ATLANTIC
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MEMORANDUM

DATE: May 10, 2024

TO: CAISO Price Formation Enhancements Working Group

FROM: Mike Cadwalader

RE: Comments on Analysis of Fast-Start Pricing

This memo contains my comments on the CAISO's Analysis of Fast-Start Pricing, presented at the April 8, 2024, meeting of the Price Formation Enhancements Working Group. It expands on the slides that I presented at the conclusion of the CAISO presentation at that meeting. In short, my recommendations and observations are:

- The CAISO's analysis demonstrates that using the Constant Adder approach to determine fast-start bids—i.e., the bids that would be used in the pricing dispatch, if fast-start pricing is implemented—would yield LMPs that are somewhat higher than the LMPs produced using the other two approaches for determining those bids. This Is consistent with expectations, since the fast-start bids produced by the Constant Adder approach are higher than the fast-start bids produced by the other two approaches analyzed by the CAISO.

- In contrast, those other two approaches for detemining fast-start bids, which differ with respect to how cost is allocated but not with respect to how much cost is allocated, yield LMPs that are very similar, on average.

- However, that does not mean that there are no important differences between those mechanisms. Although the average LMPs produced using these two approaches may be similar, there may be many hours when one approach produces LMPs that are somewhat higher than the LMPs produced by the other approach, while in another set of hours, the opposite relationship holds. This means that LMPs produced by these approaches may have different effects.

10 Tower Office Park, Suite 408, Woburn, MA 01801
T: 781-281-0553 C: 617-875-7723 mdc@AtlanticEconomics.com

- If LMPs are too low, they will not reflect the cost of using fast-start generation to meet load. Ths may lead to, or exacerbate, the need to make bid cost recovery (BCR) payments to generators. Alternatively, if LMPs are too high, they will overstate the cost of operating those generators, which may lead to lost opportunity costs (LOCs), as generators find that they would increase their profit by producing more energy than they were directed to produce in the dispatch. (This is a particular concern given that, unlike the market rules in some other ISOs, CAISO market rules do not impose explicit penalties for generators that produce energy in excess of dispatch instructions.[1]) It would be useful to expand the CAISO's analysis to examine the impact of each of these three approaches on BCR payments and LOCs. If there are material differences, that would inform the decision as to which method is preferred.

- An important caveat is that the CAISO analysis did not consider the potential for gaming. Under the Adjusted Constant Adder approach, the fast-start bids include an adder, which is based on the bid to produce the first MW above a generator's Pmin block. This provides an incentive to modify the bid for that MW, which would be very unlikely to affect the physical dispatch, but which could significantly affect the pricing dispatch. That, in turn, could increase prices. Taking the potential to use such a bidding strategy into consideration, the market outcomes that result from the use of the Adjusted Constant Adder approach may be similar to the market outcomes that result from the use of the Constant Adder approach.

Effect of Different Procedures for Determining Fast-Start Bids on BCR Payments and Lost Opportunity Costs

Under fast-start pricing (FSP), a fast-start generator (FSG) would be modeled in the pricing pass as though it was fully dispatchable at any output level between zero MW and its maximum output level (Pmax). If an FSG is on the margin in the pricing pass, its bid would set the LMP that is used for settlement purposes. FSP would not affect actual dispatch instructions.[2]

If FSP is adopted, it would be necessary to define fast-start bids for FSGs, which would be used in the pricing pass in the place of the bids actually submitted by FSGs. Fast-

[1] That does not mean that generators can ignore dispatch instructions without consequences, as failure to comply with dispatch instructions is monitored by the CAISO's Department of Market Monitoring.

[2] I understand that for reasons that are outside the scope of these comments, the CAISO currently uses its pricing dispatch to determine physical dispatch instructions. If FSP is implemented, it will be necessary to use a dispatch for the purpose of determining prices that differs from the dispatch that is used to determine dispatch instructions.

start bids would differ from the bids that are used to determine dispatch instructions for FSGs. This is necessary because the bids that are actually submitted for such generators do not indicate the incremental cost of producing each additional MWh for output between zero MW and the minimum operating level (Pmin) for these resources. Additionally, the bids that are actually submitted for generators separately specify commitment costs, including both start-up cost and the minimum load cost (MLC), which reflects the cost of operating at Pmin; the fast-start bids should incorporate these costs in some manner, since they would not include separate start-up cost and MLC bids. Finally, the fast-start bids must be non-decreasing, so that the marginal bid cannot decrease as output increases.

The April 8 presentation[3] analyzed the consequences of three different methods for determining these fast-start bids: the Constant Adder, the Adjusted Constant Adder, and the Minimum Average Cost approaches, each of which is described in more detail below.

