Improving Load Forecast with Behind-the-Meter Solar Forecast

Elizabeth Anastasio
Joseph Mulhern

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Categories of Behind the Meter Generation

Installed Capacity of BTM Generation in PJM by Category

- Non-Retail:
  - Solar ≥ 1 MW: 648 MW
  - Non-Solar ≥ 1 MW: 1,219 MW

- Retail:
  - Solar ≥ 1 MW: 2,656 MW
  - Non-Solar ≥ 1 MW: 2,373 MW

Total:
- 1,867 MW (Non-Retail)
- 5,029 MW (Retail)
Categories of Behind the Meter Generation

Installed Capacity of BTM Generation in PJM by Category

- **BTM solar forecast includes units of all sizes, regardless of Retail or Non-Retail status**

<table>
<thead>
<tr>
<th>Category</th>
<th>Installed Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-Retail</strong></td>
<td></td>
</tr>
<tr>
<td>Solar ≥ 1 MW</td>
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</tr>
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<tr>
<td><strong>Retail</strong></td>
<td></td>
</tr>
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</tr>
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<td>2,373 MW</td>
</tr>
</tbody>
</table>

Total Installed Capacity:
- Non-Retail: 1,867 MW
- Retail: 5,029 MW
5-minute granularity for next 6 hours
Hourly granularity for next 7 days

Load

Wind

Solar

By Zone

Grid-Connected by Farm

Grid-Connected by Park

Behind-the-Meter by Zone
# Two Categories of Generation

## High visibility

<table>
<thead>
<tr>
<th>PJM Grid-Connected</th>
<th>Behind the Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned by PJM Members</td>
<td>Owned by individuals or non-members</td>
</tr>
<tr>
<td>Participate in PJM wholesale markets</td>
<td>Do not participate in PJM markets</td>
</tr>
<tr>
<td>Data sent to PJM in queue process</td>
<td>Some limited public data available</td>
</tr>
<tr>
<td>Send real-time output data to PJM</td>
<td>Only some send real-time data to PJM</td>
</tr>
</tbody>
</table>
# Differences Between Grid-Connected and BTM Forecasts

<table>
<thead>
<tr>
<th></th>
<th>PJM Grid-Connected</th>
<th>Behind-the-Meter / Non-Wholesale DER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most granular forecast</strong></td>
<td>Individual site</td>
<td>PJM Transmission Zone</td>
</tr>
<tr>
<td><strong>Data source</strong></td>
<td>Resource owner</td>
<td>Generator Attribute Tracking System</td>
</tr>
<tr>
<td><strong>Static data used in forecast</strong></td>
<td>Installed AC and DC capacities</td>
<td>Installed DC capacity</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>Location</td>
</tr>
<tr>
<td></td>
<td>Fixed vs. tracking status and related details</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Panel make and model</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic data used in forecast</strong></td>
<td>MW telemetry</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Solar irradiance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Back panel temperature</td>
<td></td>
</tr>
</tbody>
</table>
Generator Attribute Tracking System

- Managed by PJM Environmental Information Systems
- Database of renewables, including individual rooftop solar units
Ten Years of Renewable Growth in PJM

**PJM Grid-Connected Solar**

**Behind-the-Meter Solar**

Source: GATS
### Timeline of Solar Forecast Activities and Improvements

<table>
<thead>
<tr>
<th>Year</th>
<th>Applicable to Behind-the-meter forecast</th>
<th>Applicable to Grid-connected forecast</th>
</tr>
</thead>
</table>
| 2016 | • Collect solar park data from Generation Owners  
      • Initiate BTM and grid-connected forecasts | |
| 2017 | • Enhance data requirements in Manual 14D  
      • Share forecasts with Members through Markets Gateway and Data Viewer | |
| 2018 | • Evaluate methods for integrating BTM forecast into load forecast  
      • Implement best performing method into Dispatch tools and processes | |
| 2019 | • Identify opportunities for improving data gathering processes  
      • Study impact of BTM on power flow to enhance transmission analysis | |
Timeline of Solar Forecast Activities and Improvements

2016
- Collect solar park data from Generation Owners
- Initiate BTM and grid-connected forecasts

2017
- Enhance data requirements in Manual 14D
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2018
- Evaluate methods for integrating BTM forecast into load forecast
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2019
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- Study impact of BTM on power flow to enhance transmission analysis
Challenges of Increased BTM Solar Penetration

- Load forecasting challenges
- Transmission congestion risks
- Increased flexibility needs

The duck curve shows steep ramping needs and overgeneration risk.

Sample Net Load – March 31, 2012

(from the California Independent System Operator)
Behind-the-Meter Solar Impacts on Zonal Load

Average March Load in Zone with High Solar Penetration

Reduced load due to increasing BTM solar
Average March Load for Zones with High BTM Solar

Zone 1

Zone 2

Zone 3

Zone 4

Zone 5

Zone 6

Thousands

2019  2017  2015  2013
Changes in Daily Load Shapes

RTO load shape is not representative of load in areas with high BTM solar
Methods of Accounting for BTM Solar in Load Forecast

- **Reconstituted Load**: retraining the existing model(s) to forecast total power used by adding historic measured load and estimated BTM generation, then subtracting forecasted BTM.

- **Error Correction**: manually modifying the existing model(s) by adding or subtracting some of the BTM forecast.

- **Direct Modeling**: adding forecasted BTM as an input variable using new forecast model type.
Train models to forecast total power used instead of net load, then adjust for forecasted BTM output.

Measured Load + BTM Solar = Reconstituted Load
Load Forecast Models for Zone with High BTM Solar Penetration
Load Forecast Models for Zone with High BTM Solar Penetration

Load Actual | Original Forecast | Forecast Using Reconstituted Load Method | BTM Solar Actual

4/3/2018 0:30 to 4/3/2018 12:30
Results from 2017 Test Data

Monthly Improvement with Rec. Load Method
1400 Day Ahead

Percent Improvement

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

-10% -5%  0%  5%  10%  15%  20%  25%  30%

PJM Mid-Atl  Zone 1  Zone 2  Zone 3  Zone 4
Hourly Improvement with Rec. Load Method
1400 Day Ahead
Current Practices

- Load forecast models using Reconstituted Load method are presented to PJM Dispatcher with other load forecast models.
- Dispatcher uses data and experience to manually adjust forecast, which begins as automated composite, for current and next day.
- Evaluate performance of Reconstituted Load forecasts after the fact.
Next Steps

• Based on performance, modify default composite weights to include Reconstituted Load forecasts

• Explore availability of real-time BTM data to validate accuracy

• Assess potential value of sub-zonal load forecasts and/or individual BTM site forecasts to enhance transmission analysis