Background Information on Price Calculation Methods

Market Pricing Working Group January 20, 2006

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Introduction

This document uses examples to demonstrate different price calculation methods. The examples used are simple and are not intended to reflect typical market conditions. They are only intended to demonstrate the basic process of price setting. Presentations will be made to the Market Pricing Working Group with simulations of market prices that would be expected if these different pricing schemes were used to settle the market.

For simplicity, these examples deal with the energy market in isolation (no joint optimization with Operating Reserve) and do not include any dispatchable load.

An example of both increasing and decreasing demand will be used for twelve times and one times ramp rates as well as MIO incremental, modified MIO incremental and highest slice price.

1.0 Scenario One – Increasing Demand

In this scenario, demand is ramping up and one generator is initially operating at its minimum output despite being non-economic at the beginning of the scenario. Information on each of the generators used in the examples can be found in Table 1.

Table 1: Generators Offer Information

Generator	Offer Price $	MinGen	MaxGen	Ramp/min
A	20	0	125	4
B	45	0	50	1
C	60	20	75	1
D	200	0	100	2
E	500	0	50	3

Calculating Market Schedules with Various Pricing Methodologies

Twelve Times Ramp Rate (12X RR)

Table 2 shows unconstrained schedules assuming a myopic 12x ramp rate. The 12X schedule assumes that generators can move at 12X their stated ramp rate, effectively removing any ramp limitations from the schedule. For example, generator B which can only move at 1 MW/min is assumed to be able to move 60 MW during a five-minute interval. The schedule is calculated to meet demand while maximizing the use of the lowest cost generators. Generator A will be taken to maximum output, then B, then C and if necessary generator D and E. Table 3 shows unconstrained schedules assuming a myopic 1x ramp rate. In both cases, each interval was solved without looking further ahead. In the myopic scenarios, minimum generation levels are not respected which allows the algorithm to produce schedules below the minimum generation point.

Table 2: Unconstrained Schedules using a Myopic Algorithm With 12X Ramp Rate

Initial Conditions			Interval		
			1	2	3
Demand		145	155	170	190
	Offer $	Output MW	Myopic 12X Schedule MW		
A	20	95	125	125	125
B	45	30	30	45	50
C	60	20	0	0	15
D	200	0	0	0	0
E	500	0	0	0	0
Total MW		145	155	170	190

One Times Ramp Rate (1X RR)

The myopic 1X ramp solution utilizes actual ramp rates as provided by the generators in their offers. In this case, generator B can only move 5 MW in five minutes. This means any schedule is limited to a 5 MW change for generator B in any one interval, and generator A can move up to 20 MW in one interval. Any change of less than 20 MW means that generator A is not ramp limited. Table 3 shows the 1X myopic schedules for this scenario.

Table 3; Market Schedules using a Myopic Algorithm With 1X Ramp Rate

Initial Conditions			Interval		
			1	2	3
Demand			155	170	190
	Offer $	Output MW	Myopic 1X Schedule MW		
A	20	95	115	125	125
B	45	30	25	30	35
C	60	20	15	15	20
D	200	0	0	0	10
E	500	0	0	0	0
Total MW		145	155	170	190

Multi-Interval Optimization (MIO)

The schedule produced by a multi-interval optimization (MIO) algorithm is shown in Table 4. In this scenario the algorithm attempts to minimizing the total cost of all three intervals simultaneously, (with equal weighting), rather than solving for each interval in isolation.

The benefit of a MIO dispatch can bee seen in interval 3. By moving Generator B early, we avoid relying on the relatively high priced Generator D during interval 3.

The MIO algorithm is designed to respect minimum generation levels. Since Generator C is required in the second and third intervals, it is not taken off line in interval one to respect its minimum generation level of 20 MW.

