White Paper #31 - Digital Control System Optimization Routines

April 28, 2009

Once installed, a Direct Digital Control (DDC) system is a very useful facility tool. Control system measure implementation is one of the most cost effective measures in most buildings.

In general, all control strategies should strive for the following:

- Decrease unnecessary equipment operation through scheduling and occupancy sensing.
- Positive control of "dead band" spacing to prevent simultaneous heating and cooling.
- Standardize indoor comfort settings and limit user adjustment to +/- 2 deg
- Match equipment operation to changing loads by sensing techniques and capacity-varying techniques.
- Vary fluid temperatures, pressures, supply air flows, water flows, outdoor air intake rates, based on demand and not worst case. The objective is always to provide enough, but just enough, of the item.
- Schedule both on-off operation and time-of-day set point adjustments. Note that you can schedule ventilation rates to correspond with planned occupancy patterns.
- Schedule loads based on actual needs, rather than worst case
- Automate to shed non-essential equipment at peak times when power costs are highest

On-peak periods Oct. - March: 4 to 10 p.m. Monday through Friday
On-peak periods April - Sept.: 11 a.m. to 6 p.m. Monday through Friday
Off-peak periods: all other hours plus legally-observed holidays

**On/Off Peak Rates.
Note that the on/off peak times shift seasonally.**

http://www.csu.org/customer/rates/rate_business/11400.pdf

Other ways to leverage modern DDC controls include:

- Utility load tracking and real-time feedback to proposed efficiency changes.
- Predictive maintenance for heat exchangers (fouling), filter changing (pressure drop), etc.
- Optimize primary equipment operation where different units have different efficiency characteristics.
- Optimize evaporative cooling processes from wet bulb or dew point measurements.
- Extend air-economizer settings based on outdoor dew point levels to keep cooling equipment off longer during mild and dry weather days.
- Global point sharing that justifies higher quality instrumentation, such as outdoor air temperature, humidity, dew point, wet bulb, etc.

Control System Measure

Calibration. For sustained savings, all analog input and output sensors, transducers, and actuators of valves and dampers (travel and tight close-off) should be re-calibrated on a 2-year cycle, and control set points and occupancy schedules should be reviewed on a 2-year cycle as well.

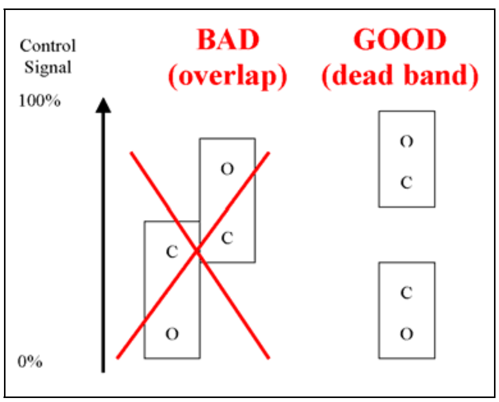
Scheduled Start Stop.
The most efficient setting for equipment is 'off'. The scheduling function can be leveraged to advantage by setting start and stop times according to user occupancy patterns, and by continually adjusting and fine tuning these schedules as those patterns change.

Optimal Start time programming can be used to turn on equipment prior to occupancy and have it reach temperature 'just in time.'

Dead Band Controls.
Control settings shall prevent preheat coil action when air economizer is operational, requiring a 5 degF dead band between mixing dampers returning to minimum position and preheat. For example, when any form of cooling is active (chilled water, DX, or Economizer) the preheat coil control would be held closed in a "one or the other but not both" control. This limits the use of a standard "proportional control" sequencing scheme where a single proportional controller output is shared by several devices for ease of sequencing. Rather, a control loop with a heating set point and a control loop with a cooling set point, with dead band spacing between the two.

It is recommended to separate space heating and cooling functions by at least 4 degF to prevent heating and cooling to occur simultaneously.

Some DDC systems have a pre-defined watch dog algorithm available that will further prevent simultaneous heating and cooling. When heating is called for it automatically overrides any other control action and forces the cooling output to zero.



