Improving Building Performance through Controls and Analytics

SRINIVAS KATIPAMULA, PHD AND RONALD UNDERHILL

Pacific Northwest National Laboratory
Washington State University Energy Extension Services Webinar Series
• Minimize or maximize control panel
• Phone lines are muted
• Please use question pane to ask questions at any time, or if you have any technical issues

NOTE: Today’s presentation is being recorded and will be available at http://www.energy.wsu.edu/PublicFacilitiesSupport/ResourceConservation.aspx
Improving Building Performance through Controls and Analytics

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Presentation Overview

- A look at direct digital control of some commonly used heating, ventilation and air conditioning systems
- Improving building operations using building analytics
- Case studies
- Question and Answer
Single Zone AHU Control Application with DDC Controller

Courtesy LAMA Books
• VAV systems vary the air supplied to each zone depending on the load, saving fan energy
• VAV systems typically use cooling only air handlers with reheat at the zones
• Volume of air delivered is varied using inlet dampers or electronic speed controls (variable frequency drives) based on supply duct static pressure set point
Energy Management Techniques of HVAC Systems

► Various AHU Fan Systems

► Single Zone/Constant Volume Systems
  • Reset discharge air temperatures and mixed air temperatures based on zone requirements.

► Variable Air Volume (VAV)
  • Use VFD at the fan motor; supply and return fans should track together, but never at the expense of building pressurization (control return fan speed for slightly positive building static pressure)
  • Create an automatic discharge static pressure set point reset algorithm (based upon VAV damper position feedback) with scheduled set point reductions (during nights and weekend vacancy periods – to account for occasional after-hours work)
  • Reset discharge air temperatures and mixed air temperatures based upon zone requirements
  • Ensure VAV terminal boxes are correctly configured for ventilation requirements (area and population count – realistic population count)
General Energy Management Techniques

General Energy Saving Techniques for AHUs

• Operate zones based on load and occupancy needs (minimum 3°F dead band values between zone heating and cooling set points)

• Configure with tight schedules and use optimal start to anticipate earlier startup requirements for hot or cold weather.

• Ensure the economizer is configured correctly for minimum OA set point values and for proper operation (fixed dry bulb set point or differential dry bulb set point)

• Disable the mechanical cooling coil and pumps when outside air temperatures drop below 55-60°F

• Disable the mechanical heating coil and pumps when outside air temperatures rise above 65-70°F

• Ensure building exhaust fan systems turn off as early as possible and startup as late as possible and only run when needed or required

• Location, location, location (sensors – especially outdoor air temperature and duct static pressure)
Boiler Control With Outdoor Air Temperature Reset

- Hot water reset based on OA should be aggressive. The schedule shown will only provide the warmest water when the OA temperature is cold.
- The configuration shown is for non-condensing boilers that requires the boiler to always stay hot (180°F) to avoid condensation issues.
- With condensing boilers, return water temps < 130°F offer greater efficiency (supply water temps < 150°F).
- Parallel boilers should have automatic isolation valves in the loop.
- A more efficient control scheme calculates a hot water set point based upon the zone demand (average deviation from zone set point or reheat average valve command position).

<table>
<thead>
<tr>
<th>O. A. Temp</th>
<th>HWS Setpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°F / -18°C</td>
<td>180°F / 82°C</td>
</tr>
<tr>
<td>70°F / 21°C</td>
<td>90°F / 32°C</td>
</tr>
</tbody>
</table>

Courtesy TAC Controls/Schneider Electric
Converter Control With Reset

- Hot water reset based on OA should be aggressive. The schedule shown will only provide the warmest water when the OA temperature is cold.
- The configuration shown is for steam-to-hot water converter. These systems have greater turn-down if the control valves are sized properly.
- OA sensor location is critical for efficiency and accuracy and should be validated quarterly.
- Consider a night setback with 20°F lower reset values for the hot water.

Courtesy Northwest Energy Efficiency Council
DDC Networks and Architecture

Site PC - Site LAN/WAN - Site PC

Subnet PC - CI - C - I - C - C

CI = Communications Interface
I = Interface
LAN = Local Area Network
S = Sensor
O = Outputs
WAN = Wide Area Network

Multiple-Subnet Works System Architecture
Modern Controls Have Four-Level Architecture
Four Level Architecture Level One “Sensors”
Four Level Architecture Level Two “Field Controllers”
Four Level Architecture Level Three “Integration”
Four Level Architecture Level Four “Management”
Improving Operations using Building Analytics

- Important reasons why we must do more to improve building operations
- Current deficiencies in building operations
- Key gaps and best practices in control system deployment and operations
- Common problems with building operations
- Building analytics basics
Only 14% (43% of conditioned space) of the building stock has building automation systems

Source: 2012 Commercial Building Energy Consumption Survey
Important reasons why we must do more to improve building operations
State of Building Operations

• U.S. EPA’s Clean Power Plan
• City and State “Tune-up” mandates
State of Building Operations (cont.)