Table 4: Unconstrained Schedules using a MIO algorithm

Initial Conditions			Interval Demand MW		
		Output MW	1	2	3
	Offer $	145	155	170	190
			MIO Schedule MW		
A	20	95	105	115	125
B	45	30	30	35	40
C	60	20	20	20	25
D	200	0	0	0	0
E	500	0	0	0	0
Total MW		145	155	170	190

Comparing the Total Cost of the Three Pricing Methodologies

Comparing the total cost of the MIO solution to the total cost of the myopic 1X solution shows the reduction in cost to supply the market for the three intervals. While costs are increased in interval one and two, the savings in interval three more than compensates for the cost of moving ramp limited generator B early.

Table 5: Comparing the Total costs of Myopic and MIO Methodologies

Interval	Myopic		MIO	
1	115 MW x $20 + 25 MW x $45 + 15 MW x $60	$4,325	105 MW x $20 + 30 MW x $45 + 20 MW x $60	$ 4,650
2	125 MW x $20 + 30 MW x $45 + 15 MW x $60	$4,750	115 MW x $20 + 35 MW x $45 + 20 MW x $60	$ 5,075
3	125 MW x $20 + 35 MW x $45 + 20 MW x $60 + 10 MW x $200	$7,275	125 MW x $20 + 40 MW x $45 + 25 MW x $60	$ 5,800
Total Cost[1]		$16,350		$ 15,525

Calculating Market Prices with Various Pricing Methodologies

Twelve Times Incremental Pricing

With incremental pricing, the dispatch scheduling optimizer establishes price as the price of an incremental change in demand. The change could be a slight increase or decrease in demand. For simplicity, in these examples we will work with an incremental change as an increase of 1 MW and will ignore joint optimization or the presence of dispatchable loads.

The incremental price in each interval is the price of the next available MW once demand is satisfied. An incremental MW can only be supplied by a generator which is capable of increasing its output during the interval. Generators at their maximum output, or ramp limited generators, cannot increase their output and consequently are unable to set the market clearing price.

In twelve times pricing, the unconstrained algorithm will use the hourly ramping capability for each five minute period. So a generator that has an actual ramp rate of 1 MW/min (or 5 MW in an interval) is assumed to be able to ramp 60 MW in five minutes. The incremental price in each interval is the price of the next available MW.

[1] For simplicity cost and CMSC are calculated based on power, not energy. The energy for each interval would be the power (MW) multiplied by 5 minutes, divided by 60 minutes/hour.

Table 6: Unconstrained Schedule with a Myopic algorithm and 12X Ramp

Initial Conditions			Interval Demand		
			1	2	3
Demand MW		145	155	170	190
	Offer $	Output MW	Myopic 12X Schedule MW		
A	20	95	125	125	125
B	45	30	30	45	50
C	60	20	0	0	15
D	200	0	0	0	0
E	500	0	0	0	0
Price			$45	$45	$60

One Times Pricing

The one times price is established in the same manner as twelve times price; the price is established based on the cost of the next available MW once demand has been satisfied. The difference between twelve and one times pricing relates to the available supply in any given interval. The available supply is smaller with one times ramping due to ramp limitations imposed by using the actual ramp rates compared with the 12X ramp rates.

In interval one, Generator B is ramping down at its maximum rate of 5 MW per interval and is not able to set price. Generator A is not ramp limited and is not at its maximum output meaning the incremental MW could be supplied from Generator A. Generator A then sets the clearing price at $20.

In interval two, Generator A is now at its maximum output of 125 MW and Generator B is ramp limited to 30 MW. The only available source for a MW is Generator C at $60 which sets price

In interval three Generator A is at its maximum output and generators B and C are both ramp limited. The only available source for a MW is Generator D at $200.

Table 7: Market Prices with a Myopic 1X Ramp

Initial Conditions			Interval Demand MW		
			1	2	3
Demand			155	170	190
	Offer $	Output MW	Myopic 1X Schedule MW		
A	20	95	115	125	125
B	45	30	25	30	35
C	60	20	15	15	20
D	200	0	0	0	10
E	500	0	0	0	0
Price			$20	$60	$200

MIO Incremental Pricing

In MIO Incremental pricing, the price is established in the same manner as 1X and 12X incremental; the next available MW once demand is satisfied will set price.