Stop Ventilation in Unoccupied Periods.
If air handler system is operated in unoccupied or morning warm up mode, control outside air damper and associated exhaust fans off (interlock). Simply turning off air handlers and ventilation while leaving exhaust fans running defers the ventilation load until morning start-up and can also create a freezing condition near building cracks that can burst pipes.

Control System Measure

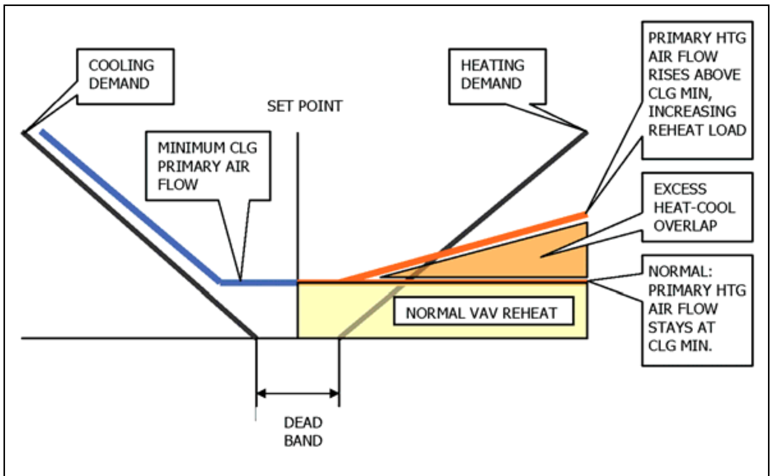
Relief Damper Lagging.

Adjust mixing damper controls so the exhaust (relief) damper lags behind the outside air damper. When the OA and XA dampers open at the same time, a common control application, sometimes air is found to be drawn in through the exhaust damper, which increases ventilation and associated ventilation costs.

VAV Box Settings.

Review all VAV box settings for minimum air flow and 'heating air flow' settings.

Excess minimum air flows increase heating burden in winter. If VAV boxes are allowed to open back up again in heating, it increases air flow across the heaters and increases winter heating costs proportionally. All VAV systems have some reheat penalty, but it is minimized when controlled properly. This measure is to reduce the "heating maximum" control setting to equal the "cooling minimum" air flow setting for all VAV boxes.



VAV BOX COOLING AND HEATING AIR FLOWS, AND INHERENT REHEAT PENALTY

Control System Measure

Supply Air Reset.

Suggested SA Reset for **Constant Volume** Systems

Return Air Temp	Supply Air Temp
77	55
71	61
65	67

Optimal SA Reset for **Variable Volume** (VAV) Systems

This requires polling individual VAV box air valve position and reheat valve positions. This utilizes a fixed temperature for cooling (e.g. 55 degrees) with no reset at all until polling of individual boxes indicates that most of the boxes are in heating – only then is the SA temperature allowed to gradually be reset upward to 62 degrees max. The reset is accomplished by polling VAV reheat valve positions and the air temperature is gradually reset upwards until at least one VAV box reheat valve is 90% open, thereby providing optimal air temperature (just warm enough). Simultaneously, VAV damper positions are polled to be sure enough cooling is being provided for any zone still calling for cooling, and cooling will prevail if the two are at odds.

Alternative SA Reset for **Variable Volume** (VAV) Systems:

This requires monitoring of the supply fan VFD speed signal or inlet vane control signal, and using this signal as implied system average VAV box position. This utilizes a fixed temperature for cooling (e.g. 55 degrees) with no reset at all until the combination of supply fan speed and outdoor temperature indicate it is likely that most of the boxes are in heating – only then is the SA temperature allowed to gradually be reset upward to 62 degrees max. The reset is accomplished by monitoring supply fan speed, and gradually resetting the air temperature upwards until once the fan speed has dropped to a value of 35% and outside air temperature is lower than 45 degrees F (which should not occur until winter. Between the threshold value (35%) and a lower threshold value (20-25%), the supply air temperature is reset linearly between minimum and maximum values. Unlike the polling method for each VAV box, this control method is open-loop to actual comfort conditions; therefore experimentation and fine-tuning will be required for the first season or two.

Hot Water Reset

Lowering hot water temperature in mild weather reduces thermal heat loss from the insulated piping system. This is an advantage of hot water heating over steam heating.

