UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

PJM Interconnection, L.L.C.	)	Docket No. ER24-1772-000

PROTEST OF THE INDEPENDENT MARKET MONITOR FOR PJM

Pursuant to Rule 211 of the Commission's Rules and Regulations,[1] Monitoring Analytics, LLC, acting in its capacity as the Independent Market Monitor for PJM[2] ("Market Monitor"), submits this protest to the filing submitted by PJM on April 16, 2024 ("April 16th Filing").

In the April 16th Filing, PJM proposes to replace the current regulation market design that includes one product and two signals ("RegA and RegD") with a market design that includes one product and one signal in Phase 1, and that would include two products and one signal (Regulation-Up ("RegUp") and Regulation-Down ("RegDown") in Phase 2. PJM also proposes a number of other changes to the regulation market, including changes to lost opportunity cost calculations, changes in the inclusion of VOM in cost offers, changes in settlement calculation, changes in price formation, reduction in the market period from 60 to 30 minutes, and changes in performance score calculations.

The Commission should reject the April 16th Filing. PJM has not shown that its proposal for the Phase 2 market design, the ultimate proposed design, is just and reasonable. Important information needed to evaluate Phase 2 is not included. The details of how the

---

1 18 CFR § 385.211 (2023).

2 Capitalized terms used herein and not otherwise defined have the meaning used in the PJM Open Access Transmission Tariff ("OATT").

Phase 2 approach would operate are missing, and it is impossible to fully evaluate the proposal. The purported benefits and efficiencies of the Phase 2 market design are based on speculation. PJM's proposed Phase 2 market design depends on incomplete, undeveloped and undefined changes to PJM's optimization and lost opportunity cost calculations which make it impossible to evaluate as a replacement for the proposed Phase 1 market design. In addition, while substantial elements of the Phase 1 proposal are improvements to the market design, the remaining flaws should be corrected before the new design is approved. The April 16th Filing should be rejected as it has not been supported as just and reasonable.

I. PROTEST: PHASE 2

The Phase 2 proposal in the April 16th Filing has not been supported as just and reasonable. The design is not final, not supported, not tested and not fully understood by PJM. Because Phase in 2 is the proposed end state regulation market design in PJM's proposal, the April 16th Filing should be rejected.

A. PJM's Request for a Proposed Phase 2 Is Premature and Not Justified.

PJM does not provide sufficient evidence that the Commission should pre approve (two years in advance of development) PJM's Phase 2 proposal. PJM provides only speculative assertions of benefits (at 9, 18–21) of the Phase 2 market over the Phase 1 market. PJM does not provide evidence of the speculative benefits of the move from Phase 1 to Phase 2 design. PJM has indicated (at 16–17)) that it is not ready to implement Phase 2 for theoretical and technical reasons.

One of the many flaws with the current PJM Regulation Market is that PJM cannot properly clear the dual product, one market system with participants offering both RegA and RegD MW. PJM has not explained or demonstrated how the Phase 2 dual market clearing construct would work, particularly with unresolved logic involving variable LOC logic (at 49–50). PJM has indicated (at 16–17) that it is not ready from a theoretical or practical perspective to implement the Phase 2 market design, which is why PJM is proposing a two phase implementation. PJM requests (at 16–17) a "two-year developmental timeframe

because PJM will need to make significant software changes to the market clearing engine, the AGC, which is the program that runs every two seconds, calculating ACE—the definitional focus of Regulation, Area Regulation, and economic dispatch, telemetry, and settlement." In short, PJM is not ready. PJM does not know it will work. PJM has not done any systematic testing of the proposal. PJM has not addressed how dual offers would be handled in the clearing engine, in light of the issues associated with dual offers in the current market design. PJM has also not addressed if and how coupled offers would be allowed (i.e. the unit must clear both RegUp and RegDown), and how they will be dealt with in the clearing process.

PJM and the Market Monitor have provided evidence that there is a need to move from the current market design (one product, two signals, two inputs, one price) and to the fundamental idea of the proposed Phase 1 market design (one signal, one input, one price, one product). PJM has not provided evidence that there is a need to move from a the proposed Phase 1 market design (one signal, one input, one price, one product) to the proposed Phase 2 market design (one signal, two inputs, two prices, two products). The Commission should reject PJM's Phase 2 proposal.

B. Arguments that Phase 2 Will Provide More Efficient Results than Phase 1 Are Unsubstantiated.

PJM provides only speculation (at 2, 9) that a regulation up and regulation down market could provide incremental efficiency gains relative to a bidirectional only market.

Moving from a bidirectional regulation signal market to a separate regulation up and regulation down signal based market does not increase the regulation efficiency or the amount of regulation MW that a regulation resource can provide. Contrary to PJM's example (at 20), a unit that can provide 10 MW of bilateral signal regulation cannot provide 20 MW of regulation up service or 20 MW of regulation down service. Under the Phase 2 market design a regulation resource can clear and provide regulation up and regulation down service in the same market interval (30 minute market period). When clearing for both regulation up and regulation down service, the signal that the resource will follow, and the MW of regulation

provided will match what would be provided under the Phase 1 market design. A unit that can provide 10 MW of bilateral signal regulation can provide 10 MW of regulation up only service, 10 MW of regulation only down service or 10 MW of regulation up and regulation down service—not the 20 MW shown in PJM's example (Figure 2, at 20). Dividing the market into regulation up and regulation down does not increase the MW of regulation related movement that a resource can provide. Correcting this error in the PJM example changes their result, with Scenario 2 in under the Phase 2 market (Figure 2, PJM at 20) having a total cost equal to the Scenario 2 result under the Phase 2 market (Figure 1, PJM at 20).

While dividing the market into regulation up and regulation down does not change the MW of regulation related movement that a resource can provide, it does effectively double the number of regulation MW that PJM must procure to meet its regulation requirement and to maintain reliable service. Under the Phase 1 market design, if a market needs 10 MW of regulation up and 10 MW of regulation down, it can clear 10 MW of bidirectional regulation MW at a single price to meet the regulation requirement. Under the Phase 2 market design, if the a market needs 10 MW of regulation up and 10 MW of regulation down, it must clear 10 MW of regulation up MW and it must clear separately 10 MW of regulation down MW, for a total of 20 MW. If there is a positive price per regulation MW for regulation up and regulation down this means that the Phase 2 market cost to procure a fixed amount of regulation can be higher than Phase 1 market procuring the same fixed amount of regulation.

PJM has recognized that the Phase 2 market requires acquiring twice as many MW. This is the reason that PJM is cutting the total offer cap in half (from $100 to $50, at 31) and cutting the maximum offer cost adder in half (from $12 to $6, at 32). PJM is (at 49) also proposing vague, undefined and undeveloped changes to the lost opportunity cost determination used for settlements, where PJM will "consider both the Regulation-Up Service and Regulation-Down Service selected MW assignments" in the opportunity cost determination. PJM states (at 49) that it "will consider whether the resource provided Regulation-Up, Regulation-Down, or both—and consider that simultaneously—in

evaluating the foregone energy market revenues above cost or additional cost incurred to provide Regulation." In other words, PJM is working on logic to only count LOC in the regulation up or the regulation down market, not both, for a given resource that clears the market, and in some cases no LOC at all.

Absent undefined changes in LOC calculation, Phase 2 will be significantly more expensive than Phase 1. It is not clear that PJM's undefined and unvetted proposed changes to the LOC calculation will be consistent with the actual lost opportunity costs of regulation resources. It is not clear how the LOC rules set will be implemented in the market clearing software, particularly given the need to handle dual offers and the ability to clear as both regulation up and regulation down simultaneously. Absent a defined LOC rule set that can be reviewed and tested for internal consistency, it is impossible and premature to determine that the LOC rule set will allow Phase to provide an efficient market outcome relative to Phase 1.

C. PJM's Argument That LOC Will Be Lower Under Phase 2 Market Is Flawed.

A good portion of PJM's assertions regarding the speculative efficiency of Phase 2 market design relative to the Phase 1 market design is based on the assumption that resources operating at economic minimum can provide regulation up service without incurring an LOC and resources operating at economic maximum can provide regulation down service without incurring an LOC. PJM, for example, asserts (at 19) that a generation resource operating at economic minimum would be able to offer and participate in regulation up services without incurring lost opportunity cost. Similarly, PJM asserts (at 18) that a generation resource operating at economic maximum (like a wind resources) would not incur an LOC if offering and participating in regulation down services. These assertions are the basis of PJM conclusion in its examples (at 20) that Phase 2 will result in a more efficient market outcome than Phase 1. These assertions are incorrect and the logic is flawed.

It is unlikely that all resources providing regulation up will be at economic minimum and all resource providing regulation down will be at economic maximum. It is far more

likely that these extreme cases would be the lowest cost providers in the supply stack, not the marginal resources setting prices. If this is the case, there will be a positive price for regulation up and down, and the issue of paying for twice as many MW in Phase 2 as in Phase 1 weighs against the conclusion that Phase 2 is, without caveat, more efficient than Phase 1 results.

More importantly, the assumption that the LOC of a resource operating at economic minimum and providing regulation up service will not incur an LOC is incorrect and the assumption that the LOC of a resource operating at economic maximum and providing regulation down service will not incur an LOC is incorrect.

PJM's assertion of lower LOC and lower costs under Phase 2 is based on the incorrect assumption that the LOC for regulation up only service, or regulation down only service, should be calculated assuming the regulation set point is the average output of the resource while providing regulation. Assuming no trends/bias in area control error (ACE), a single regulation signal (which is assumed in both Phase 1 and Phase 2) will average zero over time, with the number of positive regulation intervals equal to the number of negative regulation intervals over time. This means that the average output of a regulation up resource will be higher than the regulation set point and the average output of a regulation down resources will be lower than the regulation set point. If the economic desired MW of the unit is equal to economic minimum and the resource is providing regulation up, the assumption that the LOC is zero is incorrect. Similarly, if the economic desired MW of the unit is equal to the economic maximum of the unit, the assumption that the LOC is zero is incorrect. This means the regulation set point is only relevant as the reference point for the LOC calculation of a resource if the resource is providing both regulation up and regulation down in the same market solution (bilateral service). This means that if the economic desired MW of the unit is equal to the regulation set point of a unit providing bilateral regulation service (both up and down regulation), the LOC will be zero. This demonstrates the case where the resource offering and clearing in a bilateral market has a zero LOC, but if offering into the regulation up and/or down market, the resource would have a positive LOC.

