Contents

Executive Summary ..................................................................................................................................................... 1

Summer 2019 Overview ............................................................................................................................................... 2

Weather and Load Conditions ................................................................................................................................ 2

Emergency Procedures ........................................................................................................................................... 3

Locational Marginal Price Summary ...................................................................................................................... 5

Fuel Prices ................................................................................................................................................................ 6

Operations .................................................................................................................................................................... 7

Emergency Procedures ........................................................................................................................................... 7

Post-Contingency Local Load Relief Warnings .................................................................................................... 7

Gas Pipeline Events ................................................................................................................................................ 8

Renewable Performance ..................................................................................................................................... 10

Forced Outage Rates .......................................................................................................................................... 12

Market Operations ................................................................................................................................................ 13

Synchronized Reserve Shortage Events ............................................................................................................. 13

Demand Response and Price-Responsive Demand ........................................................................................... 14

Uplift ........................................................................................................................................................................ 14
Executive Summary

At PJM Interconnection, the reliability of the bulk power system is our primary responsibility. PJM is committed to using all of the market, operational and planning tools at our disposal to ensure that the grid is reliable today and remains reliable into the future.

This report has been prepared by PJM to document the performance of the bulk power system during the summer of 2019, examining the summer time period from June 1, 2019 through Sept. 15, 2019. The summer peak load was 151,558 MW and occurred on Friday, July 19, HE 18. The summer of 2019 was relatively uneventful, with the exception of a new all-time weekend peak of 149,751 MW, which was set on Saturday, July 20.

Our analysis shows that the grid in the PJM footprint performed well this summer and continues to be diverse, strong and reliable, with excellent coordination with and cooperation from our members. While the smooth performance of the grid this summer is partially due to relatively mild weather, it’s also a testament to the excellent coordination and cooperation of our members and our combined focus on continuous improvement for reliability.

The smooth functioning of the system has been bolstered by factors such as the responsiveness of members to PJM dispatch operators, upgrades to the grid through the Regional Transmission Expansion Plan (RTEP), capacity performance and the capacity market, which has worked to replace aging generators with new, more efficient resources, resulting in significantly reduced forced outage rates that dropped from nearly 5 percent last summer to under 3 percent this year.
Summer 2019 Overview

Weather and Load Conditions

The summer started out cool, with below-average temperatures in June. Temperatures warmed to well above average in mid-July for most of the PJM footprint before moderating a bit in August, though temperatures remained above average.

Figure 1 illustrates the close relationship between load and weather, with the cool mid-June weather producing much lower loads than the hot weather produced in mid-July. Throughout the summer, daily low temperatures were more above average than daily high temperatures. This is consistent with above-average precipitation, which limits daytime heat and increases humidity, therefore elevating overnight lows.

The RTO-average heat index, a measure of temperature and humidity, is a non-load-weighted average of 37 weather stations across the PJM footprint. The series is not load weighted so that the results are more easily replicated, but still gives a general sense of the changes in overall weather throughout the footprint. Figure 1 plots the peak load (preliminary metered load plus economic demand response) from each day with the RTO-average heat index for the same hour.

As a whole, this summer’s temperatures were near to or slightly above the 30-year average for much of the PJM footprint. In comparison, the last six years include one notably cool summer (2014) and two notably hot summers (2016 and 2018), which is reflected in Figure 4 and Figure 5.
**Emergency Procedures**

With the exception of several Hot Weather Alerts, no other emergency procedures or Performance Assessment Intervals were called during the summer. The timing of all Hot Weather Alerts is shown in Figure 3. July had the most days where Hot Weather Alerts were issued.

**Figure 3. Summer 2019 Hot Weather Alerts**

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1 Source: [https://www.esrl.noaa.gov](https://www.esrl.noaa.gov)

2 The purpose of a Hot Weather Alert is to prepare personnel and facilities for extremely hot and/or humid weather conditions, which may cause capacity requirements/unit unavailability to be substantially higher than forecast and are expected to persist for an extended period. In general, a Hot Weather alert can be issued on a Control Zone basis, if projected temperatures are to exceed 90 degrees with high humidity for multiple days. A Hot Weather Alert will be issued for the Dominion and EKPC Control Zones when projected temperatures are to exceed 93 degrees with high humidity for multiple days.

