Virtual Transactions in the PJM Energy Markets

PJM Interconnection
October 12, 2015
This page is intentionally left blank.
# Table of Contents

- Executive Summary ................................................................................................................................. 1
- Background .................................................................................................................................................. 3
- Synopsis of the Virtual Transactions ........................................................................................................... 4
  - What are Virtual Transactions? ............................................................................................................... 4
  - What They Do ......................................................................................................................................... 5
  - How They Function ................................................................................................................................. 5
  - Efficiencies of Virtual Trading ............................................................................................................... 6
- Unique Attributes of the PJM Energy Markets .............................................................................................. 7
- Market Manipulation Concerns .................................................................................................................... 9
- Recommended Improvements to Virtual Trading ....................................................................................... 10

## In-Depth Review of Virtual Transactions ................................................................................................ 12
- How Increment Offers Work ....................................................................................................................... 12
- How Decrement Bids Work ....................................................................................................................... 13
- How Up-To-Congestion Transactions Work ............................................................................................. 14
- Brief Background on the Evolution of UTCs .............................................................................................. 16
- Price Convergence and Commitment Convergence .................................................................................... 17

## Differences between INCs and DECs, and UTCs ...................................................................................... 18
- Transaction Characteristics ......................................................................................................................... 18
- Factors Impacting Risk ............................................................................................................................... 21

## Virtual Bidding in a Two-Settlement Market .............................................................................................. 22
- Spot Market Price Arbitrage ....................................................................................................................... 22
- Real-Time Spot Market Only ...................................................................................................................... 23
- Two-Settlement Market: No Virtual Bidding ............................................................................................... 24
Executive Summary

PJM Interconnection prepared this paper, which explores the role of financial trading in PJM markets, at the request of stakeholders at the April 21, 2015, Liaison Committee Meeting. Virtual transactions have been an integral part of the PJM energy markets since implementation of the Day-Ahead Market on June 1, 2000. Financial trading also is incorporated in all other organized electricity markets in the United States and elsewhere.

This paper examines:

- the purpose of virtual trading in the PJM energy markets,
- the mechanics by which virtual transactions are submitted and cleared,
- potential problems that can result from virtual transactions, and
- examples that illustrate how market participants utilize virtual transactions.

The paper concludes with PJM-recommended market design and rule changes for stakeholders to consider to improve the effectiveness of virtual trading in the PJM energy markets.

Virtual transactions are sets of bids and offers submitted in the Day-Ahead Market that take financial positions in that market without the intent of delivering or consuming physical power in the Real-Time Market. In PJM, virtual transactions include increment offers, decrement bids and up-to-congestion transactions (UTCs). Virtual transactions can be a valuable component of a two-settlement market such as the PJM market. They have the ability to mitigate both supply-side and demand-side market power by allowing market participants without physical assets to compete with asset owners and load-serving entities in the market.

Overall, virtual trading benefits the efficient operation of the PJM energy markets. It can assist in attaining efficient market outcomes and improve commitment and price convergence between the Day-Ahead and Real-Time Markets. The participation of financial traders alongside physical asset owners and load-serving entities provides enhanced competition and liquidity to support hedging. Virtual trading generally assists in achieving efficient market outcomes, i.e. Day-Ahead Market outcomes that commit those generation resources that will in fact be needed to serve load in real time.

However, this paper also points out that virtual transactions can have negative impacts on the market and explains, through examples, why certain types of transaction activities, while profitable for traders, do not bring efficiency and may even degrade market operation. When used in certain ways, these transactions profit from the market without adding commensurate benefit, skew transmission flows and congestion patterns in a manner inconsistent with transmission system topology and load levels, and, in large volumes, can significantly degrade the performance of the Day-Ahead Market.

This paper examines the purpose and potential for financial trading to provide efficiencies in PJM markets; however, it is not presented as a complete empirical assessment of financial trading. PJM also acknowledges continuing
examination of these questions across organized wholesale electricity markets by the Federal Energy Regulatory Commission’s Office of Enforcement, the PJM Independent Market Monitor, and analysis offered by industry participants.

Based on the work summarized in this paper, PJM has concluded that rule reforms are needed to address financial trading in certain circumstances and under certain conditions. These reforms should be pursued immediately. The paper presents preliminary rule changes to ensure that financial trading does not impose costs without returning reasonably expected benefits to the market.

PJM’s proposals would align eligible trading points for increment offers and decrement bids with the locations where physical generation, load and interchange transactions are settled in addition to trading hubs, and, change the biddable locations for UTCs to active generation buses as sources, trading hubs, load zones and interfaces. Additionally, PJM proposes leveling the allocation of uplift across virtual transactions by allocating uplift to a UTC transaction in a manner that is consistent with increment offers and decrement bids. These recommendations are intended to eliminate a significant amount of the negative aspects of virtual trading while preserving their reasonably expected benefits.

Currently, PJM has insufficient information to warrant further changes beyond those called for in this paper, which are common-sense reforms. Further analysis to support a shared consensus for change is warranted before departing from or qualifying long-standing principles and academic and theoretical assumptions which support financial transactions as valuable hedging, convergence and liquidity tools.

As the administrator of a large wholesale energy market, PJM’s first mission is to operate markets that are efficient, fair and lead to just and reasonable price outcomes. The design changes affecting virtual trading proposed in this paper reflect PJM’s assessment of opportunities to improve a well-functioning Day-Ahead Market.

PJM is bound to explain the need for such design changes and collaborate with stakeholders in making these changes. Accordingly, this paper is intended to promote that dialogue and educate stakeholders on why PJM recommends the design changes proposed here. The goal of this discussion is to retain the positive contribution that virtual transactions bring to the market while removing the bulk of the issues they create when used inefficiently under the existing rules.
Background

At the request of several market participants at the April 21, 2015, Liaison Committee Meeting, PJM undertook this report to explore the role of financial trading in PJM markets. Academic and industry analysis, including studies applying actual data either test or prove the validity of long-standing theories and assumptions underlying the basis for financial trading in PJM markets.

This paper adds to the body of work. It is not designed as a comprehensive academic dissertation on financial trading in organized electricity markets. Rather, it is intended to provide a practical platform to examine and address changes to what PJM regards as evident problems.

In order to provide the context necessary to meet its primary purpose, this paper explores:

- the intended use of the transaction type — including the conditions under which each transaction is profitable;
- actual use, including how the transaction type is used today; and
- how the transaction type is actually used in PJM, versus its original intent.

In the section titled Observed Bidding Strategies, PJM identifies several virtual trading strategies it has observed in which virtual trading cannot reasonably be expected to offer efficiencies. These behaviors, in addition to the arguments laid out within this paper, have led PJM to conclude that changes should be made to the rules governing virtual trading.
Synopsis of the Virtual Transactions

**What are Virtual Transactions?**

Virtual transactions is the name given to purely financial transactions in the PJM energy markets. Virtual transactions closely resemble financial transactions in other electricity commodity markets and share basic common elements with financially-settled, forward electricity contracts traded bilaterally or on electronic platforms and exchanges (such as the Intercontinental Exchange (ICE), New York Mercantile Exchange (NYMEX) and Nodal Exchange). Virtual trading in organized wholesale energy markets, such as the PJM markets, has been regarded as a valuable market feature because it:

- affords participants with physical assets or load-serving obligations or participants with positions in related markets an opportunity to hedge those positions,
- adds liquidity, enabling market participants to more easily and efficiently take on or close out forward positions,
- allows for both speculative and arbitrage trading to enhance market efficiency through price convergence and unit commitment convergence between the day-ahead and real-time markets; and
- serves to mitigate structural market power through the addition of competitive entities whose participation prevents persistent market distortions.

Virtual transactions in PJM are bids and offers submitted to take financial positions in the Day-Ahead Market without the intent of delivering or consuming physical power in the Real-Time Market.

Virtual transactions include increment offers (INCs), decrement bids (DECs) and up-to-congestion transactions (UTCs). The financial positions taken in the Day-Ahead Market by these types of transactions are settled as imbalances in the Real-Time Market.

**Increment Offers**

INCs are offers submitted in the Day-Ahead Market to sell an amount of energy at a specific location (node) if the day-ahead clearing price for that node equals or exceeds the offer price. INCs can be thought of as virtual transactions that emulate generation offers in the Day-Ahead Market.

INCs are currently allocated real-time uplift charges and are generally profitable when the day-ahead clearing price exceeds the real-time clearing price.

**Decrement Bids**

DEC bids are almost the exact opposite of INC offers. DECs are submitted into the Day-Ahead Market as a bid to purchase energy at or below a specified price. DECs can be thought of as virtual transactions that emulate load buy bids in the Day-Ahead Market.
DECs are currently allocated day-ahead and real-time uplift charges and are generally profitable when the day-ahead clearing price is lower than the real-time clearing price.

**Up-to-Congestion Transactions**

A UTC is a bid in the Day-Ahead Market to purchase congestion and losses between two points. UTC bids can be based on the prevailing flow direction where the UTC is buying a position on the Day-Ahead Market congestion, or they can be in the counterflow direction where they are paid to take a position. The UTC bid consists of a specified source and sink location and a “bid spread” that identifies how much the market participant is willing to pay for a congestion and loss position between the source and the sink.

UTCs are not allocated uplift. For prevailing flow UTCs, profitability occurs when the real-time congestion is in excess of the congestion purchased day-ahead. For counterflow UTCs the opposite is true.

**What They Do**

Virtual transactions are a valuable component of a two-settlement market such as the PJM market. They have the ability to mitigate both supply-side and demand-side market power by allowing market participants without physical assets to compete with asset owners and load-serving entities in the market.

Because virtual transactions compete with physical resources in the Day-Ahead Market, they can either displace, or cause additional scheduling of, physical resources and load, including price-sensitive demand bids. These changes in the Day-Ahead Market outcome due to virtual transactions may or may not match what is needed in the Real-Time Market. Regardless, the Day-Ahead Market results, including resource commitments, dispatch and pricing, all are impacted by virtual transactions every day.

**How They Function**

A market participant submitting a virtual transaction that clears takes a financial position in the Day-Ahead Market by agreeing to buy or sell energy at a specific location or locations that it then liquidates in the Real-Time Market. This occurs because the energy that is bought or sold in the Day-Ahead Market is not provided or consumed in real-time and creates an imbalance between the markets.

The PJM two-settlement system then settles all quantity (megawatts of power) deviations from the Day-Ahead Market at the real-time spot price. Thus, virtual transactions can speculate price differences between the two markets and be profitable.

As stated previously, because virtual transactions compete with physical resources in the Day-Ahead Market, they can displace, or cause potentially unneeded additional scheduling of, physical resources in the Day-Ahead Market that are not required in real time. Virtual transactions may also impact the dispatch of physical supply resources and clearing price-sensitive demand bids in the Day-Ahead Market, thus altering the outcome of the Day-Ahead Market, which is used to set an operating plan for the upcoming operating day.
Virtual transactions can benefit the market in several different ways that are discussed throughout this paper. However, by competing with physical resources in the Day-Ahead Market, virtual transactions can affect how physical resources are scheduled and dispatched, impacting Locational Marginal Price (LMP) and uplift costs.

**Efficiencies of Virtual Trading**

Wholesale electricity is a volatile commodity with prices that can move dramatically in hours. This volatility supports a market design that allows the hedging of inter-day price risk. PJM’s two-settlement energy markets (day-ahead and real-time) afford hedging only 24 hours in advance of the spot market. Parties looking for longer-dated hedges to protect against PJM price volatility must turn to other markets (such as Nodal Exchange, ICE or NYMEX) or reach arrangements bilaterally (an asset-tolling agreement or a structured product with a financial risk management services provider such as a bank).

Even with the short tenor of the hedge offered by the Day-Ahead Market, virtual trading has proven itself as a risk management tool for generation owners nominating and scheduling day-ahead and other physical participants, such as Load Serving Entities (LSEs), seeking to lock in a fixed price. It is also a useful risk management tool for both physical and financial participants that have positions in other energy markets, such as ICE. The participation of virtual traders in the PJM Day-Ahead Market provides added liquidity to facilitating these hedging practices. (See Virtual Transactions as Hedging Instruments).

The terms *speculative* and *arbitrage* describe related concepts and are frequently used interchangeably. Still, it is helpful to distinguish between these two forms of convergence trading.

*Speculative* trading identifies a supply-and-demand dislocation in the Day-Ahead Market, relative to what the trader expects will actually occur in real time. A speculator takes on risk; it will put on a long or short position going into real time because it has a view of expected Real-Time Market outcomes that differs from others in the Day-Ahead Market.

*Arbitrage* reflects trading between two or more price-related instruments or nodes designed to take advantage of mispricing of one, relative to the other. Apparent arbitrage opportunities often arise at the point where energy can be imported into a control area and immediately exported at different prices. Unlike speculation, arbitrage is typically regarded as a risk-free transaction.

In efficient financial and commodity markets, both arbitrage and speculative trading converge prices.

For arbitrage, this convergence can occur in seconds or even milliseconds and the price inefficiency is said to be “arbed out.” In the case of speculative trading, convergence can occur less rapidly, but consistently profitable speculative opportunities do not persist in efficient and transparent markets. In large part, this is because the opportunity attracts other speculators whose transactions over time provide added information to correct misperceptions of expected price. In other words, speculative trading, like arbitrage, offers the promise of market efficiency by converging Day-Ahead and Real-Time Market prices. A more detailed illustration of the price
convergence benefits of virtual trading is provided further in this paper. (See Virtual Bidding in a Two-Settlement Market).

The presence of virtual trading in PJM’s energy markets also adds competition and may help to discipline structural market power resulting, in part, from a concentrated ownership of generation. (See below, Use of INCs to Mitigate Supply-Side Market Power). The ability for any market participant to become a supplier in the Day-Ahead Market by submitting an INC offer inherently increases the number of suppliers and correspondingly reduces any single supplier’s market share.

The theoretical hedging, price convergence and competitive benefits of virtual trading have been demonstrated to a degree through some studies analyzing actual empirical data and efficiency metrics, such as price spreads.¹ This paper builds on these efforts and largely assumes those advantages exist based on their theoretical merits. However, it also identifies situations where actual data and particular market design features illustrate practical realities that plainly call into question the validity of the theoretical premise in such situations.

