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Day-Ahead and Real-Time Make-Whole Payments for Hydroelectric Generation Facilities

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Meeting Purpose and Agenda

Purpose :

Educate participants on make-whole payments (MWP) for hydroelectric generation resources and provide clarification on settlement of linked cascade resources

Agenda :

- Minimum Daily Energy Limit eligibility rules
- Make-whole payments for schedules associated with forbidden regions
- Make-whole payments for hydroelectric generation resource with start restrictions
- Clarify calculation of day ahead market make-whole payment for cascade resources
- Summary and next steps

Background Context

- This presentation builds from the recent education session on Economic Operating Point in April, and is in response to stakeholder requests for more background information and illustrative examples
- The equations and the rules discussed will be included in the Settlements Market Rules package, forecasted to be published in December

Minimum Daily Energy Limit

Recap Detailed Design: Minimum Daily Energy Limit

A generation resource with a minimum daily energy limit (DEL) will not be eligible to recover its lost cost if:

- it is scheduled to supply energy across a trading day to meet its minimum DEL
- it is scheduled to supply energy across the day above its minimum DEL, but the facility was only able to satisfy its minimum DEL after taking into account its minimum hourly output and minimum hourly must run across the trading day

Changes to Eligibility for Minimum DEL

- Removed the second condition
  - This was determined to be redundant in the day-ahead market (DAM) timeframe as the calculation engine will consider all constraints for the trade day when scheduling the resource
- Added a new condition for resources with shared forebays
  - The sum of the scheduled energy of the generation resources across a trading day is equal to the their minimum DEL

Forbidden Region in Day-Ahead and Real-Time Market

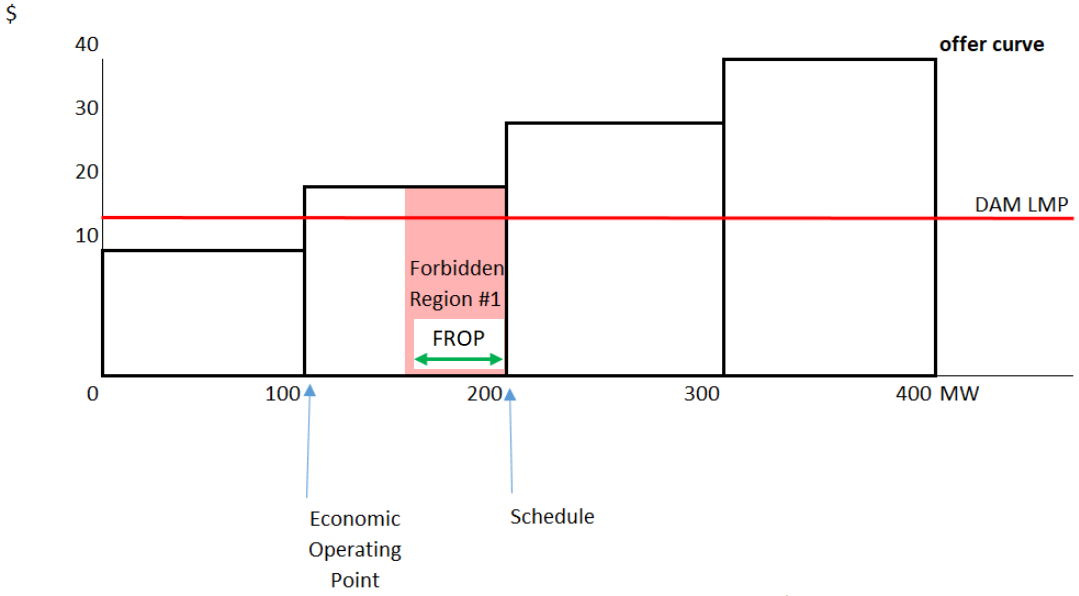
Recap Detailed Design - Forbidden Region

- A forbidden region is a pre-defined operating range within which a hydro resource cannot maintain steady operation without causing equipment damage
- A hydroelectric resource will not be compensated through the real-time MWP for any portion of energy scheduled within or at the boundary of a forbidden region
- DAM calculation engine will not schedule the resource within its forbidden region, hence the DAM MWP is not adjusted

