Congestion and Marginal Losses

The locational marginal price (LMP) is the incremental price of energy at a bus. The LMP at a bus is the sum of three components: the system marginal price (SMP) or energy component, the congestion component of LMP (CLMP), and the marginal loss component of LMP (MLMP).[1] SMP, MLMP and CLMP are products of the least cost, security constrained dispatch of system resources to meet system load.

SMP is the incremental price of energy for the system, given the current dispatch, at the load weighted reference bus, or LMP net of losses and congestion. SMP is the LMP at the load weighted reference bus. The load weighted reference bus is not a fixed location but varies with the distribution of load at system load buses.

CLMP is the incremental price of congestion at each bus, based on the shadow prices associated with the relief of binding constraints in the security constrained optimization. CLMPs are positive or negative depending on location relative to binding constraints and relative to the load weighted reference bus. In an unconstrained system CLMPs will be zero.

MLMP is the incremental price of losses at a bus, based on marginal loss factors in the security constrained optimization. Losses refer to energy lost to physical resistance in the transmission network as power is moved from generation to load.

Total losses refer to the total system-wide transmission losses as a result of moving power from injections to withdrawals on the system. Marginal losses are the incremental change in system losses caused by changes in load and generation.[2]

Congestion is neither good nor bad, but is a direct measure of the extent to which there are multiple marginal generating units dispatched to serve load as a result of transmission constraints. Congestion occurs when available, least-cost energy cannot be delivered to all load because transmission facilities are not adequate to deliver that energy to one or more areas, and higher cost units in the constrained area(s) must be dispatched to meet the load.[3] The result is that the price of energy in the constrained area(s) is higher than in the unconstrained area.

The energy, marginal losses and congestion metrics must be interpreted carefully. The term total congestion refers to what is actually net congestion, which is calculated as net implicit congestion costs plus net explicit congestion costs plus net inadvertent congestion charges. The net implicit congestion costs are the load congestion payments less generation congestion credits. This section refers to total energy costs and total marginal loss costs in the same way. As with congestion, total energy costs are more precisely termed net energy costs and total marginal loss costs are more precisely termed net marginal loss costs. Ignoring interchange, total generation MWh must be greater than total load MWh in any hour in order to provide for losses. Since the hourly integrated energy component of LMP is the same for every bus within every hour, the net energy bill is negative (ignoring net interchange), with more generation credits than load payments in every hour.[4]

Overview

Congestion Cost

- **Total Congestion.** Total congestion costs decreased by $134.2 million or 45.9 percent, from $292.2 million in the first three months of 2016 to $157.9 million in the first three months of 2017.
- **Day-Ahead Congestion.** Day-ahead congestion costs decreased by $158.0 million or 48.9 percent, from $322.9 million in the first three months of 2016 to $164.9 million in the first three months of 2017.

1 On June 1, 2013, PJM integrated the East Kentucky Power Cooperative (EKPC) Control Zone. The metrics reported in this section treat EKPC as part of MISO for the first hour of June 2013 and as part of PJM for the second hour of June 2013 through 2014.
2 See the 2014 SOM Technical Appendices for a full discussion of the relationship between marginal, average and total losses.
3 This is referred to as dispatching units out of economic merit order. Economic merit order is the order of all generator offers from lowest to highest cost. Congestion occurs when loadings on transmission facilities mean the next unit in merit order cannot be used and a higher cost unit must be used in its place. Dispatch within the constrained area follows merit order for the units available to relieve the constraint.
4 The total congestion and marginal losses were calculated as of April 20, 2017, and are subject to change, based on continued PJM billing updates.

- **Balancing Congestion.** Balancing congestion costs increased by $23.8 million or 77.4 percent, from -$30.8 million in the first three months of 2016 to -$6.9 million in the first three months of 2017.
- **Real-Time Congestion.** Real-time congestion costs decreased by $135.1 million or 45.9 percent, from $294.3 million in the first three months of 2016 to $159.2 million in the first three months of 2017.
- **Monthly Congestion.** Monthly total congestion costs in the first three months of 2017 ranged from $46.5 million in February to $59.9 million in January.
- **Geographic Differences in CLMP.** Differences in CLMP among eastern, southern and western control zones in PJM were primarily a result of congestion on the Cherry Valley Transformer, the Alpine – Belvidere Flowgate, the AP South Interface, the Emilie – Falls Line, and the Westwood Flowgate.
- **Congestion Frequency.** Congestion frequency continued to be significantly higher in the Day-Ahead Energy Market than in the Real-Time Energy Market in the first three months of 2017. The number of congestion event hours in the Day-Ahead Energy Market was about 14 times the number of congestion event hours in the Real-Time Energy Market.

  Day-ahead congestion event hours decreased significantly after September 8, 2014. The decrease was the result of the reduction in up to congestion (UTC) activity which was a result of FERC's UTC uplift refund notice, retroactive to September 8, 2014. However, day-ahead congestion frequency increased by 22.5 percent from 66,431 congestion event hours in the first three months of 2016 to 81,409 congestion event hours in the first three months of 2017. The increase was a result of the increase in UTC transactions that followed the expiration of the fifteen month resettlement period for the proceeding related to uplift charges for UTC transactions.[5]

  Real-time congestion frequency decreased by 13.9 percent from 6,763 congestion event hours in the first three months of 2016 to 5,823 congestion event hours in the first three months of 2017.
- **Congested Facilities.** Day-ahead, congestion-event hours increased on all types of facilities. Real-time, congestion-event hours increased on interfaces and transformers and decreased on lines and flowgates.

  The Cherry Valley Transformer was the largest contributor to congestion costs in the first three months of 2017. With $10.9 million in total congestion costs, it accounted for 6.9 percent of the total PJM congestion costs in the first three months of 2017.
- **Zonal Congestion.** ComEd had the largest total congestion costs among all control zones in the first three months of 2017. ComEd had $52.1 million in total congestion costs, comprised of -$56.2 million in total load congestion payments, -$108.0 million in total generation congestion credits and $0.3 million in explicit congestion costs. The Alpine – Belvidere Flowgate, the Cherry Valley Transformer, the Nelson Flowgate, the Byron - Cherry Valley Flowgate and the Lakeview – Greenfield Line contributed $27.0 million, or 51.8 percent of the total ComEd control zone congestion costs.
- **Ownership.** In the first three months of 2017, both financial entities and physical entities were net payers of congestion charges. In the first three months of 2017, financial entities paid $1.1 million in congestion charges compared to $16.7 million received in congestion credits in the first three months of 2016. In the first three months of 2017, physical entities paid $156.9 million in congestion charges, a decrease of $152.0 million or 49.2 percent compared to the first three months of 2016.

Marginal Loss Cost

- **Total Marginal Loss Costs.** Total marginal loss costs increased by $1.5 million or 0.9 percent, from $170.1 million in the first three months of 2016 to $171.5 million in the first three months of 2017. The loss MWh in PJM decreased by 10.3 GWh or 0.3 percent, from 3,879.2 GWh in the first three months of 2016 to 3,889.5 GWh in the first three months of 2017. The loss component of real-time LMP increased from $0.0141 in the first three months of 2016 to $0.0151 or 6.7 percent in the first three months of 2017.

5 *See* FERC Docket No. EL14-37.

- **Monthly Total Marginal Loss Costs.** Monthly total marginal loss costs in the first three months of 2017 ranged from $46.4 million in February to $62.8 million in March.
- **Day-Ahead Marginal Loss Costs.** Day-ahead marginal loss costs increased by $16.6 million or 9.0 percent, from $183.3 million in the first three months of 2016 to $199.9 million in the first three months of 2017.
- **Balancing Marginal Loss Costs.** Balancing marginal loss costs decreased by $15.1 million or 114.6 percent, from -$13.2 million in the first three months of 2016 to -$28.3 million in the first three months of 2017.
- **Total Marginal Loss Surplus.** The total marginal loss surplus decreased in the first three months of 2017 by $6.3 million or 11.3 percent, from $55.7 million in the first three months of 2016, to $49.4 million in the first three months of 2017.

Energy Cost

- **Total Energy Costs.** Total energy costs decreased by $8.3 million or 7.3 percent, from -$113.6 million in the first three months of 2016 to -$121.9 million in the first three months of 2017.
- **Day-Ahead Energy Costs.** Day-ahead energy costs decreased by $33.4 million or 22.2 percent, from -$150.4 million in the first three months of 2016 to -$183.8 million in the first three months of 2017.
- **Balancing Energy Costs.** Balancing energy costs increased by $27.4 million or 76.5 percent, from $35.8 million in the first three months of 2016 to $63.2 million in the first three months of 2017.
- **Monthly Total Energy Costs.** Monthly total energy costs in the first three months of 2017 ranged from -$48.2 million in January to -$31.8 million in February.

Conclusion

Congestion is defined to be the total congestion payments by load in excess of the total congestion credits received by generation. The level and distribution of congestion reflects the underlying characteristics of the power system, including the nature and capability of transmission facilities, the offers and geographic distribution of generation facilities, the level and geographic distribution of incremental bids and offers and the geographic and temporal distribution of load.

The current ARR/FTR design does not serve as an efficient way to ensure that load receives all the congestion revenues or has the ability to receive the auction revenues associated with all the potential congestion revenues. Total ARR and self scheduled FTR revenue offset only 63.8 and 86.5 percent of total congestion costs including congestion in the Day-Ahead Energy Market and the balancing energy market for the 14/15 and 15/16 planning periods. For the first 10 months of the 16/17 planning period ARRs and self scheduled FTRs offset 92.4 percent of total congestion costs.

Locational Marginal Price (LMP)

Components

On June 1, 2007, PJM changed from a single node reference bus to a distributed load reference bus. While the use of a single node reference bus or a distributed load reference bus has no effect on the total LMP, the use of a single node reference bus or a distributed load reference bus will affect the components of LMP. With a distributed load reference bus, the energy component is a load-weighted system price. There is no congestion or losses included in the load weighted reference bus price, unlike the case with a single node reference bus.

LMP at a bus reflects the incremental price of energy at that bus. LMP at any bus is the sum of three components: the system marginal price (SMP), marginal loss component of LMP (MLMP), and congestion component of LMP (CLMP).

SMP, MLMP and CLMP are a product of the least cost, security constrained dispatch of system resources to meet system load. SMP is the incremental cost of energy, given the current dispatch and given the choice of reference bus. SMP is LMP net of losses and congestion. Losses refer to energy lost to physical resistance in the transmission and distribution network as power is moved from generation to load. The greater the resistance of the system to flows of energy from generation to loads, the greater the losses of the system and the greater the proportion of energy needed to meet a given level of load. Marginal losses are the incremental change in system power losses caused by changes in the system load and generation patterns.[6] The first derivative of total losses with respect to the power flow equals marginal losses. Congestion cost reflects the incremental cost of relieving transmission constraints while maintaining system power balance. Congestion occurs when available, least-cost energy cannot be delivered to all loads because transmission facilities are not adequate to deliver that energy. When the least-cost available energy cannot be delivered to load in a transmission constrained area, higher cost units in the constrained area must be dispatched to meet that load.[7] The result is that the price of energy in the constrained area is higher than in the unconstrained area because of the combination of transmission limitations and the cost of local generation. Congestion is the difference between the total cost of energy paid by load in the transmission constrained area and the total revenue received by generation in the transmission constrained area.

Table 11-1 shows the PJM real-time, load-weighted average LMP components for January 1 through March 31, 2009 through 2017.[8]

The load-weighted average real-time LMP increased $3.48 or 13.0 percent from $26.80 in the first three months of 2016 to $30.28 in the first three months of 2017. The load-weighted average congestion component decreased by $0.01 from $0.03 in the first three months of 2016 to $0.02 in the first three months of 2017. The load-weighted average loss component increased from $0.01 in the first three months of 2016 to $0.02 in the first three months of 2017. The load-weighted average energy component increased by $3.49 or 13.1 percent from $26.75 in the first three months of 2016 to $30.25 in the first three months of 2017.

Table 11-1 PJM real-time, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2009 through 2017[9]

(Jan - Mar)	Real-Time LMP	Energy Component	Congestion Component	Loss Component
2009	$49.60	$49.51	$0.05	$0.04
2010	$45.92	$45.81	$0.06	$0.05
2011	$46.35	$46.30	$0.03	$0.03
2012	$31.21	$31.18	$0.02	$0.00
2013	$37.41	$37.37	$0.02	$0.02
2014	$92.98	$93.08	($0.13)	$0.03
2015	$50.91	$50.89	($0.00)	$0.03
2016	$26.80	$26.75	$0.03	$0.01
2017	$30.28	$30.25	$0.02	$0.02

Table 11-2 shows the PJM day-ahead, load-weighted average LMP components for January 1 through March 31 of 2009 through 2017.[10]

The load-weighted average day-ahead LMP increased $2.46, or 8.8 percent, from $27.94 in the first three months of 2016 to $30.40 in the first three months of 2017. The load-weighted average congestion component decreased $0.11, or 77.0 percent, from $0.15 in the first three months of 2016 to $0.03 in the first three months of 2017. The load-weighted average loss component decreased from -$0.002 in the first three months of 2016 to -$0.020 in the first three months of 2017. The load-weighted average energy component increased $2.59, or 9.3 percent, from $27.80 in the first three months of 2016 to $30.39 in the first three months of 2017.

6 For additional information, see the *MMU Technical Reference for PJM Markets*, at "Marginal Losses," <http://www.monitoringanalytics.com/reports/Technical_References/docs/2010-som-pjm-technical-reference.pdf>.

7 This is referred to as dispatching units out of economic merit order. Economic merit order is the order of all generator offers from lowest to highest cost. Congestion occurs when loadings on transmission facilities mean the next unit in merit order cannot be used and a higher cost unit must be used in its place.

8 The PJM real-time, load-weighted price is weighted by accounting load, which differs from the state-estimated load used in determination of the energy component (SMP). In the Real-Time Energy Market, the distributed load reference bus is weighted by state-estimated load in real time. When the LMP is calculated in real time, the energy component equals the system load-weighted price. But real-time bus-specific loads are adjusted, after the fact, based on updated load information from meters. This meter adjusted load is accounting load that is used in settlements and is used to calculate reported PJM load weighted prices. This after the fact adjustment means that the Real-Time Energy Market energy component of LMP (SMP) and the PJM real-time load-weighted LMP are not equal. The difference between the real-time energy component of LMP and the PJM-wide real-time load-weighted LMP is a result of the difference between state-estimated and metered loads used to weight the load-weighted reference bus and the load-weighted LMP.

9 Calculated values shown in Section 11, "Congestion and Marginal Losses," are based on unrounded, underlying data and may differ from calculations based on the rounded values in the tables.

10 In the Real-Time Energy Market, the energy component (SMP) equals the system load-weighted price, with the caveat about state-estimated versus metered load. However, in the Day-Ahead Energy Market the day-ahead energy component of LMP (SMP) and the PJM day-ahead load-weighted LMP are not equal. The difference between the day-ahead energy component of LMP and the PJM day-ahead load-weighted LMP is a result of the difference in the types of load used to weight the load-weighted reference bus and the load-weighted LMP. In the Day-Ahead Energy Market, the distributed load reference bus is weighted by fixed-demand bids only and the day-ahead SMP is, therefore, a system fixed demand weighted price. The day-ahead load-weighted LMP calculation uses all types of demand, including fixed, price-sensitive and decrement bids.

Table 11-2 PJM day-ahead, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2009 through 2017

(Jan - Mar)	Day-Ahead LMP	Energy Component	Congestion Component	Loss Component
2009	$49.44	$49.75	($0.18)	($0.13)
2010	$47.77	$47.74	$0.01	$0.02
2011	$47.14	$47.36	($0.11)	($0.11)
2012	$31.51	$31.45	$0.08	($0.03)
2013	$37.26	$37.19	$0.07	$0.01
2014	$94.96	$94.52	$0.43	$0.00
2015	$52.02	$51.55	$0.48	($0.02)
2016	$27.94	$27.80	$0.15	($0.00)
2017	$30.40	$30.39	$0.03	($0.02)

Zonal Components

The real-time components of LMP for each control zone are presented in Table 11-3 for the first three months of 2016 and the first three months of 2017. In the first three months of 2017, BGE had the highest real-time congestion component of all control zones and ComEd had the lowest real-time congestion component.

Table 11-3 Zonal and PJM real-time, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2016 and 2017

	2016 (Jan - Mar)				2017 (Jan - Mar)			
	Real-Time LMP	Energy Component	Congestion Component	Loss Component	Real-Time LMP	Energy Component	Congestion Component	Loss Component
AECO	$25.73	$26.67	($1.34)	$0.39	$29.59	$30.25	($1.32)	$0.66
AEP	$26.49	$26.73	$0.09	($0.32)	$29.39	$30.20	($0.23)	($0.58)
AP	$27.63	$26.85	$0.60	$0.17	$30.63	$30.31	$0.14	$0.18
ATSI	$26.03	$26.46	($0.87)	$0.44	$30.45	$30.01	($0.06)	$0.50
BGE	$36.11	$27.05	$7.89	$1.16	$34.79	$30.55	$2.85	$1.40
ComEd	$23.45	$26.33	($1.64)	($1.24)	$26.95	$29.90	($1.35)	($1.59)
DAY	$26.08	$26.69	($0.99)	$0.38	$29.88	$30.15	($0.37)	$0.10
DEOK	$25.42	$26.68	($0.61)	($0.65)	$28.57	$30.16	($0.43)	($1.17)
DLCO	$25.68	$26.52	($0.69)	($0.15)	$29.67	$30.06	($0.23)	($0.16)
Dominion	$31.29	$27.20	$3.96	$0.14	$32.58	$30.67	$1.49	$0.42
DPL	$30.56	$27.17	$2.35	$1.04	$33.13	$30.60	$1.36	$1.17
EKPC	$25.78	$27.28	($0.77)	($0.73)	$28.75	$30.63	($0.73)	($1.15)
JCPL	$23.79	$26.69	($3.33)	$0.43	$30.63	$30.26	($0.36)	$0.72
Met-Ed	$23.63	$26.76	($3.40)	$0.27	$30.41	$30.21	($0.43)	$0.63
PECO	$23.29	$26.73	($3.70)	$0.26	$29.58	$30.25	($1.03)	$0.36
PENELEC	$25.29	$26.56	($1.76)	$0.49	$29.79	$30.07	($0.77)	$0.49
Pepco	$32.38	$27.06	$4.62	$0.70	$33.26	$30.54	$1.81	$0.92
PPL	$23.88	$26.82	($3.15)	$0.21	$30.35	$30.27	($0.42)	$0.50
PSEG	$23.95	$26.50	($2.99)	$0.44	$30.51	$30.05	($0.26)	$0.72
RECO	$23.79	$26.55	($3.23)	$0.47	$30.77	$30.13	($0.15)	$0.80
PJM	$26.80	$26.75	$0.03	$0.01	$30.28	$30.25	$0.02	$0.02

The day-ahead components of LMP for each control zone are presented in Table 11-4 for the first three months of 2016 and the first three months of 2017. In the first three months of 2017, BGE had the highest day-ahead congestion component of all control zones and ComEd had the lowest day-ahead congestion component.

