What Objective Function Should be Used in the ISO and RTO Unit-Commitment Models: A Market Participant Pointview

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Objective Stated by the Commission and ISOs

- FERC stated the objective in its Standard Market Design Working paper, dated March 15, 2002
  - "The objective of standard market design for wholesale electric markets is to establish a common market framework that *promotes economic efficiency and lowers delivered energy costs*, maintains power system reliability, mitigates significant market power and increases the choices offered to wholesale market participants……"
- CAISO Tariff 31.3.1.1.
  - "In determining Day-Ahead Schedules, AS Awards, and AS Schedules the IFM optimization will *minimize total Bid Costs* based on submitted and mitigated Bids ……"
- MISO Tariff Section 39 (Sheet No. 714)
  - "The clearing and pricing of Energy and Operating Reserve in the Day-Ahead Energy and Operating Reserve Market is based on a simultaneous co-optimization process which *minimizes the total costs* of Energy and Operating Reserve."

Summary of ISOs' Practices

- Currently ISO's run a unit-commitment model (day-ahead market) on a daily basis to procure energy and ancillary services. The objective is to minimize the total bid cost
  - This optimization is treated similarly to the traditional unit commitment problem by incorporating bid cost into the objective function instead of generation marginal costs (fuel costs plus variable O&M)
- A market clearing price (MCP or LMP) mechanism to pay market participants and charge consumers for energy and ancillary service products has been adopted in these ISOs

Minimizing Total Bid Cost

- Simplified mathematical formulation

$$\min_{\{p_i(t)\}} J, \text{ with } J \equiv \sum_{t=1}^{T} \sum_{i=1}^{I} \left\{ B_i(p_i(t), t)) + S_i(t) \right\}$$

  - $B_i(p_i(t,)\ t)$ is the bid cost curve ($) for power $p_i(t)$ from Seller i, and $S_i(t)$ is the start-up cost or other capacity related costs
  - Subject to demand and reserve requirement constraints, transmission constraints, and individual generation unit constraints

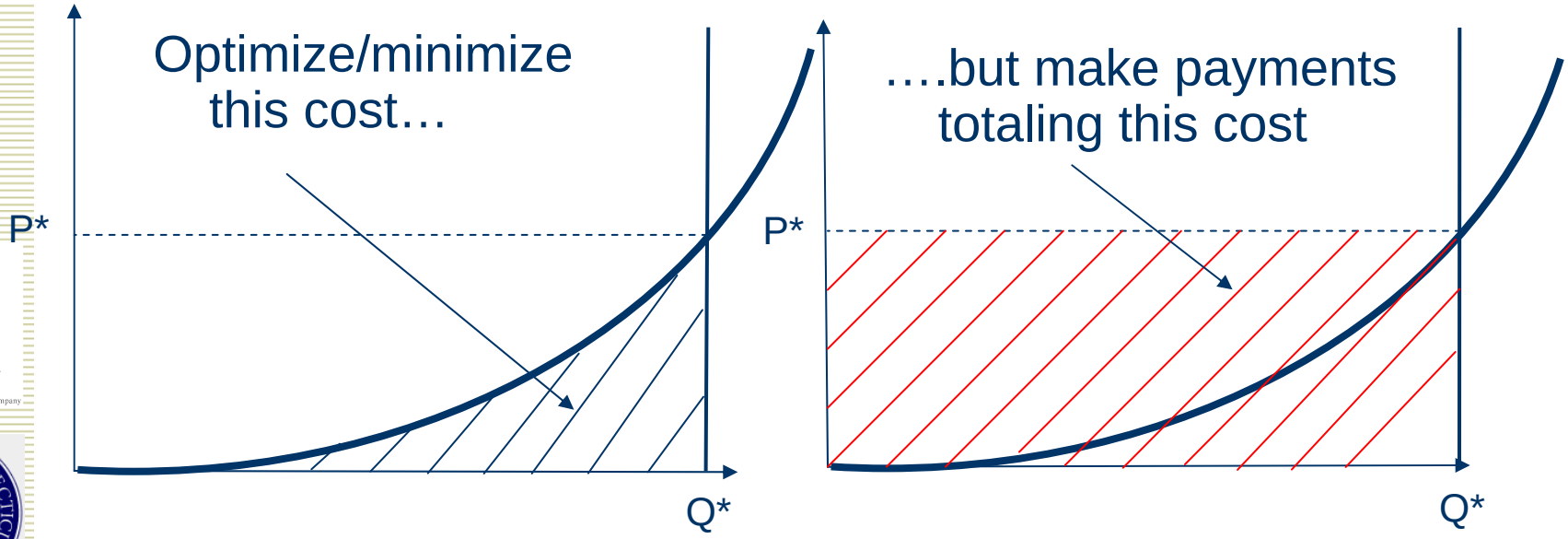
- Market Clearing Price (MCP) is equal to the system marginal cost derived from the Lagrangian Relaxation or simulated by other methods

