

# Energy and Ancillary Services Uplift in PJM

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## Purpose of this report

This report describes the different causes of energy market uplift in PJM Interconnection, and explains why payments tend to be concentrated over time to specific resources. This report provides an educational foundation to understand uplift and its causes, as well as the reasons behind observed patterns related to uplift in PJM markets.

## What is uplift?

Uplift credits are provided to generation or demand resources in certain situations to ensure these resources do not operate at a loss when following PJM dispatch instructions. Generation and demand resources that operate as requested by PJM are entitled, through currently applicable market rules, to recover the full value of their energy offers. In order for PJM to meet this obligation, supplemental compensation in the form of uplift is necessary when the full value of their offers is not recouped through the clearing prices for energy and ancillary services.<sup>1</sup>

Figure 1: Simple Example of a Resource Requiring Uplift Payments

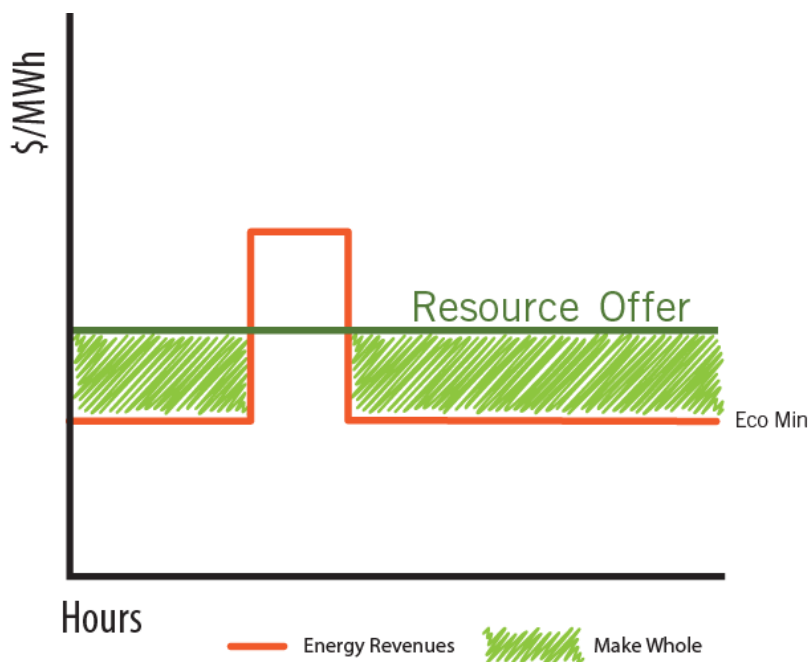


Figure 1 shows a resource's incremental energy offer at a certain cost.<sup>2</sup> Incremental energy cost is defined as the resource's variable cost per megawatt-hour and is submitted to PJM on a dollar per megawatt basis. It does not include the cost to start or operate the resource at minimum load (i.e. the resource's no-load cost). When the Locational Marginal Price (LMP) is greater than the offer, the resource is dispatched consistent with the LMP, but when the LMP is less than the incremental energy offer, the resource operates at its economic minimum. The resource could be operating at economic minimum for many reasons, including

being needed by PJM for reactive control or needed for only part of the day, but, due to a long minimum runtime, it is kept on even when operation is uneconomic for the resource. The green area in the figure represents the "make-whole payment" the

<sup>1</sup> Other causes of uplift, such as Virtual Transactions, will not be addressed in this report.

<sup>2</sup> PJM's market power mitigation procedures require that generation resources submit both cost-based and price-based offers. Cost-based offers are required to reflect marginal cost as defined in the PJM Cost Development Manual (M-15). Price-based offers may be greater than or less than the generator's calculated marginal cost. In the context of this paper, "cost" is used to refer to the value of the offer on which PJM schedules a resource without regard to whether it is cost-based or price-based.

resource must be paid to cover its cost of operating. If the resource were not paid this make-whole payment, then it would lose money relative to its accepted offer by operating at PJM's direction. Therefore, to encourage resources to operate at PJM's direction, resources are paid uplift needed to recover their costs to operate when called on by PJM to do so.

