Managing Your Building Automation System

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Honorable Mention

- BOC – Building Operator Certification
  - www.boccentral.org
- ASHRAE
  Abtar Singh
  President, SINGH360 INC.
Definitions

- BAS – Building Automated System
- EMS – Energy Management System
- BMS – Building Management System
EMS Architecture

ENTERPRISE

BUILDING INTEGRATION DEVICE

UNIT CONTROLLERS
“Protocols are languages by which two devices communicate and exchange data.”

Language = English
Media = Phone
Dictionary
Protocol Levels

- Device Level (Modbus, Canbus, BACNet etc.)
- Building Level (BacNet, Proprietary etc.)
- Enterprise Level (Web, XML)
Protocol Classification

• Proprietary

• Open (may or may not be standard)

• Standard and hence inter-operable
Proprietary Protocol

• Only devices from same company know how to communicate
  – Language is secret
  – Dictionary is unpublished
Open Protocol

• When Protocol is published and readily available

– May or may not be standard
Standard Protocol

- When everyone gets together and agree on language and dictionary:
  - BacNet
  - Modbus etc.
Inter-Operable

Standard + Open
= Inter-operable
What is Best?

•“Standard Protocol” is Ideal.
•“Open” is second best.
•“Proprietary” should not be preferred – At least ask BMS vendor to publish the protocol (make it open)
What is Practical?

• Unit Level:
  – Modbus
  – BacNet etc.
  – Proprietary

• Building Integration Device:
  – BacNet over IP
  – XML

• Enterprise:
  – XML
“Future” Trend

- IP Based Unit Controllers:
  - Meters;
  - PLC;
  - Controllers
  - Tools available in most computer OS.

- CAT5E cable

- Volume is bringing the cost down and is better than 485 network
Where do we go from here?

- •Get your BMS Vendor to “open” their protocol.

- •Get both read and write capabilities.

- •Move and look for IP based control devices.
HVAC Control Documents

Control Drawings
Sequence of Operation
Decision Tree
Training at Startup
Commissioning Training
# Control Principles

<table>
<thead>
<tr>
<th>Control Principle</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room Temperature</td>
<td>Controlled Variable</td>
</tr>
<tr>
<td>RTD Sensor</td>
<td>Thermostat</td>
</tr>
<tr>
<td>Computer</td>
<td>Controller</td>
</tr>
<tr>
<td>Valve</td>
<td>Controlled Device</td>
</tr>
<tr>
<td>Air or Electricity</td>
<td>Control Agent</td>
</tr>
<tr>
<td>Steam Valve</td>
<td>Control Process</td>
</tr>
<tr>
<td>Control Loops</td>
<td>Open or Closed</td>
</tr>
</tbody>
</table>
Control System Path

Feedback Path

Setpoint

Controller

Process Variable

Controlled Point

Controlled Variable

Room Temperature Sensor

Room or Space

Valve or Actuator

Control Function

Controlled Variable

Controlled Point
OPEN LOOP CONTROL

Sensor → Controller → Process
CLOSED LOOP CONTROL
Control System Illustration
Control Cycle Graph

- **Period**
- **Decay**
- **Overshoot**
- **Setpoint**
- **TD**: Dead Time
- **TR**: Response Time
- **T_S**: Settling Time
- **Offset**
- **Steady State**
- **Oscillation**
Data Logging
Control Strategies

- Two-position
- Floating
- Proportional
- Proportional Plus Integral (PI)
- Proportional Plus Integral and Derivative (PID)
Two Position & Floating Control Strategies

Figure 07  TWO-POSITION CONTROL

Figure 08  FLOATING ACTION
PID Loop

- PID is an acronym for "Proportional", "Integral", and "Derivative." These three types of control signals working together provide the most effective means available for maintaining a set point with good system response.

- The Proportional control signal is based on the difference between the set point and the actual error.
PID Loop

- The Integral control signal's purpose is to eliminate the offset error inherent in Proportional control. Under some conditions, the system may "overshoot" the desired set point.