The CAISO's analysis of the effect on LMPs that would result from implementation of FSP, under each of these three approaches, seems reasonable and is generally consistent with expectations. In particular, the analysis beginning on slide 71 of the April 8 presentation demonstrates that LMPs produced by the Constant Adder approach are somewhat higher than LMPs produced by the other two approaches. These results are not surprising. In my previous comments submitted in January, I compared the total as-bid cost of operating a generator at Pmax, using the bids that were actually submitted for it, to the total as-bid cost of operating that generator at Pmax using fast-start bids that were determined for that generator using the Constant Adder, Adjusted Constant Adder, and Minimum Average Cost approaches. As those comments showed, the cost of operating that generator using fast-start bids that were determined for that generator using the Constant Adder approach are higher than the actual cost of operating that generator that is used to dispatch that generator, while the cost of operating that generator using fast-start bids that were determined for that generator using the other two approaches were the same as the actual cost of operating that generator that is used to dispatch that generator.[4] Thus, it is not surprising that LMPs are higher under the Constant Adder approach, since the fast-start bids procuded by that

[3] CAISO, Price Formation Enhancements: Analysis on Fast Start Pricing (Apr. 8, 2024), available at: https://www.caiso.com/InitiativeDocuments/Presentation-Price-Formation-Enhancements-Apr8-2024.pdf.

[4] Mike Cadwalader, Comments on Presentation at Working Group Session #9, at 2-5, available at: https://www.caiso.com/InitiativeDocuments/Presentation-Price-Formation-Enhancements-Apr8-2024.pdf.

approach overstate the cost of operating the generator, while the fast-start bids produced by the other two approaches do not.

The other two approaches for calculating fast-start bids differ with respect to how the cost of operating the generator is allocated. Under the Adjusted Constant Adder approach, more of those costs are allocated to higher output levels, while under the Minimum Average Cost approach, more of those costs are allocated to lower output levels. Thus, as the examples to follow will show, the Adjusted Constant Adder approach will yield higher LMPs than the Minumum Average Cost approach in some cases, while in other cases, the opposite will occur. The April 8 presentation showed that average prices calculated under these two approaches were similar, indicating that while one approach may yield higher prices at some times and lower prices at other times, those effects offset, more or less.[5]

While the frequency with which each of these approaches would affect the LMP, and the magnitude of that impact, are certainly important areas of interest for both the CAISO and stakeholders, knowing that impact is not dispositive as to which of three approaches considered by the CAISO is the best. If the LMPs are too low when FSGs are needed to meet load, they will not reflect the cost of operating FSGs when FSGs are needed to meet load, which is one of the primary objectives of fast-start pricing. Consequently, they will fail to provide sufficient incentives for loads to reduce consumption or for additional supply to become available, and it will be necessary to make bid cost recovery (BCR) payments to FSGs to compensate for this difference. If LMPs are higher, BCR payments may be reduced or eliminated entirely, but the LMPs may overstate the cost of operating FSGs when they are needed to meet load. In addition to providing inefficient incentives, LMPs that are too high can also lead to lost opportunity costs (LOC), as generators that are not dispatched find that they could have increased their profits if they had produced more energy, given the LMPs that were actually in effect. This may give these generators an incentive to bid in a manner that would produce economically inefficient schedules, or simply to disregard dispatch instructions and produce more energy than they were dispatched to produce.

Ideally, LMPs would be neither too low nor too high, but just right—or, at least, as close to right as possible. While it will not always be possible to set prices in a manner that would ensure that both BCR payments and LOCs are zero, an assessment of the impact that each of the proposed approaches would have on BCR payments and LOCs is important to reach an informed conclusion on which approach is best. Even if LMPs

[5] In the April 8 presentation, there is one month for which the LMPs calculated for the CAISO using the Minimum Average Cost approach are significantly higher than LMPs calculated using the Adjusted Constant Adder approach. My understanding is that this was an error, and the CAISO plans to post an updated version of the presentation that will correct the error.

calculated using the Adjusted Constant Adder and the Minimum Average Cost approaches are about the same on average, one may be signficantly higher than the other in one group of hours, and signficantly lower in another group of hours, which would have significant implications for BCR payments and LOCs.

For that reason, it would be useful if the CAISO could extend the analysis presented on April 8 to illustrate the impact that each approach would have on BCR payments and LOCs. The following two examples will illustrate how each of these three approaches would function in a case involving an FSG whose bid to be dispatched above Pmin is below its average cost of starting and operating at Pmin, and the BCR payments or LOCs that would result from the use of each approach.

Assumptions for Examples

For these examples, I will use the same FSG that was used in my January comments:

- It has a Pmin of 100 MW, and offers two incremental 50 MW energy blocks, so it can be dispatched at any output level between 100 MW and 200 MW.
- It submits a start-up bid of $2000, which is allocated over a minimum up time of one hour, and an MLC of $5000/hour, so its bid cost of starting and operating at Pmin for one hour is $7000 (or $70/MWh).
- It submits incremental output bids of:
  - $40/MWh for the first incremental block ("Inc 1"), which is iess than the $70/MWh average cost of generating using the Pmin block, and
  - $80/MWh for the second incremental block ("Inc 2"), which is greater than the $70/MWh average cost of generating using the Pmin block.

In addition, assume that there are two other non-fast-start generators available: G1 and G2. Each has a Pmin of 0 MW and a Pmax of 500 MW. Start-up costs for both G1 and G2 are zero. Since neither of these generators is an FSG, the same bids will be used for them in the physical dispatch and pricing passes.

