Line Voltage Connected Thermostats (LVCTs)

Rob Penney, WSU Energy Program

Emerging Technologies Showcase

June 14, 2017
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Line Voltage Connected Thermostats (LVCTs)

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Overview

• The Need for LVCTs
• Why Now?
• Product Characteristics
• Research Highlights
• Measure Development
• Available Products
• Recommendations
• Conclusion

This information will be provided in a BPA white paper released in summer 2017.
The Need for LVCTs

- The first bimetallic thermostat was patented by Scottish chemist Andrew Ure in 1830.
- The first baseboard was invented in 1925.
- It’s time for a change.
The Need for LVCTs

Zonal electric resistance (ER) heaters and bimetallic thermostats are inefficient but cheap and therefore popular, particularly in multifamily facilities where tenants pay utility bills—and where 87% of these thermostats are installed.
• The traditional multifamily market has been too price-sensitive for most costly advanced thermostats.
The Need for LVCTs

Smart thermostats for central HVAC systems have advanced tremendously but cannot readily serve ER heaters.
Six manufacturers, mostly small, new, and Canadian, are now offering LVCTs, most for about $100.
Multifamily housing is springing up around the region, partly due to the boom of Millennials who are a good match for high-tech controls.
Innovations in Internet of Things communications, such as APIs and IFTTT, provide new opportunities for controls.
LVCT Characteristics

- Smaller deadband
- Programming
- Remote control
- Occupancy sensing
- Energy use reporting
- Heater compatibility
- Humidity & outdoor temperature

- Self-learning
- Data security
- Internal heat (droop)
- Devices connections
Deadband

- Variation in space temperature
- Conventional bimetallic thermostats: up to 6°F
- Most LVCTs: 1°F or less
- Allows users to lower temperature set points
- Deadband is a function of control interval, now typically 15 seconds for baseboard heaters and 5 to 15 minutes for fan-forced models
• If used well in good applications, programming can cut energy use
• Some LVCTs provide a set of programs that users can choose from, making setup easier
• Some LVCTs have min/max temperature settings or no programming in public spaces
Remote Control

- Monitor and control heaters remotely using smart phones and tablets
- Pre-warm home or cottage when heading there
- Increase setbacks after leaving

Source: King Electric
Occupancy Sensing

- One LVCT includes an occupancy sensor
- One connects to Nest for occupancy sensing
- One uses IFTTT to intuit occupancy from other sources, including Nest thermostat, smart phone “geofencing”, and Google calendar

Source: Walker Technologies
Energy Use Reporting

- Energy use reporting by LVCTs varies widely but is steadily becoming more granular
- This may be useful to help estimate the impacts of efficiency improvement projects

Source: Sinope
Heater Compatibility

• Baseboards, convection heaters (without fans), and wall-mounted cove radiant heaters: All LVCTs can control these

• Fan-forced wall heaters: Only models that can lengthen control interval to avoid damaging fan motors should be used

• Radiant floors: Only those with floor temperature sensors and GFI features

• DHP: So far, no LVCT thermostat can control DHPs to integrate their use; Honeywell comes closest
Humidity and OA Temperature

- CaSA’s LVCT monitors indoor humidity to help customers avoid mold and mildew issues
- Honeywell’s LVCT monitors outdoor temperature and humidity
- Empowered Homes’ LVCT monitors outdoor air temp
• Honeywell reassesses the time the heaters take to achieve a set point based on the previous day’s performance
• Empowered Homes does this based on previous performance and outdoor air temperature
Data Security

- Concern about data security is increasing—can a stranger control the heaters or track occupancy?
- Most LVCTs use dual-layer encryption or WPA-2
Internal Heat Compensation

• Heat from a thermostat’s anticipator can impact its accuracy up to 3°F (droop), causing thermostat to think the space is warmer than it actually is.

• Digital models have less droop than those with mechanical anticipators, especially if they use relays rather than triacs.

• Most thermostats use algorithms to predict and compensate for droop; one allows users to modify manually.
Internal Heat Compensation

Source: Walker Technologies Corp.
Connection to Other Devices

- Radio Frequency: Z-wave, ZigBee, RedLink
- API: Application program interface
- IFTTT: If this, then that
- Wi-Fi
I think my Nest smoke alarm is going off. Google AdWords just pitched me a fire extinguisher and an offer for temporary housing.
Measure Development

- Number of homes in the NW region
- Percentage energy savings
- Zonal electric heating energy use
- Regional technical potential
- Simple payback
  
  Conservative estimates
Number of Homes in NW Region

• As per RBSA, baseboards are used as primary or secondary heating systems in:
  – 12.3% / 21.8% of single-family (SF) homes
  – 1.5% / 8.9% of manufactured homes
  – 80.6% / 0.8% of multifamily (MF) homes

• The NWPCC estimates 4.2 million SF homes and 1.1 million MF units in Northwest

• ER heat in 135,000 SF homes, 919,000 MF units (87% are MF)
The RTF estimates 5% energy savings just from upgrading to electronic thermostats, although studies show savings as high as 20%

ENERGY STAR estimates 9% energy savings for upgrading from non-programmable to programmable

Additional savings should be generated from remote control, occupancy sensing, and droop correction.