**Unique Attributes of the PJM Energy Markets**

Although a virtual transaction is similar to a financial trade as may be found in other energy markets, important features distinguish the PJM energy markets from other commodities or markets, as well as other financial electricity markets. These distinctions are important to consider when examining whether the efficiency values that result from speculation and arbitrage in these other markets can be fully realized in PJM’s energy markets.

Virtual transactions participate in single clearing price, auction-based constructs administered by PJM to settle its Day-Ahead and Real-Time Markets.

This stands in contrast to other financial electricity markets where individual buyers and sellers are matched at the price where their respective bids and offers meet. In PJM’s markets, the marginal offer sets a single locational clearing price that represents the price paid to all market sellers, including virtual traders.

**PJM’s financially settled Day-Ahead Market is closely linked with its physically settled Real-Time Market.**

The two PJM energy markets are yoked so closely together that the design is often described as a single “two-settlement” market. Clearing the PJM Day-Ahead Market effectively sets a production schedule for more than 1,000 generation and demand response resources in PJM as well as establishing a day-ahead unit commitment for PJM as the system operator. Participants in the Day-Ahead Market include physical market participants – owners of generating stations, many of which are required by rule to submit offers into the Day-Ahead Market, and load-serving entities buying for resale to end-use consumers. As they go about their typical physical operations in real time, which


is to say generate and inject electricity onto the grid or purchase and consume electricity respectively, the commitments they assumed day ahead are met through physical performance in real time.

Alongside physical market participants are virtual traders. Unlike physical market participants, they own no actual generation or serve no actual load and, thus, are unable to bring physical resources in real time (in the form of supply or consumption) to close out positions they established day ahead. Cleared INCs and DECs in the Day-Ahead Market represent short and long positions for electricity held by these respective financial participants as they go into the Real-Time Market. Performance in the Real-Time Market is physical. In other words, any market participant (including a virtual trader) that does not meet its day-ahead commitments – in full or in part – through physical supply or consumption in real time, will have that imbalance satisfied or met physically by imputed purchases and sales in the Real-Time Market.

**In large part due to its physical unit commitment and scheduling mission, the clearing of the Day-Ahead Market and operation of the Real-Time Market are complex.**

Price formation in PJM’s energy markets is not as straightforward as meeting bids with offers. PJM employs sophisticated optimization software, load forecasting and network models with embedded algorithms that solve for bids and offers while respecting all transmission security constraints, reserve requirements, interchange transactions and generator operating constraints. Assumptions included in, and the operation of, models and rules that produce recommended solutions in light of expected system conditions can contribute significantly to price formation. Since these features can differ across pricing points and between Day-Ahead and Real-Time Market operations, they can create differing prices that cannot be converged by arbitrage trading.

A recent, comprehensive description of the numerous complex factors (beyond bids and offers) that contribute to prices differing in day-ahead and real-time energy markets can be found in *Financial Arbitrage and Efficient Dispatch in Wholesale Electricity Markets*, John E. Parsons, Cathleen Colbert, Jeremy Larrieu, Taylor Martin and Erin Mastrangelo, MIT Center for Energy and Environmental Research, February 2015 (MIT Paper). That paper observes that:

> Because the real problem is so much more complex than intersecting a pair of simple supply and demand curves, and because the day-ahead and real-time markets employ algorithms with different approximations, decompositions and judgments, a DA/RT spread can arise even when there is no simple deficiency of supply or demand bid into the Day-Ahead Market. Since the problem is not caused by a simple deficiency of supply and demand, virtual bidding may not help to converge the prices.

/MIT Paper at page 16

Trading in PJM markets is distinguished from other financial and commodity marketplaces by a number of factors. These include the single clearing price in PJM markets; the auction-based structure; the primary design objective to set a production schedule or unit commitment; a scheduling of physical resources, as well as the complex rules, models, algorithms and judgments that can vary between Day-Ahead and Real-Time Markets.
In considering when and to what degree virtual trading offers benefits to PJM markets, it is important to account for these distinctions before definitively concluding that generally accepted principles of market efficiency as demonstrated by trading in other financial and commodity marketplaces hold equally well to PJM’s energy markets.

**Market Manipulation Concerns**

In recent years, organized wholesale electricity markets, including those administered by PJM, have seen an increase in enforcement activities directed at virtual traders by the Federal Energy Regulatory Commission. Physical participants have also attracted enforcement attention and legal reform pursuant to the Energy Policy Act of 2005, and a shifting regulatory focus towards enforcement generally goes a long way to explain the rise in the number of investigations and cases brought by the FERC’s Office of Enforcement.

There can be little doubt that incidents of alleged market manipulation stemming from potentially exploitative trading practices have been sufficiently numerous and serious enough to warrant questions as to the cost and benefit of virtual transactions in organized wholesale electricity markets.

While this analysis does not express opinions or raise arguments about the lawfulness, or even the policy questions raised by the trading conduct giving rise to these investigations and cases, there is a common theme in these cases. Traders that claim to have merely followed the rules of the market operator, or at least not offended any explicit prohibition in the rules, are nonetheless subject to enforcement for manipulating the market.

The courts are likely to determine whether a case for manipulation brought by the FERC under the Federal Power Act can lie under these circumstances. If the Commission’s theories prevail in court, the enforcement risks that traders confront going forward will at least curtail, and possibly stifle outright, financial trading in organized electricity markets.

If, however, traders prevail on grounds that it is the responsibility of the FERC and market administrators like PJM to close loopholes in market design or operations, then there will likely be a call for dramatic rule changes, perhaps going so far as to eliminate outright virtual trading in RTO markets.

Those unsatisfied with either litigation outcome would be well-advised to explore rules that:

- preserve virtual trading in circumstances where there is a reasonable expectation its theoretical efficiency values can be realized,

- while eliminating clear opportunities for inefficient trading where there is a reasonable expectation that such trading promises little or no value to the market.
**Recommended Improvements to Virtual Trading**

Notwithstanding the compelling theoretical efficiency value associated with financial trading, certain types of transactions can extract money from the market without adding commensurate benefit, skew transmissions flows and congestion patterns such that they are inconsistent with system topology and load levels and, in large volumes, can significantly degrade the performance of the Day-Ahead Market. Refining the market rules that govern virtual transactions can eliminate a significant amount of the negative aspects of virtual trading while preserving their reasonably expected benefits. Specifically, the rules that determine the available trading locations for INCs, DECs, and UTCs, and the allocation of uplift to these transactions can be improved.

With that in mind, PJM proposes the following changes to the market rules for virtual transactions.

**Align the eligible trading points for INCs and DECs with nodes where either generation, load or interchange transactions are settled, or at trading hubs. This would include generator buses where active generators exist, load buses where load is settled nodally, load zones, interfaces and trading hubs.**

The intent of this change is to better align the use of INCs and DECs with the physical nature of the Real-Time Market while preserving the ability for such instruments to be used at trading hubs to facilitate longer-term hedges. Under today’s rules, INCs and DECs can be placed at nodes where there is no other settlement such as individual load busses. While these types of transactions may be profitable based on differences between the Day-Ahead and Real-Time Markets, they can result in transmission flows and load distributions that are inconsistent with physical reality of the system and potentially result in resource commitments in the Day-Ahead Market that do not align with the system needs in real time. They may aid in price convergence at the specific node, but it is at a location where there is no other settlement and therefore no real change in the incentives to other market participants.

PJM believes that it is extremely important that the Day-Ahead Market produce a resource commitment that closely mimics the set of resources required to operate the system in real time. Allowing INCs and DECs at load busses that can change the load distribution of a zone in a manner inconsistent with PJM’s expectation of the real-time load distribution only makes achieving that goal more difficult and more costly. Additionally, INCs and DECs at individual load buses can create congestion patterns inconsistent with the load levels in the Day-Ahead Market. This can cause the Day-Ahead Market to commit resources to control congestion in a zone when what really is needed are additional resources to cover underbid load or the decommitment of resources due to overbid load.

Additionally, this change will reduce unique transaction volume which will improve Day-Ahead Market solution times. This is explained further within this document. (See below, [Virtual Transaction Volumes and Day-Ahead Market Solution Time](#)).

**Alter the biddable locations for UTCs to generation buses as sources only, trading hubs, load zones and interfaces.**

For the same reasons as stated for INCs and DECs, in addition to others contained within this paper, PJM believes that the available bidding nodes for UTCs should be changed. In addition to hubs, zones and interfaces, PJM also proposes to allow generator buses as biddable UTC points but only as the source point of the transaction. Permitting
UTCs at interfaces, hubs and zones is intended to continue to permit UTC trading but remove their ability to be used in ways that do not lead to market efficiency. Because these activities are typically enacted nodally, removing individual nodes will remove much of this ability. Notwithstanding the foregoing, PJM does propose to permit UTCs to be submitted with active generation buses as the source point only. This change is proposed to allow market participants trying to hedge generation or load against real-time congestion a method to do that.

Given the volume of UTC transactions, reducing the bidding points would significantly reduce the number of unique UTC transactions and significantly improve Day-Ahead Market performance.

*Allocate uplift to UTCs consistent with INC and DEC transactions. Currently, UTCs do not face a similar uplift charge as INCs and DECs, which has led to a significantly greater volume of UTCs compared to INCs and DECs.*

The incentives created by the inconsistent allocation of uplift between UTCs, and INCs and DECs can be seen through the specific transaction volumes PJM has seen over the last few years. Currently, UTCs account for approximately 80 percent of all virtual transaction activity and collect more than 81 percent of the total virtual transaction revenues. UTCs have a much smaller risk profile than INCs and DECs due to the lack of allocation of uplift and no exposure to energy price risk between day ahead and real time. Allocating UTCs uplift consistent with INCs and DECs would better align the risk profiles of the transactions as they pertain to fees and help level the uneven playing field that exists today.

PJM believes the allocation of uplift to UTCs is a critical market design change that must be made to remove the competitive advantage afforded today to UTCs.

PJM proposes these suggested market rule changes to stimulate discussion within the stakeholder process. The goal of this discussion is to retain all of the positive aspects that virtual transactions bring to the market while removing the bulk of the issues that they can create when used inefficiently under the existing rules.
In general, the use of virtual transactions falls into two categories: price convergence and risk mitigation. Both uses play a vital role in the two-settlement market. However, the transaction type and use have different implications on the scheduling and dispatch of the power system, risk profiles and revenue streams. The multiple facets of virtual transactions must be understood in order to understand how market rules can be further enhanced to maximize the usefulness of virtual transactions.

**How Increment Offers Work**

INCs are offers submitted in the Day-Ahead Market to sell a stated amount of energy at a specified location. From a Day-Ahead Market clearing perspective, these offers can be thought of as equivalent to a generation offer without temporal restrictions (such as startup times and minimum run times). An INC will clear if the day-ahead clearing price for that node exceeds the offer price. For example, a 10 MWh INC submitted at node A with an offer price of $30/MWh will clear if the Locational Marginal Price (LMP) at that node is equal to or higher than $30/MWh. In this example, the market seller is paid the settled LMP in the Day-Ahead Market, assumed to be $40/MWh, multiplied by the cleared MW amount of the INC and has taken a short position going into the Real-Time Market. The left half of Table 1 shows the day-ahead settlement of the 10 MWh INC.

As is the case with all Day-Ahead Market transactions, a cleared INC does not represent any physical flow or injection of electricity – it establishes a financial position that must be closed out the next day in the Real Time Energy Market. The market seller closes that position in real time (or closes its short position) by purchasing physical supply at the prevailing spot price at the same location the INC was cleared in the Day-Ahead Market. By definition, this electricity was not previously scheduled in the Day-Ahead Market and the purchase therefore creates a MW deviation between the Day-Ahead and Real-Time Markets. The right half of Table 1 shows the closure of the INC position in real time. In this example, the Market Seller purchases real-time energy at $20/MWh which is less than the $40/MWh they were paid in the Day-Ahead Market to sell the power. As a result, the INC makes a profit of $20/MWh or $200 for the full 10 MWh that cleared.

<table>
<thead>
<tr>
<th>INC (MW)</th>
<th>Day-Ahead LMP at INC Location ($/MWh)</th>
<th>Day-Ahead Payment to Market Seller for INC</th>
<th>Real-Time LMP at INC Location ($/MWh)</th>
<th>Cost to Purchase Out of INC Position in Real Time</th>
<th>INC Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$40</td>
<td>$400</td>
<td>$20</td>
<td>$200</td>
<td>$200</td>
</tr>
</tbody>
</table>

As is also the case with all activity in the Day-Ahead Market, PJM analyzes and clears the market based on the feasibility of the cleared bids and offers given a transmission model that is intended to be as close as possible to the transmission model that will actually exist in real time. Therefore, while activity in the Day-Ahead Market is not physical in and of itself, PJM endeavors to ensure that the activity that clears in the Day-Ahead Market is physically feasible given the limitations on the transmission system expected to exist during the operating day.

---

2 As is also the case with all activity in the Day-Ahead Market, PJM analyzes and clears the market based on the feasibility of the cleared bids and offers given a transmission model that is intended to be as close as possible to the transmission model that will actually exist in real time. Therefore, while activity in the Day-Ahead Market is not physical in and of itself, PJM endeavors to ensure that the activity that clears in the Day-Ahead Market is physically feasible given the limitations on the transmission system expected to exist during the operating day.
Because a cleared INC represents a commitment assumed in the Day-Ahead Market that must be met with physical supply in real time, it can create deviations between the resource plan cleared in the Day-Ahead Market and what is actually needed for real-time operations the next operating day. In the case of an INC, it can displace economic resources that could have been scheduled in the Day-Ahead Market. These deviations from the optimal resource commitment can result in uplift payments to resources scheduled outside of the Day-Ahead Market in real time.

Under PJM’s current rules, cleared INC offers pay a share of these uplift charges, as do cleared DEC bids, along with generator, load and transaction deviations. Therefore, absent administrative fees assessed to every bid type, an INC bid is profitable when the following equation is true:

**Equation 1.**

\[
\text{Payoff} = \left( \text{Day-Ahead LMP ($/MWh)} - \text{Real-Time LMP ($/MWh)} - \text{Real-Time Uplift Charge ($/MWh)} \right) \times \text{Cleared MWh}
\]

INCs were originally implemented in June 1, 2000, coincident with the implementation of the Day-Ahead Market and have remained unchanged since.

**How Decrement Bids Work**

DEC bids are almost the exact opposite of INC offers. DECs are submitted into the Day-Ahead Market as a bid to purchase a stated amount of energy at a specified price at a specific location. From a Day-Ahead Market clearing perspective, cleared DEC bids can be thought of as additional demand or load. A DEC will clear the Day-Ahead Market if the day-ahead price at that location settles at or below the price specified by the DEC.