Finally, for simplicity, these examples will determine physical dispatch instructions and LMPs for the hour as a whole. Other complicating factors, such as operating reserves or FRP, will be disregarded.

Example 1: FSG is Dispatched into its First Incremental Block

Physical Dispatch

Given these assumptions, Table 1 shows the least-cost dispatch to meet 625 MW of load, under the assumption that G1 offers energy at $35/MWh for its entire output, while

G2 offers all of its energy at $65/MWh. G1 operates at Pmax, producing 500 MWh, leaving 125 MW of load to be met. The FSG is dispatched into its first incremental block, producing 125 MW, while G2 is not directed to operate, because the $7000 + 25 MWh × $40/MWh = $8000 cost of producing 125 MWh using the FSG is less than the 125 MWh × $65/MWh = $8125 cost of producing 125 MWh using G2.

Table 1: Least-Cost Physical Dispatch for Example 1, Using Bids Submitted by Generators

	Capacity (MW)	Incre. Offer ($/MWh)	Schedule (MW)	Bid Cost ($)
G1	500	$ 35.00	500	$ 17,500
G2	500	$ 65.00	-	$ -
FSG:				
Pmin	100		100	$ 7,000
Inc 1	50	$ 40.00	25	$ 1,000
Inc 2	50	$ 80.00	-	$ -
Total			**625**	**$ 25,500**

Pricing Pass Using Fast-Start Bids Determined Using the Constant Adder Approach

This approach calculates an adder by summing start-up costs and the MLC and dividing the result by the output of the generator at Pmax. The adder is then added to the bids actually submitted by the generator to determine its fast-start bids. In the case of output levels between zero and the generator's Pmin, the fast-start bid is set equal to the fast-start bid for the first MW of incremental output above Pmin.

In this example:

- The start-up costs and the MLC sum to $7000, and Pmax is 200 MWh, so the adder is $7000 / 200 MWh = $35/MWh.
- The adder is added to the bids that were actually submitted for the Inc 1 and Inc 2 blocks, yielding fast-start bids for those blocks of $40/MWh + $35/MWh = $75/MWh and $80/MWh + $35/MWh = $115/MWh, respectively.
- The fast-start bid for the Pmin block is set to $75/MWh, the fast-start bid for Inc 1.

Using these fast-start bids in the pricing pass produces the following dispatch:

Table 2: Least-Cost Dispatch In the Pricing Pass for Example 1, Using the Constant Adder Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 65.00	$ 65.00	125	$ 8,125	-	$ -	$ -	$ -
FSG:								$ -	$ 625
Pmin	100		$ 75.00	-	$ -	100	$ 7,000		
Inc 1	50	$ 40.00	$ 75.00	-	$ -	25	$ 1,000		
Inc 2	50	$ 80.00	$ 115.00	-	$ -	-	$ -		
Total				**625**	**$ 25,625**			**$ -**	**$ 625**

Since the fast-start bid for the FSG indicates that it would cost $75/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, which is more than the $65/MWh cost of generating energy using G2, G2 is dispatched in this pass. Of course, G2 is not actually directed to produce any energy. Its $65/MWh bid is simply used to set the LMP, even though it does not actually operate.

At this LMP, there are no BCR payments, since paying G1 and the FSG $65/MWh for their output more than suffices to cover their bid costs to produce 500 MWh and 125 MWh, respectively. However, there are lost opportunity costs, because at an LMP of $65/MWh, the FSG would prefer to produce 150 MWh, using the entire Inc 1 block. If it only generates 125 MWh, it will forego 25 MWh × ($65/MWh – $40/MWh) = $625 in profit (relative to the bids that it submitted) on the undispatched portion of the Inc 1 block.

Pricing Pass Using Fast-Start Bids Determined Using the Adjusted Constant Adder Approach

This approach is almost identical to the Constant Adder approach. The difference is that the adder is determined by summing start-up costs and the MLC, but then subtracting the cost of operating at Pmin under the assumption that that cost is the same as the bid submitted for the first MW of incremental output above Pmin (or zero, if that bid is negative), before dividing the result by the output of the generator at Pmax.

In this example:

- The bid that was submitted for Inc 1 is $40/MWh, so the cost of operating at Pmin at that cost is 100 MWh × $40/MWh = $4000.
- Thus, an adder of ($7000 – $4000) / 200 MWh = $15/MWh is added to the bids that were actually submitted for the Inc 1 and Inc 2 blocks.

- This yields fast-start bids for those blocks of $40/MWh + $15/MWh = $55/MWh and $80/MWh + $15/MWh = $95/MWh, respectively.
- The fast-start bid for the Pmin block is set to $55/MWh, the fast-start bid for Inc 1.[6]

Using these fast-start bids in the pricing pass produces the following dispatch:

[6] This approach implicitly assumes that the variable cost of operating in the Pmin block is the same as the variable cost of operating in the Inc 1 block ($40/MWh in this example) and subtracts that from the commitment cost to determine the numerator for the adder, but the assumption that the variable cost of operating in the Pmin block is $40/MWh is somewhat arbitrary. In this example, one could implement this approach while assuming that the variable cost for operating in the Pmin block is anywhere between $0/MWh and the $40/MWh variable cost of the Inc 1 block. As long as (1) the adder is calculated using a value for the assumed variable cost of operating in the Pmin block that is within this range, and (2) that adder is then added to a bid for the Pmin block that makes the same assumption regarding the variable cost of operating in the Pmin block, the total cost of operating at Pmax using the fast-start bid would be the same as the cost of operating at Pmax using the bids actually submitted for that FSG.

