Market Rule Amendment Proposal

PART 1 – MARKET RULE INFORMATION

Identification No.:	MR-00428				
Subject:	Day-Ahead Calculation Engine				
Title:	Review of the Day-Ahead Calculation Engine Market Rules				
Nature of Proposal:	☒ Alteration	☒ Deletion	☒ Addition		
Chapter:	7	Appendix:	7.5A		
Sections:	Appendix 7.5A, sections 4, 5, 6				
Sub-sections proposed for amending:	Various				

PART 2 – PROPOSAL HISTORY

Version	Reason for Issuing	Version Date
1.0	Draft for Technical Panel Review	September 6, 2016
2.0	Publish for Stakeholder Review and Comment	September 15, 2016
3.0	Submitted for Technical Panel Vote	October 11, 2016
4.0	Recommended by Technical Panel; Submitted for IESO Board Approval	October 18, 2016
5.0	Approved by IESO Board	December 7, 2016

Approved Amendment Publication Date:	December 8, 2016
Approved Amendment Effective Date:	December 30, 2016

PART 3 – EXPLANATION FOR PROPOSED AMENDMENT

Provide a brief description of the following:

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

Summary

The IESO proposes a number of non-material amendments to the market rules to clarify and correct several subscripts, variables, formulas and definitions related to the Day-Ahead Calculation Engine ("DACE").

Background

Please refer to MR-00428-Q00.

Discussion

Chapter 7, Appendix 7.5A provides the market rules framework for the DACE. The proposed amendments will modify parameters written in the market rules to ensure that they are used consistently, are clearly defined, and match the current and correct functioning of the DACE tool.

The proposed amendments are grouped into three categories:

- Discrepancies – between mathematical notation in the market rules equations and the calculations in the DACE tool;
- Clarifications – of parameters, variables and definitions; and
- Minor amendments – correction of typographical errors, changes to ensure consistency of language.

Discrepancies:

There are instances in Chapter 7, Appendix 7.5A where the mathematical notation in the market rules equations is inconsistent with the corresponding descriptive language of the market rules and the DACE tool. These discrepancies can be caused by incorrect subscripts or superscripts, incorrect or undefined variables, or incorrectly formatted mathematical notation. Minor changes are required to the mathematical notation in the market rules to correct the discrepancies. The following changes are proposed:

Sections 4.6.2.1, 4.9.2.6, 5.6.2.5, 5.10.2.6, 6.6.2.5, 6.9.2.6 and 6.12.3.1 – revise subscripts or description to provide consistency in the parameters throughout appendix 7.5A and to ensure that the equations in the market rules are consistent with the corresponding descriptive language in the market rules. The subscripts provide a reference to identify parameters by their individual attributes (bid/offer, hour, location). The correct subscripts are as follows:

- export subscripts are denoted by j , h, and d – replace incorrect subscript "a" with "d" and revise description to specify intertie zone sink bus "d" where applicable;

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- import subscripts are denoted by k, h, and d – replace incorrect subscript "a" with "d"; and revise description to specify intertie zone source bus "d" where applicable;
- dispatchable generator subscripts are denoted by k, h, and b – replace incorrect subscript "j" with "k" since "k" is a reference to offers applicable to generators.

Section 5.8.1 –replace incorrect and undefined variables "MGCPRG" and "SUCPRG" with the correct variables "MGOPRG" and "SUPRG" respectively, consistent with the corresponding descriptive language in sections 5.6.2.1 and 4.6.2.1. Section 5.6.2.1 states that bid and offer parameters in Pass 2 are no different than those defined for Pass 1, and MGOPRG and SUPRG are defined for Pass 1 under section 4.6.2.1.

Section 5.11.2.1 – replace superscripts "1" with "2" since section 5 of Appendix 7.5A relates to Pass 2 of the DACE, not Pass 1.

Section 6.11.1.1 – replace incorrect variable "PFL" with correct variable "AFL." Pass 3 of the DACE uses average demand (AFL) and not peak demand (PFL), consistent with sections 6.1.1 and 6.1.2, and in accordance with the intent described in the discussion section of Board approved market rule amendment MR-00348-R06 which introduced appendix 7.5A.

Clarifications:

There are instances throughout Chapter 7, Appendix 7.5A where amendments are required to add definitions for variables, or to amend the language of the market rules in order to provide clarification around specific parameters, variables, or equations. The following changes are proposed:

Section 4.6.1 – add definitions for two variables (J_d, K_d) which are undefined in sections 4.11.4.1 and 4.11.4.2.

Section 4.6.2.2 – Within the definition for the variable "$LossAdj_h$", replace "any adjustment" with "the adjustment," to reflect the fact that there will always be an adjustment to account for the difference between system losses derived from a base case power flow versus marginal transmission loss factor (i.e. static loss penalty factors employed by the scheduling sequence). In addition, within the definition for $EnCoeff_{a,z}$, replace "intertie a" with "intertie zone a" for clarification.

Sections 4.11.1.4, 5.12.1.4 and 6.11.1.3 – similar to the change in section 4.6.2.2 above, replace "any system loss adjustment" with "the adjustment."

In addition, revise each section to refer to the difference between actual and marginal system losses consistent with the description and mathematical equations in preceding sections and the revisions in section 4.6.2.2. The current language refers to "average" losses which is not a defined term, and is inconsistent with the marginal transmission loss factor (i.e. static loss penalty factors) reference used in definition of "$LossAdj_h$".

Sections 4.11.1.2, 4.11.1.3, 5.12.1.2 5.12.1.3, 6.11.1.1 and 6.11.1.2 – break each section into two paragraphs to address the fact that there are two mathematical scenarios presented (internal bus b scenario and external bus d scenario), but only a description of the internal bus b scenario in the rules language. The modification will provide clarification that the second part of each section relates to the external bus d scenario.

Section 4.11.3.3 – add clarification to the parameter used to reflect buses inside Ontario - specify "B is

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the set of buses within Ontario," consistent with language used to reflect buses outside Ontario.

Section 5.12.5.3 – replace "modified bids" with "bids" since the section is referring to exports and modifications in Pass 2 only apply to generator offers and dispatchable load bids in accordance with section 5.7.

Section 6.6.2.6 – add clarification to the parameter definition of "RAMPUP_ENGY" by specifying that the parameter represents a coefficient value which is used in calculating the fraction of the Minimum Loading Point considered in Pass 3 in the ramping hour prior to a start hour.

Section 6.6.2.8 – add a definition for the variable "$ExtLMP^{3}_{h,d}$". The market rules provide an equation for the calculation of LMPs at external buses in section 6.12.3.1, however the variable definition is omitted from the glossary of variables and parameters in section 6.6.2.8.

Section 6.12.3.3 – delete the words in the first sentence which describe the three components of the calculation as being "new", as the description is unnecessary and ambiguous.

In addition, revise the language to provide further clarity on the limits on imports and exports which are relevant for the calculation of prices in the intertie zones.

Minor amendments – typographical, consistency of language:
The following minor amendments are proposed in Chapter 7, Appendix 7.5A:

Sections 4.6.2.5, 5.6.2.6, 6.6.2.6 – revise the language within the definition to state "the amount of energy scheduled" instead of "the amount scheduled." The revised language for generation is consistent with definitions for imports and exports.

Sections 4.6.2.5, 5.6.2.5, 5.6.2.6, 6.6.2.5 and 6.6.2.6 – improve the language/grammar within parameter definitions. For example, replace "in association of bid j" with "in association with bid j", remove the word "each" when only one variable exists, and remove "for this bus" when there is a single bus in a definition.

Section 6.12.3.1 – reformat the formula to stay within appropriate page margins in pdf version.