For example, if a DEC is submitted into the Day-Ahead Market for 10 MWh at node A at a price of $60/MWh, the market buyer is bidding to purchase 10 MWh of energy at node A if the LMP at that location settles at or less than $60/MWh. The market buyer in this example pays the settled LMP in the Day-Ahead Market, assumed to be $50/MWh, and has taken a long position going into the real time market. The left half of Table 2 illustrates this.

<table>
<thead>
<tr>
<th>DEC (MW)</th>
<th>Day-Ahead LMP at DEC Location ($/MWh)</th>
<th>Day-Ahead Payment by Market Buyer for DEC</th>
<th>Real-Time LMP at DEC Location ($/MWh)</th>
<th>Payment to Sell Out of DEC Position in Real Time</th>
<th>DEC Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$50</td>
<td>$500</td>
<td>$60</td>
<td>$600</td>
<td>$100</td>
</tr>
</tbody>
</table>

In real time, the 10 MWh withdrawal position from the DEC that cleared in the Day-Ahead Market creates deviation between the Day-Ahead and Real-Time Markets that must be settled at the real-time LMP. The market buyer with a cleared DEC must sell or close out its long position from the Day-Ahead Market at the real-time LMP. In this example, assume the real-time LMP is $60/MWh and, therefore, in order to close the long position established in the
Virtual Transactions in the PJM Energy Markets

Day-Ahead Market, the market seller now sells the 10 MWh purchased in the Day-Ahead Market via the DEC at that LMP. This would result in a profit to the DEC of $10/MWh or $100 for the full 10 MWh transaction.

Like an INC, a DEC creates a deviation between the Day-Ahead and Real-Time Markets. Because a DEC acts like load in the Day-Ahead Market, it can cause changes to the scheduling of resources in the Day-Ahead Market that are not required for real-time operations, which can again result in out-of-market uplift payments to resources called on in real time to resolve the differences. Additionally, DECs require the commitment of resources to serve load in the Day-Ahead Market caused by a cleared DEC. As a result of a DEC being a causal factor for both the commitment of resources in the Day-Ahead Market to cover the load caused by the cleared DEC, and the potential resulting uplift payments in real time due to the MW deviation the DEC causes between the Day-Ahead and Real-Time Markets, a DEC is assessed an uplift charge in both the Day-Ahead and Real-Time Markets. Absent administrative fees, a DEC is profitable when:

Equation 2.

\[
\text{Payoff} = \left[ (\text{Real-Time LMP ($/MWh)}) - (\text{Real-Time Uplift Charge ($/MWh)}) \right] - \left[ (\text{Day-Ahead LMP ($/MWh)}) + (\text{Day-Ahead Uplift Charge ($/MWh)}) \right] \times \text{MWh}
\]

DECs were originally implemented in June 1, 2000, coincident with the implementation of the Day-Ahead Market and have remained unchanged since.

How Up-To-Congestion Transactions Work

A UTC is a bid in the Day-Ahead Market to purchase congestion and losses between two points. UTC bids can be based on the prevailing flow direction where the UTC is buying a position on the Day-Ahead Market congestion or they can be in the counterflow direction where they are paid to take a position. In either case, like INCs and DECs, UTCs are bids that impose flows on the transmission network in the Day-Ahead Market that do not exist in real time and therefore classify as a virtual transaction. A major difference between an INC or a DEC and a UTC is that an INC or a DEC is a discrete injection or withdrawal at a location whereas a UTC transaction is an injection at a source point and a withdrawal at a sink point. Effectively, the UTC transaction takes an identical MW position at two different locations that from an energy perspective net to zero (absent losses) but do not for congestion and losses.

Like INCs and DECs, UTCs are virtual transactions in the Day-Ahead Market that do not represent the physical delivery of power in real time and therefore represent a deviation between MWs in the Day-Ahead and Real-Time Markets that is liquidated at the real-time LMP. What makes the UTC deviation different from a discrete INC or DEC deviation is that the UTC is both a supply and demand deviation because it has a source and sink. This makes the UTC identical to an INC offer at the source point and a DEC bid at the sink that are cleared simultaneously.

More specifically, forward flow UTCs (i.e. UTCs where the LMP in the Day-Ahead Market is lower at the source point than it is at the sink point) are profitable when they increase day-ahead congestion such that it is closer to the congestion observed in real time. In the counterflow direction (i.e. UTCs where the LMP in the Day-Ahead Market is
UTCs are profitable when they relieve day-ahead congestion on a path that is less constrained in real time.

Because UTCs are profitable when they drive congestion between the Day-Ahead and Real-Time Markets closer to each other, they also work to converge price spreads between both markets but not necessarily convergence of prices at discrete source and sink locations themselves. This is because the profitability of a UTC does not depend on all three components of the LMP (energy, congestion and losses) but only congestion and losses. As a result, energy component differences between the day-ahead and real-time LMPs are irrelevant when it comes to a UTC’s profitability because, absent losses, the source and sink energy positions offset each other.

Absent administrative fees, UTCs are profitable when:

**Equation 3. UTC Profitability**

\[
\text{Payoff} = \left[ \left( \text{Real-Time LMP “B”$/MWh} - \text{Real-Time LMP “A”$/MWh} \right) - \left( \text{Day-Ahead LMP “B”$/MWh} - \text{Day-Ahead LMP “A”$/MWh} \right) \right] \times \text{MWh}
\]

A simple example that illustrates the benefits of a UTC is in the modeling of a wheel-through transaction in the Day-Ahead Market. A wheel-through transaction is one where a market participant purchases power from a balancing authority that is external to PJM and transfers that power through PJM to another external balancing authority. The example provided in Figure 1 shows how a UTC can be used to accurately model a wheel-through transaction in the Day-Ahead Market.

**Figure 1. Example UTC**

In this example, a market participant would like to purchase power in MISO and deliver it to NYISO through PJM. The market participant would only like to execute this transaction if the cost of congestion and losses for the transaction
are less than $50/MWh. From a Day-Ahead Market clearing perspective, this means that the transaction will only clear when the price difference between the NYISO interface and the MISO interface is less than, or equal to, $50/MWh. When the Day-Ahead Market clears for this case, the NYISO price is $80/MWh and the MISO price is $50/MWh. Because the difference between these prices (NYISO minus MISO) is only $30/MWh, the transaction will clear and be charged $3,000 for the position taken in the Day-Ahead Market.

### Table 3. Settlement of Example UTC

<table>
<thead>
<tr>
<th>UTC Position (MWh)</th>
<th>Day-Ahead LMP Source MISO ($/MWh)</th>
<th>Day-Ahead LMP Sink NYISO ($/MWh)</th>
<th>Congestion &amp; Losses on Path ($/MWh)</th>
<th>Payment to Create UTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>$50</td>
<td>$80</td>
<td>$30</td>
<td>$3,000</td>
</tr>
</tbody>
</table>

If this transaction represents a hedge for a physical transaction that takes place in real time, the market participant clearing the transaction now has a hedge to take into real time and can ensure that they will pay no more than $30/MWh in congestion and losses for this transaction up to the 100 MWh cleared in the Day-Ahead Market. If the transaction is purely financial, it is paid the real-time difference between the NYISO and MISO prices due to it deviating by the cleared 100 MWh in real time.

**Brief Background on the Evolution of UTCs**

UTCs have changed significantly over time. They were originally implemented on June 1, 2000, coincident with the implementation of the Day-Ahead Market and were intended to allow market participants to “lock in” the congestion charge associated with physical interchange transactions at day-ahead LMPs. Since then they have evolved into what is primarily used as a purely financial transaction. The timeline below identifies critical events in the evolution of the UTC product.

- **June 1, 2000:** The product is implemented and intended to be used as a hedge against real-time prices for a physical transaction that would flow during the next operating day. As a result, a transmission service reservation was required to submit a UTC in the Day-Ahead Market. An offer range was placed on the product of +/- $25/MWh, the sources and sinks at which a UTC could be submitted were only those available on OASIS for the purposes of scheduling physical interchange transactions, and either the source point or the sink point or both were required to be a PJM interface pricing point. The product would continue in this form for approximately the next eight years.

- **June 1, 2007:** PJM implements marginal losses. Because UTCs require a transmission service reservation, they are now allocated a portion of the marginal loss surplus along with loads and other point-to-point transmission customers.

- **March 1, 2008:** As a result of a compromise at the Reserve Market Working Group, the maximum price spread for UTCs was increased to +/- $50/MWh but the available source and sink points were decreased. The available paths had increased over time due to market participant requests to add additional sources.
and sinks to PJM’s OASIS. The decrease in available paths was necessary due to infeasible transactions that were being submitted and concern with the volume of transactions being submitted.

- **December 1, 2008:** PJM implements the balancing operating reserve cost allocation method to allocate uplift costs. These rule changes continued to allocate uplift charges to INCs and DECs as “deviations” between the Day-Ahead Market and Real-Time Market but allocated nothing to UTCs. At the time, UTCs were still considered to be a hedge for a physical transaction in real time and therefore would not actually deviate significantly between day ahead and real time. As a result, they were not included in the allocation of uplift costs as were INCs and DECs.

- **July 23, 2010:** PJM is made aware of market participants making large reservations of non-firm point-to-point service on OASIS in certain hours. PJM investigates this behavior and identifies that UTCs are being used for the sole purpose of collecting a share of the marginal loss surplus as opposed to a financial hedge or for convergence trading.

- **September 17, 2010:** As a result of the July 2010 findings, the requirement of a transmission service reservation to submit a UTC transaction into the Day-Ahead Market is removed. This rule change indicates that, even prior to this time, UTCs were being used for reasons other than purchasing a hedge against real-time prices; however, this change cemented the product as purely financial. No changes were made to the uplift allocation to UTCs to assign them a share of uplift as with other virtual transactions.

- **November 1, 2012:** The previous requirement to have one end (source or sink) of a UTC be an interface point is removed as a result of stakeholder discussion.

**Price Convergence and Commitment Convergence**

Virtual transactions are often thought of as tools that market participants can use as revenue opportunities while helping to converge prices between the Day-Ahead and Real-Time Markets. While this is true, price convergence only represents a portion of the value added by virtual transactions. In addition to promoting competition and mitigating market power, virtual transactions have the ability to enable the efficient scheduling of the physical assets on the power system needed to cost effectively maintain reliability during the subsequent operating day. This “commitment convergence” is a vital function of virtual transactions, yet is often overlooked.

As explained above, the PJM energy markets are unique in part because of the comingling of the financial trading represented by virtual transactions and the commitment and scheduling of physical assets and actual electricity consumption. Virtual transactions that impact prices in the Day-Ahead Market but that do not result in physical resource commitments that more closely reflect what are actually needed in real time do not result in more efficient market operation. The concept of converging the commitments between day ahead and real time is complicated considering that virtual transactions are often thought to offset the scheduling of physical assets. For example, in the Day-Ahead Market it is entirely possible for an INC transaction to clear and displace the scheduling of a physical generation resource. Consider the following two potential scenarios of what happens when an INC offer clears in the Day-Ahead Market.
1. The generation resource that was supplanted by the INC was not needed in real time and therefore the INC has avoided this additional system cost. In most cases the INC will be profitable and has aided in converging the commitments between day ahead and real time.

2. The generation resource that was deferred in the Day-Ahead Market was actually needed in Real-Time Market. Either this unit, or a more expensive one, is then committed in real time resulting in higher real-time LMPs – all else equal. In this case the INC has not converged the commitment of resources between day ahead and real time and, consequently, the INC is not profitable because the real-time price is higher than the day-ahead price.

Driving the day-ahead commitment closer to what is needed in real time to maintain system reliability is an important function provided by virtual transactions. In order for virtual transactions to accomplish this function, they must impact the scheduling and commitment of the physical resources on the system. When this is done in a direction leading to a day-ahead resource commitment that more closely aligns with real-time needs, market clearing prices will reflect this and the transaction will be profitable. When the opposite occurs, the transaction will not be profitable and, therefore, the market participant is incentivized not to submit the same transaction again.

If there are persistent scenarios found where virtual transactions drive physical unit commitments in the Day-Ahead Market that are different than real time and yet the transactions are still profitable, or, in cases where virtual transactions are cleared that are not meaningfully impacting the day-ahead resource commitment yet are extracting profits from the market, not only is there no value added, but the transactions are actually detrimental to efficient market operation.

**Differences between INCs and DECs, and UTCs**

**Transaction Characteristics**

An important distinction between INCs and DECs, and UTCs is that absent uplift payments, the profitability of an INC or a DEC bid is based purely on the difference between the day-ahead and real-time LMPs at a specific single pricing point. A UTC’s profitability is based on the difference between day-ahead and real-time price spreads at the source and sink points. While this difference seems straightforward because the UTC is a transaction with a specified source and sink, there are some underlying complexities to consider. Notwithstanding the current administrative fees assessed to UTCs, the following principles apply to UTCs in the prevailing flow direction.

1. The UTC is profitable when the difference between congestion and loss prices for the source and sink points is greater in real time than it is in day ahead. Under the scenario in Figure 2, the UTC has imposed forward flow between two points in the Day-Ahead Market and paid congestion and losses for that position. In real time, that flow does not occur and therefore the removal of the UTC “relieves” congestion between the same source and sink at a higher price spread than was paid for in the Day-Ahead Market.
For example, if in the Day-Ahead Market there is a price spread of $30/MWh on the path from A (source) to B (sink) as shown at the bottom of Figure 2. If a 10 MWh UTC position is taken in the direction of A to B, in order for that position to be profitable, the price spread between A and B needs to be greater in real time than it is in day ahead.

Table 4. UTC Day-Ahead Settlement

<table>
<thead>
<tr>
<th>UTC Position (MWh)</th>
<th>Day-Ahead LMP Source ($/MWh)</th>
<th>Day-Ahead LMP Sink ($/MWh)</th>
<th>Congestion &amp; Losses on Path ($/MWh)</th>
<th>Payment to Create UTC Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$50</td>
<td>$80</td>
<td>$30</td>
<td>$300</td>
</tr>
</tbody>
</table>

Table 4 illustrates the day-ahead settlement for a 10 MWh cleared UTC from A to B. The cleared transaction imposes a flow from A to B and as a result pays $300 of congestion and losses based on the cleared 10 MWh and the $30/MWh price separation between the source and sink.

