Cost responsive supply air temperature reset strategy

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Overview

Objective

- Develop and test a control strategy that identifies the optimal supply air temperature for an air handling unit

Approach

- No new hardware
- Minimize complexity so it can be implemented within building automation system software & hardware
- Test in a randomized controlled trial

Funding

- CEC PIER program
- CBE match funding
Background: Supply air temperature setpoint

Comfort constraint
- SAT should be low enough to cool the most demanding zone

Energy impact
- Lower SAT increases cooling and reheat, but decreases fan energy
- Optimal SAT varies based on weather, internal loads, and building conditions.
A brief history of best practice for SAT setpoint controls

Constant (manually adjusted) → Based on outside air temperature → Warmest to satisfy most demanding zone → Warmest with outside air temperature based limits

**Current best practice**

- **SAT** is 58 °F (14°C), modified seasonally or as needed
- **SAT** when **OAT**
- **SAT** until one zone at max airflow
- **SAT** until one zone at max airflow - within limits that vary based on **OAT**

Advent of DDC systems
Current best practice vs. cost-responsive controls

Current best practice

- Warmest with outside air temperature based limits
- Trim & respond (or PID)

Cost-responsive

Every 5 min

 Cooler air needed to provide comfort?

Yes

Cost-responsive logic
Estimate fan, cooling, and reheat power for small SAT changes (e.g. -0.5, 0.0, +0.5 °C).

Respond logic
Reduce SAT in proportion to net cooling requests.

Choose lowest cost SAT.

No

Implement new setpoint
Control system inputs and calculations

Cost per unit energy

- Need common metric to compare fan, reheat, and cooling energy
- Use actual dollar cost from tariffs
- Change later as needed
- Alternatives
  - Site/source energy
  - Carbon

Fan power estimate

- Use VFD output and motor rating

Coil ‘power’ estimates

- Use sensible heat balance
- Cooling: mixing to supply air temperature.
- Reheat: supply to discharge air temperature.
- Apply temperature ‘correction’ to account for sensor error, fan/duct heat gain, passing valves, etc.
- Temperature correction is the long term average value when the valve is closed for ≥5 minutes
Estimating overall cost at different candidate SATs

**Reheat**
- For each reheat box with an open reheat valve, re-calculate reheat estimate at candidate SAT.

**Airflow**
- For each VAV box in cooling mode, estimate new airflow at candidate SAT.

**Fan**
- Use total airflow estimate and fan affinity law to predict fan power at candidate SAT.

**Cooling**
- Use new airflow estimate and re-calculate cooling estimate at candidate SAT.
Case study in Sutardja Dai Hall

- Variable air volume system with hot water reheat
- 141,000 ft²
- Offices, an auditorium, and cleanrooms
- Completed 2010
- Siemens Apogee system
- Implemented using sMAP and pybacnet
Method: Randomized controlled trial

- Randomly select control strategy every day at midnight between Sept 2016 and Feb 2017
- **Current best practice controls:** ‘Baseline’ (77 days)
- **Cost-responsive controls:** ‘Intervention’ (68 days)
- Minimizes the effect changes in weather, occupant behavior, operation of building and systems, have on results
- Overall savings potential adjusted to match typical annual climate
Results: Overall

- 17% total HVAC savings during randomized control trial (6 months)
- Savings occur at all outside air temperatures
- Savings highest between 16 °C (60 °F) to 24 °C (75 °F) outside air temperature
- 29% total HVAC savings when normalized to typical office hours (8am-6pm) in a typical meteorological year
Results: Detail
Results: Limitations of generalizing savings to other buildings

- Climate (Berkeley, cool summer Mediterranean climate, ASHRAE 3C)
- Size of the HVAC system relative to the actual building loads
- Relative cost of fan, cooling and reheat energy.
- Zone minimum airflows
- ...

Mild Berkeley weather
Results: Parametric energy modeling

- Varied loads, zone airflow minimums, HVAC sizing, chiller efficiency, etc.
- Identified the theoretical optimum using a brute force approach
- Compared a range of different SAT reset strategies

![Bar chart showing whole building energy consumption: percentage above theoretical optimum.]

- Warmest possible
- Constant at 55 °F
- ASHRAE Guideline 36P (OAT 60-70 °F) - Current best practice
- ASHRAE Guideline 36P (OAT 50-80 °F)
- Cost-responsive

Percentages range from 0% to 12%.
Practicality

- Both approaches have the same number of required user inputs (4):
  - Current best practice: upper and lower limits for SAT at high and low OAT.
  - Cost-responsive: electricity & hot water prices, chiller plant efficiency, fan motor horse power.

- More complex to program... but hopefully can be implemented once, as standard ‘block’

- Can be expressed as sequences of operation - Draft 4 page version available to share now.

Sutardja Dai Hall. Source: Hathaway Dinwiddie
Next steps

**Publication**
- Journal article submitted and under review

**Open questions**
- Test performance in other buildings
- Identify issues implementing in native building automation system hardware & software
Q&A

Thank you for listening.
Questions?

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