Table 8: Market Prices with a MIO Schedule

Initial Conditions			Interval Demand MW		
		Output	1	2	3
	Offer $	145	155	175	190
			MIO Schedule		
A	20	95	105	115	125
B	45	30	30	35	40
C	60	20	20	20	25
D	200	0	0	0	0
E	500	0	0	0	0
Price			$20	$20	$60 or $200

In interval one, the incremental MW would come from generator A. While generator B is ramping and generator C is held on line, generator A still has ramp capability and can therefore supply the incremental MW and the price would be $20.

In interval two, Generator B is being ramped up in advance and Generator A still has ramping capability and continues to set price at $20.

In interval three, if the demand were exactly 190 MW the incremental price would be indeterminate as there is a step change in the supply at exactly 190 MW. As mentioned earlier, for simplicity we have assumed incremental pricing to be the extra cost of one more MW however the dispatch algorithm solves for a marginal increase or decrease. If demand were exactly 190 MW, the price could be either $60 or $200. In the real-market, a situation where demand falls exactly on a step change of this nature is unlikely.

Of more significance in this example is the fact that demand cannot be exactly predicted three intervals in advance. Incremental prices are calculated based on actual demand observed during the interval. It is quite possible that when interval three arrives, the demand may well be less than 190MW. In this case, given the supply options available, an incremental MW would come from generator C at a price of $60. If the actual demand were greater than 190 MW, the incremental price would be $200

Modified MIO Incremental Price

In the example of MIO incremental pricing above, we can see that the price in interval three is quite sensitive to the demand in interval three. The MIO algorithm established a supply stack for interval three which just met the anticipated 190 MW demand. As a result, if demand were 190 or higher, the incremental MW would come from the next generator in the stack, in this case $200 power. There is however another alternative to establishing the incremental MW for interval three.

In interval one, when the MIO calculation was performed for the three intervals, we could anticipate the need for an incremental MW in interval three. This would allow us to calculate the cost of an incremental MW for interval three during interval one. This is the same time that we established the schedule for interval three.

During interval one, we have a lower cost option for an incremental MW for interval three. Because generator B is ramp limited in interval three but not at it's full capacity, we can increase generator B's output by one MW in interval one and two in order to get an extra MW in interval three. This can be seen in Generators B output in Table 9 below.

Table 9: Market Schedules Using a Modified MIO Incremental

Initial Conditions			Interval Demand MW		
			1	2	3
Demand MW	145		155	170	191
Output			Modified MIO Incremental Schedule		
A	95		104	114	125
B	30		31	36	41
C	20		20	20	25
D	0			0	0
E	0				0
Total	145				

However, increasing generator B by one MW will mean backing off a less expensive MW in interval one and two. As with the previous examination of cost savings associated with MIO, we can look at the total cost of obtaining an incremental MW in interval 3 by moving B early (in other words a demand of 191 MW). Table 10 shows that the total cost for all three intervals, with a demand of 191 MW in interval three is $ 15,525. From our MIO calculation, we know the MIO cost of all three intervals, with 190 MW in interval three is $ 15,620.

Comparing the two costs, we can see that if we determine the cost of an incremental MW for interval three when we are still in interval one (and can ramp generator B early) is the difference of $95

Table 10: Calculating MIO and MIO Incremental Supply Costs to Calculate MIO Incremental Price in Interval 3

Interval	MIO cost for 190 MW		MIO incremental cost for 191 MW	
1	105 MW x $20 + 30 MW x $45 + 20 MW x $60	$ 4,650	104 MW x $20 + 31 MW x $45 + 20 MW * $60	$4,675
2	115 MW x $20 + 35 MW x $45 + 20 MW x $60	$ 5,075	114 MW x $20 + 36 MW x $45 + 20 MW * $60	$5,100
3	125 MW x $20 + 40 MW x $45 + 25 MW x $60	$ 5,800	125 MW x $20 + 41 MW x $45 + 20 MW * $60	$5,845
Total Cost[2]		$ 15,525		$ 15,620

$ 15,620 - $ 15,525 = $95.

Using a modified MIO incremental price means that any demand in interval three up to 190 MW would be priced at $95.