Table 5. UTC Balancing Settlement 1

<table>
<thead>
<tr>
<th>UTC Position (MWh)</th>
<th>Real-Time LMP Source ($/MWh)</th>
<th>Real-Time LMP Sink ($/MWh)</th>
<th>Congestion &amp; Losses on Path ($/MWh)</th>
<th>UTC Closure</th>
<th>UTC Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$600</td>
<td>$650</td>
<td>$50</td>
<td>$500</td>
<td>$200</td>
</tr>
</tbody>
</table>

For that transaction to be profitable, the price spread in the Real-Time Market needs to be more than $30/MWh, regardless of what the actual source and sink prices at nodes A and B are. In the example in Figure 2, the real-time LMPs at the source and sink are $600/MWh and $650/MWh, respectively. Table 5 illustrates the balancing settlement for the cleared 10 MWh UTC. In this example, the UTC trader has taken a 10 MWh position from A to B that it has paid $300 for in the Day-Ahead Market. In real time, the UTC flow is not imposed on the path from A to B and therefore the trader sells its long flow position at the real-time price difference between A and B, now $50/MWh. This results in a $500 credit back to the UTC trader for a net payoff of $200.
Table 6. UTC Balancing Settlement 2

<table>
<thead>
<tr>
<th>UTC Position (MWh)</th>
<th>Real-Time LMP Source ($/MWh)</th>
<th>Real-Time LMP Sink ($/MWh)</th>
<th>Congestion &amp; Losses on Path ($/MWh)</th>
<th>UTC Closure</th>
<th>UTC Payoff</th>
<th>UTC Payoff per MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$50</td>
<td>$100</td>
<td>$50</td>
<td>$500</td>
<td>$200</td>
<td>$20</td>
</tr>
</tbody>
</table>

Table 6 illustrates the same UTC settled under a different set of real-time LMPs but with the same level of price separation. In this case, the real-time LMPs at the source and sink locations are $50/MWh and $100/MWh, respectively. Because the price separation is the same, the profitability of the UTC remains the same.

2. If both the source and sink points of a UTC are analyzed independently as if they were discrete INC and DEC transactions, only one of those transactions needs to be profitable in order for the transaction to be profitable as a whole. As long as one end of the transaction is more profitable than the loss incurred by the other, the transaction, as a whole, makes money. This means that a UTC can be profitable as a whole even when one end of the transaction is not individually rational. This occurs in about 90 percent of all cleared UTCs. The following example illustrates this concept.

Figure 3. UTC Clearing Example

Figure 3 shows the same cleared UTC as used in the previous example with the same set of day-ahead and real-time LMPs. Table 7 shows the settlement of this cleared UTC transaction from a different perspective. While it results in the same UTC payoff, the settlement of each end of the transaction in isolation and then combining the total illustrates how each end of the transaction impacts the market differently.

Table 7. UTC Balancing Settlement on Injection and Withdrawal

<table>
<thead>
<tr>
<th>UTC Position (MWh)</th>
<th>Real-Time LMP Source ($/MWh)</th>
<th>Real-Time LMP Sink ($/MWh)</th>
<th>Day Ahead LMP Source ($/MWh)</th>
<th>Day-Ahead LMP Sink ($/MWh)</th>
<th>UTC Source Payoff</th>
<th>UTC Sink Payoff</th>
<th>UTC Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$600</td>
<td>$650</td>
<td>$50</td>
<td>$80</td>
<td>-$5,500</td>
<td>$5,700</td>
<td>$200</td>
</tr>
</tbody>
</table>
The settlement of the source end of the UTC at node A can be handled exactly like an INC transaction without the uplift considerations. In this example, the UTC trader sells 10 MWh in the Day-Ahead Market at a price of $50/MWh for a credit of $500 and must purchase out of that position in real time at a price of $600/MWh. This results in a loss of $5,500 to the UTC trader for the injection portion of the UTC. The withdrawal portion of the UTC can be treated exactly like a DEC. The UTC trader has cleared a 10 MWh withdrawal in the Day-Ahead Market at the sink location at a price of $80/MWh and is charged $800. In real time, the UTC trader sells that long position back into the market at $650/MWh and profits $5,700. When the independent source and sink settlements are combined they yield the original $200 UTC payoff.

Separating the settlement into injection and withdrawal components shows how each end can impact the market in very different ways. In the case of the injection or source end of the UTC, when considered as an INC transaction, it alone is not profitable which indicates that at the source location there was more supply in day ahead than in real time. That additional supply in day ahead further reduced the day-ahead LMP below real time causing a larger price divergence and thus the injection end of the UTC loses money.

The opposite occurs on the withdrawal or sink end of the UTC. The additional load at the withdrawal end from the UTC adds load at the sink location that serves to increases prices in the Day-Ahead Market beyond what they would otherwise be without the UTC. This means that the withdrawal end of the UTC helps converge prices at the sink location and therefore the withdrawal end of the UTC is profitable.

While the injection portion of the UTC loses $5,500, the withdrawal end profits by $5,700 and therefore on net, the transaction is profitable. Ideally, a DEC at the receiving end of the transmission constraint would have resulted in the most profitable outcome for the market participant and the most benefit to the market absent any major shift in the market clearing caused by removing the injection portion of the transaction. While the UTC was profitable, it created a divergence in prices at the source end which resulted in a $5,500 loss. The convergence provided on the sink end resulting in $5,700 profit is enough to cover that loss.

Factors Impacting Risk

Another factor that differentiates the UTC from an INC or a DEC is the risk types and levels associated with the different transactions. INCs and DECs settle based on LMP differences between the Day-Ahead and Real-Time Markets and therefore face risks on all three LMP components (energy, congestion, and losses). In the case of the UTC, the bid is effectively a point-to-point transaction with two energy positions that absent losses net to zero financially. This occurs because the energy component of LMP is, by definition, the same at every point on the system. Since the settlement of a UTC transaction is based upon the difference in LMP between two points on the system, the energy component of LMP nets to zero and therefore the transaction is only exposed to differences in the congestion and loss components of LMP between the Day-Ahead Market and Real-Time Market. Because the congestion and loss components of LMP differ across the system under constrained conditions, the risk level of each UTC will be dependent on the source and sink points chosen. If there is a very low probability that the path on which the UTC is cleared in the Day-Ahead Market will have congestion in the opposite direction in real time, then the UTC
is a very low-risk transaction. As the probability of congestion in the opposite direction of the cleared UTC increases, the risk level also increases.

Finally, the allocation of uplift charges to INCs and DECs adds an additional risk to those transactions that UTCs do not have to manage. Under today’s rules, UTCs effectively net the source and sink positions whereas similar positions taken by discrete INC and DEC transactions do not net. While this netting is not explicit within the existing rules, it inherently exists because UTCs are not allocated uplift today because of how the transaction type has evolved over time. This netting of injection and withdrawal positions results in no uplift allocation to UTCs which impacts the bidding behavior of these transactions. As will be shown later, a majority of the bids submitted for UTCs are between positive and negative $2.00/MWh. An allocation of uplift to these transactions would make these transactions not profitable in many cases.

More information regarding recent levels of uplift and its impact on the profitability of different virtual bid types can be found in Appendix A.

Virtual Bidding in a Two-Settlement Market

**Spot Market Price Arbitrage**

Virtual transactions add value to a two-settlement market in a number of ways. In their simplest application, they can be used to converge price differences between Day-Ahead and Real-Time Markets when physical positions are not represented in day ahead as they occur in real time. For example, if the load, generation and interchange in the Day-Ahead Market were identical to what occurred in real time, the cleared quantities and prices would be identical between the two markets and virtual transactions would not be profitable. However, when the offered quantities or prices in the Day-Ahead Market differ from what occurs in real time, virtual bids add value in a number of ways.

Under today’s market rules, the only entities required to make an offer into the Day-Ahead Market are generation owners of capacity resources. These resource owners are required to offer the committed capacity value of their resource into the Day-Ahead Market unless the resource is on an outage. However, notwithstanding PJM’s market power mitigation measures, generation capacity resource owners have the ability to submit offers that can potentially price them out of the Day-Ahead Market via their market-based offer, depending on their bidding strategy. Those resources that do not clear in the Day-Ahead Market then have the opportunity to rebid prior to the Real-Time Market and be committed via the PJM Reliability Unit Commitment process.

Load Serving Entities (LSEs) in PJM are not required bid their load into the Day-Ahead Market. This market design was chosen for two main reasons. First, it allows LSEs the maximum amount of flexibility in how they procure the needed supply to meet their load the following day. They may procure all of their energy needs day ahead, none, or somewhere in between depending on their willingness to pay along with their risk profile. Second, having the Day-Ahead Market clear based on the demand submitted by the members rather than the load forecasted by PJM removes the influence PJM’s load forecast accuracy would have on the market both in the short and long term. This
eliminates any biasing that could have existed based on load forecast accuracy and leaves the supply and demand dynamics of the market between market participants.

While there is no requirement for LSEs to bid in the Day-Ahead Market, there are financial incentives to do so. LSEs that lock in their position in the Day-Ahead Market are not exposed to potential price volatility in real time and also avoid deviation charges that apply to entities with schedule imbalances between day-ahead and real-time load positions. On average, fixed demand bids in the Day-Ahead Market account for about 95 percent of the load forecast for the next operating day. On a peak load day where the real-time load is about 150,000 MW, five percent of the load is 7,500 MW which is equivalent to about seven nuclear plants. On a percentage basis it is small but in terms of real megawatts it is substantial. Without some form of virtual trading, this amount of load could go un-procured in the Day-Ahead Market leading to discounted prices and inadequate resource commitments.

The flexibility allowed to both LSEs and generation owners in the Day-Ahead Market on how their assets are represented in the Day-Ahead Market creates differences between the Day-Ahead and Real-Time Markets in addition to market power issues. The market power issues arise from either the LSEs or generation owners being able to exert market power over the other on an aggregate basis. For example, if LSEs underbid load in the Day-Ahead Market by 20 percent, the resulting market outcome absent virtual bidding would be a procurement of 80 percent of the expected supply needed the next day at a fraction of the cost of procuring the full 100 percent of expected supply needed.

**Real-Time Spot Market Only**

The most basic market design is one with a real-time spot market only. In this case, all settlement in the market is done at the real-time price. An example of this is provided below in Figure 4 where for an example hour, the aggregate system supply curve is shown via the positively sloped line and the real-time load is 1,800 MWh. In this case, the real-time clearing price is shown by the intersection of the supply and demand curves at $60/MWh. Because all load and generation is settled at the real-time price, the total money collected from loads and paid to suppliers is $108,000. Table 8 illustrates the settlement for this market outcome.
Virtual Transactions in the PJM Energy Markets

Figure 4. Real-Time Spot Market Only

Table 8. Real-Time Spot Market Settlement

<table>
<thead>
<tr>
<th>Real-Time Load (MWh)</th>
<th>Real-Time Price ($/MWh)</th>
<th>Real-Time Load Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,800</td>
<td>$60</td>
<td>$108,000</td>
</tr>
</tbody>
</table>

Two-Settlement Market: No Virtual Bidding

The example shown in Figure 5 graphically illustrates a two-settlement system like PJM’s but without any virtual bidding. The purpose of this example is to show that absent virtual transactions, LSEs have monopsony power that can be exerted to purchase much of the required supply at a discount to what they would otherwise have to pay in real time. In this system, the demand cleared in the Day-Ahead Market is 1,600 MWh at a clearing price of $40/MWh. In real time, the actual system load is 1,800 MWh at a clearing price of $60/MWh, similar to the previous example. In this scenario, LSEs have underbid demand in the Day-Ahead Market and it has resulted in a clearing price lower than what is observed in real time at the load level of 1,800 MWh. The region in Figure 5 labeled “Day-Ahead Demand Payment” represents the total payments in the Day-Ahead Market by the cleared day-ahead demand to cleared supply resources. The region labeled “Real-Time Load Payment” shows the amount of money paid by real-time, unhedged load that has not cleared in the Day-Ahead Market. The region labeled “Day-Ahead Market Discount to Real Time” represents the amount of payments that load has avoided by underbidding in day ahead and procuring 1,600 MWh of the 1,800 MWh needed in real time at a discounted price.
Virtual Transactions in the PJM Energy Markets

Figure 5. Two-Settlement Market Without Virtual Bidding

Table 9. Two-Settlement Market Without Virtual Bidding Settlement

<table>
<thead>
<tr>
<th>Day-Ahead Demand (MWh)</th>
<th>Day-Ahead Price ($/MWh)</th>
<th>Real-Time Load (MWh)</th>
<th>Real-Time Price ($/MWh)</th>
<th>Balancing Load in Real-Time (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,600</td>
<td>$40</td>
<td>1,800</td>
<td>$60</td>
<td>200</td>
</tr>
</tbody>
</table>

As stated previously, this example illustrates that absent virtual bidding, LSEs have monopsony power because of their ability to underbid in the Day-Ahead Market and purchase much of the supply required in real time at a discount. The effect of this is illustrated in Table 10. The total payment from cleared demand in the Day-Ahead Market in this example is $64,000. This is shown in the section labeled “Day-Ahead Demand Payment”. The section labeled “Real-Time Load Payment” totals $12,000 and represents the payments made by real-time, unhedged loads for the additional 200 MWh of supply required in real time in excess of the 1,600 MWh procured day ahead. The sum of these two, $76,000, represents the total payments by load and demand to supply resources to procure 1,800 MWh of supply. This is $32,000 less than the $108,000 settled in the prior example where there was no Day-Ahead Market. This cost reduction of $32,000 is shown in the shaded region of Figure 5 titled “Day-Ahead Market Discount to Real-Time Load” and in this example is a direct result of demand in day ahead being bid in at levels that are lower than those observed in real time.

Table 10. Total Settlement for Two-Settlement Market Without Virtual Bidding

<table>
<thead>
<tr>
<th>Payment from Day-Ahead Demand</th>
<th>Real-Time Balancing Payments</th>
<th>Total Supplier Settlement</th>
<th>Cost Avoided by Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>$64,000</td>
<td>$12,000</td>
<td>$76,000</td>
<td>$32,000</td>
</tr>
</tbody>
</table>

Consistent underbidding by demand in the Day-Ahead Market and the resulting suppression of the day-ahead prices would be extremely detrimental to the long-term health of the market because the prices resulting from the PJM spot
market drives forward prices in other markets. The ability for both suppliers and load to build a portfolio of short- and long-term forward contracts to hedge their market positions is critical to their ability to manage their risk. Price suppression in the Day-Ahead Market would severely impede the efficient functioning of the markets for these longer-term hedges.