The assumption that bifurcating the market into regulation up and regulation down will always result in lower LOC (or zero LOC) and lower regulation costs is incorrect. This undermines PJM's assertion that the Phase 2 market results will necessarily be more efficient than the Phase 1 market results. PJM has recognized this problem in part (at 50–51), as raised by the Market Monitor in the stakeholder process, but has not incorporated this into its analysis of the purported benefits of Phase 2 over Phase 1 market results.

D. There Is No Basis for the Assertion that Moving From Phase 1 to Phase 2 Will Allow Renewable Resources to Participate in the Regulation Market.

PJM's assertions (*passim*) that moving from Phase 1 to Phase 2 will allow renewable resources like wind to participate in the market and this will make the Phase 2 market more efficient and lower cost than Phase 1 does not make any logical sense.

It cannot be the case that renewable resources will both increase the need for regulation due to their variable and unpredictable output (PJM at 2, 5, 12, 18) and can, at the same time, be a reliable source of regulation service (PJM at 18). If renewable resources are not dispatchable in a controlled and predicable way, they cannot provide reliable regulation service. If renewable resource can be dispatched in a controlled and predicable way, they can participate under Phase 1 as easily as Phase 2.

Nor is there any basis for the assertion that moving from Phase 1 to Phase 2 will allow renewable resources to economically participate as regulation resources. The hypothetical ability and desire by wind resources to participate as regulation resources is not evident. PJM points to California as an example (at 2), but fails to note that California does not have any wind resources providing regulation service. If regulation service was economic and practical for wind resources they could and would participate in PJM's current RegA/RegD market. PJM's current RegA/RegD market provides much higher payments for regulation service than the supposedly more efficient Phase 2 market. Renewable resources are paid more than LMP for their output. That would mean that any offer to provide regulation down would have to offset the lost revenues from both the lost LMP revenue but also the subsidy payments paid to renewable resources to provide energy. This would suggest that the

opportunity cost based regulation from a wind resource would be significantly higher than zero.

E. Arbitrary and Unjustified Changes to Cost Offer Components.

PJM is proposing changes to the "stated rules for cost-based offers to state which service, RegUp or RegDown, the specific cost may apply." In particular, PJM is proposing (at 31–32) that the capability offer cost component related to "the fuel cost increase due to the steady state heat rate increase resulting from operating the unit at lower megawatt output incurred from the provision of Regulation" only may be included in offers for RegDown service.

There are a number of issues with this proposal.

Regulation service does not contemplate steady state operation, so a cost that applies to steady state output level should not be assumed to be related to regulation service. In fact, according to PJM, this is a cost associated with operating at a point on the output supply less than economic maximum output, not for the provision of regulation service. It is not clear why the fuel cost associated with operating at a point below economic maximum output is not included in the heat rate curve used to generate a resource's cost based energy offer. If this cost component is supposed to capture heat loss for running at anything less than economic maximum then it should be included in the energy offer at any point below economic maximum, not in the regulation offer.

If, on the other hand, this cost component is contemplating heat loss from non steady state operation when providing regulation (which is not part of the description used by PJM) then it is not clear why it would only apply to regulation down service. All regulation service requires non steady state operation at output levels below economic maximum, by definition and without exception. There is no logical reason, if this is a real cost that was not included in the energy offer, that it would not apply to both the regulation offer up and the regulation offer down. If it applies to both regulation up and regulation down, then resources that clear for both Regulation Up and Regulation Down in the Phase 2 market will be paid twice as

much as they would under the Phase 1 market. This would be an issue with the fundamental logic of the Phase 2 market, not the cost component.

Fortunately for PJM, the logical conclusion from the description of the cost component that reflects "the fuel cost increase due to the steady state heat rate increase resulting from operating the unit at lower megawatt output" is that this cost does not apply to regulation service. The "fuel cost increase due to the steady state heat rate increase resulting from operating the unit at lower megawatt output" should already be part of the energy cost based offer of a resource. Including it in the regulation offer, regardless of direction, is double counting a cost in the current market design and the proposed Phase 1 and Phase 2 market designs. The Market Monitor recommends that the Commission eliminate "fuel cost increase due to the steady state heat rate increase resulting from operating the unit at lower megawatt output" as a component of regulation cost offers.

II. COMMENTS: PHASE 1

The April 16th Filing should be rejected, but PJM should be encouraged to refile the Phase 1 proposal, with appropriate modifications, as the end state regulation market design. With proposed modifications, the Phase 1 proposal is the basis for a significantly improved regulation market.

A. Overview of Market Monitor's Position on Phase 1

The Market Monitor supports the proposal to replace PJM's one product, two signal, two input, one price, inconsistent settlement market design with a one product, one signal, one input, one price regulation market design found in PJM's Phase 1 proposal.[3]

The Market Monitor agrees with these parts of PJM's Phase 1 Market proposal:

- The Market Monitor agrees with the PJM's Phase 1 proposal of a one product, one signal, one input, one price market for regulation.

---

[3] April 16th Filing at 10–17.

- The Market Monitor agrees with PJM's proposal to reduce the market period for regulation from 60 to 30 minutes.
- The Market Monitor agrees with the PJM's proposal to use the energy schedule on which a resource is dispatched for energy to calculate lost opportunity costs.
- The Market Monitor agrees with PJM's proposal to reduce the current 15 minute shoulder LOC calculation to a 10 minute shoulder LOC calculation.

The Market Monitor agrees in part and disagrees in part with these parts of PJM's Phase 1 Market proposal:

- The Market Monitor agrees with PJM that the current performance score needs to be modified, but disagrees with PJM's flawed proposed.
- The Marker Monitor agrees with PJM that there should be a minimum performance score threshold (25 percent) to receive compensation for regulation service, but the Market Monitor believes the same threshold should be used for eligibility to set the regulation price.
- The Market Monitor agrees with PJM that the current calculation of lost opportunity cost in the regulation market is flawed. The Market Monitor agrees with PJM that the LOC calculations should be based on a ramp limited output calculation. The Market Monitor disagrees with how PJM plans to calculate LOC over multiple market periods.
- The Market Monitor agrees with PJM's proposal to disallow VOM in cost based regulation offers by units with energy offers. The Market Monitor disagrees with PJM's proposal to allow VOM in the regulation cost offers of regulation only units (units without an energy offer). (Phase 1)

The Market Monitor disagrees with the following components of PJM's Phase 1 Market proposal:

- The Market Monitor disagrees with PJM that steady state heat rate loss for operating at output less than economic maximum is a cost associated with

providing regulation. Components of cost offers not clearly related to the provision of regulation service should be eliminated.

- The Market Monitor disagrees with PJM's arbitrary division of the market clearing price ($/MW) into a $/MW price for capacity and a $/MW price for performance. The market clearing price should reflect the most expensive offer that clear the market every 5 minutes, which is offer that is the largest the sum of the $/MW capacity and $/MW performance price in every 5 minute period.
- The Market Monitor disagrees with PJM's proposal to use historical values for performance and mileage to set 5 minute prices and then true up settlements based on actual 5 minute performance and mileage. The five minute prices paid to every resource and presented to the market should reflect actual 5 minute performance and mileage. Settlement should adjust compensation based on unit specific actual performance.
- The Market Monitor disagrees with PJM's failure to recognize that net revenues from the regulation market should count against uplift payments made to resources just like all other market revenues.

B. Agreements with Parts of Phase 1.

PJM's current regulation market design is severely flawed and is not efficient or competitive. The market results from the current market design do not represent the least cost solution for the defined level of regulation service. Most of these market design issues would be resolved with the move to a one product, one signal, one price, one market model which Phase 1 includes. The Market Monitor agrees with the most fundamental part of PJM's Phase 1 proposal to establish a one product, one signal, one input, one price market for regulation. The Market Monitor agrees with PJM's proposal to reduce the market period for regulation from 60 to 30 minutes. The Market Monitor agrees with the PJM's proposal to use the energy schedule on which a resource is dispatched for energy to calculate lost

opportunity costs. The Market Monitor agrees with PJM's proposal to reduce the current 15 minute shoulder LOC calculation to a 10 minute shoulder LOC calculation.

C. Partial Agreement/Disagreement with Parts of Phase 1

1. PJM's Proposed Performance Score Change is Flawed.

The Market Monitor agrees with PJM that the current performance score needs to be modified, but disagrees with PJM's inadequate proposed solution to the problem.

PJM's proposed change to the performance score (at 51–54) is based on the average regulation signal MW during the entire clearing interval. This change would unnecessarily alter the precision score of a unit based on the clearing interval behavior of the regulation signal and, as a result, would not reflect the actual regulation provided by the resource.

Regulation performance scores (0.0 to 1.0) measure the response of a regulating resource to its assigned regulation signal (RegA or RegD) every 10 seconds by measuring: delay, the time delay of the regulation response to a change in the regulation signal; correlation, the correlation between the regulating resource output and the regulation signal; and precision, the difference between the regulation response and the regulation requested.[4] Performance scores are reported on an hourly basis for each resource.

Each cleared resource in a class (RegA or RegD) is allocated a portion of the class signal (RegA or RegD). This portion of the class signal is based on the cleared regulation MW of the resource relative to the cleared MW for that class. This signal is called the Total Regulation Signal (TREG) for the resource. A resource that cleared 10 MW of capability (AREG) will be provided a percentage TREG signal asking for a positive or negative regulation movement between negative and positive 100 percent (10 MW) around its regulation set point.

---

[4] PJM "Manual 12: Balancing Operations," § 4.5.6 Performance Score Calculation, Rev. 48 (March 22, 2023).