Table 11-4 Zonal and PJM day-ahead, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2016 and 2017

	2016 (Jan - Mar)				2017 (Jan - Mar)			
	Day-Ahead LMP	Energy Component	Congestion Component	Loss Component	Day-Ahead LMP	Energy Component	Congestion Component	Loss Component
AECO	$25.38	$27.56	($2.37)	$0.18	$29.62	$30.36	($1.04)	$0.30
AEP	$27.30	$27.81	($0.27)	($0.24)	$29.69	$30.37	($0.21)	($0.47)
AP	$28.84	$27.84	$0.95	$0.06	$30.80	$30.45	$0.27	$0.08
ATSI	$27.04	$27.56	($0.89)	$0.37	$30.69	$30.24	$0.00	$0.45
BGE	$38.70	$28.14	$9.59	$0.97	$34.70	$30.65	$2.86	$1.20
ComEd	$24.21	$27.42	($2.14)	($1.07)	$27.70	$30.11	($1.37)	($1.04)
DAY	$27.02	$27.67	($1.02)	$0.37	$30.05	$30.30	($0.40)	$0.15
DEOK	$26.55	$27.77	($0.66)	($0.56)	$29.05	$30.36	($0.35)	($0.96)
DLCO	$26.71	$27.63	($0.66)	($0.26)	$29.89	$30.23	($0.09)	($0.25)
Dominion	$33.27	$28.25	$4.77	$0.25	$32.59	$30.77	$1.41	$0.42
DPL	$32.49	$28.11	$3.58	$0.81	$32.80	$30.69	$1.52	$0.59
EKPC	$26.41	$28.26	($1.18)	($0.67)	$29.21	$30.89	($0.61)	($1.07)
JCPL	$24.08	$27.75	($3.97)	$0.30	$30.42	$30.41	($0.40)	$0.41
Met-Ed	$23.96	$27.64	($3.73)	$0.05	$30.26	$30.33	($0.35)	$0.28
PECO	$23.56	$27.72	($4.24)	$0.08	$29.29	$30.36	($1.13)	$0.06
PENELEC	$26.45	$27.85	($1.73)	$0.33	$29.77	$30.27	($0.65)	$0.15
Pepco	$34.70	$28.06	$6.03	$0.62	$33.32	$30.53	$2.00	$0.78
PPL	$24.20	$27.71	($3.54)	$0.03	$30.01	$30.33	($0.46)	$0.13
PSEG	$25.19	$27.61	($2.82)	$0.40	$30.68	$30.30	($0.07)	$0.45
RECO	$24.56	$27.56	($3.38)	$0.38	$30.74	$30.17	$0.09	$0.48
PJM	$27.94	$27.80	$0.15	($0.00)	$30.40	$30.39	$0.03	($0.02)

Hub Components

The real-time components of LMP for each hub are presented in Table 11-5 for the first three months of 2016 and the first three months of 2017.

Table 11-5 Hub real-time, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2016 and 2017

	2016 (Jan - Mar)				2017 (Jan - Mar)			
	Real-Time LMP	Energy Component	Congestion Component	Loss Component	Real-Time LMP	Energy Component	Congestion Component	Loss Component
AEP Gen Hub	$25.34	$27.86	($1.25)	($1.27)	$28.07	$30.15	($0.60)	($1.47)
AEP-DAY Hub	$25.65	$27.27	($1.16)	($0.46)	$29.05	$30.17	($0.33)	($0.79)
ATSI Gen Hub	$25.96	$27.39	($1.30)	($0.14)	$29.88	$30.30	($0.33)	($0.09)
Chicago Gen Hub	$21.94	$26.36	($2.81)	($1.60)	$26.05	$29.98	($1.94)	($1.99)
Chicago Hub	$23.79	$26.62	($1.61)	($1.22)	$27.17	$30.00	($1.30)	($1.53)
Dominion Hub	$30.72	$27.10	$3.75	($0.13)	$32.59	$31.01	$1.42	$0.16
Eastern Hub	$28.94	$26.37	$1.64	$0.93	$32.60	$29.95	$1.57	$1.08
N Illinois Hub	$23.49	$26.48	($1.62)	($1.37)	$26.96	$30.12	($1.45)	($1.72)
New Jersey Hub	$24.09	$26.53	($2.85)	$0.41	$30.33	$30.10	($0.45)	$0.68
Ohio Hub	$25.21	$26.69	($1.08)	($0.40)	$29.16	$30.18	($0.27)	($0.75)
West Interface Hub	$26.97	$26.69	$0.56	($0.28)	$30.89	$30.69	$0.47	($0.27)
Western Hub	$29.48	$28.17	$1.13	$0.18	$31.55	$30.96	$0.34	$0.26

The day-ahead components of LMP for each hub are presented in Table 11-6 for January 1 through March 31, 2016 and 2017.

Table 11-6 Hub day-ahead, load-weighted average LMP components (Dollars per MWh): January 1 through March 31, 2016 and 2017

	2016 (Jan - Mar)				2017 (Jan - Mar)			
	Day-Ahead LMP	Energy Component	Congestion Component	Loss Component	Day-Ahead LMP	Energy Component	Congestion Component	Loss Component
AEP Gen Hub	$25.76	$27.68	($0.86)	($1.06)	$28.82	$30.60	($0.50)	($1.29)
AEP-DAY Hub	$26.31	$27.62	($0.94)	($0.37)	$29.33	$30.25	($0.28)	($0.64)
ATSI Gen Hub	$24.79	$25.18	($0.48)	$0.09	$27.68	($0.86)	($1.06)	$0.03
Chicago Gen Hub	$22.68	$27.66	($3.48)	($1.50)	$26.31	$29.75	($2.07)	($1.37)
Chicago Hub	$24.07	$27.35	($2.28)	($1.00)	$27.58	$29.84	($1.31)	($0.95)
Dominion Hub	$32.89	$28.28	$4.57	$0.04	$32.25	$30.80	$1.24	$0.20
Eastern Hub	$31.62	$27.86	$2.94	$0.82	$32.84	$30.48	$1.75	$0.61
N Illinois Hub	$24.09	$27.39	($2.09)	($1.20)	$27.17	$29.74	($1.42)	($1.15)
New Jersey Hub	$24.77	$27.56	($3.10)	$0.31	$30.44	$30.33	($0.28)	$0.39
Ohio Hub	$26.10	$27.56	($1.10)	($0.35)	$29.23	$30.18	($0.33)	($0.62)
West Interface Hub	$28.36	$27.91	$0.69	($0.24)	$29.71	$29.31	$0.60	($0.20)
Western Hub	$29.67	$28.00	$1.65	$0.03	$30.52	$30.18	$0.43	($0.08)

Component Costs

Table 11-7 shows the total energy, loss and congestion component costs and the total PJM billing for January 1 through March 31, 2009 through 2017. These totals are actually net energy, loss and congestion costs. Total congestion cost decreased and marginal loss cost increased in the first three months of 2017 compared to the first three months of 2016.

Table 11-7 Total PJM costs by component (Dollars (Millions)): January 1 through March 31, 2009 through 2017[11] [12]

	Component Costs (Millions)					
(Jan - Mar)	Energy Costs	Loss Costs	Congestion Costs	Total Costs	Total PJM Billing	Total Costs Percent of PJM Billing
2009	($218)	$454	$307	$543	$7,515	7.2%
2010	($208)	$417	$345	$554	$8,415	6.6%
2011	($210)	$410	$360	$560	$9,584	5.8%
2012	($136)	$234	$122	$220	$6,938	3.2%
2013	($178)	$278	$186	$286	$7,762	3.7%
2014	($515)	$776	$1,236	$1,497	$21,070	7.1%
2015	($272)	$425	$632	$785	$14,040	5.6%
2016	($114)	$170	$292	$349	$9,500	3.7%
2017	($122)	$172	$158	$208	$9,710	2.1%

11 The energy costs, loss costs and congestion costs include net inadvertent charges.
12 Total PJM billing is provided by PJM. The MMU is not able to verify the calculation.

Congestion

Congestion Accounting

Congestion occurs in the Day-Ahead and Real-Time Energy Markets.[13] Total congestion costs are equal to the net implicit congestion bill plus net explicit congestion costs plus net inadvertent congestion charges, incurred in both the Day-Ahead Energy Market and the balancing energy market.

In the analysis of total congestion costs, load congestion payments are netted against generation congestion credits on an hourly basis, by billing organization, and then summed for the given period.

Load congestion payments and generation congestion credits are calculated for both the Day-Ahead and balancing energy markets.

- **Day-Ahead Load Congestion Payments.** Day-ahead load congestion payments are calculated for all cleared demand, decrement bids and day-ahead energy market sale transactions. Day-ahead load congestion payments are calculated using MW and the load bus CLMP, the decrement bid CLMP or the CLMP at the source of the sale transaction, as applicable.
- **Day-Ahead Generation Congestion Credits.** Day-ahead generation congestion credits are calculated for all cleared generation, increment offers and day-ahead energy market purchase transactions. Day-ahead generation congestion credits are calculated using MW and the generator bus CLMP, the increment offer's CLMP or the CLMP at the sink of the purchase transaction, as applicable.
- **Balancing Load Congestion Payments.** Balancing load congestion payments are calculated for all deviations between a PJM member's real-time load and energy sale transactions and their day-ahead cleared demand, decrement bids and energy sale transactions. Balancing load congestion payments are calculated using MW deviations and the real-time CLMP for each bus where a deviation exists.
- **Balancing Generation Congestion Credits.** Balancing generation congestion credits are calculated for all deviations between a PJM member's real-time generation and energy purchase transactions and the day-ahead cleared generation, increment offers and energy purchase transactions. Balancing generation congestion credits are calculated using MW deviations and the real-time CLMP for each bus where a deviation exists.
- **Explicit Congestion Costs.** Explicit congestion costs are the net congestion costs associated with point-to-point energy transactions. These costs equal the product of the transacted MW and CLMP differences between sources (origins) and sinks (destinations) in the Day-Ahead Energy Market. Balancing energy market explicit congestion costs equal the product of the deviations between the real-time and day-ahead transacted MW and the differences between the real-time CLMP at the transactions' sources and sinks. Explicit congestion costs are calculated for internal purchase, import and export transaction, and up to congestion transactions (UTCs.)
- **Inadvertent Congestion Charges.** Inadvertent congestion charges are congestion charges resulting from the differences between the net actual energy flow and the net scheduled energy flow into or out of the PJM control area each hour. This inadvertent interchange of energy may be positive or negative, where positive interchange typically results in a charge while negative interchange typically results in a credit. Inadvertent congestion charges are common costs, not directly attributable to specific participants that are distributed on a load ratio basis.[14]

The congestion costs associated with specific constraints are the sum of the total day-ahead and balancing congestion costs associated with those constraints. The congestion costs in each zone are the sum of the congestion costs associated with each constraint that affects prices in the zone. The network nature of the transmission system means that congestion costs in a zone are frequently the result of constrained facilities located outside that zone.

Congestion costs can be both positive and negative and consequently load payments and generation credits can be both positive and negative. Total congestion costs, when positive, measure the total congestion payment by a PJM member and when negative, measure the total congestion credit paid

13 When the term *congestion charge* is used in documents by PJM's Market Settlement Operations, it has the same meaning as the term *congestion costs* as used here.

14 OA. Schedule 1 (PJM Interchange Energy Market) §3.7.

to a PJM member. Load congestion payments, when positive, measure the total congestion payment by a PJM member and when negative, measure the total congestion credit paid to a PJM member. Generation congestion credits, when negative, measure the total congestion payment by a PJM member and when positive, measure the total congestion credit paid to a PJM member. Explicit congestion costs, when positive, measure the congestion payment by a PJM member and when negative, measure the congestion credit paid to a PJM member. Explicit congestion costs are calculated for up to congestion transactions (UTCs).

The CLMP is calculated with respect to the system reference bus LMP, also called the system marginal price (SMP). When a transmission constraint occurs, the resulting CLMP is positive on one side of the constraint and negative on the other side of the constraint and the corresponding congestion costs are positive or negative. For each transmission constraint, the CLMP reflects the cost of a constraint at a pricing node and is equal to the product of the constraint shadow price and the distribution factor at the respective pricing node. The total CLMP at a pricing node is the sum of all constraint contributions to LMP and is equal to the difference between the actual LMP that results from transmission constraints, excluding losses, and the SMP. If an area experiences lower prices because of a constraint, the CLMP in that area is negative.[15]

The congestion metric requires careful review when considering the significance of congestion. The net congestion bill is calculated by subtracting generating congestion credits from load congestion payments. The logic is that congestion payments by load are offset by congestion revenues to generation, for the area analyzed. The net congestion bill is the source of payments to FTR holders. When load pays more for congestion in an area than generation receives, the positive difference is the source of payments to FTR holders as it is a measure of the value of transmission in bringing lower cost generation into the area.

Total congestion costs in PJM in the first three months of 2017 were $157.9 million, which was comprised of load congestion payments of $23.9 million, generation credits of -$130.1 million and explicit congestion of $3.9 million.

Total Congestion

Table 11-8 shows total congestion in the first three months of 2008 through 2017. Total congestion costs in Table 11-8 include congestion costs associated with PJM facilities and those associated with reciprocal, coordinated flowgates in the MISO and in the NYISO.[16 17]

Table 11-8 Total PJM congestion (Dollars (Millions)): January 1 through March 31, 2008 through 2017

Congestion Costs (Millions)				
(Jan - Mar)	Congestion Cost	Percent Change	Total PJM Billing	Percent of PJM Billing
2008	$486	NA	$7,718	6.3%
2009	$307	(36.8%)	$7,515	4.1%
2010	$345	12.4%	$8,415	4.1%
2011	$360	4.3%	$9,584	3.8%
2012	$122	(66.0%)	$6,938	1.8%
2013	$186	51.9%	$7,762	2.4%
2014	$1,236	564.8%	$21,070	5.9%
2015	$632	(48.9%)	$14,040	4.5%
2016	$292	(53.7%)	$9,500	3.1%
2017	$158	(45.9%)	$9,710	1.6%

Table 11-9 shows the congestion costs by accounting category by market in the first three months of 2008 through 2017. Table 11-9 shows that the total balancing explicit congestion cost was positive in the first three months of 2017 and was negative in the first three months of 2008 through 2016. The change was caused by the increase of total balancing explicit net congestion charges incurred by UTCs, that caused UTCs to go from $19.1 million in net balancing credits the first three months of 2016 to $0.9 million in net balancing charges in the first three months of 2017 (Table 11-10 and Table 11-11).

15 For an example of the congestion accounting methods used in this section, see *MMU Technical Reference for PJM Markets*, at "FTRs and ARRs" <http://www.monitoringanalytics.com/reports/Technical_References/docs/2010-som-pjm-technical-reference.pdf>.

16 See "Joint Operating Agreement Between the Midwest Independent Transmission System Operator, Inc. and PJM Interconnection, L.L.C.," (December 11, 2008) Section 6.1, Effective Date: May 30, 2016. <http://www.pjm.com/documents/agreements.aspx>.

17 See "NYISO Tariffs New York Independent System Operator, Inc.," (May 26, 2016) Section 35.12.1, Effective Date: October 22, 2014. <http://www.pjm.com/documents/agreements.aspx>.

Table 11-9 Total PJM congestion costs by accounting category by market (Dollars (Millions)): January 1 through March 31, 2008 through 2017

	Congestion Costs (Millions)									
	Day Ahead				Balancing					
(Jan - Mar)	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
2008	$332.4	($220.0)	$39.9	$592.3	($46.0)	$29.5	($31.2)	($106.7)	$0.0	$485.6
2009	$120.2	($221.3)	$47.9	$389.5	($14.2)	($6.0)	($74.4)	($82.6)	($0.0)	$306.9
2010	$85.9	($293.1)	$12.9	$391.9	($5.7)	$12.1	($29.1)	($47.0)	($0.0)	$344.9
2011	$176.5	($226.7)	$4.1	$407.3	$21.6	$27.8	($41.2)	($47.4)	$0.0	$359.9
2012	$21.9	($131.4)	$27.5	$180.9	($5.1)	$11.3	($42.0)	($58.4)	$0.0	$122.4
2013	$85.0	($199.1)	$47.8	$331.9	($6.6)	$73.3	($66.0)	($145.9)	$0.0	$185.9
2014	$333.7	($1,193.9)	($94.3)	$1,433.3	$73.0	$208.9	($61.3)	($197.2)	$0.0	$1,236.1
2015	$327.0	($457.9)	($11.0)	$773.9	$5.4	$69.6	($78.0)	($142.2)	($0.0)	$631.7
2016	$120.2	($193.5)	$9.2	$322.9	($1.1)	$11.9	($17.7)	($30.8)	$0.0	$292.2
2017	$24.2	($137.7)	$3.0	$164.9	($0.3)	$7.6	$0.9	($6.9)	($0.0)	$157.9

Table 11-10 and Table 11-11 show the total congestion costs for each transaction type in the first three months of 2017 and 2016. Table 11-10 shows that in the first three months of 2017 DECs were paid $0.8 million in congestion credits in the day-ahead market, were paid $4.2 million in congestion credits in the balancing energy market, and were paid $5.0 million in total congestion credits. In the first three months of 2017, INCs were paid $2.3 million in congestion credits in the day-ahead market, were paid $0.3 million in congestion credits in the balancing energy market and received $2.6 million in total congestion credits. In the first three months of 2017, up to congestion (UTCs) paid $2.3 million in congestion charges in the day-ahead market, paid $0.9 million in congestion charges in balancing market and paid $3.1 million in total congestion charges.

