Convergence Bidding Fundamentals

Farrokh A. Rahimi
and
Alan G. Isemonger

CAISO Department of Market and Product Development

Prepared for Presentation at
CAISO Panel on Convergence Bidding

Folsom, CA June 13th, 2006
Table of Contents

Introduction ...........................................................................................................3
The Two Settlement System ....................................................................................4
   Should DA and RT Prices Converge? ...............................................................7
   What Degree of Convergence is Likely? ..........................................................8
   What Drives the Convergence? .......................................................................9
      Price Arbitrage ............................................................................................9
      Physical Hedging .........................................................................................9
Types of Convergence Bidding .............................................................................10
   How Does Explicit Virtual Bidding Work? .....................................................10
   How Would Explicit Virtual Bidding Work Under MRTU ...............................10
Example 1 - Virtual Demand Bidding ...............................................................11
      Step 1 - Bid Submission .............................................................................11
      Step 2 - DAM ............................................................................................12
      Step 3 - Real-Time Market ..............................................................12
Example 2 - Virtual Supply Bidding .................................................................12
      Step 1 - Bid Submission .............................................................................13
      Step 2 - DAM ............................................................................................13
      Step 3 - Real-Time Market ..............................................................13
Physical Hedging ...............................................................................................14
Example 3 - Protecting a generation offer ........................................................14
Implicit Virtual Bidding in California ...............................................................15
   How Does Implicit Virtual Bidding Work? .....................................................15
   Can IVB Be Suppressed Under MRTU? .........................................................16
   Behavioral Changes in Market Participant Behavior .......................................16
      Implicit Virtual Bidding Using Imports and Exports Under MRTU..........17
      Implicit Virtual Bidding Using Load Under MRTU ..................................18
   How Does an ISO Mitigate the Effects of Implicit Virtual Bidding? ..........18
Concluding Remarks ...........................................................................................18
Appendix 1: Congestion Hedging .......................................................................19
Introduction

The objective of this white paper is to provide an overview of the fundamentals of Convergence Bidding (also referred to as “Virtual Bidding”), and set the stage for the panel discussion on the issue at CAISO’s June 13, 2006 Market Panel meeting. This paper does not intend to argue for or against Convergence Bidding, but merely to explain the nature of bidding in a two settlement (Day-ahead and Real-time) market and to describe the nature of the choices facing the CAISO in considering whether and how to implement Convergence Bidding in a future market design enhancement.

The panel discussion includes a variety of industry representatives, both in favor of and opposed to, Convergence Bidding, who will present their views and arguments. The panel discussion is intended to provide the CAISO Board and the stakeholders with a better understanding of what Convergence Bidding is and how it can function in the context of multi-settlement electricity Energy markets. Following this panel the CAISO intends to initiate stakeholder discussions on the subject during the third quarter of 2006, and then, based on the outcome of the stakeholder process, to present a proposal to the CAISO Board for decisions in the 4th quarter of 2006.

Executive Summary

Defined broadly as the ability to engage in purely financial transactions, Virtual Bidding\(^1\) has a long history in the more traditional commodity markets\(^2\). In the electricity markets it had to wait for deregulation to provide both centralized clearing markets, and multi-settlement Energy markets. Since its introduction in PJM on June 1\(^{st}\) 2000, and in the NYISO on November 1\(^{st}\) 2001, Virtual Bidding has become a standard part of multi-settlement electricity markets in the “Eastern” ISOs, with subsequent implementations in ISO-NE and MISO. Now that the CAISO is preparing to implement its comprehensive market redesign as part of the Market Redesign and Technology Upgrade (MRTU) project, FERC has indicated, and several stakeholders have argued, that virtual or Convergence Bidding should be an element of the CAISO’s new markets. Any implementation by the CAISO would draw heavily from the experience of the other ISOs that have implemented it.

When implementing a two settlement energy market (Day-ahead and Real-time) there is a natural tendency for both buyers and sellers in these markets to want to buy the product at a low price and sell it at a higher price where possible, thereby equalizing the prices across these two markets. Convergence Bidding provides a financial tool used at some ISOs with two-settlement energy spot markets\(^3\) for the physical hedging of production by suppliers of energy as well as the arbitrage of

---

\(^1\) In this paper both “Convergence Bidding” and “Virtual Bidding” will be used interchangeably.

\(^2\) In the commodity markets very few futures contracts go to delivery, rather they are closed out by countervailing trades before expiry.

