

Opportunity Cost Issues

MIC Special Session:
Opportunity Cost Calculator
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Standard Model of Review for OC Adders

1. A market participant requests the application of opportunity costs in a cost-based energy offer.
2. IMM evaluates the opportunity costs and all the associated inputs in detail, discusses the details with the participant and provides the results of its analysis to the participant.
3. The IMM and the participant discuss in detail and reach agreement after discussion.
4. The IMM informs the participant in writing that the opportunity cost is consistent with a competitive cost-based energy market offer.



Standard Model of Review for OC Adders

5. PJM reviews the results and decides whether to accept or reject the agreed upon opportunity cost.
6. If the IMM and the market participant do not reach agreement, the market participant has the option to request PJM's opinion or to go directly to FERC.
7. If PJM permits the participant to use an opportunity cost that the IMM believes is consistent with the exercise of market power, the IMM can raise the issue with FERC.

Standard Model of Review for OC Adders

8. If PJM requires the participant to use an opportunity cost that the IMM believes is lower than the actual opportunity cost, the market participant or the IMM can raise the issue with FERC.



Standard Model of Review for OC Adders

- If PJM were to select the standard option, the IMM would continue to work to make clear to PJM the IMM approach to the calculation of opportunity costs and would discuss, at PJM's request, the details of any specific case with PJM to ensure that PJM clearly understands the basis for the calculation of opportunity cost.
- If PJM were to decide to be the first reviewer of opportunity costs, the IMM has the obligation to refer any participant to FERC if the opportunity cost adder is not consistent with a competitive offer.

IMM Calculator Scenarios

- **The IMM calculator incorporates the following parameters that are not included in the PJM calculator:**
 - **Minimum downtime constraint**
 - **Economic minimum (EcoMin) dispatch parameter that allows the dispatch at either EcoMin or EcoMax**
 - **Start-up emissions parameters to better model the impacts of generator starts on the environmental limits**
- **The following scenarios show the impacts of removing the parameters from the IMM calculator to demonstrate the differences from the PJM calculator.**

IMM Calculator Scenarios

- **Scenario 1 – Remove the min downtime constraint**
 - Average optimal profit increased \$16,307
 - OC Adder impacts ranged from -\$6.59 to \$0.81
- **Scenario 2 – Remove the EcoMin parameter (set EcoMin = EcoMax)**
 - Average optimal profit decreased \$49,166
 - OC Adder impacts ranged from -\$6.07 to \$1.39
- **Scenario 3 – Remove start-up emissions**
 - Average optimal profit increased \$17,308
 - OC Adder impacts ranged from -\$2.69 to \$5.55

Calculator Comparison

- **The following examples compare the results of using the logic employed by the PJM calculator and a simplified version of the IMM calculator that uses an integer programming (IP) solver.**
- **Simplified version used for comparison with PJM model.**
- **Each example considers a 12 hour period with a runtime restriction of four or six hours.**
- **The hourly margins represent the hourly LMP net of the short-run marginal cost of producing energy at the generator's economic maximum output. (Start cost is not included in the hourly margin value).**

Calculator Comparison

- **The Hour On variable indicates the calculator's choice of whether the generator will operate during a particular hour**
- **The PJM calculator determines the opportunity cost by computing the average profit of the last block chosen.**
- **The IMM method first solves the problem with the hour restriction in place; then solves again with the hour restriction reduced by one hour. The opportunity cost is equal to the difference in profit between the first and second solve. This is the shadow price of the run hour constraint.**



Example 1

Hour Number	Hourly Margin	Hour On Variable		
		PJM Calculator	IP Solve 1	IP Solve 2
1	\$3.75	0	0	0
2	\$3.75	0	0	0
3	-\$2.00	0	0	0
4	\$4.00	0	0	0
5	\$4.00	0	1	0
6	\$4.00	0	1	1
7	\$4.00	0	1	1
8	-\$3.00	0	1	1
9	\$7.00	1	1	1
10	\$7.00	1	1	1
11	-\$1.00	1	0	0
12	\$4.00	1	0	0
Total Hours On		4	6	5
Revenue net hourly operating cost		\$1,700	\$2,300	\$1,900
Start Cost		\$720	\$720	\$720
Profit		\$980	\$1,580	\$1,180
Opportunity Cost (\$ per MWh)		\$2.45	\$4.00	
Assumptions:				
Start-Up Cost (\$ per start)		\$720	\$720	\$720
Economic maximum output (MWh)		100	100	100
Minimum runtime (hours)		2	2	2
Operating hour limit (hours)		6	6	5