Accounting for these make-whole payments is performed on a daily basis in both the Day-Ahead and the Real-Time Energy Markets. Such resources are made whole through uplift credits that are then allocated as charges to Market Participants. Uplift in Ancillary Service markets occurs when resources are credited the difference between what they receive when providing Regulation or Synchronized Reserve services and what they would have received for providing energy output.

### ***Benefits and Drawbacks of Energy Uplift***

Uplift is an important feature in the PJM Energy Market design due to the number of variables associated with dispatching the system and maintaining control. While there is a tradeoff between lower energy prices and uplift because, generally, as uplift is reduced, energy prices will rise, and vice versa, no solution eliminates uplift completely. Uplift incentivizes appropriate behavior from all supply resources and aids PJM in maintaining system control because only resources that operate at PJM's direction are eligible for uplift payments. For reliable operation, PJM requires supply resources to follow directives without hesitation. When resources follow directives, uplift is sometimes necessary to guarantee that supply resources cover the total value of their energy offer. Unfortunately, uplift payments lack market transparency. This lack of transparency can inhibit investment because the market is not providing the appropriate price to signal needed locational investment (via higher prices). Uplift costs are out-of-market and, as such, are not included in the price signals that are visible to the entire market. Unlike energy prices, these uplift charges are not predictable and cannot be hedged on a forward basis. Therefore, system operators, such as PJM, generally strive to minimize uplift costs and operate the system so that the vast majority of a resource's costs of operation are reflected in transparent market clearing prices.

## **Sources of Energy Market Uplift**

### ***Incremental Energy and the Total Costs of Generation and Demand Resources***

LMP reflects the value of energy at a specific location and time that it is delivered. If the lowest-priced electricity could reach all locations without restrictions, prices would be the same across the entire grid.<sup>3</sup> Prices vary when there is transmission congestion because the lowest cost generation resources cannot be dispatched to serve all loads without violating transmission constraints. Instead, more-expensive supply resources, electrically closer to the load, are dispatched to meet the demand. As a result, LMP is higher in those congested locations.

LMP is comprised of three components: energy, congestion and losses. The energy portion of LMP is set by using the incremental energy offer of the marginal resource(s). A resource is marginal when it supplies the next megawatt of generation or demand reduction to meet demand or to control a transmission constraint.

Generation and demand resources incur additional costs which are not included in their incremental energy offers (the price and megawatt quantity pairs that are used to set the market energy price). The cost to start a resource and the cost for that

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<sup>3</sup> For the purposes of this discussion, the impact on pricing of transmission system losses is ignored.

resource to operate at minimum load without generating above that value (i.e. its no-load cost) are examples of such additional costs facing generation resources. Demand resources also can incur shutdown costs, which generally reflect costs of shutting down those activities consuming electricity (similar to a generation resource's start-up cost in which a generation resource incurs costs for starting the resource). PJM market rules allow resources to submit three-part offers that do not require sellers to incorporate startup/shutdown and no-load costs into their marginal energy offers. As a result, marginal prices do not include these additional offer components. Because items like startup/shutdown costs are not included in market clearing prices, revenues based on the market price may be insufficient to cover the total cost of the resource. These costs are often recovered by infra-marginal rents, which are the additional revenue earned when the clearing price exceeds the resource's offer. However, when a resource cannot fully recover these costs in the energy market, the additional amount required to make the resource whole is credited through uplift.

## Resource Parameters and Self-Scheduled Generation

Generation and demand resources do not operate in a perfectly flexible manner: PJM must accommodate numerous operational restrictions affecting units, including: minimum notification time (i.e. the time between when the resource operator is notified by PJM that the resource is being committed and the time when the start-up cycle can actually commence), the minimum time needed to start a resource, the minimum amount of time a resource needs to stay offline before being restarted once it is shut down, a minimum running time, and its maximum/minimum megawatt operating levels. Due to these requirements, resources may operate in hours when the market clearing price is lower than the costs incurred by the resource to operate. One common example of this situation occurs when a particular resource is needed by PJM on successive days but is not operationally flexible enough to completely shut down and then restart during the overnight period. In such cases, the resource is kept on through the overnight period at PJM's direction even though staying on overnight is not economical for the resource.