\(^3\) Although Convergence Bidding may be applicable to more than two settlement energy markets, all ISOs that have implemented it thus far have had two-settlement systems.
prices between these markets. Convergence bidding allows buyers and sellers to purchase or sell energy in the forward spot market, with the explicit requirement that they sell or buy back the same energy in real time as a price taker. The term “Convergence” refers to the convergence of energy prices in the two spot markets, which is an intended or presumed outcome of the underlying bidding practice.

Convergence Bidding is also known as “Virtual Bidding” to reflect the fact that the energy purchased or sold in the forward market is not intended for actual consumption or delivery in real time. It is useful to distinguish between Explicit Virtual Bidding (EVB) and Implicit Virtual Bidding (IVB). The former refers to Virtual Bidding that occurs in accordance with explicit provisions for Virtual Bidding in an ISO market design, which typically require that virtual bids be explicitly flagged as such. The latter refers to Virtual Bidding behavior - i.e., forward purchases or sales with the intention of selling or buying back in real time - where the virtual bids are not explicitly identified as such.

In a two-settlement market where there are systematic price differences between the markets and no provisions for EVB, it will be difficult to detect IVB, and short of extensive enforcement measures it will be difficult to deter or suppress it, yet it affects reliability as it degrades the accuracy of the demand and supply forecasts by commingling physical and virtual transactions. Some of the so-called “Enron games” during the California energy crisis fall in this category. Explicit Virtual Bidding, by allowing market participants to arbitrage prices between the DA and RT markets, reduces the incentive to engage in IVB and thus can eliminate the reliability problems that characterize IVB. Moreover, the arbitrage resulting from virtual or Convergence Bidding activity tends to reduce or even eliminate systematic price differences between the two markets over time, which in turn reduces the incentives for parties to engage in Convergence Bidding. Price convergence can occur with implicit virtual bidding as well based on how the rest of the market is designed, but may in the process undermine system reliability.

The central theme of this paper is that Convergence Bidding is an explicit feature which allows normal profit maximizing participants to have ways to arbitrage price differentials between markets without violating any rules and without creating detrimental impacts to grid operations and market performance.

The Two Settlement System

One of the recent improvements in electricity market design in North America has been the move to multi-settlement markets. Multi-settlement markets allow market participants to hedge their production and consumption by contracting in more than one market, hence they reduce their exposure to any one market. Experience in different ISOs indicates that Day-ahead prices are generally more stable than the real-time prices for a variety of reasons. DA prices are less affected by the grid events, such as forced generation and/or transmission outages, and there are greater opportunities for advanced planning, so the supply curve is less steep in Day-Ahead than Real-Time. The DA market thus provides a less volatile market for participants to hedge real-time price risks.
PJM and New England ISOs started with single settlement markets (using only real-time prices for settlement). PJM implemented a two-settlement market in June 2000, and ISO-NE in March 2003. California was a pioneer of multi-settlement markets; its initial design, in conjunction with the California PowerExchange (PX), had a three settlement energy market, namely a Day-ahead market, an Hour-ahead market, and a real-time balancing market. Each of these markets produced its own prices and a binding financial settlement, meaning that energy that cleared the day-ahead market was settled at the day-ahead prices, and any incremental purchases or sales in the subsequent markets were settled at prices determined in those markets.

With the demise of the PowerExchange in January 2001 a gap opened up in the California spot market for energy, and California was left with a single settlement energy market in real-time. This is only a balancing market, meaning that most of the energy required to meet load is bilaterally contracted and is merely scheduled through the market, not traded and settled through the market. At the moment the CAISO thus has a single settlement energy market, however it does have two-settlement Ancillary Service market (Day-ahead and Hour-ahead) and a two-settlement inter-zonal congestion management market (Day-ahead and Hour-ahead).

The comprehensive market redesign being implemented as part of the MRTU project will create a transparent, bid-based day-ahead energy market thus filling the gap left by the demise of the PX. MRTU also updates and improves the CAISO’s real-time balancing market, thus creating a two-settlement energy market, namely, Day-Ahead and Real-Time. In addition, MRTU adopts the Locational Marginal Pricing (LMP) design, which has been implemented and functioning well in the other ISOs for several years, in both the day-ahead and real-time MRTU markets.

Figure 1 illustrates how a two-settlement energy spot market works consisting of a day-ahead (DA) and a real-time (RT) market. The quantity Q\textsubscript{DA} clears the DA market at price P\textsubscript{DA}. The estimated real-time demand is shown by the vertical line Q\textsubscript{ERT}. The quantity Q\textsubscript{ERT} - Q\textsubscript{DA} is deferred to RT by the entities submitting demand and supply bids by virtue of their pricing. Between the DA and RT markets the supply curve may change. The RT market graph shows the incremental real-time purchases over the DA purchases, which should be roughly equal to Q\textsubscript{ERT} - Q\textsubscript{DA}. In this instance two supply curves are shown, namely S\textsubscript{RT1} and S\textsubscript{RT2}. This indicates simply that supply changes between DA and RT can either increase or decrease the RT price compared to the DA price, depending on grid conditions.