For example, the adder could be calculated under the assumption that the variable cost of operating in the Pmin block was, say, $18/MWh. Then the adder would be ($7000 – ($18/MWh × 100 MWh)) / 200 MWh = $5200 / 200 MWh = $26/MWh. Under that assumption, the fast-start bids calculated using the Adjusted Constant Adder approach would be $18/MWh + $26/MWh = $44/MWh for the Pmin block, $40/MWh + $26/MWh = $66/MWh for the Inc 1 block, and $80/MWh + $26/MWh = $106/MWh for the Inc 2 block. The total cost of operating this FSG at Pmax, using these fast-start bids, is $44/MWh x 100 MWh + $66/MWh x 50 MWh + $106/MWh x 50 MWh = $13,000, which is the same as the cost of operating this FSG at Pmax using the bids that were actually submitted for it, which is $7000 + $40/MWh x 50 MWh + $80/MWh x 50 MWh = $13,000.

Nevertheless, there is a justification for assuming that the variable cost of operating in the Pmin block is the same as the variable cost of operating in the Inc 1 block, instead of some lower value. The higher the assumed variable cost for operating in the Pmin block, the lower the adder, so assuming that the variable cost of operating in the Pmin block is the same as the variable cost of operating in the Inc 1 block minimizes the adder. (Assuming that the variable cost of operating in the Pmin block is higher than the variable cost of operating in the Inc 1 block would yield an even lower adder, but the fast-start bid for the Pmin block that would result would exceed the fast-start bid for the Inc 1 block, which violates the requirement that the fast-start bid must be a nondecreasing function of the FSG's output.)

Table 3: Least-Cost Dispatch In the Pricing Pass for Example 1, Using the Adjusted Constant Adder Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 65.00	$ 65.00	-	$ -	-	$ -	$ -	$ -
FSG:								$ 1,125	$ -
Pmin	100		$ 55.00	100	$ 5,500	100	$ 7,000		
Inc 1	50	$ 40.00	$ 55.00	25	$ 1,375	25	$ 1,000		
Inc 2	50	$ 80.00	$ 95.00	-	$ -	-	$ -		
Total				**625**	**$ 24,375**			**$ 1,125**	**$ -**

Since the fast-start bid for the FSG indicates that it would cost $55/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, which is less than the $65/MWh cost of generating energy using G2, the FSG is dispatched in this pass, and G2 is not dispatched. The FSG's fast-start bid of $55/MWh sets the LMP.

At this LMP, there are BCR payments, since the FSG's bid cost to generate 125 MWh is $8000, and it will only receive 125 MWh × $55/MWh = $6875 in energy revenue, leaving a $1125 shortfall. But there are no LOCs. While the LMP exceeds the $40/MWh bid submitted by FSG for its Inc 1 block, it would not profit if its output was increased to 150 MWh. That would simply reduce the BCR payment it is due.

Pricing Pass Using Fast-Start Bids Determined Using the Minimum Average Cost Approach

This approach determines the output level that minimizes average cost, including start-up cost, the MLC, and any incremental costs that would result from operating at each output level above Pmin. The fast-start bid for output between zero and Pmin is then set equal to this minimum value for average cost. For output levels above Pmin, it is set to the greater of this minimum value for average cost and the actual bid submitted by the generator.

In this example:

- The average cost of operating at Pmin is the commitment cost divided by output at Pmin, or $7000 / 100 MWh = $70/MWh.
- Since the bid that was submitted for Inc 1 is less than $70/MWh, increasing output to 150 MW will reduce the average cost. At an output level of 150 MW, the average cost is ($7000 + 50 MWh × $40/MWh) / 150 MWh = $60/MWh.

- The bid that was submitted for Inc 2 exceeds $60/MWh, so increasing output above 150 MW cannot reduce the average cost. Therefore, the minimum average cost is $60/MWh.[7]

- The fast-start bid for the Pmin block is set to $60/MWh.

- The fast-start bid for the Inc 1 block is also set to $60/MWh, since the minimum average cost exceeds the $40/MWh bid actually submitted for this block.

- However, the fast-start bid for the Inc 2 block is the $80/MWh bid that was actually submitted for it, since that exceeds the $60/MWh minimum average cost.

