

Ancillary Service Markets

FERC defined six ancillary services in Order No. 888: scheduling, system control and dispatch; reactive supply and voltage control from generation service; regulation and frequency response service; energy imbalance service; operating reserve—synchronized reserve service; and operating reserve—supplemental reserve service.¹ PJM provides scheduling, system control and dispatch, and reactive on a cost basis. PJM provides regulation, energy imbalance, synchronized reserve, and supplemental reserve services through market mechanisms.² Although not defined by FERC as an ancillary service, black start service plays a comparable role. Black start service is provided on the basis of formula rates.

PJM implemented significant reserve market changes on October 1, 2022. This *State of the Market Report for PJM: January through September* is written based on the market rules that applied during the first nine months of 2022, recognizing that the rules changed on October 1. Those rule changes will be addressed in the State of the Market Report for 2022. The present tense is used when describing the rules in place during the first nine months of 2022 to reflect the pre October 1, 2022, perspective of the report.

The MMU analyzed measures of market structure, conduct and performance for the PJM Synchronized Reserve Market for the first nine months of 2022.

Table 10-1 The tier 2 synchronized reserve market results were competitive

Market Element	Evaluation	Market Design
Market Structure: Regional Markets	Not Competitive	
Participant Behavior	Competitive	
Market Performance	Competitive	Mixed

- The tier 2 synchronized reserve market structure was evaluated as not competitive because of high levels of supplier concentration.
- Participant behavior was evaluated as competitive because the market rules require cost-based offers.

¹ 75 FERC ¶ 61,080 (1996).

² Energy imbalance service refers to the real-time energy market.

- Market performance was evaluated as competitive because the interaction of participant behavior with the market design results in competitive prices.
- Market design was evaluated as mixed. Market power mitigation rules result in competitive outcomes despite high levels of supplier concentration. However, tier 1 reserves are inappropriately overcompensated when the nonsynchronized reserve market clears with a nonzero price. This settlement rule is scheduled to be removed on October 1, 2022, with the consolidation of tier 1 and tier 2 reserves.

The MMU analyzed measures of market structure, conduct and performance for the PJM DADR Market for the first nine months of 2022.

Table 10-2 The day-ahead scheduling reserve market results were competitive

Market Element	Evaluation	Market Design
Market Structure	Not Competitive	
Participant Behavior	Mixed	
Market Performance	Competitive	Mixed

- The DADR market structure was evaluated as not competitive because the DADR market failed the three pivotal supplier (TPS) test in 86.7 percent of the intervals in which the price was greater than \$0.01 per MWh.
- Participant behavior was evaluated as mixed because while most offers were equal to marginal costs, a significant proportion of offers reflected economic withholding. The ability to withhold 30 minute reserves using offers is scheduled to be removed on October 1, 2022, with the implementation of a secondary reserve market.
- Market performance was evaluated as competitive because there were adequate offers in every hour to satisfy the requirement and the clearing prices reflected in those offers, although there is concern about offers above the competitive level affecting prices. The day-ahead scheduling reserve market clearing price was above \$0 in 12.6 percent of hours in the first nine months of 2022. In 98.4 percent of hours when the clearing price was above \$0, the clearing price was the offer price of the marginal unit. The price included lost opportunity cost in 1.6 percent of hours

when the clearing price was above \$0. After October 1, 2022, clearing prices for 30 minute reserves will include only lost opportunity cost.

- Market design was evaluated as mixed because the DASR product does not include performance obligations. Offers should be based on opportunity cost only, to ensure competitive outcomes and that market power cannot be exercised. After October 1, 2022, offers will contain only opportunity cost and day-ahead 30 minute reserves will have a corresponding real-time product.

The MMU analyzed measures of market structure, conduct and performance for the PJM Regulation Market for the first nine months of 2022.

Table 10-3 The regulation market results were not competitive

Market Element	Evaluation	Market Design
Market Structure	Not Competitive	
Participant Behavior	Competitive	
Market Performance	Not Competitive	Flawed

- The regulation market structure was evaluated as not competitive because the PJM Regulation Market failed the three pivotal supplier (TPS) test in 88.8 percent of the hours in the first nine months of 2022.
- Participant behavior in the PJM Regulation Market was evaluated as competitive in the first nine months of 2022 because market power mitigation requires competitive offers when the three pivotal supplier test is failed, although the inclusion of a positive margin raises questions.
- Market performance was evaluated as not competitive, because all units are not paid the same price on an equivalent MW basis.
- Market design was evaluated as flawed. The market design has failed to correctly incorporate a consistent implementation of the marginal benefit factor in optimization, pricing and settlement. The market results continue to include the incorrect definition of opportunity cost. The result is significantly flawed market signals to existing and prospective suppliers of regulation.

Overview

Primary Reserve

PJM's primary reserves are made up of resources, both synchronized and nonsynchronized, that can provide energy within 10 minutes. Primary reserve is PJM's implementation of the NERC 15-minute contingency reserve requirement.³

PJM determines the primary reserve requirement based on the largest single contingency plus 190 MW in every approved RT SCED case. The required synchronized reserve and nonsynchronized reserve are calculated and dispatched in every real-time market solution, and there are associated clearing prices (SRMCP and NSRMCP) assigned every five minutes. Scheduled resources are credited based on a dispatched assignment and a five minute clearing price.

Market Structure

- **Supply.** Primary reserve is satisfied by both synchronized reserve (generation or demand response currently synchronized to the grid and available within 10 minutes), and nonsynchronized reserve (generation currently off line but available to start and provide energy within 10 minutes).
- **Demand.** The PJM primary reserve requirement is 150 percent of the largest single contingency plus 190 MW. In the first nine months of 2022, the average primary reserve requirement was 2,419.4 MW in the RTO Zone and 2,418.1 in the MAD Subzone.

Tier 1 Synchronized Reserve

Synchronized reserve is provided by generators and demand response resources synchronized to the grid and capable of increasing output or decreasing load within 10 minutes in response to a PJM declared synchronized reserve event. Before the reserve market changes implemented on October 1, 2022, synchronized reserve consists of tier 1 and tier 2 synchronized reserves.

³ See PJM, "PJM Manual 10: Pre-Scheduling Operations," § 3.1.1 Day-ahead Scheduling (Operating) Reserve, Rev. 42 (Oct. 1, 2022).

Tier 1 synchronized reserve is the capability of online resources following economic dispatch to ramp up in 10 minutes from their current output in response to a synchronized reserve event. Every real-time market solution calculates the available tier 1 synchronized reserve. There is no formal market for tier 1 synchronized reserve prior to October 1, 2022.

- **Supply.** No offers are made for tier 1 synchronized reserves. The market solution estimated tier 1 synchronized reserve as available 10 minute ramp from the energy dispatch. In the first nine months of 2022, there was an average hourly supply of 1,531.4 MW of tier 1 available in the RTO Zone and an average hourly supply of 693.6 MW of tier 1 synchronized reserve available within the MAD Subzone.
- **Demand.** The synchronized reserve requirement is calculated for each real-time dispatch solution as the largest single contingency plus 190 MW within both the RTO Zone and the MAD Subzone.
- **Tier 1 Synchronized Reserve Event Response.** Tier 1 synchronized reserve is paid when a synchronized reserve event occurs and it responds. When a synchronized reserve event is called, all tier 1 response is paid for increasing its output (or reducing load for demand response) at the rate of \$50 per MWh in addition to LMP.⁴ This is the synchronized energy premium price.
- **Issues.** The competitive offer for tier 1 synchronized reserves is zero, as there is no incremental cost associated with the ability to ramp up from the current economic dispatch point and the appropriate payment for responding to an event is the synchronized energy premium price of \$50 per MWh. The tariff requires payment of the tier 2 synchronized reserve market clearing price to tier 1 resources whenever the nonsynchronized reserve market clearing price rises above zero. This requirement is unnecessary and inconsistent with efficient markets. This rule has a significant impact on the cost of tier 1 synchronized reserves, resulting in a windfall payment of more than \$150 million since 2014. In the first nine months of 2022, the nonsynchronized reserve market clearing price was above \$0 in 609 intervals, none of which were during a spinning event. Both the synchronized reserve premium price

and the payment when the nonsynchronized reserve price is above zero will be removed on October 1, 2022.

Tier 2 Synchronized Reserve Market

Tier 2 synchronized reserve is part of primary reserve and is comprised of resources that are synchronized to the grid, that may incur costs to be synchronized, and that have an obligation to respond to PJM declared synchronized reserve events. Tier 2 synchronized reserve is penalized for failure to respond to a PJM declared synchronized reserve event. Tier 2 synchronized reserve, along with tier 1, will be replaced by the new consolidated synchronized reserve on October 1, 2022, which behaves similarly to tier 2. In PJM, the required amount of synchronized reserve is defined to be no less than the largest single contingency, and 10 minute primary reserve as no less than 150 percent of the largest single contingency, plus 190 MW. This is stricter than the NERC standard of the greater of 80 percent of the largest single contingency or 900 MW.⁵

When the synchronized reserve requirement cannot be met with tier 1 synchronized reserve, PJM uses the tier 2 synchronized reserve market to satisfy the balance of the requirement. The tier 2 synchronized reserve market includes the PJM RTO Reserve Zone and a subzone, the Mid-Atlantic Dominion Reserve Subzone (MAD).

Market Structure

- **Supply.** In the first nine months of 2022, the average supply of daily offered and eligible tier 2 synchronized reserve was 35,042.6 MW in the RTO Zone of which 5,478.1 MW was located in the MAD Subzone.
- **Demand.** The average hourly synchronized reserve requirement was 1,676.2 MW in the RTO Reserve Zone and 1,675.5 in the Mid-Atlantic Dominion Reserve Subzone. The hourly average cleared tier 2 synchronized reserve was 234.5 MW in the MAD Subzone and 706.4 MW in the RTO.
- **Market Concentration.** Both the Mid-Atlantic Dominion Subzone Tier 2 Synchronized Reserve Market and the RTO Synchronized Reserve Zone

⁴ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.10 Settlements, Rev. 122 (Oct. 1, 2022).

⁵ NERC (June 2, 2020) <NERC Reliability Standard BAL 002-2 Glossary_of_Terms.pdf>.

Market were characterized by structural market power in the first nine months of 2022.

The average HHI for tier 2 synchronized reserve in the RTO Zone was 2898 which is classified as highly concentrated.

Market Conduct

- **Offers.** There is a must offer requirement for tier 2 synchronized reserve. All nonemergency generation capacity resources are required to submit a daily offer for tier 2 synchronized reserve, unless the unit type is exempt. Tier 2 synchronized reserve offers from generating units are subject to an offer cap of marginal cost plus \$7.50 per MW, plus opportunity cost which is calculated by PJM. The \$7.50 per MWh will be reduced to the expected value of the synchronized reserve nonperformance penalty on October 1, 2022. PJM automatically enters an offer of \$0 for tier 2 synchronized reserve when an offer is not entered by the owner. Demand resources offering into the tier 2 market are also subject to an offer cap of \$7.50 plus costs. Cost may include shutdown costs for demand response.⁶

Market Performance

- **Price.** The weighted average price for tier 2 synchronized reserve for all cleared hours in the MAD Subzone was \$18.14 per MW in the first nine months of 2022. The weighted average price for tier 2 synchronized reserve for all cleared intervals in the RTO Synchronized Reserve Zone was \$16.16 per MW in the first nine months of 2022.

Nonsynchronized Reserve Market

Nonsynchronized reserve is part of primary reserve and includes the RTO Reserve Zone and the Mid-Atlantic Dominion Reserve Subzone (MAD). Nonsynchronized reserve is comprised of nonemergency energy resources not currently synchronized to the grid that can provide energy within 10 minutes. Nonsynchronized reserve is available to fill the primary reserve requirement above the synchronized reserve requirement. Generation owners do not

submit supply offers for nonsynchronized reserve. PJM defines the demand curve for nonsynchronized reserve and PJM defines the supply curve based on nonemergency generation resources that are available to provide energy and can start in 10 minutes or less (based on offer parameters), and on the resource opportunity costs calculated by PJM.

Market Structure

- **Supply.** In the first nine months of 2022, the average supply of eligible and available nonsynchronized reserve was 2,015.6 MW in the RTO Zone.
- **Demand.** Demand for nonsynchronized reserve equals the primary reserve requirement minus the tier 1 synchronized reserve estimate and minus the scheduled tier 2 synchronized reserve.⁷
- **Market Concentration.** The MMU calculates that the three pivotal supplier test would have been failed in 96.3 percent of intervals in which the price was above \$0.01 in the first nine months of 2022.

Market Conduct

- **Offers.** Generation owners do not submit supply offers for nonsynchronized reserve. Nonemergency generation resources that are available to provide energy and can start in 10 minutes or less are considered available for nonsynchronized reserves by the market solution software. PJM calculates the associated offer prices based on PJM calculations of resource specific opportunity costs. The reserve market design implemented on October 1, 2022, removes the approximated nonsynchronized reserve opportunity cost calculation that PJM currently uses, because offline resources do not have an opportunity cost for the market intervals when they are scheduled to be offline because PJM cannot dispatch them for energy in those intervals.⁸

⁶ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.1 Synchronized Reserve Market Eligibility, Rev. 122 (Oct. 1, 2022).

⁷ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.1 Overview of the PJM Reserve Markets, Rev. 121 (Jul. 7, 2022).

⁸ See *PJM Interconnection, LLC*, "Enhanced Price Formation in Reserve Markets of PJM Interconnection, LLC," Docket No. EL19-58 (March 29, 2019) at 84.

Market Performance

- **Price.** The nonsynchronized reserve price is determined by the opportunity cost of the marginal nonsynchronized reserve unit. The nonsynchronized reserve weighted average price for all intervals in the RTO Reserve Zone was \$0.32 per MW in the first nine months of 2022.

Secondary Reserve (DASR)

There is no NERC standard for secondary reserve. PJM defines secondary reserve in the day-ahead market as reserves (online or offline available for dispatch) that can be converted to energy in 30 minutes. PJM defines a secondary reserve requirement but is not required to maintain this level of secondary reserve in real time. Effective on October 1, 2022, a secondary reserve product will exist in both the real-time and day-ahead markets.

PJM maintains a day-ahead, offer-based market for 30 minute day-ahead secondary reserve. The PJM Day-Ahead Scheduling Reserve Market (DASR) has no performance obligations except that a unit which clears the DASR market may not be on an outage in real time.⁹ If DASR units are on an outage in real time or cleared DASR MW are not available, the DASR payment is not made. Effective October 1, 2022, PJM will have both day-ahead and real-time 30 minute reserves markets using only lost opportunity costs to determine price, not submitted offers.

Market Structure

- **Supply.** The DASR market is a must offer market. Any resources that do not make an offer have their offer set to \$0.00 per MW. DASR is calculated by the day-ahead market solution as the lesser of the 30 minute energy ramp rate or the economic maximum MW minus the day-ahead dispatch point for all resources that can provide energy within 30 minutes of a request from PJM Dispatch.
- **Demand.** The DASR requirement is the sum of the PJM requirement and the Dominion requirement based on the VACAR reserve sharing agreement. It is calculated every year for the period November 1 through October 31.

⁹ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 11.2.7 Day-Ahead Scheduling Reserve Performance, Rev. 121 (Jul. 7, 2022).

For November 1, 2021, through October 31, 2022, the DASR requirement was 4.40 percent of forecast peak load. The average hourly DASR MW purchased in the first nine months of 2022 was 4,820.4 MW, a decrease from the 5,094.2 hourly MW in the first nine months of 2021. Effective October 1, 2022, the 30-minute reserve requirement will be the maximum of: 150 percent of the synchronized reserve requirement (the same as for primary reserve); the largest active gas contingency; or 3,000 MW.

Market Conduct

- **Withholding.** Economic withholding remains an issue in the DASR Market. The direct marginal cost of providing DASR is zero. PJM calculates the opportunity cost for each resource. All offers by resource owners greater than zero constitute economic withholding. In the first nine months of 2022, 43.7 percent of daily unit offers were above \$0.00 and 16.9 percent of daily unit offers were above \$5. Effective with the reserve market changes, the offer price of secondary reserve will be \$0.00.
- **DR.** Demand resources are eligible to participate in the DASR Market. Some demand resources have entered offers for DASR. No demand resources cleared the DASR market in the first nine months of 2022.

Market Performance

- **Price.** In the first nine months of 2022, the MW weighted average DASR price for all hours when the DASRMCP was above \$0.00 was \$2.28. The MW weighted average for all hours including hours when the price was \$0 was \$0.37.

Regulation Market

The PJM Regulation Market is a real-time market. Regulation is provided by generation resources and demand response resources that qualify to follow one of two regulation signals, RegA or RegD. PJM jointly optimizes regulation with synchronized reserve and energy to provide all three products at least cost. The PJM regulation market design includes three clearing price components: capability; performance; and opportunity cost. The RegA signal

is designed for energy unlimited resources with physically constrained ramp rates. The RegD signal is designed for energy limited resources with fast ramp rates. In the regulation market RegD MW are converted to effective MW using a marginal rate of technical substitution (MRTS), called a marginal benefit factor (MBF). Correctly implemented, the MBF would be the marginal rate of technical substitution (MRTS) between RegA and RegD, holding the level of regulation service constant. The current market design is critically flawed as it has not properly implemented the MBF as an MRTS between RegA and RegD resource MW and the MBF has not been consistently applied in the optimization, clearing and settlement of the regulation market.

Market Structure

- **Supply.** In the first nine months of 2022, the average hourly offered supply of regulation for nonramp hours was 757.5 performance adjusted MW (765.8 effective MW). This was an increase of 4.1 performance adjusted MW (an increase of 13.1 effective MW) from the first nine months of 2021. In the first nine months of 2022, the average hourly offered supply of regulation for ramp hours was 1,124.4 performance adjusted MW (1,127.6 effective MW). This was an increase of 47.9 performance adjusted MW (an increase of 25.9 effective MW) from the first nine months of 2021, when the average hourly offered supply of regulation was 1,076.5 performance adjusted MW (1,101.7 effective MW).
- **Demand.** The hourly regulation demand is 525.0 effective MW for nonramp hours and 800.0 effective MW for ramp hours.
- **Supply and Demand.** The nonramp regulation requirement of 525.0 effective MW was provided by a combination of cleared RegA and RegD resources equal to 464.4 hourly average performance adjusted actual MW in the first nine months of 2022. This is an increase of 21.0 performance adjusted actual MW from the first nine months of 2021, when the average hourly total regulation cleared performance adjusted actual MW for nonramp hours were 485.4 performance adjusted actual MW. The ramp regulation requirement of 800.0 effective MW was provided by a combination of cleared RegA and RegD resources equal to 719.2 hourly average performance adjusted actual MW in the first nine months

of 2022. This is an increase of 12.4 performance adjusted actual MW from the first nine months of 2021, where the average hourly regulation cleared MW for ramp hours were 706.8 performance adjusted actual MW.

The ratio of the average hourly offered supply of regulation to average hourly regulation demand (performance adjusted cleared MW) for nonramp hours was 1.63 in the first nine months of 2022 (1.55 in the first nine months of 2021). The ratio of the average hourly offered supply of regulation to average hourly regulation demand (performance adjusted cleared MW) for ramp hours was 1.56 in the first nine months of 2022 (1.52 in the first nine months of 2021).

- **Market Concentration.** In the first nine months of 2022, the three pivotal supplier test was failed in 88.8 percent of hours. In the first nine months of 2022, the effective MW weighted average HHI of RegA resources was 2458 which is highly concentrated and the effective MW weighted average HHI of RegD resources was 1670 which is moderately concentrated. The effective MW weighted average HHI of all resources was 1433, which is moderately concentrated.

Market Conduct

- **Offers.** Daily regulation offer prices are submitted for each unit by the unit owner. Owners are required to submit a cost-based offer and may submit a price-based offer. Offers include both a capability offer and a performance offer. Owners must specify which signal type the unit will be following, RegA or RegD.¹⁰ In the first nine months of 2022, there were 183 resources following the RegA signal and 52 resources following the RegD signal.

Market Performance

- **Price and Cost.** The weighted average clearing price for regulation was \$51.04 per MW of regulation in the first nine months of 2022, an increase of \$30.13 per MW, or 144.1 percent, from the weighted average clearing price of \$20.91 per MW in the first nine months of 2021. The weighted average cost of regulation in the first nine months of 2022 was \$63.46

¹⁰ See the 2021 State of the Market Report for PJM, Vol. II, Appendix F "Ancillary Services Markets."

per MW of regulation, an increase of 150.1 percent, from the weighted average cost of \$25.37 per MW in the first nine months of 2021.

- **Prices.** RegD resources continue to be incorrectly compensated relative to RegA resources due to an inconsistent application of the marginal benefit factor in the optimization, assignment and settlement processes. If the regulation market were functioning efficiently and competitively, RegD and RegA resources would be paid the same price per effective MW.
- **Marginal Benefit Factor.** The marginal benefit factor (MBF) is intended to measure the operational substitutability of RegD resources for RegA resources. The marginal benefit factor is incorrectly defined and applied in the PJM market clearing. The current incorrect and inconsistent implementation of the MBF has resulted in the PJM Regulation Market over procuring RegD relative to RegA in most hours and in an inefficient market signal about the value of RegD in every hour.

Black Start Service

Black start service is required for the reliable restoration of the grid following a blackout. Black start service is the ability of a generating unit to start without an outside electrical supply, or is the demonstrated ability of a generating unit to automatically remain operating at reduced levels when disconnected from the grid (automatic load rejection or ALR).¹¹

In the first nine months of 2022, total black start charges were \$51.7 million, including \$51.4 million in revenue requirement charges and \$0.35 million in uplift charges. Black start revenue requirements consist of fixed black start service costs, variable black start service costs, training costs, fuel storage costs, and an incentive payment. Black start uplift charges are paid to units scheduled in the day-ahead energy market or committed in real time to provide black start service under the ALR option or for black start testing. Black start zonal charges in first nine months of 2022 ranged from \$0 in the OVEC and REC Zones to \$14.7 million in the AEP Zone.

CRF values are a key determinant of total payments to black start units. The CRF values in PJM tariff tables should have been changed for both black start

and the capacity market when the tax laws changed in December 2017. As a result of the failure to change the CRF values, black start units have been and continue to be significantly overcompensated since the changes to the tax code.

Reactive

Reactive service, reactive supply and voltage control are provided by generation and other sources of reactive power (measured in MVar). Reactive power helps maintain appropriate voltage levels on the transmission system and is essential to the flow of real power (measured in MW). The same equipment provides both MVar and MW. The current rules permit over recovery of capital costs.

Reactive capability charges are based on FERC approved filings that permit recovery based on an outdated cost of service approach.¹² All capacity costs of generators should be incorporated in the capacity market. The nonmarket cost of service approach to reactive capability payments should be eliminated. Reactive service charges are paid to units that operate in real time outside of their normal range at the direction of PJM for the purpose of providing reactive service. Total reactive charges in the first nine months of 2022 increased 6.44 percent from \$272.3 million in 2021 to \$289.9 million in 2022. In the first nine months of 2022, reactive capability charges increased 6.27 percent from \$271.6 million in the first nine months of 2021 to \$288.6 million in 2022. Total reactive service charges in the first nine months of 2022 ranged from \$0 in the REC and OVEC Zones, to \$39.4 million in the AEP Zone.

Frequency Response

The PJM Tariff requires that all new generator interconnection customers, both synchronous and nonsynchronous, have hardware and/or software that provides primary frequency responsive real power control with the ability to sense changes in system frequency and autonomously adjust real power output to correct for frequency deviations.¹³ Primary frequency response begins within a few seconds and extends up to a minute. The purpose of primary frequency response is to arrest and stabilize the system until other measures (secondary

¹² OATT Schedule 2.

¹³ Nuclear Regulatory Commission (NRC) regulated facilities are exempt from this provision. Behind the meter generation that is sized to load is also exempt.

¹¹ OATT Schedule 1 § 1.3BB. There are no ALR units currently providing black start service.

and tertiary frequency response) become active. This includes a governor or equivalent controls capable of operating with a maximum five percent droop and a +/- 36 mHz deadband.¹⁴ In addition to resource capability, resource owners must comply by setting control systems to autonomously adjust real power output in a direction to correct for frequency deviations.

The response of generators within PJM to NERC identified frequency events remains under evaluation. A frequency event is declared whenever the system frequency goes outside of 60 Hz by +/- 40 mHz and stays there for 60 continuous seconds. The NERC BAL-003-2 requirement for balancing authorities (PJM is a balancing authority) uses a threshold value (L_{10}) equal to -259.3 MW/0.1 Hz and has selected twelve frequency events between December 1, 2020, and November 30, 2021, to evaluate.

As a balancing authority, PJM requires all generators to be capable of providing primary frequency response and to operate with primary frequency response controls enabled.¹⁵ PJM does monitor primary frequency response during NERC identified frequency events for all resources 50 MW or greater. Exclusions to PJM monitoring include nuclear plants, offline units, units with no available headroom, units assigned to regulation, and units with a current outage ticket in eDART.

Ancillary Services Costs per MWh of Load

Table 10-4 shows PJM ancillary services costs for the first nine months of 1999 through 2022, per MWh of load. The rates are calculated as the total charges for the specified ancillary service divided by the total PJM real-time load in MWh.¹⁶ The scheduling, system control, and dispatch category of costs is comprised of PJM scheduling, PJM system control and PJM dispatch; owner scheduling, owner system control and owner dispatch; other supporting facilities; black start services; direct assignment facilities; and ReliabilityFirst Corporation charges. The cost per MWh of load in Table 10-4 is a different metric than the cost of each ancillary service per MW of that service. The cost

¹⁴ OATT Attachment O § 4.7.2 (Primary Frequency Response).

¹⁵ *Id.*; see also *PJM Manual 12: Balancing Operations, Rev. 47 (Oct. 1, 2022), § 3.6 (Primary Frequency Response).

¹⁶ The total prices in this table are a load-weighted average system price per MWh by category, even if each category is not charged on that basis. These totals are presented for informational purposes and should not be used to calculate the costs of any specific market activity in PJM.

per MWh of load includes the effects both of price changes per MW of the ancillary service and changes in total load.

Table 10-4 History of ancillary services costs per MWh of load: January through September, 1999 through 2022^{17 18}

Year (Jan-Sep)	Scheduling, Dispatch and System Control		Synchronized		Total
	Regulation	Reactive	Reserve		
1999	\$0.16	\$0.22	\$0.25	\$0.00	\$0.63
2000	\$0.33	\$0.29	\$0.31	\$0.00	\$0.93
2001	\$0.55	\$0.70	\$0.22	\$0.00	\$1.47
2002	\$0.42	\$0.82	\$0.19	\$0.00	\$1.43
2003	\$0.53	\$1.01	\$0.23	\$0.13	\$1.90
2004	\$0.50	\$0.99	\$0.25	\$0.14	\$1.88
2005	\$0.78	\$0.73	\$0.26	\$0.11	\$1.88
2006	\$0.55	\$0.74	\$0.28	\$0.07	\$1.64
2007	\$0.65	\$0.72	\$0.27	\$0.06	\$1.70
2008	\$0.78	\$0.44	\$0.33	\$0.07	\$1.62
2009	\$0.36	\$0.34	\$0.36	\$0.04	\$1.10
2010	\$0.38	\$0.36	\$0.36	\$0.06	\$1.16
2011	\$0.36	\$0.37	\$0.38	\$0.09	\$1.20
2012	\$0.23	\$0.42	\$0.44	\$0.03	\$1.12
2013	\$0.27	\$0.42	\$0.67	\$0.03	\$1.39
2014	\$0.36	\$0.43	\$0.40	\$0.14	\$1.33
2015	\$0.25	\$0.42	\$0.36	\$0.12	\$1.15
2016	\$0.11	\$0.43	\$0.37	\$0.05	\$0.96
2017	\$0.13	\$0.48	\$0.42	\$0.06	\$1.09
2018	\$0.20	\$0.47	\$0.40	\$0.06	\$1.13
2019	\$0.11	\$0.47	\$0.42	\$0.04	\$1.04
2020	\$0.10	\$0.48	\$0.46	\$0.02	\$1.06
2021	\$0.15	\$0.50	\$0.46	\$0.05	\$1.16
2022	\$0.36	\$0.44	\$0.49	\$0.13	\$1.42

Market Procurement of Real-Time Ancillary Services

PJM uses market mechanisms to varying degrees in the procurement of ancillary services, including primary reserves and regulation. Ideally, all ancillary services would be procured taking full account of the interactions with the energy market. When a resource is used for an ancillary service instead of providing energy in real time, the cost of removing the resource, either fully or partially, from the energy market should be weighed against the benefit the ancillary service provides. The degree to which PJM markets

¹⁷ Note: The totals in Table 10-4 account for after the fact billing adjustments made by PJM and may not match totals presented in past reports.

¹⁸ Reactive totals include FERC approved rates for reactive capability.

account for these interactions depends on the timing of the product clearing and software limitations and the accuracy of unit parameters and offers.

The synchronized reserve market clearing is more integrated with the energy market clearing than the other ancillary services. Resources categorized as flexible tier 2 reserve, those that can provide reserves by backing down according to their ramp rate, are jointly cleared along with energy in every real-time market solution. Given the joint clearing of energy and flexible tier 2, the synchronized reserve market clearing price should always cover the opportunity cost of providing flexible tier 2. PJM should never need to pay uplift to flexible tier 2. The uplift paid to flexible tier 2 results from issues with the dispatch and pricing software timing. Inflexible tier 2 reserves, provided by resources that require longer notice to take actions to prepare for reserve deployment, are not cleared along with energy in the real-time market solution. Inflexible tier 2 reserves are cleared hourly by the Ancillary Service Optimizer (ASO). The ASO uses forward looking information about the energy market, flexible tier 2, tier 1, and regulation to estimate the costs and benefits of using a resource for inflexible tier 2 synchronized reserves.

Nonsynchronized reserves are cleared with every real-time energy market solution, but their costs are not fully known by the real-time energy market software (RT SCED) because the resources are offline. PJM uses an estimate of the cost of using a resource for nonsynchronized reserve instead of energy from a previously solved IT SCED solution. IT SCED runs every 15 minutes looking ahead at target dispatch times up to two hours in the future. The energy commitment decisions for the offline resources have already been made when the RT SCED clears the nonsynchronized reserve market. RT SCED compares the IT SCED estimated cost of nonsynchronized reserve clearing to the RT SCED determined cost of synchronized reserve clearing in satisfying the primary reserve requirement. Nonsynchronized reserve clearing indirectly interacts with energy clearing through both products' substitutability with synchronized reserves.

Prices for the regulation and reserve markets are set by the pricing calculator (LPC), which uses the RT SCED solution as an input. The RT SCED partially, but not fully, clears the reserve market. The software determining the prices

is not clearing the regulation market. Since the implementation of fast start pricing on September 1, 2021, the pricing calculations in LPC are not the same prices that result from the market clearing in RT SCED.

Recommendations

- The MMU recommends that all data necessary to perform the regulation market three pivotal supplier test be saved by PJM so that the test can be replicated. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends that the total regulation (TReg) signal sent on a fleet wide basis be eliminated and replaced with individual regulation signals for each unit. (Priority: Low. First reported 2019. Status: Not adopted.)
- The MMU recommends that the ability to make dual offers (to make offers as both a RegA and a RegD resource in the same market hour) be removed from the regulation market. (Priority: High. First reported 2019. Status: Not adopted.)
- The MMU recommends that the regulation market be modified to incorporate a consistent application of the marginal benefit factor (MBF) throughout the optimization, assignment and settlement process. The MBF should be defined as the Marginal Rate of Technical Substitution (MRTS) between RegA and RegD. (Priority: High. First reported 2012. Status: Not adopted. FERC rejected.¹⁹)
- The MMU recommends that the lost opportunity cost in the ancillary services markets be calculated using the schedule on which the unit was scheduled to run in the energy market. (Priority: High. First reported 2010. Status: Not adopted.²⁰ FERC rejected.²¹)
- The MMU recommends that the lost opportunity cost calculation used in the regulation market be based on the resource's dispatched energy offer schedule, not the lower of its price or cost offer schedule. (Priority: Medium. First reported 2010. Status: Not adopted. FERC rejected.²²)

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

²⁰ This recommendation was adopted by PJM for the energy market. Lost opportunity costs in the energy market are calculated using the schedule on which the unit was scheduled to run. In the regulation market, this recommendation has not been adopted, as the LOC continues to be calculated based on the lower of price or cost in the energy market offer.

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

²² *Id.*

- The MMU 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. (Priority: Medium. First reported 2016. Status: Not adopted. FERC rejected.²³)
- The MMU recommends enhanced documentation of the implementation of the regulation market design. (Priority: Medium. First reported 2010. Status: Not adopted. FERC rejected.²⁴)
- The MMU recommends that PJM be required to save data elements necessary for verifying the performance of the regulation market. (Priority: Medium. First reported 2010. Status: Not adopted.)
- The MMU recommends that the \$12.00 margin adder be eliminated from the definition of the cost based regulation offer because it is a markup and not a cost. (Priority: Medium. First reported 2021. Status: Not adopted.)
- The MMU recommends 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. (Priority: Medium. First reported Q1, 2022. Status: Not adopted.)
- The MMU recommends that PJM replace the static MidAtlantic/Dominion Reserve Subzone with a reserve zone structure consistent with the actual deliverability of reserves based on current transmission constraints. (Priority: High. First reported 2019. Status: Not adopted.)
- The MMU recommends that the \$7.50 margin be eliminated from the definition of the cost of tier 2 synchronized reserve because it is a markup and not a cost. (Priority: Medium. First reported 2018. Status: Adopted October 1, 2022.)
- The MMU recommends that the variable operating and maintenance cost be eliminated from the definition of the cost of tier 2 synchronized reserve and that the calculation of synchronized reserve variable operations and maintenance costs be removed from Manual 15. (Priority: Medium. First reported 2019. Status: Adopted October 1, 2022.)
- The MMU recommends that the components of the cost-based offers for providing regulation and synchronous condensing be defined in Schedule 2 of the Operating Agreement. (Priority: Low. First reported 2019. Status: Not adopted.)
- The MMU recommends that the rule requiring that tier 1 synchronized reserve resources be paid the tier 2 price when the nonsynchronized reserve price is above zero be eliminated immediately and that, under the current rule, tier 1 synchronized reserve resources not be paid the tier 2 price when they do not respond. (Priority: High. First reported 2013. Status: Adopted October 1, 2022.)
- The MMU recommends that the tier 2 synchronized reserve must offer requirement be enforced on a daily and hourly basis. The MMU recommends that PJM define a set of acceptable reasons why a unit can be made unavailable daily or hourly and require unit owners to select a reason in Markets Gateway whenever making a unit unavailable either daily or hourly or setting the offer MW to 0 MW. (Priority: Medium. First reported 2013. Status: Adopted October 1, 2022.)
- The MMU recommends that, for calculating the penalty for a tier 2 resource failing to meet its scheduled obligation during a spinning event, the penalty should be based on the actual time since the last spinning event of 10 minutes or longer during which the resource performed because performance is only measured for events 10 minutes or longer and that the tier 2 shortfall penalty should include LOC payments as well as SRMCP and MW of shortfall. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that aggregation not be permitted to offset unit specific penalties for failure to respond to a synchronized reserve event. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that PJM eliminate the use of Degree of Generator Performance (DGP) in the synchronized reserve market solution and improve the actual tier 1 estimate. If PJM continues to use DGP, DGP should be documented in PJM's manuals. (Priority: Medium. First reported 2018. Status: Adopted October 1, 2022.)

²³ *Id.*

²⁴ *Id.*

- The MMU recommends that the details of VACAR Reserve Sharing Agreement (VRSAs) be made public, including any responsibilities assigned to PJM and including the amount of reserves that Dominion commits to meet its obligations under the VRSAs. (Priority: Medium. First reported 2020. Status: Not adopted.)
- The MMU recommends that the VRSAs be terminated and, if necessary, replaced by a reserve sharing agreement between PJM and VACAR South, similar to agreements between PJM and other bordering areas. (Priority: Medium. First reported 2020. Status: Adopted October 1, 2022.)
- The MMU recommends that a reason code be attached to every hour in which PJM market operations adds additional DASR MW. (Priority: Medium. First reported 2015. Status: Adopted October 1, 2022.)
- The MMU recommends that PJM modify the DASR market to ensure that all resources cleared incur a real-time performance obligation. (Priority: Low. First reported 2013. Status: Adopted October 1, 2022.)
- The MMU recommends that, in order to mitigate market power, offers in the DASR market be based on opportunity cost only. (Priority: Low. First reported 2009. Modified, 2018. Status: Adopted October 1, 2022.)
- The MMU recommends that all resources, new and existing, have a requirement to include and maintain equipment for primary frequency response capability as a condition of interconnection service. The PJM capacity and energy markets already compensate resources for frequency response capability and any marginal costs. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that new CRF rates for black start units, incorporating current tax code changes, be implemented immediately. The new CRF rates should apply to all black start units. The black start units should be required to commit to providing black start service for the life of the unit. (Priority: High. First reported 2020. Status: Not adopted.)
- The MMU recommends for oil tanks shared with other resources that only a proportionate share of the minimum tank suction level (MTSL) be allocated to black start service. The MMU further recommends that the PJM tariff be updated to clearly state how the MTSL will be calculated for

black start units sharing oil tanks. (Priority: Medium. First reported 2017. Status: Adopted 2021.)