PART 4 – PROPOSED AMENDMENT

Appendix 7.5A – The DACP Calculation Engine Process

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4. Pass 1: Constrained Commitment to

Meet Average Demand

4.6 Glossary of Sets, Indices, Variables and Parameters for Pass 1

4.6.1 Fundamental Sets and Indices

A	The set of all *intertie zones a*.
B	The set of buses *b* within Ontario, corresponding to *bids* and offers at locations on the *IESO-controlled grid.*
C	The set of contingencies conditions *c* to be considered in the *security* assessment.
D	The set of buses *d* outside Ontario, corresponding to *bids* and offers at *intertie zones*.
F	The set of transmission *facilities* (or groups of transmission *facilities*) *f* in Ontario for which constraints have been identified.
J	The set of all *bids j*. Each *price-quantity pair* of a *bid* submitted by a *market participant* would be represented by a unique element *j* in the set.
J_b	The subset of those *bids j* consisting of *bids* for a *dispatchable load* resource at a bus *b*.
J_d	The subset of those *bids j* consisting of *bids* for an export to *intertie zone* sink bus *d*.
K	The set of all *offers*. Each *price-quantity pair* of an *offer* submitted by a *market participant* would be represented by a unique element *k* in the set.
K_b	The subset of those *offers* consisting of *offers* for a *generation facility* at a bus *b.*
K_d	The subset of those *offers* consisting of *offers* for an import to *intertie zone* source bus *d.*
ORREG	The set of reserve areas, or regions, for which minimum and maximum *operating reserve* requirements have been defined. Each region *r* of the set *ORREG* consists of a set of buses at which *operating reserve* satisfying the minimum and maximum *operating reserve* requirement for that region may be located.
Z_{sch}	The set of all *interties* (or groups of *interties) z* for

	which constraints have been identified.
a	An *intertie zone*.
b	A bus corresponding to *bids* and *offers*. A single *facility* for which multiple *energy bids* are allowed may be represented as multiple buses, corresponding to the individual *bids*.
c	A contingency condition considered in the *security* assessment.
d	A bus outside Ontario corresponding to *bids* and *offers* in *intertie zones*.
f	A transmission *facility* for which a constraint has been identified. This includes groups of transmission *facilities*.
h	One of the day-ahead hours, from 1 to 24.
j	A *bid* or portion of a *bid* representing a single *price-quantity pair*.
k	An *offer* or portion of an *offer* representing a single *price-quantity pair*.
r	An *operating reserve* region within Ontario.
z	An *intertie* for which a constraint has been identified. This includes groups of *interties*.

4.6.2 Variables and Parameters

4.6.2.1 Bid and Offer Inputs

Dispatchable Loads:

$QPRL_{j,h,b}$	An incremental quantity of reduction in *energy* consumption that may be scheduled for a *dispatchable load* in hour *h* at bus *b* in association with *bid j*.
$PPRL_{j,h,b}$	The lowest *energy* price at which the incremental quantity of reduction in *energy* consumption specified in *bid j* should be scheduled in hour *h* at bus *b*.
$10SQPRL_{j,h,b}$	The synchronized *ten-minute operating reserve* quantity associated with *bid j* in hour *h* at bus *b* for *dispatchable loads* qualified to do so.
$10SPPRL_{j,h,b}$	The price of being scheduled to provided synchronized *ten-minute operating reserve* associated with *bid j* in hour *h* at bus *b*, for

	dispatchable loads qualified to do so.
$10NQPRL_{j,h,b}$	The non-synchronized *ten-minute operating reserve* quantity associated with *bid j* in hour *h* at bus *b* for *dispatchable loads* qualified to do so.
$10NPPRL_{j,h,b}$	The price of being scheduled to provide non-synchronized *ten-minute operating reserve* associated with *bid j* in hour *h* at bus *b*, for *dispatchable loads* qualified to do so.
$30RQPRL_{j,h,b}$	The *thirty-minute operating reserve* quantity associated with *bid j* in hour *h* at bus *b*, for *dispatchable loads* qualified to do so.
$30RPPRL_{j,h,b}$	The price of being scheduled to provide *thirty-minute operating reserve* associated with *bid j* in hour *h* at bus *b*, for *dispatchable loads* qualified to do so.
$ORRPRL_b$	The *operating reserve* ramp rate per minute for reductions in load consumption at bus *b*.
$URRPRL_b$	The maximum rate per minute at which a *dispatchable load* that wishes to consume *energy* at bus *b* can decrease its amount of energy consumption.
$DRRPRL_b$	The maximum rate per minute at which a *dispatchable load* that wishes to consume *energy* at bus *b* can increase its amount of load consumption.
Exports:	
$QHXL_{j,h,d}$ ~~$_a$~~	The maximum quantity of *energy* for which an export to *intertie zone* sink bus *d* ~~*intertie zone a*~~ in hour *h* may be scheduled in association with *bid j*.
$PHXL_{j,h,d}$ ~~$_a$~~	The highest price at which *energy* should be scheduled for an export to *intertie zone* sink bus *d* ~~*intertie zone a*~~ in hour *h* in association with *bid j*.
$QX10N_{j,h,d}$ ~~$_a$~~	The non-synchronized *ten-minute operating reserve* quantity associated with *bid j* in hour *h* at *intertie zone* sink bus *d* ~~*intertie zone a*~~ for an export qualified to do so.
$PX10N_{j,h,d}$ ~~$_a$~~	The price of being scheduled to provide non-synchronized *ten-minute operating reserve* associated with *bid j* in hour *h* at *intertie zone* sink bus *d*~~*intertie zone a*~~, for an export qualified to do so.

$QX30R_{j,h,d}$	The *thirty-minute operating reserve* quantity associated with *bid j* in hour *h* at *intertie zone* sink bus *d* ~~*intertie zone a*~~, for an export qualified to do so.
$PX30R_{j,h,d}$	The price of being scheduled to provide *thirty-minute operating reserve* associated with *bid j* in hour *h* at *intertie zone* sink bus *d* ~~*intertie zone a*~~, for an export qualified to do so.
$ORRHXL_{d}$	The *operating reserve* ramp rate per minute for exports at *intertie zone* sink bus *d* ~~*intertie zone a*~~, as specified by the *IESO*.

Dispatchable Generators:

$MinQPRG_{h,b}$	The *minimum loading point* which is the minimum amount of *energy* that a *generation facility* at bus *b* is willing to produce in hour *h*, if scheduled to operate.
$SUPRG_{h,b}$	The *offered start up cost* that a *generation facility* at bus *b* incurs in order to start and synchronize in hour *h*.
$SNL_{h,b}$	The *offered speed no-load cost* to maintain a *generation facility* synchronized with zero net *energy* injected into the system in hour *h*.
$MGOPRG_{h,b}$	The *offered* minimum generation cost for a *generation facility* at bus *b* in order to operate at its *minimum loading point* in hour *h*. This is calculated as the sum of $SNL_{h,b}$ and the incremental price, $PPRG_{k,h,b}$ for *energy* up to the *minimum loading point*, $MinQPRG_{h,b}$.
$QPRG_{k,h,b}$	An incremental quantity of *energy* generation (above and beyond the *minimum loading point*) that may be scheduled at bus *b* in hour *h* in association with *offer k*.
$PPRG_{k,h,b}$	The lowest *energy* price at which incremental generation should be scheduled at bus *b* in hour *h* in association with *offer k*.
$10SPPRG_{k,h,b}$	The *offered* price of being scheduled to provide synchronized *ten-minute operating reserve* in hour *h* at bus *b* in association with *offer k*.
$10SQPRG_{k,h,b}$	The *offered* quantity of synchronized *ten-minute operating reserve* in hour *h* at bus *b* in association with *offer k*.

$10NPPRG_{k,h,b}$	The *offered* price of being scheduled to provide *ten-minute operating* non-synchronized *ten-minute operating reserve* in hour *h* at bus *b* in association with *offer k*.
$10NQPRG_{k,h,b}$	The *offered* quantity of non-synchronized *ten-minute operating reserve* in association with *offer k*.
$30RPPRG_{k,h,b}$	The *offered* price of being scheduled to provide *thirty-minute operating reserve* in association with *offer k*.
$30RQPRG_{k,h,b}$	The *offered* quantity of *thirty-minute operating reserve* in hour *h* at bus *b* in association with *offer k*.
$ORRPRG_b$	The maximum *operating reserve* ramp rate per minute at bus *b*.
$MRTPRG_b$	The *minimum generation block run time* period for which a *generation facility* at bus *b* must be scheduled to operate if its *offer* to generate is accepted.
$MDTPRG_b$	The *minimum generation block down time* period between the end of one period when a *generation facility* at bus *b* is scheduled to operate and the beginning of the next period when it is scheduled to operate.
$MaxStartsPRG_b$	The maximum number of times per day a *generation facility* at bus *b* can be scheduled tostart.
$URRPRG_b$	The maximum rate per minute at which a *generation facility offering* to produce at bus *b* can increase the amount of *energy* it supplies.
$DRRPRG_b$	The maximum rate per minute at which a *generation facility offering* to produce at bus *b* can decrease the amount of *energy* it supplies.
EL_b	The daily limit on the amount of *energy* that an *energy limited resource* at bus *b* may be scheduled to generate over the course of the day (*maximum daily energy limit*).