Example 2

Hour Number	Hourly Margin	Hour On Variable		
		PJM OC Calculator	IP Solve 1	IP Solve 2
1	-\$5.00	0	0	0
2	-\$5.00	0	0	0
3	\$10.00	1	1	1
4	\$10.00	1	1	1
5	\$10.00	1	1	0
6	-\$5.00	0	0	0
7	-\$5.00	0	0	0
8	-\$5.00	0	0	0
9	\$10.00	1	1	1
10	\$10.00	1	1	1
11	\$10.00	1	1	1
12	-\$5.00	0	0	0
Total Hours On		6	6	5
Revenue net hourly operating cost		\$6,000	\$6,000	\$5,000
Start Cost		\$1,440	\$1,440	\$1,440
Profit		\$4,560	\$4,560	\$3,560
Opportunity Cost (\$ per MWh)		\$7.60	\$10.00	
Assumptions:				
Start-Up Cost (\$ per start)		\$720	\$720	\$720
Economic maximum output (MWh)		100	100	100
Minimum runtime (hours)		2	2	2
Operating hour limit (hours)		6	6	5



Example 3

Hour Number	Hourly Margin	Hour On Variable		
		PJM OC Calculator	IP Solve 1	IP Solve 2
1	\$6.00	0	1	1
2	\$5.99	0	1	1
3	-\$5.00	0	0	0
4	\$3.00	1	0	0
5	\$3.00	1	0	0
6	\$3.00	1	0	0
7	\$3.00	1	0	0
8	-\$5.00	0	0	0
9	\$4.00	0	1	0
10	\$4.00	0	1	0
11	\$3.99	0	0	0
12	-\$6.00	0	0	0
Total Hours On		4	4	2
Revenue net hourly operating cost		\$1,200	\$1,999	\$1,199
Start Cost		\$720	\$1,440	\$720
Profit		\$480	\$559	\$479
Opportunity Cost (\$ per MWh)		\$1.20	\$0.40	
Assumptions:				
Start-Up Cost (\$ per start)		\$720	\$720	\$720
Economic maximum output (MWh)		100	100	100
Minimum runtime (hours)		2	2	2
Operating hour limit (hours)		4	4	3



Example 4

Hour Number	Hourly Margin	Hour On Variable		
		PJM Calculator	IP Solve 1	IP Solve 2
1	-\$5.00	0	0	0
2	\$4.00	1	0	0
3	-\$2.00	1	0	0
4	-\$3.00	0	0	0
5	\$5.00	1	1	1
6	\$4.00	1	1	1
7	\$4.00	1	1	1
8	-\$5.00	0	0	0
9	-\$10.00	0	0	0
10	\$2.00	0	0	0
11	-\$4.00	0	0	0
12	-\$2.00	0	0	0
Total Hours On		5	3	3
Revenue net hourly operating cost		\$1,500	\$1,300	\$1,300
Start Cost		\$1,440	\$720	\$720
Profit		\$60	\$580	\$580
Opportunity Cost (\$ per MWh)		-\$2.60	\$0.00	
Assumptions:				
Start-Up Cost (\$ per start)		\$720	\$720	\$720
Economic maximum output (MWh)		100	100	100
Minimum runtime (hours)		2	2	2
Operating hour limit (hours)		6	6	5



Comments on Examples

- **The PJM Calculator uses predefined blocks of hours rather than economic dispatch.**
- **The PJM Calculator does not exhaust available hours with positive margins due to the block margin stopping logic.**
- **The PJM opportunity cost calculation does not reflect the shadow price of the constrained optimization problem**
- **The PJM calculator returns negative values**
- **On more complex problems with rolling compliance periods the errors will be worse.**



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