Operational Events and Market Impacts
January 2014 Cold Weather

May 9, 2014
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PJM Interconnection

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PJM Interconnection
Polar Vortex
January 6 - 8

Mike Kormos
Source: University of Illinois at Urbana-Champaign
Maximum Winter Peak Demands

Megawatt

142,000
140,000
138,000
136,000
134,000
132,000
130,000

1/7/2014 p.m.
1/7/2014 a.m.
1/24/2014 a.m.
1/29/2014 p.m.
1/30/2014 a.m.
2/5/2007 p.m.
1/29/2014 a.m.
1/22/2014 p.m.
1/23/2014 p.m.
2/6/2007 a.m.

141,846
January 7 Load Compared to Typical January Day

January 7: Hourly MW Load (Preliminary)

- Morning Peak: 138,733
- Evening Peak: 141,846

Typical January Demand Curve

- Morning Peak: 100,801
- Evening Peak: 106,182

Hour Ending:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
**Forecasting**

- **Jan. 2**: Weather — PJM’s meteorologist began tracking snow storm
- **Jan. 3**: Load — PJM utilized worst-case forecasts of load to proactively prepare

**Operational Planning**

- **Jan. 4**: PJM directed transmission and generation owners to cancel planned outages

- **Jan. 5**: PJM prepared a plan and communicated with stakeholders
- PJM held first operational call with major pipeline operators

- **Jan. 6**: PJM refines plan based on revised forecasts to system conditions
- Unit commitments finalized
- PJM issued alerts and increased frequency of communication

**Advance Communications**

- Gas operators expected tight conditions through January 7
- PJM requested permission to share certain operational info with natural gas pipelines
- FERC Commission granted waiver
<table>
<thead>
<tr>
<th>WEATHER CONDITIONS</th>
<th>Emergency Actions</th>
<th>Operation Expectations</th>
<th>Gas Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snowstorm across PJM Tracking extreme cold</td>
<td>Jan. 2</td>
<td>Issues with oil and emissions</td>
<td>Gas unavailability</td>
</tr>
<tr>
<td>Record low temps</td>
<td>Jan. 6</td>
<td>Voltage reduction and shortage pricing</td>
<td>Concern about reserves and losing units</td>
</tr>
<tr>
<td>Breaking cold weather records</td>
<td>Jan. 7</td>
<td>Reserve action</td>
<td>22% forced outage rate</td>
</tr>
</tbody>
</table>
Polar Vortex – Demand Response

Load Reductions (MW)

- **Jan 7 a.m.**: Expected 101%
- **Jan 7 p.m.**: Expected 76%
- **Jan 8 a.m.**: Expected

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**Notes:**
1. DR events dispatched during non-compliance period.
2. Expected Energy Load Reductions (MW) - CSP reported estimate based on current market rule.
3. MW value is average hourly load reduction for non-ramp in hours.
4. Event on Jan. 8 was cancelled by PJM prior to official start time. In order to honor the Emergency DR resource 2-hour minimum down time, PJM allowed CSPs to settle if their load reduction had started prior to cancellation and/or needed to reduce for 2 hours. PJM estimated amount of DR that needed to continue to reduce for 2 hours. “Performance” for this event cannot be measured based on the circumstances of this event.
Operating Reserves – January 6 Evening Peak

Megawatt

Primary Reserves
Synchronous Reserves
Primary Requirement
Synchronous Requirement

Voltage Reduction Action

4:00 p.m. 4:30 p.m. 5:00 p.m. 5:30 p.m. 6:00 p.m. 6:30 p.m. 7:00 p.m. 7:30 p.m. 8:00 p.m. 8:30 p.m.
Operating Reserves – January 7 Morning Peak

Megawatt

Primary Reserves
Synchronous Reserves
Primary Requirement
Synchronous Requirement

Emergency Energy Requested
Load Trending Down
Polar Vortex – Wind Generation

Wind Generation

Megawatt

Wind Capability

Wind Generation

Wind Capacity

Jan. 6
Jan. 7
Jan. 8
Jan. 9
Forced Outages – January 7 Evening Peak (7pm)

Total Forced Outages
40,200 MW (22% Total PJM Capacity)

Coal
13,700 MW
34%

Gas Plant Outages
9,700 MW
24%

Natural Gas Interruption
9,300 MW
23%

Nuclear
1,400 MW
3%

Other
6,100 MW
15%
Real-Time and Day-Ahead Prices – January 7

$1,841
PJM Real-Time LMP

PJM Day-Ahead LMP

$/MWh
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000

Hour Ending
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Winter Storms
January 17-29

