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M E M O R A N D U M

TO: **Reserves Task Force**

FROM: **Andrew Hartshorn / Scott Harvey**

DATE: **8/11/00**

RE: **Locational Reserves Whitepaper**

In keeping with the paper produced for the last task force meeting I will present how we believe the locational prices should be set consistent with the economic intent of cascading prices. I have kept the form of the discussion consistent with the constructs presented in Jim Parmalee's paper. We had previously described for the ISO a methodology for locational pricing of reserves that builds up to the reserve prices using a different construct but consistent methodology which is focussed on implementing the methodology rather than explaining it. I will attach that alternative description to the end of this memo. As you will see that methodology focuses on building the list of units that should count within each of the boxes of the matrix rather than calculating the nine prices and working out how broadly each of the nine prices apply. The ultimate outcome of either approach is the same.

The example from the prior paper looks at 9 product/location pairings in a matrix form with the highest cleared availability bid in each of those categories represented by the letters A through H.

	West	East & Not LI	LI
10 Minute Spin	A	B	C
10 Minute Non Synch	D	E	F
30 Minute Reserve	G	H	I

Currently, the prices are set as follows:

	NY
10 Minute Spin	Max(A-I)
10 Minute Non Synch	Max(D-I)
30 Minute Reserve	Max(G-I)

This occurs regardless of which of the constraints are binding or slack. This is slightly inconsistent with the economic intent of cascading prices. In the instances where the pool spin constraint is not binding, and none of the locational spin constraints are binding both the 10 minute products should clear at Max(A-I). If this methodology were used when either the East or LI spin constraints were binding the 10 minute non-synch price would be overstated.

Now that we will be explicitly pricing the locational constraints as well as the poolwide product constraints, the full and correct intent of cascaded pricing can be reflected in the locational prices we calculate.

Base Case

Initially assume that none of the locational constraints are binding but all the poolwide product constraints are binding (i.e. we clear ≤ 600 MW spin, ≤ 1200 MW of 10 minute total and ≤ 1800 MW of 30 minute total reserves). Prices in this case look very much like the existing methodology.

	West	East & Not LI	LI
10 Minute Spin	Max(A-I)	Max(A-I)	Max(A-I)
10 Minute Non Synch	Max(D-I)	Max(D-I)	Max(D-I)
30 Minute Reserve	Max(G-I)	Max(G-I)	Max(G-I)

Cascading Between Products

If we now assume there are still no binding locational constraints, that the poolwide 10 minute spin constraint is slack (we clear ≥ 600 MW spin) and the poolwide 10 minute total constraint is binding (we clear ≤ 1200 MW of 10 minute total reserves) the prices would be determined as follows:

	West	East & Not LI	LI
10 Minute Spin	Max(A-I)	Max(A-I)	Max(A-I)
10 Minute Non Synch	Max(A-I)	Max(A-I)	Max(A-I)
30 Minute Reserve	Max(G-I)	Max(G-I)	Max(G-I)

The incremental value of an additional MW of either 10 minute spin or 10 minute non-synch is equal to the shadow price of the 10 minute total constraint. At the margin 10 minute reserves are being scheduled on both on and off line units to meet the 10 minute total reserves requirement. Thus all 10 minute reserves should be paid the same clearing price regardless of whether the reserves are carried on a spin or non-synch unit because there is no scarcity value for reserves on on-line units beyond the value of 10 minute reserves and reserves on spinning units are being scheduled to meet the 10 minute reserve requirement. If we had less 10 minute reserves on spinning units the NYISO would have to schedule more 10 minute reserves at the 10 minute price.

Cascading Between Regions

Now assume that all the poolwide product constraints are binding and all locational reserve constraints are slack except the East of Central East spin constraint which is binding. Prices would be determined as follows:

	West	East & Not LI	LI
10 Minute Spin	Max(A,D-I)	Max(A-I)	Max(A-I)
10 Minute Non Synch	Max(D-I)	Max(D-I)	Max(D-I)
30 Minute Reserve	Max(G-I)	Max(G-I)	Max(G-I)

Note that spin in LI and East of Central East are paid the same amount regardless of where the last MW was cleared. The incremental value of spin from either location is equal to the shadow price of the East of Central East spin constraint. This is entirely analogous to the cascading of prices between products. If 1 MW less of spin were available in LI, the NYISO would need to schedule another MW at the East of Central east price.