The Market Monitor identified an issue with the current method of calculating the regulation performance score of a resource. The issue is that the delay and correlation components of the performance score do not accurately reflect how well a unit is responding to the regulation signal. These delay and correlation components can remain high, even when a unit is responding poorly to the regulation signal, and artificially inflate the overall performance score of the unit. For example, during the Winter Storm Elliott event, several units were not able to maintain their response to the regulation signal. These units received a precision score of zero, however, their delay and accuracy scores were near perfect (>0.95). This resulted in several units receiving regulation credits because their overall performance score was approximately 0.65 (each component of the performance score has an equal 1/3 weighting) despite not actually providing regulation. To address this issue, the Market Monitor has proposed to evaluate regulation performance using a precision based performance score, which would only depend on the difference between the regulation signal and the unit's response to that signal.

$$Performance\ Score_{10Sec} = 1 - ABS\left(\frac{RegOutputMW - SignalMW}{AReg}\right)$$

With the total performance score for the clearing interval being the average of each 10 second performance score. This means that, in a simplified 10 second interval, a unit that cleared 10 MW (AREG = 10 MW) responding with a steady 7.5 MW (75 percent of their total capability) to a positive pegged signal (Signal MW = 10; TREG = 100 percent) would logically receive a performance score of 0.75. The Market Monitor presented this recommendation to the regulation market senior task force.

PJM's proposed solution evaluates the 10 second error in a unit's output based on the average regulation signal MW during the entire clearing interval.[5]

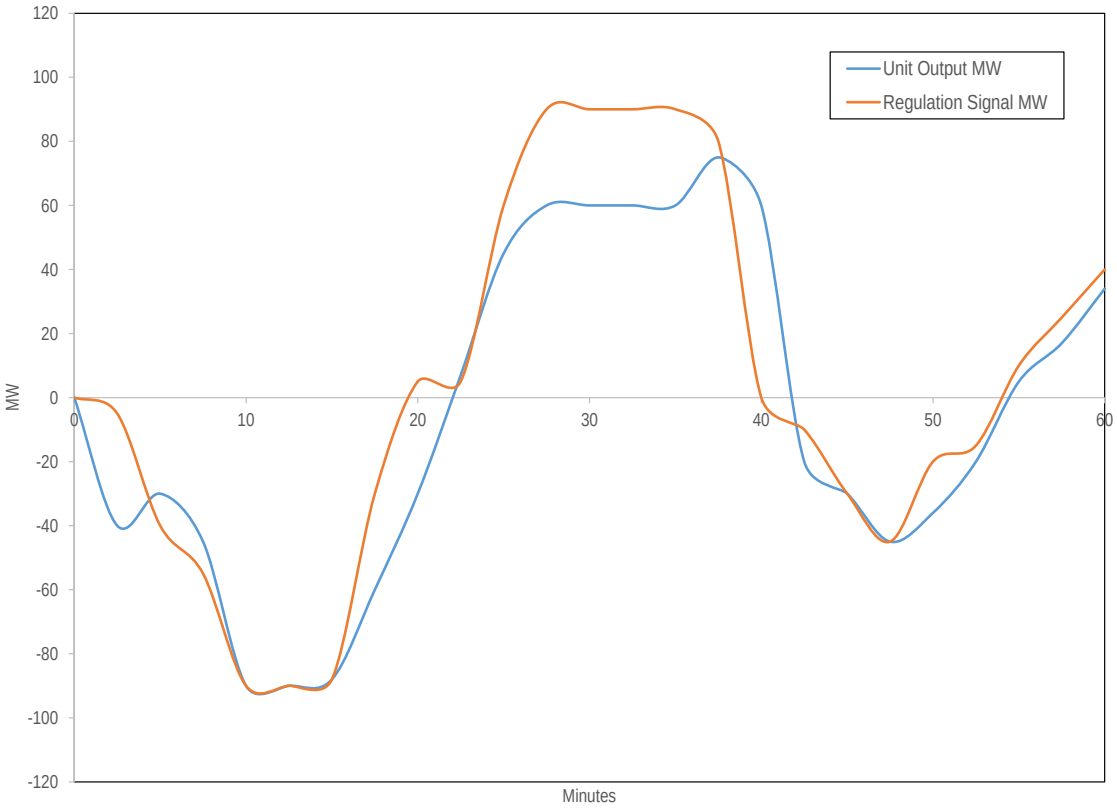
[5] The current regulation clearing interval is one hour. The proposed change is to move to a 30 minute clearing interval.

$$Performance\ Score_{10Sec} = 1 - ABS\left[\frac{(RegOutputMW - SignalMW)}{\left(\frac{ClearingIntervalAvgSignal + AReg}{2}\right)}\right]$$

This has the effect of scaling each 10 second performance score based on the clearing interval average of the overall regulation signal. Using this equation in the simplified case above would yield a performance score equal to 0.75 only if the clearing interval average signal is pegged, and less than 0.75 when the clearing interval average signal is close to zero.

Figure 1 illustrates an example unit that cleared 100 MW of regulation, following the regulation signal for one hour. Based on the MMU's proposed performance score calculation, the unit would have a performance score of 0.8450 for the hour. Using PJM's proposed calculation, that same unit would have a performance score of only 0.6981 for the hour because the clearing interval average signal is small (2.7 MW). If both the regulation signal and the unit's response in this example were shifted up (or down) by 10 MW, the MMU's result would remain the same, because it only depends on the response of the unit to the signal it is supposed to follow. The PJM result however, would change to 0.7249 because the clearing interval average signal would increase to 12.7 MW. PJM's calculation would lead to different results, based solely on the overall clearing interval average of the regulation signal; identical unit performance would yield different performance score results.

Figure 1 A unit providing 100 MW of regulation while following an almost neutral regulation signal



The Market Monitor recommends that PJM's current performance score calculations be changed to only include PJM's current calculation of the precision score. PJM's proposal to change the precision score should be rejected.

2. Performance Score Thresholds.

PJM proposes (at 58) that resources "that have a Real-time Settlement Interval performance score below 25% will be ineligible for Regulation credits for that Real-time Settlement Interval."

The Market Monitor agrees with this proposal. However, the Market Monitor believes that resources that score lower than 25 percent should be ineligible to set 5 minute regulation prices. This is only relevant if actual, rather than historic, performance scores are used to set price. (per Market Monitor recommendation above). The MMU also recommends that, to prevent gaming, there be a penalty enforced in the regulation market as a reduction in

performance score and/or a forfeiture of revenues when resource owners elect to deassign assigned regulation resources within the hour.

3. LOC Desired MW Determination.

PJM proposes (at 38–51) to replace the current 5 minute LOC calculation with a continuous tracking calculation (shadow dispatch) of desired MW at LMP ramp rate limited over the regulation commitment period. The PJM proposal will capture the physical limitation of the resource and expected output tracked over time as dictated by LMP. PJM will calculate ramp limited desired MW within and across 30 minute commitment periods for purposes of determining rank ordering for commitment cost and 5 minute price determination. As a result of this change to the calculation of the 5 minute LOC over time, PJM is proposing to eliminate the payment of after commitment period LOC uplift payments based on unlimited ramp.

The Market Monitor agrees with PJM's shadow dispatch based LOC proposal (at 38-51), with some exceptions. The Market Monitor agrees that the ramp rate limited desired MW output be used in the regulation uplift calculation, to reflect the physical limits of the unit's ability to ramp and to eliminate overpayment for opportunity costs when the payment uses an unachievable MW.

However, the Market Monitor believes that LOC should be based on differences in desired LMP based MW (ramp limited based on a shadow dispatch) and the actual output of the unit (not the regulation set point). The Market Monitor believes that the LOC used in the commitment period should be based on the commitment optimization engine's LMP assumed for the whole commitment period with cumulative ramp assumed within that period, starting from regulation set point assumed as the output of the unit at the beginning of the market period. The Market Monitor believes that the shadow dispatch should be used to determine the desired MW over time within the commitment period, but the shadow dispatch should reset desired MW equal to regulation set point at the beginning of every commitment period. The Market Monitor also believes that LOC calculation should account

for discontinuities in the ramp profile of the resource. If the unit could not move past a mill point (ramp discontinuity) during a regulation assignment, it should not be paid an LOC based on MW that ignore this reality. Further, the Market Monitor believes that ramp profiles should be included in any shadow dispatch based LOC calculation for a resource.

4. VOM Should Not Be Included in Any Regulation Offers.

PJM proposes (at 34) to eliminate Variable Operating Maintenance (VOM) from regulation cost offers of resources with energy offers. The Market Monitor agrees with this proposal. However, the Market Monitor believes that VOM should be eliminated from all regulation offers regardless of whether or not the regulation resource has an energy offer or not. VOM is not a cost that can be attributed to any specific incremental provision of regulation or energy output.

If the Commission determines that VOM should be allowed in regulation cost based offers, there should be a requirement for PJM to find a way, under Phase 2 rules, to parse VOM between regulation up and regulation down.

D. The Market Monitor disagrees with the following components of PJM's Phase 1 Market proposal:

1. Regulation Net Revenue as Offset to Uplift

The Market Monitor disagrees with PJM's failure to recognize that net revenues from the regulation market should count against uplift payments made to resources just like all other market revenues.

2. Steady State Heat Loss

The Market Monitor disagrees with PJM that steady state heat rate loss for operating at output less than economic maximum is a cost associated with providing regulation. Components of cost offers not clearly related to the provision of regulation service should be eliminated.

3. PJM's Proposed Compensation Determinations Use Historic Not Actual Prices.

PJM proposes (at 35–39) to make changes to the determination of compensation under both Phase 1 and Phase 2 proposals. Regulation payments are currently made through a two-part payment structure, with payments for capability based on a capability price times capability provide and a performance payment based on a performance price times the mileage ratio (RegD/RegA) times capability provided. PJM proposes to keep this basic structure. Prices are determined every 5 minutes.