---

The RT market does include an Hour-Ahead Scheduling Process (HASP) which enables the CAISO to obtain RT balancing energy and operating reserves from imports, and allows SCs with supply resources to self-schedule changes to their DA schedules. The HASP is not a separate settlement market, however, as the prices it calculates are only used for the settlement of interchange schedules and reserve capacity from imports. The HASP is functionally analogous to the real-time pre-dispatch that is part of today’s RT market, and its design is based on the Balancing Market Evaluation (BME) that is part of the NYISO market design.
Figure 1 shows the collective market-wide supply and demand bidding patterns, with the DA market clearing price and quantity indicated by the dashed line. The Demand Curve $D_{DA}$ shows the pricing points at which the LSEs collectively are indifferent between purchasing energy in the DA and deferring to real time. Figure 2 shows a similar graph, but it represents a single LSE. If an LSE were certain of the RT price, and presuming that the volume of its procurement would not influence that price, then it would not bother to buy any energy in the DA market that was priced higher than the RT market price. As a result the demand curve would be flat above the expected RT price. As LSEs cannot be certain of the RT price their preferences are better reflected in a curve which shows their willingness to defer procurement at different pricing points. Quite clearly this is a strategic decision as nearly all end-use demand is incapable of receiving, let alone responding to, real-time prices. This demand curve shows the manner in which load with no ability to respond to real-time prices can mitigate risk in a two-settlement system.
Should DA and RT Prices Converge?

A lesson to be drawn from the behavior of all commodity markets is that forward prices of a well-defined product - i.e., a commodity of specified quality delivered to a specified location at a specified time - will converge to the price at time of delivery, unless there are barriers to convergence. Barriers can include high transaction costs, unavailability or asymmetric availability of relevant information, or explicit rules that limit trading. In the case of electric energy delivered to specific location, such as a trading hub, at a specific time, such as a particular five-minute dispatch interval, this would mean that, in the absence of other charges or costs that may cause preference for one market with respect to another forward market, transaction prices should converge to real-time prices.

In general, prices should converge to the extent that they are the same product or substitutes for one another from the consumers’ viewpoint, or the same resource can produce them at the same cost from the suppliers’ viewpoint. This is common sense. From a consumer’s viewpoint, apples and oranges are different in kind and are poor substitutes for one another, and from a producer’s viewpoint, they entail different production costs; thus any price convergence would be largely coincidental. Electric energy is always the same product, but it can be differentiated geographically and temporally. Geographic arbitrage consists of buying the energy where it is cheap, say the Northwest, and transporting it to where it is expensive, say southern California, whilst accounting for the need for
transmission rights. Temporal arbitrage consists of buying energy when it is cheap and selling it when it is expensive. There are two ways this can work. The first - which is not the subject of this paper - would be to buy and actually take delivery of energy during the night, store it somehow, and then sell it back into the grid during peak hours when prices are high. This is not very practical for the majority of market participants because, with the exception of those with large reservoirs for water storage, storage technologies are very limited at present. The second approach - which is the subject of this paper - would be to agree in advance of the delivery time to buy energy at a specific price and then sell it back later when the price is expected to be higher, but without ever taking physical delivery of the energy.

In the context of the DA and RT energy markets implemented by ISOs, these markets are transacting the same product, in that in each case what is being transacted is energy to be delivered at a specified location during a specified real-time interval. The product is the same, but the time of transaction differs. Some may argue that DA and RT energy are not identical products in that the dispatch interval is longer in DA (one hour) and shorter in RT (five minutes). However, this bundling of 12 five-minute intervals for convenience of DA transactions is no reason to expect the day-ahead and real-time prices to have a systematic difference over the long-run. An internal generating unit or dynamically scheduled intertie resource can produce either product and will do so to capture price differences between the markets, causing the two prices to converge over time. As these sequential markets are trading the same product, economic theory indicates that market participants will seek to arbitrage systematic price differences and converge their prices, either physically or financially.6

What Degree of Convergence is Likely?