Resources can also self-schedule in real time even if they have no day-ahead market commitment. This increases price differences between the day-ahead and real-time markets, as the resource is operating as a price taker when it is self-scheduled and is placed at the bottom of the supply stack.<sup>4</sup> While self-scheduled resources themselves cannot receive uplift, they can cause uplift for pool-scheduled resources because more megawatts are being delivered onto the transmission system than originally anticipated, which may reduce LMP and necessitate uplift payments to pool scheduled resources.

## Voltage Constraints

Certain transmission constraints can be difficult to model in the algorithms that market operators use to dispatch the system and calculate LMPs. In order to include a transmission constraint in these algorithms, it must be represented as a thermal constraint where the megawatt flow on a given facility can be monitored relative to the megawatt flow limit on that facility. Constraints involving low voltage conditions must be translated into thermal constraints before they can be recognized by the dispatch algorithm. This translation is not always straightforward. Many times, low-voltage conditions can be modeled as thermal constraints by monitoring the flow on a set of transmission lines and ensuring the flow on those lines does not exceed a maximum level. However, determining which set of transmission lines to monitor that accurately represents a low

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<sup>4</sup> The supply stack is all of the available resources on the system, stacked from cheapest to most expensive. If a resource is added to the bottom of the stack, it can depress prices throughout the system.

voltage condition can be complex. In situations where an accurate thermal representation cannot be developed, resources that are operated to manage the low voltage condition will not set market prices and must be compensated through uplift.

Further, high-voltage conditions generally cannot be modeled as thermal constraints and, therefore, cannot be included in the price-setting algorithms. As a result, those resources operating to control high-voltage conditions generally will not set market prices and must be compensated through uplift.

### *Differences between the Day-Ahead and Real-Time Energy Markets*

There are a variety of reasons supply resources are paid uplift in the day-ahead market. For example, a resource could be scheduled economically in the Day-Ahead Energy Market, but its cost to start and no-load cost are not covered by market revenues. Also, a resource may be scheduled economically in the Day-Ahead Energy Market, but, due to its specified minimum run time, it also is scheduled to run uneconomically for some hours before it can be turned off. A resource could also be scheduled to operate uneconomically due to a reliability issue or requirement. Other examples of issues that may require a particular resource to be scheduled to operate uneconomically include: Automatic Load Rejection for Black Start purposes, voltage support or reactive service, and conservative operations.

Differences between Day-Ahead and Real-Time Energy Market prices also can cause uplift payments. There are many reasons why the prices in these two markets are not always aligned. For example, operational needs can occur in real-time that were not known when the Day-Ahead Energy Market cleared. This can result in Day-Ahead Energy Market prices not reflecting such real-time operational needs. While PJM resource commitment is based on economics, real-time operational needs may require PJM to dispatch resources out of economic merit order to meet these operational needs. This can make such resources eligible for uplift payments.

### **Lost Opportunity Cost**

Lost opportunity cost is an uplift cost. Lost opportunity costs result primarily from PJM scheduling a resource to operate in the Day-Ahead Energy Market but then not calling the resource to operate in real time. For example, a resource may be committed in the Day-Ahead Energy Market to operate during specified times, but is not needed in real-time due to factors such as anticipated lower demand, increased supply from interchange transactions, or increased self-scheduled generation that was not modeled in the Day-Ahead Energy Market. In these cases, the resource is compensated for lost opportunity cost if it received a Day-Ahead Energy Market award but was not run in real-time. This payment covers the resource's Day-Ahead Energy Market position and any Real-Time Energy Market charges the resource would have to pay. A generation resource's output also could be reduced in real time due to an operational issue on the system. In these cases, if the real-time LMP does not reflect the resource's offer during the time its output is reduced, the resource is made whole to the amount it could have earned had it operated at a level of output corresponding to the real-time LMP.