Impact of Forbidden Regions on the DAM MWP

Forbidden Region Operating Profit (FROP) is calculated when a resource is scheduled at the upper boundary of a forbidden region

- A resource cannot operate within the forbidden region. Therefore, a DAM MWP is unwarranted within the forbidden region



Impact of Forbidden Region in DAM and RT MWP

Energy component of the make-whole payment will be adjusted by a term called Forbidden Region Operating Profit (FROP) in DAM and RT

- Forbidden region restrictions can potentially result in a higher or lower schedule than would otherwise be determined by the calculation engine
- The economic operating point (EOP) process does not take into account forbidden region restrictions
- Remove over-compensation of make-whole payments

New: DAM Forbidden Region Operating Profit formula

Forbidden region operating profit: is the operating profit for the MW within the forbidden region

$$FROP_{k,h}^{m} = OP\left(DAM\_LMP_{h}^{m}, FR\_UL_{k,h}^{m,f}, DAM\_BE_{k,h}^{m}\right) - OP\left(DAM\_LMP_{h}^{m}, MAX\left(DAM\_EOP_{k,h}^{m}, FR\_LL_{k,h}^{m,f}\right), DAM\_BE_{k,h}^{m}\right)$$

Where

'FR_UL' forbidden region upper limit submitted by the market participant as daily dispatch data

'FR_LL' forbidden region lower limit submitted by the market participant as daily dispatch data

'f' is the forbidden region set (upper and lower limit) where the DAM_QSI is equal to the forbidden region upper limit.

Revised: DAM MWP formula

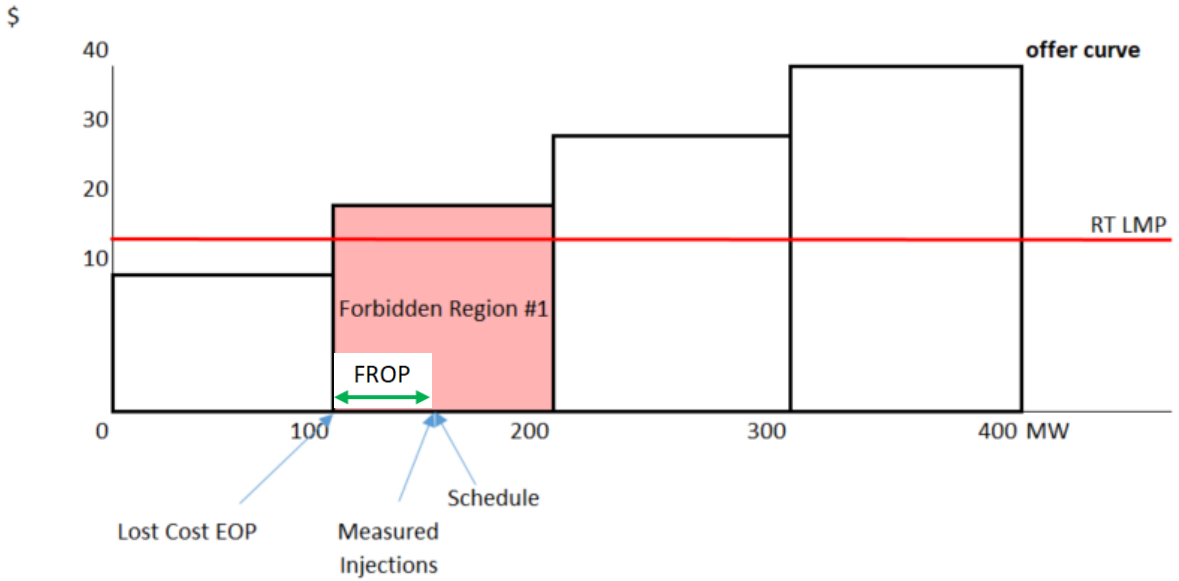
DAM MWP formula will be adjusted for forbidden region operating profit:

$$
\begin{aligned}
DAM\_COMP1^{m}_{k,h} &= (-1) \\
&\times \{OP[DAM\_LMP^{m}_{h}, DAM\_QSI^{m}_{k,h}, DAM\_BE^{m}_{k,h}] \\
&- OP[DAM\_LMP^{m}_{h}, DAM\_EOP^{m}_{k,h}, DAM\_BE^{m}_{k,h}] - FROP^{m}_{k,h}\}
\end{aligned}
$$