- The MMU recommends that separate cost of service payments for reactive capability be eliminated and the cost of reactive capability be recovered in the capacity market. (Priority: Medium. First reported 2016. Status: Not adopted.)
- The MMU recommends that payments for reactive capability, if continued, be based on the 0.90 power factor that PJM has determined is necessary. (Priority: Medium. First reported 2018. Status: Not adopted.)
- The MMU recommends that, if payments for reactive are continued, fleet wide cost of service rates used to compensate resources for reactive capability be eliminated and replaced with compensation based on unit specific costs. (Priority: Low. First reported 2019.²⁵ Status: Partially adopted.)
- The MMU recommends that Schedule 2 to OATT be revised to state explicitly that only generators that provide reactive capability to the transmission system that PJM operates and has responsibility for are eligible for reactive capability compensation. Specifically, such eligibility should be determined based on whether a generation facility's point of interconnection is on a transmission line that is a Monitored Transmission Facility as defined by PJM and is on a Reportable Transmission Facility as defined by PJM.²⁶ (Priority: Medium. First reported 2020. Status: Not adopted.)

Conclusion

The design of the PJM Regulation Market is significantly flawed.²⁷ The market design does not correctly incorporate the marginal rate of technical substitution (MRTS) in market clearing and settlement. The market design uses the marginal benefit factor (MBF) to incorrectly represent the MRTS and uses a mileage ratio instead of the MBF in settlement. The current market

²⁵ The MMU has discussed this recommendation in state of the market reports since 2016 but Q3, 2019 was the first time it was reported as a formal MMU recommendation.

²⁶ See PJM Transmission Facilities (note that this requires you first log into a PJM Tools account. If you do not, then the link sends you to an Access Request page, <<https://pjm.com/markets-and-operations/ops-analysis/transmission-facilities>>.

²⁷ The current PJM regulation market design that incorporates two signals using two resource types was a result of FERC Order No. 755 and subsequent orders. Order No. 755, 137 FERC ¶ 61,064 at PP 197–200 (2011).

design allows regulation units that have the capability to provide both RegA and RegD MW to submit an offer for both signal types in the same market hour. However, the method of clearing the regulation market for an hour in which one or more units has a dual offer incorrectly accounts for the amount of RegD and the effective MW of the RegD that it clears. The result of the flaw is that the MBF in the clearing phase is incorrectly low compared to the MBF in the solution phase and the actual amount of effective MW procured is higher than the regulation requirement. This failure to correctly and consistently incorporate the MRTS into the regulation market design has resulted in both underpayment and overpayment of RegD resources and in the over procurement of RegD resources in all hours. The market results continue to include the incorrect definition of opportunity cost. These issues are the basis for the MMU's conclusion that the regulation market design is flawed.

To address these flaws, the MMU and PJM developed a joint proposal which was approved by the PJM Members Committee on July 27, 2017, and filed with FERC on October 17, 2017.²⁸ The PJM/MMU joint proposal addresses issues with the inconsistent application of the marginal benefit factor throughout the optimization and settlement process in the PJM Regulation Market. FERC rejected the joint proposal on March 30, 2018, as being noncompliant with Order No. 755.²⁹ The MMU and PJM separately filed requests for rehearing, which were denied by order issued March 26, 2020.³⁰

The structure of the tier 2 synchronized reserve market has been evaluated and the MMU has concluded that these markets are not structurally competitive as they are characterized by high levels of supplier concentration and inelastic demand. As a result, these markets are operated with market clearing prices and with offers based on the marginal cost of producing the product plus a margin. As a result of these requirements, the conduct of market participants within these market structures has been consistent with competition, and the market performance results have been competitive. However, the \$7.50 margin is not a cost. The margin is effectively a rule-based form of economic withholding and is therefore not consistent with a competitive outcome. The \$7.50 margin should be eliminated. The variable operating and maintenance

²⁸ 18 CFR § 385.211.

²⁹ 162 FERC ¶ 61,295 (2018).

³⁰ 170 FERC ¶ 61,259 (2020).

component of the synchronized reserve offer should also be eliminated. All variable operating and maintenance costs are incurred to provide energy and to make units available to provide energy. There are no variable operating and maintenance costs associated with providing synchronized reserve. Reserve market design changes approved by FERC and scheduled for implementation on October 1, 2022 will eliminate the \$7.50 per MW margin and the variable operations and maintenance costs.³¹

Participant performance has not been adequate for tier 2 synchronized reserve. Compliance with calls to respond to actual synchronized reserve events remains significantly less than 100 percent. Actual participant performance means that the penalty structure is not an adequate incentive for performance. The October 1, 2022, reserve market design changes do not respond to the MMU's recommendations to increase the penalties for nonperformance. The rule that requires payment of the tier 2 synchronized reserve price to tier 1 synchronized reserve resources when the nonsynchronized reserve price is greater than zero, is inefficient and results in a substantial windfall payment to the holders of tier 1 synchronized reserve resources. Tier 1 resources have no obligation to perform and pay no penalties if they do not perform, and tier 1 resources do not incur any costs when they are part of the tier 1 estimate in the market solution. Tier 1 resources are already paid for their response if they do respond to a synchronized reserve event. Tier 1 resources require no additional payment. Overpayment of tier 1 resources based on this rule has added more than \$150 million to the cost of primary reserve since 2014. The reserve market design changes approved by FERC and implemented on October 1, 2022, consolidate Tier 1 and Tier 2 reserves into a single synchronized reserve product, with a stronger must offer requirement and a single clearing price.³² This eliminates the payment of Tier 1 based on the nonzero nonsynchronized reserve price.

The benefits of markets are realized under these approaches to ancillary service markets. Even in the presence of structurally noncompetitive markets, there can be transparent, market clearing prices based on competitive offers that account explicitly and accurately for opportunity cost. This is consistent

³¹ See FERC Docket No. EL19-58.

³² See FERC Docket No. EL19-58.

with the market design goal of ensuring competitive outcomes that provide appropriate incentives without reliance on the exercise of market power and with explicit mechanisms to prevent the exercise of market power.

The MMU concludes that the regulation market results were not competitive, and the market design is significantly flawed. The MMU concludes that the synchronized reserve market results were competitive, although the \$7.50 margin should be removed. The MMU concludes that the DASR market results were competitive, although offers above the competitive level continued to affect prices. The MMU recognizes that significant reserve market design changes were implemented on October 1, 2022, and these new rules will be addressed in detail in the annual *2022 State of the Market Report for PJM*.

Primary Reserve

NERC Performance Standard BAL-002-3, Disturbance Control Standard – Contingency Reserve for Recovery from a Balancing Contingency Event, requires PJM to carry sufficient contingency reserve to recover from a sudden balancing contingency (usually a loss of generation). The Contingency Event Recovery Period is the time required to return the ACE to zero if it was zero or positive before the event or to its pre-event level if it was negative at the start of the event. The Contingency Reserve Restoration period is the time required to restore contingency (primary) reserves to a level greater than or equal to the largest single contingency after the end of the Contingency Event Recovery Period. NERC standards set the Contingency Event Recovery Period as 15 minutes and Contingency Reserve Restoration Period as 90 minutes.³³ The NERC requirement is 100 percent compliance and status must be reported quarterly. PJM implements this contingency reserve requirement using primary reserves.³⁴ PJM maintains 10 minute reserves (primary reserve) to ensure reliability in the event of disturbances. PJM's primary reserves are made up of resources, both synchronized and nonsynchronized, that can provide energy within 10 minutes. PJM does not have a Contingency Reserve Restoration Period standard.

³³ See PJM. "PJM Manual 12: Balancing Operations," Rev. 47 (Oct. 1, 2022) Attachment D, "the Disturbance Recovery Period is 15 minutes after the start of a Reportable Disturbance. Subsequently, PJM must fully restore the Synchronized Reserve within 90 minutes." While this cited attachment only references restoring synchronized reserves, PJM Manuals 10 & 13 make it clear that primary reserves serve as PJM's contingency reserve.

³⁴ See PJM. "PJM Manual 10: Pre-Scheduling Operations," § 3.1 Reserve Definitions, Rev. 42 (Oct. 1, 2021).

Market Structure

Demand

The NERC standard requires a control area to carry primary reserve MW equal to or greater than the largest single contingency (also known as the most severe single contingency, or MSSC).³⁵ PJM requires primary reserves in the amount of 150 percent of the largest single contingency with at least 100 percent of the requirement made up of synchronized reserves.³⁶ In the first nine months of 2022, the average synchronized reserve requirement was 1,675.4 MW in the MAD Subzone and 1,676.2 MW in the RTO Zone. The synchronized reserve requirement is calculated for every real-time market dispatch solution. PJM can make temporary adjustments to the primary reserve requirement when grid maintenance or outages change the largest contingency or in cases of hot weather alerts or cold weather alerts.

The primary reserve market requirement is set equal to 150 percent of the largest single contingency for each market solution, ASO, IT SCED, and RT SCED. The largest single contingency is usually the output of the largest generating unit to which PJM adds 190 MW. In cases where temporary switching conditions create the risk that a single fault could remove several generators, PJM will define the largest single contingency as the sum of the output of those generators.³⁷

PJM can also increase the primary and synchronized reserve requirement in cases of hot weather or cold weather alerts or escalating emergency procedures.³⁸ Such additional reserves are committed as part of the hourly (ASO) and five minute (RT SCED) processes. In the first nine months of 2022, the average primary reserve requirement for the RTO Zone was 2,419.3 MW. The average primary reserve requirement in the MAD Subzone was 2,418.2 MW. These averages include the hours when PJM raised the requirements.

³⁵ NERC BAL-002-3. "Disturbance Control Standard – Contingency Reserve for Recovery from a Balancing Contingency Event," September 25, 2018. <<https://www.nerc.com/pa/Stand/Reliability%20Standards/BAL-002-3.pdf>>.

³⁶ See PJM. "PJM Manual 13: Emergency Operations," § 2.2 Reserve Requirements, Rev. 85 (Oct. 1, 2022).

³⁷ See PJM. "PJM Manual 11: Energy & Ancillary Services Market Operations" § 4.3 Reserve Requirement Determination, Rev. 122 (Oct. 1, 2022).

³⁸ See *id.*

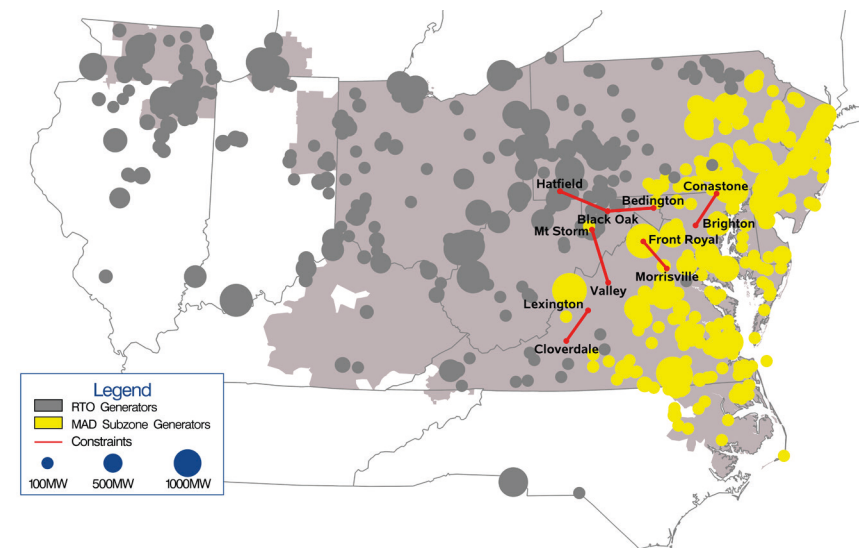
The MMU identified instances when PJM increased the primary and synchronized reserve requirements (Table 10-5).

Table 10-5 Temporary adjustments to primary and synchronized reserve: January through September, 2022

From	To	Number of Hours	Amount of Adjustment
1-Jan-22	9-Feb-22	936	Primary Reserve (64 MW), Synchronized Reserve (43 MW)
21-Feb-22	25-Feb-22	103	Primary Reserve (0 MW), Synchronized Reserve (0 MW)
29-Mar-22	31-Mar-22	54	Primary Reserve (0 MW), Synchronized Reserve (0 MW)
10-Apr-22	15-Apr-22	122	Primary Reserve (0 MW), Synchronized Reserve (0 MW)
16-May-22	20-Jun-22	848	Primary Reserve (38 MW), Synchronized Reserve (26 MW)
28-Jun-22	30-Jun-22	42	Primary Reserve (1,189 MW), Synchronized Reserve (792 MW)
26-Jul-22	26-Jul-22	1	Primary Reserve (76 MW), Synchronized Reserve (50 MW)
6-Sep-22	10-Sep-22	96	Primary Reserve (137 MW), Synchronized Reserve (92 MW)

Transmission constraints can limit the deliverability of reserves within the RTO, requiring the definition of a subzone. In the first nine months of 2022, PJM defined a single subzone, the Mid-Atlantic Dominion (MAD) Subzone (Figure 10-1).³⁹ Figure 10-1 is a map of constraints and major generation sources. The constraints separating the RTO Zone and MAD Subzone are defined by underlying grid topology. The RTO Zone into MAD Subzone constraints reflect limits on the transmission line capacity that separate the RTO Zone and MAD Subzone. If, in the case of a spinning event, the current economic dispatch plus the current synchronized market dispatch would overload the constraint, then all additional synchronized reserve MW must be cleared from the unconstrained side of the constraints. When this occurs, the synchronized reserve prices between the RTO Zone and the MAD Subzone will diverge. In practice, PJM has always maintained only the MAD Subzone but for any market solution several distinct constraining paths are analyzed and the most limiting one becomes the definition for that solution.

Figure 10-1 PJM RTO Zone and MAD Subzone map of constraints and generation sources



The most limiting transmission constraint for power flow from the RTO Zone into the MAD Subzone since August 2017 has been the AP South Interface. The most frequent constraint in the first nine months of 2022 was Bedington-Black Oak, then Brighton-Conastone, and Cloverdale-Lexington.

Supply

The demand for primary reserve is satisfied by tier 1 synchronized reserves, tier 2 synchronized reserves and nonsynchronized reserves, subject to the requirement that synchronized reserves equal 100 percent of the largest contingency. After the synchronized reserve requirement is satisfied, the remainder of primary reserves is from the least expensive combination of synchronized and nonsynchronized reserves.

³⁹ Additional subzones may be defined by PJM to meet system reliability needs. PJM will notify stakeholders in such an event. See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations" § 4.3.2 Creation of New Reserve Subzones, Rev. 122 (Oct. 1, 2022).

Estimated tier 1 contributes to meeting PJM's primary reserve requirement and PJM's synchronized reserve requirement. In the MAD Subzone, an average of 693.6 MW of tier 1 was available in the first nine months 2022 (Table 10-6).⁴⁰ Tier 1 synchronized reserve fully satisfied the MAD Subzone synchronized reserve requirement or reduced the need for tier 2 synchronized reserve to self-scheduled reserves in 4.6 percent of dispatch solutions in the first nine months of 2022. In the RTO Zone, an average of 1,531.4 MW of tier 1 was available, fully satisfying the synchronized reserve requirement in 36.0 percent of real-time dispatch solutions (Table 10-7).

Regardless of online/offline state, all nonemergency generation capacity resources must submit a daily offer for tier 2 synchronized reserve in Markets Gateway prior to the offer submission deadline (14:15 the day prior to the operating day). Resources listed as available for tier 2 synchronized reserve without a synchronized reserve offer will have their offer price automatically set to \$0.00. Offer MW and other non-cost offer parameters can be changed during the operating day. Owners who opt in for intraday updates may change their offer price up to 65 minutes before the hour. While not exempt from making an offer, units that cannot reliably provide synchronized reserve may offer zero MW of tier 2 reserve. Certain unit types, including nuclear, wind, solar, and energy storage resources, are expected to offer zero MW.⁴¹

Offer prices for synchronized reserve are capped at \$7.50 per MWh plus marginal cost, as defined in PJM Manual 15.

In the clearing process, after tier 1 is estimated, the remainder of the synchronized reserve requirement is met by tier 2.

In the first nine months of 2022, in the MAD Subzone, there was an average of 1,289.8 MW of eligible nonsynchronized reserve supply available to meet the average demand for primary reserve (Table 10-6). In the RTO Zone, an average of 1,633.2 MW of nonsynchronized reserve supply was available to meet the average demand of 2,436.9 MW (Table 10-7).

Table 10-6 provides the average dispatch solution reserves, by type of reserve, used by the RT SCED market solution to satisfy the primary reserve requirement in the MAD Subzone from January 2021 through September 2022.

Table 10-6 Average monthly reserves used to satisfy the primary reserve requirement, MAD Subzone: January 2021 through September 2022

Year	Month	Tier 1 Total MW	Tier 2 Synchronized Reserve MW	Nonsynchronized Reserve MW	Total Primary Reserve MW
2021	Jan	835.6	250.6	1,331.5	2,417.7
2021	Feb	976.5	216.5	1,240.2	2,433.2
2021	Mar	883.9	214.2	1,163.0	2,261.1
2021	Apr	686.7	316.6	1,275.6	2,279.0
2021	May	653.0	247.2	1,141.5	2,041.7
2021	Jun	835.6	203.6	1,266.7	2,305.9
2021	Jul	890.3	205.1	1,260.6	2,356.0
2021	Aug	915.6	221.9	1,270.8	2,408.4
2021	Sep	906.3	236.1	1,203.9	2,346.3
2021	Oct	592.9	433.7	1,210.1	2,236.7
2021	Nov	569.4	413.2	1,330.9	2,313.4
2021	Dec	742.3	339.1	1,336.9	2,418.3
2021	Average	787.2	276.9	1,252.8	2,316.9
2022	Jan	849.0	267.1	1,364.5	2,480.6
2022	Feb	898.3	87.8	1,221.7	2,207.7
2022	Mar	700.2	135.8	1,159.7	1,995.7
2022	Apr	567.6	253.3	1,339.4	2,160.4
2022	May	594.9	270.4	1,267.8	2,133.1
2022	Jun	654.5	294.7	1,445.8	2,395.0
2022	Jul	601.7	258.5	1,333.5	2,193.8
2022	Aug	631.1	287.4	1,372.3	2,290.8
2022	Sep	761.6	244.4	1,096.8	2,102.8
2022	Average	693.6	234.5	1,289.8	2,217.9

⁴⁰ ASO, Ancillary Services Optimizer. This is the hour-ahead market software that optimizes ancillary services with energy. ASO schedules hourly the Tier 2 Synchronized Reserve, Regulation, and Nonsynchronized Reserves.

⁴¹ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2 PJM Synchronized Reserve Market Business Rules, Rev. 121 (Jul. 7, 2022).

Table 10-7 shows the average dispatch solution reserves, by type of reserve, satisfying the primary reserve requirement in the RTO Zone in January 2021 through September 2022.

Table 10-7 Average monthly reserves used to satisfy the primary reserve requirement, RTO Zone: January 2021 through September 2022

Year	Month	Tier 1 Total MW	Tier 2 Synchronized Reserve MW	Nonsynchronized Reserve MW	Total Primary Reserve MW
2021	Jan	1,758.2	508.6	1,515.0	3,781.9
2021	Feb	1,851.4	599.4	1,510.5	3,961.2
2021	Mar	1,702.0	596.0	1,455.9	3,753.9
2021	Apr	1,308.5	753.2	1,594.0	3,655.8
2021	May	1,375.8	787.4	1,566.5	3,729.7
2021	Jun	1,696.9	618.2	1,579.9	3,895.0
2021	Jul	1,675.5	664.2	1,587.4	3,927.1
2021	Aug	1,770.6	709.1	1,598.7	4,078.4
2021	Sep	1,777.4	657.1	1,491.3	3,925.8
2021	Oct	1,109.3	1,067.4	1,694.8	3,871.5
2021	Nov	1,160.3	1,029.8	1,804.2	3,994.2
2021	Dec	1,622.7	639.8	1,560.9	3,823.3
2021	Average	1,561.7	722.9	1,581.6	3,866.2
2022	Jan	1,711.1	495.0	1,521.4	3,727.5
2022	Feb	1,949.3	358.3	1,406.6	3,714.2
2022	Mar	1,513.4	590.1	1,515.9	3,619.5
2022	Apr	1,152.3	774.7	1,733.7	3,660.8
2022	May	1,471.1	802.7	1,698.4	3,972.2
2022	Jun	1,532.6	876.0	1,871.1	4,279.7
2022	Jul	1,464.7	783.4	1,707.2	3,955.3
2022	Aug	1,428.9	940.8	1,837.4	4,207.2
2022	Sep	1,589.2	710.2	1,388.0	3,687.4
2022	Average	1,531.4	706.4	1,633.2	3,871.0

Supply and Demand

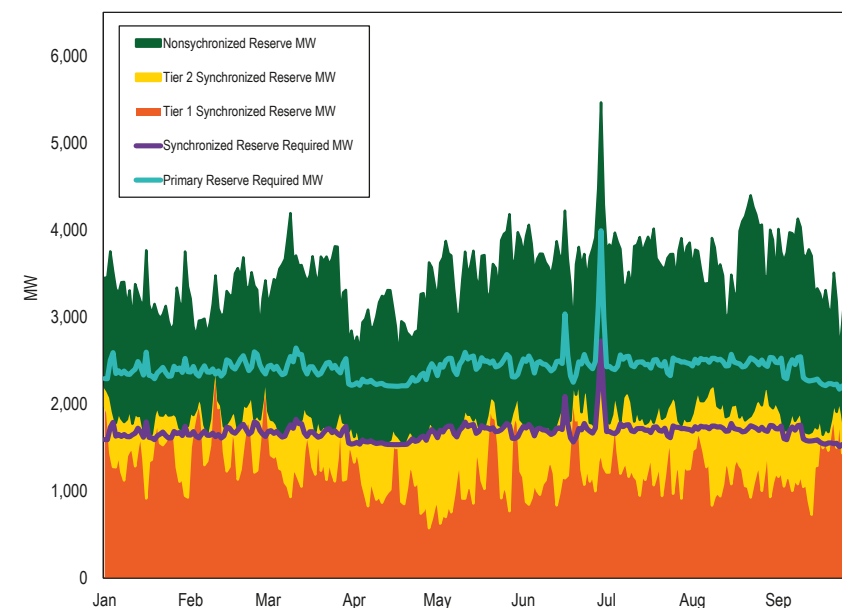
The market solution software relevant to reserves consists of: the Ancillary Services Optimizer (ASO) solving hourly; the intermediate term security constrained economic dispatch market solution (IT SCED); and the real-time (short term) security constrained economic dispatch market solution (RT SCED).

Inflexible tier 2 synchronized reserve is committed by the ASO. If there is enough estimated tier 1 MW available to satisfy the synchronized reserve

requirement, then no inflexible tier 2 synchronized reserve MW is committed. If the sum of the tier 1 MW and the ASO-committed inflexible tier 2 MW does not meet the synchronized reserve requirement, then the RT SCED will commit available flexible tier 2 synchronized reserve. If there is an excess of synchronized reserve, then the RT SCED may decommit previously committed flexible synchronized reserves. The primary reserve requirement is met by economically assigning inflexible synchronized reserves, flexible synchronized reserves, and nonsynchronized reserves.

Figure 10-2 shows how the daily average market solutions satisfy the primary reserve requirement for the RTO Zone. PJM temporarily increased the primary and synchronized reserve requirements in June. The details are in Table 10-5.

Figure 10-2 RTO reserve zone primary reserve MW by source (Daily Averages): January through September, 2022



In the first nine months of 2022, tier 1 synchronized reserve was the primary source of synchronized reserves, but tier 1 and tier 2 were both needed to meet the synchronized reserve requirement.

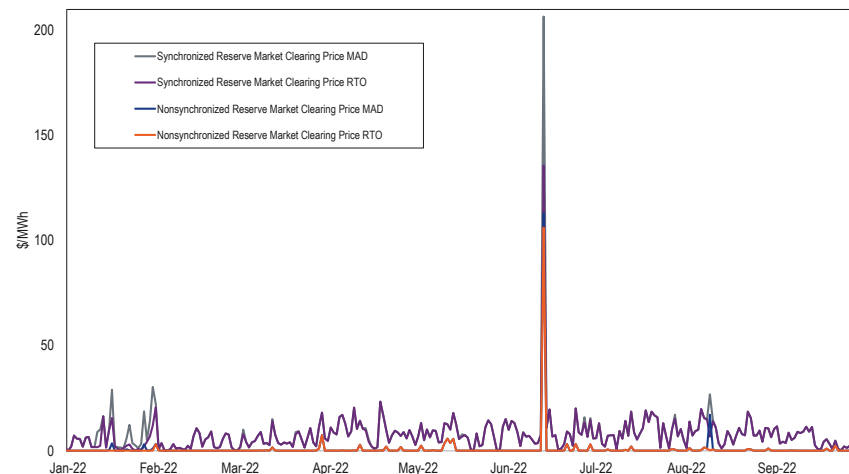
Price and Cost

The price of primary reserves results from the demand curve for primary reserves and the supply of primary reserves. The demand curve is modeled in each of the primary reserve clearing engines (ASO, IT SCED, RT SCED). The demand curve for primary reserves has two steps, with an \$850 penalty factor for primary reserve levels from 0 MW to a MW amount equal to 150 percent of the MSSC, and a \$300 penalty factor for primary reserve levels from 150 percent of MSSC, to 150 percent of MSSC plus 190 MW.

Figure 10-3 shows daily weighted average synchronized and nonsynchronized market clearing prices in the first nine months of 2022. The MAD SRMCP and RTO SRMCP prices diverged in 1,046 five-minute intervals, 0.6 percent of the total 183,708 intervals, in the first nine months of 2022.

There was a significant increase in the price of reserves on June 13, 2022 as a result of shortage pricing (Figure 10-3). On June 13, the RTO primary reserve was short for 35 intervals and the RTO synchronized reserve was short for 11 intervals, all concurrent with the primary reserve shortage. The MAD primary reserve was short for 35 intervals and the MAD synchronized reserve was short for eight intervals, all concurrent with the primary reserve shortage.

Figure 10-3 Daily average market clearing prices (\$/MWh) for synchronized reserve and nonsynchronized reserve: January through September, 2022



Tier 1 Synchronized Reserve

Tier 1 synchronized reserve is a component of primary reserve comprised of online resources following economic dispatch and able to ramp up from their current output in response to a synchronized reserve event. The tier 1 synchronized reserve for a unit is estimated as the lesser of the available 10 minute ramp or the difference between the economic dispatch point and the synchronized reserve maximum output, which by default is equal to its economic maximum. Resource owners may request a lower synchronized reserve maximum if a physical limitation exists.⁴² Tier 1 resources are identified by the market solution. Tier 1 synchronized reserves have an incremental cost of zero. Tier 1 synchronized reserves are paid under two circumstances. Tier 1 reserves are paid when they respond to a synchronized reserve event. Tier 1 reserves are paid the synchronized reserve market clearing price when the nonsynchronized reserve market clearing price is above \$0.

⁴² See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.2.1 Communication for Reserve Capability Limitation, Rev. 122 (Oct. 1, 2022).

While PJM relies on tier 1 resources to respond to a synchronized reserve event, tier 1 resources are not obligated to respond during an event. Tier 1 resources are credited if they do respond but are not penalized if they do not.

Market Structure

Supply

All generating resources operating on the PJM system with the exception of those assigned to tier 2 synchronized reserve are available for tier 1 synchronized reserve and any response to a spinning event will be credited at the synchronized energy premium price, except during intervals in which the non-synchronized reserve market clearing price was above \$0, in which case response was credited at the synchronized reserve market clearing price.

Introduced in 2014, DGP (Degree of Generator Performance) was a metric to improve the accuracy of the tier 1 MW estimate used by the market solution. In the first nine months of 2022, the available tier 1 MW estimated by the market solution for each resource is based upon its economic dispatch, and submitted synchronized reserve ramp rate, adjusted by its DGP. PJM communicates to generation operators whose tier 1 MW is part of the market solution the latest estimate of units' tier 1 MW and units' current DGP.⁴³ DGP violates the basic PJM principle that generation owners are solely responsible for their own offers. In addition, DGP is a crude estimate of ramp rates and does not account for the actual discontinuities along unit offer curves. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

The supply of tier 1 synchronized reserve available to the market solution is adjusted by eliminating tier 1 MW from unit types that cannot reliably provide synchronized reserve. These unit types are nuclear, wind, solar, landfill gas, energy storage, and hydro units.⁴⁴ These unit types are credited the synchronized energy premium price, like any other responding unit, if they respond to a spinning event, but will not, however, be paid as tier 1

resources when the nonsynchronized reserve market clearing price goes above \$0 outside of spinning events. There is a review process for resources excluded by default from the tier 1 estimate that request to be included.⁴⁵ PJM also excludes units, regardless of type, that it deems unreliable as tier 1, though it allows those resources to provide tier 2 synchronized reserve.

Table 10-8 provides tier 1 synchronized reserve supplied by resource and fuel type in the first nine months of 2022, including all tier 1 credited for responding to synchronized reserve events and paid when the nonsynchronized reserve price exceeded \$0 per MW.

Table 10-8 Supply of tier 1 synchronized reserve by resource and fuel type: January through September, 2022

Unit/Fuel Type	Percent by MW	Percent by Credits
Combined Cycle	46.3%	44.4%
Steam - Coal	19.5%	24.5%
CT - Natural Gas	12.8%	10.6%
Solar	9.9%	8.3%
Wind	5.4%	5.8%
Steam - Natural Gas	2.6%	2.6%
Hydro - Run of River	1.4%	1.8%
Steam - Other	1.3%	0.8%
RICE - Natural Gas	0.4%	0.4%
CT - Oil	0.1%	0.2%
Hydro - Pumped Storage	0.1%	0.2%
DSR	0.1%	0.2%
Nuclear	0.1%	0.2%
RICE - Other	0.0%	0.0%
Steam - Oil	0.0%	0.0%
Battery	0.0%	0.0%
CT - Other	0.0%	0.0%
RICE - Oil	0.0%	0.0%

In the first nine months of 2022, the SCED market solutions estimated that tier 1 MW from an average of 60 units could have an average of 1,531.4 MW of ramp available in a spinning event. For the 14 spinning events in the first nine months of 2022, PJM paid a total of 3,734.0 MW of tier 1 response across 37 intervals. Settlements included units like wind, solar, nuclear, and

⁴³ PJM. Ancillary Services, "Communication of Synchronized Reserve Quantities to Resource Owners," (May 6, 2015). <<http://www.pjm.com/-/media/markets-ops/ancillary/communication-of-synchronized-reserve-quantities-to-resource-owners.ashx>>

⁴⁴ See PJM. "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.1 Synchronized Reserve Market Eligibility, Rev. 121 (July 7, 2022).

⁴⁵ See *id.*

demand response which are not a part of the estimated tier 1 in the SCED market solutions.

The actual response is the sum of the products contributing to total ACE increase from the time the event is initiated to 10 minutes after the event is initiated. Total increase in ACE is a sum not only of tier 1 response, but also of tier 2 response, RegA and RegD actual response (RegD response is sometimes a MW increase and sometimes a MW decrease), and changes to net imports/exports across PJM's boundaries (sometimes an increase and sometimes a decrease in MW).

In the RTO Reserve Zone, the average estimated tier 1 synchronized reserve was 1,531.4 MW (Table 10-7). In 36.0 percent of dispatch solutions, the estimated tier 1 synchronized reserve was greater than the synchronized reserve requirement, meaning that the synchronized reserve requirement was met entirely by tier 1 synchronized reserve plus self-scheduled tier 2.

In the first nine months of 2022, the average estimated tier 1 synchronized reserve within the MAD Subzone was 693.6 MW (Table 10-6). In 4.6 percent of dispatch solutions the estimated tier 1 synchronized reserve available within the MAD Subzone plus the self-scheduled tier 2 in MAD was greater than the synchronized reserve requirement and no tier 2 market needed to be cleared.

Demand

There is no required amount of tier 1 synchronized reserve. The estimated tier 1 MW contribute to meeting the demand for synchronized and primary reserve.

The ancillary services market solution treats the cost of estimated tier 1 synchronized reserve as \$0, even when the cost of tier 1 is positive because the nonsynchronized reserve market clearing price is above \$0. As a result, the optimization cannot and does not minimize the total cost of primary reserves. The MMU recommends that tier 1 synchronized reserve not be paid when the nonsynchronized reserve market clearing price is above \$0. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

Supply and Demand

When solving for the synchronized reserve requirement the market solution first estimates the amount of tier 1 available from the energy dispatch. If the requirement is not filled by tier 1, it then commits tier 2 beginning with all self-scheduled synchronized reserve.

In the MAD Subzone, the market solution takes all tier 1 MW estimated to be available within the MAD Subzone as well as the synchronized reserve MW estimated to be available within the MAD Subzone from the RTO Zone. If the total tier 1 synchronized reserve is less than the synchronized reserve requirement, the remainder of the synchronized reserve requirement is filled with tier 2 synchronized reserve.

Tier 1 Synchronized Reserve Payments

Tier 1 synchronized reserve is awarded credits under two circumstances. The first is in response to a spinning event. The second is during intervals outside of a spinning event during which the non-synchronized reserve market clearing price is above \$0 and the unit is included in the estimated tier 1 MW.

In response to a spinning event, all resources (except scheduled tier 2 resources) are paid for increasing output (or reducing load for demand response) at the rate of \$50 per MWh in addition to LMP during intervals in which the non-synchronized reserve market clearing price is \$0.⁴⁶ This is the synchronized energy premium price. Spinning event response is calculated as the highest output between 9 minutes and 11 minutes after the event is declared minus the lowest output between one minute before and one minute after the event is declared. Generator outputs are measured and reported to PJM every four seconds via SCADA. Total response credited to a resource is capped at 110 percent of estimated capability. As a result, spinning event response involves more MW response than the original estimate of tier 1. Many resources that are not included in PJM's estimate of tier 1 nevertheless respond to spinning events and in accordance with the PJM Tariff are paid the synchronized energy premium price. This can include incidental response from nuclear units or steam turbines running at maximum output. Tier 1 synchronized reserve that

⁴⁶ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.10 Settlements, Rev. 121 (Jul. 7, 2022).

is part of the estimate when there is no spinning event is also credited for its full estimated MW whenever the nonsynchronized reserve market clearing price is above \$0.

In the event that the nonsynchronized reserve market clearing price is above \$0 and there is a spinning event, estimated tier 1 is credited with the lesser of its actual response or its estimated capability times the SRMCP. Tier 1 synchronized reserve not part of the estimate is credited the SRMCP times its actual response.⁴⁷ In the first nine months of 2022, the nonsynchronized reserve market clearing price was above \$0 in 609 five-minute intervals (0.8 percent of the total 78,612).

In the first nine months of 2022, tier 1 synchronized reserve spinning event response credits of \$246,309 were paid for 14 spinning events averaging 10.1 minutes. Table 10-9 shows the number of spinning events each month, the credits paid for tier 1 response, the number of MWh credited, and the actual response in MW.