Imports:

$QHIG_{k,h,da}$	The maximum quantity of *energy* for which an

	import from *intertie zone* source bus *d* ~~*intertie zone a*~~ in hour *h* may be scheduled in association with *offer k*.
$PHIG_{k,h,d}$ ~~$_a$~~	The lowest price at which an import from *intertie zone* source bus *d* ~~*intertie zone a*~~ in hour *h* in association with *offer k* should be scheduled.
$QI10N_{k,h,d}$ ~~$_a$~~	The non-synchronized *ten-minute operating reserve* quantity associated with *offer k* in hour *h* at *intertie zone* source bus *d* ~~*intertie zone*~~.
$PI10N_{k,h,d}$ ~~$_a$~~	The price of being scheduled to provide non-synchronized *ten-minute operating reserve* associated with *offer k* in hour *h* at *intertie zone* source bus *d* ~~*intertie zone a*~~.
$QI30R_{k,h,d}$ ~~$_a$~~	The non-synchronized *thirty-minute operating reserve* quantity associated with *offer k* in hour *h* at *intertie zone* source bus *d* ~~*intertie zone*~~.
$PI30R_{k,h,d}$ ~~$_a$~~	The price of being scheduled to provide non-synchronized *thirty-minute operating reserve* associated with *offer k* in hour *h* at *intertie zone* source bus *d* ~~*intertie zone a*~~.
$ORRHIG_{}$ ~~$_a$~~$_d$	The *operating reserve* ramp rate per minute for imports at *intertie zone* source bus *d* ~~*intertie zone a*~~, as specified by the *IESO*.

4.6.2.2 Transmission and Security Inputs and Intermediate Variables

$EnCoeff_{a,z}$	The coefficient for calculating the contribution of scheduled *energy* flows (and *operating reserve*, in the case of inflows) over *intertie zone a* which is part of the *intertie* group *z*. $EnCoeff_{a,z}$ takes the value +1 to account for limits on scheduled flows into Ontario and the value -1 to account for limits on scheduled flows out of Ontario.
$MaxExtSch_{z,h}$	The maximum flow limit over an *intertie z* in hour *h*.
$ExtDSC_h$	The maximum decrease in total net flows over all *interties* from hour to hour, which limits the hour-to-hour decreases in net imports (calculated as imports less exports) from all the *intertie zones*.
$ExtUSC_h$	The maximum increase in total net flows over all *interties* from hour to hour, which limits the hour-to-hour increases in net imports (calculated as

	imports less exports) from all the *intertie zones*.
$PF_{h,a}$	The anticipated inflow into Ontario from *intertie zone a* in hour *h* that result from loop flows.
$MglLoss_{h,b}$	The marginal impact on transmission losses resulting from transmitting *energy* from the *reference bus* to serve an increment of additional load at the bus *b* in hour *h*.
$LossAdj_h$	~~Any~~ The adjustment needed for hour *h* to correct for any discrepancy between actual Ontario total system losses using a base case power flow from the *security* assessment function and system losses that would be calculated using the marginal transmission loss factors~~losses~~.
$With^1_{h,b}$	The total amount of withdrawals scheduled in Pass 1 at each bus *b* in each hour *h*, for scheduled *dispatchable loads*.
$With^1_{h,d}$	The total amount of withdrawals scheduled in Pass 1 at each bus *d* in each hour *h*, for exports and outflows associated with loop flows for buses in *intertie zones*.
$Inj^1_{h,b}$	The total amount of injections scheduled in Pass 1 at each bus *b* in each hour *h*, for scheduled generation.
$Inj^1_{h,d}$	The total amount of injections scheduled in Pass 1 at each bus *d* in each hour *h*, for imports and inflows associated with loop flows for buses in *intertie zones*.
$PreConSF_{b,f,h}$	The fraction of *energy* injected at bus *b* which flows on transmission *facility f* during hour *h* under pre-contingency conditions.
$AdjNormMaxFlow_{f,h}$	The maximum flow allowed on transmission *facility f* in hour *h* as determined by the *security* assessment for pre-contingency conditions.
$SF_{b,f,c,h}$	The fraction of *energy* injected at bus *b* which flows on a transmission *facility f* during hour *h* under post-contingency conditions.
$AdjEmMaxFlow_{f,c,h}$	The maximum flow allowed on transmission *facility f* in hour *h* as determined by the *security* assessment for post-contingency condition *c*.

4.6.2.5 Output Schedule and Commitment Variables

$SHXL^{1}_{j,h,d}$	The amount of exports scheduled in hour *h* in Pass 1 from *intertie zone* sink bus *d* in association with ~~each~~ *bid j*.
$SX10N^{1}_{j,h,d}$	The amount of non-synchronized *ten-minute operating reserve* scheduled from the export in hour *h* in Pass 1 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SX30R^{1}_{j,h,d}$	The amount of *thirty-minute operating reserve* scheduled from the export in hour *h* in Pass 1 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SPRL^{1}_{j,h,b}$	The amount of *dispatchable load* reduction scheduled at bus *b* in hour *h* in Pass 1 in association with ~~each~~ *bid j* ~~at that bus~~.
$10SSPRL^{1}_{j,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 1 in association ~~of~~ with *bid j* ~~for this bus~~.
$10NSPRL^{1}_{j,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 1 in association ~~of~~ with *bid j* ~~for this bus~~.
$30RSPRL^{1}_{j,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 1 in association ~~of~~ with *bid j* ~~for this bus~~.
$SHIG^{1}_{k,h,d}$	The amount of hourly imports scheduled in hour *h* from *intertie zone* source bus *d* in Pass 1 in association with ~~each~~ *offer k.*
$SI10N^{1}_{k,h,d}$	The amount of imported *ten-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 1 in association with ~~each~~ *offer k.*
$SI30R^{1}_{k,h,d}$	The amount of imported *thirty-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 1 in association with ~~each~~ *offer k.*
$SPRG^{1}_{k,h,b}$	The amount of *energy* scheduled for the *generation facility* at bus *b* in hour *h* in Pass 1 in

	association with ~~each~~ *offer k* ~~at that bus~~. This is in addition to any $MinQPRG_{h,b}$, the *minimum loading point*, which must also be committed.
$OPRG^{1}_{h,b}$	Represents whether the *generation facility* at bus *b* has been scheduled in hour *h* in Pass 1.
$IPRG^{1}_{h,b}$	Represents whether the *generation facility* at bus *b* has been scheduled to start in hour *h* in Pass 1.
$10SSPRG^{1}_{k,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 1 in association ~~of~~ with *offer k* ~~for this bus~~.
$10NSPRG^{1}_{k,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 1 in association ~~of~~ with *offer k* ~~for this bus~~.
$30RSPRG^{1}_{k,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 1 in association ~~of~~ with *offer k* ~~for this bus~~.

4.9 Bid/Offer Constraints Applying to Single Hours

4.9.2 Operating Reserve Constraints

4.9.2.6 In addition, this next constraint ensures that the total (10-minute synchronized, 10-minute non-synchronized and 30-minute) from committed *dispatchable generation facility* cannot exceed the *generation facility's* ramp capability (schedules for hour, *h*=0 are obtained from the initializing inputs listed in section 3.8). Ramping considerations from start ups or shut downs are not carried forward from one day to the next:

$$\sum_{k \in K_b} (10SSPRG^{1}_{k,h,b} + 10NSPRG^{1}_{k,h,b} + 30RSPRG^{1}_{k,h,b}) \leq \sum_{k \in K_b} \left(SPRG^{1}_{k\text{-}j,h-1,b} - SPRG^{1}_{k\text{-}j,h,b}\right) + 60 \times URRPRG_b$$

and

$$\sum_{k \in K_b} \left(10SSPRG^1_{k,h,b} + 10NSPRG^1_{k,h,b} + 30RSPRG^1_{k,h,b}\right) + \sum_{k \in K_b} \left(SPRG^1_{k\text{-}j,h,b}\right) \leq [(h-n) * 60 + 30] \times URRPRG_b \times OPRG^1_{h,b}$$

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

$$\sum_{k \in K_b} \left(10SSPRG^1_{k,h,b} + 10NSPRG^1_{k,h,b} + 30RSPRG^1_{k,h,b}\right) + \sum_{k \in K_b} \left(SPRG^1_{k\text{-}j,h,b}\right) \leq [(m-h) * 60 + 30] \times DRRPRG_b \times OPRG^1_{h,b}$$

where *m* is the hour of the last shut down in or after hour *h*.