Using these fast-start bids in the pricing pass produces the following dispatch:

Table 4: Least-Cost Dispatch In the Pricing Pass for Example 1, Using the Minimum Average Cost Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 65.00	$ 65.00	-	$ -	-	$ -	$ -	$ -
FSG:								$ 500	$ -
Pmin	100		$ 60.00	100	$ 6,000	100	$ 7,000		
Inc 1	50	$ 40.00	$ 60.00	25	$ 1,500	25	$ 1,000		
Inc 2	50	$ 80.00	$ 80.00	-	$ -	-	$ -		
Total				**625**	**$ 25,000**			**$ 500**	**$ -**

Since the fast-start bid for the FSG indicates that it would cost $60/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, which is less than the $65/MWh cost of generating energy using G2, the FSG is dispatched in this pass, and G2 is not dispatched. The FSG's fast-start bid of $60/MWh sets the LMP, so the LMP produced by this approach, for this example, is higher than the LMP produced using the Adjusted

[7] Since bids into the energy market are step functions, it is not necessary to evaluate the average cost at each possible level of output for a generator to determine the minimum average cost. Instead, it suffices to evaluate the average cost at the output level that is consistent with full utilization of each block. In this example, the average cost at any output level between 100 MW and 150 MW will be a weighted average of the cost of operating at Pmin, which is $70/MWh, and the cost of operating in the Inc 1 block, which is $40/MWh. The weights reflect each block's share of total output. As the FSG's output level increases from 100 MW to 150 MW, the Pmin block's share of total output decreases and the Inc 1 block's share increases, so the weighted average of those costs must continue to decrease until reaching the 150 MW maximum output level for the Inc 1 block. Therefore, the determination of the minimum average cost only needs to compare the average cost of operating at 100 MW, 150 MW, and 200 MW; the average cost at every other output level can be disregarded.

Constant Adder approach (but lower than the LMP produced by the Constant Adder Approach).

At this LMP, there are BCR payments, since the FSG's bid cost to generate 125 MWh is \$8000, and it will only receive 125 MWh × \$60/MWh = \$7500 in energy revenue, which leaves a \$500 shortfall. There are no LOCs. While the LMP exceeds the \$40/MWh bid submitted by FSG for its Inc 1 block, it would not profit if its output was increased to 150 MWh, as that would simply eliminate the BCR payment it is due.

Comparison of Approaches

While none of these approaches are able to eliminate both BCR payments and LOCs, the Minimum Average Cost approach produces lower BCR payments than the Adjusted Constant Adder approach.

Example 2: FSG is Dispatched into its Second Incremental Block

Physical Dispatch

Table 5 shows the least-cost dispatch to meet 675 MW of load, an increase from the 625 MW of load in Example 1. G1 continues to offer all of its output at \$35/MWh, while G2 offers all of its energy at \$110/MWh (compared to \$65/MWh in Example 1). G1 continues to operates at Pmax, producing 500 MWh. The FSG is dispatched into the Inc 2 block, producing 175 MW, while G2 does not operate, as it is now far more expensive than the FSG.

Table 5: Least-Cost Physical Dispatch for Example 2, Using Bids Submitted by Generators

	Capacity (MW)	Incre. Offer (\$/MWh)	Schedule (MW)	Bid Cost (\$)
G1	500	\$ 35.00	500	\$ 17,500
G2	500	\$ 110.00	-	\$ -
FSG:				
Pmin	100		100	\$ 7,000
Inc 1	50	\$ 40.00	50	\$ 2,000
Inc 2	50	\$ 80.00	25	\$ 2,000
Total			**675**	**\$ 28,500**

Pricing Pass Using Fast-Start Bids Determined Using the Constant Adder Approach

Since the bids for the FSG are the same as in Example 1, the fast-start bids are also the same, so I will not repeat the procedure for determining those fast-start bids here. Using fast-start bids in the pricing pass that were determined using the Constant Adder approach produces the following dispatch:

Table 6: Least-Cost Dispatch In the Pricing Pass for Example 2, Using the Constant Adder Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 110.00	$ 110.00	25	$ 2,750	-	$ -	$ -	$ -
FSG:								$ -	$ 750
Pmin	100		$ 75.00	100	$ 7,500	100	$ 7,000		
Inc 1	50	$ 40.00	$ 75.00	50	$ 3,750	50	$ 2,000		
Inc 2	50	$ 80.00	$ 115.00	-	$ -	25	$ 2,000		
Total				**675**	**$ 31,500**			**$ -**	**$ 750**

Since the fast-start bid for the FSG indicates that it would cost $75/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, which is less than the $110/MWh cost of generating energy using G2, the Pmin and Inc 1 blocks of the FSG are dispatched to produce 150 MWh in this pass. However, another 25 MWh are needed to meet load, and G2's bid is less than the fast-start bid for the Inc 2 block of the FSG, so G2 is dispatched to produce 25 MWh. Since G2 is on the margin in this pass, its $110/MWh bid sets the LMP, even though it is not actually instructed to generate energy.

At this LMP, there are no BCR payments, since paying G1 and the FSG the LMP of $110/MWh more than suffices to cover their bid costs to produce 500 MWh and 175 MWh, respectively. However, there are lost opportunity costs, because at an LMP of $110/MWh, the FSG would prefer to produce 200 MWh. If it only generates 175 MWh, it will forego 25 MWh × ($110/MWh – $80/MWh) = $750 in profit (relative to the bids that it submitted) on the undispatched portion of the Inc 2 block.