The price difference between DA and RT prices can be separated into two categories, namely predictable price differences and unpredictable (or stochastic) price differences. Unpredictable price differences would be those differences that are due to forced outages, unpredictable weather and the like. If, for example, a large number of generating units unexpectedly trip after the close of the DA market and the RT price is consequently higher as more expensive units are committed to serve the load, then this price differential between DA and RT cannot be arbitragable away as it is unpredictable. It will remain. On the other hand if there is a group of generators that prefer to transact DA so that they can arrange their gas deliveries and schedule their personnel and consequently accept lower prices in the DA than in real-time, then if this pattern proves consistent arbitrageurs will buy DA and sell at higher prices in RT and converge the two prices. Thus Convergence Bidding will only arbitrage away the non-stochastic differences between DA and RT prices. Actual price differences between DA and RT will persist, but the extent of divergence, on average, will be lessened.

6 It should be noted that if arbitrage opportunities are suppressed prices will not converge.
A further nuance regarding price convergence between the day-ahead and real-time prices is that this is premised on there being no transaction cost differences between day-ahead and real-time markets. For example, if real-time transactions are discouraged by imposition of real-time transaction fees on both buyers and sellers, but no such fees are applied to the day-head purchases or sales, one would expect a systematic difference between day-ahead and real-time market-clearing prices. Alternatively, one might change the definition of the “price” to include such transaction fees (i.e., a blend of the market-clearing price and additional transaction fees), before examining price convergence.

**What Drives the Convergence?**

There are two reasons why participants would engage in bidding behavior which cause prices to convergence, namely price arbitrage and physical hedging.

**Price Arbitrage**

Normal profit maximizing behavior of market participants to buy low and sell high causes prices to converge in a two settlement market for electricity. Those arbitrageurs that correctly predict the price differentiation will trade to converge the prices between DA and RT, and will consequently have profitable trades and make money. Those that incorrectly predict the price differentiation will trade to diverge prices between DA and RT, will have unprofitable trades, and will lose money. For example, a Day Ahead purchase in expectation of a later sale at a higher price in the Real Time market has the effect of raising the Day Ahead price slightly due to the additional demand, and this tends to reduce the divergence between Day Ahead and Real Time energy prices. The incentive structure is thus self-correcting in that profitable opportunities produce the desired outcome, namely convergence. Thus, as such price differences become more purely random and less predictable, Convergence Bidding becomes more risky for the bidder and the incentive to engage in it is reduced. This is illustrated below in Examples 1 and 2.

To the extent that buyers and sellers have forward financial fixed price bilateral contracts, their incentives to arbitrage prices in the different spot markets are reduced.

**Physical Hedging**

Market participants who supply energy engage in Convergence Bidding to physically hedge their production uncertainties. Convergence bidding in this case is merely another tool which they can use to help manage their supply resources and offset their risk. A common advantage of virtual bidding for physical generators is that they can schedule in the DA but receive the RT price by using a virtual demand bid. They can also better manage physical outages, as illustrated in Example 3, as well as manage their congestion costs as illustrated in Appendix 1.
Types of Convergence Bidding

Convergence bidding can take either of two forms, Explicit Virtual Bidding or Implicit Virtual Bidding. Generally when people refer to Virtual Bidding they are referring to the explicit variation. When discussing Implicit Virtual Bidding the term is nearly always qualified. The distinction between IVB and EVB is an important one. Both IVB and EVB seek to do the same thing, namely arbitrage price differences for the same product between settlement periods. Under EVB this process is formally recognized and virtual bids are flagged so that the system operator can assess grid reliability with the appropriate information regarding unit commitment and generation schedules etc. IVB is the deleterious version of VB, because participants adjust their schedules to arbitrage the price differences between markets. Consequently the system reliability assessments are more difficult because the validity of all the physical schedules is degraded by their intermingling with virtual bids. IVB has reliability effects that EVB does not.

**How Does Explicit Virtual Bidding Work?**

Explicit Virtual Bidding is the submission of bids for the financial purchase or sale of energy in the Day-ahead and Real-time energy markets without intending to physically consume or produce energy in real time. Rather the DA position will simply be closed out with an automatic countervailing trade in RT. Virtual Demand and Virtual Supply transactions are financial transactions only and have no effect on real time physical energy production or consumption. However, if unit commitment is performed separately in the day-ahead market clearing process after the initial market run, such as in PJM and as proposed under the CAISO’s MRTU design, virtual trades will pull unit commitment into the market process from the subsequent unit commitment process, and will thus affect the market in which unit commitment occurs.

EVB enables qualified Schedule Coordinators to
- buy energy (Virtual Demand bidding) in the Day-Ahead Market (DAM) at day-ahead prices, with the explicitly declared intention to sell it in the Real-Time (RT) Market at real-time prices and;
- sell energy (Virtual Supply bidding) in the DAM at day-ahead prices, with the explicitly declared intention to buy energy to cover the sale in the RT market at real-time prices.