Table 11-10 Total PJM congestion costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2017

	Congestion Costs (Millions)									
	Day-Ahead				Balancing					
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
DEC	($0.8)	$0.0	$0.0	($0.8)	($4.2)	$0.0	$0.0	($4.2)	$0.0	($5.0)
Demand	$7.6	$0.0	$0.0	$7.6	$4.7	$0.0	$0.0	$4.7	$0.0	$12.3
Demand Response	($0.0)	$0.0	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	($0.0)
Explicit Congestion Only	$0.0	$0.0	$0.8	$0.8	$0.0	$0.0	($0.0)	($0.0)	$0.0	$0.8
Export	($10.8)	$0.0	($0.1)	($10.8)	($1.6)	$0.0	$0.8	($0.8)	$0.0	($11.6)
Generation	$0.0	($168.4)	$0.0	$168.4	$0.0	$8.0	$0.0	($8.0)	$0.0	$160.3
Grandfathered Overuse	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	($0.4)	($0.4)	$0.0	($0.4)
Import	$0.0	$0.1	$0.0	($0.1)	$0.0	($1.5)	($0.3)	$1.2	$0.0	$1.1
INC	$0.0	$2.3	$0.0	($2.3)	$0.0	$0.3	$0.0	($0.3)	$0.0	($2.6)
Internal Bilateral	$28.2	$28.2	$0.0	($0.0)	$0.7	$0.7	$0.0	($0.0)	$0.0	($0.0)
Up to Congestion	$0.0	$0.0	$2.3	$2.3	$0.0	$0.0	$0.9	$0.9	$0.0	$3.1
Wheel In	$0.0	$0.1	$0.0	($0.0)	$0.0	($0.0)	($0.0)	($0.0)	$0.0	($0.0)
Wheel Out	$0.1	$0.0	$0.0	$0.1	($0.0)	$0.0	$0.0	($0.0)	$0.0	$0.0
Total	$24.2	($137.7)	$3.0	$164.9	($0.3)	$7.6	$0.9	($6.9)	$0.0	$157.9

Table 11-11 Total PJM congestion costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2016

	Congestion Costs (Millions)									
	Day-Ahead				Balancing					
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
DEC	$17.9	$0.0	$0.0	$17.9	($18.1)	$0.0	$0.0	($18.1)	$0.0	($0.2)
Demand	$12.0	$0.0	$0.0	$12.0	$13.5	$0.0	$0.0	$13.5	$0.0	$25.5
Demand Response	($0.0)	$0.0	$0.0	($0.0)	($0.0)	$0.0	$0.0	($0.0)	$0.0	($0.0)
Export	$0.0	$0.0	$1.1	$1.1	$0.0	$0.0	($0.0)	($0.0)	$0.0	$1.1
Explicit Congestion Only	($19.2)	$0.0	($0.6)	($19.7)	($2.2)	$0.0	$0.7	($1.5)	$0.0	($21.3)
Generation	$0.0	($303.0)	$0.0	$303.0	$0.0	$20.8	$0.0	($20.8)	$0.0	$282.2
Grandfathered Overuse	$0.0	$0.0	$0.1	$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.1
Import	$0.0	($7.5)	$0.1	$7.6	$0.0	($12.7)	$0.6	$13.4	$0.0	$21.0
INC	$0.0	$7.1	$0.0	($7.1)	$0.0	($1.8)	$0.0	$1.8	$0.0	($5.4)
Internal Bilateral	$113.4	$113.7	$0.3	($0.0)	$5.7	$5.7	$0.0	($0.0)	$0.0	($0.0)
Up to Congestion	$0.0	$0.0	$6.1	$6.1	$0.0	$0.0	($19.1)	($19.1)	$0.0	($13.0)
Wheel In	$0.0	($3.9)	$2.1	$6.0	$0.0	($0.0)	$0.0	$0.0	$0.0	$6.0
Wheel Out	($3.9)	$0.0	$0.0	($3.9)	($0.0)	$0.0	$0.0	($0.0)	$0.0	($3.9)
Total	$120.2	($193.5)	$9.2	$322.9	($1.1)	$11.9	($17.7)	($30.7)	$0.0	$292.2

Table 11-12 shows the change in total congestion cost incurred by transaction type from the first three months of 2016 to the first three months of 2017. Total congestion cost incurred by generation decreased by $121.9 million, total congestion cost incurred by demand decreased by $13.2 million, and the total congestion cost incurred by up to congestion transactions (UTCs) increased by $16.1 million.

Total day-ahead congestion costs paid by UTCs decreased by $3.8 million from $6.1 million in the first three months of 2016 to $2.3 million in the first three months of 2017. Over the same period balancing congestion payments to UTCs decreased by $19.9 million, from $19.1 million in the first three months of 2016 to -$0.9 million in the first three months of 2017. UTCs were paid $13.0 million in total congestion in the first three months of 2016 but paid $3.1 million in total congestion the first three months of 2017.

Table 11-12 Change in total PJM congestion costs by transaction type by market: January 1 through March 31, 2016 and 2017 (Dollars (Millions))

	Change in Congestion Costs (Millions)									
	Day-Ahead				Balancing					
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
DEC	($18.7)	$0.0	$0.0	($18.7)	$13.9	$0.0	$0.0	$13.9	$0.0	($4.8)
Demand	($4.4)	$0.0	$0.0	($4.4)	($8.8)	$0.0	$0.0	($8.8)	$0.0	($13.2)
Demand Response	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Explicit Congestion Only	$0.0	$0.0	($0.4)	($0.4)	$0.0	$0.0	$0.0	$0.0	$0.0	($0.3)
Export	$8.4	$0.0	$0.5	$8.9	$0.6	$0.0	$0.1	$0.7	$0.0	$9.6
Generation	$0.0	$134.6	$0.0	($134.6)	$0.0	($12.7)	$0.0	$12.7	$0.0	($121.9)
Grandfathered Overuse	$0.0	$0.0	($0.1)	($0.1)	$0.0	$0.0	($0.4)	($0.4)	$0.0	($0.5)
Import	$0.0	$7.6	($0.1)	($7.7)	$0.0	$11.3	($0.9)	($12.2)	$0.0	($19.9)
INC	$0.0	($4.8)	$0.0	$4.8	$0.0	$2.1	$0.0	($2.1)	$0.0	$2.7
Internal Bilateral	($85.2)	($85.5)	($0.3)	($0.0)	($4.9)	($4.9)	$0.0	$0.0	$0.0	$0.0
Up to Congestion	$0.0	$0.0	($3.8)	($3.8)	$0.0	$0.0	$19.9	$19.9	$0.0	$16.1
Wheel In	$0.0	$3.9	($2.1)	($6.0)	$0.0	$0.0	($0.0)	($0.0)	$0.0	($6.0)
Wheel Out	$3.9	$0.0	$0.0	$3.9	$0.0	$0.0	$0.0	$0.0	$0.0	$3.9
Total	($96.0)	$55.8	($6.2)	($158.0)	$0.8	($4.3)	$18.7	$23.8	$0.0	($134.2)

Monthly Congestion

Table 11-13 shows that monthly total congestion costs ranged from $46.5 million in February to $59.9 million in January in the first three months of 2017.

Table 11-13 Monthly PJM congestion costs by market (Dollars (Millions)): January 1, 2016 through March 31, 2017

	Congestion Costs (Millions)							
	2016				2017			
	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total
Jan	$123.5	($16.0)	$0.0	$107.6	$66.4	($6.5)	($0.0)	$59.9
Feb	$123.8	($12.5)	$0.0	$111.3	$44.4	$2.1	$0.0	$46.5
Mar	$75.6	($2.2)	($0.0)	$73.3	$54.1	($2.6)	$0.0	$51.6
Apr	$81.2	($3.0)	$0.0	$78.2				
May	$41.6	$7.5	($0.0)	$49.1				
Jun	$68.2	($8.6)	($0.0)	$59.6				
Jul	$124.4	($13.6)	($0.0)	$110.8				
Aug	$116.0	($5.0)	($0.0)	$111.0				
Sep	$123.4	($2.1)	($0.0)	$121.4				
Oct	$115.7	($12.6)	($0.0)	$103.1				
Nov	$48.9	($0.9)	($0.0)	$48.0				
Dec	$58.0	($7.8)	($0.0)	$50.3				
Total	$1,100.4	($76.8)	($0.0)	$1,023.7	$164.9	($6.9)	($0.0)	$157.9

Figure 11-1 shows PJM monthly total congestion cost for January 1, 2009 through March 31, 2017.

Figure 11-1 PJM monthly total congestion cost (Dollars (Millions)): January 1, 2009 through March 31, 2017

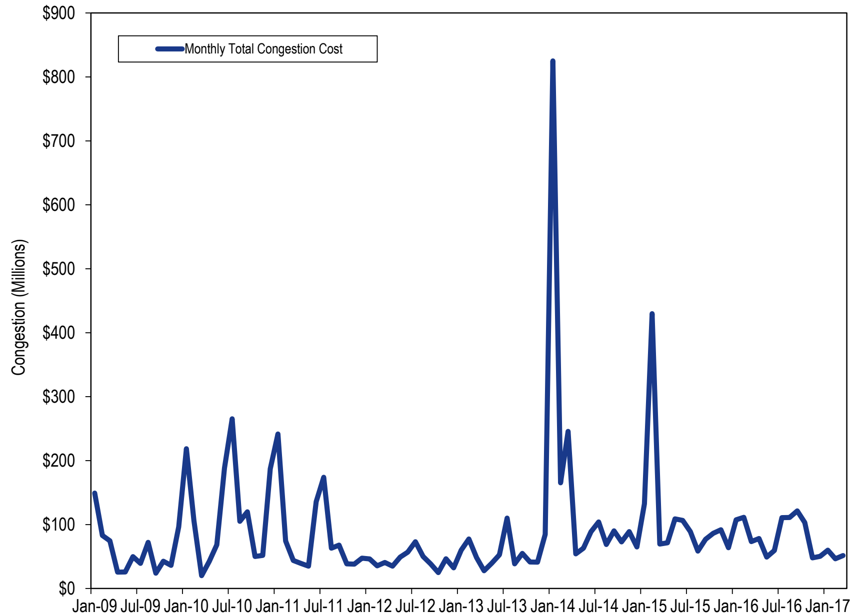


Table 11-14 shows the monthly total congestion costs for each virtual transaction type in the first three months of 2017 and Table 11-15 shows the monthly total congestion costs for each virtual transaction type in 2016. Virtual transaction congestion costs, when positive, measure the total congestion cost to the virtual transaction and when negative, measure the total congestion credit to the virtual transaction. Table 11-14 and Table 11-15 show that virtuals were paid in the first three months of 2017 and in the first three months of 2016.

Table 11-14 Monthly PJM congestion costs by virtual transaction type and by market (Dollars (Millions)): January 1 through March 31, 2017

	Congestion Costs (Millions)								
	Day-Ahead				Balancing				
	DEC	INC	Up to Congestion	Virtual Total	DEC	INC	Up to Congestion	Virtual Total	Virtual Grand Total
Jan	$1.1	$0.3	$2.9	$4.3	($3.0)	($1.1)	($2.0)	($6.1)	($1.9)
Feb	($0.7)	($4.9)	$0.7	($4.8)	($1.6)	$3.4	$1.7	$3.5	($1.4)
Mar	($1.2)	$2.3	($1.4)	($0.3)	$0.4	($2.6)	$1.2	($1.0)	($1.3)
Total	($0.8)	($2.3)	$2.3	($0.9)	($4.2)	($0.3)	$0.9	($3.6)	($4.5)

Table 11-15 Monthly PJM congestion costs by virtual transaction type and by market (Dollars (Millions)): 2016

	Congestion Costs (Millions)								
	Day-Ahead				Balancing				
	DEC	INC	Up to Congestion	Virtual Total	DEC	INC	Up to Congestion	Virtual Total	Virtual Grand Total
Jan	$6.8	($0.8)	$4.2	$10.1	($6.1)	($1.5)	($11.6)	($19.2)	($9.0)
Feb	$6.0	($1.0)	$1.2	$6.1	($8.1)	($0.5)	($6.3)	($14.9)	($8.8)
Mar	$5.1	($5.3)	$0.8	$0.5	($3.9)	$3.8	($1.2)	($1.3)	($0.8)
Apr	$5.0	($3.9)	($0.9)	$0.2	($5.1)	$4.3	($0.7)	($1.5)	($1.3)
May	$3.4	($8.9)	$0.8	($4.8)	($2.4)	$7.4	$1.8	$6.9	$2.1
Jun	$3.9	$0.0	$7.6	$11.6	($2.6)	($1.5)	($7.2)	($11.4)	$0.2
Jul	$3.5	$0.2	$5.5	$9.2	($6.0)	($1.7)	($7.5)	($15.2)	($5.9)
Aug	$7.4	($3.0)	$4.9	$9.3	($7.4)	$1.2	($5.5)	($11.8)	($2.5)
Sep	$6.8	($3.9)	$4.5	$7.4	($7.9)	$1.6	($1.2)	($7.6)	($0.2)
Oct	$4.9	($3.7)	$0.1	$1.3	($5.0)	$3.1	($4.0)	($5.8)	($4.5)
Nov	$1.7	($1.6)	$1.5	$1.6	($1.8)	$0.9	($1.0)	($1.9)	($0.3)
Dec	$1.7	($1.1)	$2.7	$3.4	($3.3)	$0.1	($2.7)	($5.9)	($2.5)
Total	$56.3	($33.1)	$32.7	$55.9	($59.6)	$17.2	($47.0)	($89.5)	($33.5)

Congested Facilities

A congestion event exists when a unit or units must be dispatched out of merit order to control for the potential impact of a contingency on a monitored facility or to control an actual overload. A congestion-event hour exists when a specific facility is constrained for one or more five-minute intervals within an hour. A congestion-event hour differs from a constrained hour, which is any hour during which one or more facilities are congested. Thus, if two facilities are constrained during an hour, the result is two congestion-event hours and one constrained hour. Constraints are often simultaneous, so the number of congestion-event hours usually exceeds the number of constrained hours and the number of congestion-event hours usually exceeds the number of hours in a year.

In order to have a consistent metric for real-time and day-ahead congestion frequency, real-time congestion frequency is measured using the convention that an hour is constrained if any of its component five-minute intervals is constrained. This is consistent with the way in which PJM reports real-time congestion. In the first three months of 2017, there were 81,409 day-ahead, congestion-event hours compared to 66,431 day-ahead congestion-event hours in the first three months of 2016. Of the first three months of 2017 day-ahead congestion-event hours, only 2,942 (3.6 percent) were also constrained in the Real-Time Energy Market. In the first three months of 2017, there were 5,823 real-time, congestion-event hours compared to 6,763 real-time, congestion-event hours in the first three months of 2016. Of the first three months of 2017 real-time congestion-event hours, 2,905 (49.9 percent) were also constrained in the Day-Ahead Energy Market.

The Cherry Valley Transformer was the largest contributor to total congestion costs in the first three months of 2017. With $10.9 million in total congestion costs, it accounted for 6.9 percent of the total PJM congestion costs in the first three months of 2017. The top five constraints in terms of congestion costs contributed $45.8 million, or 29.0 percent, of the total PJM congestion costs in the first three months of 2017. The top five constraints were the Cherry Valley Transformer, the Alpine – Belvidere Flowgate, the AP South Interface, the Emilie – Falls Line, and the Westwood Flowgate.

Congestion by Facility Type and Voltage

In the first three months of 2017, day-ahead, congestion-event hours increased on all types of facilities.

The increase in day-ahead, congestion-event hours on flowgates was largely a result of the increase of day-ahead, congestion-event hours on MISO flowgates.

The day-ahead, congestion-event hours on flowgates in MISO increased from 5,233 event hours in the first three months of 2016 to 7,528 event hours in the first three months of 2017. The increase in day-ahead, congestion-event hours on interfaces was a result of the increase of day-ahead, congestion-event hours on Pepco and West. The increase in day-ahead, congestion-event hours on lines was primarily a result of an increase in day-ahead, congestion-event hours incurred by lines in AEP, PENELEC and PSEG zones. The increase in day-ahead, congestion-event hours on transformers was primarily a result of the increase in day-ahead, congestion-event hours on transformers in the AEP, ComEd and PSEG zones.

Real-time, congestion-event hours decreased on flowgates and lines. The decrease in real-time, congestion-event hours on flowgates was primarily a result of the decrease in real-time, congestion-event hours on flowgates in NYSO. The decrease in real-time, congestion-event hours on lines was primarily a result of a decrease in real-time, congestion-event hours incurred by lines in BGE and DPL zones.

Day-ahead congestion costs decreased on all types of facilities in the first three months of 2017 compared to the first three months of 2016, primarily as a result of the decrease in day-ahead load-weighted CLMP. The load-weighted average congestion component decreased $0.11, or 77.0 percent, from $0.15 in the first three months of 2016 to $0.03 in the first three months of 2017.

Balancing congestion costs increased on all types of facilities except interfaces in the first three months of 2017 compared to the first three months of 2016. Table 11-16 provides congestion-event hour subtotals and congestion cost subtotals comparing the first three months of 2017 results by facility type: line, transformer, interface, flowgate and unclassified facilities.[18] [19] Table 11-17 presents this information for the first three months of 2016.

18 Unclassified are congestion costs related to nontransmission facility constraints in the Day-Ahead Market and any unaccounted for difference between PJM billed congestion charges and calculated congestion costs including rounding errors. Nontransmission facility constraints include day-ahead market only constraints such as constraints on virtual transactions and constraints associated with phase-angle regulators.