4.11 Constraints to Ensure Schedules Do Not Violate Reliability Requirements

4.11.1 Load

4.11.1.1 For each hour of the DACP, the total amount of *energy* generated in the DACP schedule, plus scheduled imports must be sufficient to meet forecast *demand*, scheduled exports, and transmission losses consistent with these schedules. It will be easiest to break the derivation of the constraint that will ensure this occurs into several steps.

4.11.1.2 ~~First, define t~~The total amount of withdrawals scheduled in Pass 1 at each bus *b* in each hour *h*, $With^1_{h,b}$, ~~as~~ is the sum of:

- the portion of the load forecast for that hour that has been allocated to that bus; and

- all *dispatchable load bid*, net of the amount of load reduction scheduled (since the *dispatchable load* is excluded from the *demand* forecast by the DACP calculation engine), yielding:~~;~~

$$With^{1}_{h,b} = LDF_{h,b} \cdot AFL_{h} + \left[\sum_{j \in J_b} \left(QPRL_{j,h,b} - SPRL^{1}_{j,h,b} \right) \right]; \text{and}$$

the total amount of withdrawals scheduled in Pass 1 at each *intertie zone* sink bus *d* in each hour *h*, $With^{1}_{h,d}$, is the sum of:

- exports from Ontario to each *intertie zone* sink bus; and
- outflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose, yielding:

~~$With^{1}_{h,b} = LDF_{h,b} \cdot AFL_{h} + \left[\sum_{j \in J_b} \left(QPRL_{j,h,b} - SPRL^{1}_{j,h,b} \right) \right]; \text{and}$~~

$$With^{1}_{h,d} = \sum_{j \in J_d} (SHXL^{1}_{j,h,d}) - \sum_{a \in A} ProxyUPOWt_{d,a} \cdot \min(0, PF_{h,a}).$$

4.11.1.3 The total amount of injections scheduled in Pass 1 at each bus *b* in each hour *h*, $Inj^{1}_{h,b}$, is the sum of:

- *generation facilities* scheduled at that bus~~;~~, yielding:

$$Inj^{1}_{h,b} = OPRG^{1}_{h,b} \cdot MinQPRG_{h,b} + \sum_{k \in K_b} SPRG^{1}_{k,h,b}; \text{and}$$

the total amount of injections scheduled in Pass 1 at each *intertie zone* source bus *d* in each hour *h*, $Inj^{1}_{h,b}$, is the sum of:

- imports into Ontario from each *intertie zone* source bus; and
- inflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose:

~~$Inj^{1}_{h,b} = OPRG^{1}_{h,b} \cdot MinQPRG_{h,b} + \sum_{k \in K_b} SPRG^{1}_{k,h,b}; \text{and}$~~

$$Inj^{1}_{h,d} = \sum_{k \in K_d} SHIG^{1}_{k,h,d} + \sum_{a \in A} ProxyUPIWt_{d,a} \cdot \max(0, PF_{h,a}).$$

4.11.1.4 Injections and withdrawals at each bus must be multiplied by one plus the marginal loss factor to reflect the losses (or reduction in losses) that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other, after taking into account ~~any~~ the adjustment for any discrepancy between actual~~system loss adjustment that is required due to the difference between average~~ and marginal losses. Load reduction associated with the *demand* constraint violation will be subtracted from the total load and generation reduction will be subtracted from total generation associated with the *demand* constraint violation to ensure that the DACP calculation engine will always produce a solution. These violation variables are assigned a very high cost to limit their use to infeasible cases.

$$\sum_{b\in B}(1+MglLoss_{h,b})With^{1}_{h,b}+\sum_{d\in D}(1+MglLoss_{h,d})With^{1}_{h,d}-SLdViol^{1}_{h}$$
$$=\sum_{b\in B}(1+MglLoss_{h,b})Inj^{1}_{h,b}$$
$$+\sum_{d\in D}(1+MglLoss_{h,d})Inj^{1}_{h,d}-SGenViol^{1}_{h}+LossAdj_{h}.$$

4.11.3 Internal Transmission Limits

4.11.3.1 The *IESO* must ensure that the set of DACP schedules produced by Pass 1 of the DACP calculation engine would not violate any *security limits* in either the pre-contingency state or after any contingency.

4.11.3.2 To develop the constraints to ensure that this occurs, the total amount of *energy* scheduled to be injected at each bus and the total amount of *energy* scheduled to be withdrawn at each bus will be used.

4.11.3.3 The *security* assessment function of the DACP calculation engine will linearize binding (violated) pre-contingency limits on transmission *facilities* within Ontario. The linearized constraints will take the form:

$$\sum_{b\in B}PreConSF_{b,f,h}(Inj^{1}_{h,b}-With^{1}_{h,b})+\sum_{d\in D}PreConSF_{d,f,h}(Inj^{1}_{h,d}-With^{1}_{h,d})$$
$$-SPreConITLViol^{1}_{f,h}\le AdjNormMaxFlow_{f,h}$$

where *B* is the set of buses within Ontario and *D* is the set of sink and source buses outside Ontario, for all *facilities f* and hours *h*.

4.11.3.4 Similarly, the linearized binding post-contingency limits will take the form:

$$\sum_{b \in B} SF_{b,f,c,h}(Inj^{1}_{h,b} - With^{1}_{h,b}) + \sum_{d \in D} SF_{d,f,c,h}(Inj^{1}_{h,d} - With^{1}_{h,d}) - SITLViol^{1}_{f,c,h} \leq AdjEmMaxFlow_{f,c,h}$$

for all *facilities f*, hours *h*, and monitored contingencies *c*.

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5. Pass 2: Constrained Commitment to Meet Peak Demand

5.6 Glossary of Sets, Indices, Variables and Parameters for Pass 2

5.6.1 Fundamental Sets and Indices

5.6.1.1 Same as those described in section 4.6.1.

5.6.2 Variables and Parameters

5.6.2.1 Bid and Offer Inputs

Same as those described in 4.6.2.1. In addition, the variables below are used to account for the fact that *generation facilities* and *dispatchable loads* are able to follow 5-minute dispatches to meet peak *demand* but imports and exports are only scheduled on an hourly basis:

$PmtPRG_{k,h,b}$	The lowest incremental *energy price* at which an incremental amount of *energy* should be scheduled at bus *b* in hour *h* in association with offer *k* to meet peak *demand*.
$PmtPRL_{j,h,b}$	The lowest incremental *energy price* at which an incremental quantity of reduction in *energy* consumption should be scheduled at bus *b* in hour *h* in association with bid *j* to meet peak *demand*.
PriceMultiplier	A *bid* and *offer* adjustment factor to account for the value of energy from *dispatchable loads* and *generation facilities* dispatched on a 5-minute basis to meet peak *demand* of any hour. This factor shall be 12.

5.6.2.2 Transmission and Security Inputs and Intermediate Variables

Same as those described in 4.6.2.2.

5.6.2.3 Other Inputs

Same as those described in 4.6.2.3.

5.6.2.4 Constraint Violation Price Inputs

Same as those described in 4.6.2.4.

5.6.2.5 Variables determined in Pass 1 and Used in Pass 2

$SHXL^{1}_{j,h,d}$	The amount of exports scheduled in hour *h* in Pass 1 from *intertie zone*~~,~~ sink bus *d* in association with ~~each~~ *bid j*.
$SHIG^{1}_{k,h,d}$	The amount of imports scheduled in hour *h* in Pass 1 from *intertie zone* source bus *d* in associate with ~~each~~ *offer k.*
$OPRG^{1}_{h,b}$	Indication of whether a *generation facility* at bus *b* was scheduled to operate in hour *h* in Pass 1.
$LMP^{1}_{h,b}$	The Pass 1 locational marginal price for *energy* at each bus *b* in each hour *h.*

5.6.2.6 Output Schedule and Commitment Variables

$SHXL^{2}_{j,h,d}$	The amount of exports scheduled in hour *h* in Pass 2 from *intertie zone* sink bus *d* in association with ~~each~~ *bid j*.
$SX10N^{2}_{j,h,d}$	The amount of non-synchronized *ten-minute operating reserve* scheduled from the export in hour *h* in Pass 2 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SX30R^{2}_{j,h,d}$	The amount of *thirty-minute operating reserve* scheduled from the export in hour *h* in Pass 2 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SPRL^{2}_{j,h,b}$	The amount of *dispatchable load* reduction scheduled at bus *b* in hour *h* in Pass 2 in association with ~~each~~ *bid j* ~~at that bus~~.
$10SSPRL^{2}_{j,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 2 in association ~~of~~ with *bid j* ~~for this bus~~.