Table 10-9 Tier 1 synchronized reserve event response credits: January 2021 through September 2022

Year	Month	Number of Spinning Events	Total Tier 1 Spinning Event Credits	Total Tier 1 Spinning Event Credited (MWh)	Total Tier 1 Spinning Response from Event Start to Event End (MW)
2021	Jan	1	\$6,796	135.9	1,165.0
2021	Feb	0	NA	NA	NA
2021	Mar	1	\$15,729	314.6	1,715.8
2021	Apr	2	\$40,442	808.8	4,677.8
2021	May	1	\$21,822	436.4	2,618.6
2021	Jun	2	\$16,275	325.5	3,183.2
2021	Jul	2	\$16,026	320.5	2,999.1
2021	Aug	2	\$46,487	929.7	4,666.3
2021	Sep	1	\$126,863	279.2	2,094.2
2021	Oct	2	\$27,267	545.3	3,800.4
2021	Nov	3	\$50,939	1,018.8	6,024.5
2021	Dec	1	\$7,188	143.8	1,232.3
2021	Total	18	\$375,832	5,258.6	34,177.2
2022	Jan	1	\$9,160	183.2	1,221.3
2022	Feb	0	NA	NA	NA
2022	Mar	1	\$10,600	212.0	1,817.1
2022	Apr	3	\$82,685	1,653.7	6,277.2
2022	May	4	\$76,641	1,532.8	8,854.1
2022	Jun	2	\$26,620	532.4	3,982.1
2022	Jul	1	\$14,594	291.9	2,189.1
2022	Aug	0	NA	NA	NA
2022	Sep	2	\$26,010	520.2	5,202.0
2022	Total	14	\$246,309	4,926.2	29,542.9

Paying Tier 1 the Tier 2 Price

Tier 1 synchronized reserve has zero marginal cost and the corresponding competitive price for tier 1 synchronized reserves is also zero. However, the PJM rules artificially create a marginal cost of tier 1 when the price of nonsynchronized reserve is greater than zero and tier 1 is paid the tier 2 price. The PJM market solutions do not include that marginal cost and therefore do not solve for the efficient level of tier 1, tier 2 and nonsynchronized reserve in those cases. When called to respond to a spinning event, tier 1 is compensated at the synchronized energy premium price (Table 10-12). However, the shortage pricing tariff changes (October 1, 2012) modified the pricing of tier 1 so that tier 1 synchronized reserve is paid the tier 2 synchronized reserve

⁴⁷ See PJM, "PJM Manual 28: Operating Agreement Accounting," § 6.2.1 Synchronized Reserve Clearing Price Credit, Rev. 87 (Jul. 27, 2022).

market clearing price whenever the nonsynchronized reserve market clearing price rises above zero. The rationale for this change was and is unclear, but it has had a significant impact on the cost of tier 1 synchronized reserves (Table 10-10). In the first nine months of 2022, the nonsynchronized reserve market clearing price was above \$0.00 in 0.8 percent of all intervals, or 609 of the total 78,612. This is a decrease from the first nine months of 2021, in which 2.1 percent of intervals had a market clearing price above \$0.00, or 1,631 of the total 78,601. For those intervals, estimated tier 1 synchronized reserve was paid \$6,178,605 for an average of 588.5 MW per interval of which all credits were for intervals outside of spinning events.

Table 10-10 Price of tier 1 synchronized reserve attributable to a nonsynchronized reserve price above zero: January 2021 through September 2022

Year	Month	Number of Intervals When NSRMCP > \$0	Weighted Average SRMCP When NSRMCP > \$0	Total Tier 1 MWh When NSRMCP > \$0	Total Tier 1 Credits When NSRMCP > \$0	Average Tier 1 MWh Monthly When NSRMCP > \$0
2021	Jan	31	\$36.20	3,625.7	\$75,337	604.3
2021	Feb	160	\$20.31	19,953.0	\$326,372	739.0
2021	Mar	60	\$95.30	7,775.0	\$724,173	518.3
2021	Apr	196	\$10.34	24,978.1	\$203,281	531.4
2021	May	644	\$12.75	74,895.9	\$797,736	720.2
2021	Jun	199	\$12.62	25,628.0	\$255,053	596.0
2021	Jul	95	\$27.79	13,751.7	\$325,970	528.9
2021	Aug	123	\$56.79	15,098.7	\$758,395	503.3
2021	Sep	123	\$26.95	18,665.3	\$454,768	777.7
2021	Oct	865	\$20.82	113,069.8	\$1,828,570	796.3
2021	Nov	490	\$33.16	54,585.5	\$1,527,555	941.1
2021	Dec	22	\$69.35	2,487.4	\$87,728	414.6
2021	Total	3,008	\$32.10	374,514.1	\$7,364,937	639.3
2022	Jan	17	\$147.27	2,039.3	\$200,464	407.9
2022	Feb	0	NA	NA	NA	NA
2022	Mar	30	\$116.28	3,696.5	\$329,826	528.1
2022	Apr	56	\$51.67	6,702.1	\$247,448	515.5
2022	May	240	\$33.95	29,644.6	\$767,809	871.9
2022	Jun	120	\$372.44	11,604.3	\$4,062,541	828.9
2022	Jul	29	\$47.00	3,581.9	\$141,084	398.0
2022	Aug	81	\$37.43	8,622.6	\$272,513	538.9
2022	Sep	36	\$37.48	5,570.0	\$156,920	618.9
2022	Total	609	\$105.44	71,461.3	\$6,178,605	588.5

The additional payments to tier 1 synchronized reserves under the shortage pricing rule are a windfall. Table 10-11 shows the amount of windfall paid to tier 1 resources from January 2014 through September 2022.

Table 10-11 Windfall payments made to tier 1 resources: January 2014 through September 2022

Year	Windfall Payment
2014	\$89,719,045
2015	\$34,397,441
2016	\$4,948,084
2017	\$2,197,514
2018	\$4,732,025
2019	\$3,217,178
2020	\$3,320,726
2021	\$7,354,224
2022 (Jan-Sep)	\$6,178,605
Total	\$156,064,842

The additional payment does not create an incentive to provide more tier 1 synchronized reserves. The additional payment is not a payment for performance; all estimated tier 1 receives the higher payment regardless of whether they provide any response during any spinning event. Tier 1 resources are not obligated to respond to synchronized reserve events. In the first nine months of 2022, there were three spinning events of 10 minutes or longer. In those events, an average of 70.9 percent of the estimated tier 1 responded and 51.4 percent of tier 2 responded.

Tier 1 should have been compensated only for a response to synchronized reserve events, as it was before the shortage pricing changes. This compensation required that when a synchronized reserve event was called, all tier 1 response was paid the synchronized energy premium price. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

PJM's tier 1 compensation rules prior to the October 1 changes are presented in Table 10-12.

Table 10-12 Tier 1 compensation as implemented by PJM

Tier 1 Compensation by Type of Interval as Currently Implemented by PJM		
Interval	No Synchronized Reserve Event	Synchronized Reserve Event
NSRMCP=\$0	T1 credits = \$0	T1 credits = Synchronized Energy Premium Price * actual response MWi
NSRMCP>\$0	T1 credits = T2 SRMCP * estimated tier 1 MW	T1 credits = T2 SRMCP * min(estimated tier 1 MW, actual response MWi)

The MMU's recommended compensation rules for tier 1 MW prior to the October 1 changes are in Table 10-13.

Table 10-13 Tier 1 compensation as recommended by MMU

Tier 1 Compensation by Type of Hour as Currently Recommended by MMU		
Interval	No Synchronized Reserve Event	Synchronized Reserve Event
NSRMCP=\$0	T1 credits = \$0	T1 credits = Synchronized Energy Premium Price * actual response MWi
NSRMCP>\$0	T1 credits = \$0	T1 credits = Synchronized Energy Premium Price * actual response MWi

Tier 2 Synchronized Reserve Market

Synchronized reserve is provided by generators or demand response resources synchronized to the grid and capable of increasing output or decreasing load within 10 minutes. Synchronized reserve consists of tier 1 and tier 2 synchronized reserves. When the synchronized reserve requirement cannot be met by tier 1 synchronized reserve, PJM clears a market to satisfy the requirement with tier 2 synchronized reserve. Tier 2 synchronized reserve is provided by online resources, either synchronized to the grid but not producing energy, or dispatched to provide synchronized reserve at an operating point below their economic dispatch point. Tier 2 synchronized reserve is also provided by demand resources that have offered to reduce load in the event of a synchronized reserve event. Tier 2 synchronized reserves are committed to be available in the event of a synchronized reserve event. Tier 2 resources have a must offer requirement. Some tier 2 resources are scheduled by the ASO 60 minutes before the operating hour and are committed to provide synchronized reserve for the entire hour. Tier 2 resources are paid the higher

of the SRMCP or their offer price plus lost opportunity cost (LOC). Demand response resources are paid the clearing price (SRMCP).

Synchronized reserve resources can be flexible or inflexible. Inflexible resources are defined as those resources that require an hourly commitment due to minimum run times or staffing constraints. Examples of inflexible reserves are synchronous condensers operating in condensing mode, resources with an economic minimum (EcoMin) equal to economic maximum (EcoMax), offline CTs and hydro that can operate in the condense mode, and demand resources. Inflexible synchronized reserve resources are committed for a full hour by the hour ahead ASO market solution. Inflexible resources require a 30 minute notification time and cannot be released for energy during the operating hour. The inflexible commitments made by the hour ahead ASO solution may satisfy only part of the tier 2 requirement. The actual requirement is determined by the RT SCED solution and the requirement not satisfied by inflexible units is satisfied by flexible units. Flexible resources are already online for energy, require no notification time, and can be automatically dispatched.

During the operating hour, RT SCED can dispatch additional tier 2 resources. RT SCED can redispatch online tier 1 generating resources as tier 2 synchronized reserve to meet the synchronized and primary reserve requirements within the operational hour. Resources that are redispatched as tier 2 within the hour are paid the SRMCP plus any lost opportunity costs that exceed the SRMCP.

Market Structure

Supply

PJM has a must offer tier 2 synchronized reserve requirement. All nonemergency generating resources are required to submit tier 2 synchronized reserve offers. All online, nonemergency generating resources are deemed available to provide both tier 1 and tier 2 synchronized reserve in accordance with their ability. Generating resources must be able to provide at least 0.1 MW of tier 2 reserve in order to make offers in the tier 2 synchronized reserve market. Unit types that cannot reliably provide synchronized reserve, including nuclear, wind, solar, and energy storage resources, are expected to offer zero MW of

tier 2 synchronized reserve. If PJM issues a primary reserve warning, voltage reduction warning, or manual load dump warning, all offline emergency generation capacity resources available to provide energy must submit an offer for tier 2 synchronized reserve.⁴⁸

In the first nine months of 2022, the Mid Atlantic Dominion (MAD) Reserve Subzone averaged 5,478.1 MW of tier 2 synchronized reserve offers, and the RTO Reserve Zone averaged 35,043.1 MW of tier 2 synchronized reserve offers (Figure 10-6).

The supply of tier 2 synchronized reserve offered in the first nine months of 2022 was sufficient to cover the ASO hourly requirement net of tier 1 in both the RTO Reserve Zone and the MAD Reserve Subzone.

The largest portion of cleared tier 2 synchronized reserve in the first nine months of 2022 was from demand resources followed by CTs running on natural gas (Table 10-14). Although demand resources are limited to providing no more than 33 percent of the total synchronized reserve requirement, the amount of tier 2 synchronized reserve required in any hour is often much less than the full synchronized reserve requirement because so much of it is met with tier 1 synchronized reserve. This means that in some hours demand resources make up considerably more than 33 percent of the cleared tier 2 MW. Demand resources often offer at a price of \$0, do not incur an LOC, and clear even when the price is \$0. As a result, their share of credits in the synchronized reserve market is less than their share of cleared MW.

Table 10-14 Supply of Tier 2 Synchronized Reserve by Resource Type and Fuel Type: January through September, 2022

Resource/Fuel Type	Percent by MW	Percent by Credits
DSR	34.1%	17.3%
CT - Natural Gas	27.3%	31.1%
Combined Cycle	17.5%	28.8%
CT - Oil	9.3%	11.0%
Hydro - Run of River	8.2%	7.0%
Steam - Coal	1.8%	2.7%
Hydro - Pumped Storage	1.5%	1.6%
RICE - Natural Gas	0.2%	0.3%
Steam - Natural Gas	0.1%	0.2%
Steam - Other	0.0%	0.0%
Battery	0.0%	0.0%
CT - Other	0.0%	0.0%
Distributed Gen	0.0%	0.0%
Fuel Cell	0.0%	0.0%
Nuclear	0.0%	0.0%
RICE - Oil	0.0%	0.0%
RICE - Other	0.0%	0.0%
Solar	0.0%	0.0%
Solar + Storage	0.0%	0.0%
Solar + Wind	0.0%	0.0%
Steam - Oil	0.0%	0.0%
Wind	0.0%	0.0%
Wind + Storage	0.0%	0.0%

Demand

On July 12, 2017, PJM adopted a dynamic synchronized reserve requirement set equal to 100 percent of the largest single contingency (also known as the most severe single contingency, or MSSC) as the first step, and extended by a 190 MW second step.⁴⁹ There are two circumstances in which PJM may alter the base portion of the synchronized reserve requirement from its 100 percent of the largest contingency value. Reserve requirements may be increased during a temporary switching condition when transmission outages or configuration problems cause several generation resources to be subject to a single contingency. When PJM operators anticipate periods of high load, they may bring on additional units to account for increased operational

⁴⁸ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.1 Synchronized Reserve Market Eligibility, Rev. 121 (June 1, 2022).

⁴⁹ See the 2022 Quarterly State of the Market Report: January through September, Section 3: Energy Market, at "Operating Reserve Demand Curves."

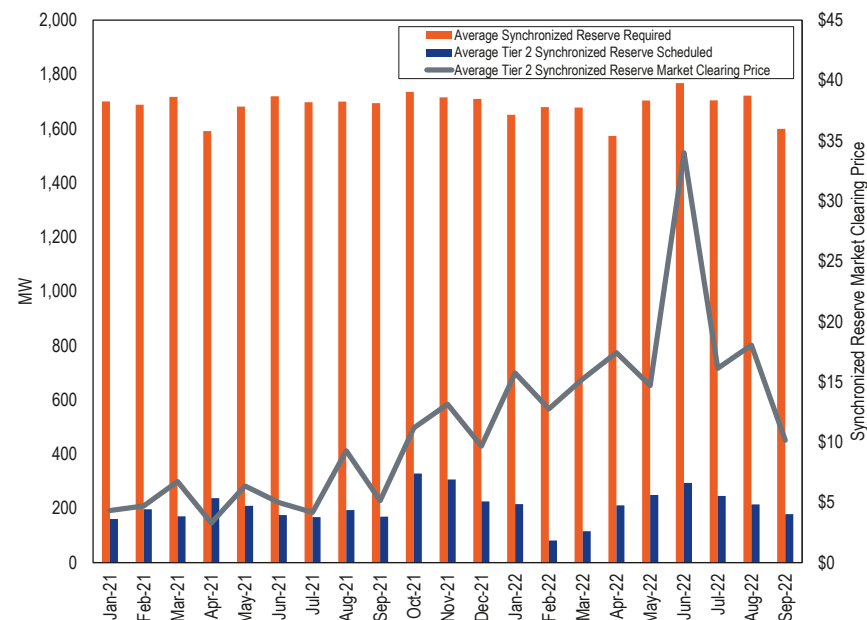
uncertainty in meeting load. When a Hot Weather Alert, Cold Weather Alert or an emergency procedure has been issued for the operating day, operators may increase the synchronized reserve requirement up to the full amount of the additional MW brought on line.⁵⁰

In the first nine months of 2022, the average synchronized reserve requirement was 1,676.2 MW in the RTO Zone and 1,675.4 in the MAD Subzone. These averages include temporary increases to the synchronized reserve requirement.

The RTO Reserve Zone scheduled and identified an average of 552.0 MW of tier 2 synchronized reserves in the first nine months of 2022. Of this, an average of 545.4 MW was scheduled hourly.

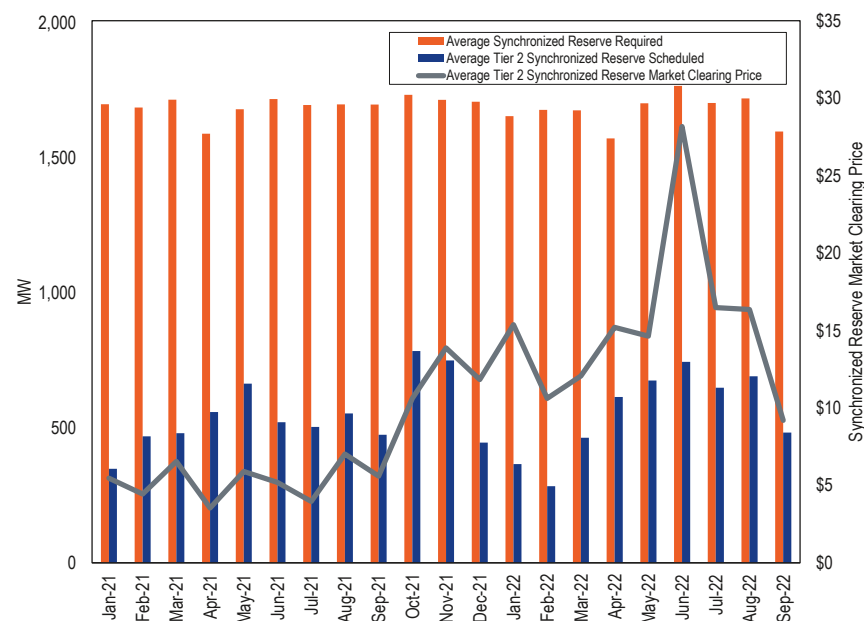
Figure 10-4 and Figure 10-5 show the average monthly synchronized reserve required and the average monthly tier 2 synchronized reserve MW scheduled (PJM scheduled plus self-scheduled) from January 2021 through September 2022, for the MAD Reserve Subzone and the RTO Reserve Zone. In the first nine months of 2021, there were 19 intervals of synchronized reserve shortage and 12 spinning events of which four were longer than 10 minutes. In the first nine months of 2022, there were 30 intervals of synchronized reserve shortage in the dispatch solution and 14 spinning events of which three were longer than 10 minutes. There were 33 intervals of synchronized reserve shortage in the pricing solution. Shortage pricing was used for synchronized reserve during 11 intervals on June 13 alone, causing a higher average price for June.

Figure 10-4 MAD monthly average tier 2 synchronized reserve scheduled MW: January 2021 through September 2022



⁵⁰ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.3 Reserve Requirement Determination, Rev. 122 (Oct. 1, 2022).

Figure 10-5 RTO monthly average tier 2 synchronized reserve scheduled MW: January 2021 through September 2022



Market Concentration

The average HHI for tier 2 synchronized reserve cleared intervals in the Mid-Atlantic Dominion Subzone Tier 2 Synchronized Reserve Market in the first nine months of 2022 was 4437, which is defined as highly concentrated. In 68.7 percent of all cleared pricing intervals the maximum market share was greater than or equal to 40 percent.

The average HHI for tier 2 synchronized reserve for cleared pricing intervals of the RTO Zone Tier 2 Synchronized Reserve Market in the first nine months of 2022 was 2898, which is defined as highly concentrated. In 31.6 percent of cleared intervals there was a maximum market share greater than or equal to 40 percent.

In the MAD Subzone, flexible synchronized reserve was 1.0 percent of all tier 2 synchronized reserve in the first nine months of 2022. In the RTO Zone, flexible synchronized reserve was 1.3 percent of all tier 2 synchronized reserve MW in the first nine months of 2022.

The market structure results indicate that the RTO Zone and Mid-Atlantic Dominion Subzone Tier 2 Synchronized Reserve Markets are not structurally competitive.

Market Behavior

Offers

Daily cost-based offers are submitted for each unit by the unit owner. For generators the offer must include, when relevant, a tier 1 synchronized reserve ramp rate, a tier 1 synchronized reserve maximum, self scheduled status, synchronized reserve availability, synchronized reserve offer quantity (MW), tier 2 synchronized reserve offer price, energy use for tier 2 condensing resources (MW), condense to gen cost, shutdown costs, condense startup cost, condense hourly cost, condense notification time, and spin as a condenser status. The tier 2 synchronized reserve offer price made by the unit owner is subject to an offer cap of marginal cost plus a markup of \$7.50 per MW. The tier 1 synchronized reserve ramp rate must be greater than or equal to the real-time economic ramp rate. If the synchronized reserve ramp rate is greater than the economic ramp rate it must be justified by the submission of actual data from previous synchronized reserve events.⁵¹ All suppliers are paid the higher of the market clearing price or their offer plus their unit specific opportunity cost. The offer quantity is limited to the economic maximum. PJM monitors this offer by checking to ensure that all offers are greater than or equal to 90 percent of the resource's ramp rate times 10 minutes. A resource that is unable to participate in the synchronized reserve market during a given hour may set its hourly offer to zero MW. Certain defined resource types are not required to offer tier 2 because they cannot reliably provide synchronized reserve. These include: nuclear, wind, solar, landfill gas and energy storage resources.⁵²

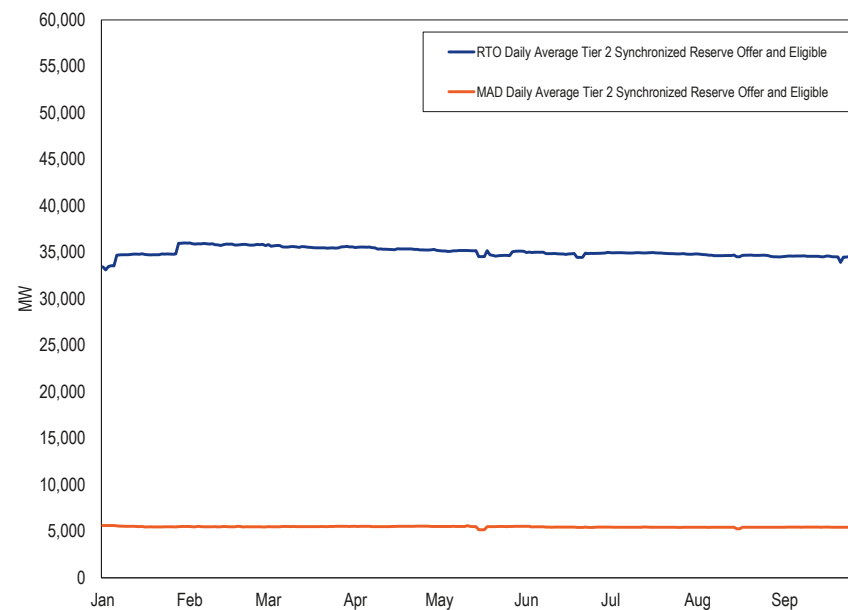
⁵¹ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.1 Synchronized Reserve Market Eligibility, Rev. 122 (Oct. 1, 2022).

⁵² See *id.*

Figure 10-6 shows the daily average of hourly offered tier 2 synchronized reserve MW for both the RTO Synchronized Reserve Zone and the Mid-Atlantic Dominion Synchronized Reserve Subzone.

PJM has a tier 2 synchronized reserve must offer requirement for all generation that is online, nonemergency, and physically able to operate with an output less than dictated by economic dispatch. Tier 2 synchronized reserve offers are made on a daily basis with hourly updates permitted. Daily offers can be changed as a result of maintenance status or physical limitations only and are required regardless of online/offline state.⁵³ The tier 2 synchronized reserve market is not cleared based on daily offers but based on hourly updates to the daily offers. As a result of hourly updates the actual amount of eligible tier 2 MW can change significantly every hour (Figure 10-6). Changes to the hourly offer status are only permitted when resources are physically unable to provide tier 2. Changes to hourly eligibility levels are the result of online status, minimum/maximum runtimes, minimum notification times, maintenance status, and grid conditions including constraints. However, resource operators can mark their units as unavailable for an hour or block of hours without having to provide a reason. In the first nine months of 2022, synchronized reserve offers averaged 35,043.6 MW in the RTO Zone and 5,478.1 MW in the MAD Subzone.

Figure 10-6 Tier 2 synchronized reserve hourly offer and eligible volume (MW):⁵⁴ January through September, 2022



Although tier 2 synchronized reserve has a must offer requirement, there are a large number of hours when many units make themselves unavailable for tier 2 synchronized reserve.

The MMU recommends that the tier 2 synchronized reserve must offer requirement be enforced. The MMU recommends that PJM define a set of acceptable reasons why a unit can be made unavailable daily or hourly and require unit owners to select a reason in Markets Gateway whenever making a unit unavailable either daily or hourly or setting the offer to 0 MW.⁵⁵ This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

⁵³ See PJM. "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.2.1 Synchronized Reserve Market Eligibility, Rev. 121 (July 7, 2022). ("Regardless of online/offline state, all non-emergency generation capacity resources must submit a daily offer for Tier 2 Synchronized Reserves in Markets Gateway...").

⁵⁴ These values less than what was previously reported.

⁵⁵ PJM adopted a new business rule in the third quarter of 2017 to enforce compliance with the tier 2 must offer requirement. PJM entered a zero dollar offer price for all units with a must offer obligation for tier 2 synchronized reserves.

Market Performance

Price

The price of tier 2 synchronized reserve is calculated in real time every five minutes by the LPC market solution for the RTO Reserve Zone and the MAD Subzone. The tier 2 synchronized reserve market price is determined not only by the offer price of each cleared MW of tier 2, but additionally by the net cost of jointly optimizing the dispatch of energy and synchronized reserve. For each MW assigned, the clearing engines determine a product substitution price, i.e. the marginal cost of replacing the reserve MW with energy from other resources. The product substitution cost is a function of the LMPs of the MW of reserve, the marginal cost of energy for the resources providing reserves, and the minimized cost of substituted MW providing energy. At the margin, the price is the sum of the offer price plus the product substitution cost of the marginal unit(s).⁵⁶ The number of marginal units by schedule type is shown in Table 10-15.

Table 10–15 Schedule used for LOC of marginal units in RTSCED Tier 2 Synchronized Reserve Market LOC calculation: January through September, 2022

Number of Marginal Units	Percent of Marginal Units with LOC Based on Cost Schedule	Percent of Marginal Units with LOC Based on Price Schedule
79,073	21.5%	78.5%

In the first nine months of 2022, the RTSCED cleared the RTO tier 2 synchronized reserve market in 63.8 percent of all dispatch solutions. In all other intervals there was enough tier 1 synchronized reserve to cover the synchronized reserve requirement. For intervals when the synchronized reserve requirement could not be met with tier 1, the market cleared an average of 751.2 MW of synchronized reserve (plus 236.1 MW of demand response) at a weighted average price of \$12.20 per MWh.

The market clearing price for the MAD Subzone diverged from the RTO Zone in 1,001 intervals during the first nine months of 2022.

⁵⁶ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations" § 4.2.9 Synchronized Reserve Market Clearing Price (SRMCP) Calculation, Rev. 121 (July 7, 2022).

Supply, demand, and performance for tier 2 synchronized reserve cleared hours (price > \$0) are reflected in the price of synchronized reserve (Table 10-16).

Table 10–16 RTO Zone, average SRMCP and average scheduled, tier 1 estimated and demand response MW in RT SCED market solutions: January 2021 through September 2022

Year	Month	Weighted Average Synchronized Reserve Market Clearing Price	Average Interval Tier 2 Generation Synchronized Reserve Purchased (MW)	Average Interval Tier 1 Synchronized Reserve Estimate (MW)	Average Interval Demand Response Cleared (MW)
2021	Jan	\$7.70	332.9	1,758.2	88.7
2021	Feb	\$10.56	459.4	1,851.4	135.9
2021	Mar	\$11.43	432.4	1,702.0	122.9
2021	Apr	\$6.03	549.3	1,308.5	165.0
2021	May	\$7.95	591.4	1,375.8	186.0
2021	Jun	\$9.22	466.7	1,696.9	143.1
2021	Jul	\$9.20	483.6	1,675.5	177.6
2021	Aug	\$13.86	495.3	1,770.6	205.5
2021	Sep	\$9.33	432.7	1,779.3	185.0
2021	Oct	\$11.52	780.1	1,109.1	250.0
2021	Nov	\$14.27	744.3	1,163.2	228.0
2021	Dec	\$15.43	440.1	1,625.2	106.7
2021	Average	\$10.83	518.7	1,563.7	166.6
2022	Jan	\$21.89	357.5	1,713.9	107.4
2022	Feb	\$16.17	255.8	1,949.3	99.6
2022	Mar	\$14.21	447.5	1,515.3	139.9
2022	Apr	\$16.64	594.8	1,154.8	171.5
2022	May	\$15.74	602.9	1,476.7	192.0
2022	Jun	\$31.01	652.1	1,535.5	219.7
2022	Jul	\$17.32	590.1	1,468.2	189.3
2022	Aug	\$18.74	656.5	1,432.1	244.5
2022	Sep	\$16.47	448.8	1,592.0	212.4
2022	Average	\$19.02	514.2	1,534.1	175.7

Settlement Cost

As a result of changing grid conditions, load forecasts, and unexpected generator performance, the prices of synchronized reserve do not always cover the full cost to customers, including the final LOC for each resource. Because price formation occurs within the hour (on a five minute basis) but inflexible synchronized reserve commitment occurs prior to the hour, the realized, within hour price can be zero even when some tier 2 synchronized

reserve is cleared. All resources cleared in the tier 2 synchronized reserve market are guaranteed to be made whole and paid uplift credits in settlement if the SRMCP does not compensate them for their offer plus LOC.

PJM implemented fast start pricing on September 1, 2021. Between September 1, 2021 and December 31, 2021 prices were 2.1 percent higher than in the dispatch run (considering only intervals where the Tier 2 Synchronized Reserve price is greater than \$0). In the first nine months of 2022, the average price was 26.1 percent higher in the pricing run than in the dispatch run. The price was above zero in the RTO Zone in 38.6 percent of intervals in the first nine months of 2022 (Table 10-17).

Prices were significantly higher in the first nine months of 2022 than they were in the first nine months of 2021 because of higher load, increased fuel costs and fast start pricing (Table 10-17). The MW weighted synchronized reserve market clearing price is computed for hours when the price was above \$0. The market clearing solution includes a constraint that forces all remaining synchronized reserve to be cleared from the MAD Subzone (Figure 10-1) when one of the constraints defining MAD binds. RTO/MAD prices diverged in 1,001 intervals in the first nine months of 2022. In the first nine months of 2022, the MW weighted average tier 2 synchronized reserve clearing price was \$16.16 in the RTO Zone and \$18.14 in the MAD Subzone.

Table 10-17 RTO Zone tier 2 synchronized reserve MW, credits, price, and cost: January 2021 through September 2022

Year	Month	Tier 2	Tier 2	LOC	Weighted	Tier 2	Price / Cost
		Generation and DSR Credited MWh	SRMCP Credits		Synchronized Reserve Market Clearing Price	Synchronized Reserve Cost	
2021	Jan	250,410	\$1,366,533	\$284,557	\$5.46	\$6.59	82.8%
2021	Feb	309,335	\$1,371,901	\$1,053,888	\$4.44	\$7.84	56.6%
2021	Mar	323,201	\$2,116,589	\$1,256,664	\$6.55	\$10.44	62.7%
2021	Apr	393,789	\$1,393,286	\$668,319	\$3.54	\$5.24	67.6%
2021	May	441,010	\$2,600,987	\$1,168,654	\$5.90	\$8.55	69.0%
2021	Jun	336,909	\$1,749,251	\$1,259,710	\$5.19	\$8.93	58.1%
2021	Jul	360,204	\$1,426,976	\$1,252,892	\$3.96	\$7.44	53.2%
2021	Aug	370,243	\$2,598,840	\$2,417,882	\$7.02	\$13.55	51.8%
2021	Sep	314,001	\$1,754,993	\$1,463,884	\$5.59	\$10.25	54.5%
2021	Oct	580,156	\$6,156,577	\$2,457,649	\$10.61	\$14.85	71.5%
2021	Nov	538,939	\$7,479,685	\$1,757,937	\$13.88	\$17.14	81.0%
2021	Dec	330,219	\$3,907,943	\$859,945	\$11.83	\$14.44	82.0%
2021		4,548,417	\$33,923,562	\$15,901,982	\$7.46	\$10.95	68.1%
2022	Jan	270,905	\$4,165,719	\$2,469,534	\$15.38	\$24.49	62.8%
2022	Feb	172,233	\$1,828,245	\$646,444	\$10.61	\$14.37	73.9%
2022	Mar	332,184	\$4,006,135	\$907,088	\$12.06	\$14.79	81.5%
2022	Apr	426,922	\$6,490,248	\$1,209,779	\$15.20	\$18.04	84.3%
2022	May	446,066	\$6,528,859	\$1,256,883	\$14.64	\$17.45	83.9%
2022	Jun	468,822	\$13,205,921	\$3,266,937	\$28.17	\$35.14	80.2%
2022	Jul	440,293	\$7,255,855	\$2,395,004	\$16.48	\$21.92	75.2%
2022	Aug	484,348	\$7,920,363	\$3,257,132	\$16.35	\$23.08	70.9%
2022	Sep	324,232	\$2,982,950	\$917,813	\$9.20	\$12.03	76.5%
2022		3,366,006	\$54,384,294	\$16,326,614	\$16.16	\$21.01	76.9%

Table 10-18 shows the effect of fast start pricing on the synchronized reserve market's monthly weighted average market clearing price from September 2021 through September 2022. The weighted average market clearing price for each month is consistently higher in the pricing run than in the dispatch run.

Table 10-18 Comparison of fast start and dispatch pricing components: September 2021 through September 2022

Year	Month	Pricing Method	Weighted Average Market Clearing Price
2021	Sep	Dispatch	\$4.76
		Fast Start	\$5.59
2021	Oct	Dispatch	\$8.52
		Fast Start	\$10.61
2021	Nov	Dispatch	\$10.94
		Fast Start	\$13.88
2021	Dec	Dispatch	\$10.12
		Fast Start	\$11.83
2022	Jan	Dispatch	\$13.86
		Fast Start	\$15.38
2022	Feb	Dispatch	\$9.72
		Fast Start	\$10.61
2022	Mar	Dispatch	\$9.95
		Fast Start	\$12.06
2022	Apr	Dispatch	\$12.53
		Fast Start	\$15.20
2022	May	Dispatch	\$11.48
		Fast Start	\$14.64
2022	Jun	Dispatch	\$23.75
		Fast Start	\$28.17
2022	Jul	Dispatch	\$11.38
		Fast Start	\$16.48
2022	Aug	Dispatch	\$12.06
		Fast Start	\$16.35
2022	Sep	Dispatch	\$7.53
		Fast Start	\$9.20

Performance

Tier 1 resource owners are paid for the actual amount of synchronized reserve they provide in response to a synchronized reserve event.⁵⁷ Tier 2 resource owners are paid for being available but are not paid based on the actual response to a synchronized reserve event. The MMU has identified and quantified the actual performance of scheduled tier 2 synchronized reserve resources when called on to deliver during synchronized reserve events since 2011.⁵⁸ When synchronized reserve resources self schedule or clear the Synchronized Reserve Market they are obligated to provide their full scheduled

⁵⁷ See PJM. "PJM Manual 28: Operating Agreement Accounting", § 6.2.1 Synchronized Reserve Clearing Price Credit, Rev. 87 (July 27, 2022).
⁵⁸ See 2011 State of the Market Report for PJM, Vol. II, Section 9, "Ancillary Services," at p. 250.

MW during a synchronized reserve event. Actual synchronized reserve event response is determined by final output minus initial output where final output is the largest output between 9 and 11 minutes after the start of the event, and initial output is the lowest output between one minute before the event and one minute after the event.⁵⁹ Clear synchronized reserve resources are obligated to sustain their final output for the shorter of the length of the event or 30 minutes. Penalties are assessed for failure of a scheduled tier 2 resource to perform during any synchronized reserve event lasting 10 minutes or longer.

Tier 2 performance has not been adequate. Compliance with calls to respond to actual synchronized reserve events remains significantly less than 100 percent. Table 10-19 shows the average amount of scheduled Tier 2 MW that responded to events 10 minutes or longer from January 2016 through September 2022. Actual participant performance means that the penalty structure is not adequate to incent performance.

Table 10-19 Average tier 2 event response, January 2016 through September 2022

Year	No. of Events Longer than 10 Minutes	Average Percent of Scheduled Tier 2 MW that Responded
2016	7	85.5%
2017	6	87.6%
2018	8	74.2%
2019	3	86.8%
2020	5	59.5%
2021	5	76.9%
2022 (Jan - Sep)	3	51.4%

The penalty structure when a resource fails to respond fully to a spinning event includes two components. The first component is the forfeiture of awarded SRMCP credits in the amount of the MW of shortfall for the day on which the event occurred. The second component is a retroactive charge applied to the SRMCP credits paid in the Immediate Past Interval (IPI), equal to the sum of the SRMCPs for each scheduled interval within the IPI multiplied by the unit's penalty obligation on the day of the event. The IPI is calculated

⁵⁹ See PJM. "PJM Manual 11: Energy & Ancillary Services Market Operations," § 4.5.1, Performance Verification, Rev. 122 (Oct. 1, 2022).

as the average number of days since the previous event over the previous two years or, if less, the number of days since the unit last failed to fully respond.