Pricing Pass Using Fast-Start Bids Determined Using the Adjusted Constant Adder Approach

Using fast-start bids in the pricing pass that were determined using the Adjusted Constant Adder approach produces the following dispatch:

Table 7: Least-Cost Dispatch In the Pricing Pass for Example 2, Using the Adjusted Constant Adder Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 110.00	$ 110.00	-	$ -	-	$ -	$ -	$ -
FSG:								$ -	$ 375
Pmin	100		$ 55.00	100	$ 5,500	100	$ 7,000		
Inc 1	50	$ 40.00	$ 55.00	50	$ 2,750	50	$ 2,000		
Inc 2	50	$ 80.00	$ 95.00	25	$ 2,375	25	$ 2,000		
Total				**675**	**$ 28,125**			**$ -**	**$ 375**

Since the fast-start bid for the FSG indicates that it would cost $55/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, and $95/MWh to generate energy using the Inc 2 block of the FSG, each of which is less than the $110/MWh cost of generating energy using G2, the FSG is dispatched in this pass, and G2 is not dispatched. The $95/MWh fast-start bid of the FSG's Inc 2 block sets the LMP.

At this LMP, there are no BCR payments, since paying G1 and the FSG $95/MWh more than suffices to cover their bid costs to produce 500 MWh and 175 MWh, respectively. However, there are lost opportunity costs, because at an LMP of $95/MWh, the FSG would prefer to produce 200 MWh. If it only generates 175 MWh, it will forego 25 MWh × ($95/MWh – $80/MWh) = $375 in profit (relative to the bids that it submitted) on the undispatched portion of the Inc 2 block.

Pricing Pass Using Fast-Start Bids Determined Using the Minimum Average Cost Approach

Using fast-start bids in the pricing pass that were determined using the Minimum Average Cost approach produces the following dispatch:

Table 8: Least-Cost Dispatch In the Pricing Pass for Example 2, Using the Minimum Average Cost Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 110.00	$ 110.00	-	$ -	-	$ -	$ -	$ -
FSG:								$ -	$ -
Pmin	100		$ 60.00	100	$ 6,000	100	$ 7,000		
Inc 1	50	$ 40.00	$ 60.00	50	$ 3,000	50	$ 2,000		
Inc 2	50	$ 80.00	$ 80.00	25	$ 2,000	25	$ 2,000		
Total				**675**	**$ 28,500**			**$ -**	**$ -**

Since the fast-start bid for the FSG indicates that it would cost $60/MWh to generate energy using the Pmin and Inc 1 blocks of the FSG, and $80/MWh to generate energy using the Inc 2 block of the FSG, each of which is less than the $110/MWh cost of generating energy using G2, the FSG is dispatched in this pass, and G2 is not dispatched. The $80/MWh fast-start bid of the FSG's Inc 2 block sets the LMP. Thus, in this example, the Minimum Average Cost Approach produced a lower LMP than the Adjusted Constant Adder Approach, whereas in Example 1, it produced a higher LMP.

At this LMP, there are no BCR payments, since the FSG would receive 175 MWh × $80/MWh = $14,000 in energy revenue, which exceeds its $11,000 bid cost to generate 175 MWh. There are also no LOCs. Since the LMP is equal to the $80/MWh bid that the FSG submitted for the Inc 2 block, it would only be paid that bid if it was to produce additional energy, so its profit (relative to the bids that it submitted) would remain the same.

Comparison

The LMP determined using the Minimum Average Cost approach clears the market, because there are no BCR payments, indicating that no generators have been directed to operate at a loss, and there are no LOCs, indicating that no generators could increase their profits by operating at a higher level than directed. The other two approaches do not clear the market, but the LOCs that result from the Adjusted Constant Adder approach are lower than the LOCs that result from the Constant Adder Approach, because the LMP that the Adjusted Constant Adder approach produces is lower than the LMP produced by the Constant Adder Approach.

Susceptibility to Gaming

When considering different approaches for determining fast-start bids, another consideration is the degree to which each approach is susceptible to gaming. As the example to follow will show, the Adjusted Constant Adder approach has this weakness. This stems from the fact that the adder is, in part, based on the bid cost to produce the first MW of output above the Pmin level. Changing the bid for that MW would likely have little or no impact on the physical dispatch of that FSG or other generators, but it could have a very large impact on the fast-start bids that are determined using that approach.

Example 3: Gaming Opportunities

Physical Dispatch

Table 9 shows the least-cost dispatch to meet 675 MW of load, under the assumption that G1 offers energy at $35/MWh for its entire output, while G2 offers all of its energy at $110/MWh. Each of those assumptions is the same as for Example 2. However, in this example, the FSG employs a different bidding strategy. Instead of bidding to produce up to 50 MW of energy from its Inc 1 block at a cost of $40/MWh, it splits that block into two separate blocks:

- An Inc 1A block that consists of just 1 MW , which bids its energy at $0/MWh.
- An Inc 1B block that includes the remaining 49 MW, bid at a cost of $40/MWh (the same bid submitted for the Inc 1 block in the preceding examples).

