Technical Bulletin

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Negative LAP Prices

For June 5, 2009 HE23

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This document reviews Real-Time Dispatch (“RTD”) case from June 5 where the binding interval has LAP price where at least one of the default Load Aggregation Price (“LAP”) more negative than -$100.   On June 5th HE 23, interval 12, it is observed that due to constrained ramping of resources the first binding interval is very negative followed by very positive LAP prices in the second interval (HE24 Interval 1). Following is an attempt to deconstruct the observed negative price. Similar scenarios have been observed since June 5.

<u>Case: Binding Interval: 6/5/2009 HE23 Interval 12 (Binding)</u>

The LAP price is negatively beyond the bid floor (-$30) but above price floor (-$2500). The change in LAP price from HE23 interval 12 to HE24 1 is about $3000. The economic bid stack is extremely tight in both inc and dec directions, both capacity and ramp capability. The reason the imbalance need in HE24 interval 1 (HE24 23:00-23:05) exists is that that there are approximately 400 MW that are shutting down in the HE24 Interval 1. In order to meet the demand in the second interval, certain slow ramping resources start ramping up in the first interval. In the meantime, decing fast-ramping resources is necessary for power balancing for first interval but economic dec bids are run out resulting in self-schedule uneconomic curtailment. This explains that LAP prices are negative in the first interval and positive in the second interval.

As for the reason of such a pricing outcome of the first two intervals of this case, the finding is the interactions between ramping constraints of 2 resources which are in lossless nature and the lossy power balance constraints of the 2 intervals. The change in loss penalty factor values for 0.015 for one of the resource from HE23 Interval 12 to HE24 Interval 1 also plays a role. Following is a more detailed analysis of the results of this scenario.

LAP Prices:

	PG&E	SCE	SDGE
HE23 Interval 12 of the case	-$1642.75	-$1595.235	-$1586.51
HE24 Interval 1 of the case	$1654.81	$1606.24	$1625.13

Data

The two resources undergoing constrained ramping from HE23 interval 12 to HE24 interval 1 and setting the market prices for the two intervals are UNITA and UNITB. The market solution of the two resources for the 2 intervals is shown in the table below.

	UNITA		UNITB	
	HE23 Interval 12	HE24 Interval 1	HE23 Interval 12	HE 24 Interval 1
Scheduling Run MW	7.757MW	24.757MW	296.6MW	417.55MW
Pricing Run MW	24.757MW	27.848MW	293.526MW	414.483MW
Loss Penalty Factor	1.0261	1.029	1.0235	1.0089
Bid Price at Dispatch MW Level	$0	$12.33	$18.11	$21.97
Ramp Rate	3.4MW/min		24.19MW/min	

Multiplier of power balance of HE23 interval 12 = -$1612.57
Multiplier of power balance of HE24 interval 1 = $1629.91

Verification of Pricing Run Prices

In this section, for notational convenience, we use UNITB_1 and UNITB_2 respectively denote MW quantities of UNITA of intervals 1 and 2. Similarly UNITB _1 and UNITB _2 respectively denote MW quantities of UNITB of intervals 1 and 2.

Under the linearized formulation, contributions to the change in power balancing for HE 23 intervals 12 and HE24 Interval 1 and to the change in resource ramping constraints by the MW changes of these two resources of HE 23 intervals 12 and HE24 Interval 1 are:

$$\Delta UNITA\_1/1.0261 + \Delta UNITB\_1/1.0235 = Change\ in\ Power\ Balance\ of\ Interval\ 12$$

$$\Delta UNITA\_2/1.029 + \Delta UNITB\_2/1.0089 = Change\ in\ Power\ Balance\ of\ Interval\ 1$$

$$-\Delta UNITA\_1 + \Delta UNITA\_2 = Change\ in\ Ramping\ Constraint\ of\ UNITA\ Between\ Interval\ 12\ and\ 1$$

$$-\Delta UNITB\_1 + \Delta UNITB\_2 = Change\ in\ Ramping\ Constraint\ of\ UNITB\ Between\ Interval\ 12\ and\ 2$$

The matrix of the LHS of this 4x4 linear system of equations is

$$\begin{bmatrix} 1/1.0261 & 0 & 1/1.0235 & 0 \\ 0 & 1/1.029 & 0 & 1/1.0089 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 \end{bmatrix}$$ where:

First and second rows correspond to the power balance equations of HE 23 intervals 12 and HE24 Interval 1. Third and fourth rows correspond to the ramping constraints of UNITA and UNITB between HE23 Interval 12 and HE24 Interval 1. First and second columns correspond to UNITA variable of intervals HE23 Interval 12 and HE24 Interval 1. Third and fourth columns correspond to UNITB variables of HE23 Interval 12 and HE24 Interval 1.

The inverse of this matrix is

$$\begin{bmatrix} 60.2071 & -59.3482 & 57.6756 & 58.8247 \\ 60.2071 & -59.3482 & 58.6756 & 58.8247 \\ -59.0310 & 59.1979 & -57.5295 & -58.6756 \\ -59.0310 & 59.1978 & -57.5295 & -57.6756 \end{bmatrix}$$

and it has very interesting interpretation. The first column is the required change of the UNITB_1, UNITB_2, UNITB _1 and UNITB _2 per MW increase of the power balance of HE23 Interval 12 while the limits of other 3 constraints remain fixed. The second column is the required change of the UNITB_1, UNITB_2, UNITB _1 and UNITB _2 per MW increase of the power balance of HE24 Interval 1 while the limits of other 3 constraints remain fixed. The third column is the required change of the UNITB_1, UNITB_2, UNITB _1 and UNITB _2 per MW increase of inter interval ramping amount of BAL while the limits of other 3 constraints remain fixed. The fourth column is the required change of the UNITB_1, UNITB_2, UNITB _1 and UNITB _2 per MW increase of inter interval ramping amount of UNITB while the limits of other 3 constraints remain fixed.

Taking the inner product between the row vector formed by the bid prices of these two resources, namely [0, 12.33, 18.11, 21.97] and the inverse, we obtain the change in the cost objective per MW increase of the each of the constraint limits. The result of the calculation is $[-1623.61 \quad 1640.88 \quad -1582.31 \quad -1604.44]$. The first two elements are the multipliers of the power balance HE23 Interval 12 and HE24 Interval 1. The third and fourth elements are the negative of the ramping constraint multipliers. Note that this verifying calculation for power balance multipliers closely matches the market solution multiplier values of -$1612.57 and $1629.91. Interestingly, should the resource ramping constraints be modified by dividing resource variable by its loss penalty factor, the matrix will become singular. In essence, the ramping constraint becomes lossy.