There are several problems with this penalty structure. First, resource owners are permitted to aggregate the response of multiple units, allowing owners to reduce the penalty obligation of a unit's underresponse by offsetting it with another unit's overresponse.⁶⁰ Second, the ISI is calculated using events of any length, even though a unit's compliance is automatically counted as 100 percent for events less than 10 minutes long, shortening the applied IPI significantly. Third, the second component of the penalty only applies to the SRMCP credits awarded during the IPI, ignoring the LOC credits, even though most credits are awarded for LOC.

Hence, the penalty structure for synchronized reserve nonperformance is inadequate for providing appropriate performance incentives. Under the penalty structure, it is possible for a resource to not respond to any spin events and yet still be paid for providing synchronized reserve. The MMU continues to recommend that the ISI be defined as the average number of days since the previous spinning event 10 minutes or longer and that the penalty's retroactive charges include the LOC credits in addition to the SRMCP credits. If only events 10 minutes or longer were considered, then the ISI would increase to 86 days from its current level of 22 days.⁶¹ However, implementing this change alone might still have been insufficient to ensure proper response.

The MMU also continues to recommend that aggregation not be permitted to offset unit-specific penalties for failure to respond to a synchronized reserve event. Including aggregate responses from all online resources weakens the incentive to perform and creates an incentive to withhold reserves from other resources. Synchronized reserve commitment is unit specific, so the obligation to respond should also be unit specific. Any potentially offsetting response from an affiliated tier 1 resource should have been included as part of the reserves in the tier 1 estimate. Any potentially offsetting response from a tier 2 resource should have been included in that resource's tier 2 offer.

⁶⁰ See PJM, "PJM Manual 28: Operating Agreement Accounting," § 6.3 Charges for Synchronized Reserve, Rev. 88 (Oct. 1, 2021).

⁶¹ The MMU recommended ISI was previously reported as 76 days.

Table 10-20 compares the outcomes of the PJM penalty structure for the first nine months of 2022 with the outcomes of the proposed MMU penalty structure following its recommendations. In the first nine months of 2022, there were three spinning events that lasted 10 minutes or longer: one on April 13, one on May 16, and one on May 23 (Table 10-21).

Table 10-20 Comparison of tier 2 shortfall penalties current IPI vs. MMU recommended: 2022

Penalty Type	Current PJM Penalty	MMU Recommended Penalty
Day Of Event	\$44,070	\$58,988
Retroactive Charges	\$986,812	\$94,937,075
Total Penalties	\$1,030,882	\$94,996,063

Spinning event response data as reported by PJM in its Operating Committee meetings is shown in Table 10-21. The tier 1 estimate is from the most recent RT SCED market solution. The tier 1 estimate includes estimated ramp only from the units that are eligible and excludes resources that have ramp available but are not part of the estimate.

Tier 1 synchronized reserve that responded to a spinning event received a bonus payment of \$50 per MWh, based on a calculation using SCADA data, regardless of whether PJM included those reserves in the estimate.

Table 10-21 shows synchronized reserve event response compliance for tier 1 and tier 2 reserves for events that lasted 10 minutes or longer as reported by PJM, using only response from tier 1 estimated and tier 2 cleared reserves. In the first nine months of 2022, there were three events that were 10 minutes or longer. Actual synchronized reserve response is the total increase in MW from all resources from the moment the spinning event is called to 10 minutes after. To determine the actual tier 1 response, the calculation would subtract tier 2 response, changes in assigned regulation output (net compliance level to both RegA and RegD), and changes to net power flow across PJM's interface boundary. The overall response to spinning events is adequate or more than adequate to meet NERC requirements. PJM not only corrects the ACE

disturbance that led to the event but over corrects. In all three of the spinning events the ACE recovered not just to the NERC required level (which is the lesser of 0 or the value before the disturbance which caused the event) but overshoots.

Table 10-21 Synchronized reserve events 10 minutes or longer, tier 1 and tier 2 response compliance as reported by PJM⁶², RTO Reserve Zone: January 2019 through September 2022

Spin Event	Duration (Minutes)	Tier 1 Estimate (Market Solution MW Adj by DGP)	Response from Tier 1 DGP Estimated (MW)	Tier 2 Scheduled (MW)	Tier 2 Response (MW)	Tier 2 Penalty (MW)	DGP Estimated Tier 1 Response Percent	Tier 2 Response Percent
23-Sep-2019 1207 (EPT)	11	1,485.1	1,212.1	723.2	632.1	91.1	81.6%	87.4%
01-Oct-2019 1456 (EPT)	11	265.4	143.7	1,177.4	1,016.4	161.0	54.1%	86.3%
2019 Average	11	924.7	664.1	723.2	632.1	91.1	71.8%	87.4%
18-Feb-2020 2015 (EPT)	10	2,216.1	1,434.8	40.0	1.7	38.3	64.7%	4.3%
06-Jul-2020 2122 (EPT)	10	1,464.0	526.1	479.7	415.1	64.6	35.9%	86.5%
25-Jul-2020 1639 (EPT)	11	868.4	421.6	302.3	264.8	37.5	48.5%	87.6%
10-Sep-2020 0029 (EPT)	10	1,275.4	453.6	782.6	782.6	0.0	35.6%	100.0%
16-Dec-2020 1649 (EPT)	10	268.4	196.9	527.6	413.2	114.4	73.4%	78.3%
2020 Average	10	1,218.5	606.6	426.4	375.5	51.0	49.7%	59.5%
09-Mar-2021 0750 (EPT)	10	1,354.9	635.4	884.0	540.8	343.2	46.9%	61.2%
30-Apr-2021 1630 (EPT)	12	1,487.6	610.2	508.3	407.2	101.1	41.0%	80.1%
26-May-2021 1017 (EPT)	10	1,138.4	811.0	685.2	600.2	85.0	71.2%	87.6%
23-Aug-2021 1644 (EPT)	18	879.8	597.5	896.2	667.1	229.1	67.9%	74.4%
12-Nov-2021 1725 (EPT)	12	510.0	606.7	890.7	714.6	176.1	119.0%	80.2%
2021 Average	12	1,074.1	652.2	772.9	586.0	186.9	69.2%	76.7%
13-Apr-2022 1725 (EPT)	28	651.9	390.0	880.6	718.4	162.2	59.8%	81.6%
16-May-2022 1532 (EPT)	11	1,490.0	895.3	295.0	91.8	203.2	60.1%	31.1%
23-May-2022 1717 (EPT)	15	757.7	670.4	1,062.2	707.8	354.4	88.5%	66.6%
2022 Average	18	967	652	746	506	240	69.5%	59.8%

Until April 2019, PJM's ASO market solution software allowed operators to bias the inflexible tier 2 synchronized reserve solution by forcing the software to assume a different tier 1 MW value than the actual estimate. PJM, in response to the MMU recommendation, no longer uses tier 1 biasing in any of its market solutions. Biasing means manually modifying (decreasing or increasing) the tier 1 synchronized reserve estimate of the market solution.

Tier 1 biasing was never referenced in PJM manuals or any public document. PJM could resume tier 1 biasing at its discretion. Although tier 1 biasing has been discontinued, PJM can and does still deselect tier 1 resources based on PJM judgment. The impact of tier 1 deselection can be very significant (Table 10-22).

62. See, for example, "Systems Operations Report," PJM presentation to the Operating Committee. (April 14, 2022) <<https://www.pjm.com/-/media/committees-groups/committees/oc/2022/20220414/item-02---review-of-operating-metrics.ashx>> at 10.

Table 10-22 Comparison of spinning event market solution tier 1 estimate, tier 1 response with PJM Settlements tier 1 MW credited: January 2021 through September 2022

Start Time	Duration (Minutes)	PJM Market Solution DGP Estimated Tier 1 Estimate MW	PJM Market Solution DGP Estimated Tier 1 Response MW	PJM Settlements Tier 1 Credited Response MWh
24-Jan-2021 2232 (EPT)	6.5	2,134.5	577.9	1,165.0
09-Mar-2021 0750 (EPT)	10.8	1,354.9	635.4	1,715.9
13-Apr-2021 1605 (EPT)	8.8	2,093.4	975.6	2,534.3
30-Apr-2021 1630 (EPT)	11.6	1,487.6	610.2	2,143.5
26-May-2021 1017 (EPT)	10.0	1,138.4	811.0	2,618.6
21-Jun-2021 0154 (EPT)	6.9	2,340.8	1,764.1	1,806.7
22-Jun-2021 2333 (EPT)	4.7	2,277.0	1,367.8	1,376.5
21-Jul-2021 1827 (EPT)	5.0	837.8	290.8	881.3
25-Jul-2021 1616 (EPT)	6.0	708.7	418.8	2,117.9
23-Aug-2021 1644 (EPT)	17.6	879.8	597.5	2,050.4
24-Aug-2021 1037 (EPT)	8.1	903.7	658.3	2,615.9
27-Sep-2021 1656 (EPT)	8.4	679.5	385.1	3,058.7
11-Oct-2021 1323 (EPT)	9.3	1,215.9	577.8	4,015.5
16-Oct-2021 0530 (EPT)	7.7	1,060.4	669.1	2,254.0
12-Nov-2021 1725 (EPT)	12.1	510.0	606.7	5,275.5
30-Nov-2021 0940 (EPT)	9.8	899.2	678.3	3,476.1
30-Nov-2021 1256 (EPT)	8.5	948.6	452.3	4,378.5
08-Dec-2021 0904 (EPT)	7.8	481.6	288.8	1,645.6
03-Jan-2022 1227 (EPT)	8.9	516.8	377.6	2,029.0
03-Mar-2022 1220 (EPT)	7.4	1,398.9	795.8	2,402.9
06-Apr-2022 1145 (EPT)	9.7	413.9	393.0	4,161.6
13-Apr-2022 1725 (EPT)	28.5	651.9	390.0	12,253.0
14-Apr-2022 0930 (EPT)	8.1	691.7	432.7	2,934.9
16-May-2022 1532 (EPT)	11.1	1,490.0	895.3	5,438.2
16-May-2022 1553 (EPT)	9.6	1,169.6	912.7	6,071.6
23-May-2022 1717 (EPT)	15.0	757.7	670.4	4,630.2
26-May-2022 1409 (EPT)	6.3	557.7	360.4	2,018.4
22-Jun-2022 1506 (EPT)	7.2	658.8	305.5	2,617.8
27-Jun-2022 1701 (EPT)	9.1	516.7	595.5	3,446.1
07-Jul-2022 1721 (EPT)	7.9	805.8	522.0	3,345.7
26-Sep-2022 0339 (EPT)	6.0	2,543.3	1,593.1	2,761.2
29-Sep-2022 1025 (EPT)	6.2	437.6	619.2	3,411.2

History of Synchronized Reserve Events

Synchronized reserve is designed to provide relief for disturbances.^{63 64} A disturbance is defined as loss of the lesser of 900 MW or 80 percent of the largest single contingency within 60 seconds. In the absence of a disturbance,

⁶³ 2013 State of the Market Report for PJM, Appendix F – PJM's DCS Performance, at 451–452.

⁶⁴ See PJM, "PJM Manual 12: Balancing Operations," § 4.1.2 Loading Reserves, Rev. 47 (Oct. 1, 2022).

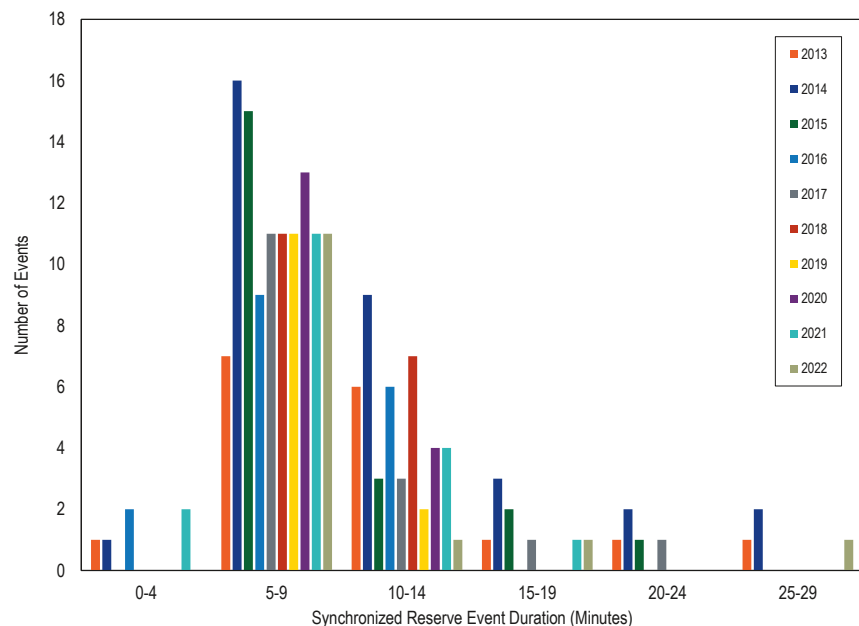
PJM operators have used synchronized reserve as a source of energy to provide relief from low ACE.

The risk of using synchronized reserves for energy or any other nondisturbance reason is that it reduces the amount of synchronized reserve available for a disturbance. Disturbances are unpredictable. Synchronized reserve has a requirement to sustain its output for only up to 30 minutes. When the need is for reserve extending past 30 minutes, secondary reserve is the appropriate source of the response. The use of synchronized reserve is an expensive solution during an hour when the hour ahead market solution and reserve dispatch indicate no shortage of primary reserve. PJM's primary reserve levels have been sufficient to recover from disturbances and should remain available in the absence of disturbances.

From January 2018 through September 2022, PJM experienced 80 synchronized reserve events, approximately 1.4 events per month, with an average duration of 8.9 minutes. Table 10-23 shows these events with their region and their duration rounded to the nearest minute.

Figure 10-7 shows spin event durations over the past five years.⁶⁶

Figure 10-7 Synchronized reserve events duration distribution curve: January 2013 through September 2022



Nonsynchronized Reserve Market

Nonsynchronized reserve consists of MW available within 10 minutes but not synchronized to the grid. Startup time for nonsynchronized reserve resources is not subject to testing and is based on parameters in offers submitted by resource owners. There is no defined requirement for nonsynchronized reserves. It is available to meet the primary reserve requirement. Generation resources that have designated their entire output as emergency are not eligible to provide nonsynchronized reserves. Generation resources that are not available to provide emergency are not eligible to provide nonsynchronized reserves.

⁶⁶ These durations were rounded to the nearest minute in previous reports. They are no longer rounded.

The market mechanism for nonsynchronized reserve does not include any direct participation by market participants. PJM defines the demand curve for nonsynchronized reserve and PJM defines the supply curve based on nonemergency generation resources that are available to provide energy and can start in 10 minutes or less and on the associated resource opportunity costs calculated by PJM. Generation owners do not submit supply offers. Since nonsynchronized reserve is a lower quality product, its clearing price is less than or equal to the synchronized reserve market clearing price. In most hours, the nonsynchronized reserve clearing price is zero.

Market Structure

Demand

Demand for primary reserve is established by PJM as one and a half times the largest contingency. Demand for primary reserve is calculated dynamically in every synchronized and nonsynchronized reserve market solution. After filling the synchronized reserve requirement the balance of primary reserve can be made up by the most economic combination of synchronized and nonsynchronized reserve. In practice this means that the primary reserve requirement minus the scheduled synchronized reserve is the nonsynchronized requirement for the interval. PJM may increase the primary reserve requirement to cover times when a single contingency could cause an outage of several generating units or in times of high load conditions causing operational uncertainty.⁶⁷

The average scheduled hourly nonsynchronized reserve in the RTO Zone in the first nine months of 2022 was 1,122.7 MW. The average scheduled nonsynchronized reserve in the MAD Subzone for primary reserve was 1,109.7 MW.

Supply

Figure 10-2 shows that when tier 1 synchronized reserve did not fully meet the synchronized reserve requirement, then most of the primary reserve

⁶⁷ See PJM, "PJM Manual 11: Energy and Ancillary Services Market Operations," § 4.3 Reserve Requirement Determination, Rev. 122 (Oct. 1, 2022).

requirement (blue line) in excess of the synchronized reserve requirement (purple line) was satisfied by nonsynchronized reserve (green area).

There are no offers for nonsynchronized reserve. The market solution considers the available supply of nonsynchronized reserve to be all generation resources currently not synchronized to the grid but available and capable of providing energy within 10 minutes. Generators that have set themselves as unavailable or have set their output to be emergency only will not be considered. The market solution considers the offered MW to be the lesser of the economic maximum or the ramp rate times 10 minutes minus the startup and notification time. The market supply curve is constructed from the nonsynchronized units' opportunity cost of providing reserves. PJM and generation owners may agree upon exceptions to the requirements.

Nonsynchronized reserve resources are scheduled economically based on estimated LOC until the Primary Reserve requirement is filled. The nonsynchronized reserve market clearing price is determined every five minutes based on the LOC of the marginal unit. When a unit clears the nonsynchronized reserve market and is scheduled, it is committed to remain offline and available to provide 10 minute reserves.

Resources that generally qualify as nonsynchronized reserve include run of river hydro, pumped hydro, combustion turbines, combined cycles that can start in 10 minutes or less, and diesels. In the first nine months of 2022, an average of 1,122.7 MW of nonsynchronized reserve was scheduled per five minute interval out of 2,015.6 eligible MW as part of the primary reserve requirement in the RTO Zone. If only intervals when the price was greater than \$0 are looked at, then an average of 612.8 MW of nonsynchronized reserve is scheduled out of 1,108.7 MW available.

In the first nine months of 2022, CTs provided 80.4 percent of scheduled nonsynchronized reserve (Table 10-24). Natural gas was the primary fuel for nonsynchronized reserve.

Table 10-24 Supply of nonsynchronized reserve by fuel and unit type: January through September, 2022

Resource / Fuel Type	Percent by MW	Percent by Credits
CT - Natural Gas	46.2%	27.0%
CT - Oil	34.2%	34.5%
Hydro - Run of River	19.0%	37.1%
CT - Other	0.2%	0.8%
Hydro - Pumped Storage	0.2%	0.1%
RICE - Oil	0.2%	0.5%
Battery	0.0%	0.0%
Combined Cycle	0.0%	0.0%
Distributed Gen	0.0%	0.0%
Fuel Cell	0.0%	0.0%
Nuclear	0.0%	0.0%
RICE - Natural Gas	0.0%	0.0%
RICE - Other	0.0%	0.0%
Solar	0.0%	0.0%
Solar + Storage	0.0%	0.0%
Solar + Wind	0.0%	0.0%
Steam - Coal	0.0%	0.0%
Steam - Natural Gas	0.0%	0.0%
Steam - Oil	0.0%	0.0%
Steam - Other	0.0%	0.0%
Wind	0.0%	0.0%
Wind + Storage	0.0%	0.0%

Market Concentration

The supply of nonsynchronized reserves in the Mid-Atlantic Dominion Subzone and the RTO Zone was highly concentrated in the first nine months of 2022. Table 10-25 shows the percent of dispatch solutions with a real-time nonsynchronized reserve market clearing price greater than \$0.01 that failed the three pivotal supplier test. In the first nine months of 2022, on average, there were 66 dispatch cases each month with a real-time price above \$0.01, of which 96.7 percent had at least one pivotal supplier. In the first nine months of 2022, in total, 569 of the 591 tested cases had at least one pivotal supplier.

Table 10-25 Percent of dispatch solutions with NSRMCP greater than \$0.01 failing the three pivotal supplier test: January through September, 2022

Year	Month	Number of Dispatch Cases NSR MCP > \$0.01	Percent of Dispatch Cases NSR MCP > \$0.01 Pivotal
2022	Jan	16	100.0%
2022	Feb	0	NA
2022	Mar	29	100.0%
2022	Apr	56	100.0%
2022	May	233	99.6%
2022	Jun	117	95.7%
2022	Jul	25	100.0%
2022	Aug	80	81.3%
2022	Sep	35	97.1%
2022	Average	66	96.7%

Price

The settled price of nonsynchronized reserve is calculated in real time every five minutes for the RTO Reserve Zone and the Mid-Atlantic Dominion Reserve Subzone.

Figure 10-8 shows the daily average nonsynchronized reserve market clearing price (NSRMCP) and average credited MW for the RTO Zone. In the first nine months of 2022, the weighted average nonsynchronized market clearing price for all intervals was \$0.25 per MW. The average nonsynchronized reserve credited was 1,122.7 MW. Shortage pricing for primary reserve was used during 35 intervals on June 13. The average price during these short intervals was \$731.71 per MW.

Figure 10-8 Daily weighted average RTO Zone nonsynchronized reserve market clearing price and MW purchased: January through September, 2022

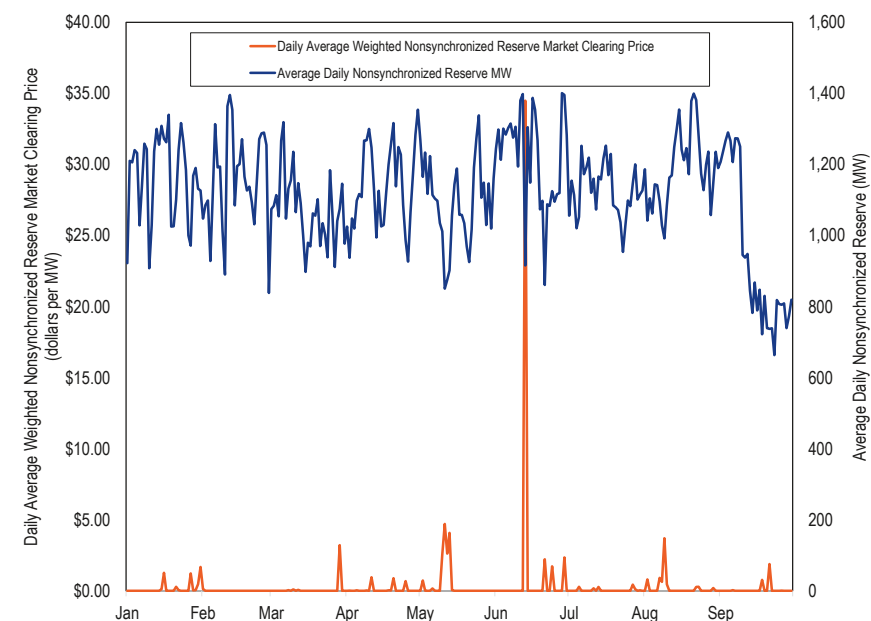


Table 10-26 shows the effect of fast start pricing on the nonsynchronized reserve market’s monthly weighted average market clearing price since September 2021. The weighted average market clearing price for each month is consistently higher in the pricing run than in the dispatch run. In the first nine months of 2022, the average price from the pricing run was 20.1 percent higher than the average price from the dispatch run.

Table 10-26 Comparison of fast start and dispatch pricing components: September 2021 through September 2022

Year	Month	Pricing Method	Weighted Average Market Clearing Price
2021	Sep	Dispatch	\$0.19
		Fast Start	\$0.20
2021	Oct	Dispatch	\$0.62
		Fast Start	\$0.80
2021	Nov	Dispatch	\$0.98
		Fast Start	\$1.23
2021	Dec	Dispatch	\$0.02
		Fast Start	\$0.04
2022	Jan	Dispatch	\$0.15
		Fast Start	\$0.16
2022	Feb	Dispatch	\$0.00
		Fast Start	\$0.00
2022	Mar	Dispatch	\$0.11
		Fast Start	\$0.11
2022	Apr	Dispatch	\$0.08
		Fast Start	\$0.09
2022	May	Dispatch	\$0.27
		Fast Start	\$0.40
2022	Jun	Dispatch	\$0.93
		Fast Start	\$1.05
2022	Jul	Dispatch	\$0.02
		Fast Start	\$0.04
2022	Aug	Dispatch	\$0.16
		Fast Start	\$0.21
2022	Sep	Dispatch	\$0.06
		Fast Start	\$0.06

Price and Cost

As a result of changing grid conditions, load forecasts, incorrect LMP and lost opportunity cost projections, and unexpected generator performance, prices frequently do not cover the full LOC of each resource. All resources cleared in the market are guaranteed to be made whole and are paid uplift credits if the NSRMCP does not fully compensate them. When real-time LMP is greater than the generator's incremental energy offer at economic minimum, then an LOC is paid, even if LMP revenue would not have covered the unit's start and no load costs.⁶⁸

⁶⁸ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 2.16 Minimum Capacity Emergency in Day-ahead Market, Rev. 121 (July 7, 2022).

The full cost to customers of nonsynchronized reserve credits, including payments for the clearing price and uplift costs is calculated and compared to the price in Table 10-27. The closer the price to cost ratio comes to one, the more compensation is provided.

In the first nine months of 2022, the average price of nonsynchronized reserve was \$0.25 per MW. The average credit for nonsynchronized reserve was \$2.11 per MW.

Resources that are not synchronized to the grid are generally off because it is not economic for them to produce energy. A resource scheduled for nonsynchronized reserve is obligated to remain unsynchronized even if its LMP increases above its energy offer. In that case, PJM pays the unit LOC. The LOC calculation does not consider the start cost or the no load cost of committing the unit for energy, which would reduce the LOC in almost all cases. In fact, in its filing to change the reserve market design, PJM explained that nonsynchronized reserves have no lost opportunity cost.⁶⁹

⁶⁹ See *PJM Interconnection, LLC*, "Enhanced Price Formation in Reserve Markets of PJM Interconnection, LLC," Docket No. EL19-58 (March 29, 2019) at 84.

Table 10-27 RTO zone nonsynchronized reserve MW, charges, price, and cost: January 2021 through September 2022

Year	Month	Total	Total	Weighted		Price/Cost Ratio
		Nonsynchronized Reserve MW	Nonsynchronized Reserve Charges	Reserve Market Price	Nonsynchronized Reserve Cost	
2021	Jan	879,221	\$533,379	\$0.04	\$0.61	6.4%
2021	Feb	705,279	\$598,281	\$0.16	\$0.85	18.6%
2021	Mar	759,861	\$1,612,024	\$0.33	\$2.12	15.5%
2021	Apr	752,169	\$425,518	\$0.09	\$0.57	16.7%
2021	May	725,583	\$1,792,770	\$0.38	\$2.47	15.6%
2021	Jun	801,961	\$965,259	\$0.13	\$1.20	10.7%
2021	Jul	821,187	\$776,427	\$0.13	\$0.95	13.6%
2021	Aug	819,528	\$2,610,204	\$0.26	\$3.19	8.3%
2021	Sep	762,247	\$1,552,275	\$0.20	\$2.04	9.9%
2021	Oct	680,605	\$1,428,602	\$0.80	\$2.10	38.2%
2021	Nov	762,277	\$2,914,501	\$1.23	\$3.82	32.2%
2021	Dec	832,563	\$1,565,673	\$0.04	\$1.88	2.0%
2021	Total	9,302,479	\$16,774,913	\$0.31	\$1.80	16.9%
2022	Jan	864,970	\$8,051,383	\$0.16	\$9.31	1.7%
2022	Feb	772,554	\$327,456	\$0.00	\$0.42	1.0%
2022	Mar	793,267	\$417,124	\$0.11	\$0.53	21.3%
2022	Apr	818,987	\$564,075	\$0.09	\$0.69	13.6%
2022	May	812,337	\$1,588,098	\$0.40	\$1.95	20.7%
2022	Jun	875,976	\$1,899,497	\$1.05	\$2.17	48.6%
2022	Jul	829,558	\$664,719	\$0.04	\$0.80	5.3%
2022	Aug	877,569	\$1,205,091	\$0.21	\$1.37	15.1%
2022	Sep	673,825	\$710,665	\$0.06	\$1.05	6.1%
2022	Total	7,319,043	\$15,428,108	\$0.25	\$2.11	11.8%

Secondary Reserve (DASR)

There is no NERC standard for secondary reserve. PJM defines secondary reserve as reserves (online or offline available for dispatch) that can be converted to energy in 30 minutes. PJM defines a secondary reserve requirement but does not have a defined reserve product to maintain this reserve requirement in real time.⁷⁰

PJM maintains a day-ahead, offer based market for 30 minute day-ahead secondary reserve. The Day-Ahead Scheduling Reserve Market (DASR) has no performance obligations except that a unit which clears the DASR market is required to be available for dispatch in real time.⁷¹

Market Structure

Supply

Both generation and demand resources are eligible to offer DASR. DASR offers consist of price only. Available DASR MW are calculated by the market clearing engine. DASR MW are the lesser of the energy ramp rate per minute for online units times 30 minutes, or the economic maximum MW minus the day-ahead dispatch point. For offline resources capable of being online in 30 minutes, the DASR quantity is the economic maximum. In the first nine months of 2022, the DASR hourly average purchased was 4,820.4 MW.⁷²

PJM excludes resources that cannot reliably provide reserves in real time from participating in the DASR market. Such resources include nuclear, run of river hydro, self-scheduled pumped hydro, wind, solar, and energy storage resources.⁷³ The intent is to limit cleared DASR resources to those resources actually capable of providing reserves in the real-time market. Owners of excluded resources may request an exemption from their default noneligibility.

⁷⁰ The reserve market changes, effective October 1, 2022, define a 30-minute reserve service which could be satisfied by a secondary reserve product cleared in the day-ahead and real-time markets.

⁷¹ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 10.5 Aggregation for Economic and Emergency Demand Resources, Rev. 121 (July 7, 2022).

⁷² The average hourly available DASR MW are modified from previously reported values because of a calculation error which has been fixed.

⁷³ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 11.2.2 Day-Ahead Scheduling Reserve Market Eligibility, Rev. 121 (July 7, 2022).

Of the scheduled DASR MW cleared in the first nine months of 2022, 78.7 percent was from CTs (Table 10-28).

Table 10-28 Scheduled DASR by fuel and unit type: January through September, 2022

Resource / Fuel Type	Percentage of DASR MW	Percentage of DASR Credits
CT - Natural Gas	61.0%	61.4%
CT - Oil	17.7%	17.7%
Hydro - Pumped Storage	12.9%	4.3%
Combined Cycle	4.3%	9.2%
Steam - Coal	3.4%	3.5%
RICE - Oil	0.3%	0.9%
Steam - Natural Gas	0.2%	2.4%
RICE - Other	0.1%	0.4%
RICE - Natural Gas	0.0%	0.1%
Steam - Other	0.0%	0.1%
Steam - Oil	0.0%	0.0%
CT - Other	0.0%	0.0%
Battery	0.0%	0.0%
DSR	0.0%	0.0%
Distributed Gen	0.0%	0.0%
Fuel Cell	0.0%	0.0%
Hydro - Run of River	0.0%	0.0%
Nuclear	0.0%	0.0%
Solar	0.0%	0.0%
Solar + Storage	0.0%	0.0%
Solar + Wind	0.0%	0.0%
Wind	0.0%	0.0%
Wind + Storage	0.0%	0.0%

Demand

Secondary reserve (30 minute reserve) requirements are determined by PJM for each reliability region. In the ReliabilityFirst (RFC) region, secondary reserve requirements are calculated based on historical under forecasted load rates and generator forced outage rates.⁷⁴ The DASR requirement is calculated daily and is equal to the peak load forecast for the ReliabilityFirst region (RFC) and EKPC times the sum of the forced outage rate and the load forecast error, plus Dominion's share of the VACAR contingency reserve commitment. Effective November 1, 2021, through September 30, 2022, the day-ahead scheduling reserve requirement is 4.40 percent of the peak load forecast, based on a

⁷⁴ See PJM, "PJM Manual 13: Emergency Operations," § 2.2 Reserve Requirements, Rev. 84 (Mar. 23, 2022).

2.03 percent LFE component and a 2.38 percent FOR component. The DASR requirement is applicable for all hours of the operating day.

The DASR requirement can be increased by PJM operators under conditions of "hot weather or cold weather alert or max emergency generation alert or other escalating emergency."⁷⁵ The amount of additional DASR MW that may be required is the Adjusted Fixed Demand (AFD) determined by a Seasonal Conditional Demand (SCD) factor.⁷⁶ The SCD factor is calculated separately for the winter (November through March) and summer (April through October) seasons. The SCD factor is calculated every year based on the top 10 peak load days from the prior year. For November 2021 through October 2022, the SCD values are 5.84 percent for winter and 4.06 percent for summer. PJM Dispatch may also schedule additional Day-Ahead Scheduling Reserves as deemed necessary for conservative operations.⁷⁷ PJM has defined the reasons for conservative operations to include, potential fuel delivery issues, forest/brush fires, extreme weather events, environmental alerts, solar disturbances, unknown grid operating state, physical or cyber attacks.⁷⁸ The result is substantial discretion for PJM to increase the demand for DASR under a variety of circumstances. PJM invoked adjusted fixed demand in 547 hours during the first nine months of 2022. The MMU recommends that PJM modify the DASR market to ensure that all resources cleared incur a real-time performance obligation. The MMU further recommends that PJM attach a reason code to all hours when adjusted fixed demand is dispatched. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

Market Concentration

DASR market three pivotal supplier test results are provided in Table 10-29. Table 10-29 shows the percent of intervals with a day-ahead scheduling reserve market clearing price greater than \$0.01 that failed the three pivotal supplier test. In the first nine months of 2022, on average, there were 85

⁷⁵ PJM, "Energy and Reserve Pricing & Interchange Volatility Final Proposal Report," <<http://www.pjm.com/~media/committees-groups/committees/mrc/20141030/20141030-item-04-erpriv-final-proposal-report.ashx>>.

⁷⁶ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 11.2.1 Day-Ahead Scheduling Reserve Market Requirement, Rev. 121 (July 7, 2022).

⁷⁷ See *id.*

⁷⁸ See PJM, "PJM Manual 13: Emergency Operations," § 3.2 Conservative Operations, Rev. 85 (Oct. 1, 2022).

testable intervals each month, of which 90.0 percent had at least one pivotal supplier. In total, there were 769 testable intervals, of which 603, or 78.4 percent, had at least one pivotal supplier.

Table 10-29 DASR market three pivotal supplier test results and number of hours with DASR MCP above \$0.01: January 2021 through September 2022

Year	Month	Number of Hours DASR MCP > \$0.01	Percent of Hours DASR MCP > \$0.01 Pivotal
2021	Jan	15	100.0%
2021	Feb	26	100.0%
2021	Mar	23	100.0%
2021	Apr	93	98.9%
2021	May	79	87.3%
2021	Jun	151	78.1%
2021	Jul	148	95.9%
2021	Aug	153	84.3%
2021	Sep	131	86.3%
2021	Oct	171	98.8%
2021	Nov	140	98.6%
2021	Dec	33	100.0%
2021	Average	97	94.0%
2022	Jan	43	100.0%
2022	Feb	12	100.0%
2022	Mar	42	90.5%
2022	Apr	16	100.0%
2022	May	62	72.6%
2022	Jun	142	84.5%
2022	Jul	212	86.8%
2022	Aug	168	86.3%
2022	Sep	72	88.9%
2022	Average	85	90.0%

Market Conduct

PJM rules allow any unit with reserve capability that can be converted into energy within 30 minutes to offer into the DASR market.⁷⁹ Units that do not offer have their offers set to \$0.00 per MW during the day-ahead market clearing process.

Economic withholding remains an issue in the DASR market. The marginal cost of providing DASR is zero. All offers greater than zero constitute economic

⁷⁹ See PJM, "PJM Manual 11: Energy & Ancillary Services Market Operations," § 11.2.2 Day-Ahead Scheduling Reserve Market Eligibility, Rev. 121 (July 7, 2022).

withholding. In the first nine months of 2022, 43.7 percent of generation units offered DASR at a daily price above \$0.00 per MW. In the first nine months of 2022, 16.9 percent of daily offers were above \$5.00 per MW.

The MMU recommends that market solutions for the DASR market be based on opportunity cost only in order to eliminate economic withholding. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

Market Performance

In the first nine months of 2022, the DASR market cleared at a price above \$0.00 per MW in 12.6 percent of all hours. The weighted average DASR price for all cleared hours was \$0.35 per MW. The average cleared MW in all hours was 4,820.2 MW. The average cleared MW in all hours when the DASRMCP was above \$0.00 was 6,321.3 MW. The highest DASR price in the first nine months of 2022 was \$34.00 per MW for one hour on May 31.

The introduction of Adjusted Fixed Demand (AFD) on March 1, 2015, created a bifurcated market. Table 10-30 shows the use of AFD in previous years. Table 10-31 shows the use of AFD in the first nine months of 2022. In the first nine months of 2022, AFD hours were only used in the months of January, May, June, July, August, and September. The resulting differences in market clearing price, MW cleared, and charges to PJM load from use of AFD could be substantial, as seen in Table 10-33. Table 10-32 shows the differences in price and MW between AFD hours and non-AFD hours in the first nine months of 2022.