### **Interchange Volatility**

Interchange refers to energy imported into the PJM Control Area from control areas bordering PJM or exported from PJM. Variable imports and exports of energy to and from PJM, which react to PJM energy prices, influence prices and commitment decisions made by PJM. The amount of interchange between PJM and other control areas can be difficult for PJM to forecast because imports are not under PJM's control. Therefore, in preparation for periods of peak demand, PJM

schedules an adequate amount of internal resources to ensure that enough generation is available should interchange not be received as expected. Intraday resources must be scheduled hours in advance of the expected peak demand to ensure adequate supply. However, a peak demand lower than anticipated can necessitate uplift payments to resources that are no longer required to meet the expected peak demand. Similarly, if imports are higher than expected, output from generation resources internal to PJM may have to be reduced, creating uplift in the form of lost opportunity cost payments to such resources. In PJM, areas on the system that are chronically constrained and also significantly impacted by interchange require generation resources to be operated for long periods of time to maintain transmission security. However, these resources can be inflexible in their parameters, meaning they must remain continuously operating in order to perform when PJM needs them. This results in such units collecting significant uplift to cover their costs during periods when they operate uneconomically.

## Unexpected Outages

Unexpected outages of generation and transmission facilities can cause poor alignment between the Day-Ahead and Real-Time Energy Markets by creating scheduling differences between the two models. Operating additional generation resources uneconomically to support outages can lead to uplift. At times, planned and unplanned outages in an area can cause competing constraints that may require oscillating generation resources in that specific area, which in turn may cause other operational challenges in surrounding areas. This also may require operating additional generation resources in other areas uneconomically to address the additional operational issues, which also may require uplift payments.

## *Stability: Black Start, Reactive Interface Control and Reactive Service*

Resources can be called on for reliability in the Day-Ahead Energy Market or in real time for Black Start service, Automatic Load Rejection (ALR), reactive interface control, or reactive service.

In some areas, ALR is used to provide Black Start service. Generators with ALR capability disconnect from the grid in the event of a system disturbance and continue operating at minimum levels, which enables them to help restore the grid. A certain amount of Black Start megawatts are needed in each zone, and as prescribed in PJM's restoration plan, such resources are called on in order of least cost.

Reactive interfaces are sets of transmission lines that are listed in [PJM Manual 37](#). Resources are called on to manage these transfer interfaces based on reliability assessments that analyze, among other inputs, power flow studies, transfer limit calculations, load forecast, and day-ahead committed resources. Additional resources may be called on to control flows, and such resources are committed in order of least cost.

Resources can be committed for reactive service for many different reasons including: reactive power required by the power flow study based on PJM's reliability assessments, managing outages, actual high or low voltage in real-time, low voltage or voltage drop, and high voltage control. Reactive service is localized because reactive power does not travel well over long distances, so resources need to be located close to the problem they are addressing. This limits the number of resources that can help relieve these local operational issues. Resources supplying reactive power are always committed in least-cost order.



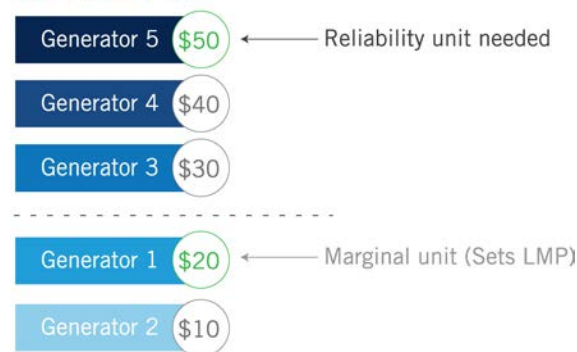
While all of these resources are committed on a least-cost basis, they may not have otherwise been economical to operate strictly for energy production, and, therefore, may require uplift payments.

## Why Reliability Resources Do Not Set LMP

The following example provides a conceptual understanding of why resources supplying reliability services, such as Black Start, ALR or reactive power, do not set LMP.

