESO-controlled grid* or the *security* of the *integrated power system,* and shall notify the *registered market participant* accordingly. Where the *IESO* intends to revoke its approval to operate a *registered facility* in a *segregated mode of operation,* it shall revoke any direction issued pursuant to section 1.3.5. Where the *IESO* intends to terminate such operation, the *IESO* shall direct the relevant *transmitter* to switch any applicable equipment or *facilities* required to cease implementation of the *segregated mode of operation*. Where the *IESO* revokes its approval to operate a *registered facility* in a *segregated mode of* *operation* or terminates the operation of a *registered facility* in a *segregated mode of operation,* as the case may be, the *registered market participant* for that *registered facility* shall not be entitled to compensation for any costs, losses or damages from the *IESO* for such revocation or termination.

1.3.7 The *IESO* shall coordinate and confirm with the applicable *control area operator:*

1.3.7.1 the switching to be effected by the relevant *transmitter* in accordance with section 1.3.5 or 1.3.6; and

1.3.7.2 the names of the *registered facilities* that will operate in a *segregated mode of operation*.

1.3.8 The *IESO* shall not issue *dispatch instructions* to a *registered facility* in respect of any *dispatch hour* during which such *registered facility* is operating in a *segregated mode of operation*. All instructions relating to *dispatch* for the *registered facility* while operating in a *segregated mode of operation* shall be sent directly by the applicable *control area operator* to the *registered market participant*.

1.4 Settlements

1.4.1 The delivery of electricity or a *physical service* by a *registered facility* while operating in a *segregated mode of operation* shall be excluded from the *IESO's settlement process* and in no event shall the *IESO* be required to effect payment in respect of any electricity or *physical service* so delivered.

1.4.2 Notwithstanding section 1.4.1, a *registered market participant* that operates a *registered facility* in a *segregated mode of operation* shall submit such scheduling information to the *IESO* as may be necessary to enable the *IESO* to determine the amounts payable by the *registered market participant* for *export service* related to such operation.

1.4.3 Any costs incurred by a *transmitter* in complying with a direction issued pursuant to section 1.3.5 or 1.3.6 shall be borne by the *registered market participant* or the *transmitter* in the manner specified in their *connection agreement.*

1.4.4 The *registered market participant* shall be solely liable in respect of any positive or negative inadvertent accumulated while its *registered facilities* are operating in the *segregated mode of operation.*