Total rough estimate of energy savings: 13%
### Zonal Electric Heating Energy Use

<table>
<thead>
<tr>
<th>House Type</th>
<th>Heating Zone</th>
<th>Total ***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Single Family</td>
<td>8,391</td>
<td>10,590</td>
</tr>
<tr>
<td>Multifamily</td>
<td>2,635</td>
<td>4,012</td>
</tr>
<tr>
<td>Multifamily *</td>
<td>3,426</td>
<td>5,216</td>
</tr>
<tr>
<td><strong>Zone Distribution</strong></td>
<td>80%</td>
<td>15%</td>
</tr>
<tr>
<td>Single Family **</td>
<td>6,713</td>
<td>1,589</td>
</tr>
<tr>
<td>Multifamily **</td>
<td>2,740</td>
<td>782</td>
</tr>
</tbody>
</table>

* Increased by 30% to compensate for data assumption of full insulation
** Weighted average heating energy use based on distribution among heating zones
*** Rounded to reflect the lack of uncertainly in input data

Source: Regional Technical Forum
Regional technical potential of replacing bimetallic thermostats with LVCTs in Northwest homes that use zonal electric heaters as their primary heating systems:

<table>
<thead>
<tr>
<th>Home Type</th>
<th># ER Homes</th>
<th>Energy Savings</th>
<th>Heat Energy (kWh/year)</th>
<th>RTP (TWh/year)</th>
<th>RTP (aMW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>135,000</td>
<td>13%</td>
<td>9,000</td>
<td>0.16</td>
<td>18.0</td>
</tr>
<tr>
<td>MF</td>
<td>919,000</td>
<td>13%</td>
<td>4,000</td>
<td>0.48</td>
<td>54.6</td>
</tr>
</tbody>
</table>
Simple Payback

- The RTF estimates 6 thermostats per zonal-electric SF home, 4 per multifamily home
- LVCTs cost roughly $100 each
- Cost per home: $606 for SF, $404/MF

<table>
<thead>
<tr>
<th>Home Type</th>
<th>Heating Energy (kWh/year)</th>
<th>Energy Savings</th>
<th>Energy Cost / kWh</th>
<th>Cost Savings</th>
<th>Cost per Tstat</th>
<th>Simply Payback (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>9,000</td>
<td>13%</td>
<td>$0.10</td>
<td>$117</td>
<td>$101</td>
<td>0.9</td>
</tr>
<tr>
<td>MF</td>
<td>4,000</td>
<td>13%</td>
<td>$0.10</td>
<td>$52</td>
<td>$101</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Research Highlights

• A general lack of good research
• Canadian research focuses on demand response
• Most U.S. research focused on electronic thermostats more than programmable or connected
• Current research by PSE and BC Hydro will hopefully yield useful results in the coming year
Older Research

• Eugene Electric and Water Board (EWEB, 2002)
  – In 2002, they studied replacement of bimetallic with electronic thermostats in 2,500 homes
  – 80% of MF homes and 50% of SF homes were low-income
  – Energy education was provided to homeowners
  – Energy savings: up to ~20%
  – Levelized cost: $0.023/kWh
Older Research

• Northeast Utilities (2000)
  – Studied energy usage impact and occupant satisfaction of replacing bimetallic with electronic thermostats
  – Included 60 sites
  – Energy use dropped 7.1%, equivalent to 1°F drop
  – Results varied wildly from -39” to +79%
  – 86% of users preferred electronic thermostats due to performance and digital displays
Older Research

• Lambert Engineering (1996)
  – Monitored energy use of 27 apartments in Portland
  – Alternate between bimetallic and electronic thermostats
  – Space temperature fluctuations were 2.5°F for bimetallic and 0.6°F for electronic
  – Energy savings 222 kWh/year without programming (~6%)
Recent Research

• Hydro Quebec’s IREQ-LT institute (2016)
  – At MEEB facility with twin SF homes
  – Study focused on the impacts of pre-heating and set point ramps on demand response and achieved a 20-61% reduction in demand during the peak demand event.
  – Explored selection of various sets of baseboards to minimize investments in controls (prioritize “master” zones from which heat usually flows to “slave” zones.
Recent Research

• The simpler strategy achieved 25% less demand response but increased occupant comfort.