$10NSPRL^2_{j,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 2 in association ~~of~~ with *bid j* ~~for this bus~~.
$30RSPRL^2_{j,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 2 in association ~~of~~ with *bid j* ~~for this bus~~.
$SHIG^2_{k,h,d}$	The amount of hourly imports scheduled in hour *h* from *intertie zone* source bus *d* in Pass 2 in association with ~~each~~ *offer k.*
$SI10N^2_{k,h,d}$	The amount of imported *ten-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 2 in association with ~~each~~ *offer k.*
$SI30R^2_{k,h,d}$	The amount of imported *thirty-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 2 in association with ~~each~~ *offer k.*
$SPRG^2_{k,h,b}$	The amount of *energy* scheduled for the *generation facility* at bus *b* in hour *h* in Pass 2 in association with ~~each~~ *offer k* ~~at that bus~~. This is in addition to any $MinQPRG_{h,b}$, the *minimum loading point*, which must also be committed.
$OPRG^2_{h,b}$	Represents whether the *generation facility* at bus *b* has been scheduled in hour *h* in Pass 2.
$IPRG^2_{h,b}$	Represents whether *generation facility* at bus *b* has been scheduled to start in hour *h* in Pass 2.
$10SSPRG^2_{k,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 2 in association ~~of~~ with *offer k* ~~for this bus~~.
$10NSPRG^2_{k,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 2 in association ~~of~~ with *offer k* ~~for this bus~~.
$30RSPRG^2_{k,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 2 in association ~~of~~ with *offer k* ~~for this bus~~.

5.8 Objective Function

5.8.1 The optimization of the objective function in Pass 2 is to maximize the expression:

$$\sum_{h=1,\ldots,24} \left\{ \begin{array}{l} \sum_{d\in DX,\, j\in J_d} \left(SHXL^{2}_{j,h,d} \cdot PHXL_{j,h,d} - SX10N^{2}_{j,h,d} \cdot PX10N_{j,h,d} - SX30R^{2}_{j,h,d} \cdot PX30R_{j,h,d}\right) \\ -\sum_{b\in B} \left[\begin{array}{l} \sum_{j\in J_b} SPRL^{2}_{j,h,b} \cdot PmtPRL_{j,h,b} \\ +\sum_{j\in J_b} 10SSPRL^{2}_{j,h,b} \cdot 10SPPRL_{j,h,b} + 10NSPRL^{2}_{j,h,b} \cdot 10NPPRL_{j,h,b} + \\ 30RSPRL^{2}_{j,h,b} \cdot 30RPPRL_{j,h,b} \end{array} \right] \\ \sum_{d\in DI,\, k\in K_d} \left(SHIG^{2}_{k,h,d} \cdot PHIG_{k,h,d} + SI10N^{2}_{k,h,d} \cdot PI10N_{k,h,d} + SI30R^{2}_{k,h,d} \cdot PI30R_{k,h,d}\right) \\ -\sum_{b\in B} \left[\begin{array}{l} \sum_{k\in K_b} \left(SPRG^{2}_{k,h,b} \cdot PmtPRG_{k,h,b}\right) \\ +OPRG^{2}_{h,b} \cdot MGCPRG_{h,b} + IPRG^{2}_{h,b} \cdot SUCPRG_{h,b} \\ +\sum_{k\in K_b} 10SSPRG^{2}_{k,h,b} \cdot 10SPPRG_{k,h,b} + 10NSPRG^{2}_{k,h,b} \cdot 10NPPRG_{k,h,b} \\ 30RSPRG^{2}_{k,h,b} \cdot 30RPPRG_{k,h,b} \end{array} \right] \\ -ViolCost^{2}_{h} \end{array} \right\};$$

$$\sum_{h=1,\ldots,24}\left\{\begin{array}{l}\sum_{d\in DX,\,j\in J_d}\left(SHXL^2_{j,h,d}\cdot PHXL_{j,h,d}-SX10N^2_{j,h,d}\cdot PX10N_{j,h,d}-SX30R^2_{j,h,d}\cdot PX30R_{j,h,d}\right)\\ -\sum_{b\in B}\left[\begin{array}{l}\sum_{j\in J_b}SPRL^2_{j,h,b}\cdot PmtPRL_{j,h,b}\\ +\sum_{j\in J_b}10SSPRL^2_{j,h,b}\cdot 10SPPRL_{j,h,b}+10NSPRL^2_{j,h,b}\cdot 10NPPRL_{j,h,b}+\\ 30RSPRL^2_{j,h,b}\cdot 30RPPRL_{j,h,b}\end{array}\right]\\ -\sum_{d\in DI,k\in K_d}\left(SHIG^2_{k,h,d}\cdot PHIG_{k,h,d}+SI10N^2_{k,h,d}\cdot PI10N_{k,h,d}+SI30R^2_{k,h,d}\cdot PI30R_{k,h,d}\right)\\ -\sum_{b\in B}\left[\begin{array}{l}\sum_{k\in K_b}\left(SPRG^2_{k,h,b}\cdot PmtPRG_{k,h,b}\right)\\ +OPRG^2_{h,b}\cdot MGOPRG_{h,b}+IPRG^2_{h,b}\cdot SUPRG_{h,b}\\ +\sum_{k\in K_b}10SSPRG^2_{k,h,b}\cdot 10SPPRG_{k,h,b}+10NSPRG^2_{k,h,b}\cdot 10NPPRG_{k,h,b}\\ +30RSPRG^2_{k,h,b}\cdot 30RPPRG_{k,h,b}\end{array}\right]\\ -ViolCost^2_h\end{array}\right\};$$

where $ViolCost^2{}_h$ is calculated as follows:

$$\begin{aligned}ViolCost^2_h &= SLdViol^2_h\cdot PLdViol-SGenViol^2_h\cdot PGenViol\\ &+S10SViol^2_h\cdot P10SViol+S10RViol^2_h\cdot P10RViol\\ &+S30RViol^2_h\cdot P30RViol\\ &+\sum_{r\in ORREG}\left(\begin{array}{l}SREG10RViol^2_{r,h}\cdot PREG10RViol\\ +SREG30RViol^2_{r,h}\cdot PREG30RViol\\ +SXREG10RViol^2_{r,h}\cdot PXREG10RViol\\ +SXREG30RViol^2_{r,h}\cdot PXREG30RViol\end{array}\right)\\ &+\sum_{z\in Z}\left(SPreConXTLViol^2_{z,h}\cdot PPreConXTLViol\right)\\ &+SURmpXTLViol^2\cdot PRmpXTLViol+SDRmpXTLViol^2\cdot PRmpXTLViol\\ &+\sum_{f\in F}SPreConITLViol^2_{f,h}\cdot PPreConITLViol\\ &+\sum_{f\in F,c\in C}SITLViol^2_{f,c,h}\cdot PITLViol.\end{aligned}$$

5.8.2 The Pass 2 maximization is subject to the constraints described in the next section.

5.10 Bid/Offer Constraints Applying to Single Hours

5.10.2 Operating Reserve Constraints

5.10.2.6 In addition, this next constraint ensures that the total(10-minute synchronized, 10-minute non-synchronized and 30-minute) from the committed *generation facility* cannot exceed its ramp capability (schedules for hour, *h*=0 are obtained from the initializing inputs listed in section 3.8). Ramping considerations from start ups or shut downs are not carried forward from one day to the next:

$$\sum_{k\in K_b}(10SSPRG^2_{k,h,b} + 10NSPRG^2_{k,h,b}+30RSPRG^2_{k,h,b}) \leq \sum_{k\in K_b}\left(SPRG^2_{k\text{-}j,h-1,b} - SPRG^2_{k\text{-}j,h,b}\right) + 60 \times URRPRG_b$$

and

$$\sum_{k\in K_b}\left(10SSPRG^2_{k,h,b} + 10NSPRG^2_{k,h,b}+30RSPRG^2_{k,h,b}\right) + \sum_{k\in K_b}\left(SPRG^2_{k\text{-}j,h,b}\right) \leq [(h-n)*60+30]\times URRPRG_b \times OPRG^2_{h,b}$$

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

and

$$\sum_{k\in K_b}\left(10SSPRG^2_{k,h,b} + 10NSPRG^2_{k,h,b}+30RSPRG^2_{k,h,b}\right) + \sum_{k\in K_b}\left(SPRG^2_{k\text{-}j,h,b}\right) \leq [(m-h)*60+30]\times DRRPRG_b \times OPRG^2_{h,b}$$

where *m* is the hour of the last shut down in or after hour *h*.