PJM proposes (at 35–36) to set the five minute mileage clearing price based on historic mileage and historic performance scores, but then use actual mileage and actual performance to adjust individual resource payments. To do this, PJM proposes (at 36) to define a new mileage ratio that measures the resource's actual mileage in a given 5-minute settlement interval against the historic requested mileage for the Regulation dispatch signal. PJM claims (at 36) that this ratio will account for the fact that, during real-time operations, "PJM's Regulation signal may generate more or less mileage than the historic value used to determine the clearing price." To align compensation with the actual mileage of a resources, PJM is proposing (p. 36) to multiply the 5 minute performance price, determined using historic average mileage, with the ratio of actual mileage/historic mileage. PJM outlines (PJM at 37) the formula as follows:

> Mileage Credit (5-minute) = Reg Assigned MW * 5-minute actual performance score * 5-minute Mileage Ratio * Mileage Clearing Price / 12.
>
> Where 5-minute Mileage Ratio = Product Signal Actual 5-minute Mileage Product Signal Historical Mileage.

PJM's proposal will result in a 5 minute price for performance that will not reflect the marginal offer of the marginal unit based on actual mileage and performance. It will reflect an estimate of the marginal offer based on historic mileage and performance scores. Resource specific compensation will have the historic based price increased or decreased by a mileage ratio and unit specific actual performance score that "corrects" the price received.

The Market Monitor disagrees with this proposal. The objective of 5 minute pricing should be to have prices that reflect the marginal offer of the marginal unit. Instead of using historic values for performance of the "marginal unit" and the historic mileage of the signal to set 5 minute prices, PJM should use the actual 5 minute performance of the marginal unit and the actual mileage of the regulation signal to determine prices every 5 minutes. PJM's proposal for determining price and for determining individual resource compensation should be rejected.

More generally, PJM's proposal to retain the current artificial break out of the components of total price into a "capability clearing price" and a "performance clearing price" should be rejected. Under the current and proposed structure, every 5 minutes PJM will determine the marginal (most expensive unit) on the basis of the sum of its $/MW offer for capability (which includes 5 minute LOC/MW) and the $/MW mileage price. This is the total price per regulation MW for the 5 minute interval. PJM then sorts the $/MW performance offer price of every cleared resources and declare the highest cleared performance/MW price to be the marginal $/MW performance price. PJM then subtract this $/MW performance price from the total price per regulation MW and call this difference the $/MW capability price. There should be a single price/MW for regulation based on the sum of the components of the marginal unit in every 5 minute period. The current practice of arbitrarily breaking the total price/MW into components needlessly complicates and obfuscates the market results, serves no other purpose than to obfuscate the results.

III. BACKGROUND: ISSUES WITH CURRENT REGULATION MARKET DESIGN

A. The Current Market Design.

PJM's regulation market design is a result of Order No. 755.[6] The objective of PJM's regulation market design is to minimize the cost to provide regulation using two resource types in a single market.

The regulation market includes resources following two signals: RegA and RegD. Resources responding to either signal help control ACE (area control error). RegA is PJM's slow oscillation regulation signal and is designed for resources with the ability to sustain energy output for long periods of time, with slower ramp rates. RegD is PJM's fast oscillation regulation signal and is designed for resources with limited ability to sustain energy output and with faster ramp rates, i.e. batteries. Resources must qualify to follow one or both of the RegA and RegD signals, but will be assigned by the market clearing engine to follow only one signal in a given market hour.

The PJM regulation market design includes three clearing price components: capability ($/MW, based on the MW being offered); performance ($/mile, based on the total MW movement requested by the control signal, known as mileage); and lost opportunity cost ($/MW of lost revenue from the energy market as a result of providing regulation). The marginal benefit factor (MBF) and performance score translate a RegD resource's capability (actual) MW into marginal effective MW and offers into $/effective MW.

The regulation market solution is intended to meet the regulation requirement with the least cost combination of RegA and RegD. When solving for the least cost combination of RegA and RegD MW to meet the regulation requirement, the regulation market will substitute RegD MW for RegA MW when RegD is cheaper. Performance adjusted RegA MW are used as the common unit of measure, called effective MW, of regulation service. All resource MW (RegA and RegD) are converted into effective MW. RegA MW are converted

---

[6] Order No. 755, 137 FERC ¶ 61,064 at P 2 (2011).

into effective MW by multiplying the RegA MW offered by their performance score. RegD MW are converted into effective MW by multiplying the RegD offered by their performance score and by the MBF. The regulation requirement is defined as the total effective MW required to provide a defined amount of area control error (ACE) control.

The regulation market converts performance adjusted RegD MW into effective MW using the MBF in the PJM design. The MBF is used to convert incremental additions of RegD MW into incremental effective MW. The total effective MW for a given amount of RegD MW equal the area under the MBF curve (the sum of the incremental effective MW contributions). RegA and RegD resources should be paid the same price per effective MW.

The marginal rate of technical substitution (MRTS) is the marginal measure of substitutability of RegD resources for RegA resources in satisfying a defined regulation requirement at feasible combinations of RegA and RegD MW. While resources following RegA and RegD can both provide regulation service in PJM's Regulation Market, PJM's joint optimization is intended to determine and assign the optimal mix of RegA and RegD MW to meet the hourly regulation requirement. The optimal mix is a function of the relative effectiveness and cost of available RegA and RegD resources.

At any valid combination of RegA and RegD, regulation offers are converted to dollars per effective MW using the RegD offer and the MBF associated with that combination of RegA and RegD. The marginal contribution of a RegD MW to effective MW is equal to the MRTS associated with that RegA/RegD combination.

For example, a 1.0 MW RegD resource with a total offer price of $2 per MW with a MBF of 0.5 and a performance score of 100 percent would be calculated as offering 0.5 effective MW (0.5 MBF times 1.00 performance score times 1 MW). The total offer price would be $4 per effective MW ($2 per MW offer divided by the 0.5 effective MW).

B. Current Market Design Issues: MBF not Correctly or Consistently Implemented.

PJM's current regulation market design is severely flawed and is not efficient or competitive. The market results do not represent the least cost solution for the defined level of regulation service.

In a well functioning market, every resource should be paid the same clearing price per unit produced. That is not true in the PJM Regulation Market. RegA and RegD resources are not paid the same clearing price in dollars per effective MW. RegD resources are being paid more than the market clearing price. This flaw in the market design has caused operational issues, has caused overinvestment in RegD resources.

If all MW of regulation were treated the same in both the clearing of the market and in settlements, many of the issues in the PJM Regulation Market would be resolved. However, the current PJM rules result in payments to RegD resources of up to 1,000 times the correct price.

RegA and RegD have different physical capabilities. In order to permit RegA and RegD to compete in the single PJM Regulation Market, RegD must be translated into the same units as RegA. One MW of RegA is one effective MW. The translation is done using the marginal benefit factor (MBF). As more RegD is added to the market, the relative value of RegD declines, based on its actual performance attributes. For example, if the MBF is 0.001, a MW of RegD is worth 0.001 MW of RegA (or 1/1,000 of a MW of RegA). This is the same thing as saying that 1.0 MW of RegD is equal to 0.001 effective MW when the MBF is 0.001.

Almost all of the issues in PJM's Regulation Market are caused by the inconsistent application of the MBF. Because the MBF is not included in settlements, when the MBF is less than 1.0, RegD resources are paid too much. When the MBF is less than 1.0, each MW of RegD is worth less than 1.0 MW of RegA. The market design buys the correct amount of RegD, but pays RegD as if the MBF were 1.0. In an extreme case, when the MBF is 0.001, RegD MW are paid 1,000 times the correct price. If the market clearing price is $1.00 per MW of RegA, RegD

is paid $1,000 per effective MW. Resolution of this problem requires that PJM pay RegD for the same effective MW it provides in regulation, 0.001 MW.

The MBF function, as implemented in the PJM Regulation Market, is not equal to the MRTS between RegA and RegD. The MBF is not consistently applied throughout the market design, from optimization to settlement, and market clearing does not confirm that the resulting combinations of RegA and RegD are realistic and can meet the defined regulation demand. The calculation of total regulation cleared using the MBF is incorrect.[7]

The result has been that the PJM Regulation Market has overprocured RegD relative to RegA in most hours, has provided a consistently inefficient market signal to participants regarding the value of RegD in every hour, and has overpaid for RegD. This over procurement has degraded the ability of PJM to control ACE in some hours while at the same time increasing the cost of regulation. When the price paid for RegD is above the level defined by an accurate MBF function, there is an artificial incentive for inefficient entry of RegD resources.

PJM and the Market Monitor filed a joint proposal with the Commission on October 17, 2017, to address issues with the inconsistent application of the marginal benefit factor throughout the optimization and settlement process in the PJM Regulation Market, but the proposal was rejected by the Commission.[8]

The MBF used in the PJM Regulation Market do not accurately reflect the MRTS between RegA and RegD resources under the old market design, and it does not accurately reflect the MRTS between RegA and RegD resources under the current design. The MBF function is incorrectly defined and improperly implemented in the current PJM Regulation Market.

---

[7] The MBF, as used in this report, refers to PJM's incorrectly calculated MBF and not the MBF equivalent to the MRTS.

[8] 162 FERC ¶ 61,295 (2018), *reh'g denied*, 170 FERC ¶ 61,259 (2020).

The MBF should be the marginal rate of technical substitution between RegA and RegD MW at different, feasible combinations of RegA and RegD that can be used to provide a defined level of regulation service. The objective of the market design is to find, given the relative costs of RegA and RegD MW, the least cost feasible combination of RegA and RegD MW. If the MBF function is incorrectly defined, or improperly implemented in the market clearing and settlement, the resulting combinations of RegA and RegD will not represent the least cost solution and may not be a feasible way to reach the target level of regulation.