This mechanism provides a transparent means for participants to arbitrage expected differences between Day Ahead and Real Time prices.

**How Would Explicit Virtual Bidding Work Under MRTU**

The Convergence Bidding implementations at PJM, NYISO, ISO-NE and MISO work in much the same manner, but have differences in their implementation detail. The examples shown below are generic in design but were based on documentation from the NYISO. Exactly how EVB would work under MRTU would depend on the design chosen in the course of the stakeholder process were the CAISO to decide to go ahead with the implementation.
**Example 1 - Virtual Demand Bidding**

Virtual demand bidding is in essence the purchase of energy in the DAM for sale in the RTM, so if the purpose of the transaction is to arbitrage the two markets then clearly a prerequisite for a transaction of this nature is the belief that the locational price\(^6\) will be lower in the DAM than in Real-Time. Virtual demand purchased in the DAM is not consumed, but is automatically liquidated in the Real-Time market, whereas physical demand consumes energy in real-time. In the absence of Convergence Bidding this arbitrage activity is available only to those entities with physical demand. For example, an LSE with 100MW of demand could purchase cheap energy in the DAM by over-scheduling (e.g. 120MW), and simply under consume in the Real-Time Market and thus be paid out at the RT price. A physical load that purchases more energy in the DAM than it consumes in real-time is indistinguishable in its financial effects from a virtual load. Such a transaction does affect reliability in that it degrades the accuracy of load forecasts by commingling virtual and physical transactions.

**Step 1 – Bid Submission**

Schedule Coordinator A believes that the DAM NP15 trading hub price on Monday (for Tuesday) will be lower than the actual NP15 real-time trading hub price on Tuesday. In particular SC A believes that the RT NP15 trading hub price will be $50 MWh. Consequently SC A inserts a virtual demand bid (i.e. buys energy DA). This bid consists of a number of bid quantity pairs depending on the convention adopted. For convenience we will use three bid pairs, similar to the NYISO.

<table>
<thead>
<tr>
<th>MW</th>
<th>Bid_Price</th>
<th>Cum_MW</th>
<th>Ex_RT_Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>40</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>30</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
</tbody>
</table>

\(^6\) The locational price would either be at the nodal level, at the LAP, trading hub, or sub-LAP level depending on the nature of the design chosen. The NYISO limits Virtual Bidding to NY Control Area zones for those without physical resources, whereas PJM allows Virtual Bidding by any market participant that can meet the credit requirements wherever there is an LMP or an aggregate LMP.
**Step 2 – DAM**

The DAM then runs and bid-in load clears against bid-in supply at a price of $34 in the DAM at NP15TH (NP15 Trading Hub).

Thus Schedule Coordinator A has only the highest price bid accepted, namely the first bid quantity pair of $10 @ $40. As the price cleared at $34, this purchase went through at $34. This means that physical generation has been identified, and committed if needed, to serve this virtual demand.

**Step 3 – Real-Time Market**

In real-time virtual bids are automatically cleared and no further bid submission by the Schedule Coordinator is needed. In the example on the right the RT market clears at $55, leaving a profit margin of ($55- $34) * 10MW = $210.

**Example 2 - Virtual Supply Bidding**

Virtual supply bidding is the sale of energy in the DAM with a countervailing purchase of energy in the RTM. For the arbitrage to work the market participant clearly has to believe that the locational price of energy will be higher in the DAM than in Real-Time. Virtual supply purchased in the DAM is not produced, but is automatically liquidated in the Real-Time market by an offsetting purchase of energy. In the absence of Convergence Bidding this arbitrage activity is available only to those entities with physical supply. For example, an SC with a 100MW unencumbered unit could sell 100MW of energy at a high price in the DAM and simply purchase that energy back in real-time without ever having run the generator. A virtual supplier cannot provide ancillary services.
Step 1 – Bid Submission
Schedule Coordinator A believes that the DAM NP15 trading hub price on Monday (for Tuesday) will be higher than the actual NP15 real-time trading hub price on Tuesday. In particular SC A believes that the RT NP15 trading hub price will be $50 MWh.
Consequently SC A inserts a virtual supply bid (i.e. offers to sell energy DA). Three bid pairs are shown on the right, namely 10 MW at $70, $80, and $90.

Step 2 – DAM
The DAM then runs and bid-in load clears against bid-in supply at a price of $76 in the DAM at NP15TH (NP15TradingHub).