**Two Settlement Market with Virtual Bidding**

The introduction of virtual transactions, in this case a DEC, is extremely helpful in mitigating this monopsony power. Consider the same example but now with a 100 MWh DEC that has fully cleared and set the Day-Ahead Market clearing price as shown Figure 6. The cleared DEC in this case is converging the Day-Ahead and Real-Time Markets by increasing the demand and price in the Day-Ahead Market closer to what is observed in real time. The additional 100 MWh of demand provided causes an increase in the supply needed to meet the demand in the Day-Ahead Market and a corresponding increase in price.

Assume in this case that the cleared DEC was not submitted by an LSE as part of a load-hedging strategy but rather by a financial trader. The financial trader believes that the real-time LMP will be greater than $50/MWh and therefore submits the DEC bid with an offer price of $50/MWh. If the DEC clears and the real-time price is greater than $50/MWh, the DEC will be profitable as the trader will sell out of the long position at a price that is higher than the cost to take that position.

**Figure 6. Two-Settlement Market with Virtual Bidding**

![Two-Settlement Market with Virtual Bidding](image)

**Table 11. Two-Settlement Market with Virtual Bidding**

<table>
<thead>
<tr>
<th>Day-Ahead Demand (MWh)</th>
<th>DEC Position (MWh)</th>
<th>Day-Ahead Price ($/MWh)</th>
<th>Real-Time Load (MWh)</th>
<th>Real-Time Price ($/MWh)</th>
<th>Balancing Load in Real Time (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,600</td>
<td>100</td>
<td>$50</td>
<td>1,800</td>
<td>$60</td>
<td>200</td>
</tr>
</tbody>
</table>
From a macro perspective, the cleared DEC has increased demand in the Day-Ahead Market and has also resulted in an increase in price from what it would have been without the DEC. Both of these increases bring the Day-Ahead Market clearing closer to real time. The new dark purple shaded region titled “Impact of DEC Convergence” shows the amount of convergence created by the cleared DEC. The light purple shaded region titled “DEC Revenue” shows the profit made by the DEC transaction. Additionally, both the “Day-Ahead Market Discount to Real Time”, which includes the light purple section, and the “Real-Time Load Payment” which illustrate differences between the Day-Ahead and Real-Time Markets have both decreased as a result of the DEC transaction.

Because the clearing price in the Day-Ahead Market has increased to $50/MWh from the prior example, the LSEs who have secured their load in the Day-Ahead Market now pay a total of $80,000 ($50/MWh * 1,600 MWh) for that hedge. The DEC also must pay $50/MWh for the cleared 100 MWh to take the long position in the Day-Ahead Market. The additional demand created by the DEC results in the scheduling of an additional 100 MW of supply resulting in an increase in cleared supply in the Day-Ahead Market. The $5,000 paid by the DEC for its hedge is also used to fund the supply cleared in the Day-Ahead Market. As a result, the total payments from demand to supply in day ahead are $85,000. From the previous example, this is an increase of $21,000.

In real time, the LMP is now $60/MWh as a result of a 100 MWh increase in load above the cleared demand in the Day-Ahead Market. The supply cleared in the Day-Ahead Market is 1,700 MW as a result of the 100 MWh cleared DEC and the 1,600 MWh of cleared demand from LSEs. As a result, only an additional 100 MWh of supply are needed in real time to meet the 1,800 MWh load. It is important to note that because LSEs only cleared 1,600 MWh of demand in the Day-Ahead Market, there is still a balancing load settlement of 200 MWh as the real-time load is 1,800 MWh. This means that real-time, unhedged loads will pay a total of $12,000. Half of that $12,000 is paid to the cleared DEC that closes its 100 MWh long position in real time for $6,000. The remaining $6,000 is paid to the additional 100 MWh of supply required to cover the addition 100 MWh of load in real time.

Table 12. Settlement of Two-Settlement with Virtual Bidding

<table>
<thead>
<tr>
<th>Payment from Day-Ahead Demand (not including DEC)</th>
<th>Payment to Create DEC Position</th>
<th>Total Day-Ahead Settlement</th>
<th>DEC Closure in Real-Time</th>
<th>DEC Payoff</th>
<th>Real-Time Balancing</th>
<th>Total Supplier Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$80,000</td>
<td>$5,000</td>
<td>$85,000</td>
<td>$6,000</td>
<td>$1,000</td>
<td>$12,000</td>
<td>$91,000</td>
</tr>
</tbody>
</table>

Because the DEC has brought the day-ahead and Real-Time Markets closer together, the DEC makes a profit of $1,000. In Figure 6, this is shown via the light purple shaded region titled “DEC Revenue”. Importantly, the profit accrued by the DEC is much smaller than the convergence value it brings to the market as a whole. In this example, the DEC increased the day-ahead clearing price by $10/MWh and increased the day-ahead demand by 100 MWh. This results in an increase in total Day-Ahead Market billing of $21,000. This additional $21,000 increases revenues to suppliers who have cleared in the Day-Ahead Market and brings their settlement closer to what it would have been had they cleared in real time only. The total market billing in this case would be $91,000 which is significantly closer.
to the original $108,000 in the Real-Time Spot Market Only example than the $76,000 in the prior example without virtual bidding.

The assumption in this example is that the cleared DEC represents a purely financial position and therefore there are still 200 MWh of load that need to be settled in real time at a cost of $12,000. In Figure 6, this is represented via the orange and light and dark purple shaded regions between the amounts of 1,600 MWh and 1,800 MWh. The difference in this example is that for 100 MWh of those 200 MWh, PJM would have already scheduled and compensated supply in the Day-Ahead Market because of the 100 MWh cleared DEC. Therefore, in real time only 100 MWh of additional supply needs to be scheduled and compensated at the real-time LMP. The $12,000 collected from loads in real time that did not hedge day ahead ends up being split between the 100 MWh of additional supply needed in real time and purchasing the long position taken by the DEC that is liquidated in real time. Essentially, the DEC holder sells the supply it procured in the Day-Ahead Market for $50/MWh to unhedged loads in real time at a price of $60/MWh. As a result, the DEC holder profits on the difference between those prices for a total of $1,000.

Table 13 shows the same scenario but with a cleared DEC of 199 MWh. The additional cleared demand in the Day-Ahead Market pushes the day-ahead LMP closer to real time thus providing even greater convergence. The total cleared demand in the Day-Ahead Market has now increased to 1,799 MWh at a clearing price of $58/MWh.

Table 13. DEC Near Convergence – 199 MWh

<table>
<thead>
<tr>
<th>Day-Ahead Demand (MWh)</th>
<th>DEC Position (MWh)</th>
<th>Day-Ahead Price ($/MWh)</th>
<th>Real-Time Load (MW)</th>
<th>Real-Time Price ($/MWh)</th>
<th>DEC Position (MW)</th>
<th>Balancing Load in Real Time (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,600</td>
<td>199</td>
<td>$58</td>
<td>1,800</td>
<td>$60</td>
<td>199</td>
<td>200</td>
</tr>
</tbody>
</table>

Table 14 shows the resulting market outcome. Between the payments from cleared demand in the Day-Ahead Market and the DEC, the total day-ahead settlement is now $104,342 which is just below the $108,000 settled in the Spot Market Only example. The $12,000 collected from unhedged load in real time is again split between supply that was not committed in the Day-Ahead Market and the payment required to purchase the supply procured by the DEC in the Day-Ahead Market. Because the DEC position is larger in this example, the payment required to close the DEC’s position is larger; however, the payoff to the DEC is much smaller because of the converged prices between day ahead and real time.

Table 14. DEC Near Convergence Settlement

<table>
<thead>
<tr>
<th>Payment from Day-Ahead Demand</th>
<th>Payment to Create DEC</th>
<th>Total Day-Ahead Settlement</th>
<th>DEC Closure</th>
<th>DEC Payoff</th>
<th>Real-Time Balancing</th>
<th>Total Supplier Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$92,800</td>
<td>$11,542</td>
<td>$104,342</td>
<td>$11,940</td>
<td>$398</td>
<td>$12,000</td>
<td>$104,402</td>
</tr>
</tbody>
</table>
The ideal example of market convergence in this case would be a 200 MWh DEC offered in with a bid price of $60/MWh. This would result in the Day-Ahead Market clearing perfectly matching real time with 1,800 MW cleared at a price of $60/MWh. However, this would also result in the 200 MWh DEC making no profit because the day-ahead and real-time clearing prices matched perfectly. Because INCs and DECs only profit when the real-time and day-ahead prices are not equal, these products alone will not perfectly converge the Day-Ahead and Real-Time Markets. However, they are critical components of the market because they drive markets towards convergence while mitigating market power.

**Table 15. DEC at Total Convergence**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1,600</td>
<td>200</td>
<td>$60</td>
<td>1,800</td>
<td>$60</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

**Table 16. DEC at Total Convergence Settlement**

<table>
<thead>
<tr>
<th>Payment from DA Demand</th>
<th>Payment to Create DEC</th>
<th>Total DA Settlement</th>
<th>DEC Closure</th>
<th>DEC Payoff</th>
<th>RT Balancing</th>
<th>Total Supplier Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>$96,000</td>
<td>$12,000</td>
<td>$108,000</td>
<td>$12,000</td>
<td>$0</td>
<td>$12,000</td>
<td>$108,000</td>
</tr>
</tbody>
</table>

The examples in this section illustrate the use of DEC bids but similar examples can be constructed using INC offers. This discussion is contained in the following section.

**Use of INCs to Mitigate Supply-Side Market Power**

As stated previously, generation owners in PJM can submit market-based offers to sell energy that if high enough will result in the offer failing to clear and thus, the associated resource not being committed in the Day-Ahead Market. Market-based offers allow generators to price many risks into their generation offer that their cost-based offers do not permit. For example, a generation owner submitting a day-ahead offer for a resource that has a high risk of tripping in real time may want to reflect that risk in its offer into the Day-Ahead Market. One strategy for this would be to submit a market-based offer that ensures that an at-risk resource does not receive a day-ahead award when the day-ahead LMPs are less than what it anticipates the real-time LMPs will be the following day. This strategy would minimize the financial risk of buying out of the day-ahead commitment in real time should the generator actually trip.

While market-based offers provide generation owners additional flexibility on how to construct their offers above what the prescriptive cost-based offer methodology permits, they also provide the opportunity for generation resources to withhold from the Day-Ahead Market similar to the way LSEs can underbid load positions. For example, in theory, a generation owner could submit a high market-based offer on a resource in the Day-Ahead Market in an attempt to price that resource out of the market, resulting in higher day-ahead LMPs for the rest of its portfolio.
In the prior example, a generation resource owner with a portfolio of assets submits a high market-based offer into the Day-Ahead Market for one resource in the portfolio. The resource owner’s goal in this case is to not receive an award on one resource in its portfolio in the hope that the increase in Day-Ahead LMPs from economically withholding one resource results in a net benefit to their portfolio, because of the increased LMPs paid to the remaining committed resources. The generation owner then reduces its offer on the resource during the re-bid period in an attempt to receive a real-time commitment for that resource. The final offer for the withheld resource is one that is infra-marginal based on the Day-Ahead Market results. In this case, the INC offer provides a measure of protection to LSEs trying to hedge in the Day-Ahead Market by allowing virtual supply to moderate, if not eliminate, the price increase.

If we further assume that the resource either received a real-time commitment during the reliability analysis or the generation owner elected to self-schedule the resource, the additional supply from this resource in real time will push real-time LMPs below what they were day ahead, all other things equal. Because the INC profits when day-ahead LMP exceeds the real-time LMP, the artificially increased day-ahead LMPs resulting from the withheld resource provide a revenue opportunity for any market participant to take a position with the INC. In this scenario, any market participant willing to submit and clear an INC in the Day-Ahead Market has the ability to mitigate the generation resource owner’s market power.

The INC offer will clear any time the offer price is below the day-ahead LMP. Submitting and clearing an INC offer in this scenario creates supply in the Day-Ahead Market at a level below the day-ahead LMP replacing the supply withheld by the generation resource owner. This additional supply in the Day-Ahead Market moderates the increase in the day-ahead LMP which minimizes or eliminates the revenues the generation owner was attempting to collect. In addition to this, the moderation in the day-ahead LMP increase protects loads from the impacts of the generation owner’s behavior.

Market rules and dynamics designed particularly to address supply-side market power serve to limit the role that INCs play to mitigate supply-side market power as compared to the role DECs play to check demand-side market power. The following features, for which there are no analogs on the demand side, illustrate this point:

1. Generation capacity resources owners are required to offer into the Day-Ahead Market. While there is flexibility on how that offer is priced, the “must-offer” requirement for generation capacity resources exists and there is no corollary for loads. This rule removes much of the ability for generation capacity resource owners to physically withhold from the Day-Ahead Market. Some ability still exists if the generation resource owner is willing to take a forced outage but there are significant compliance risks in doing so.

2. Generation capacity resource owners must also submit a cost-based offer that is used in the scheduling and dispatch of the resource when it is determined to have local market power. This removes the ability for a generation capacity resource to withhold their resources economically when they have local market power.

3. Because of the competition inherent in PJM’s markets, market participants behave in a competitive manner. The IMM states,
“Participant behavior was evaluated as competitive because the analysis of markup shows that marginal units generally make offers at, or close to, their marginal costs in both Day-Ahead and Real-Time Markets, although the behavior of some participants during the high demand periods in the first quarter raises concerns about economic withholding.”

2014 State of the Market Report for PJM, page 70

The additional market rules for generation capacity resource owners in addition to the IMM’s statement regarding competitive behavior indicate that outside of infrequent high demand periods, the opportunities for INCs to mitigate supply-side market power are few whereas the market design features of the Day-Ahead Market that result in persistent underbidding of load in the Day-Ahead Market provide opportunities for DEC bids to mitigate demand-side market power much more often. This is likely a primary driver in the reason cleared DEC volume exceeds cleared INC volume over the previous three planning years by a ratio of 1.5 to 1. (See Appendix A for more detail)

Virtual Transactions as Hedging Instruments

One of the primary uses of virtual transactions is to hedge the financial risks inherent in the volatility of the spot energy market. They can be used in a variety of different ways ranging from a simple hedge procured to protect a generation asset from real-time price exposure to a more complex scenario such as converting a forward contract into the physical delivery of power.