If actual demand were greater than 190 MW, the price would be the simple incremental price of the next available MW, in this case $200.

High Slice Price

The High Slide Price (HSP) uses the MIO schedule when calculating prices. The price in any interval is the greater of the MIO incremental price and the cost of the most expensive unit which is not ramping down or constrained on.

Table 11: Market Schedule and Prices Using a MIO Algorithm

Initial Conditions			Interval Demand MW		
		Output	1	2	3
	Offer $	145	155	175	190
			MIO Schedule		
A	20	95	105	115	125
B	45	30	30	35	40
C	60	20	20	20	25
D	200	0	0	0	0
E	500	0	0	0	0
MIO Incremental Price			$20	$20	$60 or $200

[2] For simplicity cost and CMSC are calculated based on power, not energy. The energy for each interval would be the power (MW) multiplied by 5 minutes, divided by 60 minutes/hour.

During interval one, the MIO incremental price is $20 however we have generator B on line at $45 (generator C is constrained on and is not allowed to set price) therefore the high slice price for interval one would be $45.

During interval two, the MIO incremental price is $20, however once again we have generator B on line, therefore the high slice price for the interval is $45.

Once again, the price for interval three is indeterminate for a demand of exactly 190 MW. It could be $60 or $200. If demand is less than 190 MW, the price would be $60. If demand is greater than 190 MW, the price would be $200.

Congestion Management Settlement Credits

Congestion Management Settlement Credits (CMSC) are used in our uniform pricing model to ensure that market participants are no better or worse off by following dispatch instructions than by deviating from them. CMSC restores participants operating profit to what it would have been in the absence of physical constraints on the system.

The simple formulae for CMSC for a generator is (assuming dispatch and actual injection are equal):

CMSC = (Price – Offer)x Market Schedule - (Price – Offer)x Dispatch Quantity
CMSC = (Price – Offer)x MQSI - (Price – Offer)x DQSI
CMSC = (MCP – Offer) x (MQSI-DQSI)

If there is a difference between the quantity in the unconstrained market schedule and the constrained dispatch quantity, that difference can create a CMSC payment. Differences between the two quantities can come from any difference between the unconstrained and the constrained algorithm including differences caused by physical constraints such as transmission congestion.

The cost of CMSC is recovered from loads as uplift. The total CMSC payments for any given hour are allocated back to the loads based on their consumption during the hour.
Currently, the constrained algorithm uses a MIO process, so the dispatch quantities are MIO quantities. Any method other than a MIO algorithm used to create unconstrained quantities has the potential to create CMSC payments and uplift. We can compare the uplift for each pricing method using the above examples.

Twelve Times Pricing (Myopic)

In twelve times pricing we can see differences in the unconstrained and constrained quantities for all three generators at different times

Table 12: Market Schedules and Prices with a 12X RR

Initial Conditions			Interval Demand		
			1	2	3
		Demand			
		145	155	170	190
	Offer $	Output MW	Myopic 12X Schedule MW		
A	20	95	125	125	125
B	45	30	30	45	50
C	60	20	0	0	15
D	200	0	0	0	0
E	500	0	0	0	0
Price			$45	$45	$60

Table 13: MIO Constrained Schedule

Initial Conditions			Interval Demand MW		
		Output MW	1	2	3
	Offer $	145	155	170	190
			MIO Dispatch MW		
A	20	95	105	115	125
B	45	30	30	35	40
C	60	20	20	20	25
D	200	0	0	0	0
E	500	0	0	0	0
Total MW		145	155	170	190

Table 14 below shows the CMSC for each interval using the previously mentioned formula. This CMSC payment would be made to the generators to restore their operating profit (the difference between price and offer price) to the level it would have been based on the unconstrained market quantities established when establishing market price.

Table 14: CMSC Calculation using 12 X RR Pricing

Interval	Generator	MQSI (MW)	DQSI (MW)	Price ($)	Offer ($)	CMSC ($)
1	A	125	105	45	20	500
	B	30	30	45	45	0
	C	0	20	45	60	300
	D					
Total CMSC						800
2	A	125	115	45	20	250
	B	45	35	45	45	0
	C	0	20	45	60	300
	D					
Total CMSC						550
3	A	125	125	60	20	0
	B	50	40	60	45	150
	C	15	25	60	60	0
	D					
Total CMSC						150

The uplift for each period is the sum of the CMSC divided by the total demand[3].