Coordinating this reset schedule with chilled water reset schedules limits the times when both run. Some overlap is unavoidable in most buildings, but to the extent the overlap can be minimized it will inherently limit heating and cooling activities at the same time. I.e. if the boiler is off in summer it doesn't matter if the control valve opens.

Hot Water Reset Schedule – Suggested Starting Spot

Outside Air	**Leaving HW temp**
Above 65	BOILER OFF
65	120 (or minimum temperature)
10	180 (or maximum temperature)

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Control System Measure

Reset VAV fan static pressure set points in mild and cold weather, to reduce fan energy.

Fan Static Pressure Reset Schedule – Suggested Starting Spot

OA	SP
70	1.2
40	0.8

Standardized Temperatures

74 cooling and 70 heating are reasonable temperatures for most facilities that involve people comfort. Significant is the differential or "dead band" between the two. By maintaining 4-5 degF between heat/cool settings the opportunity for unintended heat/cool overlap is reduced.

Set Back Temperatures

Savings from this measure are from reduced envelope losses – reducing envelope temperature difference reduces thermal transmission directly. Envelope savings are typically 1 percent (heating or cooling) per degree set back/set up, provided the set back/set up period is at least 8 hours. Where indoor temperatures are moved up/down permanently savings are approximately double (2 percent per degree F).

Coordinating Upstream/Downstream Set Points

This concept applies to any system that includes a main "upstream" air handler with associated "downstream" terminal units with heating capability. The concept is simple enough, but will require some programming. The objective is to provide enough, but just enough, cooling and heating from the upstream device and to avoid heating and cooling fighting between upstream and downstream components. Typical control system design does not include interaction between air handler and terminal unit and each behaves as if the other does not exist. Because of this, heat/cool overlap can easily occur and not be detected. The same concept applies to fan pressure when variable fan capacity is used (VAV).

Examples:

1. Resetting AHU supply temperature upwards until at least one terminal unit heating coil is at least 95% closed.
2. Resetting AHU fan static pressure downwards until at least one VAV box damper is at least 95% open.
3. Resetting boiler hot water supply temperature downward until at least one heating control valve is 95% open.
4. Resetting chilled water supply temperature upward until at least one chilled water control valve is 95% open.
5. etc.

The benefit of this measure can sometimes be observed with two DDC screens open: one for the main air handler and another for a terminal unit (if several are in heating mode). If the terminal unit is operating in heating mode and the supply air is relatively low (less than 60 degF), slowly raise the supply air temperature, 2 degF at a time, and wait several minutes – you may see the reheat coil stop heating, which demonstrates that they were 'bucking' each other, silently consuming energy. The control strategies described above police this automatically.

Control System Measure
Extend Full Economizer Switch Point To 60 Degrees When Outside Conditions Are Favorable. If outside air dew point levels are below 47 degrees and outside air dry bulb temperature is below 70 degrees, it should be possible in most cases to circulate 60 degree air instead of 55 degree air and maintain comfort in the buildings. Doing this will delay the use of mechanical cooling, creating savings for those hours the cooling equipment is off instead of on.
Occupancy Sensors for HVAC in Variable Occupancy Rooms. In conjunction with the DDC controls and HVAC systems, provide ceiling-mounted occupancy sensors in classrooms, meeting rooms, auditoriums, etc. When unoccupied: o turn lights off o reset minimum setting to 10% of occupied air flow to reduce ventilation cost o applies to VAV boxes, unit ventilators, and single zone HVAC units HVAC energy savings are unknown due to the number of variables involved. A conservative value would be 10% HVAC savings for the affected room.
After-Hours Tenant Billing. Depending on the tenant billing arrangement, it may be possible to utilize override buttons on space sensors in tenant areas to turn on equipment after hours, and simultaneously to record the hours and provide information for billing purposes.
EMS Override Report. With a large energy management system and a variety of system users, it is inevitable that settings will be changed. This usually takes the form of an override. The issue is when the override or changed setting is forgotten and left. An easily configurable feature of most EMS systems is to report overridden system values or outputs. If such a list were reviewed at the first of each week, it would help eliminate long-standing forgotten overrides and whatever environmental or energy impacts they have.