- Derivative control works by effectively applying the "brakes" to the Integral control signal. The Derivative control detects that the error is approaching zero and incrementally cancels the Integral correction signal, thus minimizing overshoot while allowing the control signal to bring the system to the exact setpoint.
Proportional & PI Control Strategies

Figure 09  PROPORTIONAL CONTROL

Figure 10  PI CONTROL
PID Control: Proportional Plus Integral & Derivative

Proportional Plus Integral Plus Derivative (PID) control action

Courtesy Northwest Energy Efficiency Council
Controller Direct Action: Illustration

![Diagram of a controller direct action system](image)

 Courtesy TAC Controls/Schneider Electric
Controller Direct Action: Illustration

- This relationship between the input to a controller (temperature) and its output (current) can be displayed on a graph as follows:

![Graph showing the relationship between room temperature and current (mA)](Courtesy TAC Controls/Schneider Electric)
Controller Reverse Action: Illustration

[Diagram showing a control system with labels for °F/°C, Controller, Reverse Acting LOOP, Sensor, Transducer, PSI/kPa, and a normally closed valve.]

Courtesy TAC Controls/Schneider Electric
Controller Reverse Action: Illustration

- This relationship is displayed on a graph as follows:

![Graph showing the relationship between mA and Room Temperature](image)
Energy Sources

Pneumatic
Electronic/Computerized
Self-powered Controls
Wireless
Hybrid Systems
Controllers

Electric

Electronic

Pneumatic

DDC Controllers
Types of Controllers

Electric Controls

Electronic Controls

Pneumatic Controls

DDC Controls

Courtesy Johnson, Honeywell, and Alerton Controls
Controllers Basic Principles

The Controller Receives the Input and Processes an Output

- **Sensors**
  - Input points:
    - Analog (Variable) or Digital (2 State)
  - Temperature
  - Air Flow (Static Pressure)
  - Low Limit (Freeze stat)
  - Smoke
  - Humidity

- **Controlled Devices**
  - Output points:
    - Analog (Variable) or Digital (2 State)
  - Supply Fan
  - Outside Air Dampers
  - Chilled Water Supply Pump
  - Humidifier
  - Electric Heat
  - Valve
Electronic Control System

Courtesy Honeywell Controls
The DDC Controller

Receives the Input from the Sensor, Performs a Logic Function, and Processes an Output
# DDC Controller Input and Output Chart

<table>
<thead>
<tr>
<th>Digital</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two state information from the building into the SCU</td>
<td>Two state information from the SCU out to the building</td>
</tr>
</tbody>
</table>
|         | Switches:  
  • Differential Pressure/Proof  
  • Smoke Alarm  
  • Level Alarm  
  • High/Low Pressure Alarm  
  • Filters |  
  • On/Off Control – fans, pumps, lights  
  • Open/Close 2-position valve damper  
  • Control of 2-speed motors  
  • Energize/De-energize E/P valves for heat/cool and day/night changeovers |

<table>
<thead>
<tr>
<th>Analog</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variable Information from the building into the SCU</td>
<td>Variable information from the SCU out to the building</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
  • Temperature – room, duct, outdoor  
  • Humidity – room, duct, outdoor  
  • Pressure – static, velocity, total  
  • Flow rate – water and air |  
  • Modulate valve, damper, actuator  
  • Motor speed control  
  • Modulate fan inlet volume dampers  
  • Adjust air pressure to P/E switches |
## Preventive Maintenance