Impact of Forbidden Regions on the RT MWP

RT_FROP_LC is calculated when a resource is scheduled at the upper boundary or within a forbidden region

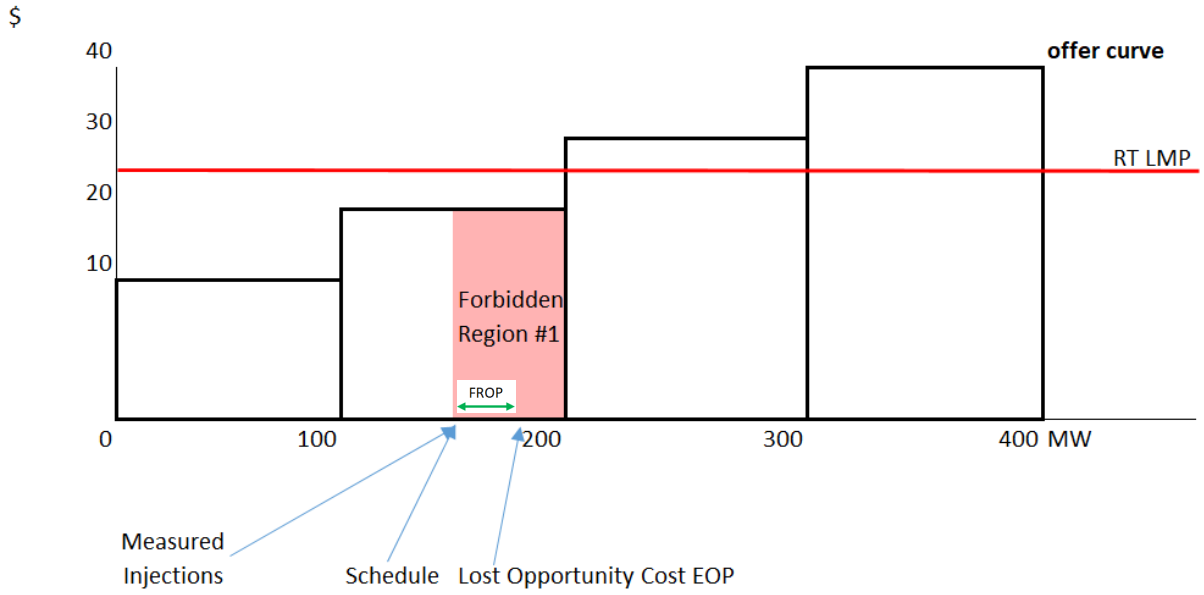
- A resource that operates within the forbidden region will not be compensated with lost cost (LC) RT MWP within the forbidden region



Impact of Forbidden Regions on the RT MWP

RT_FROP_LOC is calculated when a resource is scheduled at the lower boundary or within a forbidden region

- A resource that operates within the forbidden region will not be compensated with lost opportunity cost (LOC) RT MWP within the forbidden region



New: RT Lost Cost Forbidden Region formula

Forbidden region operating profit: is the operating profit for the MW within the forbidden region

$$RT\_FROP\_LC_{k,h}^{m,t} = Min\{0, OP\left(RT\_LMP_{h}^{m,t}, Min(RT\_QSI_{k,h}^{m,t}, AQEI_{k,h}^{m,t}), BE_{k,h}^{m,t}\right) - OP\left(RT\_LMP_{h}^{m,t}, Max(FR\_LL_{k,h}^{m,t,f}, DAM\_QSI_{k,h}^{m}, RT\_LC\_EOP_{k,h}^{m,t}), BE_{k,h}^{m,t}\right)\}$$

Where

'FR_UL' forbidden region upper limit submitted by the market participant as daily dispatch data

'FR_LL' forbidden region lower limit submitted by the market participant as daily dispatch data

'f' is the forbidden region set (upper and lower limit) where the RT_QSI > FR_LL and RT_QSI <= FR_UL.