19 The term flowgate refers to MISO reciprocal coordinated flowgates and NYISO M2M flowgates.

Table 11-16 Congestion summary (By facility type): January 1 through March 31, 2017

	Congestion Costs (Millions)										
	Day Ahead				Balancing					Event Hours	
Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
Flowgate	($19.6)	($65.5)	($6.0)	$39.9	$1.1	$1.4	($0.1)	($0.4)	$39.5	8,043	1,743
Interface	$10.4	($9.4)	($1.3)	$18.5	($0.2)	$1.6	$0.3	($1.6)	$16.9	1,850	250
Line	$24.9	($51.7)	$6.7	$83.4	($1.1)	$6.1	$1.7	($5.5)	$77.9	42,817	2,566
Other	$3.3	$0.5	$0.1	$2.9	$0.4	$0.3	$0.2	$0.4	$3.3	4,059	240
Transformer	$5.2	($11.5)	$3.5	$20.1	($0.3)	($1.8)	($0.4)	$1.1	$21.3	24,640	1,024
Unclassified	$0.0	($0.0)	$0.0	$0.0	($0.2)	$0.0	($0.8)	($1.0)	($1.0)	NA	NA
Total	$24.2	($137.7)	$3.0	$164.9	($0.3)	$7.6	$0.9	($6.9)	$157.9	81,409	5,823

Table 11-17 Congestion summary (By facility type): January 1 through March 31, 2016

	Congestion Costs (Millions)										
	Day Ahead				Balancing					Event Hours	
Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
Flowgate	$17.6	($39.1)	($2.9)	$53.8	($0.9)	$3.9	($5.3)	($10.1)	$43.7	5,240	1,832
Interface	$15.1	($11.4)	($1.4)	$25.1	($0.1)	$0.3	$0.3	($0.0)	$25.0	1,746	86
Line	$62.8	($85.8)	$10.7	$159.2	$0.5	$5.4	($11.1)	($16.1)	$143.1	39,241	3,890
Other	($0.2)	($0.6)	$0.0	$0.4	$0.1	$0.0	$0.1	$0.1	$0.5	1,393	39
Transformer	$24.9	($56.6)	$2.7	$84.2	($1.8)	$2.0	($2.1)	($6.0)	$78.3	18,811	916
Unclassified	$0.0	($0.1)	$0.1	$0.2	$1.2	$0.3	$0.5	$1.4	$1.5	NA	NA
Total	$120.2	($193.5)	$9.2	$322.9	($1.1)	$11.9	($17.7)	($30.8)	$292.2	66,431	6,763

Table 11-18 and Table 11-19 compare day-ahead and real-time congestion event hours. Among the hours for which a facility is constrained in the Day-Ahead Energy Market, the number of hours during which the facility is also constrained in the Real-Time Energy Market are presented in Table 11-18.

In the first three months of 2017, there were 81,409 congestion-event hours in the Day-Ahead Energy Market. Of those day-ahead congestion-event hours, only 2,942 (3.6 percent) were also constrained in the Real-Time Energy Market. In the first three months of 2016, of the 66,431 day-ahead congestion-event hours, only 3,988 (6.0 percent) were binding in the Real-Time Energy Market.[20]

Among the hours for which a facility was constrained in the Real-Time Energy Market, the number of hours during which the facility was also constrained in the Day-Ahead Energy Market are presented in Table 11-19. In the first three months of 2017, of the 5,823 congestion-event hours in the Real-Time Energy Market, 2,905 (49.9 percent) were also constrained in the Day-Ahead Energy Market. In the first three months of 2016, of the 6,763 real-time congestion-event hours, 3,980 (58.8 percent) were also in the Day-Ahead Energy Market.

20 Constraints are mapped to transmission facilities. In the Day-Ahead Energy Market, within a given hour, a single facility may be associated with multiple constraints. In such situations, the same facility accounts for more than one constraint-hour for a given hour in the Day-Ahead Energy Market. Similarly in the real-time market a facility may account for more than one constraint-hour within a given hour.

Table 11-18 Congestion event hours (day-ahead against real-time): January 1 through March 31, 2016 and 2017

	Congestion Event Hours					
	2016 (Jan - Mar)			2017 (Jan - Mar)		
Type	Day Ahead Constrained	Corresponding Real Time Constrained	Percent	Day Ahead Constrained	Corresponding Real Time Constrained	Percent
Flowgate	5,240	776	14.8%	8,043	910	11.3%
Interface	1,746	42	2.4%	1,850	179	9.7%
Line	39,241	2,603	6.6%	42,817	1,450	3.4%
Other	1,393	6	0.4%	4,059	0	0.0%
Transformer	18,811	561	3.0%	24,640	403	1.6%
Total	66,431	3,988	6.0%	81,409	2,942	3.6%

Table 11-19 Congestion event hours (real-time against day-ahead): January 1 through March 31, 2016 and 2017

	Congestion Event Hours					
	2016 (Jan - Mar)			2017 (Jan - Mar)		
Type	Real Time Constrained	Corresponding Day Ahead Constrained	Percent	Real Time Constrained	Corresponding Day Ahead Constrained	Percent
Flowgate	1,832	778	42.5%	1,743	904	51.9%
Interface	86	44	51.2%	250	208	83.2%
Line	3,890	2,583	66.4%	2,566	1,394	54.3%
Other	39	6	15.4%	240	0	0.0%
Transformer	916	569	62.1%	1,024	399	39.0%
Total	6,763	3,980	58.8%	5,823	2,905	49.9%

Table 11-20 shows congestion costs by facility voltage class for the first three months of 2017. Congestion costs in the first three months of 2017 decreased for all facilities except facilities rated at 138 kV, 115 kV, and 34 kV compared to the first three months of 2016 (Table 11-21).

Table 11-20 Congestion summary (By facility voltage): January 1 through March 31, 2017

	Congestion Costs (Millions)										
	Day Ahead				Balancing					Event Hours	
Voltage (kV)	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
765	$0.5	($0.7)	$0.3	$1.6	($0.2)	$0.0	$0.0	($0.2)	$1.4	476	31
500	$11.6	($10.5)	($1.0)	$21.1	($0.1)	$1.6	$1.1	($0.5)	$20.6	2,077	194
345	($5.5)	($25.5)	$0.6	$20.6	$2.5	$1.6	($1.8)	($0.8)	$19.7	16,697	1,368
230	$24.8	($11.8)	($0.1)	$36.6	$0.8	$2.9	$0.7	($1.4)	$35.2	13,820	1,436
161	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	6	0
138	($5.6)	($80.4)	$2.9	$77.6	($1.2)	$4.4	$0.1	($5.5)	$72.1	35,601	2,015
115	($2.1)	($8.6)	$0.6	$7.1	$0.2	$1.2	$1.1	$0.1	$7.3	8,250	395
69	$0.3	($0.1)	($0.4)	$0.0	($2.2)	($4.0)	$0.5	$2.4	$2.4	3,170	384
34	$0.1	$0.0	$0.0	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	1,284	0
18	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	1	0
13	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	27	0
Unclassified	$0.0	($0.0)	$0.0	$0.0	($0.2)	$0.0	($0.8)	($1.0)	($1.0)	NA	NA
Total	$24.2	($137.7)	$3.0	$164.9	($0.3)	$7.6	$0.9	($6.9)	$157.9	81,409	5,823

Table 11-21 Congestion summary (By facility voltage): January 1 through March 31, 2016

	Congestion Costs (Millions)										
	Day Ahead				Balancing					Event Hours	
Voltage (kV)	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
765	$0.1	($0.8)	$0.5	$1.4	$0.0	$0.0	$0.0	$0.0	$1.4	636	0
500	$21.4	($23.6)	($1.8)	$43.2	$1.9	$1.9	$1.1	$1.2	$44.4	2,364	372
345	$0.0	($53.6)	$5.7	$59.3	$0.1	$6.6	($4.5)	($10.9)	$48.4	13,191	884
230	$81.4	($42.2)	($3.1)	$120.5	$4.5	$2.7	$1.8	$3.6	$124.1	13,359	2,115
161	($7.4)	($24.9)	($2.9)	$14.6	($2.1)	$2.6	($1.1)	($5.8)	$8.8	2,040	580
138	$16.7	($46.9)	$9.0	$72.6	($3.7)	$3.3	($13.9)	($20.9)	$51.7	24,017	1,652
115	$2.2	($2.2)	$0.5	$4.9	($1.3)	$0.6	($1.0)	($2.9)	$2.0	4,762	404
69	$5.7	$0.7	$1.1	$6.1	($1.7)	($6.0)	($0.7)	$3.6	$9.7	5,339	756
34	$0.0	$0.0	$0.0	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	719	0
12	($0.0)	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	4	0
Unclassified	$0.0	($0.1)	$0.1	$0.2	$1.2	$0.3	$0.5	$1.4	$1.5	NA	NA
Total	$120.2	($193.5)	$9.2	$322.9	($1.1)	$11.9	($17.7)	($30.8)	$292.2	66,431	6,763

Constraint Duration

Table 11-22 lists the constraints in the first three months of 2016 and 2017 that were most frequently binding and Table 11-23 shows the constraints which experienced the largest change in congestion-event hours from the first three months of 2016 to the first three months of 2017.

Table 11-22 Top 25 constraints with frequent occurrence: January 1 through March 31, 2016 and 2017

			Event Hours						Percent of Annual Hours					
			Day Ahead (Jan - Mar)			Real Time (Jan - Mar)			Day Ahead (Jan - Mar)			Real Time (Jan - Mar)		
No.	Constraint	Type	2016	2017	Change	2016	2017	Change	2016	2017	Change	2016	2017	Change
1	Emilie - Falls	Line	461	2,049	1,588	26	355	329	5%	23%	18%	0%	4%	4%
2	Olive	Other	327	1,898	1,571	0	0	0	4%	22%	18%	0%	0%	0%
3	Waukegan	Transformer	241	1,742	1,501	0	0	0	3%	20%	17%	0%	0%	0%
4	Westwood	Flowgate	0	1,477	1,477	0	198	198	0%	17%	17%	0%	2%	2%
5	Cherry Valley	Transformer	1,026	1,544	518	141	85	(56)	12%	18%	6%	2%	1%	(1%)
6	Zion	Line	688	1,436	748	0	0	0	8%	16%	8%	0%	0%	0%
7	Quad Cities	Transformer	201	1,370	1,169	0	0	0	2%	16%	13%	0%	0%	0%
8	Loretto - Vienna	Line	502	1,272	770	0	7	7	6%	14%	9%	0%	0%	0%
9	Saddlebrook	Transformer	128	1,255	1,127	0	0	0	1%	14%	13%	0%	0%	0%
10	Hudson	Transformer	662	1,110	448	0	0	0	8%	13%	5%	0%	0%	0%
11	West Chicago	Transformer	270	1,081	811	0	0	0	3%	12%	9%	0%	0%	0%
12	Maywood	Transformer	499	1,069	570	0	0	0	6%	12%	6%	0%	0%	0%
13	Lakeview - Greenfield	Line	82	972	890	0	94	94	1%	11%	10%	0%	1%	1%
14	Graceton - Safe Harbor	Line	49	775	726	19	277	258	1%	9%	8%	0%	3%	3%
15	Powerton - Goodings Grove	Line	163	862	699	92	142	50	2%	10%	8%	1%	2%	1%
16	Elwood - Elwood	Other	787	981	194	0	0	0	9%	11%	2%	0%	0%	0%
17	Howard - Shelby	Line	524	940	416	0	0	0	6%	11%	5%	0%	0%	0%
18	West Moulton-City Of St. Marys	Line	468	921	453	0	0	0	5%	10%	5%	0%	0%	0%
19	Kendall Co. Energy Ctr.	Transformer	238	898	660	0	0	0	3%	10%	8%	0%	0%	0%
20	East Bend	Transformer	1,086	879	(207)	0	0	0	12%	10%	(2%)	0%	0%	0%
21	Tanners Creek	Transformer	903	878	(25)	0	0	0	10%	10%	(0%)	0%	0%	0%
22	Gould Street - Westport	Line	569	869	300	0	0	0	6%	10%	3%	0%	0%	0%
23	Bellefonte - Grangston	Line	345	855	510	0	0	0	4%	10%	6%	0%	0%	0%
24	Central East	Flowgate	0	515	515	516	332	(184)	0%	6%	6%	6%	4%	(2%)
25	Braidwood	Transformer	1,346	830	(516)	0	0	0	15%	9%	(6%)	0%	0%	0%

Table 11-23 Top 25 constraints with largest year-to-year change in occurrence: January 1 through March 31, 2016 and 2017

			Event Hours						Percent of Annual Hours					
			Day Ahead (Jan - Mar)			Real Time (Jan - Mar)			Day Ahead (Jan - Mar)			Real Time (Jan - Mar)		
No.	Constraint	Type	2016	2017	Change	2016	2017	Change	2016	2017	Change	2016	2017	Change
1	Mercer IP - Galesburg	Flowgate	1,713	0	(1,713)	549	0	(549)	20%	0%	(20%)	6%	0%	(6%)
2	Monroe - Vineland	Line	1,917	101	(1,816)	252	3	(249)	22%	1%	(21%)	3%	0%	(3%)
3	Emilie - Falls	Line	461	2,049	1,588	26	355	329	5%	23%	18%	0%	4%	4%
4	Milford - Steele	Line	1,481	0	(1,481)	265	0	(265)	17%	0%	(17%)	3%	0%	(3%)
5	Westwood	Flowgate	0	1,477	1,477	0	198	198	0%	17%	17%	0%	2%	2%
6	Olive	Other	327	1,898	1,571	0	0	0	4%	22%	18%	0%	0%	0%
7	Graceton	Transformer	1,114	0	(1,114)	427	0	(427)	13%	0%	(13%)	5%	0%	(5%)
8	Waukegan	Transformer	241	1,742	1,501	0	0	0	3%	20%	17%	0%	0%	0%
9	Miami Fort	Transformer	1,671	239	(1,432)	2	0	(2)	19%	3%	(16%)	0%	0%	(0%)
10	Bagley - Graceton	Line	1,051	230	(821)	433	30	(403)	12%	3%	(9%)	5%	0%	(5%)
11	Quad Cities	Transformer	201	1,370	1,169	0	0	0	2%	16%	13%	0%	0%	0%
12	Saddlebrook	Transformer	128	1,255	1,127	0	0	0	1%	14%	13%	0%	0%	0%
13	Kewanee - Hennepin Tap	Line	1,004	0	(1,004)	107	0	(107)	11%	0%	(11%)	1%	0%	(1%)
14	Lakeview - Greenfield	Line	82	972	890	0	94	94	1%	11%	10%	0%	1%	1%
15	Graceton - Safe Harbor	Line	49	775	726	19	277	258	1%	9%	8%	0%	3%	3%
16	Mardela - Vienna	Line	773	172	(601)	380	5	(375)	9%	2%	(7%)	4%	0%	(4%)
17	East Danville - Banister	Line	1,001	31	(970)	0	0	0	11%	0%	(11%)	0%	0%	0%
18	Cedar Grove Sub - Roseland	Line	870	0	(870)	10	0	(10)	10%	0%	(10%)	0%	0%	(0%)
19	Bremo	Transformer	870	1	(869)	0	0	0	10%	0%	(10%)	0%	0%	0%
20	Tidd	Transformer	1,111	276	(835)	0	0	0	13%	3%	(10%)	0%	0%	0%
21	Hinchman	Transformer	0	830	830	0	0	0	0%	9%	9%	0%	0%	0%
22	Roxana - Praxair	Flowgate	662	164	(498)	335	13	(322)	8%	2%	(6%)	4%	0%	(4%)
23	West Chicago	Transformer	270	1,081	811	0	0	0	3%	12%	9%	0%	0%	0%
24	Loretto - Vienna	Line	502	1,272	770	0	7	7	6%	14%	9%	0%	0%	0%
25	Powerton - Goodings Grove	Line	163	862	699	92	142	50	2%	10%	8%	1%	2%	1%

Constraint Costs

Table 11-24 and Table 11-25 show the top constraints affecting congestion costs by facility for the first three months of 2017 and 2016. The Cherry Valley Transformer was the largest contributor to congestion costs in the first three months of 2017. With $10.9 million in total congestion costs, it accounted for 6.9 percent of the total PJM congestion costs in the first three months of 2017.