<table>
<thead>
<tr>
<th>Description</th>
<th>Comment</th>
<th>Maintenance Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall visual inspection</td>
<td>Complete overall visual inspection to be sure all equipment is operating and that safety systems are in place.</td>
<td>Daily: X</td>
</tr>
<tr>
<td>Verify control schedules</td>
<td>Verify in control software that schedules are accurate for season and occupancy.</td>
<td>Weekly: X</td>
</tr>
<tr>
<td>Verify setpoints</td>
<td>Verify in control software that setpoints are accurate for season and occupancy.</td>
<td>Monthly: X</td>
</tr>
<tr>
<td>Time clocks</td>
<td>Reset after every power outage.</td>
<td>Annually: X</td>
</tr>
<tr>
<td>Check all gauges</td>
<td>Check all gauges to make sure readings are as expected.</td>
<td>Daily: X, Weekly: X</td>
</tr>
<tr>
<td>Control tubing (pneumatic system)</td>
<td>Check for proper control and cleanliness.</td>
<td>Monthly: X</td>
</tr>
<tr>
<td>Check outside air volumes</td>
<td>Check for proper function.</td>
<td>Daily: X, Weekly: X</td>
</tr>
<tr>
<td>Check setpoints</td>
<td>Temperatures should not exceed or drop below design limits.</td>
<td>Daily: X, Monthly: X</td>
</tr>
<tr>
<td>Check schedules</td>
<td>Verify the bottom, surface and water column blow downs are occurring and are effective.</td>
<td>Daily: X, Monthly: X</td>
</tr>
<tr>
<td>Check deadbands</td>
<td>Assure that all deadbands are accurate and that the only simultaneous heating and cooling is by design.</td>
<td>Daily: X, Monthly: X</td>
</tr>
<tr>
<td>Check sensors</td>
<td>Conduct thorough check of all sensors for temperature, pressure, humidity and flow for expected values.</td>
<td>Daily: X, Monthly: X</td>
</tr>
<tr>
<td>Calibrate sensors</td>
<td>Calibrate all sensors for temperature, pressure, humidity and flow.**</td>
<td>Daily: X, Monthly: X</td>
</tr>
</tbody>
</table>

**Critical sensors should be calibrated seasonally or more often. Critical sensors include Outside Air Sensors, discharge air sensors on large systems, or other sensors that have a large influence on multiple control sequences.
Computerized Control Systems

Hardware

Software

Points

Features and Capabilities

Microprocessor Systems

- Open source
- Closed source
- Wireless
Building Automation System (BAS)

PC-Based DDC Control System

Internet Based?

Graphical User Interface

LAN Devices
DDC Network Architecture: Large Systems

Multiple-Subnet Works System Architecture

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

Courtesy DDC-Online Org
DDC Network Architecture:
LAN Configurations
DDC Network Architecture: LAN Configurations

Peer-to-Peer LAN

C = Controller
I = Interface
S = Sensor
O = Outputs

Peer-to-Peer & Polling LAN

Communications Interface

C = Controller
Cl = Communications Interface
I = Interface
S = Sensor
O = Outputs

Courtesy DDC-Online Org
Modern DDC Controls: Four Level Architecture
Four Level Architecture
Level One: “Sensors”
Four Level Architecture
Level Two: “Field Controllers”
Four Level Architecture
Level Three: “Integration”

BACnet IP Ethernet WAN

Integration Level

Field Controller Level

Sensor/Actuator Level

BACnet MS/TP LAN

Alerton VLCs
VAV-SDC3
Automated Logic
I/O 6104
Delta Controls
DAC 304
VAV-SDA
Nailor
VAV Box
VLC-MQ-WSHP
Lithonia Lighting
Delta MODBUS
Gateway
Mammoth
KMC Controller

Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II
Microset II

BTP-Modbus
Phoenix Interface
FieldServer Gateway
KMC LAN Controller
FieldServer Gateway

BACnet IP WAN

WEBtalk iPort
Renton, WA
Atlanta, GA
Los Angeles, CA

EBtron
ABB VFD
Fume Hood Controls
EST Fire System

Courtesy Alerton Controls
Four Level Architecture
Level Four: “Management”
Communication Standards Software Integration (TCP/IP, BACnet, LON)

Automation systems allow communication with multiple vendors including:

- HVAC Equipment
- Fire alarm, security
- Lighting, fan units
- PLCs (Programmable Logic Controllers)
- Boilers and chillers
Communication Standards
Communication Standards
VAV with Terminal Reheat
Energy Conservation Considerations

- Optimum Setpoints
- Calibration of CO$_2$?
- Alarms?
- Trend Logging?
- System Integration
- Preventive Maintenance Checklist
Energy Efficiency Considerations

Are the controls calibrated?