- The customers will be charged and the suppliers will be paid at the MCP

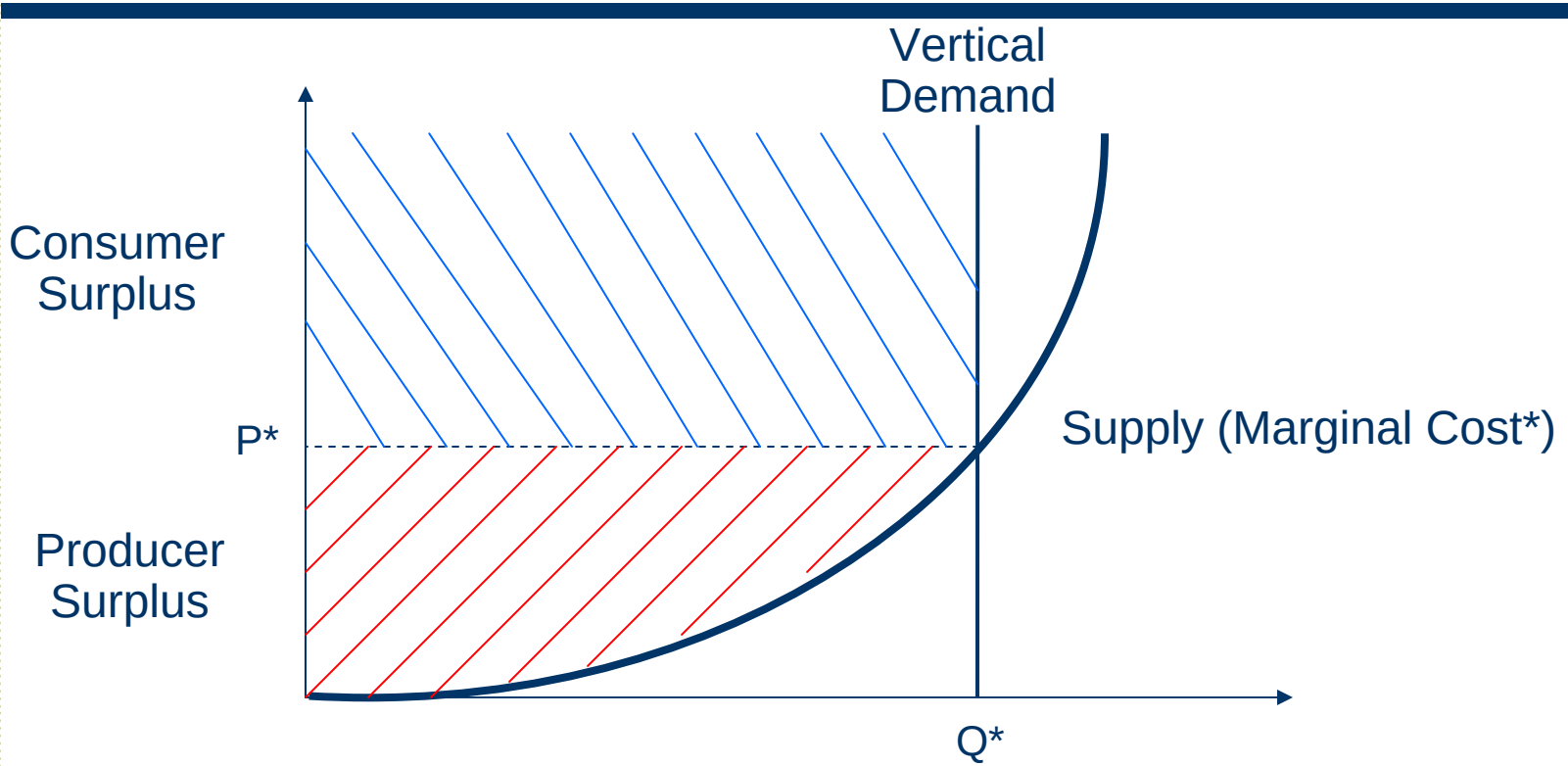
The Issue with Bid Cost Minimization

- The total payment cost is the product of MCP and MWhs for energy, which is not the minimized bid cost

$$\sum_{t=1}^{T}\sum_{i=1}^{I}\left\{ B_i(p_i(t),t)) + S_i(t) \right\} \neq \sum_{t=1}^{T}\sum_{i=1}^{I}\left\{ MCP(t)\cdot p_i(t) + S_i(t) \right\}$$



Consumer and Producer Surplus



* Hal R. Varian, Microeconomic Analysis, W. W. Norton & Company, 1978. Page 214.