Table 11-24 Top 25 constraints affecting PJM congestion costs (By facility): January 1 through March 31, 2017

				Congestion Costs (Millions)									Percent of Total PJM Congestion Costs
				Day Ahead				Balancing					
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	2017 (Jan - Mar)
1	Cherry Valley	Transformer	ComEd	$3.7	($6.7)	$1.1	$11.6	($0.2)	$0.8	$0.4	($0.6)	$10.9	6.9%
2	Alpine - Belvidere	Flowgate	MISO	($2.3)	($14.0)	($0.9)	$10.8	$0.0	$0.0	$0.0	$0.0	$10.8	6.8%
3	AP South	Interface	500	$6.3	($3.7)	($0.8)	$9.2	($0.0)	$1.3	$0.8	($0.5)	$8.7	5.5%
4	Emilie - Falls	Line	PECO	$3.5	($4.7)	$0.5	$8.7	$0.0	$0.5	($0.0)	($0.5)	$8.2	5.2%
5	Westwood	Flowgate	MISO	($9.5)	($17.3)	($0.4)	$7.4	$1.2	$0.8	($0.5)	($0.1)	$7.3	4.6%
6	Conastone - Northwest	Line	BGE	$6.3	($0.5)	($0.3)	$6.4	($0.2)	($0.1)	$0.7	$0.6	$7.0	4.4%
7	Lakeview - Greenfield	Line	ATSI	($0.6)	($7.3)	$0.1	$6.9	($0.2)	$0.6	$0.4	($0.4)	$6.5	4.1%
8	Greentown	Flowgate	MISO	($1.4)	($7.6)	($0.7)	$5.6	($0.8)	($0.2)	$1.1	$0.5	$6.1	3.8%
9	Graceton - Safe Harbor	Line	BGE	$6.5	$1.2	$0.0	$5.3	$0.3	$0.5	$0.5	$0.4	$5.7	3.6%
10	Bedington - Black Oak	Interface	500	$2.4	($1.9)	($0.2)	$4.1	($0.0)	$0.2	$0.4	$0.2	$4.3	2.7%
11	Middletown Jct - Brunner Island	Line	PPL	$1.7	($2.3)	($0.2)	$3.8	$0.0	$0.0	$0.0	$0.0	$3.8	2.4%
12	Capital Hill - Chemical	Line	AEP	$1.6	($0.7)	$0.4	$2.7	$0.0	$0.0	$0.0	$0.0	$2.7	1.7%
13	Nottingham	Other	PECO	$3.2	$0.5	($0.0)	$2.6	$0.0	$0.0	$0.0	$0.0	$2.6	1.7%
14	Nelson	Flowgate	MISO	($1.7)	($4.2)	($0.1)	$2.4	$0.0	$0.0	$0.0	$0.0	$2.4	1.5%
15	Piney Grove	Transformer	DPL	($0.7)	($0.6)	($0.4)	($0.5)	($2.1)	($4.4)	$0.6	$2.9	$2.4	1.5%
16	Jenkins - Susquehanna	Line	PPL	$1.4	($1.1)	($0.1)	$2.4	$0.0	$0.0	$0.0	$0.0	$2.4	1.5%
17	Loretto - Vienna	Line	DPL	$2.3	$0.5	$0.5	$2.3	$0.0	($0.0)	($0.0)	($0.0)	$2.3	1.4%
18	Byron - Cherry Valley	Flowgate	MISO	($0.5)	($2.8)	($0.0)	$2.3	$0.0	$0.0	$0.0	$0.0	$2.3	1.4%
19	Conastone - Peach Bottom	Line	500	$2.0	$0.1	$0.1	$2.0	$0.1	($0.0)	$0.1	$0.1	$2.2	1.4%
20	AEP - DOM	Interface	500	$1.1	($1.2)	$0.2	$2.5	($0.0)	$0.1	($0.3)	($0.4)	$2.1	1.3%
21	Nelson - Garden Plain	Line	ComEd	$0.2	($0.1)	$0.1	$0.4	($1.8)	$0.3	($0.4)	($2.5)	($2.1)	(1.3%)
22	Bagley - Raphaerd	Line	BGE	$1.9	$0.2	($0.1)	$1.6	($0.0)	($0.1)	$0.1	$0.1	$1.7	1.1%
23	Bagley - Graceton	Line	BGE	$1.4	($0.3)	$0.0	$1.7	($0.0)	$0.0	$0.1	$0.0	$1.7	1.1%
24	Nelson	Transformer	ComEd	$0.0	$0.0	$0.0	$0.0	($0.2)	$0.9	($0.6)	($1.7)	($1.7)	(1.1%)
25	Crozet - Dooms	Line	Dominion	$1.5	($0.1)	$0.1	$1.7	$0.2	$0.4	$0.1	($0.1)	$1.6	1.0%

Table 11-25 Top 25 constraints affecting PJM congestion costs (By facility): January 1 through March 31, 2016

				Congestion Costs (Millions)									Percent of Total PJM Congestion Costs
				Day Ahead				Balancing					
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	2016 (Jan - Mar)
1	Graceton	Transformer	BGE	$17.7	($11.5)	($1.8)	$27.4	($0.5)	($0.9)	$2.0	$2.4	$29.8	10.2%
2	Bagley - Graceton	Line	BGE	$21.5	($1.8)	($1.4)	$21.8	$0.6	($1.2)	$1.2	$3.0	$24.8	8.5%
3	Conastone - Northwest	Line	BGE	$20.1	($4.4)	($2.0)	$22.5	$0.5	$0.4	$2.2	$2.3	$24.8	8.5%
4	Milford - Steele	Line	DPL	($8.3)	($25.7)	$0.1	$17.5	$2.2	$1.4	($1.7)	($0.9)	$16.6	5.7%
5	Person - Halifax	Flowgate	MISO	$29.9	$16.1	($0.2)	$13.5	$0.0	$0.0	($0.2)	($0.2)	$13.3	4.5%
6	Kanawha River - Matt Funk	Line	AEP	$2.7	($17.1)	($1.1)	$18.8	($0.7)	$2.5	($3.3)	($6.6)	$12.2	4.2%
7	Loudoun	Transformer	500	$1.1	($9.8)	($0.3)	$10.6	$0.8	$0.7	$0.5	$0.6	$11.1	3.8%
8	AP South	Interface	500	$8.8	($3.2)	($1.2)	$10.7	$0.0	$0.0	$0.0	$0.0	$10.7	3.7%
9	Mercer IP - Galesburg	Flowgate	MISO	($7.3)	($23.2)	($2.8)	$13.1	($0.0)	$2.2	($0.8)	($3.0)	$10.1	3.4%
10	Conastone - Peach Bottom	Line	500	$5.8	($2.6)	($0.2)	$8.2	$0.7	$1.0	$0.4	$0.1	$8.3	2.8%
11	Cherry Valley	Transformer	ComEd	$7.3	($8.2)	$1.1	$16.5	($2.6)	$1.5	($4.2)	($8.3)	$8.2	2.8%
12	Bedington - Black Oak	Interface	500	$4.5	($4.2)	($0.7)	$8.0	$0.1	$0.1	$0.2	$0.2	$8.2	2.8%
13	Cherry Valley	Flowgate	MISO	($0.4)	($7.6)	$0.4	$7.7	$0.0	$0.0	$0.0	$0.0	$7.7	2.6%
14	Cherry Valley - Silver Lake	Flowgate	MISO	($1.3)	($7.2)	$0.7	$6.6	$0.0	$0.0	$0.0	$0.0	$6.6	2.3%
15	Kanawha	Transformer	AEP	$0.1	($5.7)	$0.3	$6.1	$0.0	$0.0	$0.0	$0.0	$6.1	2.1%
16	Mardela - Vienna	Line	DPL	($1.4)	($3.5)	($0.1)	$2.0	($0.6)	($4.1)	$0.5	$4.0	$6.0	2.1%
17	AEP - DOM	Interface	500	$1.4	($2.6)	$0.7	$4.7	$0.2	($0.0)	$0.1	$0.4	$5.1	1.7%
18	Meadow Brook - Strasburg	Line	AP	$8.0	$4.1	($0.2)	$3.6	($0.9)	($0.7)	$0.9	$0.6	$4.2	1.5%
19	Bremo	Transformer	Dominion	($1.4)	($5.1)	$0.3	$4.0	$0.0	$0.0	$0.0	$0.0	$4.0	1.4%
20	Braidwood - East Frankfurt	Flowgate	MISO	($0.0)	($3.2)	$0.4	$3.6	$0.0	$0.0	$0.0	$0.0	$3.6	1.2%
21	Kammer	Transformer	AEP	($1.3)	($5.5)	($0.2)	$4.0	$0.3	$0.6	($0.5)	($0.8)	$3.2	1.1%
22	Batesville - Hubble	Flowgate	MISO	($1.2)	($4.5)	($0.3)	$3.0	$0.2	($0.2)	($0.5)	($0.2)	$2.8	1.0%
23	Monroe - Vineland	Line	AECO	$6.4	$4.7	$1.7	$3.4	($1.0)	($1.6)	($1.3)	($0.6)	$2.7	0.9%
24	Richmond - Waneeta	Line	PECO	$0.5	($2.0)	$0.0	$2.5	$0.1	$0.6	$0.7	$0.2	$2.7	0.9%
25	Braidwood - East Frankfort	Line	ComEd	($0.1)	($2.6)	$0.1	$2.6	$0.0	$0.0	$0.0	$0.0	$2.6	0.9%

Figure 11-2 shows the locations of the top 10 constraints by total congestion costs on a contour map of the real-time, load-weighted, average CLMP in the first three months of 2017. Figure 11-3 shows the locations of the top 10 constraints by balancing congestion costs on a contour map of the real-time, load-weighted, average CLMP in the first three months of 2017. Figure 11-4 shows the locations of the top 10 constraints by day-ahead congestion costs on a contour map of the day-ahead, load-weighted, average CLMP in the first three months of 2017.

Figure 11-2 Location of the top 10 constraints by PJM total congestion costs: January 1 through March 31, 2017

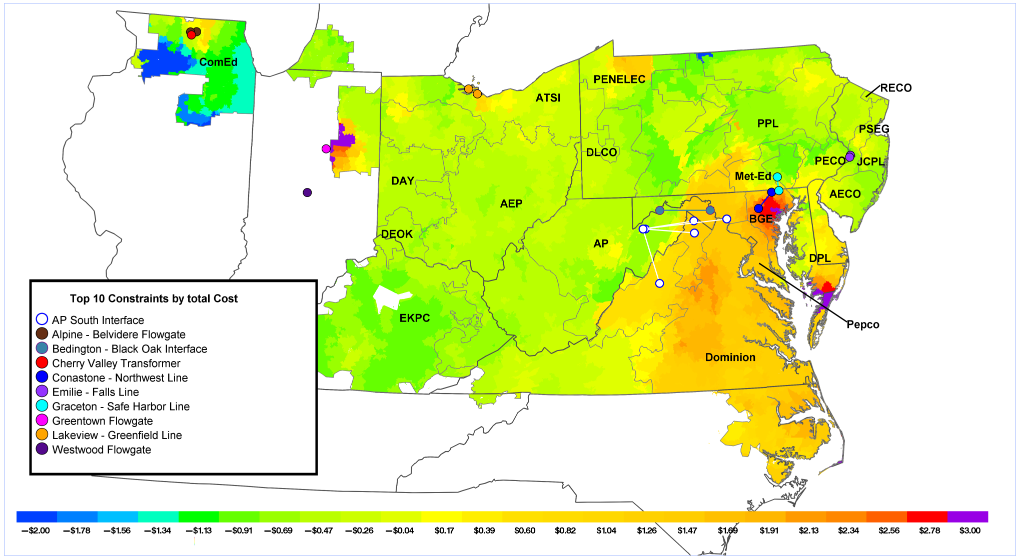


Figure 11-3 Location of the top 10 constraints by PJM balancing congestion costs: January 1 through March 31, 2017

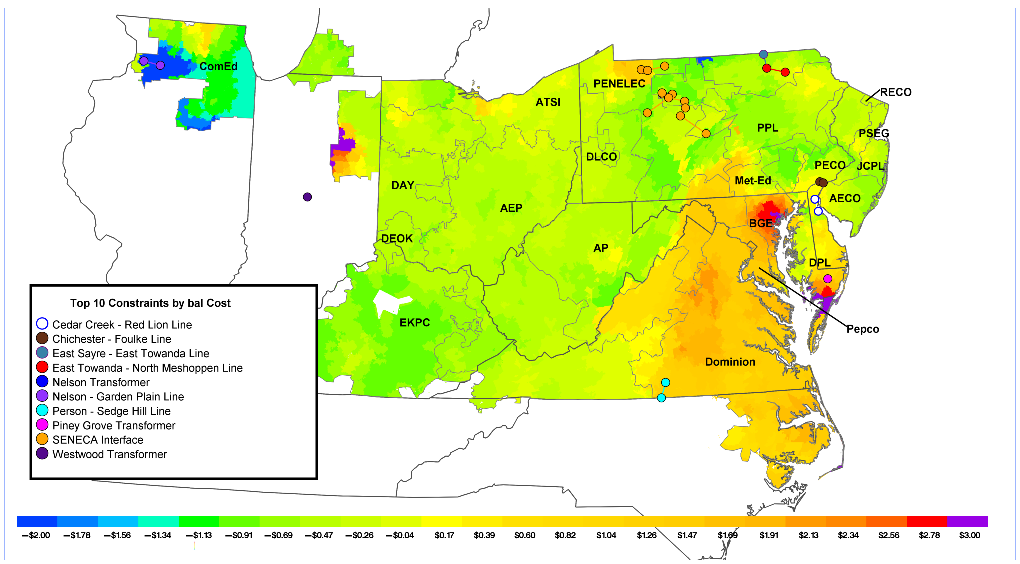
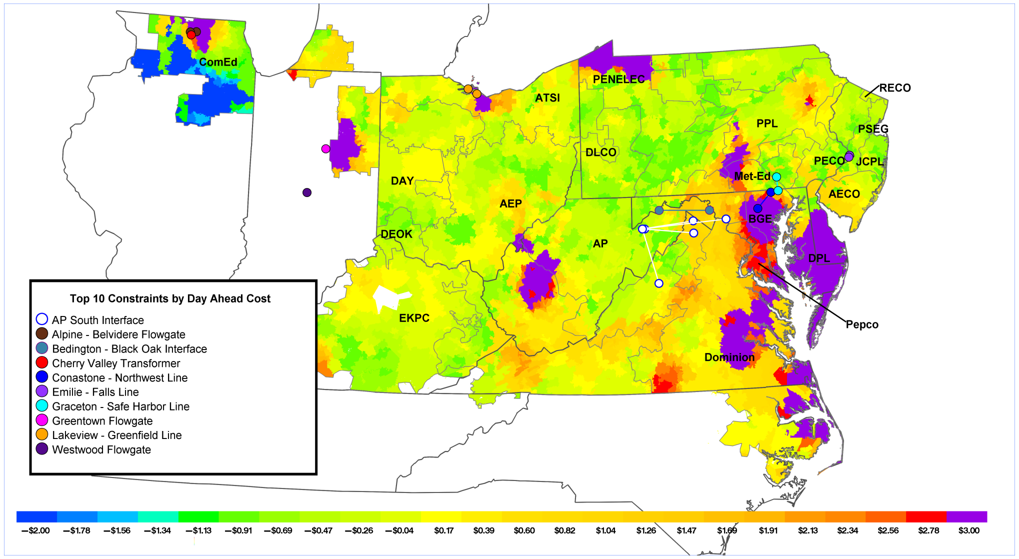


Figure 11-4 Location of the top 10 constraints by PJM day-ahead congestion costs: January 1 through March 31, 2017



Congestion-Event Summary for MISO Flowgates

PJM and MISO have a joint operating agreement (JOA) which defines a coordinated methodology for congestion management. This agreement establishes reciprocal, coordinated flowgates in the combined footprint whose operating limits are respected by the operators of both organizations.[21] A flowgate is a facility or group of facilities that may act as constraint points on the regional system.[22] PJM models these coordinated flowgates and controls for them in its security-constrained, economic dispatch.

As of March 31, 2017, PJM had 151 flowgates eligible for M2M (Market to Market) coordination and MISO had 270 flowgates eligible for M2M coordination.

21 See "Joint Operating Agreement Between the Midwest Independent Transmission System Operator, Inc. and PJM Interconnection, L.L.C.," (December 11, 2008), Section 6.1, Effective Date: May 30, 2016. <http://www.pjm.com/documents/agreements.aspx>.

22 See "Joint Operating Agreement Between the Midwest Independent Transmission System Operator, Inc. and PJM Interconnection, L.L.C.," (December 11, 2008), Section 2.2.24, Effective Date: February 14, 2017. <http://www.pjm.com/documents/agreements.aspx>.

Table 11-26 and Table 11-27 show the MISO flowgates which PJM and/or MISO took dispatch action to control during the first three months of 2017 and 2016, and which had the greatest congestion cost impact on PJM. Total congestion costs associated with a given constraint may be positive or negative in value. The top congestion cost impacts for MISO flowgates affecting PJM and MISO dispatch are presented by constraint, in descending order of the absolute value of total congestion costs. Among MISO flowgates in the first three months of 2017, the Alpine – Belvidere Flowgate made the most significant contribution to positive congestion while the Rising Flowgate made the most significant contribution to negative congestion.

Table 11-26 Top 20 congestion cost impacts from MISO flowgates affecting PJM dispatch (By facility): January 1 through March 31, 2017

		Congestion Costs (Millions)										
		Day Ahead				Balancing					Event Hours	
No.	Constraint	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	Alpine - Belvidere	($2.3)	($14.0)	($0.9)	$10.8	$0.0	$0.0	$0.0	$0.0	$10.8	339	0
2	Westwood	($9.5)	($17.3)	($0.4)	$7.4	$1.2	$0.8	($0.5)	($0.1)	$7.3	1,477	198
3	Greentown	($1.4)	($7.6)	($0.7)	$5.6	($0.8)	($0.2)	$1.1	$0.5	$6.1	425	248
4	Nelson	($1.7)	($4.2)	($0.1)	$2.4	$0.0	$0.0	$0.0	$0.0	$2.4	343	0
5	Byron - Cherry Valley	($0.5)	($2.8)	($0.0)	$2.3	$0.0	$0.0	$0.0	$0.0	$2.3	94	0
6	Reynolds - Magnetation	($0.2)	($1.3)	$0.3	$1.4	$0.0	($0.0)	($0.1)	($0.0)	$1.4	256	19
7	Westwood	$0.0	$0.0	$0.0	$0.0	$2.4	$0.7	($0.4)	$1.3	$1.3	0	348
8	Eugene - Cayuga	($0.4)	($1.8)	($0.1)	$1.2	$0.2	$0.0	($0.1)	($0.0)	$1.2	262	66
9	Monroe - Lallendorf	($0.3)	($1.7)	($0.4)	$1.0	$0.0	$0.0	$0.0	$0.0	$1.0	37	0
10	Pleasant Prairie - Zion	($0.3)	($1.4)	($0.1)	$1.0	$0.0	$0.0	($0.0)	($0.1)	$1.0	492	100
11	Brokaw - Leroy	$0.1	($0.8)	($0.4)	$0.6	($0.0)	$0.1	$0.3	$0.2	$0.8	330	149
12	Babcock - Stillwell	($0.6)	($1.5)	($0.5)	$0.4	($0.2)	($0.2)	$0.3	$0.3	$0.7	206	102
13	Burnham - Munster	$0.1	($0.5)	$0.0	$0.6	$0.0	$0.0	$0.0	$0.0	$0.6	276	0
14	Shadelnd - Lafaysouth	($0.2)	($0.4)	($0.0)	$0.2	$0.5	$0.0	($0.0)	$0.4	$0.6	60	92
15	Michigan City - Bosserman	$0.0	($0.7)	($0.4)	$0.4	$0.0	$0.0	$0.0	$0.0	$0.4	210	0
16	Rising	$0.0	($0.4)	($0.4)	$0.1	$0.1	$0.1	($0.4)	($0.5)	($0.4)	72	42
17	Nelson - Garden Plain	$0.7	$0.1	($0.2)	$0.4	$0.0	$0.0	$0.0	$0.0	$0.4	347	0
18	Todd Hunter	($0.1)	($0.4)	$0.0	$0.3	$0.0	$0.0	$0.0	$0.0	$0.3	731	0
19	Dumont	$0.0	($0.3)	$0.0	$0.3	$0.0	$0.0	$0.0	$0.0	$0.3	96	0
20	Labadie - Graysum	($0.1)	($0.5)	($0.1)	$0.3	($0.0)	$0.0	($0.0)	($0.0)	$0.2	55	75