**Figure 2: Why Reliability Resources Do Not Set LMP**

### \$20 Paid By All



In this example, PJM has dispatched Generators 1 and 2 to meet system energy needs, but PJM also requires a resource for reliability purposes (Generator 5). Generator 5 is needed for voltage support in a local area and is the only generator that can help with the problem. Generator 5 would not have been dispatched based on economics, and it does not set LMP because all of the megawatts the unit produces when operating at its minimum output are not needed to solve the reliability issue. Therefore, the unit is operated at its minimum output level but is not marginal and does not set LMP. The

marginal resource (Generator 1) will set LMP at \$20, rather than Generator 5's offer of \$50. Here, an uplift payment of \$30 would need to be made to Generator 5 to cover its costs of operating because it only received \$20 from the Energy Market.

## Prudent Operations

Some scenarios that lead to increased uplift involve PJM committing resources for expected extreme system conditions. Such operations are typical during Cold Weather Alerts when additional resources are needed to operate and provide reserves to account for increased forced outage rates. As a result, sometimes more expensive resources are required to cover reserves and operate at their minimum output levels. In such cases, these resources are placed at the bottom of the supply stack and sometimes suppress LMPs. PJM may need to schedule additional generation to be available to mitigate any potential power shortfalls due to generator forced outages. The additional generation needed and committed after the execution of the Day-Ahead Energy Market increases the differences between day-ahead and real-time energy prices, but also creates situations where the resources called to supply reserves are not marginal, causing them to operate at their economic minimums. This may require uplift payments to these generators when LMPs are not adequate to cover their operational costs.

## Fuel Prices

Uplift is often correlated with high fuel prices. High natural gas prices can exacerbate the cost of uplift as resources operating at PJM's direction are more expensive than normal. In January 2014, due to restrictions on natural gas deliveries, many resources required PJM to maintain strict megawatt output levels during periods when they were uneconomic to operate to ensure they were available during peak conditions. Additionally, the lack of alignment between the gas and electric days often required PJM to commit to running gas-fired resources prior to the PJM Day-Ahead Energy Market. In these cases, some generation resources operated for long periods of time uneconomically, which in turn necessitated their receiving uplift payments.

Occasionally, PJM has seen generation needed in a particular part of the system where fuel prices have been erratic, and, in the case of natural gas, there have been periods when gas has been restricted in such areas. These situations required PJM operators to schedule generation resources in a conservative manner, resulting in conditions that required additional uplift payments described above.

## Sources of Ancillary Services Markets Uplift

Lost opportunity cost in Ancillary Service markets, also called product substitution cost, is the difference in net compensation between what a resource receives when providing regulation or synchronized reserve and what it would have received for providing energy output. The implementation of lost opportunity cost is different across the different Ancillary Service markets. Lost opportunity cost is most commonly incurred by a generation resource when its output is reduced from an otherwise economic output so that it can provide an Ancillary Service such as synchronized reserve or regulation. The goal of this lost opportunity cost calculation is to accurately capture the revenue that a generation resource has foregone in the energy market by producing less energy in order to provide an ancillary service that PJM requires. The clearing prices for synchronized reserve and regulation are calculated simultaneously every five minutes using a co-optimization algorithm. The five-minute prices are then integrated into an hourly clearing price and applied to all resources assigned to provide these services in that hour. After this process is complete, PJM determines whether certain units are eligible for uplift payments based on the hourly integrated results.

### *Synchronized Reserve Market*

The Synchronized Reserve market is an offer-based market, which clears resources that can be fully converted into energy within 10 minutes or customer load that can be removed from the system within 10 minutes at the request of PJM and that must be provided by equipment electrically synchronized to the system. These resources provide a quick increase of generation (or load reduction) to recover the balance between supply and demand after certain events occur, such as a resource going offline, large changes in interchange or low frequency conditions. The total price for synchronized reserve includes the resource offer plus estimated lost opportunity cost (plus energy usage and start-up costs, if any, for synchronous condensers only). To the extent the estimated lost opportunity cost is different from the final lost opportunity cost calculated using the final, hourly integrated LMP and the hourly clearing price is not at least equal to the resource's offer plus actual opportunity cost, uplift is paid to resources to ensure they are fully compensated for providing synchronized reserve.