Cascading Between Regions and Products

There are many combinations of locational and poolwide product constraints that solve to different outcomes. There are too many to enumerate but we can examine one particular outcome and see how the prices would be determined.

In this example the constraint configuration is as follows:

- Spin
  - The poolwide constraint is slack
  - The East of Central East constraint is binding
  - The LI constraint is slack
- 10 minute total
  - The poolwide constraint is slack (almost always true as the East and pool requirements are both 1200)
  - The East constraint is binding
  - The LI constraint is slack
- 30 minute total
  - The poolwide constraint is binding (it will always be binding)
  - The East constraint is binding
  - The LI constraint is slack

	West	East & Not LI	LI
10 Minute Spin	Max(A,D,G)	Max(A-I)	Max(A-I)
10 Minute Non Synch	Max(A,D,G)	Max(A,D-I)	Max(A,D-I)
30 Minute Reserve	Max(A,D,G)	Max(A,D,G-I)	Max(A,D,G-I)

This result may not seem completely intuitive but if you work through each box of the matrix determining which requirements the reserves are actually being counted towards meeting and which shadow price the reserve is being valued against these answers fall out.

Because the LI spin constraint is not binding, the East of Central East spin constraint has the highest shadow price so the East of Central East and LI spin prices will be the highest of any of the products in any of the locations, hence they are the Max(A-I). The reserves used to meet this requirement meet all of the other reserve requirements that are binding in this case. Therefore a MW of additional reserves meeting the East of Central East spin requirement sets a ceiling on the shadow price of the other reserves. A MW of spin East of Central East could be scheduled to meet the East 10 minute total constraint, the East 30 minute total constraint and the Pool 30 minute total constraint.

The next highest shadow price will be the East of Central East 10 minute total constraint. The prices for the Eastern 10 minute non synch must be highest of all 10 minute non-synch or 30 minute bids plus it must be higher than the west spin bid as some of the West spin is being used to meet the 30 minute poolwide requirement which has a lower shadow price. This is because the 10 minute non-synch reserves East of Central East meet the requirements of all the other binding constraints except the East of Central East spin constraint. Thus, this shadow price sets a ceiling on the shadow prices of the other binding 10 minute total and 30 minute reserve constraints. If the prices for Eastern 10 minute non-synch were not higher than A then we would have used additional 10 minute reserves in the East to meet the 30 minute requirement in place of A. This price does not include B or C because that capacity is necessary to meet a binding constraint with a higher shadow price.

The next highest shadow price will be the East of Central East 30 minute total constraint. The price of the Eastern 30 minute reserves must be the highest of all 30 minute bids plus it must be higher than he bids for spin or 10 minute non-synch in the West as they are being used to meet the 30 minute pool requirement. This is because 30 minute reserves East of Central East also meet the requirements of the 30 minute pool constraint and thus set a ceiling on the shadow price of this constraint. Because additional spin in the West is scheduled to meet the 30 minute pool constraint the East of Central East 30 minute price is greater than or equal to the western spin price. If the prices for Eastern 30 minute reserves were not higher than A then we would have used additional 30 minute reserves in the East to meet the 30 minute requirement in place of A or D. This price does not include B, C, E or F because that capacity is necessary to meet binding constraints with higher shadow prices.

The lowest shadow price will always be the 30 minute total poolwide constraint as all reserves scheduled meet this requirement. This means the lowest cost MW in any location for any type of reserve can always be used to meet this requirement. All reserves in the West are being used to meet this requirement so the price for all Western reserves is equal to the Western 30 minute price. Hence each of the Western prices is the Max(A,D,G). None of the Eastern bids are included as they are all used to meet binding constraints with higher shadow prices.

Some Simplifications

There was some discussion at the last meeting that LI was prepared to not set the price for a particular product if the LI constraint for that product was binding. This would simplify the solution greatly, as the LI price would then always be equal to the East price. When determining the price in the East if the LI constraint is binding both prices are set excluding C from the evaluation. If the constraint is slack both Band C are considered. It effectively reduces the size of the matrix down to 6.

The poolwide and Eastern constraint for 10 minute total reserve are identical which removes another box from the evaluation. The 10 minute non-synch price in the West is always equal to the 30 minute price in the West.