The MBF is not included in PJM's settlement process. This is a design flaw that results in incorrect payments for regulation. The issue results from two Commission orders. From October 1, 2012, through October 31, 2013, PJM implemented a Commission order that required the MBF to be fixed at 1.0 for settlement calculations only. On October 2, 2013, the Commission directed PJM to eliminate the use of the MBF entirely from settlement calculations of the capability and performance credits and replace it with the RegD to RegA mileage ratio in the performance credit paid to RegD resources, effective retroactively to October 1, 2012.[9] That rule continues in effect. The result of the current Commission order is that the MBF is used in market clearing to determine the relative value of an additional MW of RegD, but the MBF is not used in the settlement for RegD.

If the MBF were consistently applied, every resource would receive the same clearing price per marginal effective MW. But the MBF is not consistently applied and resources do not receive the same clearing price per marginal effective MW.

The change in design decreased RegA mileage (the change in MW output in response to regulation signal per MW of capability), increased the proportion of cleared RegD resources' capability that was called by the RegD signal (increased REG for a given MW) to better match offered capability, increased the mileage required of RegD resources and changed the energy neutrality component of the signal from a strict 15 minute neutrality to a

---

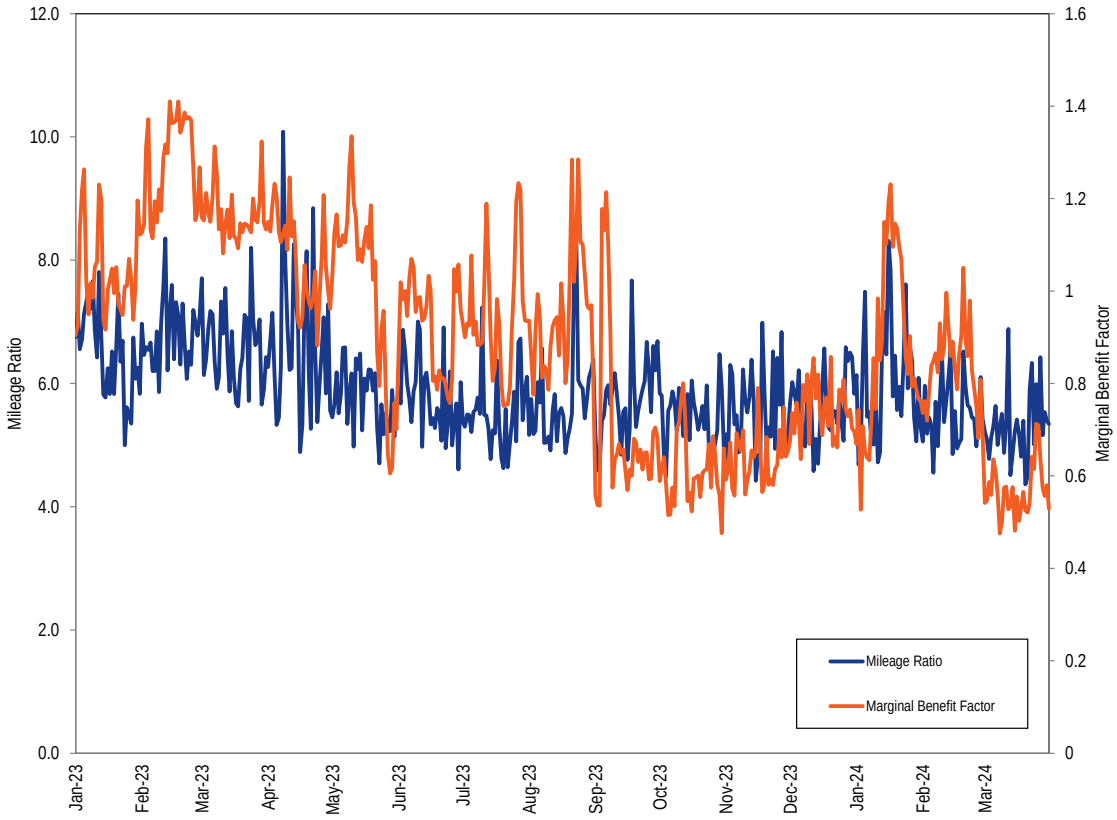
[9] 145 FERC ¶ 61,011 (2013).

conditional 30 minute neutrality. The changes in signal design increased the mileage ratio (the ratio of RegD mileage to RegA mileage). In addition, to adapt to the 30 minute neutrality requirement, some RegD resources decreased their offered capability to maintain their performance.

Figure 2 shows the daily average MBF and the mileage ratio. The weighted average mileage ratio decreased from 6.62 in the first three months of 2023, to 5.62 in the first three months of 2024 (a decrease of 15.1 percent). The average MBF decreased from 1.15 in the first three months of 2023, to 0.76 in the first three months of 2024 (a decrease of 34.2 percent). The high mileage ratios are the result of the mechanics of the mileage ratio calculation. Extreme mileage ratios result when the RegA signal is fixed at a single value (pegged) to control ACE and the RegD signal is not. If RegA is held at a constant MW output, mileage is zero for RegA. The result of a fixed RegA signal is that RegA mileage is very small and therefore the mileage ratio is very large.

These results are an example of why it is not appropriate to use the mileage ratio, rather than the MBF, to measure the relative value of RegA and RegD resources. In these events, RegA resources are providing ACE control by providing a fixed level of MW output which means zero mileage, while RegD resources alternate between helping and hurting ACE control, both of which result in positive mileage.

Figure 2 Daily average MBF and mileage ratio: January 2023 through March 2024



The increase in the average mileage ratio caused by the signal design changes introduced on January 9, 2017, caused a large increase in payments to RegD resources on a performance adjusted MW basis.

Table 1 shows RegD resource payments on a performance adjusted actual MW basis and RegA resource payments on a performance adjusted MW basis by month, from January 1, 2023, through March 31, 2024. The average regulation market clearing price in the first three months of 2024 was $10.16 lower than in the first three months of 2023 (See Table 1.) In the first three months of 2024, RegD resources earned 19.6 percent more per performance adjusted actual MW than RegA resources (28.6 percent in the first three months of 2023) due to the inclusion of the mileage ratio in RegD MW settlement.

Table 1 Average monthly price paid per performance adjusted actual MW of RegD and RegA: January 2023 through March 2024

		Settlement Payments		
		RegD	RegA	Percent RegD Overpayment
Year	Month	($/Performance Adjusted MW)	($/Performance Adjusted MW)	($/Performance Adjusted MW)
2023	Jan	$21.52	$17.01	26.6%
	Feb	$21.57	$15.49	39.2%
	Mar	$20.50	$16.82	21.9%
	Apr	$27.77	$23.00	20.8%
	May	$31.40	$24.78	26.7%
	Jun	$27.01	$20.64	30.9%
	Jul	$26.74	$22.53	18.7%
	Aug	$24.85	$20.62	20.5%
	Sep	$27.41	$22.73	20.6%
	Oct	$36.21	$31.66	14.4%
	Nov	$21.56	$19.69	9.5%
	Dec	$22.24	$17.97	23.8%
Yearly		$25.76	$21.12	22.0%
2024	Jan	$42.62	$35.76	19.2%
	Feb	$23.01	$19.04	20.9%
	Mar	$27.25	$22.86	19.2%
Total		$31.14	$26.04	19.6%

The current settlement process does not result in paying RegA and RegD resources the same price per effective MW. RegA resources are paid on the basis of dollars per effective MW of RegA. RegD resources are not paid in terms of dollars per effective MW of RegA because the MBF is not used in settlements. Instead of being paid based on the MBF, (RMCCP + RMPCP)*MBF, RegD resources are paid based on the mileage ratio (RMCCP + (RMPCP*mileage ratio)). Because the RMCCP component makes up the majority of the overall clearing price, when the MBF is above one, RegD resources can be underpaid on a per effective MW basis by the current payment method, unless offset by a high mileage ratio. When the MBF is less than one, RegD resources are overpaid on a per effective MW basis, unless offset by a low mileage ratio. The average MBF was less than 1.0 in the first three months of 2024 (0.76).

The effect of using the mileage ratio instead of the MBF for purposes of settlement is illustrated in Table 2. Table 2 shows how much RegD resources are currently being paid, adjusted to a per effective MW basis, on average, in 2023 and the first three months of 2024 under the current rules, compared to how much RegD resources should have been paid if