### *Performance Based Regulation Market*

Regulation is an ancillary service that corrects for short-term changes in electricity usage that might affect the stability of the power system. It matches generation and load and adjusts generation output to maintain the desired frequency. The Regulation Market is an offer-based market and is co-optimized with the Synchronized Reserve Market. Regulation lost opportunity cost calculations are more complex than for other markets. In the Regulation Market, lost opportunity cost can occur when a resource is lowered or raised to provide regulation service. For a resource to be able to regulate, it has to be dispatched within its regulation range, determined by the minimum and maximum megawatt levels it can quickly operate between. If the resource is at its maximum output, it will have to be lowered into its regulation range to ensure that it is able to provide the full amount of regulation that the resource has cleared. Similarly, if the resource is at its minimum output, it will



have to be raised into its regulation range. Both scenarios create a lost opportunity cost component because the resource is operating at an output level above or below which would be dictated strictly by energy market economics. Regulation lost opportunity costs are a resource's foregone revenue or increase in costs, relative to the energy market, experienced by a resource when it provides regulation service. Similar to synchronized reserve, if the actual opportunity cost incurred by a regulating resource plus its offer price is greater than the clearing price for regulation during a given hour, then it is provided an uplift credit to ensure that it is fully compensated for providing regulation.

## Concentration of Energy Uplift for Specific Resources

Uplift payments tend to be concentrated among relatively few resources in PJM. In 2013, the top 10 resources received 38 percent of total energy market uplift credits. The concentration is due to the need for these resources to operate for specific reasons outside of purely economic market operation and because these resources generally are not flexible. As discussed above, PJM may request a resource to operate outside of economic merit order to address a wide range of issues, including transmission constraints, voltage issues, reactive interfaces, and interchange transactions. The local nature of these issues sometimes requires the same resources to address these issues on a recurring basis. For example, certain parts of the electrical system are chronically constrained and need specific, inflexible resources to manage those constraints. Major concentration of uplift credits to certain resources is linked to the relative inflexibility of those resources to manage those constraints, as well as the reliability needs of the system. Alternatively, concentration of uplift also may result from the difficulty of modeling some types of constraints in a particular area. PJM's models, as is the case with any security constrained commitment and dispatch algorithm, are based on thermal constraints, and such models have difficulty modelling voltage issues. Further, stability constraints are sometimes difficult to represent as thermal constraints, which can make it difficult to ensure that all resources operating to maintain a reliable system set marginal prices on a consistent basis.