Andy Ott
Minimum Temperatures – January 2014
Columbus, Philadelphia, Chicago and Richmond

Winter Storm

Date
1/1 1/3 1/5 1/7 1/9 1/11 1/13 1/15 1/17 1/19 1/21 1/23 1/25 1/27 1/29 1/31

°F
40 30 20 10 0 -10 -20
## Weather Expectations

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Operation Expectations</th>
<th>Gas Expectations</th>
</tr>
</thead>
</table>
| **Jan. 17**  
Temperatures lower than expected | Unknown forced outage rate                    | Dispatchers contact units on fuel availability | Conditions seem tighter |
| **Jan. 22**  
Max. emergency conditions         | Max. emergency conditions                     | Oil inventories depleted | Critical notices across footprint |
| **Jan. 25**  
Dual fuel units prepare to switch to oil | Lack of oil inventory                        |                        | Weekend packages |
| **Jan. 27**  
Forecasts more severe than actual |                                |                        |                        |
| **Jan. 28-27**  
Snowstorm in the south and east  |                                |                        |                        |
Holiday Considerations

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>PJM</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fri.</td>
<td>Jan. 17</td>
<td>130,000 MW</td>
<td>Generators purchasing gas commodity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>expected peak</td>
<td></td>
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<tr>
<td>Sat.</td>
<td>Jan. 18</td>
<td>127,270 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>expected peak</td>
<td></td>
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<tr>
<td>Sun.</td>
<td>Jan. 19</td>
<td>125,610 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>expected peak</td>
<td></td>
</tr>
<tr>
<td>Mon.</td>
<td>Jan. 20</td>
<td>131,000 MW</td>
<td>10 a.m. Monday</td>
</tr>
<tr>
<td></td>
<td></td>
<td>expected peak</td>
<td>Gas Day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MLK Holiday</td>
<td>10 a.m. Tuesday</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tue.</td>
<td>Jan. 21</td>
<td>129,213 MW</td>
<td>10 a.m. Tuesday</td>
</tr>
<tr>
<td></td>
<td></td>
<td>actual peak</td>
<td>Gas Day</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 a.m. Tuesday</td>
</tr>
<tr>
<td>Wed.</td>
<td>Jan. 22</td>
<td>135,874 MW</td>
<td>10 a.m. Wednesday</td>
</tr>
<tr>
<td></td>
<td></td>
<td>actual peak</td>
<td></td>
</tr>
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Buying for delivery on Jan. 20, 21 & 22
Notes:
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Extraordinary Fuel Price Relationships

- Market East
- Oil - MMBtu Equivalent

Chart showing price trends from January 2013 to March 2014.
Gas Prices (Market East) – January 2014

$/MMbtu

Winter Storm
PJM Load-Weighted LMPs – January 2014

$/MWh

Average of Real-Time LMP

Average of Day-Ahead LMP

Total Balancing Operating Reserves & Lost Opportunity Cost $555 M

- Jan. 3 - Jan. 9 $98 M
- Rest of January $19 M
- Jan. 21 - Jan. 30 $438 M
Balancing Operating Reserves

**Reliability Credit**
- Generator committed in advance of the operating day and outside of the Day-Ahead Market.
- Generator committed during the operating day and is out of the economic meter order.

**Deviation Credit**
- Generator is needed to meet anticipated load plus reserves.
- Generator is committed during the operating day and cost is greater than locational marginal prices most of the time.
Balancing Operating Reserves – January 2014

$ Millions

- Total Deviation Credit
- Total Reliability Credit

Winter Storm
Gas Prices and Reliability Balancing Operating Reserves – January 2014

$ Millions

$MMBtu

[Graph showing the relationship between Total Reliability Credit and Natural Gas Prices over the period from Jan. 1 to Jan. 29, 2014.]
• Improve generator availability and performance during extreme weather events,
• Implement performance verification or testing of generation in advance of winter operations,
• Continue to engage in discussions with industry and regulators to improve natural gas and electricity market alignment,
Key Recommendations (cont.)

• Implement market mechanisms that encourage better generator availability, such as incentives for ensuring fuel availability or dual-fuel capability, and

• Review the cost allocation for uplift charges and investigate a mechanism to allocate uplift costs during emergency operations that minimizes volatility.