Table 10-30 Hours with Adjusted Fixed Demand (AFD) added to the normal DASR requirement: 2015 through 2021

Year	Number of Hours with AFD	Normal Requirement as Percent of Forecast Load
2015	367	5.9%
2016	522	5.7%
2017	336	5.5%
2018	598	5.3%
2019	447	5.3%
2020	430	5.1%
2021	516	5.5%

Table 10-31 Hours with Adjusted Fixed Demand (AFD) and average increase in DASR requirement: January through September, 2022

Year	Month	Number of Hours with AFD	Average Increase in Requirement
2022	Jan	16	15.2%
2022	Feb	0	NA
2022	Mar	0	NA
2022	Apr	0	NA
2022	May	63	65.1%
2022	Jun	67	74.4%
2022	Jul	214	26.3%
2022	Aug	163	30.8%
2022	Sep	24	20.0%
2022	Total	547	37.0%

Table 10-32 Impact of Adjusted Fixed Demand on DASR prices and demand: January through September, 2022

Metric	Number of Hours	Weighted Day-Ahead Scheduling Reserve Market Clearing Price (DASRMCP)	Average Hourly Total DASR MW
All hours	6,551	\$0.35	4,626.5
All hours when DASRMCP > \$0	827	\$2.28	5,702.3
All hours when AFD used	547	\$2.15	7,292.5

While the new rules allowed PJM operators' substantial discretion to add to DASR demand for a variety of reasons, the rationale for each specific increase is not always clear. The MMU recommends that PJM Market Operations attach a reason code to every hour in which PJM operators add additional DASR MW above the default DASR hourly requirement. The addition of such

a code would make the reason explicit, increase transparency and facilitate analysis of the use of PJM's ability to add DASR MW. This recommendation was adopted effective October 1, 2022, with the market changes for the new secondary reserve product.

Comparing the Normal Hour column against the AFD Hour column for five metrics (Table 10-33) shows that the use of AFD for 574 hours in the first nine months of 2022 significantly increased the cost of DASR by increasing the DASR MW cleared. Table 10-33 shows the cost increase. The average DASR clearing price in the first nine months of 2022 was \$0.77 per MW for hours when the clearing price was above \$0.00 and \$4.49 per MW during hours when adjusted fixed demand was invoked by PJM Dispatch.

Table 10-33 DASR market, regular hours vs. adjusted fixed demand hours with price greater than \$0: January 2021 through September 2022

Year	Month	Number of Hours				Average PJM Load		Hourly Average		Average Hourly	
		DASRMCP > \$0		Weighted DASRMCP		MW		Cleared DASR MW		DASR Credits	
		Normal Hour	AFD Hour	Normal Hour	AFD Hour	Normal Hour	AFD Hour	Normal Hour	AFD Hour	Normal Hour	AFD Hour
2021	Jan	28	NA	\$0.08	NA	106,153	NA	4,847	NA	\$380	NA
2021	Feb	32	NA	\$0.16	NA	108,947	NA	4,974	NA	\$815	NA
2021	Mar	24	NA	\$0.17	NA	92,014	NA	4,327	NA	\$732	NA
2021	Apr	129	NA	\$0.21	NA	83,962	NA	3,983	NA	\$846	NA
2021	May	68	11	\$0.60	\$1.91	99,007	105,454	4,661	9,514	\$2,785	\$18,147
2021	Jun	83	77	\$0.41	\$4.55	115,654	118,494	5,170	8,973	\$2,124	\$40,839
2021	Jul	115	46	\$0.44	\$1.41	122,396	129,739	5,460	7,842	\$2,424	\$11,095
2021	Aug	110	83	\$0.35	\$3.85	121,022	133,350	5,399	7,869	\$1,877	\$30,312
2021	Sep	107	40	\$0.58	\$3.45	104,852	105,046	4,776	9,117	\$2,769	\$31,492
2021	Oct	222	NA	\$0.50	NA	87,526	NA	4,335	NA	\$2,159	NA
2021	Nov	228	NA	\$0.30	NA	89,025	NA	4,208	NA	\$1,258	NA
2021	Dec	41	NA	\$0.26	NA	100,378	NA	4,544	NA	\$1,188	NA
2021		1,187	257	\$0.39	\$3.51	99,647	122,653	4,633	8,460	\$1,791	\$29,689
2022	Jan	52	1	\$0.29	\$0.19	114,012	116,746	4,799	4,856	\$1,407	\$923
2022	Feb	13	NA	\$0.31	NA	112,857	NA	4,542	NA	\$1,390	NA
2022	Mar	42	NA	\$0.49	NA	98,063	NA	4,368	NA	\$2,124	NA
2022	Apr	22	NA	\$0.18	NA	88,142	NA	3,818	NA	\$681	NA
2022	May	45	31	\$0.29	\$8.26	97,273	113,745	4,196	9,418	\$1,237	\$77,802
2022	Jun	110	42	\$1.55	\$4.23	118,219	115,167	5,017	9,746	\$7,764	\$41,216
2022	Jul	132	89	\$0.59	\$3.10	119,220	131,062	5,006	7,333	\$2,958	\$22,748
2022	Aug	103	68	\$0.73	\$4.58	121,415	128,332	4,969	7,413	\$3,609	\$33,967
2022	Sep	69	8	\$0.96	\$2.09	108,371	110,701	4,584	5,915	\$4,380	\$12,334
2022		588	239	\$0.77	\$4.49	113,189	124,504	4,771	7,992	\$3,690	\$35,886

Table 10-34 shows total number of hours when a DASR market cleared at a price above \$0 along with average load, cleared MW, additional MW under AFD, and total charges for the DASR market in January 2021 through September 2022.

Table 10-34 DASR market all hours of DASR market clearing price greater than \$0: January 2021 through September 2022

Year	Month	Number of Hours DASRMCP > \$0	Weighted DASR Market Clearing Price	Average Hourly RT Load MW	PJM Cleared DASR MW	PJM Cleared Additional DASR MW	Credits
2021	Jan	28	\$0.08	106,153	135,710	0	\$10,640
2021	Feb	32	\$0.16	108,947	159,163	0	\$26,076
2021	Mar	24	\$0.17	92,014	103,839	0	\$17,564
2021	Apr	129	\$0.21	83,962	513,819	0	\$109,108
2021	May	79	\$0.92	99,905	421,593	53,470	\$389,001
2021	Jun	160	\$2.97	117,021	1,120,041	351,422	\$3,320,941
2021	Jul	161	\$0.80	124,494	988,574	97,972	\$789,171
2021	Aug	193	\$2.18	126,324	1,246,974	168,469	\$2,722,344
2021	Sep	147	\$1.78	104,905	875,744	150,928	\$1,555,947
2021	Oct	222	\$0.50	87,526	962,369	0	\$479,311
2021	Nov	228	\$0.30	89,025	959,331	0	\$286,853
2021	Dec	41	\$0.26	100,378	186,320	0	\$48,719
2021	Total	1,444	\$1.27	103,741	7,673,478	822,262	\$9,755,675
2022	Jan	53	\$0.29	114,063	254,387	1,089	\$74,083
2022	Feb	13	\$0.31	112,857	59,044	0	\$18,065
2022	Mar	42	\$0.49	98,063	183,452	0	\$89,213
2022	Apr	22	\$0.18	88,142	83,989	0	\$14,973
2022	May	76	\$5.13	103,992	480,783	148,406	\$2,467,548
2022	Jun	152	\$2.69	117,376	961,196	209,266	\$2,585,054
2022	Jul	221	\$1.84	123,989	1,313,439	178,880	\$2,415,045
2022	Aug	171	\$2.64	124,166	1,015,863	156,422	\$2,681,484
2022	Sep	77	\$1.10	108,613	363,635	10,696	\$400,897
2022	Total	827	\$2.28	116,459	4,715,788	704,759	\$10,746,362

When the DASR requirement was increased by PJM dispatch, the reserve requirement frequently could not be met without redispatching online resources which significantly affected the price by creating an LOC.

Regulation Market

Regulation matches generation with short term changes in load by moving the output of selected resources up and down via an automatic control signal. Regulation is provided by generators with a short-term response capability (less than five minutes) or by demand response (DR). The PJM Regulation Market is operated as a single real-time market.

Market Design

PJM's regulation market design is a result of Order No. 755.⁸⁰ 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. 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

⁸⁰ Order No. 755, 137 FERC ¶ 61,064 at P 2 (2011).

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 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 marginal 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).

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.⁸¹ Performance scores are reported on an hourly basis for each resource.

Table 10-35 and Figure 10-9 show the average performance score by resource type and the signal followed in the first nine months of 2022. In these figures, the MW used are actual MW and the performance score is the hourly performance score of the regulation resource.⁸² Each category (color bar) is based on the percentage of the full performance score distribution for each resource (or signal) type. As Figure 10-9 shows, 76.8 percent of RegD resources had average performance scores within the 0.91-1.00 range, and 19.7 percent of RegA resources had average performance scores within that range in the first nine months of 2022. In the first nine months of 2021, 76.7 percent of RegD resources had average performance scores within the 0.91-1.00 range, and 26.4 percent of RegA resources had average performance scores within that range.

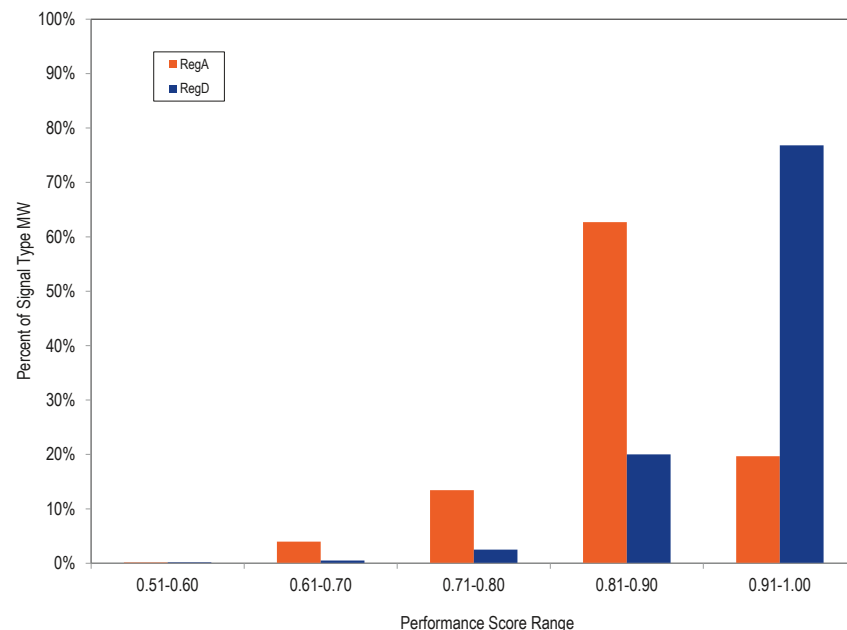
Table 10-35 Hourly average performance score by unit type: January through September, 2022

		Performance Score Range				
		51-60	61-70	71-80	81-90	91-100
RegA	Battery	-	-	-	-	-
	CT	0.0%	0.0%	1.6%	59.7%	38.8%
	Diesel	0.0%	0.0%	0.0%	21.6%	78.4%
	DSR	-	-	-	-	-
	Hydro	0.0%	0.0%	0.1%	57.4%	42.5%
	Steam	0.2%	5.5%	18.5%	64.9%	10.8%
	Battery	0.2%	0.0%	0.1%	18.0%	81.7%
RegD	CT	0.0%	0.0%	15.1%	69.3%	15.6%
	Diesel	0.0%	0.0%	3.7%	55.1%	41.3%
	DSR	0.0%	0.2%	21.5%	27.2%	51.1%
	Hydro	0.0%	16.7%	0.0%	29.6%	53.8%
	Steam	-	-	-	-	-
	Battery	-	-	-	-	-

⁸¹ PJM "Manual 12: Balancing Operations," § 4.5.6 Performance Score Calculation, Rev. 47 (Oct. 1, 2022).

⁸² Except where explicitly referred to as effective MW or effective regulation MW, MW means actual MW unadjusted for either MBF or performance factor.

Figure 10-9 Hourly average performance score by regulation signal type: January through September, 2022



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 with 10 MW of capability will be provided a TREG signal asking for a positive or negative regulation movement between negative and positive 10 MW around its regulation set point.

Resources are paid Regulation Market Clearing Price (RMCP) credits and lost opportunity cost credits, which are uplift payments. If a resource's lost opportunity costs for an hour are greater than its RMCP credits, that resource receives lost opportunity cost credits equal to the difference. PJM posts clearing prices for the regulation market (RMCCP, RMPCP and RMCP)

in dollars per effective MW. The regulation market clearing price (RMCP in \$/effective MW) for the hour is the simple average of the 12 five minute RMCPs within the hour. The RMCP is set in each five minute interval based on the marginal offer in each interval. The performance clearing price (RMPCP in \$/effective MW) is based on the marginal performance offer (RMPCP) for the hour. The capability clearing price (RMCCP in \$/effective MW) is equal to the difference between the RMCP for the hour and the RMPCP for the hour. This is done so the total of RMPCP plus RMCCP equals the total clearing price (RMCP) but the RMPCP is maximized.

Market solution software relevant to regulation consists of the Ancillary Services Optimizer (ASO) solving hourly; the intermediate term security constrained economic dispatch market solution (IT SCED) solving every 15 minutes; and the real-time security constrained economic dispatch market solution (RT SCED) solving approximately every five minutes. The market clearing price is determined by pricing software (LPC) that looks at the units cleared in the most recently approved RT SCED case, approximately 10 minutes ahead of the target solution time. The marginal prices assigned by the LPC to five minute intervals are averaged over the hour for an hourly regulation market clearing price.

Market Design Issues

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 over investment 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 the payment to RegD resources being 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 too much. 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.

To address the identified market flaws, the MMU and PJM developed a joint proposal which was approved by the PJM Members Committee on July 27, 2017, and filed with FERC on October 17, 2017. The PJM/MMU joint proposal addresses issues with the inconsistent application of the marginal benefit factor throughout the optimization and settlement process in the PJM Regulation Market. FERC rejected the proposal finding it inconsistent with Order No. 755.

The MBF related issues with the regulation market have been raised in the PJM stakeholder process. In 2015, PJM stakeholders approved an interim, partial solution to the RegD over procurement problem which was implemented on December 14, 2015. The interim solution was designed to reduce the

relative value of RegD MW in all hours and to cap purchases of RegD MW during critical performance hours. But the interim solution did not address the fundamental issues in the optimization or the lack of consistency in the application of the MBF.

Additional changes were implemented on January 9, 2017. These modifications included changing the definition of off peak and on peak hours, adjusting the currently independent RegA and RegD signals to be interdependent, and changing the 15 minute neutrality requirement of the RegD signal to a 30 minute neutrality requirement.

The January 9, 2017, design changes appear to have been intended to make RegD more valuable. That is not a reasonable design goal. The design goal should be to determine the least cost way to provide needed regulation. The RegA signal is now slower than it was previously, which may make RegA following resources less useful as ACE control. RegA is now explicitly used to support the conditional energy neutrality of RegD. The RegD signal is now the difference between ACE and RegA. RegA is required to offset RegD when RegD moves in the opposite direction of that required by ACE control in order to permit RegD to recharge. These changes in the signal design will allow PJM to accommodate more RegD in its market solutions. The new signal design is not making the most efficient use of RegA and RegD resources. The explicit reliance on RegA to offset issues with RegD is a significant conceptual change to the design that is inconsistent with the long term design goal for regulation. PJM increased the regulation requirement as part of these changes.

The January 9, 2017, design changes replaced off peak and on peak hours with nonramp and ramp hours with definitions that vary by season. The regulation requirement for ramp hours was increased from 700 MW to 800 MW (Table 10-36). These market changes still do not address the fundamental issues in the optimization or the lack of consistency in the application of the MBF.

Table 10-36 Seasonal regulation requirement definitions⁸³

Season	Dates	Nonramp Hours	Ramp Hours
Winter	Dec 1 - Feb 28(29)	00:00 - 03:59	04:00 - 08:59
		09:00 - 15:59	16:00 - 23:59
Spring	Mar 1 - May 31	00:00 - 04:59	05:00 - 07:59
		08:00 - 16:59	17:00 - 23:59
Summer	Jun 1 - Aug 31	00:00 - 04:59	05:00 - 13:59
		14:00 - 17:59	18:00 - 23:59
Fall	Sep 1 - Nov 30	00:00 - 04:59	05:00 - 07:59
		08:00 - 16:59	17:00 - 23:59

Performance Scores

Performance scores, by class and unit, are not an indicator of how well resources contribute to ACE control. Performance scores are an indicator only of how well the resources follow their TREG signal. High performance scores with poor signal design are not a meaningful measure of performance. For example, if ACE indicates the need for more regulation but RegD resources have provided all their available energy, the RegD regulation signal will be in the opposite direction of what is needed to control ACE. So, despite moving in the wrong direction for ACE control, RegD resources would get a good performance score for following the RegD signal and will be paid for moving in the wrong direction.

The RegD signal prior to January 9, 2017, is an example of a signal that resulted in high performance scores, but due to 15 minute energy neutrality built into the signal, ran counter to ACE control at times. Energy neutrality means that energy produced equals energy used within a defined timeframe. With 15 minute energy neutrality, if a battery were following the regulation signal to provide MWh for 7.5 minutes, it would have to consume the same amount of MWh for the next 7.5 minutes. When neutrality correction of the RegD signal is triggered, it overrides ACE control in favor of achieving zero net energy over the 15 minute period. When this occurs, the RegD signal runs counter to the control of ACE and hurts rather than helps ACE. In that situation, the control of ACE, which must also offset the negative impacts of RegD, depends entirely on RegA resources following the RegA signal. High

⁸³ See PJM. "Regulation Requirement Definition," <<http://www.pjm.com/~media/markets-ops/ancillary/regulation-requirement-definition.ashx>>.

performance scores under the signal design prior to January 9, 2017, was not an indication of good ACE control.

The January 9, 2017, design changes did not address the fundamental issues with the definition of performance or the nature of payments for performance in the regulation market design. The regulation signal should not be designed to favor a particular technology. The signal should be designed to result in the lowest cost of regulation to the market. Only with a performance score based on full substitutability among resource types should payments be based on following the signal. The MRTS must be redesigned to reflect the actual capabilities of technologies to provide regulation. The PJM regulation market design remains fundamentally flawed.

In addition, the absence of a performance penalty, imposed as a reduction in performance score and/or as a forfeiture of revenues, for deselection initiated by the resource owner within the hour, creates a possible gaming opportunity for resources which may overstate their capability to follow the regulation signal. The MMU recommends that there be a penalty enforced as a reduction in performance score and/or a forfeiture of revenues when resource owners elect to deassign assigned regulation resources within the hour, to prevent gaming.

Battery Settlement

The change from 15 to 30 minute signal neutrality, implemented in the January 9, 2017, design changes, resulted in the reduction of performance scores for short duration batteries. In April 2017 several participants filed a complaint against PJM, asserting that these changes discriminated against their battery units.⁸⁴ The MMU objected to the complaints. Despite the unsupported assertions in the complaint, PJM settled with the participants that was approved by FERC on April 7, 2020.⁸⁵ Table 10-37 shows the battery units that are part of the settlement. Starting July 1, 2020, the affected battery units began receiving compensation based on the greater of their current performance score, or their rolling average actual hourly performance score for the last 100 hours the resource operated prior to the January 9, 2017,

⁸⁴ See FERC Docket Nos. EL17-64-000 and EL17-65-000.

⁸⁵ See 170 FERC ¶ 61,258 (2020).

implementation of the 30-minute conditional neutrality. The additional regulation credits received in the first nine months of 2022 as a result of the settlement are shown in Table 10-38.

Table 10-37 Batteries in settlement

Parent Company	Unit	MW
The AES Corporation	Laurel Mountain	32.0
	Warrior Run	10.0
Energy Capital Partners, LLC	Hazel	20.0
	Trent	4.0
Galt Power, Inc.	McHenry	20.0
	Beckjord 1	2.0
	Beckjord 2	2.0
	Beech Ridge	31.5
Invenergy, LLC	Grand Ridge 6	4.5
	Grand Ridge 7	31.5
	Lee Dekalb	20.0
NextEra Energy, Inc.	Garrett	10.4
	Meyersdale	18.0
	Mantua Creek	2.0
	Joliet	20.0
Renewable Energy Systems Holdings, LTD	West Chicago	20.0
	Sumitomo Corporation	Willey

Table 10-38 Excess regulation credits received by settlement batteries: January through September, 2022

Month	Excess Regulation Credit (\$)
Jan	\$230,764
Feb	\$84,963
Mar	\$70,375
Apr	\$128,896
May	\$104,817
Jun	\$179,703
Jul	\$160,327
Aug	\$216,929
Sep	\$169,958
Total	\$1,346,731

In addition to paying uneconomic regulation credits based on inflated performance scores, the settlement also requires that the affected battery units be cleared in the regulation market regardless of whether their offer was economic. As long as the settlement batteries are offered as either self

scheduled with a zero offer, or as a zero priced offer, they must be cleared despite the fact that these units would not necessarily have cleared based on economics.⁸⁶ In order to comply with this condition, PJM clears additional MW beyond what is needed for the regulation requirement in cases where the settlement battery units did not clear but met the offer rules of the settlement. This results in excess charges to customers for regulation service. Table 10-39 shows the impact of clearing additional MW beyond what is needed for the regulation requirement, as a result of the battery settlement, in the first nine months of 2022. Other changes in market dynamics starting in the third quarter of 2021 reduced the impact of this settlement rule because most of the settlement units clear based on economics. In the first nine months of 2022, the battery settlement resulted in customers paying \$97,634 more than needed, in order to compensate the additional MW from settlement batteries that would not have otherwise cleared. As a result of the battery settlement, PJM customers in the first nine months of 2022 over paid for regulation by \$1.4 million (the sum of Table 10-38 and Table 10-39).

Table 10-39 Excess payments and MW cleared due to battery settlement: January through September, 2022

Month	Battery Settlement Impact	
	Regulation Credits	Additional Cleared Regulation MW
Jan	\$3,576	54.5
Feb	\$9,974	384.3
Mar	\$43,880	833.3
Apr	\$829	24.7
May	\$4,056	78.9
Jun	\$904	33.5
Jul	\$10,454	240.9
Aug	\$10,487	234.9
Sep	\$13,474	182.8
Total	\$97,634	2,067.7

Regulation Signal

As with any signal design for substitutable resources, the MBF function should be determined by the ability of RegA and RegD resources to follow their signals, including conditions under which neutrality cannot be maintained by RegD resources. The ability of energy limited RegD to provide ACE control

⁸⁶ See *id.* at P 17.

depends on the availability of excess RegA capability to support RegD under the conditional neutrality design. When RegD resources are largely energy limited resources, a correctly calculated MBF would exhibit a rapid decrease in the MBF value for every MW of RegD added. The result is that only a small amount of energy limited RegD is economic. The current and proposed signals and corresponding MBF functions do not reflect these principles or the actual substitutability of resource types.

Marginal Benefit Factor Issues

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.⁸⁷

The result has been that the PJM Regulation Market has over procured 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 MMU filed a joint proposal with FERC 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 FERC.⁸⁸

Marginal Benefit Factor Not Correctly Defined

The MBF used in the PJM Regulation Market prior to the December 14, 2015, changes did 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

⁸⁷ The MBF, as used in this report, refers to PJM's incorrectly calculated MBF and not the MBF equivalent to the MRTS.

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

function is incorrectly defined and improperly implemented in the current PJM Regulation Market.

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 FERC orders. From October 1, 2012, through October 31, 2013, PJM implemented a FERC order that required the MBF to be fixed at 1.0 for settlement calculations only. On October 2, 2013, FERC 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, 2012.⁸⁹ That rule continues in effect. The result of the current FERC 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

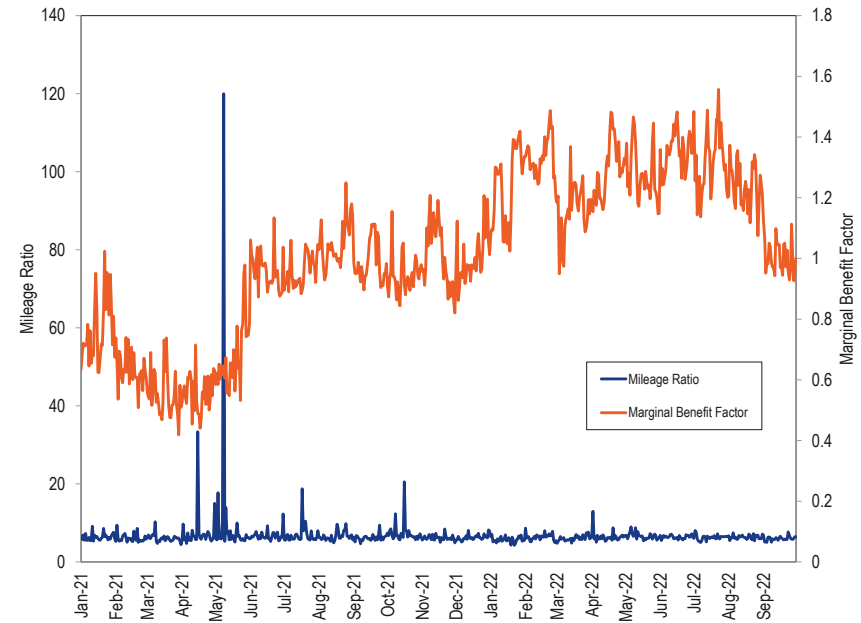
⁸⁹ 145 FERC ¶ 61,011 (2013).

component of the signal from a strict 15 minute neutrality to a 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 10-10 shows the daily average MBF and the mileage ratio. The weighted average mileage ratio decreased from 7.06 in the first nine months of 2021, to 6.25 in the first nine months of 2022 (a decrease of 11.4 percent). The average MBF increased from 0.79 in the first nine months of 2021, to 1.25 in the first nine months of 2022 (an increase of 56.8 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 10-10 Daily average MBF and mileage ratio: January 2021 through September 2022



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 10-40 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, 2021, through September 30, 2022. The average regulation market clearing price in the first nine months of 2022 was \$30.13 higher than in the first nine months of 2021 (See Table 10-54.) In the first nine months of 2022, RegD resources earned 17.0 percent more per performance adjusted actual MW than RegA resources (21.7 percent in the first nine months of 2021) due to the inclusion of the mileage ratio in RegD MW settlement.

Table 10-40 Average monthly price paid per performance adjusted actual MW of RegD and RegA: January 2021 through September 2022

		Settlement Payments		
Year	Month	RegD (\$/Performance Adjusted MW)	RegA (\$/Performance Adjusted MW)	Percent RegD Overpayment (\$/Performance Adjusted MW)
2021	Jan	\$14.29	\$11.43	25.1%
	Feb	\$23.87	\$19.90	19.9%
	Mar	\$20.81	\$17.93	16.0%
	Apr	\$20.86	\$16.73	24.6%
	May	\$20.22	\$16.42	23.2%
	Jun	\$23.01	\$18.40	25.1%
	Jul	\$24.09	\$19.34	24.6%
	Aug	\$37.86	\$31.77	19.2%
	Sep	\$34.62	\$28.59	21.1%
	Oct	\$46.15	\$38.91	18.6%
	Nov	\$61.59	\$52.92	16.4%
	Dec	\$33.56	\$26.85	25.0%
Yearly		\$30.08	\$24.93	20.7%
2022	Jan	\$74.63	\$68.59	8.8%
	Feb	\$39.28	\$31.51	24.6%
	Mar	\$33.90	\$25.56	32.6%
	Apr	\$60.31	\$49.00	23.1%
	May	\$49.81	\$41.57	19.8%
	Jun	\$63.28	\$54.47	16.2%
	Jul	\$60.45	\$53.40	13.2%
	Aug	\$71.87	\$63.64	12.9%
	Sep	\$55.22	\$46.90	17.7%
Yearly		\$56.69	\$48.46	17.0%

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 $(RMCCP + (RMPCP * \text{mileage ratio}))$. 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 greater than 1.0 in the first nine months of 2022 (1.25).

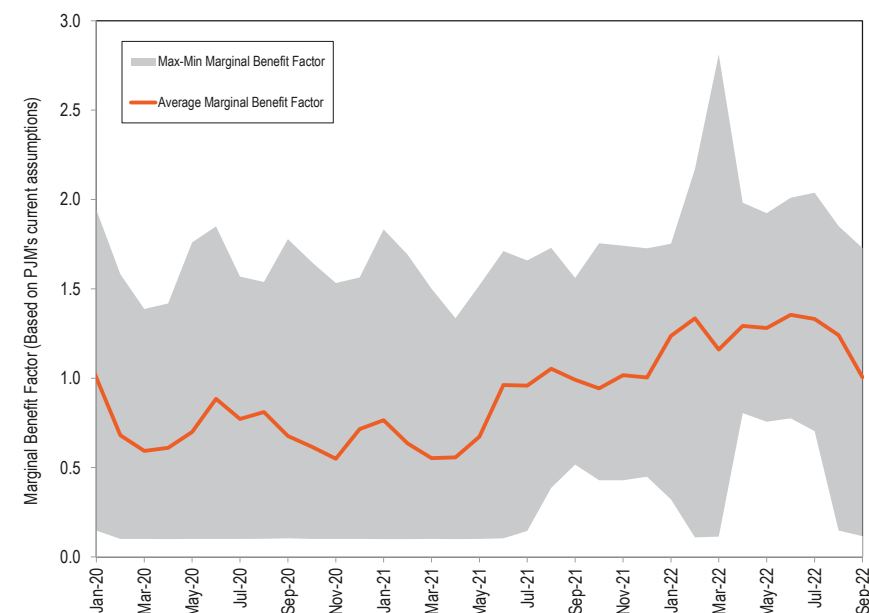
The effect of using the mileage ratio instead of the MBF for purposes of settlement is illustrated in Table 10-41. Table 10-41 shows how much RegD resources are currently being paid, adjusted to a per effective MW basis, on average, in the first nine months of 2021 and 2022 under the current rules, compared 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 nine months of 2022, the MBF averaged 1.25, while the average daily mileage ratio was 6.25, resulting in RegD resources being paid \$6.4 million less than they would have been paid on an effective MW basis if the MBF were correctly implemented. In the first nine months of 2021, the MBF averaged 0.79, and the average mileage ratio was 7.06, resulting in RegD resources being paid \$7.4 million more than they would have been paid if the MBF were correctly implemented. The shift from overpayment to underpayment of RegD resources between 2021 and the first nine months of 2022 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 prices.

Table 10-41 Average monthly price paid per effective MW of RegD and RegA under mileage and MBF based settlement: January 2021 through September 2022

RegD Settlement Payments						
Year	Month	Marginal Rate of		RegA (\$/Effective MW)	Percent RegD Overpayment (\$/Effective MW)	Total RegD Overpayment (\$)
		Mileage Based RegD (\$/Effective MW)	Technical Substitution Based RegD (\$/Effective MW)			
2021	Jan	\$30.47	\$11.43	\$11.43	166.6%	\$558,397
	Feb	\$88.91	\$19.90	\$19.90	346.7%	\$1,310,279
	Mar	\$61.03	\$17.93	\$17.93	240.4%	\$1,277,850
	Apr	\$65.99	\$16.73	\$16.73	294.3%	\$1,492,094
	May	\$39.55	\$16.42	\$16.42	140.9%	\$1,081,445
	Jun	\$26.57	\$18.40	\$18.40	44.4%	\$457,543
	Jul	\$27.36	\$19.34	\$19.34	41.5%	\$513,073
	Aug	\$38.23	\$31.77	\$31.77	20.4%	\$288,112
	Sep	\$35.63	\$28.59	\$28.59	24.6%	\$410,694
	Oct	\$51.13	\$38.91	\$38.91	31.4%	\$688,515
	Nov	\$63.20	\$52.92	\$52.92	19.4%	\$377,458
	Dec	\$33.94	\$26.85	\$26.85	26.4%	\$399,675
Yearly		\$46.48	\$24.93	\$24.93	86.4%	\$8,855,253
2022	Jan	\$62.73	\$68.59	\$68.59	(8.5%)	(\$1,580,376)
	Feb	\$29.38	\$31.51	\$31.51	(6.8%)	(\$516,687)
	Mar	\$31.86	\$25.56	\$25.56	24.7%	\$281,052
	Apr	\$46.90	\$49.00	\$49.00	(4.3%)	(\$550,585)
	May	\$39.30	\$41.57	\$41.57	(5.4%)	(\$582,040)
	Jun	\$47.78	\$54.47	\$54.47	(12.3%)	(\$1,133,591)
	Jul	\$45.45	\$53.40	\$53.40	(14.9%)	(\$1,438,918)
	Aug	\$60.51	\$63.64	\$63.64	(4.9%)	(\$1,069,872)
	Sep	\$55.46	\$46.90	\$46.90	18.2%	\$239,007
Yearly		\$46.75	\$48.46	\$48.46	(3.5%)	(\$6,352,011)

Figure 10-11 shows, the monthly maximum, minimum and average MBF, for January 2020 through September 2022. The average daily MBF in the first nine months of 2022 was 1.25. The average daily MBF in the first nine months of 2021 was 0.79. The bottom of the MBF range results from PJM’s administratively defined MBF minimum threshold of 0.1. The large increase in the maximum and average MBF 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 10-11 Maximum, minimum, and average PJM calculated MBF by month: January 2020 through September 2022



The MMU recommends that the regulation market be modified to incorporate a consistent and correct application of the MBF throughout the optimization, assignment and settlement process.⁹⁰

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 10-42 shows, by month, cleared RegD MW with an effective price of \$0.00 (units with zero offers plus self scheduled units) for January 2021

⁹⁰ See "Regulation Market Review," Operating Committee (May 5, 2015) <<http://www.pjm.com/~media/committees-groups/committees/oc/20150505/20150505-item-17-regulation-market-review.ashx>>.

through September 2022. In the first nine months of 2022, an average of 96.0 percent of all RegD MW clearing the market had an effective offer of \$0.00. In the first nine months of 2021, an average of 99.0 percent of all cleared RegD MW had an effective cost of \$0.00. In the first nine months of 2022, an average of 58.5 percent of all RegD offers were self scheduled, compared to an average of 72.9 percent of all RegD offers in the first nine months of 2021.

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 decreased 35.8 MW (19.0 percent), from 188.6 MW in the first nine months of 2021 to 152.8 MW in the first nine months of 2022. The average monthly RegD cleared with an effective cost of zero decreased 40.2 MW (21.5 percent), from 186.8 MW in the first nine months of 2021 to 146.7 MW in the first nine months of 2022. Self scheduled RegD cleared MW decreased 48.5 MW (35.2 percent), from 137.9 MW in the first nine months of 2021 to 89.4 MW in the first nine months of 2022. Average cleared RegD MW with a zero cost offer increased 8.3 MW (17.1 percent), from 48.9 MW in the first nine months of 2021 to 57.3 MW in the first nine months of 2022. 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 10-11.

Table 10-42 Average cleared RegD MW and average cleared RegD with an effective price of \$0.00 by month: January 2021 through September 2022

		Average Performance Adjusted Cleared RegD MW						
Year	Month	\$0.00 Offer		Self Scheduled		Total Effective Cost of Zero	Effective Cost of Zero Percentage of Total	Total
		\$0.00 Offer	Percent of Total	Self Scheduled	Percentage of Total			
2021	Jan	49.6	26.1%	139.9	73.7%	189.6	99.9%	189.8
	Feb	52.4	25.6%	152.3	74.4%	204.7	100.0%	204.7
	Mar	47.2	23.3%	155.4	76.7%	202.6	100.0%	202.6
	Apr	48.6	24.0%	154.0	76.0%	202.7	100.0%	202.7
	May	47.5	24.8%	143.8	75.0%	191.3	99.9%	191.6
	Jun	45.8	25.2%	133.3	73.4%	179.2	98.6%	181.7
	Jul	48.4	26.4%	130.7	71.4%	179.1	97.8%	183.1
	Aug	49.9	28.4%	120.8	68.6%	170.8	97.0%	176.0
	Sep	50.8	30.6%	111.1	67.1%	161.8	97.7%	165.6
	Oct	50.6	30.2%	114.6	68.3%	165.3	98.5%	167.7
	Nov	50.2	30.6%	109.0	66.5%	159.2	97.1%	164.0
	Dec	49.4	28.6%	118.0	68.2%	167.5	96.8%	173.0
Yearly		49.2	26.8%	131.8	71.9%	181.0	98.7%	183.4
2022	Jan	51.8	33.8%	95.5	62.2%	147.4	96.0%	153.5
	Feb	59.6	40.6%	84.1	57.2%	143.8	97.8%	147.0
	Mar	59.7	38.2%	93.3	59.7%	153.0	98.0%	156.2
	Apr	52.9	36.8%	84.3	58.5%	137.2	95.3%	144.0
	May	52.5	37.0%	85.7	60.4%	138.1	97.4%	141.8
	Jun	51.6	34.1%	89.2	59.0%	140.8	93.1%	151.2
	Jul	59.9	38.4%	84.9	54.4%	144.8	92.8%	156.1
	Aug	62.1	38.6%	92.2	57.3%	154.4	95.9%	160.9
	Sep	65.2	39.6%	95.2	57.9%	160.5	97.5%	164.6
Yearly		57.3	37.5%	89.4	58.5%	146.7	96.0%	152.9

Incorrect MBF and total effective MW when clearing units with dual product 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.