Interval one uplift = $800/155 = $5.16/MW
Interval two uplift = $550/170 = $3.24/MW
Interval three uplift =$150/190 = $0.79/MW

[3] As with total cost, CMSC has been based on demand not energy for simplicity. For consistency the per MW uplift has also been calculated based on demand and not energy. In fact, all demand should be converted to energy by multiplying by 5 minutes and dividing by 60 minutes/hour to yield a number in MWh. Converting the CMSC and the total market demand in each interval in this manner will yield the same uplift in $/MWh

CMSC with a One Times Myopic Unconstrained Algorithm

Table 15: Market Schedules and Prices with a Myopic 1X Ramp

Initial Conditions			Interval Demand MW		
			1	2	3
Demand			155	170	190
	Offer $	Output MW	Myopic 1X Schedule MW		
A	20	95	115	125	125
B	45	30	25	30	35
C	60	20	15	15	20
D	200	0	0	0	10
E	500	0	0	0	0
Price			$20	$60	$200

Table 16: CMSC Calculation using a Myopic 1X RR

Interval	Generator	MQSI (MW)	DQSI (MW)	Price ($)	Offer ($)	CMSC ($)
1	A	115	105	20	20	0
	B	25	30	20	45	125
	C	15	20	20	60	200
	D					
Total CMSC						325

2	A	125	115	60	20	400
	B	30	35	60	45	-75
	C	15	20	60	60	0
	D					
Total CMSC						325

3	A	125	125	200	20	0
	B	35	45	200	45	-1550
	C	20	25	200	60	-700
	D	10		200	200	0
Total CMSC						-2250

In this case, even though a 1X ramp rate is used, there are still differences from the MIO constrained schedule that can create CMSC. The temporal optimization used in MIO creates different dispatch and the myopic unconstrained does not respect minimum generation levels which can lead to CMSC.

Note: CMSC is not always a payment. It can be a charge if that is required to return the participant to their unconstrained operating profit. These negative uplifts return the generator to their offer price for any output beyond the unconstrained quantity.

Interval one uplift = $325/155 = $2.10/MW
Interval two uplift = $325/170 = $1.91/MW
Interval three uplift =-$2250/190 = -$11.84/MW

CMSC with a MIO Incremental, MIO Modified Incremental and High Slice Price

In these two pricing methods, the unconstrained schedule and the constrained schedule use the same assumptions. There would be no CMSC directly attributable to the price calculation methodology. As with any uniform price calculation method there may still be CMSC payments and uplift due to physical constraints and other differences to the input parameters.

Summary

The prices and CMSC results for this scenario and the different pricing methods are summarized in the table below. As stated earlier, these are not intended to imply typical market situations. They are based on a simple scenario and only intended to illustrate how different pricing methods work, not typical prices from each method.

Table 17: Summary of Price and CMSC Information for the Various Methodologies

	Price + CMSC ($)		
Interval	**One**	**Two**	**Three**
12X RR Price	$45	$45	$60
12X RR CMSC	$5.16	$3.24	$0.79
12X Price + CMSC	50.16	48.24	60.79
1X RR Price	$20	$60	$200
1X RR CMSC	$2.10	1.91	$11.84
1X Price + CMSC	22.10	61.91	188.16
MIO Incremental	$20	$20	$60 or $200
Modified MIO	$20	$20	$95
High Slice	$45	$45	$60 or $200

Note: Recall there is no CMSC directly associated with the MIO pricing options as the constrained algorithm currently in use in the real time markets is a MIO algorithm.

2.0 Scenario Two – Decreasing Demand

In this scenario, demand is ramping down and is expected to continue ramping down beyond the MIO study period. Table 18 below represents the offer data, which is the same as was used in scenario one. In this scenario, demand starts at 200 MW and drops to 185, 170 and 155 over the three intervals.

