VELCO Load Curves & PV Penetration

Rob D’Arienzo
Meteorologist
VELCO

Operating Committee Meeting
July 16, 2015
Outline

• Motivation
• Case Studies
• PV Offset Summary
• Distribution of PV Offset (daily + monthly)
• Conclusions
• Future Work
Explosion of renewable generation in VT is creating a “Duck Curve” profile in daily statewide demand. This is largely contributed to PV generation that is “Behind-the-Meter” which is offsetting daily load.
VELCO Load Curve Study
Case #1

Increase of solar generation “behind the meter” is offsetting VELCO demand curve

<table>
<thead>
<tr>
<th></th>
<th>3/30/2015 (Mon)</th>
<th>3/31/2015 (Tue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover</td>
<td>Overcast</td>
<td>Sunny</td>
</tr>
<tr>
<td>High/Low (°F)</td>
<td>41/26</td>
<td>42/24</td>
</tr>
<tr>
<td>Max Radiation (w/m^2)</td>
<td>241</td>
<td>965</td>
</tr>
</tbody>
</table>

VELCO Load Curves (Overcast vs. Sunny Days)
VELCO Load Curve Study
Case #2

Increase of solar generation “behind the meter” is offsetting VELCO demand curve

<table>
<thead>
<tr>
<th></th>
<th>4/6/2015 (Mon)</th>
<th>3/31/2015 (Tue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover</td>
<td>Overcast</td>
<td>Sunny</td>
</tr>
<tr>
<td>High/Low (°F)</td>
<td>45/27</td>
<td>42/24</td>
</tr>
<tr>
<td>Max Radiation (w/m^2)</td>
<td>417</td>
<td>965</td>
</tr>
</tbody>
</table>

VELCO Load Curves (Overcast vs. Sunny Days)
VELCO Load Curve Study
Case #3

Increase of solar generation “behind the meter” is offsetting VELCO demand curve

<table>
<thead>
<tr>
<th></th>
<th>3/3/2015 (Tue)</th>
<th>3/19/2015 (Thu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Cover</td>
<td>Overcast</td>
<td>Sunny</td>
</tr>
<tr>
<td>High/Low (°F)</td>
<td>30/0</td>
<td>28/6</td>
</tr>
<tr>
<td>Max Radiation (w/m^2)</td>
<td>583</td>
<td>820</td>
</tr>
</tbody>
</table>

VELCO Load Curves (Overcast vs. Sunny Days)
PV Offset Summary

<table>
<thead>
<tr>
<th>Month</th>
<th>Correlation^</th>
<th>Average Load Offset* (MW)</th>
<th>Average Solar~ (w/m^2)</th>
<th>Average Temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb</td>
<td>0.69</td>
<td>67.8</td>
<td>108.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Mar</td>
<td>0.74</td>
<td>97.3</td>
<td>149.0</td>
<td>27.4</td>
</tr>
<tr>
<td>Apr</td>
<td>0.37</td>
<td>75.0</td>
<td>176.9</td>
<td>44.0</td>
</tr>
<tr>
<td>May</td>
<td>-0.02</td>
<td>43.4</td>
<td>243.9</td>
<td>61.1</td>
</tr>
</tbody>
</table>

*Correlation calculated was between daily load offset and solar.

*Offset is defined as the difference between the morning maximum load (6AM-12PM) and afternoon minimum load (12PM-6PM). This is identified as the “PV Offset”.

~Average solar calculation included 24hr period (day + night).

Notes:

Rutland, VT (VELCO weather station)
Distribution of PV Offset

Average VELCO Load Curves – Feb through May 2015

Feb $\Delta = 68$ MW
Mar $\Delta = 97$ MW
Apr $\Delta = 75$ MW
May $\Delta = 43$ MW

$\Delta = PV$ Offset
Distribution of PV Offset

\[ y = -0.2504x + 10612 \]
Distribution of PV Offset

Average PV Offset vs. Day of Week

- February
- March
- April
- May

PV Offset (MW)

Monday: 58.7, 96.3
Tuesday: 30.8, 71.2
Wednesday: 45.8, 89.5
Thursday: 51.9, 117
Friday: 34.1, 106.8
Saturday: 37.9, 74.5
Sunday: 38.6, 65.3

Month:
- February
- March
- April
- May
Conclusions

- Large amounts of “Behind the meter” PV is clearly seen when examining the solar radiation received in each of the 3 case studies.
- March 2015 had the highest correlation with regard to load offset and solar radiation (0.74). Following March was February (0.69), April (0.37), and May (-0.02).
- March 2015 also had the highest average load offset (97.3 MW). Following March was April (75 MW), February (68 MW), and May (43 MW).
- Due to the increasing sun angle, average solar rose steadily from February through May. As expected, this also lead to an increase in average temperatures.
Future Work

- Continue analysis to examine load and PV distribution for summer months.
- Examine seasonal peak load days (i.e. winter, spring, summer) to find any additional correlations.
- Begin to utilize demand model forecasts driven by Deep Thunder/VTWAC (once available) to get better guidance on distributed PV at the state and town levels.
Future Work
Future Work

Residual Demand, Burlington Electric Dept.

Forecast Daily Maximum: 56.51 MWh/h
Forecast Daily Maximum: 48.68 MWh/h
Forecast Daily Maximum: 51.28 MWh/h

Measurement
Forecast
Uncertainty
Future Work

Residual Demand, #353: Hinesburg

Forecast Daily Maximum: 2.63 MWh/h
Measurement
Forecast
Uncertainty

Forecast Daily Maximum: 2.26 MWh/h
Forecast Daily Maximum: 2.43 MWh/h
Future Work

Distributed PV, Vermont

Forecast Daily Maximum: 47.15 MWh/h
Forecast Daily Maximum: 59.81 MWh/h
Forecast Daily Maximum: 53.48 MWh/h
Future Work
Questions?