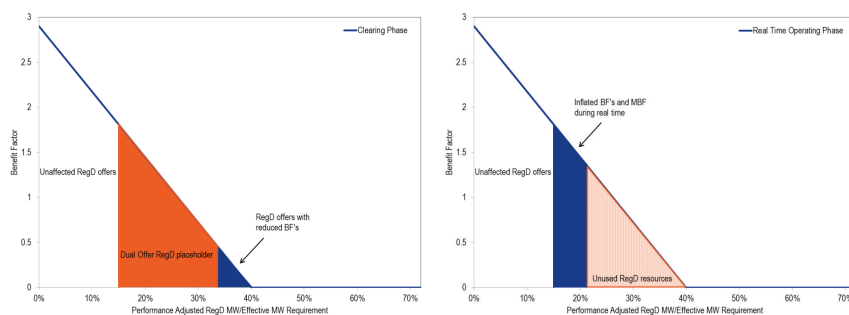
During the clearing phase, the MBF of RegD resources is a function of the RegD MW that clear. The MBF for all RegD resources declines as more RegD resources are cleared. Based on this relationship, in the case where a dual offer unit is assigned to be a RegA resource rather than a RegD resource, the 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.

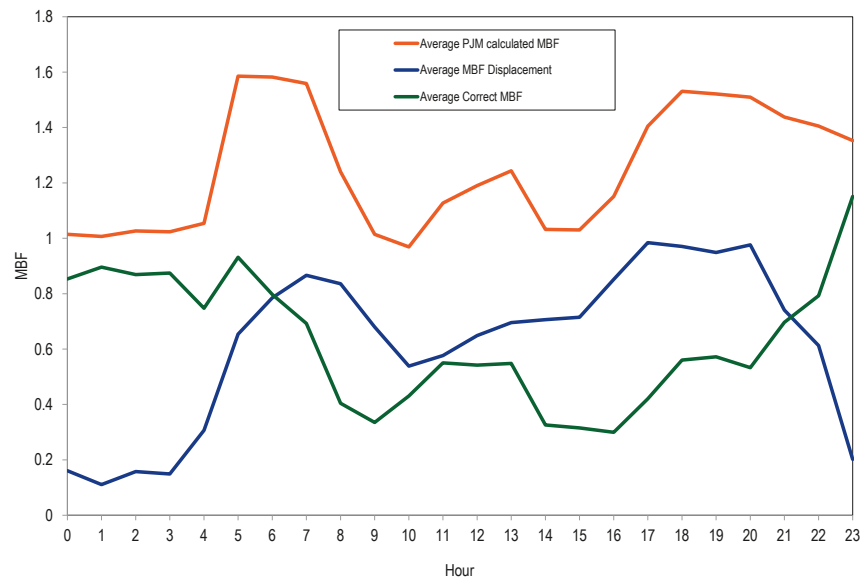
The issue is illustrated in Figure 10-12. The example shows a clearing phase and a real time operating phase. In this example, a 150 MW unit offers both RegA and RegD. The 150 MW unit's position in the RegD effective cost curve and the potential effective MW are represented as the orange area under the 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 10-12 Clearing phase BF/effective MW reduction, real-time BF/effective MW inflation, and exclusion of available RegD resources



In the first nine months of 2022, all hours had at least one unit with a dual offer. In the first nine months of 2022, 38.8 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 0.78 in the operating phase. The average MBF increase due to dual offers clearing as RegA in the first nine months of 2021 was 0.48. This indicates that the amount of MW clearing as RegA from dual offers has increased, the amount of RegD clearing has been artificially reduced, resulting in higher MBF of RegD in the market solution in the first nine months of 2021. In the first nine months of 2022, 6,181 dual offers from generating units were cleared as RegA, an increase of 24.9 percent from the first nine months of 2021 (4,950 dual offers clearing as RegA). 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 10-13 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 nine months of 2022 if the clearing solution were solved correctly.

Figure 10-13 Effect of PJM's current dual offer clearing method on the average MBF in each hour of the day: January through September, 2022



Absent the ability to correctly clear dual offers, the MMU recommends that the ability of resources to submit dual offers be removed. Under this revision to the rules, resources could offer as either RegA or RegD in a given hour, but not both within the same market hour.

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.

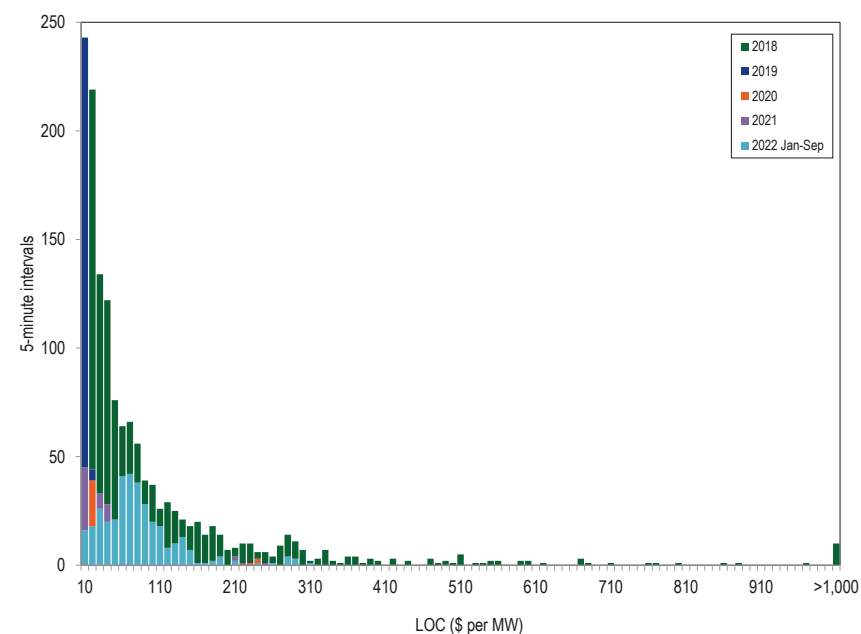
The regulation market is cleared on an hour ahead basis, using offers that are adjusted by dividing each component of an offer (capability, performance, and lost opportunity cost) by the product of the unit specific benefit factor and unit specific performance score. To calculate the hour ahead estimate

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, FERC approved PJM's proposal to create a 0.1 floor for the MBF to reduce the occurrence of these price spikes.⁹¹ This change reduced the amount and frequency of the price spikes, but it was not designed to eliminate them and it did not eliminate them.

Figure 10-14 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 2018 through September 2022.

Figure 10-14 LOC distribution in each five minute interval with a RegD marginal unit and an LOC greater than zero: 2018 through September 2022



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.

⁹¹ See 166 FERC ¶ 61,040 (2019).

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.

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.⁹² If the sum of the resources offer plus LOC is greater than the amount of clearing price credits received, additional uplift credits are given equal to the difference.

The calculation of regulation uplift during settlements for coal and natural gas units is incorrect, and results in the overpayment of uplift.⁹³ 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 amount of MW output at LMP used in the calculation of regulation uplift during settlements 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 does not take into account the physical limitations of the unit's ability to ramp. 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.

Table 10-43 shows the amount of uplift overpayment by fuel type for the first nine months of 2022, 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 based on the units' ramp rates. In the first nine months of 2022, overpayments totaled \$23.7 million. Coal units received 45.2 percent of the overpayment while providing 5.5 percent of settled regulation MW.

The MMU recommends 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.

⁹² 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.

⁹³ 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 affect that calculation. Also, demand response and battery units do not receive uplift.

Table 10-43 Amount of LOC overpayment: January 2021 through September 2022

Year	Month	Uplift overpayment		
		Coal	Natural Gas	Total
2021	Jan	\$189,413	\$151,479	\$340,892
	Feb	\$362,280	\$458,780	\$821,059
	Mar	\$213,908	\$313,696	\$527,604
	Apr	\$409,813	\$527,769	\$937,582
	May	\$384,659	\$175,792	\$560,451
	Jun	\$387,173	\$231,534	\$618,707
	Jul	\$152,339	\$180,229	\$332,568
	Aug	\$135,911	\$360,753	\$496,664
	Sep	\$217,114	\$516,718	\$733,833
	Oct	\$137,579	\$741,654	\$879,233
	Nov	\$926,402	\$2,365,660	\$3,292,061
	Dec	\$327,458	\$945,934	\$1,273,392
Total		\$3,844,048	\$6,969,998	\$10,814,046
2022	Jan	\$1,959,942	\$2,308,232	\$4,268,174
	Feb	\$432,077	\$1,103,635	\$1,535,711
	Mar	\$297,947	\$990,141	\$1,288,088
	Apr	\$1,447,659	\$1,627,371	\$3,075,030
	May	\$625,195	\$1,318,174	\$1,943,369
	Jun	\$752,995	\$1,529,581	\$2,282,575
	Jul	\$2,816,672	\$1,359,550	\$4,176,222
	Aug	\$1,945,760	\$1,772,383	\$3,718,143
	Sep	\$409,138	\$973,280	\$1,382,418
Total		\$10,687,385	\$12,982,346	\$23,669,731

Market Structure

Supply

Table 10-44 shows average hourly offered MW (actual and effective), and average hourly cleared MW (actual and effective) for all hours in the first nine months of 2022.⁹⁴ Actual MW are adjusted by the historic 100-hour moving average performance score to get performance adjusted MW, and by the resource specific benefit factor to get effective MW. A resource can choose to follow either signal. For that reason, the sum of each signal type's capability can exceed the full regulation capability. Offered MW are calculated based on the offers from units that are designated as available for the day. These are daily offers that can be modified on an hourly basis up to 65 minutes before

⁹⁴ Unless otherwise noted, analysis provided in this section uses PJM market data based on PJM's internal calculations of effective MW values, based on PJM's currently incorrect MBF curve. The MMU is working with PJM to correct the MBF curve.

the hour.⁹⁵ Eligible MW are calculated from the hourly offers from units with daily offers and units that are offered as unavailable for the day, but still offer MW into some hours. Units with daily offers are permitted to offer above or below their daily offer from hour to hour. As a result of these hourly MW adjustments, the average hourly Eligible MW can be higher than the Offered MW.

In the first nine months of 2022, the average hourly offered supply of regulation for nonramp hours was 757.5 actual MW (765.8 effective MW). This was an increase of 4.1 actual MW (an increase of 13.1 effective MW) from the first nine months of 2021, when the average hourly offered supply of regulation was 753.4 actual MW (752.8 effective MW). In the first nine months of 2022, the average hourly offered supply of regulation for ramp hours was 1,124.4 actual MW (1,127.6 effective MW). This was an increase of 47.9 actual MW (an increase of 25.9 effective MW) from the first nine months of 2021, when the average hourly offered supply of regulation was 1,076.5 actual MW (1,101.7 effective MW).⁹⁶

The ratio of the average hourly offered supply of regulation to average hourly regulation demand (actual cleared MW) for nonramp hours was 1.63 in the first nine months of 2022 (1.55 in the first nine months of 2021). The ratio of the average hourly offered supply of regulation to average hourly regulation demand (actual cleared MW) for ramp hours was 1.56 in the first nine months of 2022 (1.52 in the first nine months of 2021).

⁹⁵ See "PJM Manual 11: Energy & Ancillary Services Market Operations," § 3.2.2 Regulation Market Eligibility, Rev. 122 (Oct. 1, 2022).

⁹⁶ Effective MW equal actual MW multiplied by the performance score and benefit factor for each unit. In the case of RegA, the benefit factor is always equal to one, and performance scores are always less than one, so effective MW of RegA are less than actual MW. For RegD resources effective MW can be larger than actual MW, if the benefit factor is greater than one. When adding RegA and RegD total MW together, actual MW can be larger or smaller than effective MW, depending on the influence of RegA MW and RegD MW.

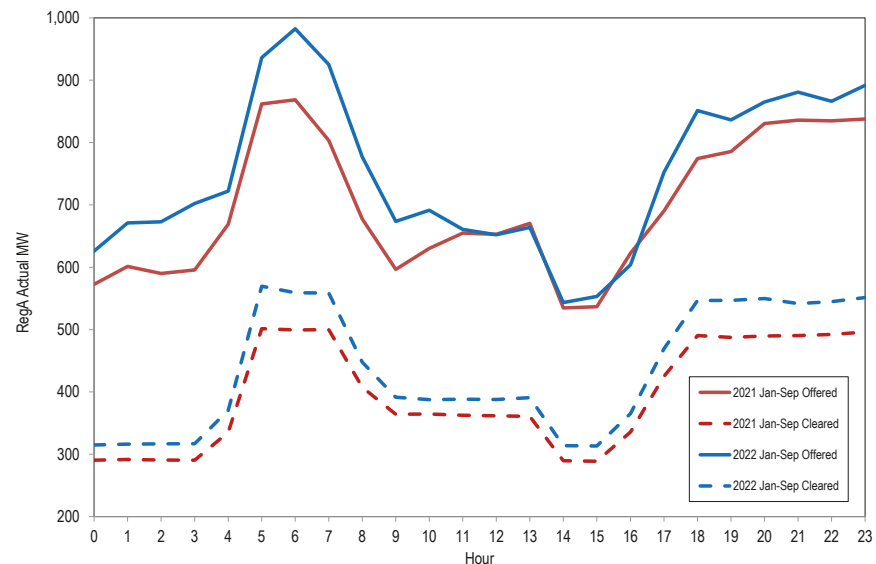
Table 10-44 Hourly average actual and effective MW offered and cleared: January through September, 2022⁹⁷

		By Resource Type			By Signal Type	
		All Regulation	Generating Resources	Demand Resources	RegA Following Resources	RegD Following Resources
Actual Offered MW	Ramp	1,124.4	1,104.8	19.6	897.5	226.9
	Nonramp	757.5	743.5	14.1	594.2	163.3
Effective Offered MW	Ramp	1,127.6	1,098.7	29.0	766.8	360.9
	Nonramp	765.8	748.8	17.1	505.5	260.4
Actual Cleared MW	Ramp	718.9	699.3	19.6	551.5	167.4
	Nonramp	464.8	450.9	13.9	313.6	151.2
Effective Cleared MW	Ramp	800.0	771.1	28.9	474.8	325.2
	Nonramp	525.2	508.4	16.8	269.4	255.8

The average hourly offered and cleared actual MW from RegA resources are shown in Figure 10-15. The average hourly offered MW from RegA resources during ramp hours for the first nine months of 2022 was 897.5 actual MW, an increase of 8.1 percent from the first nine months of 2021 (830.3 actual MW.) The average hourly offered MW from RegA resources during nonramp hours for the first nine months of 2022 was 594.2 actual MW, an increase of 6.9 percent from the first nine months of 2021 (555.6 actual MW). The average hourly cleared MW from RegA resources during ramp hours for the first nine months of 2022 was 551.5 actual MW, an increase of 11.1 percent from the first nine months of 2021 (496.4 actual MW). The average hourly cleared MW from RegA resources during nonramp hours for the first nine months of 2022 was 313.6 actual MW, an increase of 8.2 percent from the first nine months of 2021 (289.7 actual MW).

⁹⁷ PJM operations treats some nonramp hours as ramp hours, with a regulation requirement of 800 MW rather than 525 MW. All ramp/nonramp analysis performed is based on the requirement used in each hour rather than the definitions given in Table 10-2. A ramp hour occurring during what is normally a nonramp period is treated as a ramp hour.

Figure 10-15 Average hourly RegA actual MW offered and cleared: January through September, 2021 through 2022⁹⁸



The average hourly offered MW from RegD resources during ramp hours for the first nine months of 2022 was 226.9 actual MW, a decrease of 7.9 percent from the first nine months of 2021 (246.2 actual MW). (Figure 10-16) The average hourly offered MW from RegD resources during nonramp hours for the first nine months of 2022 was 163.3 actual MW, a decrease of 17.4 percent from the first nine months of 2021 (197.8 actual MW) (Figure 10-16). The average hourly cleared MW from RegD resources during ramp hours for the first nine months of 2022 was 167.4 actual MW, a decrease of 20.3 percent from the first nine months of 2021 (209.9 actual MW). The average hourly cleared MW from RegD resources during nonramp hours for the first nine months of 2022 was 151.2 actual MW, a decrease of 23.0 percent from the first nine months of 2021 (196.3 actual MW).

⁹⁸ Offered MW includes MW from units that are dual offering as both RegA and RegD.

Figure 10-16 Average hourly RegD actual MW offered and cleared: January through September, 2021 through 2022⁹⁹

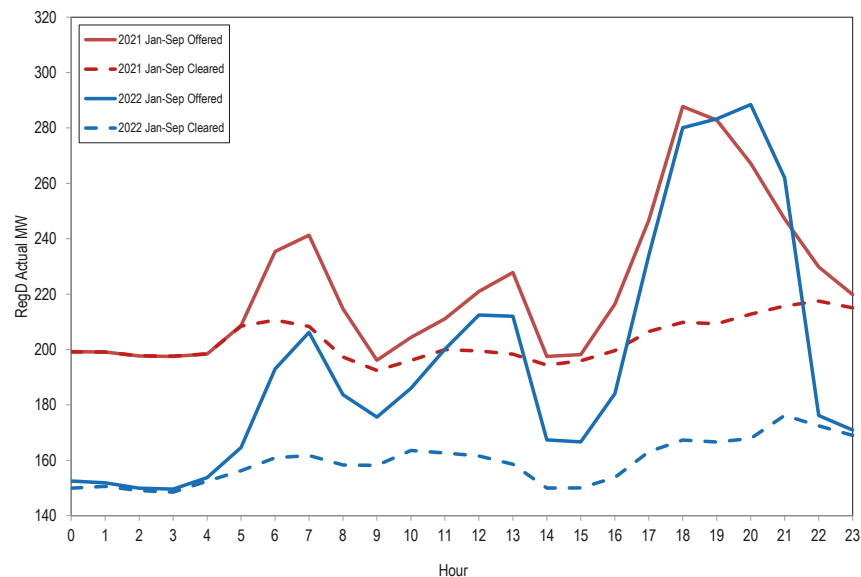


Table 10-46 provides the settled regulation MW by source unit type, the total settled regulation MW provided by all resources, the percent of settled regulation provided by unit type, and the clearing price, uplift, and total regulation credits. In Table 10-46 the MW have been adjusted by the performance score since this adjustment forms the basis of payment for units providing regulation. Total regulation performance adjusted settled MW decreased 2.0 percent from 3,476,601.8 MW in the first nine months of 2021 to 3,407,381.2 MW in the first nine months of 2022. The average proportion of regulation provided by natural gas units increased the most, by 10.0 percent from the first nine months of 2021 to the first nine months 2022. Battery units had the largest decrease in average proportion of regulation provided, decreasing 9.5 percent, from the first nine months of 2021 to the first nine months of 2022. The total regulation credits in the first nine months of 2022 were \$211,778,160, an increase of 141.1 percent from \$87,852,568 in the first

⁹⁹ Offered MW includes MW from units that are dual offering as both RegA and RegD.

nine months of 2021. The increase in regulation credits is due, in part, to a higher LOC component of regulation prices as a result of higher energy prices in the first nine months of 2022 compared to the first nine months of 2021.

When a resource offers into the regulation market, an estimated regulation LOC is added by PJM to form a total offer (units self scheduled or not providing in the energy market have a regulation LOC of zero). After a unit clears, the actual five minute interval LMP is used to calculate each unit’s regulation LOC, update their total offers, and determine a marginal unit/clearing price in each five minute interval. This within hour calculation of total offers, including LOC, uses each cleared resource’s rolling 100 hour average performance score. During settlements, each unit’s regulation LOC and total offers are recalculated using each unit’s within hour actual performance score. This recalculated LOC and offer using the actual within hour performance score is not used to recalculate the within hour clearing price. This means that the clearing price for the hour will not equal the correct clearing price. Where the resulting market price is lower than an individual resource offer adjusted for the within hour performance score, the resource is paid uplift to make up the difference.

The top ten units that received the most uplift in the first nine months of 2022 are shown in Table 10-45.

Table 10-45 Top 10 recipients of regulation uplift credits: January through September, 2022

Rank	Parent Company	Unit Name	Fuel Type	Total Regulation Uplift Credit	Share of Total
					Regulation Uplift Credits
1	American Electric Power Company Inc	AEP MITCHELL - KAMMER 1 F	COAL	\$1,689,152	5.9%
2	Constellation Energy Generation LLC	PE MUDDY RUN 1-8 H	HYDRO	\$1,473,599	5.2%
3	American Electric Power Company Inc	AEP MOUNTAINEER 1 F	COAL	\$1,316,448	4.6%
4	American Electric Power Company Inc	AEP AMOS 1 F	COAL	\$1,217,607	4.3%
5	American Electric Power Company Inc	AEP BIG SANDY 1 F	NATURAL GAS	\$1,083,635	3.8%
6	American Electric Power Company Inc	AEP MITCHELL - KAMMER 2 F	COAL	\$1,015,022	3.6%
7	American Electric Power Company Inc	AEP AMOS 2 F	COAL	\$896,048	3.1%
8	Dominion Energy Inc	VP BATH COUNTY 1-6 H	HYDRO	\$883,179	3.1%
9	Ontario Power Generation Inc	AP LKLYN 1-4 H	HYDRO	\$857,019	3.0%
10	American Municipal Power Inc	FE FREMONT ENERGY CENTER 3 CC	NATURAL GAS	\$814,979	2.9%
Total of Top 10				\$11,246,689	39.4%
Total Regulation Uplift Credits				\$28,559,008	100.0%

The uplift credits received for each unit type are shown in Table 10-46. The total uplift credits received increased 217.0 percent from \$9,010,280 in the first nine months of 2021 to \$28,559,008 in the first nine months of 2022. This increase, like the increase in total credits, is due in part to higher LOC components of regulation prices and offers as a result of higher energy prices in the first nine months of 2022 compared to the first nine months of 2021. Coal units had the largest increase in uplift payments, increasing from \$2,464,124 (29.2 percent of total uplift) in the first nine months of 2021, to \$11,294,407 (39.5 percent of total uplift) in the first nine months of 2022.

Table 10-46 PJM regulation by source: January through September, 2021 and 2022¹⁰⁰

Year (Jan-Sep)	Source	Number of Units	Performance		Percent		Clearing Price Credits	Uplift Credits	Total Regulation Credits
			Adjusted Regulation (MW)	Settled Regulation	of Settled Regulation	of Settled Regulation			
2021	Battery	23	1,186,261		34.1%		\$28,722,356	\$0	\$28,722,356
	Coal	19	298,507		8.6%		\$5,807,902	\$2,464,124	\$8,272,026
	Hydro	28	639,791		18.4%		\$15,219,294	\$2,628,568	\$17,847,862
	Natural Gas	184	1,303,471		37.5%		\$27,778,939	\$3,917,589	\$31,696,528
	DR	19	48,572		1.4%		\$1,313,796	\$0	\$1,313,796
Total		273	3,476,601.8		100.0%		\$78,842,288	\$9,010,280	\$87,852,568
2022	Battery	21	837,450		24.6%		\$47,874,499	\$0	\$47,874,499
	Coal	17	188,124		5.5%		\$12,243,762	\$11,294,407	\$23,538,169
	Hydro	24	668,383		19.6%		\$39,502,288	\$4,361,532	\$43,863,821
	Natural Gas	141	1,617,032		47.5%		\$77,884,270	\$12,903,068	\$90,787,339
	DR	21	96,392		2.8%		\$5,714,333	\$0	\$5,714,333
Total		224	3,407,381.2		100.0%		\$183,219,152	\$28,559,008	\$211,778,160

¹⁰⁰ Biomass data have been added to the natural gas category for confidentiality purposes.

Significant flaws in the regulation market design have led to an over procurement of RegD MW primarily in the form of storage capacity. The incorrect market signals have contributed to more storage projects entering PJM's interconnection queue, despite clear evidence that the market design is flawed and despite operational evidence that the RegD market is saturated (Table 10-47).

Table 10-47 Active battery storage projects by submitted year: 2014 through September 2022

Year	Number of Storage Projects	Total Capacity (MW)
2014	1	10.0
2015	5	61.0
2016	0	0.0
2017	1	2.0
2018	16	600.1
2019	55	3,609.4
2020	153	9,458.9
2021	312	24,282.1
2022	106	11,472.5
Total	649	49,496.0

The supply of regulation can be affected by regulating units retiring from service. If all units that are requesting retirement through the first nine months of 2022 retire, the supply of regulation in PJM will be reduced by less than one percent.

Demand

The demand for regulation does not change with price. The regulation requirement is set by PJM to meet NERC control standards, based on reliability objectives, which means that a significant amount of judgment is exercised by PJM in determining the actual demand. Prior to October 1, 2012, the regulation requirement was 1.0 percent of the forecast peak load for on peak hours and 1.0 percent of the forecast valley load for off peak hours. Between October 1, 2012, and December 31, 2012, PJM changed the regulation requirement several times. It had been scheduled to be reduced from 1.0 percent of peak load forecast to 0.9 percent on October 1, 2012, but instead it was changed from 1.0 percent of peak load forecast to 0.78 percent of peak load forecast.

It was further reduced to 0.74 percent of peak load forecast on November 22, 2012 and reduced again to 0.70 percent of peak load forecast on December 18, 2012. On December 14, 2013, it was reduced to 700 effective MW during peak hours and 525 effective MW during off peak hours. The regulation requirement remained 700 effective MW during peak hours and 525 effective MW during off peak hours until January 9, 2017. A change to the regulation requirement was approved by the RMISTF in 2016, with an implementation date of January 9, 2017. The regulation requirement was increased from 700 effective MW to 800 effective MW during ramp hours (Table 10-36).

Table 10-48 shows the average hourly required regulation by month and the ratio of supply to demand for both actual and effective MW, for ramp and nonramp hours. The average hourly required regulation by month is an average of the ramp and nonramp hours in the month. Changes in the actual MW required to satisfy the regulation requirement are the result of the amount of RegD actual MW cleared. When more RegD MW are cleared, the MBF is lower, resulting in those actual MW being worth less effective MW, requiring more actual MW to satisfy the requirement. When MBFs are higher, the actual MW of RegD are worth more effective MW, reducing the amount of actual MW needed to satisfy the requirement.

The nonramp regulation requirement of 525.0 effective MW was provided by a combination of cleared RegA and RegD resources equal to 464.4 hourly average performance adjusted actual MW in the first nine months of 2022. This is a decrease of 21.0 performance adjusted actual MW from the first nine months of 2021, when the average hourly total regulation cleared performance adjusted actual MW for nonramp hours were 485.4 performance adjusted actual MW. The ramp regulation requirement of 800.0 effective MW was provided by a combination of cleared RegA and RegD resources equal to 719.2 hourly average performance adjusted actual MW in the first nine months of 2022. This is an increase of 12.4 performance adjusted actual MW from the first nine months of 2021, where the average hourly regulation cleared MW for ramp hours were 706.8 performance adjusted actual MW.¹⁰¹

¹⁰¹ The supply of performance adjusted MW is less than the demand because the regulation requirement is based on effective MW. Effective MW are performance adjusted MW multiplied by the MBF, and the average MBF in the first nine months of 2022 was 1.25.

Table 10-48 Required regulation and ratio of supply to requirement: January 2021 through September 2022

Hours	Month	Average Required Regulation (MW)		Average Required Regulation (Effective MW)		Ratio of Supply MW to MW Requirement		Ratio of Supply Effective MW to Effective MW Requirement	
		2021	2022	2021	2022	2021	2022	2021	2022
Ramp	Jan	713.2	720.6	800.0	800.0	1.59	1.51	1.42	1.37
	Feb	709.7	729.4	800.0	800.0	1.53	1.71	1.37	1.52
	Mar	713.8	723.0	800.0	800.0	1.54	1.54	1.38	1.39
	Apr	702.8	729.3	800.0	800.0	1.48	1.47	1.33	1.34
	May	705.5	720.2	800.0	800.0	1.45	1.54	1.32	1.38
	Jun	698.8	714.4	799.9	800.0	1.50	1.60	1.36	1.44
	Jul	699.0	720.3	799.9	800.0	1.54	1.55	1.38	1.40
	Aug	707.4	710.9	800.0	800.0	1.58	1.60	1.43	1.43
	Sep	710.7	704.3	800.0	800.0	1.47	1.53	1.35	1.38
	Oct	712.9	-	799.9	-	1.44	-	1.32	-
	Nov	708.4	-	800.0	-	1.41	-	1.30	-
	Dec	705.7	-	799.9	-	1.51	-	1.38	-
Nonramp	Jan	495.1	467.4	525.2	525.0	1.52	1.62	1.42	1.45
	Feb	500.4	466.9	525.1	525.0	1.59	1.78	1.47	1.56
	Mar	495.9	468.8	525.2	525.1	1.59	1.63	1.47	1.46
	Apr	490.9	469.1	525.1	525.1	1.51	1.56	1.41	1.41
	May	487.1	461.5	525.5	525.3	1.54	1.60	1.43	1.43
	Jun	478.6	459.6	525.4	525.8	1.50	1.66	1.39	1.48
	Jul	475.5	459.9	525.1	525.1	1.51	1.64	1.40	1.47
	Aug	474.4	461.3	525.2	525.3	1.60	1.65	1.47	1.48
	Sep	470.9	465.0	525.1	525.2	1.58	1.59	1.44	1.43
	Oct	471.8	-	525.1	-	1.51	-	1.39	-
	Nov	468.8	-	525.0	-	1.45	-	1.34	-
	Dec	469.5	-	525.0	-	1.57	-	1.42	-

Market Concentration

In the first nine months of 2022, the effective MW weighted average HHI of RegA resources was 2458 which is highly concentrated and the effective MW weighted average HHI of RegD resources was 1670 which is moderately concentrated. The effective MW weighted average HHI of all resources was 1433, which is moderately concentrated. The weighted average HHI reflects the fact that different owners have large market shares in the RegA and RegD markets.

Table 10-49 includes a monthly summary of three pivotal supplier (TPS) results. In the first nine months of 2022, the three pivotal supplier test was failed in 88.8 percent of hours. The MMU concludes that the PJM Regulation Market in the first nine months of 2022 was characterized by structural market power. The results presented here are calculated by PJM. The MMU has been unable to verify these results, as some of the underlying data necessary to replicate these calculations are not saved. PJM has submitted a request to the vendor to save all data necessary for verification.

Table 10-49 Regulation market monthly three pivotal supplier results: January 2020 through September 2022

Month	Percent of Hours Pivotal		
	2020	2021	2022
Jan	99.1%	91.4%	94.5%
Feb	97.4%	88.7%	84.1%
Mar	98.3%	87.2%	90.1%
Apr	96.5%	88.5%	92.8%
May	94.9%	83.9%	91.4%
Jun	89.8%	86.4%	85.7%
Jul	89.0%	86.4%	88.2%
Aug	94.6%	76.3%	86.4%
Sep	93.3%	82.9%	86.1%
Oct	94.0%	91.9%	-
Nov	91.0%	86.7%	-
Dec	83.6%	80.1%	-
Average	93.5%	85.9%	88.8%

Market Conduct

Offers

Resources seeking to regulate must qualify to follow a regulation signal by passing a test for that signal with at least a 75 percent performance score. The regulating resource must be able to supply at least 0.1 MW of regulation and not allow the sum of its regulating ramp rate and energy ramp rate to exceed its overall ramp rate.¹⁰² When offering into the regulation market, regulating resources must submit a cost-based offer and may submit a price-based offer (capped at \$100 per MW) by 14:15 the day before the operating day.¹⁰³

¹⁰² See "PJM Manual 11: Energy & Ancillary Services Market Operations," § 3.2.1 Regulation Market Eligibility, Rev. 122 (Oct. 1, 2022).

¹⁰³ Id. at 3.2.2, at p 62.

Offers in the PJM Regulation Market consist of a capability component for the MW of regulation capability provided and a performance component for the miles (Δ MW of regulation movement) provided. The capability component for cost-based offers is not to exceed the increased fuel costs resulting from operating the regulating unit at a lower output level than its economically optimal output level, plus a \$12.00 per MW margin. The \$12.00 margin embeds market power in the regulation offers, is not part of the cost of regulation, and should be eliminated. The performance component for cost-based offers is not to exceed the increased costs (increased short run marginal costs including increased fuel costs) resulting from moving the unit up and down to provide regulation. Batteries and flywheels have zero cost for lower efficiency from providing regulation instead of energy, as they are not net energy producers. There is an energy storage loss component for batteries and flywheels as a cost component of regulation performance offers to reflect the net energy consumed to provide regulation service.¹⁰⁴

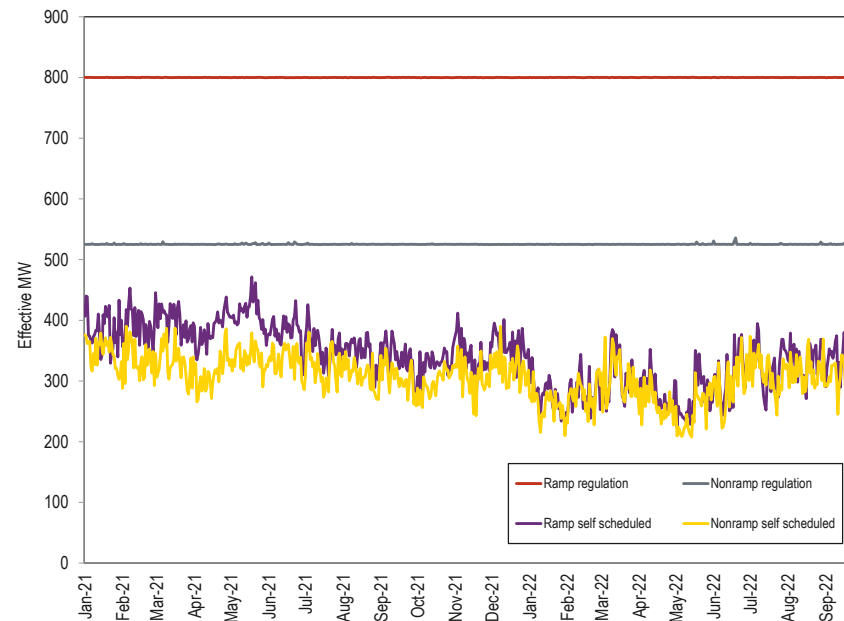
Up until one hour before the operating hour, the regulating resource must provide: status (available, unavailable, or self-scheduled); capability (movement up and down in MW); regulation maximum and regulation minimum (the highest and lowest levels of energy output while regulating in MW); and the regulation signal type (RegA or RegD). Resources may offer regulation for both the RegA and RegD signals, but will be assigned to follow only one signal for a given operating hour. Resources have the option to submit a minimum level of regulation they are willing to provide.¹⁰⁵

All LSEs are required to provide regulation in proportion to their load share. LSEs can purchase regulation in the regulation market, purchase regulation from other providers bilaterally, or self-schedule regulation to satisfy their obligation (Table 10-52).¹⁰⁶ Figure 10-17 compares average hourly regulation and self-scheduled regulation during ramp and nonramp hours on an effective MW basis. Self-scheduled regulation averaged 37.8 percent of all effective MW during ramp hours (47.1 percent in the first nine months of 2021) and 54.5 percent of all effective MW during nonramp hours (62.1 percent in the first nine months of 2021) in the first nine months of 2022. Over all hours

¹⁰⁴ See "PJM Manual 15: Cost Development Guidelines," § 7.8 Regulation Cost, Rev. 41 (Oct. 1, 2022).
¹⁰⁵ See "PJM Manual 11: Energy & Ancillary Services Market Operations," § 3.2.1 Regulation Market Eligibility, Rev. 122 (Oct. 1, 2022).
¹⁰⁶ See "PJM Manual 28: Operating Agreement Accounting," § 4.1 Regulation Accounting Overview, Rev. 88 (Oct. 1, 2022).

in the first nine months of 2022, self-scheduled regulation averaged 44.4 percent of all effective MW (53.0 percent in the first nine months of 2021) (See Table 10-50). The average hourly regulation is the amount of regulation that actually cleared and is not the same as the regulation requirement because PJM clears the market within a two percent band around the requirement.¹⁰⁷

Figure 10-17 Nonramp and ramp regulation levels: January 2021 through September 2022



¹⁰⁷ See "PJM Manual 11: Energy & Ancillary Services Market Operations," § 3.2.1 Regulation Market Eligibility, Rev. 122 (Oct. 1, 2022).