Source: Fournier
Recent Research

• CLEAResult (2016)
  – Surveyed LVCT markets (mfgs, retail, wholesale)
  – Almost all line-voltage models are bimetallic
  – Hard to get market actors to share information
  – ER applications are price-sensitive; split incentives
  – Digital models ~$35 (70%) more than bimetallic
  – MF renters are disinclined to use programmable thermostats even if provided
  – Digital target market: “high-income empty nesters”
Current Research

• Puget Sound Energy (2017)
  – A pilot study of energy savings from replacing bimetallic thermostats
  – Using Honeywell low-voltage thermostats
  – Preliminary results are expected fall 2017
  – Final results expected by summer 2018
• BC Hydro (2016-2017)
  – Two studies on the demand response impact of various load control strategies
  – One uses Sinope LVCTs for direct control, not taking advantage of remote control.
  – The other uses CaSA LVCTS and connected control
  – Data has been gathered, but results have not yet been reported
• NWPCC’s Regional Technical Forum
  – The RTF proposed a research strategy for SF and MF homes with zonal electric heat, no DHP
  – Compare bimetallic and electronic thermostats
  – Optimum sample size: 608 SF homes, 150 MF homes
  – Compare retrofitted homes with those having no changes
  – Collect pre- and post- retrofit data
LVCT Products

- Sinope
- Stelpro Ki
- CaSA Caleo
- Walker
- King Electric
- Empowered Homes
- Honeywell
- Dimplex
- Nuheat
Sinope TH1120RF-4000

- Uses ZigBee RF communication
- Controls baseboards, fan-forced heaters, and radiant floors
- Public spaces model lacks display and programmability
- Can connect to Samsung SmartThing, Control-4, RTI home automation system
Stelpro Ki

- Uses ZigBee or Z-Wave
- Requires a home automation system and can connect to Vera, Wink, Nexia, and Samsung’s SmartThings (only Vera with ZigBee)
CaSA Caleo

- Can’t control fan-forced heaters or radiant floors
- Uses IFTTT to intuit occupancy through Nest, Google calendar, and smart photo geofencing, and intuits sleep mode with Fitbit
Walker Technologies WZ_LVS250

- Uses ZigBee
- Includes a motion sensor with adjustable delay for short- and long-term setbacks
- Uses a central programmable hub for Internet connection
- Focuses on multifamily market in Toronto
• Ten models for various applications, including an LVCT and two models targeting multifamily occupants with wasteful behaviors:
  – One sets back to a lower temperature every 2 hours regardless of occupancy and sets back further after 12-60 hours without manual adjustment
  – Another has two window/door sensors and sets back to 40°F when either is open, and to 58°F whenever occupancy is not detected
Empowered Homes Mysa

• Product is due out in November 2017
• Can control fan-forced heaters
• Uses smart phone geofencing
• Uses weather data to calculate ramp-up timing
• Interfaces with home automation systems and accepts vacation schedules
Honeywell EConnect

- Low-voltage w/ Red Link relays; old controls are disabled
- Outdoor humidity and temperature sensor
- Portable Comfort Control
- More costly
Dimplex CONNEX Controller

- Low-voltage, not line-voltage
- Works only with their CONNEX heaters, which have relays pre-installed, so do not need junction boxes
- Programmable and remote control
- Dimplex recently purchased Cadet
Nuheat Signature

- Controls Nuheat radiant floors
- Can connect to Nest thermostat for occupancy sensing ("works with Nest")
- Can monitor outdoor temperature and connect to weather forecasts
Non-Energy Benefits

• End Users:
  – Increased comfort due to smaller deadband and pre-warming before waking or arrival
  – Convenience of remote monitoring and control with large, bright screens

• Utilities:
  – Peak demand reduction
  – Tracking savings from efficiency measures
Non-Energy Benefits

• Property Owners:
  – Remote monitor and control
  – Alerts for equipment malfunction and freezing space temperatures
  – Ability to adjust rent based on energy use
  – Monitors humidity to avoid mildew
  – More comfortable tenants result in fewer expensive turnovers and higher rent
Recommendations

• Perform field studies of replacing bimetallic thermostats with LVCTs in SF and MF homes in the Northwest
• Upgrade incentivized measure from electronic thermostat to LVCT, and include MF homes
• Promote non-energy benefits
• Engage manufacturers and trade allies
• Raise awareness of LVCT opportunities
Summary

• Zonal electric heat is used as the primary heating system in over 1 million homes, 87% multifamily

• Replacing bimetallic thermostats with LVCTs is a great, untapped opportunity for SF/MF homes:
  - Energy savings: 13%
  - Demand Reduction: 20-61%
  - Simple payback of 0.9 /1.9 years
  - Regional technical potential: 0.2/0.5 TWh, 18/55 aMW

• Lack of awareness of LVCTs in the NW region
Conclusion

• While upgrading zonal electric heating systems to LVCTs could be a transition technology leading to DHP, at $400-$600 vs. $2,000-$4,000 per home and a price-sensitive market, that transition could take a while.

• With awareness-raising, regional studies, utility incentives, and promotion of non-energy benefits for homeowners, MF managers, and utilities, LVCTs could be a great opportunity.
Questions and Answers

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