Table 11-27 Top 20 congestion cost impacts from MISO flowgates affecting PJM dispatch (By facility): January 1 through March 31, 2016

		Congestion Costs (Millions)										
		Day Ahead				Balancing					Event Hours	
No.	Constraint	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	Person - Halifax	$29.9	$16.1	($0.2)	$13.5	$0.0	$0.0	($0.2)	($0.2)	$13.3	719	5
2	Mercer IP - Galesburg	($7.3)	($23.2)	($2.8)	$13.1	($0.0)	$2.2	($0.8)	($3.0)	$10.1	1,713	549
3	Cherry Valley	($0.4)	($7.6)	$0.4	$7.7	$0.0	$0.0	$0.0	$0.0	$7.7	293	0
4	Cherry Valley - Silver Lake	($1.3)	($7.2)	$0.7	$6.6	$0.0	$0.0	$0.0	$0.0	$6.6	365	0
5	Braidwood - East Frankfurt	($0.0)	($3.2)	$0.4	$3.6	$0.0	$0.0	$0.0	$0.0	$3.6	169	0
6	Batesville - Hubble	($1.2)	($4.5)	($0.3)	$3.0	$0.2	($0.2)	($0.5)	($0.2)	$2.8	284	58
7	Summer ShadeTVA - Summer Shade Tap	($0.2)	($1.4)	($0.1)	$1.1	($2.1)	$0.4	($0.3)	($2.8)	($1.7)	209	26
8	Roxana - Praxair	($0.9)	($2.3)	($1.0)	$0.4	$0.5	($0.3)	($2.4)	($1.6)	($1.2)	662	335
9	Reynolds - Magnetation	($0.5)	($3.2)	$0.3	$3.1	$0.0	$0.7	($1.3)	($2.0)	$1.1	334	205
10	Monroe - Bayshore	($0.2)	($0.8)	($0.1)	$0.5	($0.0)	($0.0)	($0.0)	($0.0)	$0.4	23	18
11	Rantoul - Rantoul Jct	($0.1)	($0.4)	($0.1)	$0.2	$0.0	$0.0	$0.0	$0.0	$0.2	61	0
12	Pleasant Valley - Belvidere	($0.0)	($0.3)	($0.0)	$0.2	$0.0	$0.0	$0.0	$0.0	$0.2	12	0
13	Dixon - McGirr Rd	($0.0)	($0.2)	$0.0	$0.2	$0.0	$0.0	$0.0	$0.0	$0.2	48	0
14	Burnham - Munster	($0.0)	($0.1)	$0.1	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	44	0
15	West Dekalb - Glidden	($0.0)	($0.1)	$0.0	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	59	0
16	Gary Ave	($0.1)	($0.3)	($0.1)	$0.2	$0.0	($0.0)	($0.1)	($0.1)	$0.1	56	12
17	North Champaign - Vermilion	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	($0.1)	($0.1)	($0.1)	0	3
18	Vermilion - Tilton	($0.0)	($0.1)	$0.0	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	56	0
19	Butler - Karns City	$0.1	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	9	4
20	Bunsonville	($0.0)	($0.1)	($0.0)	$0.0	($0.0)	$0.0	$0.0	($0.0)	$0.0	34	0

Congestion-Event Summary for NYISO Flowgates

PJM and NYISO have a joint operating agreement (JOA) which defines a coordinated methodology for congestion management. This agreement establishes a structure and framework for the reliable operation of the interconnected PJM and NYISO transmission systems and efficient market operation through M2M coordination.[23] Only a subset of all transmission constraints that exist in either market are eligible for coordinated congestion management. This subset of transmission constraints is identified as M2M flowgates. Flowgates eligible for the M2M coordination process are called M2M flowgates.[24]

Table 11-28 and Table 11-29 show the NYISO flowgates which PJM and/or NYISO took dispatch action to control during the first three months of 2017 and 2016, and which had the greatest congestion cost impact on PJM.

23 See "New York Independent System Operator, Inc. NYISO Tariffs" (May 26, 2016) Section 35.3.1, Effective Date: January 15, 2013. <http://www.pjm.com/documents/agreements.aspx>.
24 See "New York Independent System Operator, Inc. NYISO Tariffs" (May 26, 2016) Section 35.23, Effective Date: June 11, 2014. <http://www.pjm.com/documents/agreements.aspx>.

Table 11-28 Top congestion cost impacts from NYISO flowgates affecting PJM dispatch (By facility): January 1 through March 31, 2017

				Congestion Costs (Millions)										
				Day Ahead				Balancing					Event Hours	
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	Central East	Flowgate	NYISO	($2.7)	($5.7)	($1.7)	$1.3	$0.2	$0.4	($0.1)	($0.3)	$1.0	515	332

Table 11-29 Top two congestion cost impacts from NYISO flowgates affecting PJM dispatch (By facility): January 1 through March 31, 2016

				Congestion Costs (Millions)										
				Day Ahead				Balancing					Event Hours	
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	Central East	Flowgate	NYISO	$0.0	$0.0	$0.0	$0.0	$0.4	$1.0	$0.2	($0.3)	($0.3)	0	516
2	Dysinger East	Flowgate	NYISO	$0.0	$0.0	$0.0	$0.0	$0.0	($0.0)	$0.0	$0.0	$0.0	0	2

Congestion-Event Summary for the 500 kV System

Constraints on the 500 kV system generally have a regional impact. Table 11-30 and Table 11-31 show the 500 kV constraints affecting congestion costs in PJM for the first three months of 2017 and 2016. Total congestion costs are the sum of the day-ahead and balancing congestion cost components. Total congestion costs associated with a given constraint may be positive or negative in value. The 500 kV constraints affecting congestion costs in PJM are presented by constraint, in descending order of the absolute value of total congestion costs.

Table 11-30 Regional constraints summary (By facility): January 1 through March 31, 2017

				Congestion Costs (Millions)										
				Day Ahead				Balancing					Event Hours	
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	AP South	Interface	500	$6.3	($3.7)	($0.8)	$9.2	($0.0)	$1.3	$0.8	($0.5)	$8.7	376	63
2	Bedington - Black Oak	Interface	500	$2.4	($1.9)	($0.2)	$4.1	($0.0)	$0.2	$0.4	$0.2	$4.3	467	38
3	Conastone - Peach Bottom	Line	500	$2.0	$0.1	$0.1	$2.0	$0.1	($0.0)	$0.1	$0.1	$2.2	450	56
4	AEP - DOM	Interface	500	$1.1	($1.2)	$0.2	$2.5	($0.0)	$0.1	($0.3)	($0.4)	$2.1	298	17
5	West	Interface	500	($0.3)	($1.7)	($0.1)	$1.3	$0.0	$0.0	$0.0	$0.0	$1.3	150	0
6	Three Mile Island	Transformer	500	$0.6	($0.3)	$0.1	$1.0	($0.0)	($0.1)	$0.1	$0.1	$1.1	157	17
7	5004/5005 Interface	Interface	500	($0.3)	($1.3)	($0.2)	$0.7	$0.0	$0.0	$0.0	$0.0	$0.7	47	1
8	East	Interface	500	($0.2)	($0.4)	($0.0)	$0.2	$0.0	$0.0	$0.0	$0.0	$0.2	82	0
9	502 Junction	Transformer	500	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	9	0
10	Elmont	Transformer	500	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	8	0
11	Redlion	Transformer	500	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	1	0
12	Black Oak	Transformer	500	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	1	0

Table 11-31 Regional constraints summary (By facility): January 1 through March 31, 2016

				Congestion Costs (Millions)										
				Day Ahead				Balancing					Event Hours	
No.	Constraint	Type	Location	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total	Day Ahead	Real Time
1	Loudoun	Transformer	500	$1.1	($9.8)	($0.3)	$10.6	$0.8	$0.7	$0.5	$0.6	$11.1	212	45
2	AP South	Interface	500	$8.8	($3.2)	($1.2)	$10.7	$0.0	$0.0	$0.0	$0.0	$10.7	416	0
3	Conastone - Peach Bottom	Line	500	$5.8	($2.6)	($0.2)	$8.2	$0.7	$1.0	$0.4	$0.1	$8.3	502	254
4	Bedington - Black Oak	Interface	500	$4.5	($4.2)	($0.7)	$8.0	$0.1	$0.1	$0.2	$0.2	$8.2	542	52
5	AEP - DOM	Interface	500	$1.4	($2.6)	$0.7	$4.7	$0.2	($0.0)	$0.1	$0.4	$5.1	592	4
6	West	Interface	500	($0.0)	($0.6)	($0.1)	$0.5	$0.0	$0.0	($0.0)	($0.0)	$0.5	38	2
7	5004/5005 Interface	Interface	500	($0.1)	($0.6)	($0.0)	$0.5	$0.0	$0.0	$0.0	$0.0	$0.5	29	0
8	Wylie Ridge	Transformer	500	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	($0.0)	($0.1)	($0.1)	0	6
9	East	Interface	500	($0.0)	($0.1)	($0.0)	$0.1	$0.0	$0.0	$0.0	$0.0	$0.1	27	0
10	Three Mile Island	Transformer	500	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	6	0

Congestion Costs by Physical and Financial Participants

In order to evaluate the recipients and payers of congestion, the MMU categorized all participants in PJM as either physical or financial. Physical entities include utilities and customers which primarily take physical positions in PJM markets. Financial entities include banks and hedge funds which primarily take financial positions in PJM markets. International market participants that primarily take financial positions in PJM markets are generally considered to be financial entities even if they are utilities in their own countries.

Financial entities incurred a net increase in congestion charges between the first three months of 2016 and the first three months of 2017. The result was that financial entities were a net recipient of congestion credits in the first three months of 2016 but a net payer of congestion charges in the first three months of 2017. In the first three months of 2016 financial entities received $18.9 million in net congestion credits. In the first three months of 2017, financial entities paid $1.1 million in net congestion charges. Physical entities incurred a net decrease in total congestion charges between the first three months of 2016 and the first three months of 2017. In the first three months of 2016, physical entities paid $308.9 million in congestion charges. In the first three months of 2017, physical entities paid $156.9 million in congestion charges.

Table 11-32 Congestion cost by type of participant: January 1 through March 31, 2017

	Congestion Costs (Millions)									
	Day Ahead				Balancing					
Participant Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
Financial	$1.8	$0.9	($0.1)	$0.8	($2.9)	$0.1	$3.2	$0.2	$0.0	$1.1
Physical	$22.4	($138.5)	$3.1	$164.1	$2.6	$7.5	($2.3)	($7.2)	$0.0	$156.9
Total	$24.2	($137.7)	$3.0	$164.9	($0.3)	$7.6	$0.9	($6.9)	$0.0	$157.9

Table 11-33 Congestion cost by type of participant: January 1 through March 31, 2016

	Congestion Costs (Millions)									
	Day Ahead				Balancing					
Participant Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
Financial	$2.2	($0.5)	($0.5)	$2.2	($10.4)	($2.5)	($11.0)	($18.9)	$0.0	($16.7)
Physical	$118.0	($193.0)	$9.7	$320.7	$9.3	$14.4	($6.8)	($11.9)	$0.0	$308.9
Total	$120.2	($193.5)	$9.2	$322.9	($1.1)	$11.9	($17.7)	($30.8)	$0.0	$292.2

The increase for financial entities was primarily a result of the positive balancing explicit congestion cost. Explicit congestion costs are the primary source of congestion credits to financial entities, primarily UTCs. Total explicit congestion cost is equal to day-ahead explicit congestion cost plus balancing explicit congestion cost. In the first three months of 2017, the total explicit congestion cost was $3.9 million, of which $3.1 million (78.8 percent) was contributed by UTCs. In the first three months of 2016, the total explicit cost was -$8.5 million, of which -$13.0 million (153.0 percent) was credited to UTCs.

Congestion-Event Summary: Impact of Changes in UTC Volumes

FERC issued a notice, effective September 8, 2014, that UTCs could be liable on a retroactive basis for paying uplift charges.[25] That potential refund period ended, after 15 months, on December 7, 2015.[26]

Day-ahead congestion event hours decreased significantly after September 8, 2014, when UTC activity declined. In the first three months of 2015, the average hourly UTC submitted MW decreased by 73.6 percent and UTC cleared MW decreased 72.3 percent compared to the first three months of 2014. Day-ahead congestion event hours decreased by 55.7 percent from 113,666 congestion event hours in the first three months of 2014 to 50,385 congestion event hours in the first three months of 2016.

Day-ahead congestion event hours increased significantly after December 7, 2015, when UTC activity increased. In the first three months of 2016, the average hourly UTC submitted MW increased 146.1 percent and UTC cleared MW increased 113.6 percent, compared to the first three months of 2015. Day-ahead congestion event hours increased by 31.7 percent from 50,384 congestion event hours in the first three months of 2015 to 66,373 congestion event hours In the first three months of 2016.

In the first three months of 2017, the average hourly UTC submitted MW increased 30.1 percent and UTC cleared MW increased 15.9 percent, compared

25 See 18 CFR § 385.213 (2014).
26 *See* FERC Docket No. EL14-37.

to the first three months of 2016. Day-ahead congestion event hours increased by 22.5 percent from 66,431 congestion event hours in the first three months of 2016 to 81,490 congestion event hours in the first three months of 2017.

Figure 11-5 shows the daily day-ahead and real-time congestion event hours for 2014 through March 2017.

Figure 11-5 Daily congestion event hours: January 1, 2014 through March 31, 2017

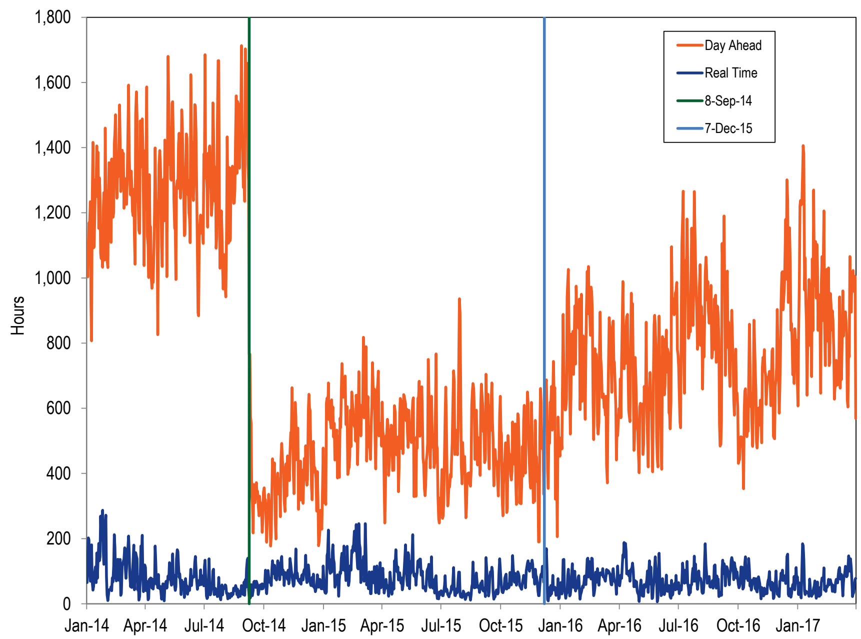
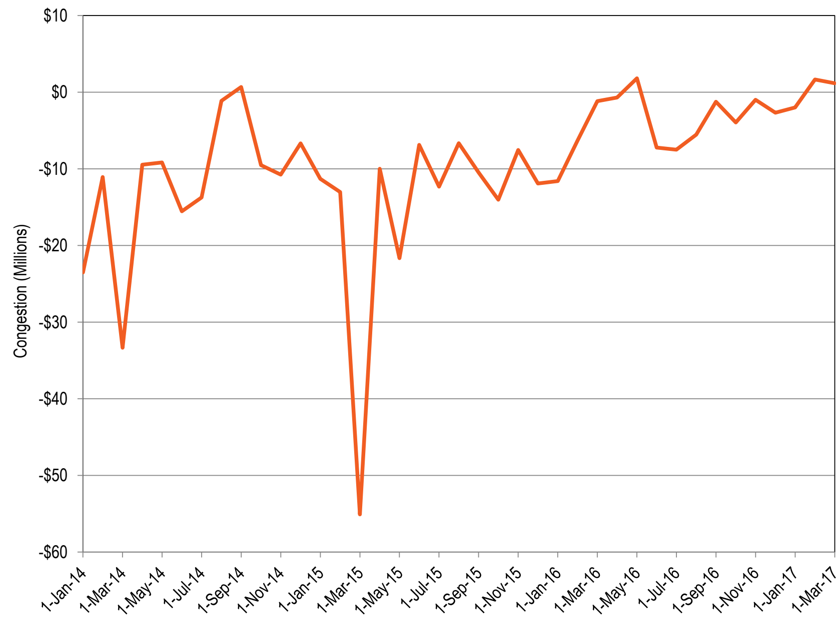


Figure 11-6 shows the change in up to congestion balancing explicit congestion costs from January 1, 2014 through March 31, 2017. Within this period, Figure 11-6 shows the highest monthly payment ($55.1 million) in balancing congestion credits to up to congestion transactions occurred in March of 2015 and the highest monthly charge ($1.8 million) in balancing congestion charges occurred in May of 2016.

Figure 11-6 Monthly balancing congestion cost incurred by up to congestion: January 1, 2014 through March 31, 2017



Marginal Losses

Marginal Loss Accounting

Marginal losses occur in the Day-Ahead and Real-Time Energy Markets. PJM calculates marginal loss costs for each PJM member. The loss cost is based on the applicable day-ahead and real-time marginal loss component of LMP (MLMP). Each PJM member is charged for the cost of losses on the transmission system. Total marginal loss costs, analogous to total congestion costs, are equal to the net of the load loss payments minus generation loss credits, plus explicit loss costs, incurred in both the Day-Ahead Energy Market and the balancing energy market.

Total marginal loss costs can be more accurately thought of as net marginal loss costs. Total marginal loss costs equal net implicit marginal loss costs plus net explicit marginal loss costs plus net inadvertent loss charges. Net implicit marginal loss costs equal load loss payments minus generation loss credits. Net explicit marginal loss costs are the net marginal loss costs associated with point-to-point energy transactions. Net inadvertent loss charges are the losses associated with the hourly difference between the net actual energy flow and the net scheduled energy flow into or out of the PJM control area.[27] Unlike the other categories of marginal loss accounting, inadvertent loss charges are common costs not directly attributable to specific participants. Inadvertent loss charges are assigned to participants based on real-time load (excluding losses) ratio share.[28] Each of these categories of marginal loss costs is comprised of day-ahead and balancing marginal loss costs.