Table 10-50 Total Effective MW and Self Scheduled Effective MW during ramp and non ramp hours: January through September, 2021 and 2022.

Year (Jan-Sep)		Self Scheduled		
		Effective MW	Effective MW	Percent Effective MW
2021	Ramp	218,394.7	102,880.5	47.1%
	Non Ramp	143,385.2	89,030.7	62.1%
Total		361,779.9	191,911.2	53.0%
2022	Ramp	218,400.6	82,451.2	37.8%
	Non Ramp	143,382.8	78,209.5	54.5%
Total		361,783.4	160,660.7	44.4%

Table 10-51 shows the role of RegD resources in the regulation market. RegD resources are both a growing proportion of the market (10.9 percent of the total effective MW at the start of the performance based regulation market design in October 2012 and 46.9 percent of the total effective MW in September 2022) and a growing proportion of resources that self schedule (25.0 percent of all self scheduled effective MW in October 2012 and 62.5 percent of all self scheduled effective MW in September 2022). In the first nine months of 2022, the average RegD percentage of total self scheduled effective MW was 67.9 percent, a decrease of 4.3 percentage points from the first nine months of 2021, when the average was 72.2 percent.

Table 10-51 RegD self scheduled regulation by month: January 2021 through September 2022

Year	Month	RegD Self Scheduled		Total Self Scheduled		RegD Percent of Total Self Scheduled	
		Effective MW	RegD Effective MW	Effective MW	Total Effective MW	Effective MW	Effective MW
2021	Jan	250.5	322.4	367.7	674.0	68.1%	47.8%
2021	Feb	262.0	335.3	366.7	674.3	71.4%	49.7%
2021	Mar	263.0	321.7	359.0	639.9	73.3%	50.3%
2021	Apr	266.0	325.9	343.1	639.6	77.5%	51.0%
2021	May	256.8	320.6	368.0	639.9	69.8%	50.1%
2021	Jun	266.5	329.9	362.7	697.0	73.5%	47.3%
2021	Jul	255.4	331.6	344.6	696.9	74.1%	47.6%
2021	Aug	242.6	326.1	330.2	698.9	73.5%	46.7%
2021	Sep	219.8	302.0	319.6	639.6	68.8%	47.2%
2021	Oct	223.6	301.0	311.1	639.8	71.9%	47.1%
2021	Nov	218.5	298.9	321.2	640.3	68.0%	46.7%
2021	Dec	239.3	316.3	341.4	673.9	70.1%	46.9%
2021 Average		247.0	332.0	344.6	662.8	71.7%	48.2%
2022	Jan	211.8	295.7	267.8	674.0	79.1%	43.9%
2022	Feb	193.7	285.2	278.7	674.0	69.5%	42.3%
2022	Mar	202.1	285.3	305.6	639.8	66.1%	44.6%
2022	Apr	191.5	274.9	270.0	639.6	70.9%	43.0%
2022	May	191.2	276.4	258.3	639.8	74.0%	43.2%
2022	Jun	201.5	296.7	302.4	697.2	66.6%	42.6%
2022	Jul	192.7	299.8	321.1	696.9	60.0%	43.0%
2022	Aug	205.6	308.3	328.0	697.0	62.7%	44.2%
2022	Sep	196.4	300.0	314.3	639.3	62.5%	46.9%
2022 Average		198.5	291.4	294.0	666.4	67.9%	43.7%

LSE's can satisfy their obligation to provide regulation by purchasing in the spot market, self scheduling, or through bilateral agreements. Increased self scheduled regulation lowers the requirement for cleared regulation, resulting in fewer MW cleared in the market and lower clearing prices. Of the LSEs' obligation to provide regulation in the first nine months of 2022, 56.0 percent was purchased in the PJM market, 36.0 percent was self scheduled, and 8.0 percent was purchased bilaterally (Table 10-52). Table 10-53 shows the total regulation by source including spot market regulation, self scheduled regulation, and bilateral regulation for January through September, 2012 through 2022. Table 10-52 and Table 10-53 are based on settled (purchased) MW.

Table 10-52 Regulation sources: spot market, self scheduled, bilateral purchases: January 2021 through September 2022

Year	Month	Spot Market Regulation (Unadjusted MW)	Spot Market Percent of Total	Self Scheduled Regulation (Unadjusted MW)	Self Scheduled Percent of Total	Bilateral Regulation (Unadjusted MW)	Bilateral Percent of Total	Total Regulation (Unadjusted MW)
2021	Jan	186,762.8	46.6%	192,708.2	48.1%	21,466.0	5.4%	400,937.0
2021	Feb	172,967.1	47.4%	174,470.7	47.9%	17,095.5	4.7%	364,533.3
2021	Mar	182,812.8	47.3%	189,176.1	48.9%	14,910.0	3.9%	386,898.9
2021	Apr	190,444.5	51.0%	170,255.4	45.6%	12,763.0	3.4%	373,462.9
2021	May	171,841.5	44.5%	198,026.9	51.3%	16,270.0	4.2%	386,138.5
2021	Jun	211,800.7	54.2%	163,167.4	41.8%	15,526.0	4.0%	390,494.1
2021	Jul	225,587.1	55.9%	162,774.7	40.4%	15,017.5	3.7%	403,379.4
2021	Aug	234,148.0	57.9%	154,435.7	38.2%	15,577.5	3.9%	404,161.2
2021	Sep	190,656.5	53.7%	150,785.2	42.4%	13,896.0	3.9%	355,337.7
2021	Oct	212,564.6	57.0%	150,788.9	40.4%	9,873.5	2.6%	373,226.9
2021	Nov	191,647.2	53.7%	151,450.1	42.4%	13,883.0	3.9%	356,980.3
2021	Dec	211,012.8	54.1%	164,679.9	42.2%	14,258.5	3.7%	389,951.2
	Total	2,382,245.5	52.0%	2,022,719.3	44.1%	180,536.5	3.9%	4,585,501.3
2022	Jan	257,948.1	67.0%	110,706.4	28.8%	16,315.0	4.2%	384,969.5
2022	Feb	220,778.9	63.1%	113,317.3	32.4%	15,659.5	4.5%	349,755.8
2022	Mar	208,538.9	56.8%	145,113.8	39.5%	13,349.5	3.6%	367,002.2
2022	Apr	215,631.5	60.6%	116,433.1	32.7%	23,836.0	6.7%	355,900.6
2022	May	219,531.8	60.8%	111,742.8	31.0%	29,596.0	8.2%	360,870.6
2022	Jun	217,223.5	56.4%	134,779.2	35.0%	32,944.0	8.6%	384,946.7
2022	Jul	188,416.3	47.5%	158,033.3	39.8%	50,157.0	12.6%	396,606.5
2022	Aug	193,928.6	49.6%	158,307.5	40.5%	38,824.0	9.9%	391,060.2
2022	Sep	148,455.0	42.8%	153,563.6	44.3%	44,869.0	12.9%	346,887.7
	Total	1,870,452.6	56.0%	1,201,997.0	36.0%	265,550.0	8.0%	3,337,999.7

Table 10-53 Regulation sources: January through September, 2012 through 2022

Year (Jan-Sep)	Spot Market Regulation (Unadjusted MW)	Spot Market Percent of Total	Self Scheduled Regulation (Unadjusted MW)	Self Scheduled Percent of Total	Bilateral Regulation (Unadjusted MW)	Bilateral Percent of Total	Total Regulation (Unadjusted MW)
2012	5,110,747.9	79.7%	1,122,671.9	17.5%	180,121.0	2.8%	6,413,540.8
2013	2,528,830.3	60.8%	1,478,608.5	35.5%	152,328.5	3.7%	4,159,767.3
2014	1,836,488.7	51.8%	1,543,266.0	43.5%	166,857.0	4.7%	3,546,611.7
2015	1,897,225.7	54.7%	1,380,004.7	39.8%	193,529.1	5.6%	3,470,759.5
2016	1,672,795.5	47.8%	1,598,231.6	45.7%	226,803.5	6.5%	3,497,830.6
2017	1,849,333.5	54.1%	1,372,996.2	40.2%	196,759.5	5.8%	3,419,089.2
2018	2,124,551.1	61.8%	1,135,540.8	33.0%	178,593.5	5.2%	3,438,685.4
2019	1,755,035.5	52.6%	1,405,707.9	42.2%	174,186.0	5.2%	3,334,929.4
2020	1,608,960.6	46.7%	1,667,128.2	48.3%	172,159.5	5.0%	3,448,248.3
2021	1,766,633.1	51.0%	1,555,694.7	44.9%	142,521.5	4.1%	3,464,849.2
2022	1,870,452.6	56.0%	1,201,997.0	36.0%	265,550.0	8.0%	3,337,999.7

In the first nine months of 2022, DR provided an average of 19.6 MW of regulation per hour during ramp hours (10.3 MW of regulation per hour during ramp hours in the first nine months of 2021), and an average of 13.9 MW of regulation per hour during nonramp hours (6.9 MW of regulation per hour during nonramp hours in the first nine months of 2021). Generating units supplied an average of 699.3 MW of regulation per hour during ramp hours in the first nine months of 2022 (696.0 MW of regulation per hour during ramp hours in the first nine months of 2021), and an average of 450.9 MW per hour during nonramp hours in the first nine months of 2022 (479.1 MW of regulation per hour during nonramp hours in the first nine months of 2021).

Market Performance

Price

Table 10-54 shows the regulation price and regulation cost per MW for January through September, 2009 through 2022. The weighted average RMCP for the first nine months of 2022 was \$51.04 per MW. This is an increase of \$30.13 per MW, or 144.1 percent, from the weighted average RMCP of \$20.91 per MW in the first nine months of 2021. This increase in the regulation clearing price was the result of an increase in energy prices in the first nine months of 2022 and the related increase in the opportunity cost component of RMCP.

Table 10-54 Comparison of average price and cost for regulation: January through September, 2009 through 2022

Year (Jan-Sep)	Weighted Regulation Market Price	Weighted Regulation Market Cost	Regulation Price as Percent of Cost
2009	\$24.94	\$32.28	77.3%
2010	\$19.47	\$34.54	56.4%
2011	\$17.04	\$32.70	52.1%
2012	\$15.16	\$21.07	71.9%
2013	\$33.29	\$38.49	86.5%
2014	\$50.19	\$60.94	82.4%
2015	\$35.56	\$43.00	82.7%
2016	\$16.52	\$18.99	87.0%
2017	\$15.70	\$21.70	72.4%
2018	\$28.21	\$35.06	80.5%
2019	\$14.97	\$19.15	78.1%
2020	\$12.59	\$15.59	80.8%
2021	\$20.91	\$25.37	82.4%
2022	\$51.04	\$63.46	80.4%

The introduction of fast start pricing in the PJM energy market on September 1, 2021, had an effect on the regulation market LOC included in regulation offers and in the resulting clearing price for regulation. Table 10-55 shows the effect of fast start pricing on the regulation market monthly capability component of price and the total regulation market clearing price from September 2021 through September, 2022. In the first nine months of 2022, fast start pricing increased the average regulation market clearing price by 8.4 percent compared to dispatch pricing.

Table 10-55 Comparison of fast start and dispatch pricing: September 2021 through September 2022¹⁰⁸

Weighted Average Price (\$/Perf. Adj. Actual MW)						
Year	Month	Capability Clearing Price		Regulation Market Clearing Price		Percent Fast Start Increase
		Dispatch	Fast Start	Dispatch	Fast Start	
2021	Sep	\$27.22	\$29.08	\$28.55	\$30.41	6.5%
	Oct	\$35.64	\$39.92	\$37.12	\$41.40	11.5%
	Nov	\$50.56	\$54.40	\$52.43	\$56.28	7.3%
	Dec	\$25.62	\$27.37	\$27.05	\$28.79	6.4%
2022	Jan	\$68.25	\$71.14	\$69.68	\$72.56	4.1%
	Feb	\$31.14	\$31.93	\$32.76	\$33.55	2.4%
	Mar	\$23.91	\$25.94	\$25.70	\$27.73	7.9%
	Apr	\$45.07	\$48.85	\$47.49	\$51.27	7.9%
	May	\$38.09	\$41.85	\$39.84	\$43.60	9.4%
	Jun	\$47.26	\$52.57	\$49.17	\$54.48	10.8%
	Jul	\$47.40	\$54.51	\$48.92	\$56.04	14.5%
	Aug	\$57.43	\$64.13	\$59.17	\$65.87	11.3%
	Sep	\$46.17	\$48.84	\$48.07	\$50.73	5.5%
Total		\$45.30	\$49.26	\$47.08	\$51.04	8.4%

Figure 10-18 shows the capability price, performance price, and the opportunity cost component for the PJM Regulation Market on a performance adjusted MW basis. The regulation clearing price is determined based on the marginal unit’s total offer (RCP + RPP + PJM calculated LOC). Then the maximum performance offer price (RPP) of any of the cleared units is used to set the marginal performance clearing price for the purposes of settlements. The difference between the marginal total clearing price and the highest performance clearing price (RMPCP) is the marginal capability clearing price (RMCCP). The capability price presented here is equal to the clearing price, minus the maximum cleared performance offer price. This data is based on actual five minute interval operational data.

Figure 10-18 illustrates the components of the regulation market clearing price. Each section represents the contribution of the lost opportunity cost (green area), capability price (blue area), and performance price (orange area), to the total price. From this figure, it is clear that the lost opportunity cost is the predominant component of the total clearing price.

¹⁰⁸ The performance component of the regulation market clearing price is unaffected by fast start pricing.

Figure 10-18 Regulation market clearing price components (Dollars per MW): January through September, 2022

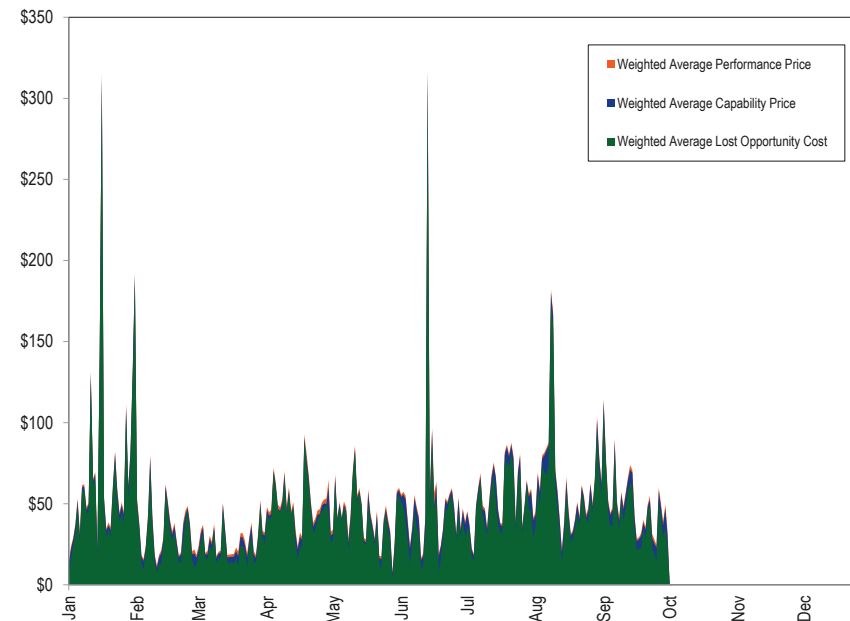


Table 10-56 shows the capability and performance components of the monthly average regulation prices. These components differ from the components of the marginal unit’s offers in Figure 10-18 because the performance component of the settlement price for each hour is determined from the average of the highest performance offers in each five minute interval, calculated independent of the marginal unit’s offers in those intervals.

Table 10-56 Regulation market monthly component of price (Dollars per MW): January through September, 2022

Month	Weighted Average Regulation Market Capability Clearing Price (\$/Perf. Adj. Actual MW)	Weighted Average Regulation Market Performance Clearing Price (\$/Perf. Adj. Actual MW)	Weighted Average Regulation Market Clearing Price (\$/Perf. Adj. Actual MW)
Jan	\$71.14	\$1.43	\$72.56
Feb	\$31.93	\$1.62	\$33.55
Mar	\$25.94	\$1.79	\$27.73
Apr	\$48.85	\$2.42	\$51.27
May	\$41.85	\$1.75	\$43.60
Jun	\$52.57	\$1.92	\$54.48
Jul	\$54.51	\$1.52	\$56.04
Aug	\$64.13	\$1.74	\$65.87
Sep	\$48.84	\$1.89	\$50.73
Average	\$49.26	\$1.78	\$51.04

Monthly and total annual scheduled regulation MW and regulation charges, as well as monthly average regulation price and regulation cost are shown in Table 10-57. Total scheduled regulation is based on settled performance adjusted MW. The total of all regulation charges in the first nine months of 2022 was \$211.8 million, compared to \$87.9 million in the first nine months of 2021.

Table 10-57 Total regulation charges: January 2021 through September 2022

Year	Month	Scheduled Regulation (MW)	Total Regulation Charges (\$)	Weighted Average Regulation Market Price (\$/MW)	Cost of Regulation (\$/MW)	Price as Percent of Cost
2021	Jan	400,937.0	\$6,038,564	\$12.12	\$15.06	80.5%
2021	Feb	364,533.3	\$9,401,619	\$20.60	\$25.79	79.9%
2021	Mar	386,898.9	\$8,793,373	\$19.20	\$22.73	84.5%
2021	Apr	373,462.9	\$7,951,303	\$17.34	\$21.29	81.5%
2021	May	386,138.5	\$8,051,297	\$16.62	\$20.85	79.7%
2021	Jun	390,494.1	\$9,654,112	\$19.22	\$24.72	77.8%
2021	Jul	403,379.4	\$9,696,300	\$20.02	\$24.04	83.3%
2021	Aug	404,161.2	\$15,414,276	\$33.13	\$38.14	86.9%
2021	Sep	355,337.7	\$12,923,840	\$30.41	\$36.37	83.6%
2021	Oct	373,226.9	\$18,334,407	\$41.40	\$49.12	84.3%
2021	Nov	356,980.3	\$24,453,797	\$56.28	\$68.50	82.2%
2021	Dec	389,951.2	\$13,662,814	\$28.79	\$35.04	82.2%
	Yearly	4,585,501.3	\$144,375,702	\$26.00	\$31.49	82.6%
2022	Jan	384,969.5	\$34,046,042	\$72.56	\$88.44	82.1%
2022	Feb	349,755.8	\$14,317,381	\$33.53	\$40.94	81.9%
2022	Mar	367,002.2	\$13,057,959	\$27.73	\$35.58	77.9%
2022	Apr	355,900.6	\$23,257,413	\$51.27	\$65.35	78.5%
2022	May	360,870.6	\$19,641,413	\$43.60	\$54.43	80.1%
2022	Jun	384,946.7	\$25,593,008	\$54.48	\$66.48	82.0%
2022	Jul	396,606.5	\$28,295,746	\$56.04	\$71.34	78.5%
2022	Aug	391,060.2	\$32,350,728	\$65.87	\$82.73	79.6%
2022	Sep	346,887.7	\$21,260,643	\$50.73	\$61.29	82.8%
	Yearly	3,337,999.7	\$211,820,333	\$51.04	\$63.46	80.4%

The capability, performance, and opportunity cost components of the cost of regulation are shown in Table 10-58. Total scheduled regulation is based on settled performance adjusted MW. In the first nine months of 2022, the average total cost of regulation was \$63.46 per MW, 150.1 percent higher than \$25.37 in the first nine months of 2021. In the first nine months of 2022, the monthly average capability component cost of regulation was \$50.64, 150.8 percent higher than \$20.19 in the first nine months of 2021. In the first nine months of 2022, the monthly average performance component cost of regulation was \$4.25, 66.0 percent higher than \$2.56 in the first nine months of 2021. The increase of the average total cost in the first nine months of 2022 versus the first nine months of 2021, was primarily a result of higher LOC values due to higher prices in the energy market.

Table 10-58 Components of regulation cost: January 2021 through September 2022

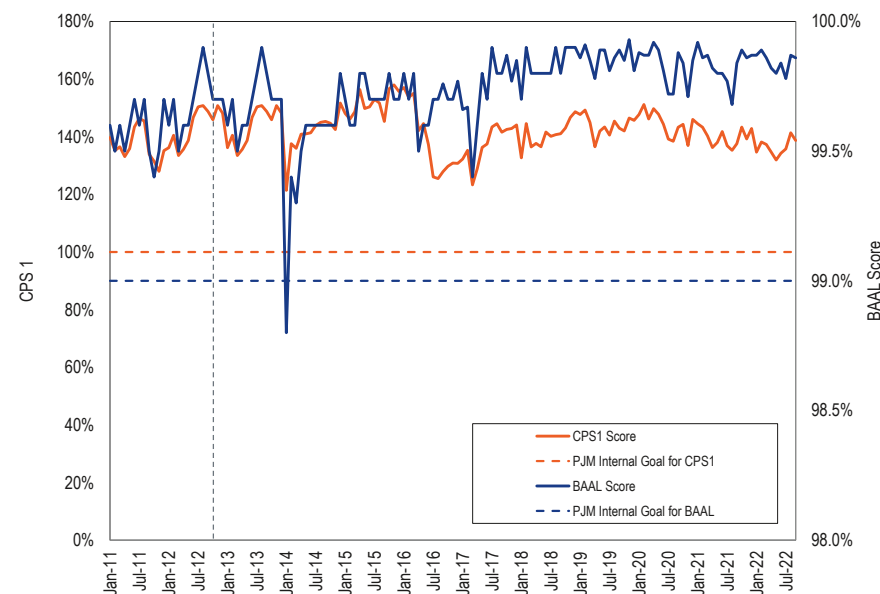
Year	Month	Scheduled Regulation (MW)	Cost of Regulation Capability (\$/MW)	Cost of Regulation Performance (\$/MW)	Opportunity Cost (\$/MW)	Total Cost (\$/MW)
2021	Jan	400,937.0	\$11.71	\$1.67	\$1.68	\$15.06
	Feb	364,533.3	\$19.90	\$2.52	\$3.37	\$25.79
	Mar	386,898.9	\$18.70	\$1.86	\$2.16	\$22.73
	Apr	373,462.9	\$16.63	\$2.66	\$2.00	\$21.29
	May	386,138.5	\$15.87	\$2.40	\$2.58	\$20.85
	Jun	390,494.1	\$18.45	\$2.54	\$3.73	\$24.72
	Jul	403,379.4	\$19.25	\$2.68	\$2.10	\$24.04
	Aug	404,161.2	\$32.19	\$3.36	\$2.58	\$38.14
	Sep	355,337.7	\$29.45	\$3.41	\$3.52	\$36.37
	Oct	373,226.9	\$40.60	\$3.97	\$4.55	\$49.12
	Nov	356,980.3	\$55.46	\$4.80	\$8.24	\$68.50
	Dec	389,951.2	\$27.87	\$3.67	\$3.50	\$35.04
Yearly		4,585,501.3	\$25.25	\$2.94	\$3.29	\$31.49
2022	Jan	384,969.5	\$72.12	\$3.22	\$13.10	\$88.44
	Feb	349,755.8	\$32.50	\$3.77	\$4.66	\$40.94
	Mar	367,002.2	\$26.45	\$4.35	\$4.78	\$35.58
	Apr	355,900.6	\$49.80	\$5.67	\$9.88	\$65.35
	May	360,870.6	\$43.22	\$4.19	\$7.02	\$54.43
	Jun	384,946.7	\$53.72	\$4.38	\$8.38	\$66.48
	Jul	396,606.5	\$56.22	\$3.59	\$11.53	\$71.34
	Aug	391,060.2	\$66.80	\$4.32	\$11.61	\$82.73
	Sep	346,887.7	\$51.27	\$4.87	\$5.16	\$61.29
Yearly		3,337,999.7	\$50.64	\$4.25	\$8.57	\$63.46

Performance Standards

PJM’s performance as measured by CPS1 and BAAL standards is shown in Figure 10-19 for every month from January 2011 through September 2022 with the dashed vertical line marking the date (October 1, 2012) of the implementation of the Performance Based Regulation Market design.¹⁰⁹ The horizontal dashed lines represent PJM internal goals for CPS1 and BAAL performance.

¹⁰⁹ See 2019 State of the Market Report for PJM, Appendix F: Ancillary Services.

Figure 10-19 Monthly CPS1 and BAAL performance: January 2011 through September 2022



Black Start Service

Black start service is required for the reliable restoration of the grid following a blackout. Black start service is the ability of a generating unit to start without an outside electrical supply, or the demonstrated ability of a generating unit to automatically remain operating at reduced levels when disconnected from the grid (automatic load rejection or ALR).¹¹⁰ Although the issue is being addressed in the stakeholder process, there are currently no firm fuel requirements for black start units.

PJM does not have a market to provide black start service, but compensates black start resource owners on the basis of cost of service rates defined in the tariff.¹¹¹ Currently, there is a small number of units in unique circumstances

¹¹⁰ OATT Schedule 1 § 1.3BB.

¹¹¹ See OATT Schedule 6A para. 18.

with bilateral agreements with their transmission operator (TO) to provide black start service that were entered into prior to joining PJM. These units are compensated directly from the TO.

PJM defines required black start capability zonally, while recognizing that the most effective way to provide black start service may be across zones. Under the current rules PJM has substantial flexibility in procuring black start resources and is responsible for black start resource selection.

On April 7, 2021, PJM issued an incremental RFP for additional black start service in the BGE and PEPCO Zones. The RFP is a two stage process. Level one submissions were due May 10, 2021. Level two submissions were due May 31, 2021. On November 1, 2021, PJM made awards for the April 7, 2021 incremental RFP. The planned in service date is April 1, 2023.¹¹²

Total black start charges are the sum of black start revenue requirement charges and black start uplift (operating reserve) charges.

Black start revenue requirements for black start units consist of fixed black start service costs, variable black start service costs, training costs, fuel storage costs, and an incentive factor applicable when CRF rates are not used. The tariff specifies how to calculate each component of the revenue requirement formula.¹¹³

Fixed black start service costs are calculated using one of three methods chosen by the black start provider from the options defined in the OATT Schedule 6A: base formula rate; capital cost recovery rate; or incremental black start NERC-CIP cost recovery. The base formula rate is calculated by taking the net CONE multiplied by the black start unit's capacity multiplied by an x factor. The x factor is 0.01 for hydro units and 0.02 for CT units. The capital recovery rate is calculated by multiplying the capital investment by the CRF rate. The incremental NERC-CIP cost, for existing black start resources that need to add additional capital to meet NERC-CIP requirements, is calculated using the capital cost recovery rate. Black start uplift charges are paid to units committed in real time to provide black start service or for

black start testing.¹¹⁴ Total black start charges are allocated monthly to PJM customers based on their zone and nonzone peak transmission use and point to point transmission reservations.¹¹⁵ It is not clear why it is reasonable to have different charges for black start service across zones as the service is to ensure that PJM as a whole can recover from a large scale outage.

In the first nine months of 2022, total black start charges were \$51.70 million, an increase of \$1.22 million (2.42 percent) from the first nine months of 2021. In the first nine months of 2022, total revenue requirement charges were \$51.35 million, an increase of \$1.07 million (2.14 percent) from the first nine months of 2021. In the first nine months of 2022, total uplift charges were \$0.353 million, an increase of \$0.149 million (73.35 percent) from the first nine months of 2021. Table 10-59 shows total charges for the first nine months of each year from 2010 through 2022.¹¹⁶

Table 10-59 Black start revenue requirement charges: January through September, 2010 through 2022

Jan-Sep	Revenue Requirement Charges	Uplift Charges	Total
2010	\$8,527,000	\$0	\$8,527,000
2011	\$9,996,898	\$0	\$9,996,898
2012	\$13,288,491	\$0	\$13,288,491
2013	\$15,728,447	\$68,903,357	\$84,631,804
2014	\$18,395,320	\$26,661,658	\$45,056,978
2015	\$39,718,855	\$5,070,944	\$44,789,799
2016	\$51,565,656	\$180,265	\$51,745,921
2017	\$52,422,434	\$186,752	\$52,609,186
2018	\$48,938,203	\$152,720	\$49,090,923
2019	\$48,231,346	\$175,400	\$48,406,746
2020	\$49,052,199	\$163,301	\$49,215,499
2021	\$50,278,321	\$203,620	\$50,481,941
2022	\$51,352,216	\$352,984	\$51,705,199

Black start zonal charges in the first nine months of 2022 ranged from \$0 in the OVEC and REC Zones to \$14,722,406 in the AEP Zone. For each zone,

¹¹⁴ There are no black start units currently using the ALR option.

¹¹⁵ OATT Schedule 6A (paras. 25, 26 and 27 outline how charges are to be applied).

¹¹⁶ Starting December 1, 2012, PJM defined a separate black start uplift category. ALR units accounted for the high uplift charges in 2013 - 2015. All ALR units had been replaced by April 2015.

¹¹² RFPs issued can be found on the PJM website. See PJM. <<http://www.pjm.com/markets-and-operations/ancillary-services.aspx>>.
¹¹³ See OATT Schedule 6A para. 18.

Table 10-60 shows black start charges, zonal peak loads, and black start rates (calculated as charges per MW-day).^{117 118} Customers paid an average of \$1.14 per MW-day for black start service in the first nine months of 2022.

Table 10-60 Black start zonal charges: January through September, 2021 and 2022¹¹⁹

Zone	Jan- Sep 2021					Jan- Sep 2022				
	Revenue Requirement Charges	Uplift Charges	Total Charges	Peak Load (MW)	Black Start Rate (\$/MW-day)	Revenue Requirement Charges	Uplift Charges	Total Charges	Peak Load (MW)	Black Start Rate (\$/MW-day)
ACEC	\$1,750,738	\$11,402	\$1,762,140	2,635	\$2.45	\$1,481,369	\$2,207	\$1,483,576	2,631	\$2.07
AEP	\$14,792,052	\$38,346	\$14,830,398	21,615	\$2.51	\$14,637,240	\$85,166	\$14,722,406	21,925	\$2.46
APS	\$3,712,845	\$1,135	\$3,713,980	8,638	\$1.58	\$4,864,033	\$8,630	\$4,872,663	8,865	\$2.01
ATSI	\$4,186,573	\$0	\$4,186,573	12,465	\$1.23	\$4,159,414	\$0	\$4,159,414	12,604	\$1.21
BGE	\$33,058	\$95	\$33,153	6,700	\$0.02	\$28,843	\$210	\$29,053	6,486	\$0.02
COMED	\$6,979,677	\$21,647	\$7,001,324	20,220	\$1.27	\$6,859,560	\$55,482	\$6,915,042	21,167	\$1.20
DAY	\$172,201	\$13,958	\$186,159	3,309	\$0.21	\$162,590	\$24,487	\$187,076	3,330	\$0.21
DUKE	\$284,041	\$12,598	\$296,638	4,975	\$0.22	\$263,414	\$14,831	\$278,245	5,306	\$0.19
DUQ	\$34,533	\$0	\$34,533	2,668	\$0.05	\$768,644	\$1,575	\$770,218	2,759	\$1.02
DOM	\$3,917,188	\$40,029	\$3,957,217	20,061	\$0.72	\$3,794,072	\$67,128	\$3,861,201	20,405	\$0.69
DPL	\$1,300,463	\$14,191	\$1,314,654	4,086	\$1.18	\$891,534	\$20,906	\$912,440	4,006	\$0.83
EKPC	\$246,074	\$2,076	\$248,150	2,720	\$0.33	\$202,246	\$8,053	\$210,299	2,851	\$0.27
JCPLC	\$525,736	\$2,564	\$528,300	5,903	\$0.33	\$421,468	\$6,005	\$427,473	6,169	\$0.25
MEC	\$357,434	\$3,555	\$360,989	2,976	\$0.44	\$368,800	\$8,322	\$377,121	3,072	\$0.45
OVEC	\$0	\$0	\$0	NA	NA	\$0	\$0	\$0	NA	NA
PECO	\$1,089,366	\$2,199	\$1,091,565	8,148	\$0.49	\$1,030,855	\$4,489	\$1,035,344	8,479	\$0.45
PE	\$3,264,496	\$12,851	\$3,277,347	2,911	\$4.12	\$3,248,504	\$11,347	\$3,259,850	2,900	\$4.12
PEPCO	\$242,012	\$8,802	\$250,814	5,887	\$0.16	\$234,502	\$6,507	\$241,009	5,829	\$0.15
PPL	\$3,646,821	\$0	\$3,646,821	7,260	\$1.84	\$3,659,238	\$401	\$3,659,639	7,517	\$1.78
PSEG	\$1,297,147	\$9,300	\$1,306,447	9,557	\$0.50	\$1,279,035	\$8,379	\$1,287,415	10,064	\$0.47
REC	\$0	\$0	\$0	NA	NA	\$0	\$0	\$0	NA	NA
(Imp/Exp/Wheels)	\$2,445,867	\$8,873	\$2,454,740	7,798	\$1.15	\$2,996,856	\$18,860	\$3,015,716	9,702	\$1.14
Total	\$50,278,321	\$203,620	\$50,481,941	160,530	\$1.15	\$51,352,216	\$352,984	\$51,705,199	166,066	\$1.14

Table 10-61 provides a revenue requirement estimate by zone for the 2022/2023, 2023/2024, and 2024/2025 Delivery Years.¹²⁰ Revenue requirement values are rounded up to the nearest \$50,000, reflecting the uncertainty about future black start revenue requirement costs. These values are illustrative only. The estimates are based on the best available data including current black start unit revenue requirements, expected black start unit termination and in service dates, changes in recovery rates, and owner provided cost estimates of incoming black start units at the time of publication and may change significantly. The estimates do not reflect the impact of FERC decisions that could affect compensation for black start.

¹¹⁷ See "PJM Manual 27: Open Access Transmission Tariff Accounting," § 7.3 Black Start Service Charges, Rev. 95 (Oct. 1, 2022).

¹¹⁸ For each zone and import export/wheels the black start rates (\$/MW day) are calculated by taking total charges by zone and divided by peak load then divided by days in the period.

¹¹⁹ Peak load for each zone is used to calculate the black start rate per MW day.

¹²⁰ The System Restoration Strategy Task Force requested that the MMU provide estimated black start revenue requirements.

Table 10-61 Black start zonal revenue requirement estimate: 2022/2023 through 2024/2025 Delivery Years¹²¹

Zone	2022 / 2023 Revenue Requirement	2023 / 2024 Revenue Requirement	2024 / 2025 Revenue Requirement
ACEC	\$2,100,000	\$2,100,000	\$2,100,000
AEP	\$20,600,000	\$20,700,000	\$15,800,000
APS	\$6,950,000	\$6,950,000	\$6,950,000
ATSI	\$5,950,000	\$5,950,000	\$3,950,000
BGE	\$50,000	\$350,000	\$3,500,000
COMED	\$9,400,000	\$9,650,000	\$9,650,000
DAY	\$250,000	\$250,000	\$250,000
DUKE	\$350,000	\$400,000	\$400,000
DUQ	\$1,100,000	\$1,100,000	\$1,100,000
DOM	\$5,250,000	\$5,350,000	\$5,350,000
DPL	\$1,250,000	\$1,350,000	\$1,350,000
EKPC	\$300,000	\$350,000	\$350,000
JCPLC	\$550,000	\$650,000	\$650,000
MEC	\$500,000	\$550,000	\$550,000
OVEC	\$0	\$0	\$0
PECO	\$1,400,000	\$1,550,000	\$1,550,000
PE	\$4,550,000	\$4,650,000	\$4,650,000
PEPCO	\$250,000	\$650,000	\$5,550,000
PPL	\$5,250,000	\$5,300,000	\$5,300,000
PSEG	\$1,750,000	\$1,800,000	\$1,800,000
REC	\$0	\$0	\$0
Total	\$67,800,000	\$69,650,000	\$70,800,000

CRF Issues

The capital recovery factor (CRF) defines the revenue requirement of black start units when new equipment is added to provide black start capability.¹²² The CRF is a rate, which when multiplied by the investment, provides for a return on and of capital over a defined time period. CRFs are calculated using a formula (or a correctly defined standard financial model) that accounts for the weighted average cost of capital and its components, plus depreciation and taxes. The PJM CRF table was created in 2007 as part of the new RPM capacity market design and incorporated in Attachment DD to the PJM OATT. That CRF table provided for the accelerated return of incremental investment in capacity resources based on concerns about the fact that some old coal units would be making substantial investments related to pollution control.