An equally important and more complicated usage of INCs and DECs is to convert forward financial contracts used as either risk-based revenue streams or risk-hedging mechanisms into physical deliveries of power. This type of strategy may originate with a forward contract on an open exchange such as the Intercontinental Exchange (ICE) or the New York Mercantile Exchange (NYMEX), or, simply an internal bilateral transaction between two different counterparties, but can incorporate the use of INCs and DECs to fully effectuate a strategy.

Generator at Risk of Tripping

A simple risk mitigation strategy to consider is a generation capacity resource that is required to offer into the Day-Ahead Market but is at risk of tripping in real time on a peak-load day where real-time prices are anticipated to be high. In this case, a generation owner may use a DEC in the Day-Ahead Market to hedge a portion, or all, of the risk of purchasing out of a day-ahead commitment in real time.

Assume the generation capacity resource at risk of tripping is an 800 MW unit. If the resource clears all 800 MWs in day ahead for all 24 hours of the day at an average price of $200/MWh, the resource will be paid a total of $3.84 million. Table 17 shows this settlement.

---

3 2014 State of the Market Report for PJM, Monitoring Analytics
Table 17. Generator at Risk – Day-Ahead Clearing

<table>
<thead>
<tr>
<th>DA Commitment (MWs)</th>
<th>Hours Committed</th>
<th>Average Day-Ahead Price ($/MWh)</th>
<th>Day-Ahead Revenue to Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>24</td>
<td>$200</td>
<td>$3,840,000</td>
</tr>
</tbody>
</table>

However, based on a simple approach, if the generation owner feels that the unit has a 50 percent chance of tripping the next day, then in order to mitigate that risk the owner may submit and clear a 400 MW DEC at the generator bus for all 24 hours of the same day.

Table 18. DEC Position

<table>
<thead>
<tr>
<th>DEC Position (MWs)</th>
<th>DEC Hours Cleared</th>
<th>Average Day-Ahead Price ($/MWh)</th>
<th>Payment to Create DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>24</td>
<td>$200</td>
<td>$1,920,000</td>
</tr>
</tbody>
</table>

Under PJM's current settlement rules, the DEC and the generation position at the same location do not net against each other. Therefore, the day-ahead settlement for the generator is the same $3.84 million regardless of whether the DEC clears or not. However, the DEC has created a financial hedge for the generator because it was submitted at the same location. In this example, the generation owner would also pay a $1.92 million charge for the cleared DEC that financially offsets the $3.84 million paid to the generation resource. This results in a net settlement of a $1.92 million credit to the generation owner, exclusive of the day-ahead uplift charges allocated to the cleared DEC. Absent the uplift charges, it is the same day-ahead settlement that would have occurred had the generator only cleared for 400 MWs throughout the day.

In real time, any quantity deviations from the day-ahead schedule for both the generator and the DEC are settled at the real-time LMP. If the generator trips, it must buy out of its day-ahead position at the real-time LMP. If it does not and it meets its day-ahead schedule then the balancing settlement for the generator is $0.00 because there are no quantity deviations in the schedule for the generator in real time. Because the DEC is a virtual bid, it deviates in real time for the full 400 MWs that cleared day ahead. The balancing settlement for the DEC is a credit to the generation owner at the value of the real-time LMP in addition to an uplift charge resulting from the deviation.

Regardless of the generator’s performance in real time, the generation owner will always receive the real-time LMP for the position established by the DEC when it is liquidated in real time. As a result, the generation owner has created a market outcome that results in being compensated at the day-ahead LMP for half of the resource and the real-time LMP for the other half. From a risk mitigation perspective, if the generator trips in real time the owner must fully purchase out of the 800 MWs position established in day ahead. However, the balancing settlement of the cleared DEC will offset half of those costs because it results in a credit back to the owner at the real-time LMP for half of the unit’s output.
**Bilateral Transaction with Day-Ahead and Real-Time Pricing**

Suppose an LSE wants to bilaterally contract with supply to serve their load rather than be exposed to spot market energy prices. The LSE finds a seller and they agree on a 100 MWh contract at a specific location but the Seller wants real-time pricing and the buyer wants day-ahead pricing. The two parties agree to enter into an internal bilateral transaction (IBT) that is priced at day ahead.

For the buyer, nothing more needs to be done unless it wants to hedge congestion additionally between the location of the IBT and the location of the LSE’s actual load. The simplest way to do this would be to procure a Financial Transmission Right (FTR).

For the seller who wants real-time pricing, it would need to clear a 100 MWs INC in the Day-Ahead Market at the location of the IBT.

The IBT would result in a net negative position for the seller such that absent any other market activity, the seller would receive a charge for the 100 MWs sold in the IBT. The 100 MWs cleared INC at that same location will financially offset the sell position created by the IBT. The resulting day-ahead settlement for the seller would be a purchase of 100 MWs at the location of the IBT as well as a 100 MWs credit at the same location due to the cleared INC. In real time, the IBT has no deviation and therefore the balancing settlement is zero. However, the liquidation of the INC position in real time will result in a 100 MWs purchase at the location of the IBT at the real-time LMP. In this scenario, the seller is not charged uplift because the INC is permitted to net with the IBT.

**Demand Hedging with a DEC Bid**

Another demand-side hedging strategy incorporates the use of DEC bids to express an LSE’s willingness to pay for power in Day-Ahead Market at a given price. This practice allows LSEs to procure some portion of their load in the Day-Ahead Market up to a specified price and have the rest procured in real time at the real-time LMP.

Assume that an LSE has estimated their load forecast the next day to be between 140 MWs and 150 MWs for a given hour. The LSE would like to procure the full amount of its load in the Day-Ahead Market if possible but does not know what the exact amount will be. Because the LSE knows that its load will be greater than or equal to 140 MWh, it submits a fixed demand bid in the Day-Ahead Market for 140 MWh. This leaves the LSE with a potential 10 MWh of load exposed to real-time prices.
Based on the LSE’s risk management strategy, it would prefer to buy an additional 10 MWs of potential load at a price of $75/MWh or less rather than be exposed to real-time prices for those 10 MWs. However, if the day-ahead price exceeds $75/MWh, the LSE would prefer to take that portion of the load into real time. To effectuate this strategy, the LSE can submit a 10 MWh DEC bid into the Day-Ahead Market at a price of $75/MWh.

If the LMP at the load location is $60/MWh such that the DEC clears, the LSE is charged $9,000 ($60/MWh * 150 MWh) and carries a 150 MWh load position into the Real-Time Market. If the LSE’s load is less than the cleared 150 MWh position, the LSE will sell out of that position in real time and be paid the real-time LMP for any imbalances on that 150 MW position. Regardless of whether the real-time LMP is higher or lower than the day-ahead LMP, the LSE has been successful in protecting its load from real-time volatility based on its own internal strategy and the use of a DEC bid. If the real-time LMP is higher than the day-ahead LMP of $60/MWh, the LSE will sell back its long load position at the real-time LMP and make a profit on that position.

While it is not the case in this example, if the LSE had a real-time load in excess of 150 MWh, it would have to purchase the balance at the real-time LMP.
Virtual Transaction Volumes

Figures 9 and 10 show the trend in submitted and cleared volumes of virtual bids, respectively. Both of these figures show generally the same trend, which is a reduction in the number of INCs and DECs that have been submitted and cleared since 2008 and a meteoric rise in the amount of submitted and cleared UTCs up until September of 2014.

Figure 8. 12-Month Rolling Average of Submitted Virtual Transactions

Figure 9. 12-Month Rolling Average of Cleared Virtual Transactions

As stated in the section titled, Brief Background on the Evolution of UTCs, the UTC product has changed significantly over time which no doubt led to the significant increase in its popularity. The expansion of bidding points combined with the reduction in transaction costs via the removal of the transmission service reservation requirement has made the UTC transaction extremely low cost to those deciding to use it.
The migration to UTCs has shifted the virtual trading market from what was primarily an INC and DEC traded market to one that is now dominated by UTCs. The benefit of no uplift allocation that is currently afforded to UTCs is likely a significant driver of this behavior. Additional information is provided on this in the *Observed Bidding Strategies* section of this paper.

The significant change in the volume of submitted and cleared UTCs in September 2014 is due to an open FERC 206 proceeding regarding FTR forfeiture rules and, more significantly, the allocation of uplift to UTCs. The Order established a refund effective date of September 8, 2015, after which any virtual transaction (including INCs and DECs) would potentially be responsible for paying uplift based on a method that is yet to be determined. This creates a significant risk for UTC traders because, today, they are not allocated any uplift as those participants submitting INCs and DECs are. This risk has significantly decreased both the number of UTCs submitted and the associated MW volumes.

A common discussion with regard to virtual trading is that high volumes are indicative of the health of the market. While this may be true in some cases, this presumes that the market rules and incentives in place always guide virtual activity towards trades that are both beneficial to efficient operation of the market and profitable to the trader. The section titled *Observed Bidding Strategies* provides simple examples that show bidding behaviors that PJM has witnessed that are permitted by today’s market rules but do not positively contribute to market efficiency or price or commitment convergence.

**Virtual Transaction Volumes and Day-Ahead Market Solution Time**

The time required to clear the Day-Ahead Market has become a critical topic since the issuance of FERC Order 809. In addition to revising gas nomination deadlines on interstate pipelines, Order 809 requires RTOs and ISOs to review the timing of their resource commitment processes. The obligation for RTOs includes adjusting the Day-Ahead Market timing to ensure that those commitments are provided to generation owners in enough time to allow them to make gas nominations for the Timely deadline. More specifically, Order 809 requires,

> “each ISO and RTO within ninety days of the publication of a Final Rule in this proceeding to: (1) make a filing that proposes tariff changes to adjust the time at which the results of its Day-Ahead Market and reliability unit commitment process (or equivalent) are posted to a time that is sufficiently in advance of the Timely and Evening Nomination Cycles, respectively, to allow gas fired generators to procure natural gas supply and pipeline transportation capacity to serve their obligations; or (2) show cause why such changes are not necessary.”

In response to the Order, PJM filed changes to its longstanding Day-Ahead Market timeline that included moving the gate closure for bid and offer submissions from 12:00 p.m. to 10:30 a.m. PJM also committed to change the time of the publication of the Day-Ahead Market results from 4:00 p.m. to no later than 1:30 p.m. These changes will result in a decrease in the Day-Ahead Market clearing window from four hours to three hours.

---

To achieve the reduction in the Day-Ahead Market clearing time PJM has primarily focused on technology enhancements. However, PJM believes that technology should not be the sole focus to improve the Day-Ahead Market solution time. The market rules that govern the set of viable bids and offers that can be submitted into the Day-Ahead Market can increase both the complexity and time required to clear the market. Thus market rules should be investigated as a potential area to improve Day-Ahead Market clearing times.

With respect to virtual transactions, both simple transaction volume and unique transaction volume are significant contributors to the complexity of the Day-Ahead Market solution and solution time. Simple transaction volume can be thought of as total number of virtual transactions at any location for INCs and DECs or with any source and sink for UTCs. For example, 1,500 MWh of additional DECs at Zone X only would be an increase in simple volume. Unique transaction volume can be thought of as additional transactions with different locations for INCs and DECs or sources and sinks for UTCs.

Increases in simple transaction volume can negatively affect data transfer times because of increases in the information that needs to be moved from one system to another. It can also increase solution complexity because it can cause transmission constraints to bind which further complicates the Day-Ahead Market and thus requires additional processing time. However, because those transactions are submitted at the same location, the ability for multiple different constraints to bind because of increases in simple volume is relatively small.

Unique transaction volume has an even more significant effect on the solution time of the Day-Ahead Market. Unique transaction volume is more impactful in terms of both solution time and complexity because it creates additional injections and withdrawals at different locations on the system and increases the number of transmission constraints that need to be controlled. Additional transmission constraints require additional controlling actions to be taken and, therefore, increase the complexity of the solution. As the complexity of the Day-Ahead Market solution increases, the solution scales exponentially, not linearly. The exponential impact is caused by the less efficient computational methods required to solve the increasingly complex problem.

To minimize the added complexity resulting from general transaction volume PJM has implemented a soft cap of 3,000 UTC transactions per market participant. PJM enforces the soft cap only when it experiences performance issues that could be mitigated by reducing the UTC volume.

This cap only indirectly limits unique transaction volume. However, the unique transaction volume issue can be addressed directly by reducing the number of available trading locations. The direct approach to limiting unique transaction volumes would reduce the number of different locations where virtual transactions can inject and withdraw on the system as well as the number of different transmission constraints encountered in the Day-Ahead Market. The reduction in the number of transmission constraints would reduce solution complexity and improve overall solution times.
Observed Bidding Strategies

All of the strategies contained within this section are possible within the existing PJM market rules. PJM believes that these types of trades, while profitable, do not add value to the market commensurate with the revenues collected by them. Thus, to the greatest extent practicable, where the rules or market operations cannot be changed without compromising more fundamental objectives (such as system reliability), the optimal approach to resolving these kinds of problems is simply to eliminate the opportunity for inefficient trading. Such an approach avoids enforcement uncertainty as well as legal and policy debates as to whether participants who follow market rules can nonetheless manipulate markets. Rather than prosecuting participants after the fact for exploiting opportunities left open by market design and operations, certain circumstances can be defined to prevent virtual trading where such trading can reasonably be assumed to provide little or no efficiency value to the market.

Small Positions on Low-Risk Paths

This strategy is observed exclusively with UTCs and is characterized by taking very small low-risk, positions in the Day-Ahead Market over a number of days and weeks and waiting for a particular path to bind in real time consistent with the flow direction of the UTC in the Day-Ahead Market.

In this strategy, large volumes of UTCs are submitted throughout the system with very small price spreads of typically plus or minus $1.00/MWh or less. The large volume of UTCs submitted loads the transmission system causing a multitude of constraints in the Day-Ahead Market at very low shadow prices due to the low offer prices of the UTCs that are marginal on those paths. In real time, any price spread between the source and sink points that is in the same direction and of greater magnitude than what was purchased in the Day-Ahead Market now makes that UTC, as well as others in the same situation, profitable.

From the perspective of the market participant making this trade, this type of strategy provides many benefits with very low risk.

1. The position in the Day-Ahead Market can be taken with a very small monetary obligation.
2. Under the current rules, UTCs are not allocated uplift and therefore there is no risk that an allocation of uplift will make the transaction unprofitable.
3. There is a very low probability that the path binds in the opposite direction causing the transaction to lose money.