- Prior to deregulation
  - A utility would minimize the cost of serving its load, including fuel costs, start-up costs, etc of production.
  - Maximizing the sum of producer and consumer surplus was equivalent to minimizing the production costs.

Consumer and Producer Surplus (Cont'd)

- After deregulation, the bid cost is not equivalent to the production cost
  - virtual bids are purely financial, and virtual bidding has been implemented in PJM, NY, NE, and MISO. FERC has ordered California to implement virtual bidding in Spring 2011
  - Opportunity cost is frequently used to establish bids
- Producer surplus can not be measured with bid information, therefore social welfare cannot be maximized.

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Minimize Total Payment Cost

- Simplified mathematical formulation

$$\min_{\{MCP(t),p_i(t)\}} J, \text{ with } J \equiv \sum_{t=1}^{T} \sum_{i=1}^{I} \left\{ MCP(t) \cdot p_i(t) + S_i(t) \right\}$$

  - Where MCP(t) is defined as the maximum bid price of the selected bids at time t. It is not fixed, but depends on $\{p_i(t)\}$
  - Subject to demand and reserve requirement constraints, transmission constraints, and individual generation unit constraints

- Market Clearing Price (MCP) is a decision variable and will be determined through the optimization process

- This problem is much more complicated and difficult to solve than the bid cost minimization problem

Example

- An auction for one hour with four bids and 100 MWh demand

	Capacity (MW)	Bid Price ($/MWh)	Start-up Cost ($)
Bid 1	45	10	0
Bid 2	45	20	0
Bid 3	20	100	0
Bid 4	20	30	2,000

- A bid may represent a physical generation resource or a financial transaction (Virtual Bid)

Example (Cont'd)

- Optimal solution of minimizing total bid cost

	Bid Cost Minimization				**MCP = $100/MWh**		
	Energy Selected (MWh)	Energy Cost ($)	Start-up Cost ($)	Sub-Total ($)	Energy Payment ($)	Start-up Payment ($)	Sub-Total ($)
Bid 1	45	450	0	450	4,500	0	4,500
Bid 2	45	900	0	900	4,500	0	4,500
Bid 3	10	1,000	0	1,000	1,000	0	1,000
Bid 4	0	0	0	0	0	0	0
Total	100	2,350	0	***2,350***	10,000	0	***10,000***

* **The minimized bid cost is not equal to the total payment cost**

Example (Cont'd)

- Optimal solution of minimizing total payment cost

***Payment Minimization* (MCP = $30/MWh)**

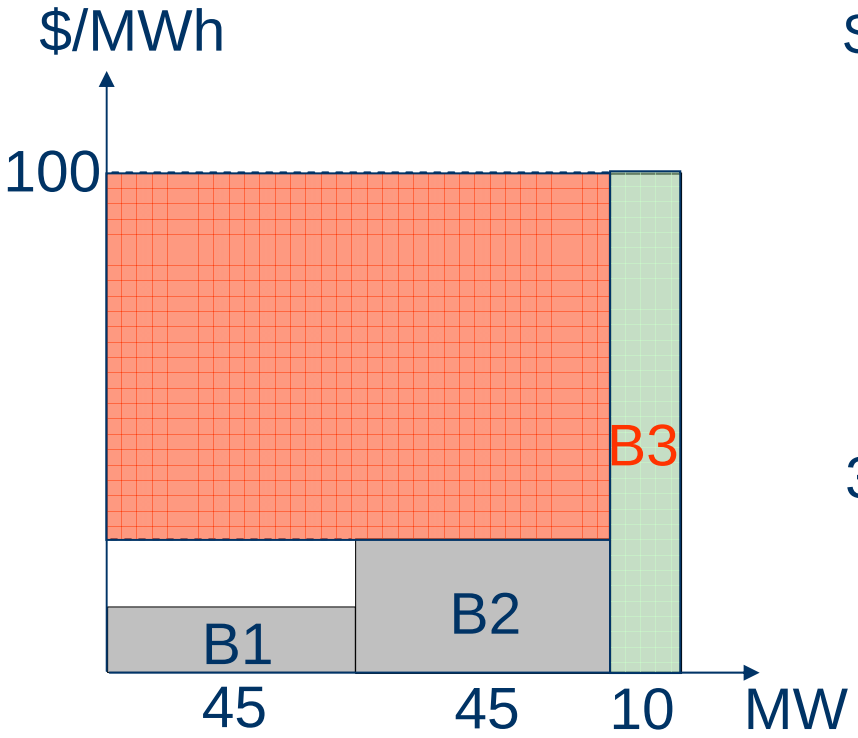
	Energy Selected (MWh)	Energy Cost ($)	Start-up Cost ($)	Sub-Total ($)
Bid 1	45	1,350	0	1,350
Bid 2	45	1,350	0	1,350
Bid 3	0	0	0	0
Bid 4	10	300	2,000	2,300
Total	100	3,000	2,000	***5,000***