We also discussed removing the East of Central East 30 minute requirement which would reduce the 30 minute market back to a single price if the binding LI constraint made them ineligible to set price. Before we write the tariff we need to establish how the LI constraints will be treated.

Some Other Suggestions

We may want to give some consideration to paying day-ahead opportunity costs to units selected day-ahead by setting the reserve prices for spin and 10 minute non-synch to the sum of the availability bid and the opportunity cost of each unit to set the clearing price. The clearing price would then truly reflect the shadow prices of the reserve constraints. These units would then be obligated to provide the reserves in real time unless they are unable to, for synch providers because they tripped or for non-synch providers because they were previously started for energy.

This system would result in some double payment to the extent that reserve pickups were called and reserve got converted to energy. These units would receive the opportunity cost day-ahead and then also receive a real-time balancing energy payment. However, this approach would avoid paying all reserve providers twice the market clearing price. Right now we pay the highest cleared availability bid from day ahead to all providers and then the market clearing opportunity cost in real time for spinning reserve provider and have proposed to pay each units opportunity cost for the non synch providers.

Consider an example where there are two spin providers and suppose day-ahead and real-time prices are identical. One has an availability bid of $1 and an opportunity cost of $20. The other has an availability bid of $20 and an opportunity cost of $1. Currently we would pay each of these spin providers a $20 availability bid and a $20 opportunity cost payment for a total of $40. Paying both day-ahead as a single price would result in a payment to both providers of $21.

Another important advantage of this approach is that it moves the NY market closer to a two settlement system for reserves which would see all reserve switching hour-ahead

covered by balancing payments by the reserve providers cleared day-ahead and not in the hour-ahead.

Alternative Description

The excerpt from the paper written for the NYISO for implementation of the locational reserves follows:

Methodology 1

The first methodology requires knowing the shadow prices on each of the eight locational reserve constraints. There are only eight as opposed to nine as the East 10 minute total constraint is the same as the pool constraint for 10 minute total. The eight constraints are therefore LI constraints for 10 minute spin, 10 minute total and 30 minute total, East constraints for 10 minute spin, 10 minute total and 30 minute total. The methodology will be generalized such that if the NYPP 10 minute total requirement is ever changed to be less than the East 10 minute total requirement the pricing structure will still work.

Given a particular pattern of constraints you can infer what accepted availability bids need to be included in the stack of bids used to determine the prices for each region and each product.

If LI constraints are binding for the same quality of product the LI units will be removed from the stack so they cannot set the price for the respective locational prices. If the LI constraint is slack the LI units are able to set price.

We will set up 9 stacks of availability bids:
East spin including LI
East spin excluding LI
Not East spin
East 10 minute non-spin including LI
East 10 minute non-spin excluding LI
Not East 10 minute non-spin
East 30 minute reserve including LI
East 30 minute reserve excluding LI
Not East 30 Minute reserve

This will get reduced to six stacks by determining whether or not LI will be included in the East stack. If either the LI constraint for a particular reserve is binding and the East constraint is not or if both are binding and the LI constraint has a higher shadow price then we use East stack excluding LI otherwise we use the stack including the LI units. This determination is made independently for each level of reserves.

Knowing the highest cleared availability bid for each of these 6 stacks and which constraints are binding at what shadow price we can construct a logical framework that gets the price right for each product and each location.

The complete listing of the combinations of state for the four constraints that affect the locational prices are shown below