Table 18: Generator Offer Information

Generator	Offer Price $	MinGen	MaxGen	Ramp/min
A	20	0	125	4
B	45	0	50	1
C	60	20	75	1
D	200	0	100	2
E	500	0	50	3

Table 19: Initial Conditions

Initial Conditions	
Demand MW	200
Output MW	
A	125
B	50
C	25
D	0
E	0

Calculating Market Schedules with Various Pricing Methodologies

In this scenario, where demand is decreasing, the schedules are created in the same manner as they were in the first scenario. Generators are dispatched according to economics and their ability to ramp.

Market Schedule Using a 12X RR

Table 20 below shows the schedule for the three intervals if twelve times ramping is used. In this case, generators are assumed to be able to ramp at their hourly ramp ability over the course of five minutes. So a generator that can ramp at 1 MW/min will be capable of moving 60 MW over a five minute interval. As demand drops, the highest offer price generators are backed off to accommodate lower demand.

Table 20: Market Schedules with a Myopic 12X RR

Initial Conditions			Interval		
			1	2	3
Demand (MW)	200		185	170	155
Output (MW)					
A	125		125	125	125
B	50		50	45	30
C	25		10	0	0
D	0		0	0	0
E	0		0	0	0

Market Schedule with a 1X RR

The schedule for 1X RR is established in the same manner as the 12X RR. In this case the ramp rate may limit the ability of higher cost generators to reduce their output to keep pace with falling demand. As the higher cost generators B and C are limited in their ability to ramp, the lower priced generator A must lower output in order to accommodate falling demand.

Table 21: Market Schedules with a Myopic 1X RR

Initial Conditions			Interval		
			1	2	3
Demand	200		185	170	155
Output					
A	125		120	115	110
B	50		45	40	35
C	25		20	15	10
D	0		0	0	0
E	0		0	0	0

MIO Schedule

A MIO schedule will also use a 1X ramp rate to establish schedules, will respect minimum generation levels and will optimize to minimize total cost over several intervals. In this example, there is no difference between a MIO schedule and a one times ramp schedule.

Table 22: Market Schedules with a MIO algorithm

Initial Conditions			Interval		
			1	2	3
Demand	200		185	170	155
Output			MIO Schedule		
A	125		120	115	110
B	50		45	40	35
C	25		20	15	10
D	0		0	0	0
E	0		0	0	0

Calculating Market Prices with Various Pricing Methodologies

Twelve Times Ramp Rate

As with scenario one, the twelve times ramp rate price is set by the incremental MW. Generators at their maximum output, or ramp limited generators cannot increase their output and cannot provide an incremental MW.

Initial Conditions			Interval		
			1	2	3
Demand MW	200	Offer $	185	170	155
Output MW			MYPOPIC 12X Schedule		
A	125	20	125	125	125
B	50	45	50	45	30
C	25	60	10	0	0
D	0	200	0	0	0
E	0	500	0	0	0
Price $			$60	$45	$45

In this case, because there are no ramp limitations, the price is simply the price of the highest cost generator in the stack.

One Times Ramp Rate

As with twelve times ramp rate, the price is set by the incremental MW. Generators at their maximum output, or ramp limited generators cannot increase their output and cannot provide an incremental MW. In this case, because the actual ramp rate is being used, generators B and C are ramp limited. Both generators are ramping down at their maximum rate; however, they cannot keep pace with the falling demand. Generator A is therefore moved down in output to compensate and becomes the marginal resource.

Initial Conditions			Interval		
		Offer $	1	2	3
Demand	200		185	170	155
Output			Myopic 1X Schedule		
A	125	20	120	115	110
B	50	45	45	40	35
C	25	60	20	15	10
D	0	200	0	0	0
E	0	500	0	0	0
Price $			$20	$20	$20

MIO, MIO Incremental and High Slice Price

In this scenario, the schedule from the MIO unconstrained would be identical to the schedule from the one times ramp method. Demand is ramping down beyond the study period, so there is no need to keep higher priced generators in operation at their minimum generation level. Given the falling demand, there is no cost savings that can be achieved through a temporal optimization.