New: RT Lost Opportunity Cost Forbidden Region formula

Forbidden region operating profit: is the operating profit for the MW within the forbidden region

$$RT\_FROP\_LOC_{k,h}^{m,t} = OP\left(RT\_LMP_{h}^{m,t},\ Min(FR\_UL_{k,h}^{m,t,f}, RT\_LOC\_EOP_{k,h}^{m,t}), BE_{k,h}^{m,t}\right) - Max\left[0, OP\left(RT\_LMP_{h}^{m,t}, Max(RT\_QSI_{k,h}^{m,t,f}, AQEI_{k,h}^{m,t}), BE_{k,h}^{m,t}\right)\right]$$

Where

'FR_UL' forbidden region upper limit submitted by the market participant as daily dispatch data

'FR_LL' forbidden region lower limit submitted by the market participant as daily dispatch data

'f' is the forbidden region set (upper and lower limit) where the RT_QSI >= FR_LL and RT_QSI < FR_UL.

Revised: Real Time MWP formulas

RT MWP for energy lost cost

$$ELC_{k,h}^{m} = -1\ x \sum_{T} Min\{0, [OP(RT\_LMP_{h}^{m,t}, Min(RT\_QSI_{k,h}^{m,t}, AQEI_{k,h}^{m,t}), BE_{k,h}^{m,t}) - OP(RT\_LMP_{h}^{m,t}, Max(RT\_LC\_EOP_{k,h}^{m,t}, DAM\_QSI_{k,h}^{m}/12), BE_{k,h}^{m,t})]\} - RT\_FROP\_LC_{k,h}^{m,t}$$

RT MWP for energy lost opportunity cost

$$ELOC_{k,h}^{m} = \sum_{m,t} \{OP(RT\_LMP_{h}^{m,t}, RT\_LOC\_EOP_{k,h}^{m,t}, BE_{k,h}^{m,t}) - Max[0, OP(RT\_LMP_{h}^{m,t}, Max(RT\_QSI_{k,h}^{m,t}, AQEI_{k,h}^{m,t}), BE_{k,h}^{m,t})] - RT\_FROP\_LOC_{k,h}^{m,t}\}$$

Hydroelectric Generation Resources with Start Restrictions

Recap Detailed Design: Start Restrictions

- DAM MWP for hydroelectric resources will be assessed on a per-start basis when the number of starts within a trading day is equal to the maximum number of starts per day (i.e. max start is binding)
- A start is a set of hours with a DAM financial binding schedule at or above a start indicator value
- All hours that are not part of a start will be assessed DAM MWP separately

DAM MWP Methodology for Binding Max Starts

- Determine lost cost MWP for any hours within the start event that the resource was uneconomically scheduled (i.e. DAM schedule > EOP)
- Determine if the resource earned profit for any hours within the start event that the resource was economically schedule (i.e. calculation will be based on DAM schedules only)
- Offset profits earned against any lost cost MWP over the period of the start
- Resource will receive a payment if the result is a net loss

New: Binding Max Starts Formula

A new settlement equation for component 1 (energy) of DAM MWP will apply when maximum number of starts is binding

$$DAM\_COMP1^{m}_{k,s} = (-1) \times \{[\sum_{Hp} OP(DAM\_LMP^{m}_{h}, DAM\_QSI^{m}_{k,h}, DAM\_BE^{m}_{k,h}) - FROP^{m}_{k,h}] + [\sum_{Hn} OP(DAM\_LMP^{m}_{h}, DAM\_QSI^{m}_{k,h}, DAM\_BE^{m}_{k,h}) - OP(DAM\_LMP^{m}_{h}, DAM\_EOP^{m}_{k,h}, DAM\_BE^{m}_{k,h}) - FROP^{m}_{k,h}]\}$$

Where:

Hp is the set of all hours in start ‘s’ where the operating profit at DAM_QSI is positive, and

Hn is the set of all hours in start ‘s’ where the operating profit at DAM_QSI is negative and DAM_QSI is greater than DAM EOP.

New: Binding Max Starts Formula (cont.)