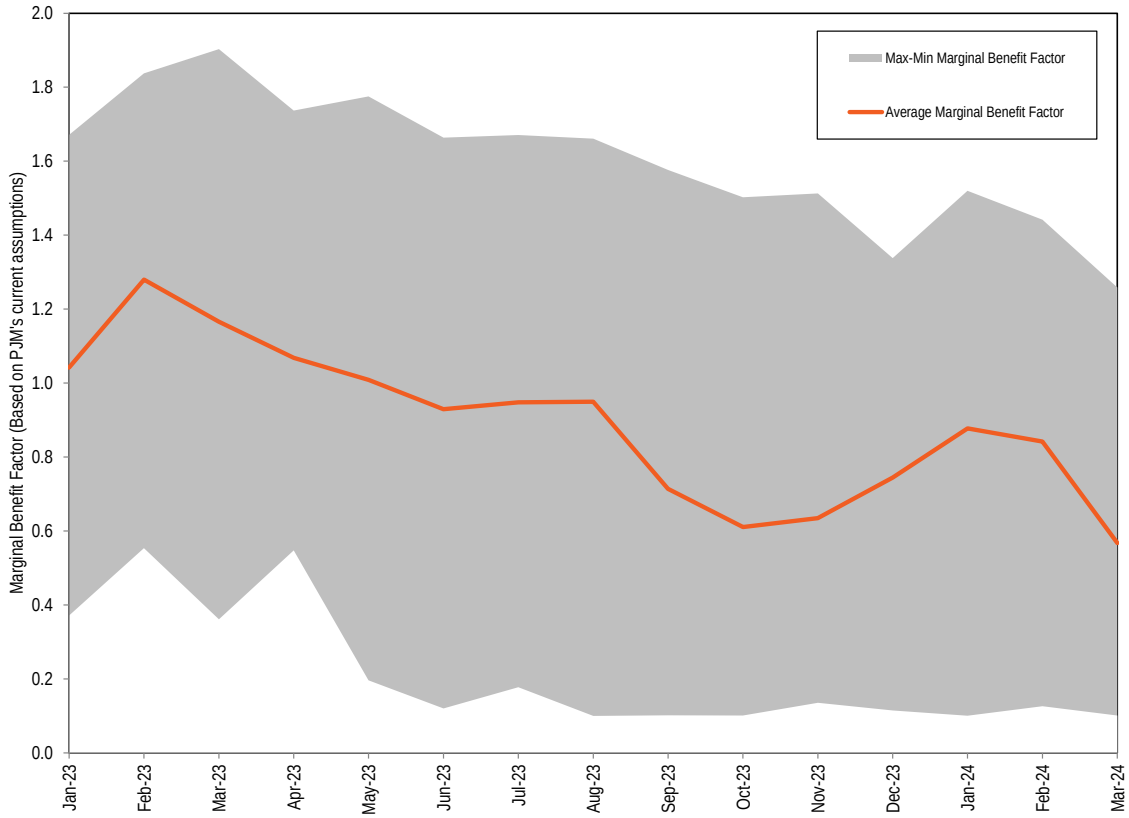
they were actually paid for effective MW. Using the MBF consistently throughout the PJM Regulation Market would result in RegA and RegD resources being paid exactly the same on a per effective MW basis. However, the PJM Regulation Market only uses the MBF in the market clearing and setting of price on a dollar per effective MW basis, it does not use the MBF to convert RegD MW into effective MW for purposes of settlement. Because the MBF is not used to convert RegD MW into effective MW for purposes settlement, RegD resources are paid the dollar per effective MW price, but this is paid for performance adjusted MW, not for effective MW. This causes the MW value of RegD resources to be inflated in settlement when the MBF is less than one and to be undervalued in settlement when the MBF is greater than one. In the first three months of 2024, the MBF averaged 0.76, while the average daily mileage ratio was 5.62, resulting in RegD resources being paid $3.3 million more than they would have been paid on an effective MW basis if the MBF were correctly implemented. In the first three months of 2023, the MBF averaged 1.16, and the average mileage ratio was 6.62, resulting in RegD resources being paid $0.2 million more than they would have been paid if the MBF were correctly implemented. The increase in overpayment of RegD resources between the first three months of 2023 and the first three months of 2024 is the result of an incorrect calculation of the MBF, as a result of the way dual offers are handled by PJM. This error has led to a decrease in the amount of RegD cleared and a resulting increase in the MBF of RegD resources. The higher MBF values have not been accurately reflected in settlement.

Table 2 Average monthly price paid per effective MW of RegD and RegA under mileage and MBF based settlement: January 2023 through March 2024

		RegD Settlement Payments				
Year	Month	Mileage Based RegD ($/Effective MW)	Marginal Rate of Technical Substitution Based RegD ($/Effective MW)	RegA ($/Effective MW)	Percent RegD Overpayment ($/Effective MW)	Total RegD Overpayment ($)
2023	Jan	$22.25	$17.01	$17.01	30.9%	$293,915
	Feb	$16.90	$15.49	$15.49	9.1%	$63,924
	Mar	$17.10	$16.82	$16.82	1.7%	($115,093)
	Apr	$26.48	$23.00	$23.00	15.1%	$176,675
	May	$32.82	$24.78	$24.78	32.4%	$438,285
	Jun	$32.81	$20.64	$20.64	59.0%	$824,293
	Jul	$29.16	$22.53	$22.53	29.4%	$391,521
	Aug	$35.51	$20.62	$20.62	72.2%	$535,233
	Sep	$47.29	$22.73	$22.73	108.1%	$1,082,569
	Oct	$83.65	$31.66	$31.66	164.2%	$1,940,934
	Nov	$41.59	$19.69	$19.69	111.2%	$910,484
	Dec	$40.18	$17.97	$17.97	123.6%	$1,078,581
Yearly		$35.62	$21.12	$21.12	68.6%	$7,621,320
2024	Jan	$56.67	$35.76	$35.76	58.4%	$879,903
	Feb	$33.20	$19.04	$19.04	74.4%	$670,940
	Mar	$72.24	$22.86	$22.86	216.0%	$1,774,338
Total		$54.49	$26.04	$26.04	109.2%	$3,325,181

Figure 3 shows, the monthly maximum, minimum and average MBF, for January 2023 through March 2024. The average daily MBF in the first three months of 2024 was 0.76. The average daily MBF in the first three months of 2023 was 1.16. The bottom of the MBF range results from PJM's administratively defined MBF minimum threshold of 0.1. The increase in the maximum and average MBF compared to previous years is due to an incorrect calculation of the MBF, as a result of the way dual offers are handled by PJM. This error has led to a decrease in the amount of RegD cleared, and an increase in the MBF.

Figure 3 Maximum, minimum, and average PJM calculated MBF by month: January 2023 through March 2024



The overpayment of RegD has resulted in offers from RegD resources that are almost all at an effective cost of $0.00 ($0.00 offers plus self scheduled offers). RegD MW providers are ensured that such offers will clear and will be paid a price determined by the offers of RegA resources. This is evidence of the impact of the flaws in the clearing engine and the overpayment of RegD resources on the offer behavior of RegD resources.

Table 3 shows, by month, cleared RegD MW with an effective price of $0.00 (units with zero offers plus self scheduled units) for January 2023 through March 2024. In the first three months of 2024, an average of 93.8 percent of all RegD MW clearing the market had an effective offer of $0.00. In the first three months of 2023, an average of 97.5 percent of all cleared RegD MW had an effective cost of $0.00. In the first three months of 2024, an average of 67.7 percent of all RegD offers were self scheduled, compared to an average of 58.2 percent of all RegD offers in the first three months of 2023.

The high percentage of self scheduled offers is a result of the incentives created by the flaws in the regulation market. Because self scheduled offers are price takers, they are cleared along with the zero cost offers in the market clearing engine. However, unlike zero cost offers, self scheduled offers do not risk having an LOC added to their offer during the market clearing process, ensuring that self scheduled offers have a zero cost during market clearing. Given the increasing saturation of the regulation market with RegD MW, specifically demand response and battery units which do not receive LOC, market participants eligible for LOC that offer at zero instead of self scheduling, run the risk of an LOC added to their offer, and thus not clearing the market.

The average monthly RegD cleared in the market increased 34.8 MW (22.0 percent), from 158.7 MW in the first three months of 2023 to 193.6 MW in the first three months of 2024. The average monthly RegD cleared with an effective cost of zero increased 26.8 MW (17.3 percent), from 154.8 MW in the first three months of 2023 to 181.6 MW in the first three months of 2024. Self scheduled RegD cleared MW increased 38.3 MW (41.3 percent), from 92.7 MW in the first three months of 2023 to 131.0 MW in the first three months of 2024. Average cleared RegD MW with a zero cost offer decreased 11.5 MW (18.5 percent), from 62.2 MW in the first three months of 2023 to 50.7 MW in the first three months of 2024. The incorrect way that dual offers are offered and cleared in the regulation market has led to the decrease in the average monthly RegD cleared and the increase in the average monthly MBF seen in Figure 2.

Table 3 Average cleared RegD MW and average cleared RegD with an effective price of $0.00 by month: January 2023 through March 2024

Year	Month	$0.00 Offer	$0.00 Offer Percent of Total	Self Scheduled	Self Scheduled Percentage of Total	Total Effective Cost of Zero	Effective Cost of Zero Percentage of Total	Total
2023	Jan	56.6	33.4%	110.5	65.2%	167.1	98.5%	169.6
	Feb	66.6	43.0%	82.9	53.5%	149.5	96.6%	154.8
	Mar	63.3	41.7%	84.7	55.8%	147.9	97.4%	151.8
	Apr	63.9	39.2%	88.7	54.4%	152.7	93.6%	163.0
	May	55.2	32.8%	100.0	59.5%	155.2	92.3%	168.2
	Jun	59.6	31.5%	120.4	63.6%	179.9	95.1%	189.2
	Jul	57.4	30.4%	124.0	65.6%	181.4	96.0%	189.0
	Aug	52.7	27.9%	120.9	64.0%	173.6	92.0%	188.8
	Sep	58.1	29.9%	128.6	66.3%	186.7	96.2%	194.1
	Oct	57.8	29.4%	130.5	66.4%	188.2	95.8%	196.5
	Nov	56.5	28.9%	129.3	66.1%	185.8	95.0%	195.6
	Dec	57.8	29.4%	128.0	65.2%	185.9	94.6%	196.5
Yearly		58.7	32.6%	112.6	62.6%	171.3	95.2%	179.9
2024	Jan	54.5	28.0%	126.2	64.9%	180.7	92.9%	194.5
	Feb	45.5	24.5%	128.6	69.2%	174.1	93.7%	185.9
	Mar	52.0	26.0%	138.1	68.9%	190.1	94.9%	200.3
Total		50.8	26.2%	131.0	67.6%	181.8	93.8%	193.7

C. Current Market Design Issues: PJM's Optimization Cannot Handle Dual Offers.

Under PJM market rules, regulation units that have the capability to provide both RegA and RegD MW are permitted to submit an offer for both signal types in the same market hour. While the objective of the PJM market design is to find the least cost combination of RegA and RegD resources to provide the required level of regulation service, the method of clearing the regulation market for an hour in which one or more units has a dual offer is incorrect and leads to solutions that are not the most economic. The result of the flaw is that the MBF in the regulation market clearing phase is incorrectly low compared to the MBF in the market solution phase, too little RegD is cleared relative to the efficient amount, the RegD resources that do clear are underpaid when the resulting MBF is greater than 1.0 and the actual amount of effective MW procured is higher than the regulation requirement.

In order for the clearing engine to provide the correct economic solution when the pool of available resources contains one or more units with dual offers, the calculation would have to be performed iteratively to determine which of the dual offers would provide the least cost solution. But this is not how PJM clears the regulation market when there are dual offer units. PJM rank orders the regulation supply curve by potential effective cost assuming the dual offer resources are available as both RegA and RegD resources simultaneously, and assigns every RegD resource, including dual offer resources, a unit specific benefit factor.