Marginal loss costs can be both positive and negative and consequently load payments and generation credits can also be both positive and negative. Total loss costs, when positive, measure the total loss payment by a PJM member and when negative, measure the total loss credit paid to a PJM member. Load loss payments, when positive, measure the total loss payment by a PJM member and when negative, measure the total loss credit paid to a PJM member. Generation loss credits, when negative, measure the total loss payment by a PJM member and when positive, measure the total loss credit paid to a PJM member.

The loss component of LMP is calculated with respect to the system marginal price (SMP). An increase in generation at a bus that results in an increase in losses will cause the marginal loss component of that bus to be negative. If the increase in generation at the bus results in a decrease of system losses, then the marginal loss component is positive.

Day-ahead marginal loss costs are based on day-ahead MWh priced at the marginal loss price component of LMP. Balancing marginal loss costs are based on the load or generation deviations between the Day-Ahead and Real-Time Energy Markets priced at the marginal loss price component of LMP in the Real-Time Energy Market. If a participant has real-time generation or load that is greater than its day-ahead generation or load then the deviation will be positive. If there is a positive load deviation at a bus where the real-time LMP has a positive marginal loss component, positive balancing marginal loss costs will result. Similarly, if there is a positive load deviation at a bus where real-time LMP has a negative marginal loss component, negative balancing marginal loss costs will result. If a participant has real-time generation or load that is less than its day-ahead generation or load then the deviation will be negative. If there is a negative load deviation at a bus where real-time LMP has a positive marginal loss component, negative balancing marginal loss costs will result. Similarly, if there is a negative load deviation at a bus where real-time LMP has a negative marginal loss component, positive balancing marginal loss costs will result.

The total loss surplus is the remaining loss amount from collection of marginal losses, after accounting for total energy costs and net residual market adjustments that is allocated to PJM market participants based on real-time load plus export ratio share as marginal loss credits.[29]

- **Day-Ahead Load Loss Payments.** Day-ahead load loss payments are calculated for all cleared demand, decrement bids and day-ahead energy market sale transactions. Day-ahead, load loss payments are calculated using MW and the load bus MLMP, the decrement bid MLMP or the MLMP at the source of the sale transaction.
- **Day-Ahead Generation Loss Credits.** Day-ahead generation loss credits are calculated for all cleared generation and increment offers and day-ahead energy market purchase transactions. Day-ahead, generation loss credits are calculated using MW and the generator bus MLMP, the increment offer MLMP or the MLMP at the sink of the purchase transaction.
- **Balancing Load Loss Payments.** Balancing load loss payments are calculated for all deviations between a PJM member's real-time load and energy sale transactions and their day-ahead cleared demand, decrement bids and energy sale transactions. Balancing, load loss payments are calculated using MW deviations and the real-time MLMP for each bus where a deviation exists.

27 OA. Schedule 1 (PJM Interchange Energy Market) §3.7
28 *Id.*
29 See PJM. "Manual 28: Operating Agreement Accounting," Revision 75 (November 18, 2016), p.70.

- **Balancing Generation Loss Credits.** Balancing generation loss credits are calculated for all deviations between a PJM member's real-time generation and energy purchase transactions and the day-ahead cleared generation, increment offers and energy purchase transactions. Balancing, generation loss credits are calculated using MW deviations and the real-time MLMP for each bus where a deviation exists.
- **Explicit Loss Costs.** Explicit loss costs are the net loss costs associated with point to point energy transactions, including UTCs. These costs equal the product of the transacted MW and MLMP differences between sources (origins) and sinks (destinations) in the Day-Ahead Energy Market. Balancing energy market explicit loss costs equal the product of the differences between the real-time and day-ahead transacted MW and the differences between the real-time MLMP at the transactions' sources and sinks.
- **Inadvertent Loss Charges.** Inadvertent loss charges are the net loss charges resulting from the differences between the net actual energy flow and the net scheduled energy flow into or out of the PJM control area each hour. This inadvertent interchange of energy may be positive or negative, where positive interchange typically results in a charge while negative interchange typically results in a credit. Inadvertent loss charges are common costs, not directly attributable to specific participants, that are distributed on a load ratio basis.[30]

Total Marginal Loss Cost

The total marginal loss cost in PJM for the first three months of 2017 was $171.5 million, which was comprised of load loss payments of -$13.0 million, generation loss credits of -$196.2 million, explicit loss costs of -$11.6 million and inadvertent loss charges of $0.0 million. Monthly marginal loss costs in the first three months of 2017 ranged from $46.4 million in February to $62.8 million in March. Total marginal loss surplus decreased in the first three months of 2017 by $6.3 million or 11.3 percent from $55.7 million in the first three months of 2016 to $49.4 million in the first three months of 2017.

Table 11-34 shows the total marginal loss costs as a component of total energy related costs for January 1 through March 31, 2009 through 2017.

Table 11-34 Total component costs (Dollars (Millions)): January 1 through March 31, 2009 through 2017[31]

(Jan - Mar)	Loss Costs	Percent Change	Total PJM Billing	Percent of PJM Billing
2009	$454	NA	$7,515	6.0%
2010	$417	(8.2%)	$8,415	5.0%
2011	$410	(1.7%)	$9,584	4.3%
2012	$234	(42.8%)	$6,938	3.4%
2013	$278	18.5%	$7,762	3.6%
2014	$776	179.5%	$21,070	3.7%
2015	$425	(45.2%)	$14,040	3.0%
2016	$170	(60.0%)	$9,500	1.8%
2017	$172	0.9%	$9,710	1.8%

Table 11-35 shows PJM total marginal loss costs by accounting category for January 1 through March 31, 2009 through 2017. Table 11-36 shows PJM total marginal loss costs by accounting category by market for January 1 through March 31, 2009 through 2017.

Table 11-35 Total PJM marginal loss costs by accounting category (Dollars (Millions)): January 1 through March 31, 2009 through 2017

	Marginal Loss Costs (Millions)				
(Jan - Mar)	Load Payments	Generation Credits	Explicit Costs	Inadvertent Charges	Total
2009	($21.3)	($460.6)	$14.7	$0.0	$454.0
2010	($3.8)	($414.1)	$6.3	($0.0)	$416.6
2011	($26.5)	($421.2)	$14.9	$0.0	$409.6
2012	($11.2)	($252.1)	($6.6)	$0.0	$234.3
2013	$8.0	($277.8)	($8.2)	($0.0)	$277.6
2014	($15.1)	($813.7)	($22.8)	$0.0	$775.9
2015	($4.0)	($434.0)	($4.9)	$0.0	$425.1
2016	($8.0)	($184.4)	($6.3)	$0.0	$170.1
2017	($13.0)	($196.2)	($11.6)	($0.0)	$171.5

30 OA. Schedule 1 (PJM Interchange Energy Market) §3.7.

31 The loss costs include net inadvertent charges.

Table 11-36 Total PJM marginal loss costs by accounting category by market (Dollars (Millions)): January 1 through March 31, 2009 through 2017

	Marginal Loss Costs (Millions)									
	Day-Ahead				Balancing					
(Jan - Mar)	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
2009	($23.3)	($457.6)	$30.9	$465.2	$2.1	($3.0)	($16.3)	($11.2)	$0.0	$454.0
2010	($8.5)	($413.5)	$12.8	$417.8	$4.7	($0.6)	($6.5)	($1.2)	($0.0)	$416.6
2011	($37.1)	($430.1)	$26.0	$419.1	$10.6	$8.9	($11.1)	($9.5)	$0.0	$409.6
2012	($16.7)	($256.8)	$8.0	$248.1	$5.6	$4.7	($14.6)	($13.8)	$0.0	$234.3
2013	($0.1)	($288.2)	$8.1	$296.2	$8.1	$10.4	($16.3)	($18.6)	($0.0)	$277.6
2014	($48.6)	($847.4)	$32.3	$831.1	$33.5	$33.7	($55.1)	($55.3)	$0.0	$775.9
2015	($17.4)	($441.6)	$7.8	$432.0	$13.5	$7.6	($12.8)	($6.9)	$0.0	$425.1
2016	($10.7)	($186.3)	$7.6	$183.3	$2.7	$1.9	($14.0)	($13.2)	$0.0	$170.1
2017	($15.1)	($197.5)	$17.5	$199.9	$2.1	$1.3	($29.1)	($28.3)	($0.0)	$171.5

Table 11-37 and Table 11-38 show the total loss costs for each transaction type in the first three months of 2017 and 2016. In the first three months of 2017, generation paid loss costs of $183.3 million, 106.9 percent of total loss costs. In the first three months of 2016, generation paid loss costs of $167.4 million, 98.4 percent of total loss costs.

Virtual transaction loss costs, when positive, measure the total loss costs to virtual transactions and when negative, measure the total loss credits to virtual transaction. In the first three months of 2017, DECs were paid $2.3 million in loss credits in the day-ahead market, paid $1.1 million in congestion costs in the balancing energy market and received $1.2 million in net payment for losses. In the first three months of 2017, INCs paid $5.4 million in loss costs in the day-ahead market, were paid $4.4 million in congestion credits in the balancing energy market and paid $1.0 million in net payment for losses. In the first three months of 2017, up to congestion paid $17.3 million in the day-ahead market, were paid $29.2 million in loss credits in the balancing energy market and received $11.9 million in net payment for losses.

Table 11-37 Total PJM loss costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2017

	Loss Costs (Millions)									
	Day-Ahead				Balancing					
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
DEC	($2.3)	$0.0	$0.0	($2.3)	$1.1	$0.0	$0.0	$1.1	$0.0	($1.2)
Demand	($1.8)	$0.0	$0.0	($1.8)	$2.1	$0.0	$0.0	$2.1	$0.0	$0.4
Demand Response	($0.0)	$0.0	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Export	($5.0)	$0.0	$0.0	($5.0)	($2.1)	$0.0	$0.3	($1.9)	$0.0	($6.8)
Generation	$0.0	($185.0)	$0.0	$185.0	$0.0	$1.7	$0.0	($1.7)	$0.0	$183.3
Grandfathered Overuse	$0.0	$0.0	($0.1)	($0.1)	$0.0	$0.0	($0.1)	($0.1)	$0.0	($0.2)
Import	$0.0	($1.0)	$0.0	$1.0	$0.0	($5.8)	($0.1)	$5.7	$0.0	$6.7
INC	$0.0	($5.4)	$0.0	$5.4	$0.0	$4.4	$0.0	($4.4)	$0.0	$1.0
Internal Bilateral	($6.0)	($6.0)	$0.0	($0.0)	$1.0	$1.0	$0.0	($0.0)	$0.0	($0.0)
Up to Congestion	$0.0	$0.0	$17.3	$17.3	$0.0	$0.0	($29.2)	($29.2)	$0.0	($11.9)
Wheel In	$0.0	$0.0	$0.3	$0.3	$0.0	$0.0	($0.0)	($0.0)	$0.0	$0.3
Total	($15.1)	($197.5)	$17.5	$199.9	$2.1	$1.3	($29.1)	($28.3)	$0.0	$171.5

Table 11-38 Total PJM loss costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2016

	Loss Costs (Millions)									
	Day-Ahead				Balancing					
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
DEC	$0.4	$0.0	$0.0	$0.4	($0.7)	$0.0	$0.0	($0.7)	$0.0	($0.3)
Demand	($1.0)	$0.0	$0.0	($1.0)	$2.6	$0.0	$0.0	$2.6	$0.0	$1.6
Demand Response	($0.0)	$0.0	$0.0	($0.0)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Export	($3.6)	$0.0	$0.1	($3.6)	($0.1)	$0.0	$0.3	$0.2	$0.0	($3.4)
Generation	$0.0	($173.8)	$0.0	$173.8	$0.0	$6.5	$0.0	($6.5)	$0.0	$167.4
Grandfathered Overuse	$0.0	$0.0	($0.2)	($0.2)	$0.0	$0.0	($0.0)	($0.0)	$0.0	($0.2)
Import	$0.0	($3.0)	$0.5	$3.6	$0.0	($8.3)	$0.3	$8.6	$0.0	$12.2
INC	$0.0	($3.1)	$0.0	$3.1	$0.0	$2.9	$0.0	($2.9)	$0.0	$0.2
Internal Bilateral	($6.4)	($6.3)	$0.0	($0.0)	$0.8	$0.8	$0.0	($0.0)	$0.0	($0.0)
Up to Congestion	$0.0	$0.0	$6.9	$6.9	$0.0	$0.0	($14.5)	($14.5)	$0.0	($7.7)
Wheel In	$0.0	$0.0	$0.3	$0.3	$0.0	$0.0	$0.0	$0.0	$0.0	$0.4
Total	($10.7)	($186.3)	$7.6	$183.3	$2.7	$1.9	($14.0)	($13.2)	$0.0	$170.1

Monthly Marginal Loss Costs

Table 11-39 shows a monthly summary of marginal loss costs by market type for January 1, 2016 through March 31, 2017.

Table 11-39 Monthly marginal loss costs by market (Millions): January 1, 2016 through March 31, 2017

	Marginal Loss Costs (Millions)							
	2016				2017			
	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total
Jan	$78.2	($6.2)	$0.0	$72.0	$75.5	($13.2)	($0.0)	$62.3
Feb	$61.3	($3.8)	$0.0	$57.5	$54.2	($7.8)	$0.0	$46.4
Mar	$43.8	($3.2)	($0.0)	$40.6	$70.2	($7.4)	$0.0	$62.8
Apr	$52.1	($6.0)	$0.0	$46.1				
May	$40.4	($3.9)	($0.0)	$36.6				
Jun	$59.6	($6.5)	($0.0)	$53.1				
Jul	$93.8	($7.5)	($0.0)	$86.4				
Aug	$95.6	($9.8)	($0.0)	$85.8				
Sep	$70.6	($6.6)	($0.0)	$64.0				
Oct	$51.6	($6.6)	($0.0)	$45.0				
Nov	$49.0	($6.9)	($0.0)	$42.1				
Dec	$77.2	($9.7)	($0.0)	$67.5				
Total	$773.2	($76.7)	($0.0)	$696.5	$199.9	($28.3)	($0.0)	$171.5

Figure 11-7 shows PJM monthly marginal loss costs for January 1, 2009 through March 31, 2017.

Figure 11-7 PJM monthly marginal loss costs (Dollars (Millions)): January 1, 2009 through March 31, 2017

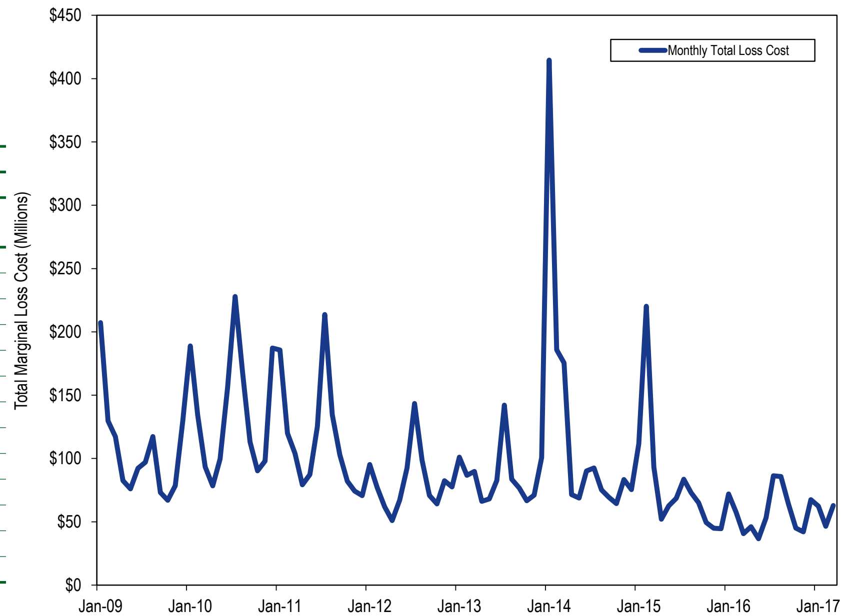


Table 11-40 and Table 11-41 show the monthly total loss costs for each virtual transaction type in the first three months of 2017 and 2016.

Table 11-40 Monthly PJM loss costs by virtual transaction type and by market (Dollars (Millions)): January 1 through March 31, 2017

	Loss Costs (Millions)								
	Day-Ahead				Balancing				
	DEC	INC	Up to Congestion	Virtual Total	DEC	INC	Up to Congestion	Virtual Total	Virtual Grand Total
Jan	($0.6)	$1.5	$6.7	$7.6	($0.0)	($1.3)	($13.4)	($14.7)	($7.1)
Feb	($0.6)	$1.3	$5.3	$6.0	$0.4	($1.1)	($7.7)	($8.4)	($2.4)
Mar	($1.1)	$2.6	$5.3	$6.7	$0.7	($2.0)	($8.1)	($9.3)	($2.6)
Total	($2.3)	$5.4	$17.3	$20.4	$1.1	($4.4)	($29.2)	($32.5)	($12.2)

Table 11-41 Monthly PJM loss costs by virtual transaction type and by market (Dollars (Millions)): 2016

	Loss Costs (Millions)								
	Day-Ahead				Balancing				
	DEC	INC	Up to Congestion	Virtual Total	DEC	INC	Up to Congestion	Virtual Total	Virtual Grand Total
Jan	$0.3	$1.2	$3.7	$5.1	($0.6)	($1.1)	($6.8)	($8.5)	($3.3)
Feb	$0.1	$0.8	$1.9	$2.8	($0.0)	($0.8)	($4.3)	($5.2)	($2.4)
Mar	($0.0)	$1.1	$1.3	$2.4	($0.1)	($1.0)	($3.4)	($4.5)	($2.0)
Apr	($0.1)	$1.0	$3.9	$4.8	($0.1)	($0.8)	($6.3)	($7.3)	($2.5)
May	($0.3)	$0.7	$2.1	$2.4	$0.0	($0.5)	($4.7)	($5.2)	($2.8)
Jun	($0.7)	$1.0	$4.8	$5.1	$0.7	($1.0)	($7.6)	($7.9)	($2.8)
Jul	($1.0)	$1.4	$5.8	$6.2	$0.7	($1.2)	($8.5)	($9.0)	($2.7)
Aug	($0.5)	$1.0	$7.7	$8.2	$0.4	($1.3)	($11.6)	($12.5)	($4.3)
Sep	($0.7)	$0.8	$5.0	$5.1	$0.5	($1.1)	($7.0)	($7.6)	($2.5)
Oct	($0.8)	$0.9	$4.6	$4.7	$0.5	($0.7)	($6.3)	($6.5)	($1.8)
Nov	($0.3)	$0.8	$4.6	$5.1	($0.3)	($0.7)	($6.9)	($7.9)	($2.8)
Dec	($1.1)	$1.1	$6.3	$6.3	$0.5	($0.9)	($11.3)	($11.7)	($5.3)
Total	($5.2)	$11.9	$51.6	$58.3	$2.2	($11.1)	($84.8)	($93.7)	($35.4)

Marginal Loss Costs and Loss Credits

Total loss surplus are calculated by adding the total energy costs, the total marginal loss costs and net residual market adjustments. The total energy costs are equal to the net implicit energy costs (load energy payments minus generation energy credits) plus net explicit energy costs plus net inadvertent energy charges. Total marginal loss costs are equal to the net implicit marginal loss costs (generation loss credits less load loss payments) plus net explicit loss costs plus net inadvertent loss charges.