- Number of starts will increase by 1 every time the schedule crosses over a registered start indication value (SIV) for the resource
- A start event will end when the schedule drops below the lowest SIV
- A start event will excludes hours with a reliability reason code

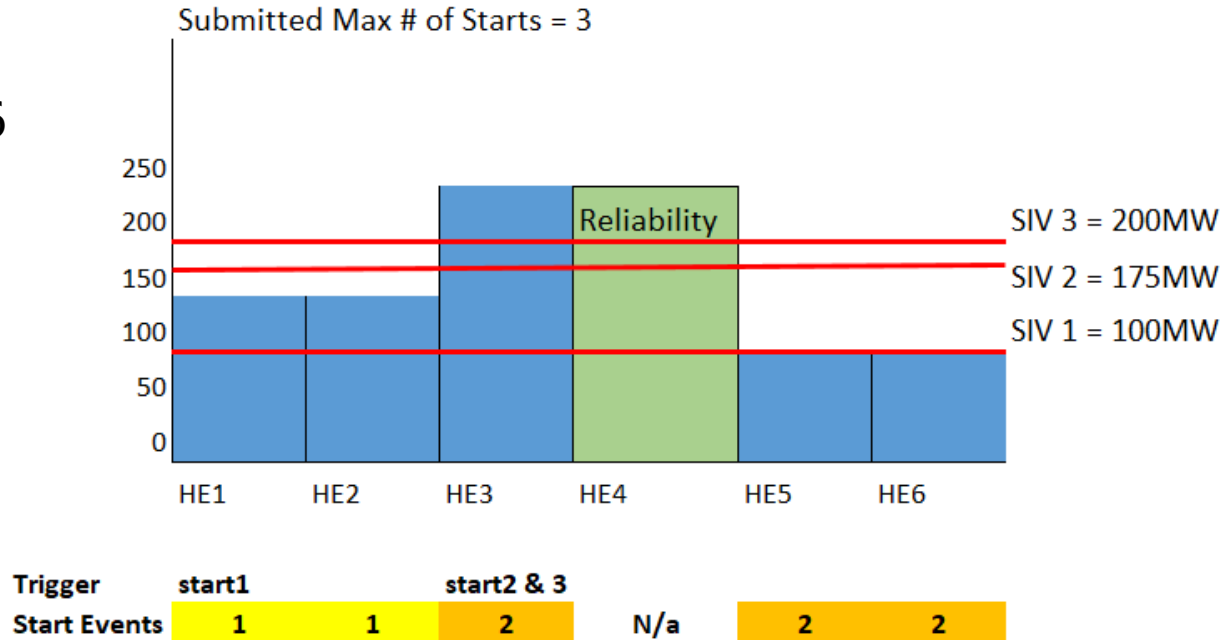
Max Number of Starts Example

Number of start events = 2

Start event #1 = HE 1, 2

Start event #2 = HE 3, 5, 6

HE4 = Reliability Constraint (excluded from the start event #2, it's DAM MWP will be calculated separately)



Example : DAM MWP for Start Event 2

DAM Offer for all hours		
PQ#	Quantity	Price
1	0 MW	$20
2	250 MW	$20

DAM Input			
Hour Ending (HE)	3	5	6
DAM LMP	$25	$2	$2
DAM Qty	250 MW	100 MW	100 MW
EOP	250 MW	50 MW	0 MW

$$DAM\_COMP1_{k,s}^{m} = (-1) \times \{[\sum_{Hp} OP(DAM\_LMP_{h}^{m}, DAM\_QSI_{k,h}^{m}, DAM\_BE_{k,h}^{m}) - FROP_{k,h}^{m}] + [\sum_{Hn} OP(DAM\_LMP_{h}^{m}, DAM\_QSI_{k,h}^{m}, DAM\_BE_{k,h}^{m}) - OP(DAM\_LMP_{h}^{m}, DAM\_EOP_{k,h}^{m}, DAM\_BE_{k,h}^{m}) - FROP_{k,h}^{m}]\}$$

Assumption : Resource does not have a forbidden region, FROP = 0

Example : DAM MWP for Start Event 2

$$DAM\_COMP1^{m}_{k,s} = (-1) \times \left\{\left[\sum_{Hp} OP\left(DAM\_LMP^{m}_{h}, DAM\_QSI^{m}_{k,h}, DAM\_BE^{m}_{k,h}\right) - FROP^{m}_{k,h}\right]\right\}$$

Operating Profit is Positive (Hp)	
HE3	OP (DAM QSI)
Revenue	250MW X $25 = $ 6,250
Costs	250MW X $20 = $ 5,000
Total	($6250 - $5000) = $ 1,250
DAM COMP1	-1 X ($1250) = -$ 1,250