Each dual offer resource is assigned to run as either a RegD or RegA resource based on which of the two offers has a lower effective cost. But PJM does not redefine the supply curve using appropriately recalculated unit specific benefit factors for the remaining RegD resources prior to clearing the market.

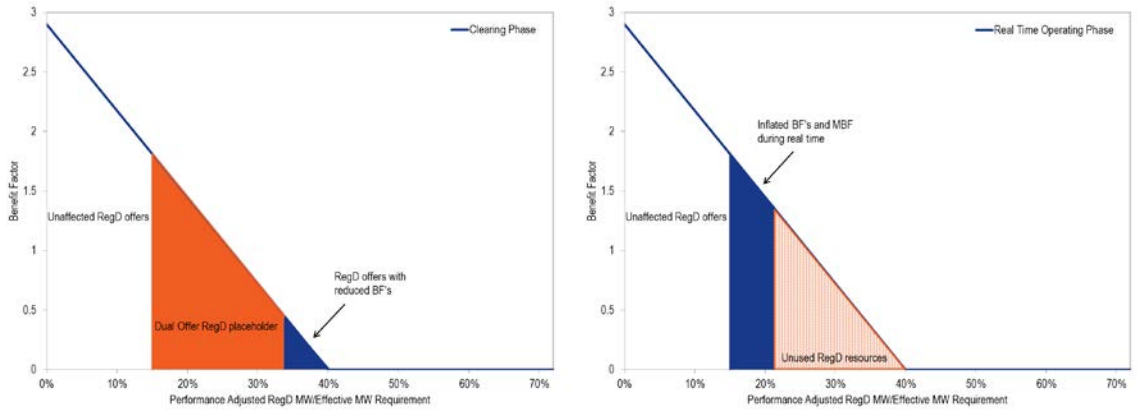
During the clearing phase, the MBF of RegD resources is a function of the RegD MW that clear. The MBF for all RegD resources declines as more RegD resources are cleared. Based on this relationship, in the case where a dual offer unit is assigned to be a RegA resource rather than a RegD resource, the MBF of remaining RegD resources in the supply curve should increase. The placeholder RegD MW from the dual offer should be removed, the cleared MW from below the placeholder should be shifted up the supply/MBF curve, and additional RegD MW offers that were pushed below an MBF of zero and initially not included, should be considered. But PJM does not recalculate the MBF values for the remaining RegD resources when determining the cleared effective MW needed to satisfy the regulation requirement during the clearing phase. The result is that the MBF in the clearing phase is incorrectly low, and the actual amount of effective MW procured is higher.

After meeting the target effective MW to satisfy the regulation requirement for that hour through the clearing process, the unit specific benefit factors of those displaced units are recalculated in the real-time operating phase and increased based on their actual contribution. The effective MW contributions of those originally displaced units are correctly calculated in the operating phase, but because the supply for that hour has already been set based on their incorrect effective MW, the solution includes more effective MW than calculated in the clearing phase. As a result, the market solution includes more than the target level of effective MW in the actual operating hour.

The issue is illustrated in Figure 4. The example shows a clearing phase and a rea-time operating phase. In this example, a 150 MW unit offers both RegA and RegD. The 150 MW unit's position in the RegD effective cost curve and the potential effective MW are represented as the orange area under the curve in the clearing phase. The effective MW of the cleared RegD resources with higher effective costs are represented by the blue triangle in

the clearing phase. Not shown are additional RegD MW with higher effective costs that were assigned an MBF of 0 and not cleared. The 150 MW dual offer unit is chosen to operate as a RegA resource in the operational hour. As a result, the cleared supply for RegA in the clearing phase is the same RegA supply realized in the real-time operating phase. But that is not the case for the RegD supply. Since the supply curve and unit specific benefit factors of RegD MW are not recalculated in the clearing phase after the 150 MW RegD offer is removed, the amount of effective MW realized in the real-time operating phase is inconsistent with the clearing phase. Because the RegD portion of the 150 MW dual offer unit was not chosen to be RegD MW, the RegD resources represented by the blue triangle in the clearing phase will contribute more effective MW (the blue area in the real-time solution phase) in the real-time solution phase than was assumed in the clearing phase because the MBF in the clearing phase was too low. Since the blue area under the curve in the real-time solution phase is greater than the blue area in the clearing phase and the amount of RegA remains the same between the clearing phase and real-time operating phase, the market will have cleared too many effective MW relative to the effective MW requirement. The MBF in the operating phase is higher than if the clearing had been solved correctly.

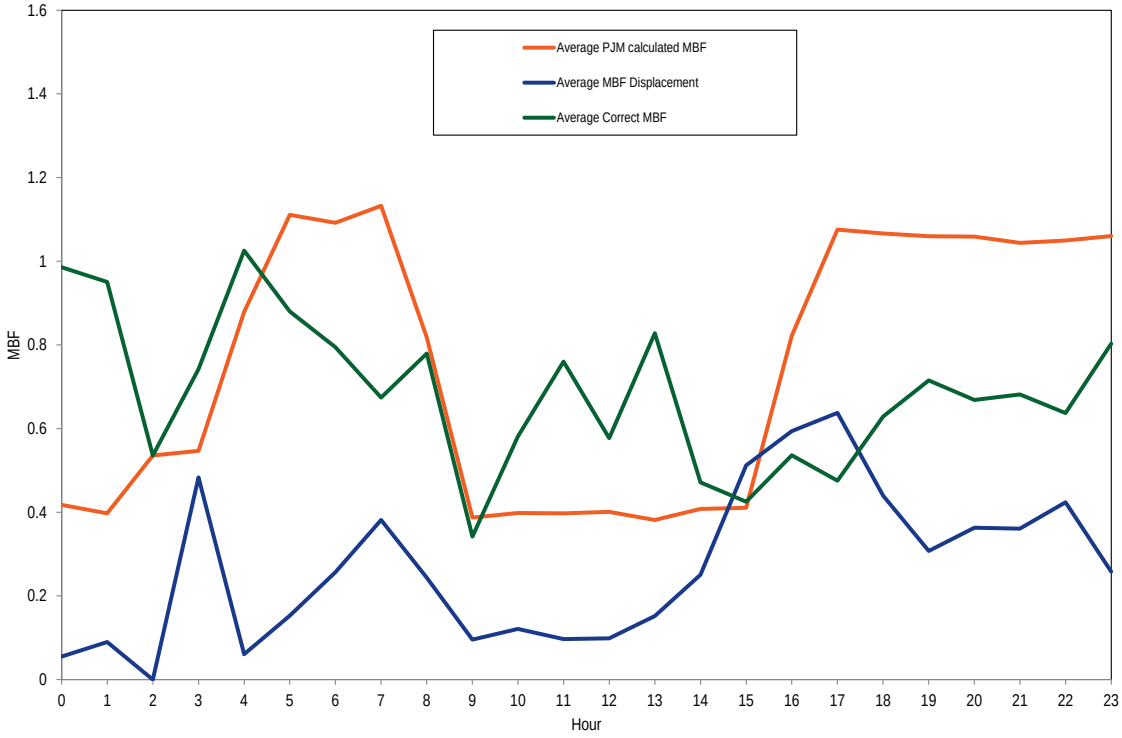
Figure 4 Clearing phase BF/effective MW reduction, real-time BF/effective MW inflation, and exclusion of available RegD resources



In the first three months of 2024, 59.8 percent of all hours had at least one unit with a dual offer. In the first three months of 2024, 12.6 percent of all hours had at least one dual offer unit that was chosen to run as RegA, resulting in an average MBF increase of 0.33 in the

operating phase. The average MBF increase due to dual offers clearing as RegA in the first three months of 2023 was 0.77. This indicates that the amount of MW clearing as RegA from dual offers has increased, and the amount of RegD clearing has been artificially reduced, resulting in higher MBF of RegD in the market solution in 2023. If the market had been cleared correctly, the correct average MBF would have been significantly lower in real time (operating phase), because additional RegD offers with lower benefit factors that were initially excluded, would have been included after the removal of the dual offer placeholder, reducing the MBF. Figure 5 illustrates the PJM calculated average MBF in real time (operating phase), the average amount the MBF is artificially increased (MBF displacement) due to dual offers clearing as RegA, and what the correct average MBF would have been in each hour of the day for the first three months of 2024 if the clearing solution were solved correctly.

Figure 5 Effect of PJM's current dual offer clearing method on the average MBF in each hour of the day: January through March, 2024



D. Current Market Design Issues: Market Flaws Cause Perverse Incentives and Price Spikes.

Beginning in 2018, extreme price spikes were identified in the regulation market. The price spikes were caused by a combination of the inconsistent application of the MBF in the market design and the discrepancy between the hour ahead estimated LOC and the actual realized within hour LOC.

The regulation market is cleared on an hour ahead basis, using offers that are adjusted by dividing each component of an offer (capability, performance, and lost opportunity cost) by the product of the unit specific benefit factor and unit specific performance score. To calculate the hour ahead estimate of the adjusted LOC offer component, hour ahead projections of LMPs are used. Units are then cleared based on the sum of each of their hour ahead adjusted offer components. The actual LOC is used to determine the final, actual interval specific all in offer of RegD resources.