3 Performance Assessment Intervals (PAI) are increments of time throughout the year during which Capacity Performance generators will be held to the Capacity Performance standard of deliverability. Generators subject to appraisal during PAI are those that cleared in the capacity auction with a Capacity Performance, or “pay-for-performance,” requirement.
Summer 2019 loads were average. Figure 4 plots the top 10 summer peaks for each year from 2014 through 2019. Only the top two peaks of 2019 were relatively high, whereas the remainder of the top 10 peaks drop off and are lower than those experienced last summer, and in 2016, when the temperatures were higher and more sustained across the season. Additionally, as shown in Figure 5, total energy usage across the summer tracks closely with cooling degree days.\footnote{Cooling degree days measure the temperature’s cumulative deviation from a base point, in this case 65 degrees, over a specified time period.}

**Figure 4.** Top 10 PJM Summer Peaks by Year

**Figure 5.** Total Summer Energy and Cooling Degree Days
**Locational Marginal Price Summary**

In Figure 6, the daily average locational marginal price (LMP) was approximately $25. The average hourly LMP at the time of the daily peak was approximately $46. In Figure 7, average LMPs were the lowest in 2019 for all months except September.

**Figure 6.** Real Time LMPs

![Real Time LMPs](image)

**Figure 7.** Historic Average Real Time LMPs by Month

![Historic Average Real Time LMPs by Month](image)
**Fuel Prices**

In addition to the hottest weather in the summer of 2019 occurring during times when electricity usage is typically lower (Fridays and weekends), lower fuel prices in 2019 may have also contributed to low LMPs. In Figure 8, the average gas price over the summer was $2.02 and the average coal price was $1.90. These prices are found by averaging a number of commodity pricing points across PJM. Over the same time period in 2018, the average gas price was $2.66 and the average coal price was $2.21.

**Figure 8. Average Daily Commodity Prices**

Fuel Price Source: S&P Global Platts
Operations

Emergency Procedures

PJM operated through the summer of 2019 without the need for any capacity emergency procedures. Despite having a summer peak of 150,000+ MW, PJM experienced no severe operational issues. PJM’s summer operations required the fewest hot weather alerts within the past four years and the second fewest within the past five years. It also experienced the fewest number of emergency procedures overall during the summer within the past five years.

Figure 9. Summer Emergency Procedures Summary

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Spinning Reserve - RTO and/or MAD</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>High System Voltages</td>
<td>13</td>
<td>17</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Minimum Generation Alert</td>
<td>26</td>
<td>26</td>
<td>12</td>
<td>20</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Manual Load Dump Warning or Action</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Hot Weather Alert - Any Region</td>
<td>9</td>
<td>17</td>
<td>23</td>
<td>15</td>
<td>19</td>
<td>13</td>
</tr>
</tbody>
</table>

Post-Contingency Local Load Relief Warnings

A post-contingency local load relief warning (PCLLRW) is a procedure to provide advance notice to transmission owners (TOs) of the potential for manual load shed in their areas. It is issued only after all other means of transmission constraint control have been exhausted and only remains in effect until sufficient generation is online within the limits to control the constraint. Since a thermal PCLLRW is related to weather, fewer hot weather days will result in fewer thermal PCLLRWs. Other factors potentially leading to fewer PCLLRWs include system reinforcements and improved outage scheduling. Figure 10 shows the cumulative number of PCLLRWs for summer 2019 and the previous five summers.

Figure 10. Cumulative Summer Period PCLLRWs
Gas Pipeline Events

While overall impacts to PJM generation due to natural gas pipeline operations were minimal throughout the summer period, there were two notable events. One occurred just outside of the PJM footprint, in central Kentucky, while the second event occurred in Northern Virginia, within the PJM operating area.

In the early morning hours of Aug. 1, 2019, there was an explosion that occurred on the 30-inch segment of the Texas Eastern (Enbridge) interstate pipeline in central Kentucky, near the Danville compressor station. While there is a gas-fired generator a short distance north of the incident site which serves the PJM market, it was not impacted. Natural gas flows south from the Marcellus and Utica supply basin through this region, and the impacted segment was isolated south of this generator shortly after the event, thus eliminating any loss of supply to the unit.