Example : DAM MWP for Start Event 2

$$DAM\_COMP1^{m}_{k,s} = (-1) \times \{[\sum_{Hn} OP(DAM\_LMP^{m}_{h}, DAM\_QSI^{m}_{k,h}, DAM\_BE^{m}_{k,h}) - OP(DAM\_LMP^{m}_{h}, DAM\_EOP^{m}_{k,h}, DAM\_BE^{m}_{k,h}) - FROP^{m}_{k,h}]\}$$

Operating Profit is Negative (Hn)		
HE5	OP (DAM QSI)	OP (DAM_EOP)
Revenue	100MW X $2 = $ 200	50MW X $2 = $ 100
Costs	100MW X $20 = $ 2,000	50MW X $20 = $ 1,000
Total	$200 - $2000 = -$ 1,800	$100 - $1000 = -$ 900
DAM COMP1	-1 X (-$1800 - -$900) = $ 900	

Operating Profit is Negative (Hn)		
HE6	OP (DAM QSI)	OP (DAM_EOP)
Revenue	100MW X $2 = $ 200	0MW X $2 = $0
Costs	100MW X $20 = $ 2,000	0MW X $20 = $0
Total	$200 - $2000 = -$ 1,800	$0 - $0 = $0
DAM COMP1	-1 X (-$1800 - $0) = $ 1,800	

Example: DAM MWP for Start Event 2

DAM MWP Calculation For all hours in Start Event 2

$$DAM\_MWP^{m}_{k,h} = Max\left[0, DAM\_COMP1^{m}_{k,h} + DAM\_COMP2^{m}_{k,h}\right]$$

$$DAM\_MWP^{m}_{k,h} = Max[0, -\$1250 + \$900 + \$1800]$$

$$DAM\_MWP^{m}_{k,h} = \$1450$$

Outcome for the start event	
Positive DAM MWP	DAM MWP for each hour
Negative/Zero DAM MWP	No settlement for any hour

DAM MWP for Cascade River System

Recap Detailed Design – Cascade River System

- For a cascade hydroelectric generation resources with linkages between one or more forebays, DAM MWP need to be calculated across all resources with linked forebays in order to offset profit and loss
- Resources with linked forebays will only receive a payment if the sum of DAM MWP for all resources associated with linked forebays is greater than zero
- Submitted linked forebays and time lags for a trade day will be used to determine the DAM MWP

Clarification: Calculation of Linked Forebays

For a cascade river system with linked forebays where one or more resources have restrictions on the number of starts for a trade day:

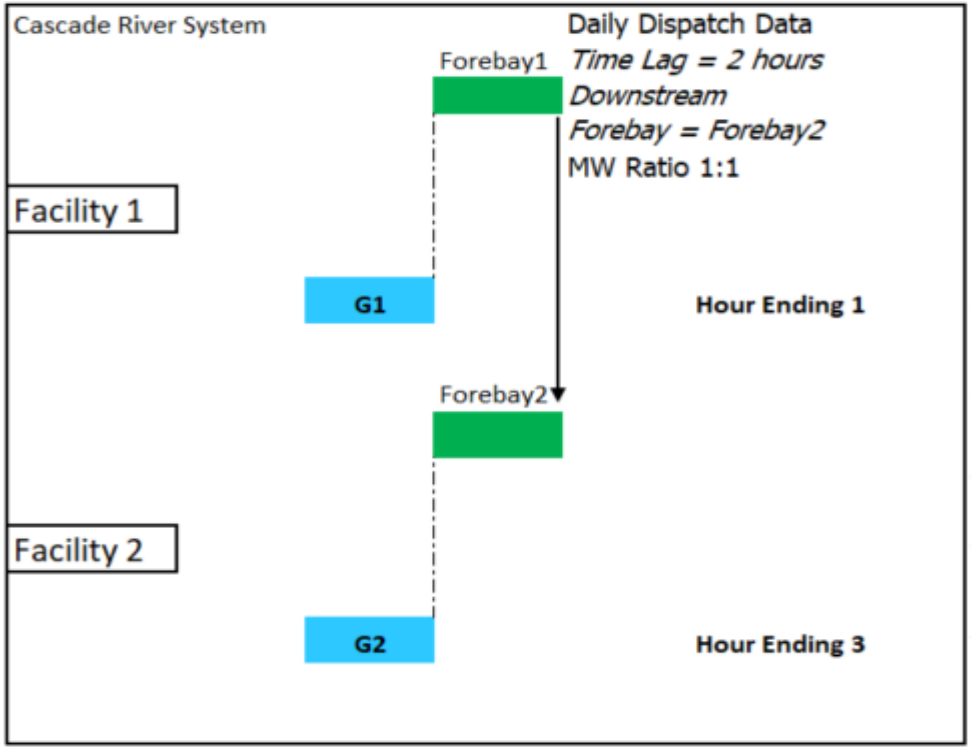
- If a resource has binding maximum number of starts, it will be paid based on DAM MWP calculated using binding Max Start formula, whether or not the sum of DAM MWP for the all linked resources is greater than zero
- If a resource's maximum number of starts is not binding or it does not have start restrictions, it will only receive a lost cost payment if DAM MWP for all resources associated with linked forebays is greater than zero