<table>
<thead>
<tr>
<th>MW</th>
<th>Bid_Price</th>
<th>Cum_MW</th>
<th>Actual_DA_Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>70</td>
<td>10</td>
<td>76</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>20</td>
<td>76</td>
</tr>
<tr>
<td>10</td>
<td>90</td>
<td>30</td>
<td>76</td>
</tr>
</tbody>
</table>

Thus Schedule Coordinator A has only the highest price bid accepted, namely the first bid quantity pair of 10MW @ $70. As the price cleared at $76, this purchase went through at $76. This means that SC A has sold virtual generation in the DAM for $76.

Step 3 – Real-Time Market
In real-time virtual bids are automatically cleared and no further bid submission by the Schedule Coordinator is needed. In the example on the right the RT market clears at $55, leaving a profit margin of ($76- $55) * 10MW = $210.
**Physical Hedging**

Explicit Virtual Bidding is not just a price arbitrage mechanism, but is also an additional mechanism for generators to hedge their physical production and their congestion risks. There are other methods to do this but using virtuals is often the preferred method\(^7\). A further example of congestion hedging is given in Appendix 1.

**Example 3 – Protecting a generation offer**

Marketer X is offering a generation resource that is good for 100 MW under normal circumstances. However, the unit on a particular day is having potential mechanical problems that may reduce the output of the unit by 10 MW for the next day. The situation is not critical enough that a partial de-rating of the unit is required, but the marketer is not one hundred percent confident that the unit will be able to produce 100 MW.

Marketer X bids in 100MW at $50, and a 10MW virtual demand bid (PJM dec) at $50.

Both bids clear at $60, thus Marketer X has a financially binding commitment for 100MW at $60 in the DAM, and has bought 10MW at $60 (i.e. has effectively bought back the last 10MW). This virtual will then be liquidated in real time.

There are four possible scenarios.

**Unit produces 100MW in RT**

1. RTM closes higher than $60, say $70, in which case Marketer X receives 
   \[(100\text{MW}*60= $6000 \text{ from DA}) + (10\text{MW}*[70-60]=)$100 \text{ from virtual}\] = $6100 Total

2. RTM closes lower than $60, say $50, in which case Marketer X receives 
   \[(100\text{MW}*60= $6000 \text{ from DA}) + (10\text{MW}*[50-60]=)$100 \text{ from virtual}\] = $5900 Total

**Unit produces 90MW in RT**

3. RTM closes higher than $60, say $70, in which case Marketer X receives 
   \[(100\text{MW}*60= $6000 \text{ from DA}) - (10\text{MW}*[70-60]=)$100 \text{ due to RT under delivery} \] + (10\text{MW}*70-60=$100 due to the virtual) = $5400 Total

4. RTM closes lower than $60, say $50, in which case Marketer X receives 
   \[(100\text{MW}*60= $6000 \text{ from DA}) - (10\text{MW}*50=)$500 – due to under delivery \] + (10\text{MW}*50-60=-$100 due to the virtual) = $5400 Total

In this example Physical hedging allows the unit to contract in the DA for the RT price, rather than actually wait for the RTM. This exposes a portion of the output to the real-time price. This has the added reliability benefit of shifting the unit completely into the DAM. Without VB the unit owner would have to do this exercise physically by selling 90MW DA and then waiting for the RTM to bid in the last 10MW. By using VB to sell in the DA for the RT price the unit owner can schedule the entire unit in the DA, but pick up the RT price for the last 10MW.

\(^7\) Both this example and the congestion example in Appendix 1 come from PJM (Guide to Generation Offers and Schedules p.61) where Virtual Bidding is allowed at the nodal level for all participants. If bidding is only allowed at the trading hubs then the generating units cannot hedge as cleanly as under the nodal market, as it is likely that there will be unhedged differences between the nodal price and the hub price.
Implicit Virtual Bidding in California

Currently there is neither IVB nor EVB in the CAISO markets as the CAISO does not have a DA energy market, so it lacks a two settlement system. California has never had EVB, but prior to the collapse of the PX there was IVB between the DA, HA and RT markets. Two of the Enron games, Fat Boy (basically over-scheduling demand) and Slim Man (under-scheduling demand) were IVB strategies. With the demise of the PX and the DAM this arbitrage opportunity disappeared. This previous experience indicates that unless the markets are completely broken, day-ahead and real-time prices will converge even with a less than perfect market design. During 1999 when the California markets were fairly competitive despite separation of the forward and real time energy markets (between PX and CAISO) and differences of price caps ($2,500/MWh in PX and $250/MWh, $500/MWh, and $750/MWh at different time periods in CAISO’s real-time market) the annual average price in the PX and the CAISO were within a few cents of each other as shown in the 24 hour price profile below (Figure 3). This occurred due to the price arbitrage (Implicit Virtual Bidding) between these settlement periods, as well as physical arbitrage. Parties could take positions in the PX, consolidate those positions in real-time and arbitrage prices between the markets.