*** The minimized payment cost is equal to the total payment cost, and it is below the payment cost under bid cost minimization**

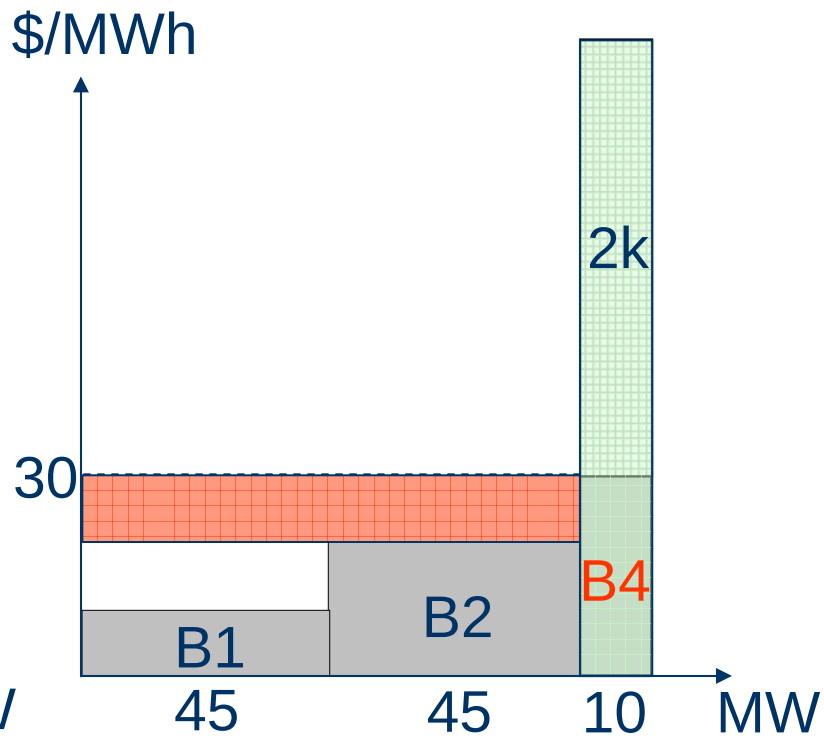
Illustration of Solutions Under the Two Objectives

- Which bid is selected for the last 10 MW demand?

Bid cost minimization



Payment minimization



Incremental bid cost

Incremental total payment

Simple Example - Insights

- The bid cost minimization creates inconsistency between the minimized total bid cost and total payment cost, and results in a higher cost to consumers.
- The bid cost minimization may not commit the appropriate set of units.
- In the pay-at-MCP (or LMP) mechanism with simultaneous co-optimization of energy and ancillary services, the bid cost minimization may not allocate the limited capacity efficiently and result in a higher cost to consumers.
- Small bids (Virtual Bids) with high prices are more likely to be selected under bid cost minimization (as compared to payment cost minimization), inducing the hockey-stick bidding, and causing high MCPs and high consumer payments
  - This is because the bid cost minimization auction ignores the total cost impact caused by selecting those small and high-price bids.
- The payment minimization determines LMPs, energy and ancillary service awards simultaneously, and produces a consistent solution with a lower cost.