Ignoring interchange, total generation MWh must be greater than total load MWh in any hour in order to provide for losses. Since the hourly integrated energy component of LMP is the same for every bus within every hour, the net energy bill is negative (ignoring net interchange), with more generation credits than load payments in every hour. Total energy costs plus total marginal loss costs plus net residual market adjustments equal marginal loss credits which are distributed to the PJM market participants according to the ratio of their real-time load plus their real-time exports to total PJM real-time load plus real-time exports as marginal loss credits. The net residual market adjustment is calculated as known day-ahead error value minus day-ahead loss MW congestion value and minus balancing loss MW congestion value.

Table 11-42 shows the total energy costs, the total marginal loss costs collected, the net residual market adjustments and total marginal loss credits redistributed for January 1 through March 31, 2009 through 2017. The total marginal loss surplus decreased $6.3 million in the first three months of 2017 from the first three months of 2016.

Table 11-42 Marginal loss credits (Dollars (Millions)): January 1 through March 31, 2009 through 2017[32]

	Loss Credit Accounting (Millions)					
			Net Residual Market Adjustment			
(Jan - Mar)	Total Energy Charges	Total Marginal Loss Charges	Known Day-ahead Error	Day-ahead Loss MW Congestion	Balancing Loss MW Congestion	Total Loss Surplus
2009	($218.3)	$454.0	$0.0	($0.9)	($0.0)	$236.6
2010	($207.6)	$416.6	$0.0	$0.0	($0.0)	$208.9
2011	($209.9)	$409.6	($0.0)	($0.5)	$0.0	$200.1
2012	($136.4)	$234.3	$0.1	$0.3	$0.0	$97.7
2013	($177.9)	$277.6	$0.1	$0.3	($0.0)	$99.4
2014	($515.3)	$775.9	$0.0	$3.1	$0.2	$257.2
2015	($271.7)	$425.1	($0.5)	$2.9	($0.0)	$150.0
2016	($113.6)	$170.1	$0.0	$0.8	($0.0)	$55.7
2017	($121.9)	$171.5	$0.0	$0.2	($0.0)	$49.4

32 The net residual market adjustments included in the table are comprised of the known day-ahead error value minus the sum of the day-ahead loss MW congestion value, balancing loss MW congestion value and measurement error caused by missing data.

Energy Costs

Energy Accounting

The energy component of LMP is the system reference bus LMP, also called the system marginal price (SMP). The energy cost is based on the day-ahead and real-time energy components of LMP. Total energy costs, analogous to total congestion costs or total loss costs, are equal to the load energy payments minus generation energy credits, plus explicit energy costs, incurred in both the Day-Ahead Energy Market and the balancing energy market, plus net inadvertent energy charges. Total energy costs can by more accurately thought of as net energy costs.

Total Energy Costs

The total energy cost for the first three months of 2017 was -$121.9 million, which was comprised of load energy payments of $8,789.4 million, generation energy credits of $8,910.0 million, explicit energy costs of $0.0 million and inadvertent energy charges of -$1.3 million. The monthly energy costs for the first three months of 2017 ranged from -$48.2 million in January to -$31.8 million in February.

Table 11-43 shows total energy component costs and total PJM billing, for January 1 through March 31, 2009 through 2017. The total energy component costs are net energy costs.

Table 11-43 Total PJM costs by energy component (Dollars (Millions)): January 1 through March 31, 2009 through 2017[33]

(Jan - Mar)	Energy Costs	Percent Change	Total PJM Billing	Percent of PJM Billing
2009	($218)	NA	$7,515	(2.9%)
2010	($208)	(4.9%)	$8,415	(2.5%)
2011	($210)	1.1%	$9,584	(2.2%)
2012	($136)	(35.0%)	$6,938	(2.0%)
2013	($178)	30.4%	$7,762	(2.3%)
2014	($515)	189.7%	$21,070	(2.4%)
2015	($272)	(47.3%)	$14,040	(1.9%)
2016	($114)	(58.2%)	$9,500	(1.2%)
2017	($122)	7.3%	$9,710	(1.3%)

Energy costs for January 1 through March 31, 2009 through 2017 are shown in Table 11-44 and Table 11-45. Table 11-44 shows PJM energy costs by accounting category for January 1 through March 31, 2009 through 2017 and Table 11-45 shows PJM energy costs by market category for January 1 through March 31, 2009 through 2017.

Table 11-44 Total PJM energy costs by accounting category (Dollars (Millions)): January 1 through March 31, 2009 through 2017

	Energy Costs (Millions)				
(Jan - Mar)	Load Payments	Generation Credits	Explicit Costs	Inadvertent Charges	Total
2009	$14,058.4	$14,277.4	$0.0	$0.7	($218.3)
2010	$13,424.4	$13,629.0	$0.0	($3.0)	($207.6)
2011	$11,943.9	$12,160.7	$0.0	$6.9	($209.9)
2012	$8,485.4	$8,628.7	$0.0	$6.8	($136.4)
2013	$10,357.2	$10,535.1	$0.0	($0.0)	($177.9)
2014	$28,506.2	$29,014.7	$0.0	($6.9)	($515.3)
2015	$15,702.1	$15,976.4	$0.0	$2.6	($271.7)
2016	$7,764.7	$7,879.3	$0.0	$1.0	($113.6)
2017	$8,789.4	$8,910.0	$0.0	($1.3)	($121.9)

33 The energy costs include net inadvertent charges.

Table 11-45 Total PJM energy costs by market category (Dollars (Millions)): January 1 through March 31, 2009 through 2017

	Energy Costs (Millions)									
	Day-Ahead				Balancing					
(Jan - Mar)	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Inadvertent Charges	Grand Total
2009	$14,129.6	$14,375.6	$0.0	($246.0)	($71.2)	($98.2)	$0.0	$27.0	$0.7	($218.3)
2010	$13,408.9	$13,619.2	$0.0	($210.2)	$15.5	$9.8	$0.0	$5.6	($3.0)	($207.6)
2011	$12,055.5	$12,259.3	$0.0	($203.9)	($111.6)	($98.6)	$0.0	($12.9)	$6.9	($209.9)
2012	$8,534.4	$8,649.0	$0.0	($114.6)	($49.0)	($20.4)	$0.0	($28.6)	$6.8	($136.4)
2013	$10,387.2	$10,580.9	$0.0	($193.7)	($29.9)	($45.8)	$0.0	$15.9	($0.0)	($177.9)
2014	$28,412.1	$29,082.9	$0.0	($670.9)	$94.2	($68.3)	$0.0	$162.4	($6.9)	($515.3)
2015	$15,764.8	$16,077.5	$0.0	($312.6)	($62.7)	($101.1)	$0.0	$38.4	$2.6	($271.7)
2016	$7,847.5	$7,997.9	$0.0	($150.4)	($82.8)	($118.6)	$0.0	$35.8	$1.0	($113.6)
2017	$8,927.5	$9,111.3	$0.0	($183.8)	($138.1)	($201.3)	$0.0	$63.2	($1.3)	($121.9)

Table 11-46 and Table 11-47 show the total energy costs for each transaction type in the first three months of 2017 and 2016. In the first three months of 2017, generation was paid $5,982.8 million and demand paid $5,766.1 million in net energy payment. In the first three months of 2016, generation was paid $5,383.3 million and demand paid $5,441.3 million in net energy payment.

Table 11-46 Total PJM energy costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2017

	Energy Costs (Millions)								
	Day-Ahead				Balancing				
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total
DEC	$322.0	$0.0	$0.0	$322.0	($320.7)	$0.0	$0.0	($320.7)	$1.2
Demand	$5,782.3	$0.0	$0.0	$5,782.3	($16.1)	$0.0	$0.0	($16.1)	$5,766.1
Demand Response	($0.1)	$0.0	$0.0	($0.1)	$0.1	$0.0	$0.0	$0.1	($0.0)
Export	$189.8	$0.0	$0.0	$189.8	$79.8	$0.0	$0.0	$79.8	$269.6
Generation	$0.0	$6,052.3	$0.0	($6,052.3)	$0.0	($69.5)	$0.0	$69.5	($5,982.8)
Import	$0.0	$33.8	$0.0	($33.8)	$0.0	$137.3	$0.0	($137.3)	($171.1)
INC	$0.0	$391.8	$0.0	($391.8)	$0.0	($388.1)	$0.0	$388.1	($3.7)
Internal Bilateral	$2,633.5	$2,633.5	$0.0	$0.0	$118.9	$118.9	$0.0	$0.0	$0.0
Total	$8,927.5	$9,111.4	$0.0	($184.0)	($138.1)	($201.5)	$0.0	$63.3	($120.6)

Table 11-47 Total PJM energy costs by transaction type by market (Dollars (Millions)): January 1 through March 31, 2016

	Energy Costs (Millions)								
	Day-Ahead				Balancing				
Transaction Type	Load Payments	Generation Credits	Explicit Costs	Total	Load Payments	Generation Credits	Explicit Costs	Total	Grand Total
DEC	$256.1	$0.0	$0.0	$256.1	($246.1)	$0.0	$0.0	($246.1)	$10.0
Demand	$5,436.9	$0.0	$0.0	$5,436.9	$4.4	$0.0	$0.0	$4.4	$5,441.3
Demand Response	($0.2)	$0.0	$0.0	($0.2)	$0.2	$0.0	$0.0	$0.2	($0.0)
Export	$114.9	$0.0	$0.0	$114.9	$31.6	$0.0	$0.0	$31.6	$146.4
Generation	$0.0	$5,559.1	$0.0	($5,559.1)	$0.0	($175.8)	$0.0	$175.8	($5,383.3)
Import	$0.0	$102.0	$0.0	($102.0)	$0.0	$213.5	$0.0	($213.5)	($315.5)
INC	$0.0	$296.9	$0.0	($296.9)	$0.0	($283.4)	$0.0	$283.4	($13.5)
Internal Bilateral	$2,039.9	$2,039.9	$0.0	($0.0)	$127.1	$127.1	$0.0	($0.0)	($0.0)
Total	$7,847.5	$7,997.9	$0.0	($150.4)	($82.8)	($118.6)	$0.0	$35.8	($114.6)

Monthly Energy Costs

Table 11-48 shows a monthly summary of energy costs by market type for January 1, 2016 through March 31, 2017. Marginal total energy costs in the first three months of 2017 decreased from the first three months of 2016. Monthly total energy costs in the first three months of 2017 ranged from -$48.2 million in January to -$31.8 million in February.

Table 11-48 Monthly energy costs by market type (Dollars (Millions)): January 1, 2016 through March 31, 2017

	Energy Costs (Millions)							
	2016				2017			
	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total	Day-Ahead Total	Balancing Total	Inadvertent Charges	Grand Total
Jan	($63.8)	$15.4	$0.6	($47.7)	($75.6)	$28.9	($1.5)	($48.2)
Feb	($50.0)	$11.1	$0.4	($38.5)	($48.3)	$16.5	$0.0	($31.8)
Mar	($36.6)	$9.3	($0.1)	($27.4)	($59.9)	$17.7	$0.2	($42.0)
Apr	($43.6)	$12.7	$0.3	($30.6)				
May	($37.4)	$11.5	($0.3)	($26.1)				
Jun	($50.9)	$17.6	($0.6)	($33.8)				
Jul	($74.3)	$17.5	($0.9)	($57.8)				
Aug	($72.9)	$18.2	($1.2)	($55.9)				
Sep	($54.0)	$14.8	($1.2)	($40.5)				
Oct	($42.7)	$16.4	($3.5)	($29.9)				
Nov	($43.9)	$16.7	($1.5)	($28.8)				
Dec	($70.4)	$22.9	($1.8)	($49.4)				
Total	($640.6)	$184.0	($9.8)	($466.3)	($183.8)	$63.2	($1.3)	($121.9)

Figure 11-8 shows PJM monthly energy costs for January 1, 2009 through March 31, 2017.

Figure 11-8 PJM monthly energy costs (Millions): January 1, 2009 through March 31, 2017

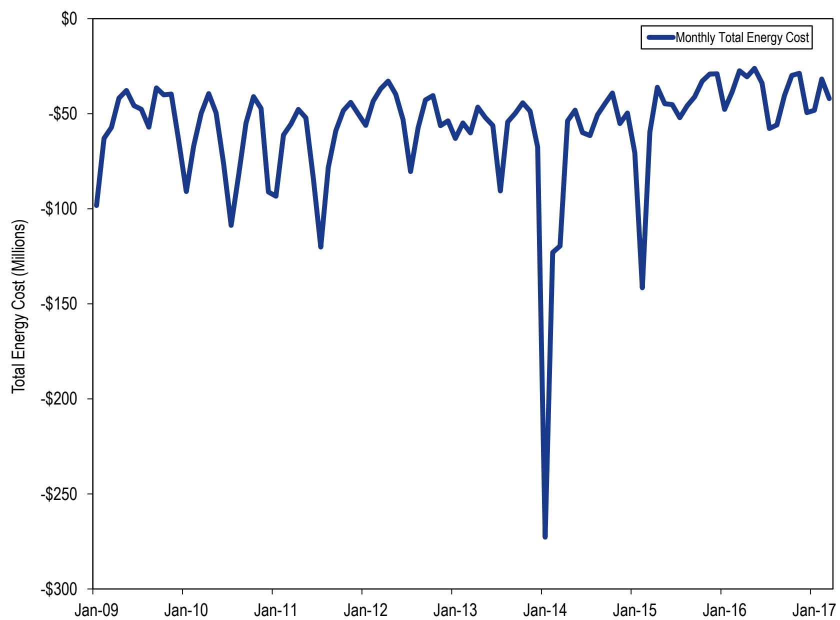


Table 11-49 and Table 11-50 show the monthly total energy costs for each virtual transaction type in the first three months of 2017 and the first three months of 2016. In the first three months of 2017, DECs paid $322.0 million in energy costs in the day-ahead market, were paid $320.7 million in energy credits in the balancing energy market and paid $1.2 million in net payment for energy. In the first three months of 2017, INCs were paid $391.8 million in energy credits in the day-ahead market, paid $388.1 million in energy cost in the balancing market and received $3.7 million in net payment for energy. In the first three months of 2016, DECs paid $256.1 million in energy costs in the day-ahead market, were paid $246.1 million in energy credits in the balancing energy market and paid $10.0 million in net payment for energy. In the first three months of 2016, INCs were paid $296.9 million in energy credits in the day-ahead market, paid $283.4 million in energy cost in the balancing energy market and received $13.5 million in net payment for energy.

Table 11-49 Monthly PJM energy costs by virtual transaction type and by market (Dollars (Millions)): January 1 through March 31, 2017

	Energy Costs (Millions)						
	Day-Ahead			Balancing			
	DEC	INC	Virtual Total	DEC	INC	Virtual Total	Virtual Grand Total
Jan	$115.3	($134.8)	($19.5)	($116.4)	$135.6	$19.2	($0.3)
Feb	$82.8	($107.0)	($24.2)	($79.8)	$103.3	$23.5	($0.7)
Mar	$123.9	($150.0)	($26.1)	($124.5)	$149.2	$24.7	($1.4)
Total	$322.0	($391.8)	($69.8)	($320.7)	$388.1	$67.4	($2.4)

Table 11-50 Monthly PJM energy costs by virtual transaction type and by market (Dollars (Millions)): 2016

	Energy Costs (Millions)						
	Day-Ahead			Balancing			
	DEC	INC	Virtual Total	DEC	INC	Virtual Total	Virtual Grand Total
Jan	$102.0	($109.3)	($7.2)	($101.0)	$106.1	$5.1	($2.1)
Feb	$85.5	($87.5)	($2.1)	($81.3)	$84.3	$3.0	$1.0
Mar	$68.6	($100.2)	($31.6)	($63.8)	$93.0	$29.2	($2.4)
Apr	$84.9	($109.3)	($24.3)	($86.5)	$112.0	$25.6	$1.2
May	$78.3	($87.2)	($8.9)	($79.4)	$86.1	$6.8	($2.1)
Jun	$105.0	($91.0)	$14.0	($110.0)	$94.5	($15.5)	($1.5)
Jul	$139.7	($130.5)	$9.2	($128.9)	$119.4	($9.6)	($0.3)
Aug	$138.1	($119.8)	$18.3	($145.6)	$123.4	($22.2)	($3.8)
Sep	$124.7	($104.7)	$20.0	($124.3)	$104.0	($20.4)	($0.3)
Oct	$111.4	($110.5)	$1.0	($107.4)	$106.9	($0.5)	$0.5
Nov	$84.6	($100.7)	($16.1)	($82.9)	$98.5	$15.6	($0.6)
Dec	$131.2	($124.7)	$6.5	($128.2)	$122.2	($6.1)	$0.4
Total	$1,254.0	($1,275.2)	($21.2)	($1,239.3)	$1,250.4	$11.1	($10.2)