Example: Linked Forebays with Binding Max Start

Scenario:

G1 does not have binding maximum number of starts in HE 1

G2 has binding maximum number of starts and HE3 is part of a start event



Cascade Example

- Need to calculate the hourly DAM MWP for G2 in HE3 for use in the cascade DAM MWP assessment

$$DAM\_COMP1_{k,h}^{m} = (-1) \times \{OP[DAM\_LMP_{h}^{m}, DAM\_QSI_{k,h}^{m}, DAM\_BE_{k,h}^{m}] - OP[DAM\_LMP_{h}^{m}, DAM\_EOP_{k,h}^{m}, DAM\_BE_{k,h}^{m}] - FROP_{k,h}^{m}\}$$

G2 Hourly DAM MWP Calculation		
HE3	OP (DAM QSI)	OP (DAM_EOP)
Revenue	250MW X $25 = $ 6,250	250MW X $25 = $ 6,250
Costs	250MW X $20 = $ 5,000	250MW X $20 = $ 5,000
Total	$6250 - $5000 = $ 1,250	$6250 - $5000 = $ 1,250
DAM COMP1	-1 X ($1250 - $1250) = $0	

Cascade Example

G1 HE1 will be calculated using the hourly DAM MWP equation

Inputs (HE1)	
DAM LMP	$5
DAM Schedule	100MW
DAM EOP	0MW

DAM Offer for all hours		
PQ#	Quantity	Price
1	0 MW	$20
2	250 MW	$20

G1 Hourly DAM MWP Calculation		
HE1	OP (DAM QSI)	OP (DAM_EOP)
Revenue	100MW X $5 = $ 500	0MW X $25 = $ -
Costs	100MW X $20 = $ 2,000	0MW X $20 = $ -
Total	$500 - $2000 = -$ 1,500	$0 - $0 = $ -
DAM COMP1	-1 X (-$1500 - $0) = $ 1,500	

Assumption : G1 does not have a forbidden region, FROP = 0

Cascade Example

The equation for the overall assessment of cascade DAM MWP is:

$$\sum^{M}\left[DAM\_COMP1_{HE1+0}^{G1} + DAM\_COMP1_{HE3}^{G2}\right] > 0$$

$$\sum^{M}[1500\$ + 0\$] > 0$$

Outcome for the cascade	
G2	The DAM MWP will be calculated using the max start DAM MWP equation ($1450 for the event)
G1	The overall assessment of cascade DAM MWP is positive, therefore, DAM MWP will be calculated using the hourly DAM MWP equation ($1500 for HE1)

Summary

- New settlement equations have been added to adjust MWP to account for forbidden regions in DAM and RT
- New settlement equations have been added to clarify calculation of DAM MWP for resources that have their maximum number of starts binding
- Resources with shared forebays will be required to meet minimum DEL eligibility rules in order to receive DAM MWP
- Resources that have binding maximum number of starts will be assessed on a per-start basis, even if they are part of a cascade model

Next Steps

- Further questions, comments, or requests for additional examples and scenarios can be sent to engagement@ieso.ca
- Details will be included as part of the Settlements Market Rules/Manuals available for stakeholder review in December

Thank You

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