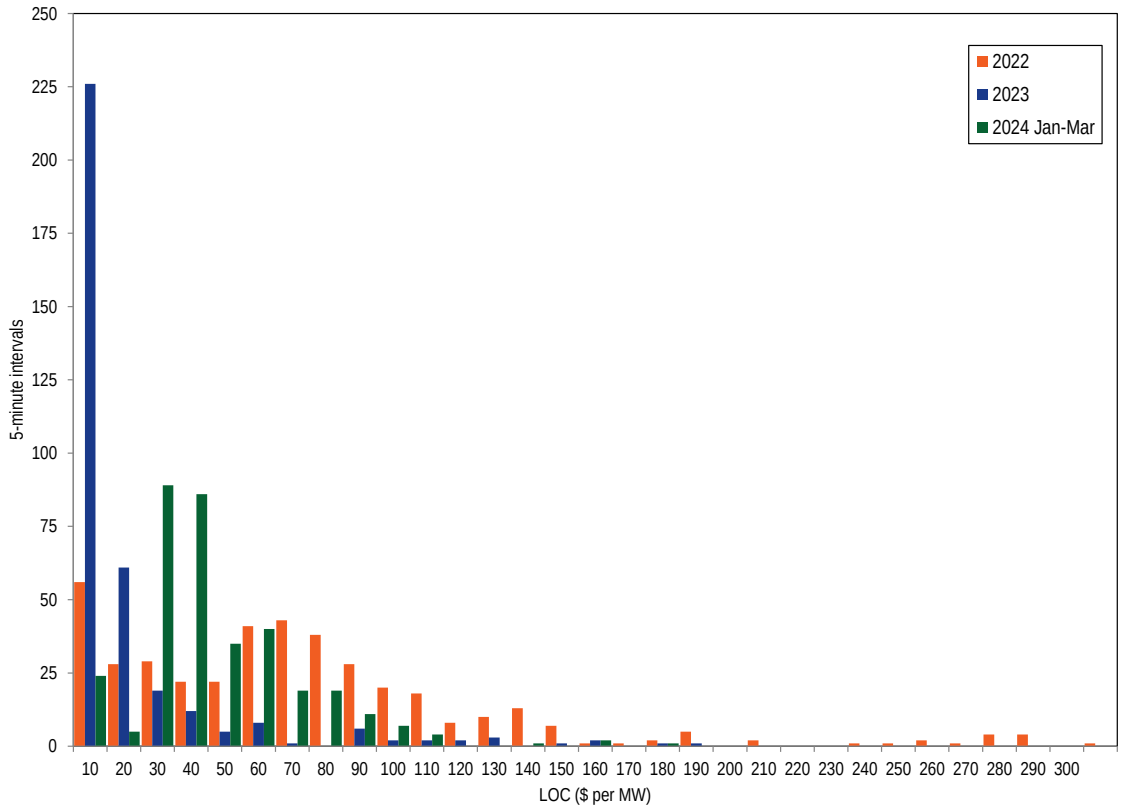
In some cases the estimated LOC is very low or zero but the actual within hour LOC is a positive number. In instances where the MBF of the within hour marginal unit is less than one (e.g. the marginal unit is a RegD unit), this discrepancy in the estimated and realized LOC will cause a large discrepancy between the expected offer price (as low as $0/MW) and the realized offer price of the resource in the actual market result. This will cause a significant price spike in the regulation market. In cases where the MBF of the marginal resource is very low, such as 0.001, the price spikes can be very significant for a small change between expected and actual LOC. In January 2019, the Commission approved PJM's proposal to create a 0.1 floor for the MBF to reduce the occurrence of these price spikes.[10] This change effectively ignored the issue.

---

[10] See 166 FERC ¶ 61,040 (2019).

Figure 6 shows the LOC in each five minute interval in which the marginal unit had a unit specific benefit factor less than one (e.g. a RegD unit) and the LOC was greater than zero from 2022 through the first three months of 2024.

Figure 6 LOC distribution in each five minute interval with a RegD marginal unit and an LOC greater than zero: 2022, 2023, and January through March, 2024



For a RegD resource to clear the regulation market with an MBF of 0.001, the resource's offer, in dollars per marginal effective MW, must be less than or equal to competing offers from RegA MW. A RegD offer of 1 MW with an MBF of 0.001 and a price of $1 per MW, would provide 0.001 effective MW at a price of $1,000 per effective MW. So long as RegA MW are available for less than $1,000 per effective MW, this resource will not clear. The only way for RegD MW to clear to the point where the MBF of the last MW is 0.001, is if the offer price of the relevant resources that clear, including estimated LOC, is $0.00. But, if the same resource(s) has a positive LOC within the hour, based on real-time changes in

LMP, the zero priced offer is adjusted to reflect the positive LOC, resulting in an extremely high offer and clearing price for regulation.

While an incorrect estimate of a potential LOC can result in an extremely high price, the resulting regulation market prices are mathematically correct for the price of each effective MW. The prices in every interval reflect the marginal costs of regulation given the resources dispatched and accurately reflect the marginal offer of minimally effective resources which had unexpectedly high LOC components of their within hour offers. But, due to the current market design's failure to use the MBF in settlement, RegD is not paid on a dollar per effective MW basis. This disconnect between the process of setting price and the process of paying resources is the primary source of the market failure in PJM's Regulation Market and the cause of the observed price spikes in the regulation market. In the example, the 0.001 MW from the RegD resource should be paid $1,000 times 0.001 MW or $1.00. But the current rules would pay the RegD resource $1,000 times 1.0 MW or $1,000. If the market clearing and the settlements rules were consistent, the incentive for this behavior would be eliminated. The current rules provide a strong incentive for this behavior.

The price spikes observed in PJM's Regulation Market are a symptom of a market failure in PJM's Regulation Market caused by an inconsistent application of the MBF between market clearing and market settlement. Due to the inconsistent application of the MBF, the current market results are not consistent with a competitive market outcome. In any market, resources should be paid the marginal clearing price for their marginal contribution. In the regulation market, all resources should be paid the marginal clearing price per effective MW and all resources in the regulation market should be paid for each of their effective MW. PJM's Regulation Market does not do this. PJM's market applies the MBF in determining the relative and total value of RegD MW in the market solution for purposes of market clearing and price, but does not apply the same logic in determining the payment of RegD for purposes of settlement. As a result, market prices do not align with payment for contributions to regulation service in market settlements.

The inconsistent application of the MBF in PJM's regulation market design is generating perverse incentives and perverse market results. The price spikes are a symptom of the problem, not the problem itself.

E. Current Market Design Issues: Uplift Calculation Issues.

Regulation uplift is calculated by comparing a resource's regulation offer price plus its regulation lost opportunity cost (including shoulder LOC if applicable) adjusted by the performance score, to the clearing price credits the unit received.[11] If the sum of the resource's offer plus LOC is greater than the clearing price, the resource is paid uplift equal to the difference.

The calculation of regulation uplift for coal and natural gas units is incorrect, and results in the overpayment of uplift.[12] In order to determine the amount of regulation uplift, the difference between the MW output of the unit while it was providing regulation is compared to the desired MW output of the unit if it had not provided regulation. The desired MW output at LMP used in the calculation of regulation uplift is determined based on a unit's energy offer and the LMP during the interval being evaluated. But this desired MW does not account for the ability of a unit to actually produce the desired output because it ignores the fact that units have a limited physical ability ramp. It does not take into account the ramp rate. This results in the overpayment of uplift by paying for MW that the unit could not have produced given their energy market output at the beginning of the interval and their ramp rate.

---

[11] The clearing price for each interval is set by the marginal unit's total offer (capability and performance offers plus LOC), adjusted by the marginal unit's performance score, and does not include any shoulder LOC.

[12] Hydro units operate on a schedule rather than an energy bid, therefore a different equation is used to calculate their regulation LOC and uplift. The issue discussed does not effect that calculation. Also, demand response and battery units do not receive uplift.

Table 4 shows the amount of uplift overpayment by fuel type for all of 2023 and the first three months of 2024, as a result of the ramp rate not being used in the current calculation. The overpayments are calculated using a desired MW level that can be achieved in a five minute market interval based on the units' ramp rates. In the first three months of 2024, overpayments totaled $4.7 million. Coal units received 63.9 percent of the overpayment while providing 5.5 percent of settled regulation MW.

Table 4 Amount of LOC overpayment: January 2023 through March 2024

		Uplift overpayment		
Year	Month	Coal	Natural Gas	Total
2023	Jan	$219,632	$409,362	$628,995
	Feb	$304,776	$399,282	$704,058
	Mar	$606,703	$547,406	$1,154,109
	Apr	$825,524	$602,421	$1,427,946
	May	$528,304	$847,798	$1,376,102
	Jun	$857,736	$787,690	$1,645,426
	Jul	$1,061,210	$508,118	$1,569,328
	Aug	$1,810,618	$511,049	$2,321,667
	Sep	$937,997	$544,952	$1,482,949
	Oct	$395,527	$1,011,206	$1,406,733
	Nov	$307,590	$538,204	$845,794
	Dec	$709,710	$469,619	$1,179,329
Total		$8,565,327	$7,177,108	$15,742,435
2024	Jan	$1,232,475	$668,296	$1,900,771
	Feb	$776,377	$351,419	$1,127,796
	Mar	$1,004,166	$685,613	$1,689,779
Total		$3,013,018	$1,705,328	$4,718,346

IV. CONCLUSION

The Market Monitor respectfully requests that the Commission afford due consideration to this protest as the Commission resolves the issues raised in this proceeding.

Respectfully submitted,

Jeffrey W. Mayes

Joseph E. Bowring
Independent Market Monitor for PJM
President
Monitoring Analytics, LLC
2621 Van Buren Avenue, Suite 160
Eagleville, Pennsylvania 19403
(610) 271-8051
joseph.bowring@monitoringanalytics.com

Howard J. Haas
Chief Economist
Monitoring Analytics, LLC
2621 Van Buren Avenue, Suite 160
Eagleville, Pennsylvania 19403
(610) 271-8054
howard.haas@monitoringanalytics.com

General Counsel
Monitoring Analytics, LLC
2621 Van Buren Avenue, Suite 160
Eagleville, Pennsylvania 19403
(610) 271-8053
jeffrey.mayes@monitoringanalytics.com

Dated: May 7, 2024

CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document upon each person designated on the official service list compiled by the Secretary in this proceeding.

Dated at Eagleville, Pennsylvania,
this 7th day of May, 2024.

Jeffrey W. Mayes
General Counsel
Monitoring Analytics, LLC
2621 Van Buren Avenue, Suite 160
Eagleville, Pennsylvania 19403
(610) 271-8053
jeffrey.mayes@monitoringanalytics.com