Figure 11. Aug. 1, 2019 Gas Pipeline Event

During the morning hours of Sept. 11, 2019, a compressor station on the Dominion Energy Transmission pipeline, located in Northern Virginia, failed. This incident occurred at the same time that pipeline maintenance was taking place. A spell of late summer heat and normal generator outage season, resulted in a loss of gas supply to certain units near to and downstream of the compressor station. This event did not result in the issuance of any emergency procedures by PJM, but did reinforce the importance of communication of operational conditions and the coordination of scheduling planned outages between the gas and electric sectors.

Figure 12. Sept. 11, 2019 Gas Pipeline Event
**Generation Online**

Over the course of the summer of 2019, on average during daily peak hours, natural gas made up 42 percent of the online fuel mix, followed by nuclear at 27 percent and coal at 24 percent. Renewables, including wind, solar, hydro and storage, made up 6 percent and other fuel types made up the remaining 1 percent.

In order to help describe how the resource mix varies during the summer in response to various events, six events were selected and are listed in Figure 13 below.

**Figure 13. Selected Significant Events**

<table>
<thead>
<tr>
<th>Date</th>
<th>Hour Ending</th>
<th>Details of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/1/2019</td>
<td>18</td>
<td>Transient shortage event and highest LMPs of the summer</td>
</tr>
<tr>
<td>7/19/2019</td>
<td>18</td>
<td>2019 summer peak</td>
</tr>
<tr>
<td>7/20/2019</td>
<td>17</td>
<td>All-time weekend summer peak &amp; 2nd overall summer peak of 2019</td>
</tr>
<tr>
<td>8/4/2019</td>
<td>18</td>
<td>The hour with the highest overall forced outage rate of the summer 2019</td>
</tr>
<tr>
<td>9/3/2019</td>
<td>17</td>
<td>Transient shortage event</td>
</tr>
<tr>
<td>9/11/2019</td>
<td>17</td>
<td>Gas compressor failure</td>
</tr>
</tbody>
</table>

The total online generation (in megawatts), as well as the percent of the total that each fuel type contributed for the days of note, including the RTO peak day, are shown in Figure 14.

**Figure 14. Summer 2019 Online Fuel Mix for Selected Hours**
As shown in Figure 15, since the summer of 2016, coal and natural gas have swapped places as the most utilized online fuel during summer daily peak hours, with nuclear and renewables generally maintaining their share of the online fuel mix.

**Figure 15. Historic Online Fuel Mix for Summer Daily Peak Hours**

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Natural Gas</th>
<th>Nuclear</th>
<th>Renewables</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>30%</td>
<td>36%</td>
<td>26%</td>
<td>5%</td>
</tr>
<tr>
<td>2017</td>
<td>24%</td>
<td>42%</td>
<td>27%</td>
<td>6%</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Renewable Performance**

The data in Figure 16 and Figure 17 depicts energy production of wind and grid-connected solar resources during the days of the summer identified in Figure 13 as compared with average production during all peak hours of summer 2019.

**Figure 16. Summer 2019 Wind Performance**
Figure 17. Summer 2019 Solar Performance

Figure 18 shows the increasing contribution of wind and solar resources during the daily peak summer hours since 2016.

Figure 18. Average Historic Performance of Wind and Solar on Daily Summer Peak Hours
**Forced Outage Rates**

In Figure 19, the average forced outage rate for the summer of 2019 (based on GADS data for June through August 2019) was 2.9 percent – the lowest in the last five summers. Outage rates were higher in July when the weather was the warmest, but overall, were only loosely correlated with heat index. The maximum forced outage rate, 6.7 percent, occurred on Aug. 4, 2019. Figure 20 shows that average summer forced outage rates have generally been trending down since 2016.

**Figure 19. Summer 2019 Daily Forced Outage Rates**

**Figure 20. Historic Summer Forced Outage Rates**

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5 September GADS data was not available at the time of this report.
Market Operations

Synchronized Reserve Shortage Events

Daily average Synchronized Reserve Market clearing prices (SRMCP) in the PJM and Mid-Atlantic regions remained low throughout June, but spiked on Monday, July 1 when the available Tier 1 resources fell below the requirement due to the loss of generation. This resulted in a transient reserve shortage — and therefore shortage pricing — for three intervals during the evening peak (hour 17:00).