**Figure 3: Percentage of Energy Uplift Credits Paid to the Top 10 Resources**

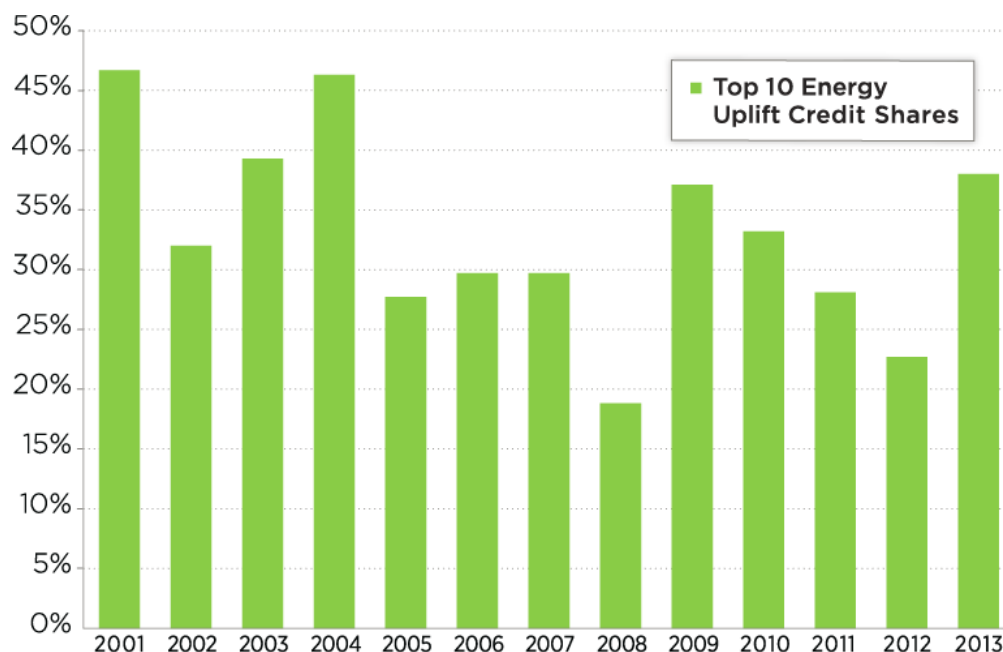


Figure 4 shows that energy uplift is consistently concentrated to a small amount of resources and has been for a long time.

## Current PJM Efforts to Reduce Uplift

In the summer of 2013, PJM stakeholders created the Energy Market Uplift Senior Task Force to evaluate causes for energy market uplift, develop ways to minimize uplift while maintaining prices that are consistent with operational reliability needs, and explore new methodologies for the allocation of uplift payments as directed by the PJM Markets and Reliability Committee. In the winter of 2013, stakeholders created a subgroup of the PJM Market Implementation Committee, called the Energy Reserve Pricing and Interchange Volatility Subgroup. This subgroup was tasked with finding solutions to better manage interchange and to better reflect operator actions in price solutions.

Figure 4: Total Uplift to Total Gross Billing Percentage (Monthly)