Initial Conditions			Interval		
		Offer $	1	2	3
Demand	200		185	170	155
Output			MIO Schedule		
A	125	20	120	115	110
B	50	45	45	40	35
C	25	60	20	15	10
D	0	200	0	0	0
E	0	500	0	0	0
Price $			$20	$20	$20

As before, the price will be established by the incremental MW. Since generator B and C are both ramp limited, the incremental MW in all three intervals comes from generator A.

Since there is no opportunity to ramp generator B or C early to produce an incremental change in interval 3, the modified MIO incremental prices would be the same as the MIO and one times ramp prices.

Similarly, since generators ramping down cannot set price in the high slice price method, once again prices would be the same as one times ramp and MIO prices.

Congestion Management Settlement Credits

The only price scheme which generates CMSC in this scenario is the twelve times ramp method. Since the market and dispatch schedules are identical for all other pricing methods, there is no CMSC impact specifically associated with the price calculation. As discussed in scenario one, there are still other sources of CMSC such as transmission constraints.

CMSC with Twelve Times Ramp Rate

With the use of twelve times ramp rates in the unconstrained algorithm, the market schedules (MQSI) are calculated using an assumption that cannot be carried out. Units cannot achieve their full one hour ramp capability in five minutes. This means the constrained dispatch quantity (DQSI) may be different than the MQSI. As discussed previously, when there is a difference between DQSI and MQSI, congestion management settlement credits are used to return the generator to the operating profit they would have received based upon the market schedule.

Even if there is a difference in the constrained and unconstrained quantity, CMSC payments will only flow if there is also a difference between the offer price and the market clearing price.

The simple formulae for CMSC for a generator (assuming dispatch and actual injection are equal):

CMSC = (Price – Offer)x Market Schedule - (Price – Offer)x Dispatch Quantity
CMSC = (MCP – Offer) x (MQSI-DQSI)

Twelve Times Ramp Rate

Interval	Generator	MQSI (MW)	DQSI (MW)	Price ($)	Offer ($)	CMSC ($)
1	A	125	120	60	20	200
	B	50	45	60	45	75
	C	10	20	60	60	0
	D					
					Total CMSC	275
2	A	125	115	45	20	250
	B	45	40	45	45	0
	C	0	15	45	60	225
	D					
					Total CMSC	475
3	A	125	110	45	20	375
	B	30	35	45	45	0
	C	0	10	45	60	150
	D					
					Total CMSC	525

- In interval one, generator A and B are constrained off to compensate for the ramp limitations of generator C
- In interval two, generator A and B are constrained off to compensate for the ramp limitations of generator C
- In interval three, Generator A is constrained off to compensate for the ramp limitations of generators B and C

As in scenario one, an uplift for CMSC will be required for each interval to recover the payments.

Interval One uplift = 275/185 = $1.49/MW
Interval Two uplift = 475/170 = $2.79/MW
Interval Three uplift = 525/155 = $3.39

CMSC with a MIO Incremental, MIO Modified Incremental and High Slice Price

In these two pricing methods, the unconstrained schedule and the constrained schedule use the same assumptions. There would be no CMSC directly attributable to the price calculation methodology. As with any uniform price calculation method there may still be CMSC payments and uplift due to physical constraints and other differences to the input parameters.

Scenario Two Summary

The prices and CMSC results for this scenario and the different pricing methods are summarized in the table below. As stated earlier, these are not intended to imply typical market situations. They are based on a simple scenario and only intended to illustrate how different pricing methods work, not typical market prices from each method.

Generator	Offer Price $	MinGen	MaxGen	Ramp/min
A	20	0	125	4
B	45	0	50	1
C	60	20	75	1
D	200	0	100	2
E	500	0	50	3

Interval	One	Two	Three
Demand	185	170	155
	Price + CMSC		
12 X	$ 60 + $1.49	$ 45 +$2.79	$ 45 + $3.39
1X	$20	$20	$20
MIO Incremental	$20	$20	$20
Modified MIO	$20	$20	$20
High Slice	$20	$20	$20