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

5.11.1 Status Variables

5.11.1.1 For the same reasons as discussed for Pass 1, for *generation facilities* that are scheduled to start up, and for hour, $h > 1$:

$$IPRG^{2}_{h,b} = \begin{cases} 1, \text{ if } OPRG^{2}_{h-1,b} = 0 \text{ and } OPRG^{2}_{h,b} = 1 \\ 0, \text{ otherwise.} \end{cases}$$

For $h = 1$:

$$IPRG^{2}_{h,b} = \begin{cases} 1, \text{ if } InitOperHrs_{b} = 0 \text{ and } OPRG^{2}_{h,b} = 1 \\ 0, \text{ otherwise.} \end{cases}$$

5.11.2 Ramping

5.11.2.1 Constraints limiting hour-to-hour changes in *energy* schedules are congruous to those used in Pass 1.

Start Up Scenario ($OPRG^{\cancel{1}2}_{h,b} = 1$, and $OPRG^{\cancel{1}2}_{h-1,b} = 0$)

$$0 \leq \sum_{k \in K_b} SPRG^{2}_{k,h,b} \leq \sum_{k \in K_b} 30 \times URRPRG_b$$

Continued On Scenario ($OPRG^{\cancel{1}2}_{h-1,b} = OPRG^{\cancel{1}2}_{h,b} = 1$)

$$\sum_{k \in K_b} \left(SPRG^{\cancel{1}2}_{k,h-1,b}\right) - 60 \times DRRPRG_b \leq \sum_{k \in K_b} SPRG^{2}_{k,h,b} \leq \sum_{k \in K_b} \left(SPRG^{2}_{k,h-1,b}\right) + 60 \times URRPRG_b$$

Shut Down Scenario ($OPRG^{\cancel{3}2}_{h,b} = 1$, and $OPRG^{\cancel{1}2}_{h+1,b} = 0$)

$$0 \leq \sum_{k \in K_b} SPRG^{2}_{k,h,b} \leq \sum_{k \in K_b} 30 \times DRRPRG_b$$

5.12 Constraints to Ensure Schedules Do Not Violate Reliability Requirements

5.12.1 Load

5.12.1.1 Load constraints are structured in the same manner as described in section 4.11.1 for Pass 1.

5.12.1.2 The total amount of withdrawals scheduled in Pass 2 at each bus *b* in each hour *h*, $With^2_{h,b}$, is the sum of:

- the portion of the load forecast for that hour that has been allocated to that bus; and
- all *dispatchable load bid*, net of the amount of load reduction scheduled (since the *dispatchable load* is excluded from the *demand* forecast by the DACP calculation engine)~~;~~, yielding:

$$With^2_{h,b} = LDF_{h,b} \cdot PFL_h + \left[\sum_{j \in J_b} \left(QPRL_{j,h,b} - SPRL^2_{j,h,b}\right)\right]; \text{ and}$$

the total amount of withdrawals scheduled in Pass 2 at each *intertie zone* sink bus *d* in each hour *h*, $With^2_{h,d}$, is the sum of:

- exports from Ontario to each *intertie zone* sink bus; and
- outflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose, yielding:

~~$With^2_{h,b} = LDF_{h,b} \cdot PFL_h + \left[\sum_{j \in J_b} \left(QPRL_{j,h,b} - SPRL^2_{j,h,b}\right)\right]$; and~~

$$With^2_{h,d} = \sum_{j \in J_d} (SHXL^2_{j,h,d}) - \sum_{a \in A} ProxyUPOWt_{d,a} \cdot \min(0, PF_{h,a}).$$

5.12.1.3 The total amount of injections scheduled in Pass 2 at each bus *b* in each hour *h*, $Inj^2_{h,b}$, is the sum of:

- *generation facilities* scheduled at that bus~~;~~, yielding:

$$Inj^2_{h,b} = OPRG^2_{h,b} \cdot MinQPRG_{h,b} + \sum_{k \in K_b} \left(SPRG^2_{k,h,b}\right); \text{ and}$$

the total amount of injections scheduled in Pass 2 at each *intertie zone* source bus *d* in each hour *h*, $Inj^2_{h,d}$, is the sum of:

- imports into Ontario from each *intertie zone* source bus; and
- inflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose, yielding:

$$Inj^2_{h,b} = OPRG^2_{h,b} \cdot MinQPRG_{h,b} + \sum_{k \in K_b} \left(SPRG^2_{k,h,b} \right); \text{ and}$$

$$Inj^2_{h,d} = \sum_{k \in K_d} (SHIG^2_{k,h,d}) + \sum_{a \in A} ProxyUPIWt_{d,a} \cdot \max(0, PF_{h,a}).$$

5.12.1.4 Injections and withdrawals at each bus must be multiplied by one plus the marginal loss factor to reflect the losses (or reduction in losses) that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other, after taking into account the adjustment for any discrepancy between actual ~~any system loss adjustment that is required due to the difference between average~~ and marginal losses. Load reduction associated with the *demand* constraint violation will be subtracted from the total load and generation reduction associated with the *demand* constraint violation will be subtracted from total generation to ensure that the calculation engine will always produce a solution. These violation variables are assigned a very high cost to limit their use to infeasible cases.

$$\sum_{b \in B} (1 + MglLoss_{h,b}) With^2_{h,b} + \sum_{d \in D} (1 + MglLoss_{h,b}) With^2_{h,d} - SLdViol^2_h$$
$$= \sum_{b \in B} (1 + MglLoss_{h,b}) Inj^2_{h,b}$$
$$+ \sum_{d \in D} (1 + MglLoss_{h,d}) Inj^2_{h,d} - SGenViol^2_h + LossAdj_h.$$

5.12.5 Intertie Schedule Limits Based on Pass 1 Output

5.12.5.1 Pass 2 will not reduce the amount of imported *energy* scheduled from each *intertie zone* in any hour. Additional imports of *energy* may be scheduled in Pass 2. Therefore, for imports that are not part of a linked wheeling transaction:

$$SHIG^2_{k,h,d} \geq SHIG^1_{k,h,d}$$

for all *offers k*, hours *h* and *intertie zones* source bus *d*.

5.12.5.2 Pass 2 will not increase the amount of exported *energy* scheduled from each *intertie zone* sink bus in any hour over the amount scheduled in Pass 1.

5.12.5.3 Therefore, for exports that are not part of a linked wheeling transaction:

$$SHXL^{2}_{j,h,d} \leq SHXL^{1}_{j,h,d}$$

for all ~~modified~~ *bids j*, hours *h* and *intertie zones* sink bus *d*.

5.12.5.4 Finally, the purpose of Pass 2 is to determine whether additional *generation facilities* need to be committed to ensure that the *IESO* can meet peak forecast load, given the resources committed in Pass 1 (and if so, which resources are committed). Consequently, it will be necessary to ensure that resources committed in Pass 1 are not de-committed in this pass. Therefore:

$$OPRG^{2}_{h,b} \geq OPRG^{1}_{h,b}$$

for all hours *h* and buses.

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6. Pass 3: Constrained Scheduling to Meet Average Demand

6.6 Glossary of Sets, Indices, Variables and Parameters for Pass 3

6.6.1 Fundamental Sets and Indices

6.6.1.1 Same as those described in section 4.6.1.

6.6.2 Variables and Parameters

6.6.2.1 Bid and Offer Inputs

Same as those described in 4.6.2.1.