![Figure 3 - Convergence of PX and CAISO Energy Prices in 1999](image)

**How Does Implicit Virtual Bidding Work?**

In contrast to EVB where virtual transactions are flagged as such and clearly differentiated from physical transactions, IVB works simply by piggybacking the virtual transactions onto existing physical transactions. Explicit Virtual Bidding requires a design, software changes, and cost allocation rules. Implicit Virtual Bidding uses the existing physical functionality to arbitrage prices. As the physical functionality is not designed for Virtual Bidding it is not possible to hedge production using IVB in the same manner as one can under EVB. IVB is simply...
used to arbitrage prices, and the physical hedging risk management aspects of EVB are absent. In addition IVB affects reliability as it compromises the integrity of load and generation forecasts. If grid operators are uncertain how much generation is physical and how much virtual, they might well over-procure to be safe, and this pushes up costs. IVB is a compromised variant of EVB. It has less functionality, it degrades reliability by commingling virtual bids with physical bids, and the cost allocation issues are not explicitly thought through, which could lead to unintended consequences.

**Can IVB Be Suppressed Under MRTU?**

Market mechanisms by themselves cannot deter IVB. Suppressing IVB may prove to be difficult and may require administrative rules, or penalties and sanctions through the provisions of Market Monitoring and Information Protocols (MMIP). The exaggeration of supply or demand schedules could easily be judged to be a “factual inaccuracy” and seen as a contravention of existing market rules by the Department of Market Monitoring. If this happened then there would be a reason to try and suppress IVB, not only because it was a contravention of the Market Monitoring and Information Protocol, but also because of the CAISO’s legitimate reliability concerns. Suppression however, is extremely difficult as there are always grid events that necessitate schedule changes. Implicit Virtual Bidding may be present in one form or another as long as there are predictable price differences between the DA and RT markets. IVB may well be inevitable under the MRTU design. The reason why the suppression of IVB is so difficult relates to the nature of the electricity system. The CAISO currently has no visibility into the resources backing intertie schedules, and this is not likely to change. Thus it is impossible to verify that intertie schedules are physically backed. In addition, market participants change their bids and schedules right up to real-time due to changing grid and plant conditions. The exercise of trying to make sure each schedule change is due to a physical reason and not an implicit virtual bid requires second guessing judgment decisions made under time constraints after the fact. This is likely to be highly unpopular amongst market participants. As a result only the most egregious cases will be investigated, which means that implicit Virtual Bidding must be tolerated. This is the type of monitoring and enforcement that is the most difficult. It cannot be done for imports, only for internal generators, which means that there is an element of discrimination between internal and external entities, and it consists of the ex-post auditing of decisions made with imperfect knowledge.

**Behavioral Changes in Market Participant Behavior**

If virtual bidding is suppressed (i.e., neither explicit nor implicit virtual bidding is tolerated) then short of heavy-handed system-wide mitigation and penalties and sanctions, it is likely that market participants will alter their bidding behavior even in an otherwise competitive environment. This is illustrated in Figure 4 below. If demand collectively decides to under-schedule in the DA market in an attempt to reduce the price they receive from the expected real-time price \( P_{RT} \) to \( P_{US} \) to lower the costs of procurement, then certain suppliers, in the absence of EVB or IVB, will bid the expected Real-Time price into the DAM (with no change in
quantity as such change is assumed here to be prevented by disallowing virtual bidding). This has the effect of shifting the DA supply curve upward so that the DAM once again clears at the expected $P_{RT}$. In this manner more demand will be met in the RT market, which will no longer be simply a balancing market.

