The Effects of Demand Response Programs and Residential Energy Efficiency On Consumer Comfort

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PSERC Webinar
October 21, 2014
Demand Response

- FERC 2009 National Assessment of Demand Response Potential:
  - up to 100 GW, 10%, residential peak demand reduction potential by 2019
  - residential is the largest single contributor with saturation of central a/c the key factor.
  - No improvements assumed to a/c or residential efficiency
  - Report notes efforts to integrate demand response and energy efficiency
  - Also notes lack of data and need for research on combined programs and of energy efficiency alone
Demand Response

- How will improved residential energy efficiency affect electric system energy, system peak demand and the demand reduction available from demand response programs?


- How will demand response programs affect peak demand, total energy consumption, consumer comfort, and economics of residences with different energy efficiency profiles?

Residential Cooling Comfort

• Maintain indoor air temperature of 75°F for 97.5% of the hours from June through September

• Acceptable temperatures: 19-28°C (67-83°F)

• allowable cyclic variation, 15 minutes or less: 1.1°C (2.0°F)
  — ASHRAE standard 55-2010
Six houses were simulated

Gridlab-D

<table>
<thead>
<tr>
<th>Case</th>
<th>Thermal Integrity</th>
<th>A/C size (Btu/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Little</td>
<td>87,900 (oversized)</td>
</tr>
<tr>
<td>2</td>
<td>Little</td>
<td>56,800 (proper)</td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>56,800 (oversized)</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>36,350 (proper)</td>
</tr>
<tr>
<td>5</td>
<td>Good</td>
<td>36,350 (oversized)</td>
</tr>
<tr>
<td>6</td>
<td>Good</td>
<td>28,550 (proper)</td>
</tr>
</tbody>
</table>
Demand Response Programs:
5, 10, and 20 minute a/c shutoff once between 2-4 pm
24 houses

No demand response event
20 minute a/c cycling
Evenly distributed throughout 2 hour period
## Relative Demand Reduction from 20 minute a/c cycling

<table>
<thead>
<tr>
<th>Thermal Integrity</th>
<th>A/C size (Btu/hr)</th>
<th>Demand Reduction from DR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little</td>
<td>87,900 (oversized)</td>
<td>15%</td>
</tr>
<tr>
<td>Normal</td>
<td>56,800 (proper)</td>
<td>12%</td>
</tr>
<tr>
<td>Normal</td>
<td>36,350 (proper)</td>
<td>8%</td>
</tr>
<tr>
<td>Good</td>
<td>36,350 (oversized)</td>
<td>6%</td>
</tr>
<tr>
<td>Good</td>
<td>28,550 (proper)</td>
<td>4%</td>
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</table>

- **Blue**: All oversized a/c
- **Red**: All proper a/c size
- **Green**: Mixed a/c sizing; half proper, half oversized
## Relative Demand Reduction from 20 minute a/c cycling

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Effect of demand response event on seasonal time outside a/c design bandwidth

- Properly-sized a/c
- Improved thermal integrity
- Oversized a/c

Time outside +2°F bandwidth (% of summer season) vs. Length of a/c shutoff (min)
Indoor and outdoor temperatures hottest (105°F) summer day good thermal integrity properly-sized a/c.

No demand response event 20 minute a/c cycling
Indoor and outdoor temperatures cooler (97°F) summer day good thermal integrity properly-sized a/c.

No demand response event

20 minute a/c cycling
Effect of demand response program on time above 75°F, peak summer cooling day.
Effect of demand response program on maximum indoor temperature, peak summer cooling day.

- Properly-sized a/c
- Oversized a/c
- Improved thermal integrity

Graph shows the maximum indoor temperature in °F for July 15 as a function of the length of a/c shutoff (min).
Effect of demand response program on residential energy use, peak summer cooling day

Properly-sized a/c

Oversized a/c

Little thermal integrity

Normal thermal integrity

Good thermal integrity

Energy consumed, July 15

Length of a/c shutoff (min)
Conclusions

• Demand response degrades occupant comfort
• Longer events produce worse occupant comfort
• Results vary significantly with thermal integrity and a/c size
• Changes to occupant comfort may affect participation
• Changes to a/c size and thermal integrity by participants in a demand response program will change available demand reduction.
• Thermal integrity and a/c size should be considered in the design of demand response programs.