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Summary of Methodology Development for Payment Cost Minimization

- Market clearing prices are part of decision variables under payment cost minimization
- A novel surrogate subgradient method combined with augmented Lagrangian has been developed
  - Key idea: Approximate optimization of the relaxed problem is sufficient if certain condition is satisfied
- Results
  - Payment cost minimization with uniform MCP (Luh et al., 2006)
  - With demand bids and partial compensation of startup costs (Luh et al., 2005, book chapter)
  - With transmission constraints (Zhao et al., 2007)
  - Bidding behavior study (Zhao et al., 2010)
  - Significant progress made to solve the problem by using CPLEX

Conclusions

- We provide mathematical formulation for both the bid cost and MCP payment minimization, and demonstrate that inconsistency of the bid cost minimized and the actual cost paid by consumers
  - This inconsistency may result in higher costs to consumers, and send the wrong investment signal to the markets
- A novel solution methodology has been developed based on augmented Lagrangian Relaxation and Surrogate Optimization
  - Numerical testing results show that the method is promising, and will lead to a significant cost savings for consumers

Recommendations

- We urge that the Commission issue an order requiring each ISO to file a report
  - Confirming whether bid cost minimization is used in its day-ahead market
  - Reporting the daily minimized total bid cost and total payment for year 2009
  - Proposing necessary changes in its day-ahead market unit-commitment models to address the significant difference if any between the minimized total bid cost and total payment cost

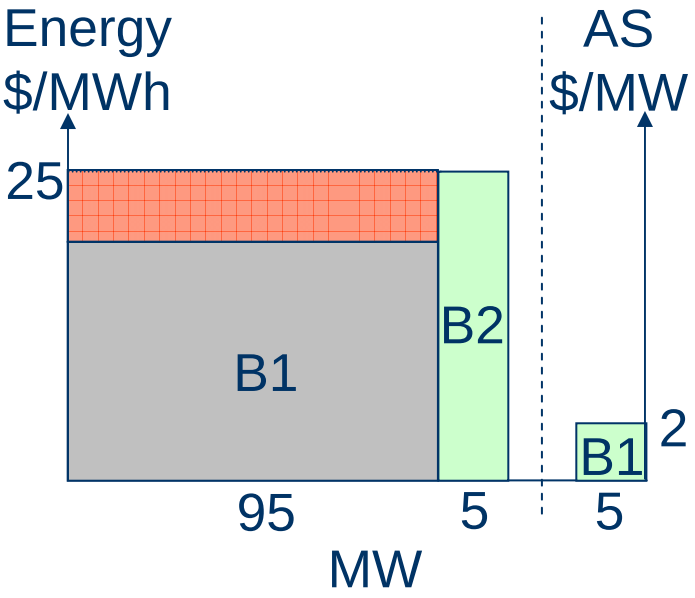
Example 2

Backup

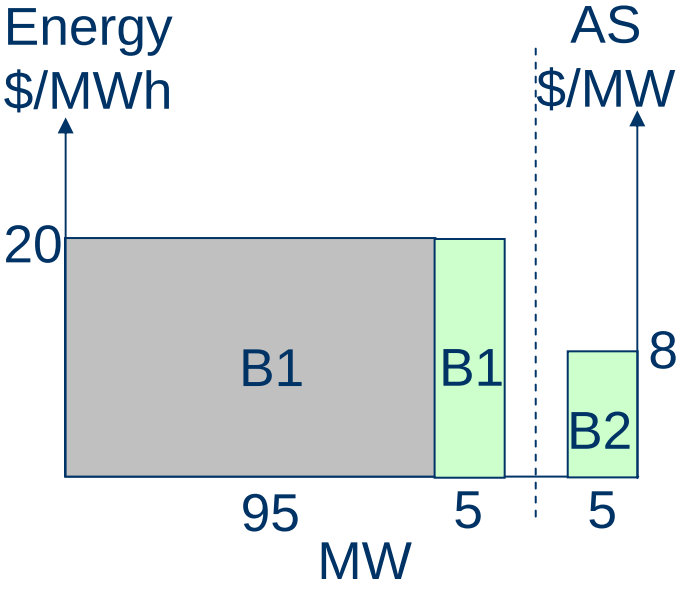
- Demand =100 MWh; AS requirement = 5 MW

	Capacity (MW)	Ancillary Service (MW)	Energy Bid Price ($/MWh)	AS Bid Price ($/MW)
Bid 1	100	6	20	2
Bid 2	10	6	25	8

Bid Cost Minimization



Payment Minimization



Issues of Market Design

Backup

- The issue of whether “Pay-as-bid” or “Pay-at-MCP” should be used for settlement has been much debated
  - With “Pay-as-bid,” market participants would bid substantially higher than their marginal costs to increase their revenue, and thus very likely exceed the expected payment reduction (Blue Ribbon Panel Report, 2001)
  - Currently, ISO’s in the U.S. adopt the “Pay-at-MCP” mechanism for settlement
- However, significantly less attention has been paid to the choice of objective function
  - Is minimizing the total bid cost wrong?
  - Should ISO minimize the total payment?