6.6.2.2 Transmission and Security Inputs and Intermediate Variables

Same as those described in 4.6.2.2.

6.6.2.3 Other Inputs

Same as those described in 4.6.2.3.

6.6.2.4 Constraint Violation Price Inputs

Same as those described in 4.6.2.4.

6.6.2.5 Variables determined in Pass 2 and Used in Pass 3

$SHXL^{2}_{j,h,d}$	The amount of exports scheduled in hour *h* in Pass 2 from *intertie zone*~~,~~ sink bus *d*~~d~~ in association with ~~each~~ *bid j*.
$SHIG^{2}_{k,h,d}$	The amount of imports scheduled in hour *h* in Pass 2 from *intertie zone* ~~*d*~~ source bus *d* in association with ~~each~~ *offer k*.
$OPRG^{2}_{h,b}$	Indication of whether a *generation facility* at bus *b* was scheduled to operate in hour *h* in Pass 2.
$IPRG^{2}_{h,b}$	Indication of whether a *generation facility* at bus *b* was scheduled to start in hour *h* in Pass 2.

6.6.2.6 Output Schedule and Commitment Variables

$SHXL^{3}_{j,h,d}$	The amount of exports scheduled in hour *h* in Pass 3 from *intertie zone* sink bus *d* in association with ~~each~~ *bid j*.
$SX10N^{3}_{j,h,d}$	The amount of non-synchronized *ten-minute operating reserve* scheduled from the export in hour *h* in Pass 3 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SX30R^{3}_{j,h,d}$	The amount of *thirty-minute operating reserve* scheduled from the export in hour *h* in Pass 3 from *intertie zone* sink bus *d* in association ~~of~~ with *bid j*.
$SPRL^{3}_{j,h,b}$	The amount of *dispatchable load* reduction scheduled at bus *b* in hour *h* in Pass 3 in association with ~~each~~ *bid j* ~~at that bus~~.
$10SSPRL^{3}_{j,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 3

	in association ~~of~~ with *bid j* ~~for this bus~~.
$10NSPRL^{3}_{j,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 3 in association ~~of~~ with *bid j* ~~for this bus~~.
$30RSPRL^{3}_{j,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *dispatchable load* is scheduled to provide at bus *b* in hour *h* in Pass 3 in association ~~of~~ with *bid j* ~~for this bus~~.
$SHIG^{3}_{k,h,d}$	The amount of hourly imports scheduled in hour *h* from *intertie zone* source bus *d* in Pass ~~2~~ 3 in association with ~~each~~ *offer k.*
$SI10N^{3}_{k,h,d}$	The amount of imported *ten-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 3 in association with ~~each~~ *offer k.*
$SI30R^{3}_{k,h,d}$	The amount of imported *thirty-minute operating reserve* scheduled in hour *h* from *intertie zone* source bus *d* in Pass 3 in association with ~~each~~ *offer k.*
$SPRG^{3}_{k,h,b}$	The amount of *energy* scheduled for the *generation facility* at bus *b* in hour *h* in Pass 3 in association with ~~each~~ *offer k* ~~at that bus~~. This is in addition to any $MinQPRG_{h,b}$, the *minimum loading point*, which must also be committed.
$OPRG^{3}_{h,b}$	Represents whether the *generation facility* at bus *b* has been scheduled in hour *h* in Pass 3.
$IPRG^{3}_{h,b}$	Represents whether *generation facility* at bus *b* has been scheduled to start in hour *h* in Pass 3.
RAMPUP_ENRG	The coefficient used to calculate the estimated fraction of a *generation facility*'s *minimum loading point* in the hour prior to the first hour it is scheduled. This value is used by the DACP calculation engine to determine constrained schedules in Pass 3 so that the *energy* produced by the *generation facility* during ramping to their *minimum loading point* is accounted for.
$10SSPRG^{3}_{k,h,b}$	The amount of synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass 3 in association ~~of~~ with *offer k* ~~for this bus~~.
$10NSPRG^{3}_{k,h,b}$	The amount of non-synchronized *ten-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h*

	in Pass 3 in association ~~of~~ with *offer k* ~~for this bus~~.
$30RSPRG^{3}_{k,h,b}$	The amount of *thirty-minute operating reserve* that a qualified *generation facility* at bus *b* is scheduled to provide in hour *h* in Pass ~~2~~ 3 in association ~~of~~ with *offer k* ~~for this bus~~.

6.6.2.8 Output Shadow Prices

Shadow Prices of Constraints:

SPL^{3}_{h}	The Pass 3 shadow price measuring the rate of change of the objective function for a change in load at the *reference bus* in hour *h*.
$SPNormT^{3}_{f,h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the limit, $AdjNormMaxFlow_{f,h}$, on flows over transmission *facilities* in normal conditions for *facility f* in hour *h*.
$SPEmT^{3}_{f,c,h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the limit, $AdjEmMaxFlow_{f,c,h}$, on flows over transmission *facilities* in emergency conditions for *facility f* in monitored contingency *c* in hour *h*.
$SPExtT^{3}_{z,h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the limit, $MaxExtSch_{z,h}$, on flows over transmission *facilities* on the boundary between Ontario and other *control areas* for each constraint z in hour *h*.
$SPRUExtT^{3}_{h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the limit, $ExtUSC_{h}$, on the upward change of the sum of net imports over all *interties* from the previous hour to hour *h*.
$SPRDExtT^{3}_{h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the limit, $ExtDSC_{h}$, on the downward change of the sum of net imports over all *interties* from the previous hour to hour *h*.
$SP10S^{3}_{h}$	The Pass 3 shadow price measuring the rate of change of the objective function for a change in the total synchronized *ten-minute operating*

reserve requirement, $TOT10S_h$, in hour *h*.

$SP10R^3_h$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the total *ten-minute operating reserve* requirement, $TOT10R_h$, in hour *h*.

$SP30R^3_h$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the total *thirty-minute operating reserve* requirement, $TOT30R_h$, in hour *h*.

$SPREGMin10R^3_{r,h}$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the minimum *ten-minute operating reserve* requirement, $REGMin10R_{r,h}$, for region *r* in hour *h*.

$SPREGMin30R^3_{r,h}$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the minimum *thirty-minute operating reserve* requirement, $REGMin30R_{r,h}$, for region *r* in hour *h*.

$SPREGMax10R^3_{r,h}$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the maximum *ten-minute operating reserve* limit, $REGMax10R_{r,h}$, for region *r* in hour *h*.

$SPREGMax30R^3_{r,h}$ — The Pass 3 shadow price measuring the rate of change of the objective function for a change in the maximum *thirty-minute operating reserve* limit, $REGMax30R_{r,h}$, for region *r* in hour *h*.

Shadow Price for Energy:

$LMP^3_{h,b}$ — The Pass 3 locational marginal price for *energy* at each bus *b* in each hour *h*. It measures the *offered* price of meeting an infinitesimal change in the amount of load at that bus in that hour, or equivalently, measures the value of an incremental amount of supply at that bus in that hour in Pass 3.

$ExtLMP^3_{h,d}$ — The Pass 3 locational marginal price for *energy* at each *intertie zone* sink and source bus *d* in each hour *h*. It measures the *offered* price of meeting an infinitesimal change in the amount of load at that bus in that hour, or equivalently, measures the value of an incremental amount of supply at that bus in that hour in Pass 3.

6.6.2.9 Energy Ramp Rates

Same as those in section 4.6.2.8.