CONTRIBUTION OF U.S. BUILDINGS TO TOTAL WORLD ENERGY: 9%

U.S. BUILDINGS PRIMARY ENERGY USE: 40%

COMMERCIAL BUILDINGS: 18 QUADS

U.S. GREENHOUSE GAS EMISSIONS: 38%

BUILDING & EQUIPMENT EFFICIENCY: 20-60%

DISTRIBUTED RENEWABLE GENERATION: 15-30%

OPERATING EFFICIENCY: 20-30%
Current deficiencies in building operations
Deficiencies in Building Operations

Savings Opportunity

Hour of Day

Electricity Consumption

0 50
12am 6am 12pm 6pm 12am
Building Systems Lack “Self-Awareness”

Systems are designed and sized to provide comfort for a “design” day …

… but they are operated as if every day is a design day…
Operations of Variable-Air-Volume Air-Handling Systems
Discharge Air Temperature Control

**Graph: Discharge-Air Temperature Control**

- **Y-axis:** Temperature (°F)
- **X-axis:** Time (12:00 AM to 6:00 PM)

**Lines:**
- **Discharge-Air Set Point**
- **Discharge-Air Temperature**

**Key Points:**
- **Unoccupied**
- **Occupied**

**Legend:**
- **Bad Operation:** Constant discharge air temperature set point, no reset-schedule
Discharge Air Temperature Control (cont.)

Good Operation: Discharge-air temperature is reset to 55°F from 12 PM to 6 PM (peak load conditions)
Duct Static Pressure Control

Bad Operation: Constant set point and no reset schedule

Static Pressure (in. w.c.)

12:00 AM 12:00 PM 12:00 AM 12:00 PM 12:00 AM 12:00 PM 12:00 AM 12:00 PM

Occupied

Unoccupied

Duct Static Pressure

Duct Static Pressure Set point
Duct Static Pressure Control (cont.)

Good Operation: Static pressure reset-schedule based on building load

Peak Demand Hours
Duct Static Pressure Control (cont.)

Good Operation: Static pressure reset-schedule based on zone conditions
Integration of Other Systems
Key gaps and best practices in control system deployment and operations
Goals of Building Operations Staff
True Goals of Building Operations Staff
• Lack of monitoring and self-awareness
• Lack of initial commissioning
• Limited hands-on training options
• Shortage of experienced workforce
• Reduced operating budgets
Common problems with building operations
Common Opportunities

Lack of Reset Strategies
- Discharge temperature and duct static pressure in AHUs
- Chilled/hot water temperature reset
- Differential pressure reset on chilled/hot water distribution loop

Lack of Use
- Occupancy-based controls for common areas
- One or more faulty sensors or sensors in the wrong location
- Night setbacks
- Photo sensors in the wrong location
Common Opportunities

**Improper Settings**
- Heating/cooling set points
- Outdoor air during warm-up
- Dead bands
- Automatic lighting controls

**Improper Schedules**
- AHUs and fans
- Exhaust fans during warm-up
Building analytics basics
Need of Analytics

- Outdoor Air Damper on Air Handling Unit 10 is stuck open (100%)
- Economizer Controls are not working on Air Handling Unit 13
- Air Handling 1 does not appear to be using Static Pressure Reset
- The Delta-T on the Chilled Water Loop is Low (5°F)
First Step - Benchmarking

![Graph showing electricity consumption over the day with a peak around 12pm and a savings opportunity highlighted.](Image)
Beyond benchmarking of whole building data, building automation systems provide a rich source of “raw” data that can be used to create:

- Actionable information (i.e., identify operational problems)
Automated Fault Detection, Diagnostics and Self-Correction

Building System -> Fault Detection -> Fault Diagnosis
-> Configuration Information -> Actionable Information

Auto-Correction
Life Cycle of Existing Building-Commissioning

Energy Consumption vs. Time

Typical commercial building behavior over time

Continuous Re-tuning Maximizes Persistence

Periodic Re-tuning Ensures Persistence
Take Control
Using Analytics to Drive Building Performance: A Case Study – What to Expect
### Lack of Reset Strategies

<table>
<thead>
<tr>
<th>Lack of Reset</th>
<th>Percent of Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Temperature</td>
<td>75%</td>
</tr>
<tr>
<td>Static Pressure</td>
<td>73%</td>
</tr>
<tr>
<td>Chilled Water Temperature</td>
<td>50%</td>
</tr>
<tr>
<td>Hot Water Temperature</td>
<td>42%</td>
</tr>
<tr>
<td>Chilled Water Differential Pressure</td>
<td>32%</td>
</tr>
<tr>
<td>Hot Water Differential Pressure</td>
<td>24%</td>
</tr>
</tbody>
</table>
Lack of Use

- Occupancy-Based Controls for Common Areas: 34%
- Faulty or Sensors in Wrong Location: 33%
- Night Setbacks: 30%
- Photo Sensors or Sensors in Wrong Location: 26%
Improper Settings

- Heating/Cooling Set Points: 32%
- Outdoor Air During Warm-up: 30%
- Dead Bands: 25%
- Automatic Lighting Controls: 13%
Lack of Proper Schedules

- Lack of Proper Schedule for AHUs & Fans: 50%
- Exhaust Fans During Warm-up: 46%
Distribution of Buildings by State

Median Savings 13%

Mean Savings 17%
• Implemented night setback for air temperature and pressure
• Reduced interior zone reheat
• Reduced overcooling or overheating
• Reduced reheat during summer/cooling season for exterior zones
• Implemented discharge air reset
• Eliminated zones that were out of control, oscillating between heating and cooling
Building in TX

- Relocated outdoor air temperature
- Reviewed and removed all the overrides
- Recalibrated pneumatic devices
- Replaced gaskets on all dampers
- Implemented discharge air temperature reset
- Updated building automation system code
- “Optimized” the start and stop times
- Adjusted the static pressure of AHUs
Key Lessons Learned

- Many commercial buildings have an array of operational problems.
- Trained building operations staff can re-tune buildings, if empowered.
- Building re-tuning can yield energy savings between 5% and 20% through implementation of no-cost and low-cost measures.
- But, the human factor is a real issue in realizing re-tuning benefits in practice.
- In the long run, automation is key to persistence of “optimal” building operation.
Questions?

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Thank you for attending!

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