The third point above is important. The flow direction on a facility is based on the physics of the transmission system and is not a random variable. Therefore, absent topology changes in the area (which PJM posts) or uncommon weather patterns, the probability that the flows on a given facility change direction and do so to the extent that there is congestion opposite the flow of the UTC, is extremely small. The extremely low probability of this occurring combined with the first two points makes this a very common bidding strategy. The example below illustrates this strategy numerically.
Figure 10. Example of Low Risk UTC Position – Day-Ahead Market

Assume there is a 100 MWh UTC bid in on the path from A to B in the Day-Ahead Market. This UTC is submitted with a bid price of $0.05/MWh. This UTC will clear in day ahead any time the spread between A and B is less than or equal to $0.05/MWh. In this example, assume that spread is $0.01/MWh so that the UTC clears. The Day-Ahead Market settlement for the UTC in this hour would be a charge for the 100 MWh cleared from A to B, times the difference of $0.01/MWh between those two points, or $1.00. If this bidding strategy is put in place every hour of the day for a week with no congestion on that path or a neighboring one in real-time, absent administrative fees, the financial trader ends up spending only $168 in total (100 MWh * $0.01/MWh * 24 hours per day * 7 days per week).

As stated before, if the path being bid by the financial trader binds in real-time in the direction of A to B, the UTC will be profitable because the position taken in the Day-Ahead Market is so small. In the outcome shown below, there is congestion in real time between points A and B. In this case, the price at point B is $50/MWh and the price at point A is $10/MWh. For this given hour, the UTC profits $4,000 (100 MW * ($50/MWh - $10/MWh)).

Figure 11. Example of Low Risk UTC Position – Real-Time Market

PJM’s opinion is that this bidding behavior, while permitted by today’s market rules, does not provide the type of convergence sought through the inclusion of virtual transactions in the market. The position taken by the financial trader in the Day-Ahead Market is not significant enough to influence the commitment and dispatch of resources in the Day-Ahead Market such that the resulting commitment matched the controlling actions taken by PJM system operators in real-time to manage congestion. Additionally, if positions like this are taken over multiple days or weeks, as PJM has observed, the relatively small impacts to other market participants due to the additional congestion in day ahead grow larger. Finally, when the constraint does bind in real-time, the UTC has not provided any material convergence because clearing it only resulted in a day-ahead price spread of $0.01/MWh whereas the real-time split was $40/MWh.
In this example the impacts appear small when viewed in isolation but they can increase depending on the size of the position taken by the UTC and the amount of time over which it is not profitable. Because the risk associated with the bid is so low, the financial trader can afford to take the position over a significant period of time which increases the chances that the trader will have taken the position in Day-Ahead Market if the constraint ever binds in real time. When the transaction is profitable, the revenues paid come from balancing congestion and the marginal loss surplus. Because the UTC takes injection and withdrawal positions in the Day-Ahead Market, any difference between the energy component of LMP nets to zero. For example, if the energy component of LMP in day ahead was $5/MWh higher than real time, the injection portion of the UTC would make a $5/MWh profit whereas the withdrawal end would lose $5/MWh. As a result, the credits paid to UTCs when profitable come purely from congestion and marginal losses because they are different across the system. Large volumes of transactions of this type can significantly impact the funding in these areas.

Below is a histogram and accompanying chart showing the bidding activity for UTCs. As shown in the graphic below, despite the +/- $50/MWh bid cap on UTC trades, more than 95 percent of UTCs offered into the market are at a price between +/- $10/MWh. Further, more than 72 percent of all UTC bids are between +/- $2/MWh and more than half of the total activity falls between +/- $1/MWh. These types of bids are indicative of the low-risk positions that can be extremely lucrative without adding commensurate value to the market.

**Figure 12. UTC Activity by Offer Price 2012/2013 Through 2014/2015**
### Table 19. UTC Volumes and Revenues by Offer Price

<table>
<thead>
<tr>
<th>Price Group</th>
<th>Bid Volume (MWh)</th>
<th>Cleared Volume (MWh)</th>
<th>Total Revenue ($)</th>
<th>Bid Volume (% Total)</th>
<th>Cleared Volume (% Total)</th>
<th>Total Revenue (% Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between $1/MWh and -$1/MWh</td>
<td>1,944,017,063.8</td>
<td>583,234,516.0</td>
<td>205,399,911.0</td>
<td>50.1%</td>
<td>51.1%</td>
<td>32.0%</td>
</tr>
<tr>
<td>Between $2/MWh and -$2/MWh</td>
<td>2,817,091,856.7</td>
<td>808,596,221.3</td>
<td>298,096,610.1</td>
<td>72.6%</td>
<td>70.9%</td>
<td>46.5%</td>
</tr>
<tr>
<td>Between $10/MWh and -$10/MWh</td>
<td>3,705,847,375.1</td>
<td>1,055,814,343.7</td>
<td>508,025,079.0</td>
<td>95.4%</td>
<td>92.5%</td>
<td>79.2%</td>
</tr>
</tbody>
</table>

### Modeling Discrepancies

Another strategy PJM observes involves entities using UTCs to extract revenues from the market arising from modeling discrepancies between PJM’s day-ahead and real-time models. While INCs and DECs could be used to enact this strategy, they are not typically used in these cases because the UTC presents a much lower risk option because its energy positions net to zero and it receives no uplift allocation. These attributes make the UTC extremely attractive.

During the process of solving the Day-Ahead Market and calculating real-time LMPs, PJM encounters “dead buses”. A dead bus is completely disconnected from the system due to the topology surrounding that bus. Typically these are caused due to scheduled transmission outages. Because the bus is completely disconnected from the system, PJM cannot calculate an LMP for that bus as it does for all other connected buses. The dead bus scenario is addressed differently in the day-ahead and real-time technical systems.

In the day-ahead system, the dead bus is reconnected to the system so that virtual bids submitted at the dead bus can still be cleared. This method ensures that, even though a bus is dead, it remains a valid trading point. Once the bus is reconnected in day ahead, its price is reflective of the path through which it was reconnected to the system. In real time, there are no virtual bids to clear so the bus remains dead. In order to determine a price for the bus, the price from the nearest electrically equivalent node is used as a replacement for the dead bus.

Under most scenarios, these two methods produce prices at the dead bus that are electrically equivalent to each other. However, there are times when prices can deviate. When the discrepancy occurs in the PJM model, it becomes a focal point to attract opportunistic virtual transactions and creates a profit stream that provides no efficiency to the market.

Market participants do not have visibility into the logic by which dead bus situations are resolved in the day-ahead and real-time models. Therefore, market participants are likely to identify modeling discrepancies such as the one described above by analyzing the day-ahead and real-time nodal prices in a constrained area. If there are buses that are priced in the opposite direction relative to a reference point, it may be indicative of a location where arbitraging the potential price differences would be profitable.
For example, assume that Western Hub is the reference point and a market participant has noticed over several days that the price of node A is less than Western Hub in the Day-Ahead Market and higher than Western Hub in real time under the same congestion pattern.

Table 20. Western Hub and Node A Pricing During Modeling Discrepancy

<table>
<thead>
<tr>
<th>Node</th>
<th>Day-Ahead LMP</th>
<th>Real-Time LMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$58.00/MWh</td>
<td>$22.00/MWh</td>
</tr>
<tr>
<td>Western Hub</td>
<td>$30.00/MWh</td>
<td>$36.00/MWh</td>
</tr>
<tr>
<td>Payoff</td>
<td>$28.00/MWh</td>
<td>$14.00/MWh</td>
</tr>
</tbody>
</table>

Once this pricing profile has been noticed, a market participant may take a number of actions to create a profit. One example is a counterflow UTC from node A to Western Hub. For a 100 MWh counterflow UTC, the market participant is paid $280 (100 MWh * ($58/MWh - $30/MWh)) in the Day-Ahead Market to take the position against prevailing congestion. In real time, however, the prices are in the opposite direction such that the counterflow UTC profit increases in real time by $140 (-100 MWh * ($22/MWh - $36/MWh)).

Table 21. Settlement of UTC

<table>
<thead>
<tr>
<th>UTC Settlement</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day-Ahead</td>
<td>$280</td>
</tr>
<tr>
<td>Real-Time</td>
<td>$140</td>
</tr>
<tr>
<td>Total</td>
<td>$420</td>
</tr>
</tbody>
</table>

In this example, the market participant, while potentially unaware that the observed price profiles were the result of a modeling discrepancy, identified the anomaly and was able to profit from it. However, there was no ability for the market participant to converge prices in the Day-Ahead Market closer to real time because the cause of the price differentials was a modeling discrepancy. As in the prior example, the product typically used in this practice is a UTC and therefore the revenues to the profitable UTC come from balancing congestion and the marginal loss surplus. The market participant may not know that a modeling discrepancy is the cause of the issue, but rather merely observes the consistent price differences and submits virtual transactions that it believes will be profitable if the differences persist. Therefore, the participant may not knowingly be exploiting the modeling discrepancy. However, because the revenue extracted from the market by the participant that engages in such a strategy is collected at the expense of other market participants with no positive impact on the efficiency of the market operation, PJM believes that the opportunity to profit from such discrepancies must be minimized to the greatest extent possible.

Virtual Trading at Nodes with no Physical Settlement

The next two examples illustrate undesirable market implications of having virtual transactions submitted and cleared at a nodal level at buses where there is no physical settlement. PJM’s current market rules allow these transactions to occur and so the examples provided in this section are not intended to reflect bidding strategies that PJM
considers to be market manipulation. They show the outcome of legitimate trading activities under today’s rules that do not contribute to increasing the efficiency of the market operation.

**Implications to the Zonal Definition**

Today, INCs and DECs are able to be bid or offered at all hubs, zones, aggregates and individual nodes for which PJM posts a price. UTCs may be submitted at any source and sink combination that meets the following criteria set forth in Section 1.10.1A(c-1) of Attachment K of the Tariff.

1. The node is part of the historic set of eligible nodes that were available as sources and sinks for interchange transactions on the PJM OASIS.
2. The node is not on a load bus that is less than 69 kV.
3. The node is not connected to a generator of less than 100 MW.
4. The node is not part of a set of nodes determined by PJM to be electrically equivalent to another node on the system.

As of August 1, 2015, there were 11,295 biddable nodes for INCs and DECs and 437 nodes that are eligible source and sink points for UTCs. Of the 11,295 biddable nodes for INCs and DECs, 86.3 percent are nodes where there is no settlement of physical assets. Of the 437 eligible source and sinks for UTCs, 29.3 percent are nodes where there is no settlement of physical assets. Of the total 11,390 posted prices by PJM, only 13.6 percent actually have a physical settlement associated with them.

When virtual bids are cleared at points or sets of points where there are no physical settlements, it can create deviations in the power flow modeling of the Day-Ahead Market and ultimately the commitment, dispatch and pricing in the Day-Ahead Market compared to what actually occurs in real time. Under today’s rules, INCs and DECs are allocated an uplift charge for the energy deviation they create between the Day-Ahead Market and real time, but it is important to fully understand the implication of clearing an INC, DEC or UTC at the nodal level.

For example, consider load zone X in PJM composed of two pricing nodes, A and B, which each compose 50 percent of the zonal definition. The definition of a zone has several implications to the market and dispatch solutions. First, it determines the allocation of bids placed at that level to the individual buses for the purpose of power flow analysis. If there is a 20 MW fixed demand bid placed at this specific zone, for the purpose of solving the power flow, 10 MW of load would be placed at each of nodes A and B because of the fifty-fifty split in the definition. The second impact is the price calculation. The 50/50 split in load zone X between nodes A and B means that the zonal price for zone X will be composed of 50 percent of the price from node A and 50 percent from node B. Zonal definitions in the Real-Time Market in PJM are based on the load weighted average of the load buses in each zone. In the Day-Ahead Market they are based on the definitions used from a recent similar day in real time. This is done to ensure that the allocation of demand cleared in the Day-Ahead Market is done consistent with what was observed in real time.
If a market participant submits an INC, DEC or UTC that sources or sinks at zone X, the injection or withdrawal associated with that transaction is allocated in an equal share to nodes A and B. For a 100 MWh DEC at zone X, 50 MWh would appear at each of nodes A and B. However, if a 5 MWh INC was offered and cleared at node A only in the example above where there was a 20 MWh fixed demand bid at zone X, there would be some adverse implications. This would create a net load of 5 MWh at node A and 10 MWh at node B because the 5 MWh injection due to the INC at node A would net out of the load created by the fixed demand bid. This drives the day-ahead allocation of load within the zone away from what is anticipated in real time and consequently the surrounding transmission line flows away from the initial zonal model chosen from a similar day in real time. The cleared 5 MWh INC at node A has effectively changed the zonal definition used for the distribution of load to be 33 percent at node A and 67 percent at node B. This is different than the description used to mimic the real-time load distribution and is inconsistent with the day-ahead zonal LMP calculated for zone X which still uses the 50-50 split.

This transaction will be profitable any time the difference between the Real-Time LMP for node A is greater than the Day-Ahead LMP in excess of the uplift rate charged to the INC offer. Regardless of whether or not the bid is profitable, it has caused a difference between the distribution of load in zone X that PJM believes will occur in real time and what has cleared day ahead in a way that be cannot be replicated in real time.
This example shows several undesirable outcomes of an INC offer cleared at a nodal level. Similar examples can be constructed for DEC bids and UTCs as well.

1. The cleared INC changes the zonal definition for load distribution implemented by PJM to ensure that the cleared demand in the Day-Ahead Market follows the load allocations observed in real time.

2. As a result of #1, the INC changes transmission flows inconsistent with the patterns observed by PJM in real time and embedded in the zonal definition. This potentially impacts congestion patterns, resource commitments, market-clearing prices, uplift amounts and FTR funding.

3. As a result of #1, the day-ahead zonal load distribution and the zonal LMP calculation are not done with a consistent definition because the INC has changed the net withdrawal at node A.

**Congestion Patterns Inconsistent with Day-Ahead Market Demand Levels**

In addition to a creating a zonal load distribution that is inconsistent with the calculation of the zonal LMP, permitting virtual transactions at individual nodes can have other implications. The scenario below shows a potentially constrained transmission path, A-B, between zones X and Y. This example uses a constraint between two zones for simplicity but it can occur with constraints wholly contained within a zone as well. Additionally, the virtual transaction used in the example is a DEC although similar examples can be created with INCs and UTCs.