	1		2		3		4		Total
1	TRUE	EastSpin constrained	TRUE	TotalSpin constrained	TRUE	EastTen constrained	TRUE	EastThirty constrained	TRUE
2	TRUE	EastSpin constrained	TRUE	TotalSpin constrained	TRUE	EastTen constrained	FALSE	EastThirty Unconstrained	FALSE
3	TRUE	EastSpin constrained	TRUE	TotalSpin constrained	FALSE	EastTen Unconstrained	TRUE	EastThirty constrained	FALSE
4	TRUE	EastSpin constrained	TRUE	TotalSpin constrained	FALSE	EastTen Unconstrained	FALSE	EastThirty Unconstrained	FALSE
5	TRUE	EastSpin constrained	FALSE	TotalSpin Unconstrained	TRUE	EastTen constrained	TRUE	EastThirty constrained	FALSE
6	TRUE	EastSpin constrained	FALSE	TotalSpin Unconstrained	TRUE	EastTen constrained	FALSE	EastThirty Unconstrained	FALSE
7	TRUE	EastSpin constrained	FALSE	TotalSpin Unconstrained	FALSE	EastTen Unconstrained	TRUE	EastThirty constrained	FALSE
8	TRUE	EastSpin constrained	FALSE	TotalSpin Unconstrained	FALSE	EastTen Unconstrained	FALSE	EastThirty Unconstrained	FALSE
9	FALSE	EastSpin Unconstrained	TRUE	TotalSpin constrained	TRUE	EastTen constrained	TRUE	EastThirty constrained	FALSE
10	FALSE	EastSpin Unconstrained	TRUE	TotalSpin constrained	TRUE	EastTen constrained	FALSE	EastThirty Unconstrained	FALSE
11	FALSE	EastSpin Unconstrained	TRUE	TotalSpin constrained	FALSE	EastTen Unconstrained	TRUE	EastThirty constrained	FALSE
12	FALSE	EastSpin Unconstrained	TRUE	TotalSpin constrained	FALSE	EastTen Unconstrained	FALSE	EastThirty Unconstrained	FALSE
13	FALSE	EastSpin Unconstrained	FALSE	TotalSpin Unconstrained	TRUE	EastTen constrained	TRUE	EastThirty constrained	FALSE
14	FALSE	EastSpin Unconstrained	FALSE	TotalSpin Unconstrained	TRUE	EastTen constrained	FALSE	EastThirty Unconstrained	FALSE
15	FALSE	EastSpin Unconstrained	FALSE	TotalSpin Unconstrained	FALSE	EastTen Unconstrained	TRUE	EastThirty constrained	FALSE
16	FALSE	EastSpin Unconstrained	FALSE	TotalSpin Unconstrained	FALSE	EastTen Unconstrained	FALSE	EastThirty Unconstrained	FALSE

These combinations can then be mapped to a series of equations that calculate the price for each locational reserve price and only one of these combinations can be valid.

The following table outlines the calculations that would be made to create each locational price where:
M() is a function taking the maximum of the availability bids scheduled to provide reserves in the stacks listed in the parameters;
X is the spin stack used for the East;
Y is the spin stack used for the West;
Z is the 10 minute non-spin stack used for the East;
A is the 30 minute stack used for the East;
B is the 10 minute non-spin and and 30 minute stack used for the East.

East Spin	**West Spin**	**East 10 Non Spin**	**East 30 minute**	**West 30 Minute**
M(X,Y,Z,A,B)	M(Y,B)	M(Z,A,B)	M(A,B)	M(B)
M(X,Y,Z,A,B)	M(Y,B,A)	M(Z,A,B)	M(A,B)	M(A,B)
M(X,Y,Z,A,B)	M(Y,B)	M(Z,A,B)	M(Z,A,B)	M(B)
M(X,Y,Z,A,B)	M(Y,Z,A,B)	M(Z,A,B)	M(Z,A,B)	M(Z,A,B)
M(X,Y,Z,A,B)	M(Y,B)	M(Z,A,B,Y)	M(Y,B,A)	M(Y,B)
M(X,Y,Z,A,B)	M(Y,B,A)	M(Z,A,B,Y)	M(Y,B,A)	M(Y,B,A)
M(X,Y,Z,A,B)	M(Y,B)	M(Z,A,B,Y)	M(Z,A,B,Y)	M(Y,B)
M(X,Y,Z,A,B)	M(Y,Z,A,B)	M(Z,A,B,Y)	M(Z,A,B,Y)	M(Z,A,B,Y)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Z,A,B)	M(A,B)	M(B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Z,A,B)	M(A,B)	M(A,B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Z,A,B)	M(Z,A,B)	M(B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Z,A,B)	M(Z,A,B)	M(Z,A,B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Y,B,A)	M(Y,B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Y,B,A)	M(Y,B,A)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(Y,B)
M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)	M(X,Y,Z,A,B)

It can be seen that in the completely unconstrained case at the bottom of the table the price for all reserves is the maximum of all availability bids in all the stacks.

The first row of the table shows the outcome when all the constraints are binding.