¹²¹ The 2024/2025 estimated revenue requirement is based on the CONE values for the 2023/2024 RPM Base Residual Auction because the 2024/2025 RPM Base Residual Auction has not been run.

¹²² See OATT Schedule 6A para. 18.

The CRF values were later added to the black start rules.¹²³ The CRF table in the tariff included assumptions about tax rates that were significantly too high after the changes to the tax code in 2017. The PJM tariff tables including CRF values should have been changed for both black start and the capacity market when the tax laws changed in 2017.

The CRF table for existing black start units includes the column header, term of black start commitment, which is misleading and incorrect. The column is simply the cost recovery period. Accelerated recovery reduces risk to black start units and should not be the basis for a shorter commitment. Full payment of all costs of black start investment on an accelerated basis should not be a reason for a shortened commitment period. Regardless of the recovery period, payment of the full costs of the black start investment should require commitment for the life of the unit.¹²⁴ In addition, there is no need for such short recovery periods for black start investment costs. Two periods, based on unit age, are more than adequate.

The U.S. Internal Revenue Code changed significantly in December 2017. The PJM CRF table did not change to reflect these changes. As a result, CRF values have overcompensated black start units since the changes to the tax code. The new tax law allow for a more accelerated depreciation and reduced the corporate tax rate to 21 percent.

Updated CRF rates, incorporating the tax code changes and applicable to all black start units, should be implemented immediately. The updated CRF rates should apply to all black start units because the actual tax payments for all black start units were reduced by the tax law changes. Without this change, black start units are receiving and will continue to receive an unexpected and inappropriate windfall.

On April 7, 2021, PJM filed with FERC to update the CRF values for new black start service units.¹²⁵ PJM proposed to bifurcate the CRF calculation, applying an updated CRF calculation that incorporates the new federal tax law to new black start units while leaving the outdated and incorrect CRF in place for

¹²³ *Id.*

¹²⁴ PJM's recent filing to revise Schedule 6A includes a required commitment to provide black start service for the life of the unit. See FERC Docket No. ER21-1635.

¹²⁵ See Docket No. ER21-1635-000.

existing black start units. Rather than fix the inaccurate CRF values used for existing black units, PJM's filing would have made the use of inaccurate values permanent. The MMU filed comments on April 28, 2021.¹²⁶ The MMU objected to the continued use of the outdated CRF for existing units. The MMU also introduced a CRF formula for calculating the CRF for new black start units and requested that the CRF formula be included in the tariff.¹²⁷ ¹²⁸ On August 10, 2021, FERC issued an order ("August 10th Order") that accepted PJM's tariff revisions that apply to new black start units (selected for service after June 6, 2021) and directed PJM to include the CRF formula proposed by the MMU.¹²⁹ The August 10th Order also established a show cause proceeding in a new docket to "determine whether the existing rates for generating units providing Black Start Service (Black Start Units), which are based on a federal corporate income tax that pre-dates the Tax Cuts and Jobs Act of 2017 (TCJA), remains just and reasonable."¹³⁰ The MMU requested rehearing over the Commission's conclusion that the MMU had requested "retroactive changes to the rates previously paid to generators."¹³¹ ¹³² The request for rehearing was denied.¹³³ PJM's compliance filing to address the August 10 Order was accepted by letter order, subject to edits proposed by the MMU, on December 16, 2021.¹³⁴

PJM's response to the show cause directive in the August 10th Order continued to support the use of the outdated CRF despite the Commission's statement that the CRF values "appear to be unjust, unreasonable, unduly discriminatory or preferential, or otherwise unlawful."¹³⁵ ¹³⁶ The MMU responded with analysis showing that PJM's proposal for maintaining the outdated CRF values would result in \$126 million of over recovery of black start capital investments.¹³⁷ Table 10-62 shows the over recovery of capital payments by resources awarded black start service prior to Jun 6, 2021 as result of PJM's continued application of the old CRF rate.

¹²⁶ See Comments of the Independent Market Monitor for PJM, FERC Docket No. ER21-1635-000 (April 28, 2021), which can be accessed at http://www.monitoringanalytics.com/filings/2021/IMM_Comments_Docket_No_ER21-1635_20210428.pdf.

¹²⁷ Answer and Motion for Leave to Answer of the independent Market Monitor for PJM, ER21-1635 (May 20, 2021).

¹²⁸ Comments of the Independent Market Monitor for PJM, FERC Docket No. ER21-1635 (July 2, 2021).

¹²⁹ 176 FERC ¶ 61,080 at 42 and 44 (2021).

¹³⁰ 176 FERC ¶ 61,080 at 2 (2021).

¹³¹ Id. at 50.

¹³² Request for Rehearing of the Independent Market Monitor for PJM, FERC Docket No. ER21-1635 (September 9, 2021).

¹³³ 177 FERC ¶ 62,017 (2021).

¹³⁴ 177 FERC ¶ 61,202 (2021).

¹³⁵ *PJM Interconnection, LLC, Response to Commission's Show Cause Order*, Docket No. EL21-91 (October 12, 2021).

¹³⁶ August 10th Order at 47.

¹³⁷ Errata Filing of the Independent Market Monitor for PJM, Attachment B at 17, Docket No. EL21-91 (November 18, 2022).

Table 10-62 CRF over recovery if CRF not corrected for changes in tax laws

	Excess Payback (\$ million)	Percent
Selected for Service Prior to January 1, 2017	\$36.05	28.6%
Selected for Service After January 1, 2019 and Before June 6, 2021	\$89.93	71.4%
Total	\$126.00	100.0%

The MMU also proposed an update to the CRF that reflects the return of capital already received by existing black start units and eliminates the over recovery that occurs under the PJM proposal. The updated CRF would be set at the level that covers the tax liabilities going forward, pays a return at the required rates on the remaining capital investment, pays back the full investment and results in the required return on and of capital over the CRF term. A description of the MMU's proposal and a formula for calculating the updated CRF are included in the MMU Comments.¹³⁸

NERC – CIP

No black start units have requested new or additional black start NERC – CIP Capital Costs.¹³⁹

Reactive Power Service and Capability

Suppliers of reactive power are compensated separately for reactive power service and reactive capability.

Compensation for reactive power service is based on real-time lost opportunity costs.¹⁴⁰ Reactive service is generally provided by units reducing real power output in order to increase reactive power output. These units are paid uplift based on lost opportunity costs.¹⁴¹

Compensation for reactive capability is approved separately for each resource or resource group by FERC per Schedule 2 of the OATT. Resources may

¹³⁸ Id. (Attachment B, Section H at 18).

¹³⁹ OATT Schedule 6A para. 21. "The Market Monitoring Unit shall include a Black Start Service summary in its annual State of the Market report which will set forth a descriptive summary of the new or additional Black Start NERC-CIP Capital costs requested by Black Start Units, and include a list of the types of capital costs requested and the overall cost of such capital improvements on an aggregate basis such that no data is attributable to an individual Black Start Unit."

¹⁴⁰ See OA Schedule 1 § 3.2.3B.

¹⁴¹ Id.

obtain FERC approval to recover a reactive revenue requirement, the reactive capability rate, from PJM customers.¹⁴²

Reactive Service, Reactive Supply and Voltage Control are provided by generation and other sources of reactive power (such as static VAR compensators and capacitor banks).¹⁴³ PJM in its role as the independent RTO and transmission provider determines the reactive capability it needs from all sources in order to reliably operate the grid. PJM, as part of its Interconnection Agreements with resources, requires that all resources over 20 MW be able to operate at a power factor of 0.90 lagging to 0.95 leading throughout their entire operating range. Reactive power helps maintain appropriate voltages on the transmission system and must be sourced locally.

Total reactive capability charges are the sum of FERC approved reactive supply revenue requirements. Zonal reactive supply revenue requirement charges are allocated monthly to PJM customers based on their zonal and to any nonzonal (outside of PJM) peak transmission use and daily average point to point transmission reservations.^{144 145}

In 2016, FERC began to reexamine its policies on reactive compensation.¹⁴⁶ On November 18, 2021, the FERC issued a notice of inquiry (NOI) concerning reactive power capability compensation.¹⁴⁷ The Market Monitor responded to the NOI.¹⁴⁸

Issues with Reactive Capability Market Design

The NOI inquires about reactive power capability compensation under the *AEP* Method, alternative methods of compensation, and resources interconnected at the distribution level. The fundamental question is whether market design in the organized wholesale markets requires separate, guaranteed cost of

service compensation for reactive capability. The answer is no. In the PJM market design, investment in resources is fully recoverable through markets. The PJM markets are a complete set of markets that are self sustaining. Unlike some ISO/RTO designs, the PJM market relies on markets rather than cost of service regulation or bilateral contracts to pay for capacity. Generators will invest in markets when the expected revenues provide for the payment of all costs and a return on and of capital. That is the way competitive markets work. It would be more equitable, more consistent with the PJM competitive market design, and more consistent with appropriate compensation for all generator costs, including reactive, to rely on PJM markets than to continue the outdated mixing of regulatory paradigms.

Even if the PJM design worked in the way asserted by supporters of cost of service payments for reactive, the best possible outcome would be the same as the market outcome. There would be an opportunity to recover all costs. A simple application of Occam's razor implies that the market approach should be used, as it is overwhelmingly more efficient than the current rate case, cost of service approach. Supporters of the cost of service approach have never explained why a nonmarket approach is required in PJM or why it is preferable to a market approach.

The current process is an inefficient waste of time because it relies on an atavistic regulatory paradigm that is not relevant in the PJM market framework. The *AEP* Method was created, before the creation of the PJM markets, by a regulated utility that had regulatory and financial reasons to want to define some generation costs as transmission costs. At the time, *AEP* collected both generation and transmission costs under the same cost of service approach. There is no reason to include complex rules that arbitrarily segregate a portion of a resource's capital costs as related to reactive power and that require recovery of that arbitrary portion through guaranteed revenue requirement payments based on burdensome cost of service rate proceedings. The practice persists in PJM only because it provides a significant, guaranteed stream of riskless revenue.

Applying cost of service rules is costly and burdensome and unnecessary. Most reactive proceedings for generators in PJM are resolved in black box

¹⁴² See "PJM Manual 27: Open Access Transmission Tariff Accounting," § 3.2 Reactive Supply and Voltage Control Credits, Rev. 95 (Oct. 1, 2022).

¹⁴³ OATT Schedule 2.

¹⁴⁴ OATT Schedule 2.

¹⁴⁵ See "PJM Manual 27: Open Access Transmission Tariff Accounting," § 3.3 Reactive Supply and Voltage Control Charges, Rev. 95 (Oct. 1, 2022).

¹⁴⁶ See *Reactive Supply Compensation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, Docket No. AD16-17-000 (March 17, 2016) (Notice of Workshop).

¹⁴⁷ *Reactive Power Capability Compensation*, 177 FERC ¶ 61,118 (2021).

¹⁴⁸ See Comments of the Independent Market Monitor for PJM, Docket No. RM22-2-000 (February 22, 2022); Reply Comments of the Independent Market Monitor for PJM, Docket No. RM22-2-000 (March 23, 2022); see also Comments of the Independent Market Monitor for PJM, Docket No. AD16-17-000 (July 29, 2016).

settlements that fail to address the merits of the cost support provided, result from an unsupported split the difference approach, and that, not surprisingly, produce a wide, unreasonable and discriminatory disparity among the rates per paid per MW-year for the same service.

Payments based on cost of service approaches result in distortionary impacts on PJM markets. Elimination of the reactive revenue requirement and recognition that capital costs are not distinguishable by function would increase prices in the capacity market. The VRR curve would shift to the right, the maximum VRR price would increase and offer caps in the capacity market would increase. The simplest way to address this distortion would be to recognize that all capacity costs are recoverable in the PJM markets.

The NOI presents an opportunity to address the reactive issue using a market based approach. The best approach would be to issue a rule eliminating cost of service rates for reactive capability and allowing for recovery of capacity costs through existing markets, including a removal of any offset for reactive revenue in offers and in the capacity market demand (VRR) curve. A second best approach would be to limit the revenue requirement that could be filed for under the OATT Schedule 2 to a level less than or equal to the reactive revenue credit included in the capacity market design, in the VRR curve Net CONE value, currently \$2,199 per MW-year.

As with all things in PJM markets, it is easy to focus on extreme complexity and lose sight of the big picture. The complexity includes power factors and power factor testing and convoluted and arbitrary allocation factors. The big picture here is that in PJM, the interrelated and self sustaining markets provide the opportunity for all power plants to recover all their costs, including a return on and of capital, including any identifiable reactive costs. There is no reason that part of those capacity costs should be paid directly in a non market, guaranteed, riskless revenue stream rather than in the market. The existence of the current option creates strong incentives for generators to attempt to maximize the allocation of capital costs to reactive in order to maximize guaranteed, nonmarket revenues.

The current process does not actually compensate resources based on their costs of investment in reactive power capability. The *AEP* Method assigns costs between real and reactive power based on a unit's power factor. This is effectively an allocation based on a subjective judgment rather than actual investment. There are few if any identifiable costs incurred by generators in order to provide reactive power. Separately compensating resources based on a judgment based allocation of total capital costs was never and is not now appropriate in the PJM markets. Generating units are fully integrated power plants that produce both the real and reactive power required for grid operation.

There is no logical reason to have a separate fixed payment for any part of the capacity costs of generating units in PJM. If separate cost of service rates for reactive continue, they need to be correctly integrated in the PJM market design.

The best and straightforward solution is to remove cost of service rates for reactive supply capability and to remove the offset. Investment in generation can and should be compensated entirely through markets. Removing cost of service rules would avoid the significant waste of resources incurred to develop unneeded cost of service rates.

The result would be to pay generators market based rates for both real and reactive capacity.

The PJM market design allows for the competitive investment in generation resources. The addition of separate rules allowing for the recovery of an arbitrarily defined portion of the same investment on a cost of service basis introduces a flaw into the competitive market design. The flaw is exacerbated when separate cost of service proceedings define the revenue requirement cost to supply reactive at values ranging from \$13,044 to \$964 per MW-year. (See Table 10-67)

The real issue is that the revenue requirement approach is inconsistent with both the theory and mechanics of PJM markets. The impact is to distort market outcomes.

The rules that account for recovery of reactive revenues are built into the auction parameters, specifically, the VRR curve. The PJM market rules explicitly account for recovery of reactive revenues of \$2,199 per MW-Year through inclusion in the Net CONE parameter of the capacity market demand (VRR) curve.¹⁴⁹ The Net CONE parameter directly affects clearing prices by affecting both the maximum capacity price and the location of the downward sloping part of the VRR curve. In addition, market sellers, when submitting offers based on net avoidable costs must account for revenues received through cost of service reactive capability rates in the calculation.¹⁵⁰ Unit specific reactive capability rates up to that \$2,199 per MW-Year level are at least consistent with that parameter. Reactive capability rates either above or below that level distort capacity market outcomes. For example, a marginal resource with reactive revenue of \$5,000 per MW-Year reflected in their net ACR offer would suppress the capacity market clearing price. Conversely, a marginal resource with a reactive revenue of \$1,000 per MW-Year reflected in their net ACR offer would inflate the capacity market clearing price.

Interconnection Requirements

A generating facility is not eligible for reactive payments when it is not connected directly to the PJM system and therefore does not provide reactive capability to PJM under Schedule 2, and should not receive payments for a service that it does not and cannot provide. In a number of cases now pending, the Market Monitor has challenged the eligibility of resources filing under OATT Schedule 2 because they are interconnected to facilities that PJM does not monitor and does not rely on to provide reactive capability.¹⁵¹

Schedule 2 provides, “Reactive Supply and Voltage Control from Generation or Other Sources Service is to be provided *directly* by the Transmission Provider” [emphasis added]. PJM cannot rely on resources on an adjacent unmonitored system to directly provide reactive capability because the adjacent unmonitored system is under the control of another entity. PJM cannot attempt to directly dispatch a resource on an adjacent system without knowing the voltage conditions on that system. PJM would have to

request assistance and cooperation of the entity responsible for the adjacent unmonitored system. Including a third party in the dispatch decision means PJM is not relying on the resources to directly provide Reactive Supply and Voltage Control Service.

The best place to understand PJM’s role regarding the Lines is in the Designated Facilities List contained in the PJM manual on Transmission Operations referenced in the definition of Transmission Provider. PJM Manual 3 (Transmission Operations) sets forth the criteria for determining Monitored Transmission Facilities and the criteria for determining Reportable Transmission Facilities. PJM explains that “Monitored Transmission Facilities are monitored and controlled for limit violations using PJM’s Security Analysis programs.”¹⁵² PJM explains that transmission facilities are “reportable if a change of its status can affect, or has the potential to affect, a transmission constraint on any Monitored Transmission Facility,” or “if it impedes the free-flowing ties within the PJM RTO and/or adjacent areas.”¹⁵³ The Monitored and Reportable Transmission Facilities are included in the Transmission Facilities List. The Transmission Facilities List is located on the PJM website.

PJM’s criteria for defining Monitored Transmission Facilities and the criteria for defining Reportable Transmission Facilities determine which power lines constitute the PJM transmission system and which do not.

A resource interconnected on power lines that fail to meet the criteria defining Monitored Transmission Facilities *and* the criteria for defining Reportable Transmission Facilities are not interconnected to PJM’s transmission facilities. PJM is not the Transmission Provider for such power lines. PJM does not directly rely on resources to provide Reactive Supply and Voltage Control Service, and they are therefore ineligible for compensation under Schedule 2.¹⁵⁴

¹⁴⁹ See PJM Manual 03:Transmission Operations, Rev. 64 (June 1, 2022).

¹⁵⁰ See PJM, PJM Transmission Providers Facilities List On-Line Help (Last Updated: May 4, 2017), which can be accessed at: <[trans-fac-help.ashx](#) (pjm.com)>.

¹⁵¹ A facility that does not meet the criteria defining Reportable Transmission Facilities but does meet the criteria for defining Monitored Transmission Facilities is also not eligible under Schedule 2. If PJM does not operate the Lines, they are not PJM’s transmission facilities. There is no evidence that PJM would rely on a resource to provide Reactive Supply and Voltage Control Service if the resource was located on a portion of the grid that PJM was monitoring but not operating. Coordination with the responsible operator would still be needed.

¹⁴⁹ See OATT Attachment DD § 5.10(a)(v)(A).

¹⁵⁰ OATT Attachment DD § 6.8(d).

¹⁵¹ See, e.g., FERC Docket Nos. ER21-2091, ER21-936, ER21-737, ER20-1863 & ER20-1851.

The issue will be decided in a hearing currently pending at the FERC.¹⁵⁵ The MMU has filed a motion for summary disposition, a prehearing brief and direct and answering testimony in that proceeding.¹⁵⁶ The hearing concluded on May 21, 2022. An initial decision is expected by July 15, 2022.

The issue of eligibility is significant because the number of facilities interconnecting at points that are not on the PJM system is expected to increase. Such facilities do not contribute reactive capability to PJM, and based on anticipated power factor levels and the way the AEP Method has been applied for calculating reactive rates under Schedule 2, such facilities would receive significantly larger payments per MW than the facilities that do provide reactive power capability useful to PJM.¹⁵⁷ These payments are for services not provided, but also would distort the PJM Capacity Market by paying a large share of the fixed costs of such facilities as reactive. This approach is a faulty and inefficient and noncompetitive market design.

Fleet Reactive Rates

Cost of service rates are established under Schedule 2 of the OATT and may cover rates for single units or a fleet of units.¹⁵⁸ Until the Commission took corrective action, fleet rates remained in place in PJM even when the actual units in the fleet changed as a result of unit retirements or sales of units.¹⁵⁹ New rules require unit owners to give notice of fleet changes in an informational filing or to file a new rate based on the remaining units, but do not yet require unit specific reactive rates.¹⁶⁰

Table 10-63 identifies fleet rates currently effective in PJM.

Table 10-63 Fleet rates currently effective in PJM

Company	Fleet Rates	Number of Resources	FERC Dockets
Indiana Municipal Power Agency	\$489,001.00	5	ER05-971-000
PBF Power Marketing (DCRC)	\$588,597.00	3	ER14-357
Dominion Virginia Power	\$27,500,000.00	66	ER06-554, ER17-512
Ingenco Wholesale Power, LLC	\$888,913.24	11	ER20-1863

Fleet rates create confusion about what revenue is properly attributable to each unit in the fleet. Reactive rates should be stated separately for each unit, even if multiple plants or units are considered in a single proceeding. The MMU filed with the Commission to require unit specific rates when PJM proposed limited reforms that could have corrected the oversight and compliance problems posed by fleet rates.¹⁶¹ But PJM rules require fleet owners only to submit informational filings when a reactive unit is transferred or deactivated.¹⁶² The current rules do not require a rate filing, which would place the burden of proof on the company and allow for cost review.¹⁶³

The MMU also raised issues related to fleet rates in a settlement establishing a fleet rate without specifying the actual portion of the fleet rate attributable to each unit in the fleet.¹⁶⁴ The approach could prevent or inhibit an appropriate adjustment of the fleet requirement if a unit receiving an unspecified portion of such requirement is deactivated or transferred because third parties without access to cost information would bear the burden of proof in a complaint proceeding.¹⁶⁵ The MMU also explained that the approach makes it impossible to calculate cost-based offers from such units in the PJM Capacity Market. The settlement was approved over the MMU's objection on the grounds that the tariff does not prohibit fleet rates.¹⁶⁶

The MMU recommends that fleet rates be eliminated and that compensation be based on unit specific costs and rates and that rates be appropriately reduced when units with reactive payments retire.

¹⁵⁵ See Whitetail Solar 1, LLC, et al., Docket No. ER20-714-003, et al.

¹⁵⁶ Direct and Answering Testimony of Joseph E. Bowring, Docket No. ER20-714-003, et al. (November 15, 2021); Motion for Summary Disposition of the Independent Market Monitor for PJM, Docket No. ER20-714-003, et al. (April 5, 2022); Prehearing Brief of the Independent Market Monitor for PJM, Docket No. ER20-714-003, et al. (April 14, 2022).

¹⁵⁷ See 80 FERC ¶ 63,006 (1997), *aff'd*, 88 FERC ¶ 61,141 (1999).

¹⁵⁸ See, e.g., OATT Schedule 2; 114 FERC ¶ 61,318 (2006).

¹⁵⁹ See 149 FERC ¶ 61,132 (2014); 151 FERC ¶ 61,224 (2015); OATT Schedule 2.

¹⁶⁰ *Id.*

¹⁶¹ 151 FERC ¶ 61,224 at P 29 (2015).

¹⁶² OATT Schedule 2.

¹⁶³ *Id.*

¹⁶⁴ See Letter Opposing Settlement, Docket No. ER06-554 et al. (June 14, 2017).

¹⁶⁵ *Id.*

¹⁶⁶ 162 FERC ¶ 61,029 (2018).

Reactive Costs

In the first nine months of 2022, total reactive charges were \$289.9 million, an increase of \$17.5 million (6.44 percent) from the first nine months of 2021. In the first nine months of 2022, total reactive capability charges were \$288.6 million, an increase of \$17.0 million (6.27 percent) from the first nine months of 2021. In the first nine months of 2022, total reactive service charges were \$1.2 million, an increase of \$0.49 million (65.98 percent) from the first nine months of 2021. In the first nine months of 2022, \$1.2 million for reactive service charges were paid to 12 units for operation in 41 unit hours.

Table 10-64 shows reactive service charges for the first nine months of each year from 2010 through 2022.

Table 10-64 Reactive service charges and reactive capability charges: January through September, 2010 through 2022

Jan-Sep	Reactive Service Charges	Reactive Capability Charges	Total
2010	\$8,813,427	\$181,213,186	\$190,026,613
2011	\$20,783,028	\$190,228,706	\$211,011,735
2012	\$49,432,233	\$204,638,358	\$254,070,591
2013	\$184,710,913	\$207,126,733	\$391,837,646
2014	\$27,516,739	\$210,968,737	\$238,485,476
2015	\$9,989,075	\$206,994,671	\$216,983,746
2016	\$838,204	\$219,793,594	\$220,631,798
2017	\$14,047,245	\$226,620,331	\$240,667,577
2018	\$12,428,626	\$225,234,508	\$237,663,134
2019	\$465,836	\$245,251,333	\$245,717,170
2020	\$412,336	\$257,951,271	\$258,363,607
2021	\$738,644	\$271,583,400	\$272,322,045
2022	\$1,225,976	\$288,624,151	\$289,850,127

Table 10-65 shows zonal reactive service charges for the first nine months in 2021 and 2022, reactive capability charges and total charges. Reactive service charges show charges to each zone for reactive service. Reactive capability charges show charges to each zone for reactive capability.

Table 10-65 Reactive service charges and reactive capability charges by zone: January through September, 2021 and 2022

Zone	Jan-Sep 2021			Jan-Sep 2022		
	Reactive Service Charges	Reactive Capability Charges	Total Charges	Reactive Service Charges	Reactive Capability Charges	Total Charges
ACEC	\$0	\$3,218,354	\$3,218,354	\$0	\$2,758,706	\$2,758,706
AEP	\$21,582	\$36,387,800	\$36,409,383	\$0	\$39,359,197	\$39,359,197
APS	\$0	\$14,763,169	\$14,763,169	\$0	\$16,745,023	\$16,745,023
ATSI	\$0	\$18,985,976	\$18,985,976	\$0	\$22,467,120	\$22,467,120
BGE	\$0	\$4,978,284	\$4,978,284	\$267,035	\$4,926,968	\$5,194,003
COMED	\$0	\$30,577,228	\$30,577,228	\$0	\$32,620,776	\$32,620,776
DAY	\$0	\$2,111,251	\$2,111,251	\$0	\$2,089,488	\$2,089,488
DUKE	\$0	\$7,350,101	\$7,350,101	\$0	\$7,036,013	\$7,036,013
DOM	\$0	\$34,605,721	\$34,605,721	\$225,700	\$38,255,967	\$38,481,667
DPL	\$1,517	\$7,810,181	\$7,811,698	\$229,648	\$7,458,256	\$7,687,904
DUQ	\$0	\$427,864	\$427,864	\$0	\$181,654	\$181,654
EKPC	\$1,231	\$1,634,607	\$1,635,838	\$0	\$1,617,757	\$1,617,757
JCPLC	\$0	\$5,651,066	\$5,651,066	\$0	\$5,592,814	\$5,592,814
MEC	\$8,696	\$4,597,462	\$4,606,159	\$20,196	\$4,521,660	\$4,541,856
OVEC	\$0	\$0	\$0	\$0	\$0	\$0
PECO	\$0	\$15,692,833	\$15,692,833	\$0	\$14,913,242	\$14,913,242
PE	\$0	\$12,940,806	\$12,940,806	\$0	\$12,975,137	\$12,975,137
PEPCO	\$0	\$7,499,913	\$7,499,913	\$483,396	\$7,440,158	\$7,923,554
PPL	\$705,618	\$27,453,430	\$28,159,048	\$0	\$27,242,143	\$27,242,143
PSEG	\$0	\$20,866,073	\$20,866,073	\$0	\$22,718,329	\$22,718,329
REC	\$0	\$0	\$0	\$0	\$0	\$0
(Imp/Exp/Wheels)	\$0	\$14,031,282	\$14,031,282	\$0	\$17,703,745	\$17,703,745
Total	\$738,644	\$271,583,400	\$272,322,045	\$1,225,976	\$288,624,151	\$289,850,127

Table 10-66 shows the units which received reactive service credits in the first nine months of 2022.

Table 10-66 Reactive service credits by plant (Total dollars): January through September, 2022

Jan-Sep 2022		
Zone	Plant	Reactive Service Credits
BGE	BC BRANDON SHORES 1 F	\$264,582
BGE	BC PERRYMAN 51 F	\$2,453
DPL	DPL BAYVIEW 1 D	\$2,668
DPL	DPL BAYVIEW 2 D	\$2,927
DPL	DPL BAYVIEW 3 D	\$1,920
DPL	DPL BAYVIEW 4 D	\$962
DPL	DPL INDIAN RIVER 4 F	\$221,172
METED	ME MOUNTAIN 2 CT	\$9,637
METED	ME TOLNA 2 CT	\$10,560
PEPCO	PEP CHALKPOINT 4 F	\$483,396
DOM	VP ELIZABETH RIVER 1 CT	\$206,962
DOM	VP ELIZABETH RIVER 3 CT	\$18,738
Total		\$1,225,976

Table 10-67 shows the settled reactive capability revenue requirements by technology effective on September 1, 2022.¹⁶⁷ These revenue requirements do not include revenue requirements that were filed but not yet final. The table demonstrates the wide disparity in payments for reactive capability that result from the current cost of service rate case model settlement process.

¹⁶⁷ The total amount in the final row of Table 10-32 is the amount that would be paid if the total rate effective on September 1, 2022 were effective for an entire year. The total rates effective on any given day depend on requests made by resource owners in filings to FERC and FERC approval of those rates.

Table 10-67 Total settled reactive revenue requirements by unit type and fuel type: September 1, 2022

Unit Type	Fuel Type	Total Revenue Requirement per Year	MW	Number of Resources	Requirement per MW-year
CC	Gas	\$122,983,072.65	49,423.2	155	\$2,488.37
CT	Gas	\$45,501,271.72	28,281.7	247	\$1,608.86
CT	Oil	\$4,693,276.29	3,291.2	114	\$1,426.01
Diesel	Gas	\$1,380,092.00	105.8	5	\$13,044.35
Diesel	Oil	\$1,028,787.05	168.2	36	\$6,116.45
Diesel	Other - Gas	\$915,140.45	115.4	11	\$7,930.16
FC	Gas	\$45,000.00	2.6	1	\$17,307.69
Hydro	Water	\$17,816,329.48	6,891.4	52	\$2,585.30
Nuclear	Nuclear	\$57,525,544.92	32,648.6	31	\$1,761.96
Solar	Solar	\$3,409,893.89	424.1	15	\$8,040.31
Steam	Coal	\$53,331,287.42	41,241.3	67	\$1,293.15
Steam	Gas	\$5,202,743.36	5,603.6	18	\$928.46
Steam	Oil	\$3,516,274.05	2,872.3	9	\$1,224.20
Steam	Other - Solid	\$340,000.00	34.0	2	\$10,000.00
Steam	Wood	\$207,803.43	153.0	3	\$1,358.19
Wind	Wind	\$18,664,267.97	4,791.6	37	\$3,895.21
Total		\$336,560,784.68	176,048.0	803	\$1,911.76

Frequency Response

On February 15, 2018, the Commission issued Order No. 842, which modified the pro forma large and small generator interconnection agreements and procedures to require newly interconnecting generating facilities, both synchronous and nonsynchronous, to include equipment for primary frequency response capability as a condition to receive interconnection service.¹⁶⁸ Such equipment must include a governor or equivalent controls with the capability of operating at a maximum 5 percent droop and ± 0.036 Hz deadband (or the equivalent or better).

PJM filed revisions in compliance with Order No. 842 that substantively incorporated the pro forma agreements into its market rules.¹⁶⁹

The MMU recommends that the same capability be required of both new and existing resources. The MMU agrees with Order No. 842 that RTOs not be required to provide additional compensation specifically for frequency response. The current PJM market design provides compensation for all

¹⁶⁸ 157 FERC ¶ 61,122 (2016).

¹⁶⁹ See 164 FERC ¶ 61,224 (2018).

capacity costs, including these, in the capacity market. The current market design provides compensation, through heat rate adjusted energy offers, for any costs associated with providing frequency response. Because the PJM market design already compensates resources for frequency response capability and any costs associated with providing frequency response, any separate filings submitted on behalf of resources for compensation under section 205 of the Federal Power Act should be rejected as double recovery.

Frequency Control Definition

There are four distinct types of frequency control, distinguished by response timeframe and operational nature: Inertial Response, Primary Frequency Response, Secondary Frequency Control (Regulation), and Tertiary Frequency Control (Primary Reserve).

- **Inertial Response.** Inertial response to frequency excursion is the natural resistance of rotating mass turbine generators to changes in their stored kinetic energy. This response is immediate and resists short term changes to ACE from the instant of the disturbance up to twenty seconds after the disturbance.
- **Primary Frequency Response.** Primary frequency response is a response to a disturbance based on a local detection of frequency and local operational control settings. Primary frequency response begins within a few seconds and extends up to a minute. The purpose of primary frequency response is to arrest and stabilize the system until other measures (secondary and tertiary frequency response) become active.
- **Secondary Frequency Control.** Secondary frequency control is called regulation. In PJM it begins to respond within 10 to 15 seconds and can continue up to an hour. Regulation is controlled by PJM which detects the grid frequency, calculates a counterbalancing signal, and transmits that signal to all regulating resources.
- **Tertiary Frequency Control.** Tertiary frequency control and imbalance control lasting 10 minutes to an hour is called primary reserve.

VACAR Reserve Sharing Agreement

The VACAR Reserve Sharing Agreement (VRSA) was a combination of agreements among the entities in the VACAR Subregion including Dominion.¹⁷⁰ VACAR is a Subregion of the SERC Reliability Corporation (SERC) region. The agreement was terminated on October 1, 2022. The agreement required that each entity maintain primary reserves to meet the VACAR contingency reserve commitment (VACAR reserves) and deploy such reserves in the case of an emergency (e.g. loss of a unit in VACAR).¹⁷¹ Dominion was the only party to the VRSA that is also a transmission owner and a generation owner in PJM. The VRSA was not a public agreement. PJM was not a party to the VRSA. However, as the reliability coordinator for Dominion Virginia Power, PJM was responsible for scheduling Dominion's required reserves in the SERC region as described in the PJM manuals.¹⁷²

PJM procures synchronized reserves and primary reserves for the PJM region, including Dominion. The synchronized reserve and primary reserve requirements are equal to the largest single contingency and 150 percent of the largest contingency. The requirement is procured separately for the RTO and the MidAtlantic Dominion area (MAD) when the largest contingency is located outside of MAD. All units in PJM that meet the synchronized or primary reserve operating parameter requirements are eligible to meet the synchronized and primary requirements as long as PJM does not deselect them.

PJM procures Day-Ahead Scheduling Reserves (DASR) for the PJM region, including Dominion, as Secondary Reserves. The DASR requirement is calculated daily and is equal to the peak load forecast for the ReliabilityFirst region (RFC) and EKPC times the sum of the forced outage rate and the load forecast error, plus Dominion's share of the VACAR contingency reserve commitment. All units in PJM that meet the DASR operating parameter requirements are eligible to meet the DASR requirement.¹⁷³ There is no

¹⁷⁰ VRSA entities: Dominion, Duke Energy Progress, Duke Energy Carolinas, South Carolina Electric & Gas Company, South Carolina Public Service Authority and Cube Hydro Carolinas.

¹⁷¹ See SERC Regional Criteria, Contingency Reserve Policy, NERC Reliability Standard BAL-002 at 10-11.

¹⁷² See PJM. "Manual 13: Emergency Operations," Rev. 84 (March 23, 2022).

¹⁷³ DASR can be provided by units that do not clear the day-ahead energy market and can start within 30 minutes or by units that clear the day-ahead energy market and can ramp up within 30 minutes.

requirement that a specific amount of DASR be located in Dominion. Equation 1 shows the DASR requirement calculation.¹⁷⁴

Equation 1: DASR Requirement Formula

$$\text{DASR Requirement} = (\text{RFC and EKPC Peak}) \times (\text{FOR} + \text{LFE}) + \text{DOM VACAR}$$

Issues

PJM implemented the reserve market changes effective October 1, 2022. These changes include the consolidation of synchronized reserves tier 1 and tier 2 and the reserve must offer requirement. With these changes, it would not have been possible for Dominion to hold reserves to meet its obligations under the VRSA without failing the must offer requirement in PJM. Under the reserve market changes, it would not have been possible for Dominion to meet both the VRSA and the PJM reserve rules.

Recommendations

The Market Monitor recommends that the VRSA be terminated and, if necessary, replaced by a reserve sharing agreement between PJM and VACAR South, similar to agreements between PJM and other bordering areas.¹⁷⁵

¹⁷⁴ During cold weather alerts and hot weather alerts, the DASR requirement is increased to procure additional reserves.

¹⁷⁵ The VACAR RSA was terminated on October 1, 2022.