In the Day-Ahead Market, constraint A-B does not bind causing a uniform LMP of $50/MWh between zones X and Y. There is a fixed-demand bid at zone Y of 300 MWh that settles in the Day-Ahead Market for $15,000 ($50/MWh * 300 MWh).

**Figure 15. Day-Ahead Path A to B Between Zones X and Y**

In real time, the load in zone Y is now 400 MWh. The additional load zone Y has now caused congestion on path A-B such that the Real-Time LMP at A is $40/MWh and at B it is $70/MWh. The congestion also increases the zonal LMP of zone Y to be $60/MWh. The resulting balancing settlement for the load in zone Y would be $6,000 ($60/MWh * 100 MWh).
As a result of underbidding load in the Day-Ahead Market, the LSE of zone Y is able to procure its load at a discounted rate to what it would have had to pay in real time. This scenario, as illustrated above, provides an opportunity for virtual bidding to profit by converging the Day-Ahead Market and Real-Time Markets. Focusing in on the use of a DEC, a market participant can either submit a DEC at zone Y or at some individual node at the receiving end of the constraint (in this example use node B) in order to profit from converging the markets.

Based on the real-time clearing it is evident that node B has a higher distribution factor on constraint A-B than zone Y does because its price increases by more than zone Y’s does when the path is constrained. Assume in this case zone Y’s distribution factor on constraint A-B is 20 percent and node B’s is 40 percent. The relationship between these distribution factors means that a DEC at the zone will have to be twice as large as a DEC at B to impose the same flow on A-B. In this example, a 100 MWh DEC at zone Y or a 50 MWh DEC at node B would create similar congestion patterns between day ahead and real time and push day-ahead and real-time prices closer together. These different options have vastly different impacts on the commitment and dispatch of the resources in the Day-Ahead Market.

In the case where the DEC is submitted at B, congestion is created on path A-B, the prices between day-ahead and real-time converge at that point and the DEC makes a profit. However, the DEC at B does not address the amount of underbid load in the Day-Ahead Market that is causing the original divergence in congestion. Notwithstanding the location differences explained in the previous section, the 50 MW DEC at node B is 50 MWh short of the ideal activity that would converge both the prices and the resource commitments between day ahead and real time. Essentially, if the DEC at node B clears, the Day-Ahead Market load is still underbid by 50 MWh which means that PJM has to now schedule additional resources in the reliability commitment to meet the real-time needs of the system. If the DEC at zone Y clears, it requires more MWs to create the same amount of congestion and price convergence. The additional MWs required at the zone cover the difference in underbid load in zone Y and therefore the scheduling of resources in the Day-Ahead Market solution is also improved over the solution with the DEC at B.

Another outcome shown in the previous example is that allowing virtual transactions to occur at some locations, in this case an individual bus within a zone, can result in congestion levels in the Day-Ahead Market that are inconsistent with the system’s level of cleared demand. The prior example shows that in real time, 400 MWh of load in Zone Y results in congestion on the path A-B. However, as a result of the DEC at node B, the same congestion is
created in the Day-Ahead Market at a cleared demand level of 300 MWh. This phenomenon can be created in the opposite direction as well where there is more cleared demand in the Day-Ahead Market than load in real time yet congestion patterns are the same as a result of nodal virtual transactions relieving congestion. Both cases can result in inefficient resource commitment in the Day-Ahead Market. In the scenario provided in the example, PJM may commit resources in the Day-Ahead Market to resolve the congestion created by the DEC when what is really needed are resources scheduled to both control the congestion and serve the load that was underbid in Zone Y. In the second scenario where there is less congestion than the cleared demand levels in the Day-Ahead Market would otherwise reflect, PJM may commit resources to serve the additional day-ahead demand but not those that would be effective to resolve the additional congestion in real-time. In both cases, the result of the inefficient commitments can be price divergences between the Day-Ahead and Real-Time Markets in addition to uplift.

Recommended Improvements to Virtual Trading

Restated below are the recommendations put forth by PJM regarding virtual trading. The goals of these proposed rule changes are to maintain the benefits added to PJM’s markets by virtual trading, eliminate opportunities for inefficient trades to profit in the market, and level the allocation of uplift across all virtual transactions.

*Align the eligible trading points for INCs and DECs with nodes where either generation, load or interchange transactions are settled, or at trading hubs. This would include generator buses where active generators exist, load buses where load is settled nodally, load zones, interfaces and trading hubs.*

The intent of this change is to better align the use of INCs and DECs with the physical nature of the Real-Time Market while preserving the ability for such instruments to be used at trading hubs to facilitate longer-term hedges. Under today’s rules, INCs and DECs can be placed at nodes where there is no other settlement such as individual load buses. While these types of transactions may be profitable based on differences between the Day-Ahead and Real-Time Markets, they can result in transmission flows and load distributions that are inconsistent with physical reality of the system and potentially result in resource commitments in the Day-Ahead Market that do not align with the system needs in real-time. They may aide in price convergence at the specific node, but it is at a location where there is no other settlement and therefore no real change in the incentives to other market participants.

PJM believes that it is extremely important that the Day-Ahead Market produce a resource commitment that closely mimics the set of resources required to operate the system in real time. Allowing INCs and DECs at load buses that can change the load distribution of a zone in a manner inconsistent with PJM’s expectation of the real-time load distribution only makes achieving that goal more difficult and more costly. Additionally, INCs and DECs at individual load buses can create congestion patterns inconsistent with the load levels in the Day-Ahead Market. This can cause the Day-Ahead Market to commit resources to control congestion in a zone when what really is needed are additional resources to cover underbid load or the decommitment of resources due to overbid load.

Additionally, this change will reduce unique transaction volume which will improve Day-Ahead Market solution times. (See [Virtual Transaction Volumes](#) and [Day-Ahead Market Solution Time](#).)
**Alter the biddable locations for UTCs to generation buses as sources only, trading hubs, load zones and interfaces.**

For the same reasons as stated for INCs and DECs, in addition to others contained within this paper, PJM believes that the available bidding nodes for UTCs should be changed. In addition to hubs, zones and interfaces, PJM also proposes to allow generator buses as biddable UTC points but only as the source point of the transaction. Permitting UTCs at interfaces, hubs and zones is intended to continue to permit UTC trading but remove their ability to be used in ways that do not lead to market efficiency. Because these activities are typically enacted nodally, removing individual nodes will remove much of this ability. Notwithstanding the foregoing, PJM does propose to allow UTCs to be submitted with active generation buses as the source point only. This change is proposed to allow market participants trying to hedge generation or load against real-time congestion a method to do that.

Given the volume of UTC transactions, reducing the bidding points would significantly reduce the number of unique UTC transactions and significantly improve Day-Ahead Market performance.

**Allocate uplift to UTCs consistent with INC and DEC transactions. Currently, UTCs do not face a similar uplift charge as INCs and DECs, which has led to a significantly greater volume of UTCs as compared to INCs and DECs.**

The incentives created by the inconsistent allocation of uplift between UTCs, and INCs and DECs can be seen through the specific transaction volumes PJM has seen over the last few years. Currently, UTCs account for approximately 80 percent of all virtual transaction activity and collect more than 81 percent of the total virtual transaction revenues. UTCs have a much smaller risk profile than INCs and DECs due to the lack of allocation of uplift and no exposure to energy price risk between day ahead and real time. Allocating UTCs uplift consistent with INCs and DECs would better align the risk profiles of the transactions as they pertain to fees and help level the uneven playing field that exists today.

PJM believes the allocation of uplift to UTCs is a critical market design change that must be made to remove the competitive advantage afforded to UTCs today.

PJM is proposing these suggested market rule changes to stimulate discussion within the stakeholder process. The goal of this discussion is to retain all of the positive aspects that virtual transactions bring to the market while removing the bulk of the issues that they can create when used inefficiently under the existing rules.
APPENDIX A – Usage Statistics

Provided below are some high level statistics regarding the usage and profitability of virtual transactions in recent history. Table 22 shows the total cleared MWh for all virtual transaction types for each of the last three Planning Years and the percentage of the total cleared virtual transaction volume for which they accounted. Considering a cleared UTC as a single transaction as opposed to a paired INC and DEC, they average 79 percent of the total cleared virtual transaction activity over the period with DECs following at 12.5 percent and INCs at 8.5 percent.

Table 22. Cleared Virtual Transaction Volumes and Percentage of Total Virtual Transaction Activity by Year (MWh)

<table>
<thead>
<tr>
<th>Planning Year</th>
<th>DEC</th>
<th>INC</th>
<th>UTC</th>
<th>TOTAL</th>
<th>DEC</th>
<th>INC</th>
<th>UTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014/2015</td>
<td>51,458,286</td>
<td>36,195,902</td>
<td>255,036,657</td>
<td>342,690,845</td>
<td>15.0%</td>
<td>10.6%</td>
<td>74.4%</td>
</tr>
<tr>
<td>2013/2014</td>
<td>58,855,754</td>
<td>36,391,984</td>
<td>506,553,192</td>
<td>601,800,930</td>
<td>9.8%</td>
<td>6.0%</td>
<td>84.2%</td>
</tr>
<tr>
<td>2012/2013</td>
<td>70,732,526</td>
<td>49,661,232</td>
<td>379,581,312</td>
<td>499,975,069</td>
<td>14.1%</td>
<td>9.9%</td>
<td>75.9%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>181,046,566</td>
<td>122,249,118</td>
<td>1,141,171,160</td>
<td>1,444,466,845</td>
<td>12.5%</td>
<td>8.5%</td>
<td>79.0%</td>
</tr>
</tbody>
</table>

UTC volumes dropped significantly in September 2014 (month four of the 2014/2015 Planning Year) due to an open 206 proceeding that the FERC initiated regarding the allocation of uplift to virtual transactions. As a result, roughly nine of the 12 months in the 2014/2015 Planning Year saw an on-average 78 percent reduction in UTC volume from what it was in the first three months of the Planning Year. In cleared MWh, there was an average drop in UTC volume from 1.6 million MWh/day during the period of June 1, 2014 through September 8, 2014 to 0.36 million MWh/day from September 9, 2014 through May 31, 2015. Despite this significant reduction, cleared UTCs still account for almost 75 percent of the total cleared virtual transaction volume in that year.

As shown in Table 23, the revenues accumulated by UTCs far outweigh any other virtual transaction over the past three years. On-average over the last three planning years they collect just over 81 percent of the total credits paid to all virtual transactions which aligns with them accounting for about 80 percent of the total volume. Despite the reduction in volumes in the 2014/2015 Planning Year, UTC revenues still account for over 75 percent of all revenues paid to virtual transactions.

Table 23. Virtual Transactions Gross Revenues by Planning Year

<table>
<thead>
<tr>
<th>Planning Year</th>
<th>DEC Payoff</th>
<th>INC Payoff</th>
<th>UTC Payoff</th>
<th>Total Payoff</th>
<th>DEC</th>
<th>INC</th>
<th>UTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014/2015</td>
<td>$13,633,746</td>
<td>$50,109,473</td>
<td>$195,337,617</td>
<td>$259,080,836</td>
<td>5.26%</td>
<td>19.34%</td>
<td>75.40%</td>
</tr>
<tr>
<td>2013/2014</td>
<td>($61,805,475)</td>
<td>$92,103,332</td>
<td>$305,225,638</td>
<td>$335,523,495</td>
<td>-18.42%</td>
<td>27.45%</td>
<td>90.97%</td>
</tr>
<tr>
<td>2012/2013</td>
<td>$32,748,471</td>
<td>$20,715,093</td>
<td>$140,840,798</td>
<td>$194,304,362</td>
<td>16.85%</td>
<td>10.66%</td>
<td>72.48%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>($15,423,258)</td>
<td>$162,927,898</td>
<td>$641,404,054</td>
<td>$788,908,693</td>
<td>-1.96%</td>
<td>20.65%</td>
<td>81.30%</td>
</tr>
</tbody>
</table>
Table 24 shows the average gross payoff per cleared MWh of each transaction type for each year. On a per cleared MWh basis, INCs are the most profitable virtual transaction whereas DECs are the least profitable from a gross perspective.

### Table 24. Virtual Transaction Gross Payoff per Cleared MWh by Planning Year

<table>
<thead>
<tr>
<th>Planning Year</th>
<th>DEC</th>
<th>INC</th>
<th>UTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014/2015</td>
<td>$0.26</td>
<td>$1.38</td>
<td>$0.77</td>
</tr>
<tr>
<td>2013/2014</td>
<td>-1.05</td>
<td>$2.53</td>
<td>$0.60</td>
</tr>
<tr>
<td>2012/2013</td>
<td>$0.46</td>
<td>$0.42</td>
<td>$0.37</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>-$0.11</td>
<td>$1.44</td>
<td>$0.58</td>
</tr>
</tbody>
</table>

During the 2014/2015 Planning Year, the average Day-ahead Operating Reserve Rate was about $0.13/MWh while the Balancing Operating Reserve Rate for RTO deviations was about $1.20/MWh. This means that absent locational adders, each DEC paid $1.33/MWh in deviation charges and each INC paid $1.20/MWh. Because UTCs are currently not allocated uplift, their profitability is not impacted by these rates. If these uplift rates are subtracted from the gross profitability rates in Table 24, DECs become unprofitable in 2014/2015 and the net profitability for a cleared INC drops to about $0.18/MWh. On a net basis, the UTC becomes by far the most profitable transaction at $0.77/MWh due to the lack of uplift charge.

In addition to the aforementioned uplift charges, each virtual transaction is allocated a share of the administrative fees to maintain PJM’s technical systems. This fee is allocated on a per transaction basis and is uniform across all market transactions.

Table 25 shows the usage and payoff of virtual transactions by sector. The data below shows that the Other Supplier sector dominates virtual transaction activity and also collects by far the most revenues. With the exception of the Transmission Owner Sector, the revenues and the virtual transaction volumes follow each other.

### Table 25. Virtual Transaction Usage and Revenues by Sector – June 1, 2013 through May 31, 2015

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage Of Total Cleared MWh</th>
<th>Percentage Of Total Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Supplier</td>
<td>87%</td>
<td>111%</td>
</tr>
<tr>
<td>Transmission Owner</td>
<td>8%</td>
<td>-14%</td>
</tr>
<tr>
<td>Generation Owner</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Electric Distributor</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>