At its highest, the 5-minute energy market LMP exceeded $2,800/MWh, and the RTO and Mid-Atlantic Dominion (MAD) SRMCP reached $1,472 and $1,700 respectively. To compensate resources that were called on to restore reserve levels following the loss of generation that triggered the shortage event, uplift costs exceeded $1.18 million on July 1, which accounts for 10 percent of the total uplift in July.

On Tuesday, Sept. 3, PJM called a synchronized reserve event in the Mid-Atlantic and Dominion regions that lasted for nine minutes during hour beginning 09:00. Later, during the evening ramp, two generators tripped offline, resulting in a transient shortage event. Synchronized reserves fell below the reserve requirement in both the RTO and Mid-Atlantic regions, and primary reserves fell below the reserve requirement in the Mid-Atlantic region only. The deficiency of multiple reserve products in multiple regions triggered significant transient shortage pricing leading into hour 17:00.

Four days later, on Saturday, Sept. 7, shortage pricing occurred for two intervals in the RTO and Mid-Atlantic-Dominion reserve zone and subzone respectively when the available synchronized reserves dropped below the requirement during hour beginning 15:00. SRMCP exceeded $1,000/MWh in the Mid-Atlantic-Dominion reserve subzone, and reached nearly $850/MWh for the RTO reserve zone.

Figure 21 provides a summary of the 5-minute prices observed in the Real-Time Energy and Ancillary Reserve Markets on July 1, Sept. 3 and Sept. 7, which proved to the be most elevated days for energy prices. In all cases, the operating reserve demand curve functioned as intended to signal transient shortage conditions and incent resource response to alleviate the condition.

### Figure 21. Summary of 5-Minute Prices in Real-Time and Ancillary Reserve Markets

<table>
<thead>
<tr>
<th>Price ($/MWh)</th>
<th>Monday, July 1</th>
<th>Tuesday, Sept. 3</th>
<th>Saturday, Sept. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily Average</td>
<td>5-min Max Price</td>
<td>Daily Average</td>
</tr>
<tr>
<td>RTO LMP</td>
<td>$45</td>
<td>$2,846</td>
<td>$47</td>
</tr>
<tr>
<td>MAD Synchronized Reserve MCP</td>
<td>$12</td>
<td>$1,700</td>
<td>$16</td>
</tr>
<tr>
<td>RTO Synchronized Reserve MCP</td>
<td>$9</td>
<td>$1,472</td>
<td>$10</td>
</tr>
<tr>
<td>MAD Non-Synchronized Reserve MCP</td>
<td>$2</td>
<td>$600</td>
<td>$5</td>
</tr>
<tr>
<td>RTO Non-Synchronized Reserve MCP</td>
<td>$1</td>
<td>$300</td>
<td>$2</td>
</tr>
</tbody>
</table>
Demand Response and Price-Responsive Demand

There were 9,500 MW of emergency/pre-emergency demand response (also called DR or load management) and 2,600 MW of economic DR registered during the summer of 2019. DR has a firm capacity commitment and was not dispatched over this period. Economic DR participates in the Energy and Ancillary Services Markets when it is economic for the end-use customer to participate. It is estimated that approximately 400 MW of economic DR participated in the energy market on July 17 and 600 MW on July 19 during this high-load period. There was no committed price-responsive demand during the summer of 2019.

Uplift

Energy market uplift from June 1 to Sept. 15, 2019, totaled $36.4 million, which is the second-lowest amount over the same period compared to the last five summers. Additionally, the Reactive category is at its lowest level over the period. Figure 22 shows uplift by category, as well as the total uplift over the period of June 1 to Sept. 15 for 2019 and the previous five summers. A majority of the energy uplift in 2019 came via balancing operating reserve make-whole payments. Warmer weather in September resulted in four of the top five uplift days for this time period.

Figure 22. Summer Uplift by Category

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6 Any quoted uplift values are subject to change in accordance with PJM's settlement rules and guidelines.
7 Balancing Operating Reserve: Make whole credit for a unit committed in real-time whose offer amount exceeds the day-ahead and/or real-time market revenue. Day-Ahead Operating Reserve: Make whole credit for a unit committed in Day-Ahead whose offer amount exceeds the day-ahead market revenue. Lost Opportunity Cost: Credit for forgone revenue incurred by a generation resource following PJM dispatch instructions. Reactive: Balancing Operating Reserve specifically for units that are providing reactive support to the PJM system.
8 Ibid.