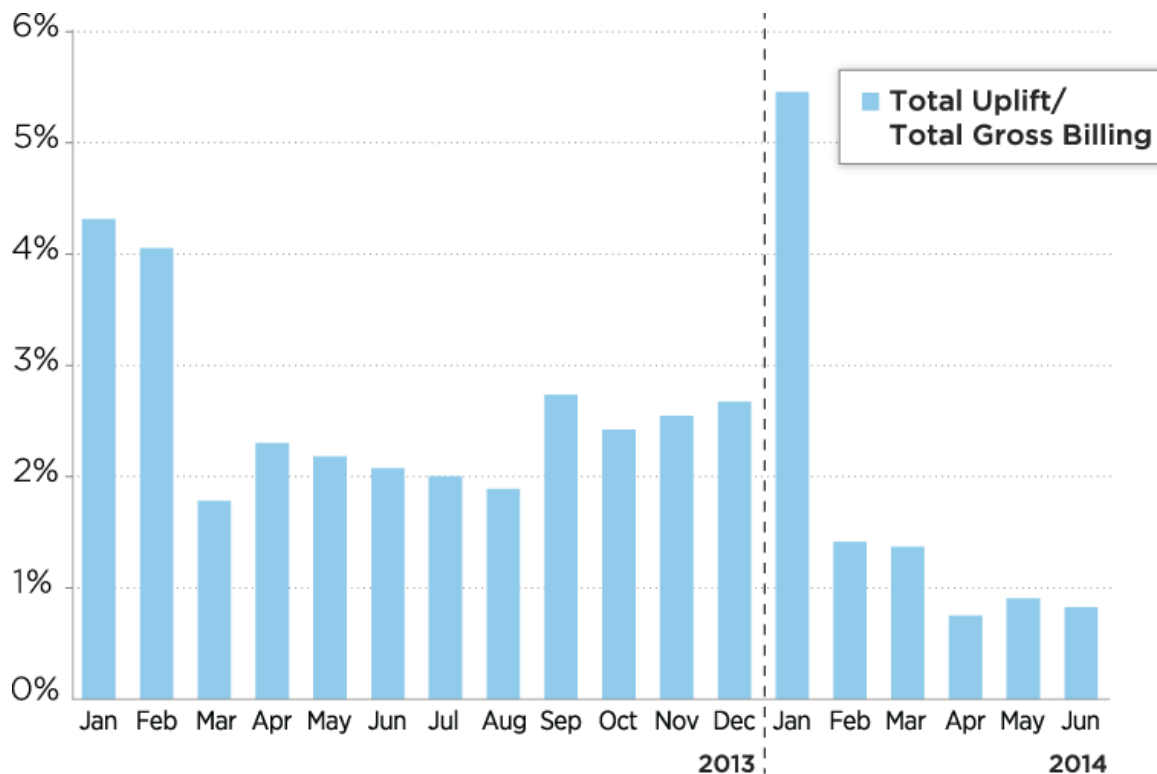


Figure 5 shows that, since February 2014, there has been a steady reduction in uplift payments. This is in part due to PJM's making changes to scheduling and price setting. PJM has reduced the amount of uplift paid to resources providing reactive service by committing less base-load generation for reactive services, instead relying on shorter-term, more flexible and higher marginal cost resources to manage those constraints. PJM also has implemented transmission upgrades identified through its Regional Transmission Expansion Planning Process, such as reactive devices to resolve chronic voltage issues. This has allowed PJM to resolve transmission conditions which previously required operating generation resources that were eligible for uplift payments. PJM is continually looking to implement improvements in the process by which costs of resources operating at PJM direction are reflected in prices. One of the ways this is accomplished is through closed loop interfaces, as described below.

## *Closed-Loop Interfaces*

PJM thinks that the most appropriate vehicle to reduce uplift costs is ensuring that scheduling protocols for resources are as efficient as possible and implementing pricing solutions to recognize the need for specific resources. PJM believes that these solutions, in conjunction with incorporating more transmission constraints in the real-time and day-ahead LMP calculations, will lead to a significant reduction in uplift costs and to LMP price formation that will better reflect system needs. PJM has created closed loop interfaces to set prices within a defined area to facilitate more accurate price formation in areas that are chronically constrained.

A closed-loop interface is a circular interface defined by a set of transmission lines that form a “pocket” with load and generation. These types of interfaces are used to translate voltage conditions into thermal constraints that can be used by the dispatch and pricing algorithms. This allows PJM’s pricing algorithms to use generation and/or load management within the closed loop to set the LMP, allowing the price to reflect generation and/or load management needed for reliability purposes. PJM began addressing chronic issues that contributed to uplift in the summer of 2014. Such issues included large incremental and no-load costs for resources operating at economic minimum megawatt levels for reactive/voltage support and thermal constraints. PJM models closed-loop interface constraints to allow these generators to set price within their constrained areas. This causes LMPs in areas where generation is running under these circumstances to reflect the incremental costs of the required resources and eliminates the need for the amount of uplift that would otherwise be necessary to make the resources whole to their offers. PJM also will begin to extend existing algorithm logic that sets prices for inflexible resources to generators operating at economic minimum for a transmission constraint (reactive/voltage or thermal) so such resources can set LMP. This will further increase the alignment of LMPs with the offers of the marginal resources required to manage transmission constraints.

## *Reserve Pricing*

Since the fall of 2013, PJM has been discussing with its stakeholders how to improve the pricing of reserves when additional resources are scheduled on the system in the anticipation of peak load conditions. As described above, when peak load conditions are expected to occur, system operators at times will schedule additional resources to ensure that reliability will be maintained, despite uncertainties with interchange volumes and the potential for additional forced outage rates. PJM and its stakeholders have been discussing how these additional reserves should be included in the PJM pricing algorithms so that both energy and reserves are priced accurately and uplift is minimized. In June 2014, PJM stakeholders approved process improvements whereby PJM would increase the Synchronized Reserve requirement on the PJM system when resources are scheduled during a Hot Weather Alert to account for interchange and availability uncertainty. Given the relatively mild summer PJM has experienced in 2014, PJM has not invoked these new procedures to date. PJM and its stakeholders continue to discuss a long-term solution for this issue and the potential exists to implement further enhancements prior to the upcoming winter period and the summer of 2015.