In addition, the FSG increases its MLC cost from $5000 to $5040. This $40 increase offsets the impact of reducing its incremental output bid to increase output from 100 MW to 101 MW by $40/MWh. As as result, the bid cost for the FSG to operate at 101 MW, and at every output level above 101 MW, is the same using these bids as it was using the bids that were submitted for the FSG for Examples 1 and 2.

Using these bids, G1 continues to operates at Pmax, producing 500 MWh, and the FSG continues to be dispatched into the Inc 2 block, producing 175 MW. The total cost of the dispatch is $28,500, matching the total cost calculated in Table 5 using the original set of bids for the FSG.

Table 9: Least-Cost Physical Dispatch for Example 3, Using Bids Submitted by Generators

	Capacity (MW)	Incre. Offer ($/MWh)	Schedule (MW)	Bid Cost ($)
G1	500	$ 35.00	500	$ 17,500
G2	500	$ 110.00	-	$ -
FSG:				
Pmin	100		100	$ 7,040
Inc 1A	1	$ -	1	$ -
Inc 1B	49	$ 40.00	49	$ 1,960
Inc 2	50	$ 80.00	25	$ 2,000
Total			**675**	**$ 28,500**

Pricing Pass Using Fast-Start Bids Determined Using the Constant Adder Approach

Since the bids for the FSG are not the same as the bids in Examples 1 and 2, the constant adder that is calculated for this example is slightly different from the constant adder that was calculated for Examples 1 and 2:

- The start-up costs and the MLC now sum to $7040, rather than $7000.
- Since the Pmax remains 200 MWh, an adder of $7040 / 200 MWh = $35.20/MWh is added to the bids that were actually submitted for the Inc 1A, Inc 1B and Inc 2 blocks. (In Examples 1 and 2, the adder was $35/MWh.)

- This yields fast-start bids for those blocks of $0/MWh + $35.20/MWh = $35.20/MWh, $40/MWh + $35.20/MWh = $75.20/MWh and $80/MWh + $35.20/MWh = $115.20/MWh, respectively.

- The fast-start bid for the Pmin block is set to $35.20/MWh, the fast-start bid for Inc 1.

Using these fast-start bids in the pricing pass produces the following dispatch:

Table 10: Least-Cost Dispatch In the Pricing Pass for Example 3, Using the Constant Adder Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 110.00	$ 110.00	25	$ 2,750	-	$ -	$ -	$ -
FSG:								$ -	$ 750
Pmin	100		$ 35.20	100	$ 3,520	100	$ 7,040		
Inc 1A	1	$ -	$ 35.20	1	$ 35	1	$ -		
Inc 1B	49	$ 40.00	$ 75.20	49	$ 3,685	49	$ 1,960		
Inc 2	50	$ 80.00	$ 115.20	-	$ -	25	$ 2,000		
Total				**675**	**$ 27,490**			**$ -**	**$ 750**

The fast-start bid for the FSG indicates that it would cost $35.20/MWh to generate energy using the Pmin and Inc 1A blocks of the FSG, and $75.20/MWh to generate energy using the Inc 1B block of the FSG. Each of these is less than the $110/MWh cost of generating energy using G2, so the Pmin, Inc 1A and Inc 1B blocks of the FSG are dispatched to produce 150 MWh in this pass. However, another 25 MWh are needed to meet load, and G2's bid is less than the fast-start bid for the Inc 2 block of the FSG, so G2 is dispatched to produce 25 MWh. Since G2 is on the margin in this pass, its $110/MWh bid sets the LMP, even though it is not actually instructed to generate energy.

At this LMP, there are no BCR payments, since paying G1 and the FSG $110/MWh more than suffices to cover their bid costs to produce 500 MWh and 175 MWh, respectively. However, there are lost opportunity costs, because at an LMP of $110/MWh, the FSG would prefer to produce 200 MWh. If it only generates 175 MWh, it will forego 25 MWh × ($110/MWh – $80/MWh) = $750 in profit (relative to the bids that it submitted) on the undispatched portion of the Inc 2 block. This is the same outcome as when this approach was used for Example 2.

Pricing Pass Using Fast-Start Bids Determined Using the Adjusted Constant Adder

While the change in the bids for the FSG only slightly affects the calculation of the constant adder in this example, it **signficantly** affects the calculation of the adjusted constant adder:

- The bid that was submitted for Inc 1A is $0/MWh, so the cost of operating at Pmin at that cost is 100 MWh × $0/MWh = $0.
- Thus, an adder of ($7040 – $0) / 200 MWh = $35.20/MWh is added to the bids that were actually submitted for the Inc 1A, inc 1B and Inc 2 blocks, rather than the $15/MWh adder that was calculated when this approach was used in Example 2.