6.9 Bid/Offer Constraints Applying to Single Hours

6.9.2 Operating Reserve Constraints

6.9.2.6 In addition, this next constraint ensures that the total (10-minute synchronized, 10-minute non-synchronized and 30-minute) from a committed *generation facility* cannot exceed its ramp capability (schedules for hour, *h*=0 are obtained from the initializing inputs listed in section 3.8). Ramping considerations from start ups or shut downs are not carried forward from one day to the next:

$$\sum_{k\in K_b}(10SSPRG^3_{k,h,b} + 10NSPRG^3_{k,h,b}+10RSPRG^3_{k,h,b}) \leq \sum_{k\in K_b}\left(SPRG^3_{k,h-1,b} - SPRG^3_{k,h,b}\right) + 60 \times URRPRG_b$$

and

$$\sum_{k\in K_b}\left(10SSPRG^3_{k,h,b} + 10NSPRG^3_{k,h,b}+30RSPRG^3_{k,h,b}\right) + \sum_{k\in K_b}\left(SPRG^3_{k,h,b}\right) \leq [(h-n)*60+30]\times URRPRG_b \times OPRG^3_{h,b}$$

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

and

$$\sum_{k\in K_b}\left(10SSPRG^3_{k,h,b} + 10NSPRG^3_{k,h,b}+30RSPRG^3_{k,h,b}\right) + \sum_{k\in K_b}\left(SPRG^3_{k,h,b}\right) \leq [(m-h)*60+30]\times DRRPRG_b \times OPRG^3_{h,b}$$

where *m* is the hour of the last shut down in or after hour *h*

6.11 Constraints to Ensure Schedules Do Not Violate Reliability Requirements

6.11.1 Load

6.11.1.1 The total amount of withdrawals scheduled in Pass 3 at each bus *b* in each hour *h*, $With^{3}_{h,b}$, is the sum of:

- the portion of the load forecast for that hour that has been allocated to that bus; and

- all *dispatchable load bid*, net of the amount of load reduction scheduled (since the *dispatchable load* is excluded from the *demand* forecast by the DACP calculation engine), yielding:;

$$With^{3}_{h,b} = LDF_{h,b} \cdot AFL_{h} + \left[\sum_{j \in J_b}\left(QPRL_{j,h,b} - SPRL^{3}_{j,h,b}\right)\right]; \text{and}$$

the total amount of withdrawals scheduled in Pass 3 at each *intertie zone* sink bus *d* in each hour *h* , $With^{3}_{h,b}$, is the sum of:

- exports from Ontario to each *intertie zone* sink bus; and

- outflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose, yielding:

~~$With^{3}_{h,b} = LDF_{h,b} \cdot PFL_{h} + \left[\sum_{j \in J_b}\left(QPRL_{j,h,b} - SPRL^{3}_{j,h,b}\right)\right]$; and~~

$$With^{3}_{h,d} = \sum_{j \in J_d}(SHXL^{3}_{j,h,d}) - \sum_{a \in A} ProxyUPOWt_{d,a} \cdot \min(0, PF_{h,a}).$$

6.11.1.2 The total amount of injections scheduled in Pass 3 at each bus *b* in each hour *h*, $Inj^{3}_{h,b}$, is the sum of:

- generation scheduled at that bus, yielding:;

$$Inj^{3}_{h,b} = (OPRG^{3}_{h,b} + RAMPUP\_ENRG \cdot IPRG^{3}_{h+1,b})MinQPRG_{h,b} + \sum_{k \in K_b}\left(SPRG^{3}_{k,h,b}\right); \text{and}$$

the total amount of injections scheduled in Pass 3 at each *intertie zone* source bus *d* in each hour *h*, $Inj^{3}_{h,d}$, is the sum of:

- imports into Ontario from each *intertie zone* source bus; and
- inflows from Ontario associated with loop flows between Ontario and each *intertie zone*, allocated among the buses in the *intertie zones* using the distribution factors developed for that purpose:

$$Inj^{3}_{h,b} = (OPRG^{3}_{h,b} + RAMPUP\_ENRG \cdot IPRG^{3}_{h+1,b})MinQPRG_{h,b} + \sum_{k \in K_b}(SPRG^{3}_{k,h,b}); \text{ and}$$

$$Inj^{3}_{h,d} = \sum_{k \in K_d}(SHIG^{3}_{k,h,d}) + \sum_{a \in A} ProxyUPIWt_{d,a} \cdot \max(0, PF_{h,a}).$$

6.11.1.3 Injections and withdrawals at each bus must be multiplied by one plus the marginal loss factor to reflect the losses (or reduction in losses) that result when injections or withdrawals occur at locations other than the *reference bus*. These loss-adjusted injections and withdrawals must then be equal to each other, after taking into account ~~any~~ the adjustment for any discrepancy between actual~~system loss adjustment that is required due to the difference between average~~ and marginal losses. Load reduction associated with the *demand* constraint violation will be subtracted from the total load and generation reduction associated with the *demand* constraint violation will be subtracted from total generation to ensure that the calculation engine will always produce a solution. These violation variables are assigned a very high cost to limit their use to infeasible cases.

$$\sum_{b \in B}(1 + MglLoss_{h,b})With^{3}_{h,b} + \sum_{d \in D}(1 + MglLoss_{h,b})With^{3}_{h,d} - SLDViol^{3}_{h} = \sum_{b \in B}(1 + MglLoss_{h,b})Inj^{3}_{h,b} + \sum_{d \in D}(1 + MglLoss_{h,d})Inj^{3}_{h,d} - SGenViol^{3}_{h} + LossAdj_{h}.$$

6.12 Shadow Prices

6.12.1 The *IESO* shall also determine *energy* and *operating reserve* prices in Pass 3 that will be *published* for informational purposes.

6.12.2 Shadow Energy Prices

6.12.2.1 The Pass 3 shadow price at each bus *b* in each hour *h* shall be calculated at buses in Ontario as:

$$LMP^3_{h,b} = \left(1 + MglLoss_{h,b}\right) \cdot SPL^3_h + \sum_{f \in F} \left(\begin{array}{l} PreConSF_{b,f,h} \cdot SPNormT^3_{f,h} \\ + \sum_{c \in C} SF_{b,f,c,h} \cdot SPEmT^3_{f,c,h} \end{array} \right)$$

6.12.3 Shadow Energy Prices at *Intertie Zones*

6.12.3.1 The Pass 3 shadow price at each *intertie zone* source/sink bus ~~*a*~~ *d* in each hour *h* is calculated as:

~~$$ExtLMP^3_{h,d} = \left(1 + MglLoss_{h,d}\right) \cdot SPL^3_h + \sum_{f \in F} \left(PreConSF_{d,f,h} \cdot SPNormT^3_{f,h} + \sum_{c \in C} (SF_{d,f,c,h} \cdot SPEmT^3_{f,c,h}$$~~

$$+ \sum_{z \in Z_{sch}} (EnCoeff_{a,z} \cdot SPExtT^3_{z,h}) + SPRUExtT^3_h - SPRDExtT^3_h$$

$$ExtLMP^3_{h,d} = \left(1 + MglLoss_{h,d}\right) \cdot SPL^3_h + \sum_{f \in F} \left(\begin{array}{l} PreConSF_{d,f,h} \cdot SPNormT^3_{f,h} \\ + \sum_{c \in C} (SF_{d,f,c,h} \cdot SPEmT^3_{f,c,h}) \end{array} \right)$$

$$+ \sum_{z \in Z_{sch}} (EnCoeff_{a,z} \cdot SPExtT^3_{z,h}) + SPRUExtT^3_h - SPRDExtT^3_h$$

6.12.3.2 The first component of this calculation, the cost of meeting load at each *intertie zone* reflecting marginal losses incurred in transmitting *energy* from the *reference bus* to that *intertie zone*, is the same as the first component of the previous equation. The second component of this calculation determines the effect of congestion on internal transmission *facilities* on the price at each bus.

6.12.3.3 The last three components ~~of this calculation are new. They~~ reflect the impact of limits on imports or exports, ~~which are not relevant for the calculation of shadow *energy* prices, but~~ which are relevant for the calculation of prices at *intertie zones*. The first of the three components provides the effect of congestion resulting from *security limits* associated with *interties* between Ontario and *intertie zones*, for all constraints *z* in the set Z_{sch}. The last two components reflect the congestion cost resulting from the upward/downward limits of hour-to-hour net *energy* changes across all *interties*.~~To illustrate why these components are as they are, let us first review some preceding definitions. There are two categories of limits on external transactions: limits on the net flows of *energy* scheduled over any given *intertie* or set of *interties*, *operating reserve* imports scheduled over any given *intertie* or set of *interties*, or combinations of these; and limits on hour-to-hour changes in net flows over all *interties*. The set containing~~

~~limits of the first type was previously denoted as Z_{sch}, while the other two constraints set an upper limit on increases and decrease in net flows. Finally, recall that the factor $EnCoeff_{a,z}$ describes the impact of imported *energy* and *operating reserve* from *intertie zone a* on one of these constraints *z*.~~

PART 5 – IESO BOARD DECISION RATIONALE

These amendments clarify and correct several subscripts, variables, formulas and definitions related to the Day-Ahead Calculation Engine ("DACE").