**Implicit Virtual Bidding Using Imports and Exports Under MRTU**

An SC that wanted to bid virtually in the CAISO markets prior to the implementation of explicit Virtual Bidding would be able to do so by using import and export schedules. If an SC believed that the DA price would be higher than the RT price it could Implicitly Virtual Bid (IVB) into the DAM (virtual supply or what PJM terms inc bidding). The SC in question would bid into the DAM at an intertie point without physically arranging supply in the neighboring control area. As the CAISO has poor visibility into the neighboring control areas it would be unaware that this import was not physically scheduled. If the bid was taken in the DAM it would be a binding financial commitment and the SC would be paid out the DA price. In the real-time processes (HASP) the SC would cancel the import and would be charged the HASP price (which is equal to the simple average of the four 15 minute LMPs for that hour as determined by the HASP run at T-67.5). The arbitrage would thus be between the DAM and the HASP prices. In this manner the SC would profit by the difference between these two prices. A similar strategy would work for exports. An SC could IVB into the DAM with an export bid, which is akin to virtual demand (PJM decs). In the HASP process the SC
could cancel the export, and it would receive the HASP price. This is a strategy to buy generation at a low price in the DAM and sell it back in HASP at a higher price. Both of these strategies are implicit strategies because there is no mechanism to differentiate the virtual import from a real import, so the import is represented as being physical.

**Implicit Virtual Bidding Using Load Under MRTU**

Implicit Virtual Bidding would not be limited to Schedule Coordinators with import and export schedules, but would also be possible for load-serving entities (LSEs). If an LSE believed that generation in the DAM was particularly cheap it could over-schedule in the DAM (Implicit Virtual Demand) and pay the DAM price for the generation, and then under-consume in real-time, where it would be paid out at the real-time price. In this manner it would arbitrage the DAM price and the real-time price\(^8\). The ability of the LSEs to undertake such actions may well be constrained by either its regulator, the institutional characteristics of the CAISO market, such as the Resource Adequacy rules, as well as explicitly, e.g. through the CAISO 95% scheduling requirement should it still exist under the MRTU framework.

**How Does an ISO Mitigate the Effects of Implicit Virtual Bidding?**

When faced with IVB there seem to be only two ways to mitigate its effects, namely suppression, as detailed above via Market Monitoring, or the implementation of EVB. Once there is an approved method of arbitraging between markets the incentive to engage in IVB is greatly reduced. The NYISO was one of the first to introduce Virtual Bidding and this has been their strategy. Participants are given a legal avenue to physically hedge and arbitrage prices and the Market Monitoring Unit monitors load and generation schedules for IVB\(^9\).

**Concluding Remarks**

Short of heavy-handed system-wide mitigation and penalties and sanctions, virtual bidding is inevitable in multi settlement energy spot markets. Implicit Virtual Bidding (IVB) is detrimental to system reliability. To the extent Explicit Virtual Bidding (Convergence Bidding) can reduce the incentives for Implicit Virtual Bidding (IVB) it can help improve system reliability.

---

\(^8\) The under-scheduling of demand in the DAM by LSEs cannot be classified as IVB as the LSE physically possesses the demand, so there is nothing virtual about it at all, however the LSEs can shift their demand between markets and cost minimize by exposing the greater portion of demand to the market with the lowest price. To the extent that an LSE is not a price-taker for its entire expected real-time demand in the DAM it is explicitly forming an opinion about the pricing between the two markets and taking a financial position.

\(^9\) At the NYISO there is still an incentive for participants to engage in IVB due to the credit and collateral requirements required for EVB.
Appendix 1: Congestion Hedging

From PJM

A generator (A) is offering to sell 50 MW at $15/MWh. An LSE (B) is looking to buy 50 at $20/MWh. A marketer picks up both deals and enters a bilateral transaction from point A to point B. The marketer is buying 50 MW from A at $15/MWh and selling to B at $20/MWh and therefore, does not wish to pay more than $5/MWh in congestion charges. How does he/she cover the position?

Answer: The marketer enters a 50 MW Dec bid at point B where the generator is located for $15/MWh so that this resembles a spot purchase. A 50 MW Inc offer is placed at point B for $20/MWh so that it resembles a spot sale. If LMPs from the Day-Ahead Market are $14/MWh at point A and $21/MWh at point B, the marketer is selling to the spot market at A and buying at B. As a result, the marketer knows his/her position by 16:00 on the day prior to the operating day and has time to make appropriate arrangements to respond to his/her resulting position. A summary of the charges is listed below:

<table>
<thead>
<tr>
<th>Charges &amp; Credits</th>
<th>Calculation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Congestion Charge</td>
<td>$15 * (21-14)</td>
<td>$350 charge</td>
</tr>
<tr>
<td>Dec Bid (Charge)</td>
<td>50 MW * $14</td>
<td>$700 charge</td>
</tr>
<tr>
<td>Inc Offer (Credit)</td>
<td>50 MW * $21</td>
<td>-$1,050 credit</td>
</tr>
<tr>
<td>Net Position</td>
<td></td>
<td>$0</td>
</tr>
</tbody>
</table>

---

10 From PJM (Guide to Generation Offers and Schedules p.61)