At $35.20/MWh, the adder is identical to the adder that was calculated using the Constant Adder approach, so the fast-start bids that are calculated for the FSG will be the same fast-start bids that were calculated using the Constant Adder approach. Therefore, the LMP will be $110/MWh, just as it was under the Constant Adder approach, and the FSG will have $750 in LOCs, just as under the Constant Adder approach.[8]

Pricing Pass Using Fast-Start Bids Determined Using the Minimum Average Cost Approach

Finally, consider how this change in the bids submitted by the FSG will affect its fast-start bids under this approach:

- The average cost of operating at Pmin is the commitment cost divided by output at Pmin, which is now $7040 / 100 MWh = $70.40/MWh.
- Since the bid that was submitted for Inc 1A is less than $70.40/MWh, increasing output to 101 MW will reduce the average cost. At an output level of 101 MW, the average cost is ($7040 + 1 MWh × $0/MWh) / 101 MWh = $69.70/MWh.
- Since the bid that was submitted for Inc 1B is less than $69.70/MWh, increasing output to 150 MW will reduce the average cost further. At an output level of

[8] As noted above, the proposed procedure for calculating the adjusted constant adder would replace negative bids to produce energy using the first incremental block (Inc 1A in this example). That limits the opportunity to employ this strategy to inflate prices. If that constraint were not in place, and a negative bid had been submitted for the Inc 1 block, then the adder calculated under this approach would have been higher than the adder calculated under the Constant Adder approach. That would not have led to a higher LMP in this example, since the price is bounded by G2's bid, but in other examples, it could permit the LMP that would result from the Adjusted Constant Adder approach to be higher than the LMP that would result from the Constant Adder Approach.

150 MW, the average cost is ($7040 + 1 MWh × $0/MWh + 49 MWh × $40/MWh) / 150 MWh = $60/MWh.

- The bid that was submitted for Inc 2 exceeds $60/MWh, so increasing output above 150 MW cannot reduce the average cost. Therefore, the minimum average cost is $60/MWh, the same as in Example 2.
- The fast-start bid for the Pmin block is set to $60/MWh.
- The fast-start bid for the Inc 1A and Inc 1B blocks are also set to $60/MWh, since the minimum average cost exceeds the $0/MWh and $40/MWh bids actually submitted for these blocks.
- The fast-start bid for the Inc 2 block is the $80/MWh bid that was actually submitted for it, since that exceeds the $60/MWh minimum average cost.

In other words, the change in the FSG's bidding strategy had no effect: the fast-start bids for the FSG that are calculated using this approach are identical to the fast-start bids that were calculated when the original bidding strategy was employed. While fast-start bids are now separately calculated for the 1 MW inc 1A block and the 49 MW Inc 1B block, those fast-start bids are both $60/MWh, identical to the $60/MWh fast-start bid calculated previously for the 50 MW Inc 1 block.

Thus, using fast-start bids in the pricing pass that were determined using the Minimum Average Cost approach produces the following dispatch:

Table 11: Least-Cost Dispatch In the Pricing Pass for Example 3, Using the Minimum Average Cost Approach for Determining Fast-Start Bids for the FSG

	Capacity (MW)	Actual Incre. Offer ($/MWh)	FSP Offer ($/MWh)	Pricing Schedule (MW)	Bid Cost ($)	Physical Schedule (MW)	Bid Cost for Phys. Sch. ($)	BCR ($)	LOC ($)
G1	500	$ 35.00	$ 35.00	500	$ 17,500	500	$ 17,500	$ -	$ -
G2	500	$ 110.00	$ 110.00	-	$ -	-	$ -	$ -	$ -
FSG:								$ -	$ -
Pmin	100		$ 60.00	100	$ 6,000	100	$ 7,040		
Inc 1A	1	$ -	$ 60.00	1	$ 60	1	$ -		
Inc 1B	49	$ 40.00	$ 60.00	49	$ 2,940	49	$ 1,960		
Inc 2	50	$ 80.00	$ 80.00	25	$ 2,000	25	$ 2,000		
Total				**675**	**$ 28,500**			**$ -**	**$ -**

As was the case in Example 2, the $80/MWh bid for the Inc 2 block sets the LMP, and there are no BCR payments or LCRs, indicating that the $80/MWh LMP clears the market.

Comparison

As this example demonstrates, if the Adjusted Constant Adder approach were adopted, FSGs may be able to use bidding strategies that cause LMPs, BRC payments and LOCs to be similar to the LMPs, BRC payments and LOCs that would be observed if the Constant Adder approach were adopted. The CAISO's evaluation of the different approaches did not consider the use of such bidding strategies, so the results of that evaluation should be interpreted with this in mind.

SUMMARY

Table 12 summarizes the outcomes from these examples.

Table 12: Summary of Results from Examples 1, 2 and 3

	LMP ($/MWh)	BCR Payments	LOCs
Example 1			
Constant Adder	$ 65.00	$ -	$ 625
Adjusted Constant Adder	$ 55.00	$ 1,125	$ -
Minimum Average Cost	$ 60.00	$ 500	$ -
Example 2			
Constant Adder	$ 110.00	$ -	$ 750
Adjusted Constant Adder	$ 95.00	$ -	$ 375
Minimum Average Cost	$ 80.00	$ -	$ -
Example 3			
Constant Adder	$ 110.00	$ -	$ 750
Adjusted Constant Adder	$ 110.00	$ -	$ 750
Minimum Average Cost	$ 80.00	$ -	$ -