■ How often?

Heating and cooling simultaneously?

Sensing correct medium and location(s)?

Preventive maintenance checklist.
BAS Screen Checks

A methodology for using the GUI as a cost-effective means of keeping track of key indicators of building performance
Graphic User Interface (GUI) as a Diagnostic Tool
Dampers
Exhaust Air Dampers
GUI Terminal Unit
GUI Terminal Unit
Benefits of the BAS GUI

Benefits of using the BAS GUI as a maintenance tool:

- It’s quick!
- It’s a proactive way to identify problems and verify proper building HVAC performance.
Verify the GUI for Accuracy

- It’s important to first verify the GUI for accuracy.
  - Ensure the system has been commissioned.
  - Ensure sensors are calibrated.
  - Perform a thorough and documented point-to-point check if necessary.
System Design & Control Sequences

- Gather Building Information.
  - Sequence of operation
  - Controls drawings
  - TAB report
  - Commissioning report
  - System design documents
Trend Data Availability

- Chilled Water Pump Speed
- Documenting Actual Operation
  - Ensure trend data will be available for review.
Screen Check Forms

- Forms should be tailored to specific types of equipment.
  - Air handlers, chillers, boilers, pumps, exhaust fans

- Data to be recorded:
  - Inputs, outputs and setpoints
  - Active alarms
  - Date, time, OSA temperature, user’s initials.
Screen Check Forms

- Examples of Inputs, Outputs and Setpoints:
  - Building static pressure
  - Duct static pressure
  - Outside air damper position
  - Terminal unit minimum and maximum CFM setpoints
  - Valve positions
  - Fan and pump VFD % speed.
## Screen Check Forms

<table>
<thead>
<tr>
<th>Terminal Unit</th>
<th>TU-1624</th>
<th>Value/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Fan Speed Setpoint (CFM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min Fan Speed Setpoint (CFM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Fan Speed (CFM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room Temperature Setpoint (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Room Temperature (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Air Temperature (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Discharge Air Temperature (F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date/Time/Initials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TU Fan Command (ON/OFF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reheat ON/OFF (Stage 1, 2, 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Screen Check Process

- Order of checks
  - Start with the central plant systems and equipment, including boilers, chillers, cooling towers and pumps.
    - Complete one system at a time.
  - Try to get through all of the checks in one sitting.
Screen Check Process

- Order of Checks
  - For VAV systems, check AHU, then look at zone temperatures.
  - Spot check several TUs, especially those serving zones with the greatest deviation from setpoint.
Screen Check Process

- As you record the data, question whether it makes sense.
- Does the data indicate expected and proper operation?
- Do other systems operate in a similar fashion?
Screen Check Process

- Frequency
  - Depends on the facility. Complex systems may require daily or weekly checks.
  - For typical buildings, quarterly or semi-annually to capture seasonal effects.
  - Consider incorporating into your PM schedule.
Screen Check Process

- Complete the screen check forms in their entirety.
  - Pursue anomalies until you are comfortable systems are working properly.

- Document and communicate your findings.
  - Incorporating screen checks into your scheduled PM’s can be an effective way to ensure they are documented.
  - Communicate your findings so the necessary corrective action can be taken when anomalies are noted.

- Be persistent!
Trending

- Review trend data when more information is needed to support a screen check.
- Your ability to trend depends on your BAS capability
- What to trend:
  - Outside air temperature
  - Supply air temperature
  - Hydronic temperatures
  - Setpoints, etc.

Image: Penn State University
Trending

- **Multi-point trends**
  - Combine associated data point trends into groups.
  - Include an independent variable in the group to assist in the analysis (time, OSA temperature).

- **Proving the trends**
  - Collect the data and see if the trends work.
  - Does the data behave as you expect?
  - Customize additional points as necessary.
Energy Efficiency

- Common problems:
  - Simultaneous heating & cooling
  - OSA damper position not correct
  - MAT, OSAT, RAT and OSA damper position not proportionally correct
  - Mechanical cooling on when it’s not needed.
Minimum OSA Dampers
Minimum OSA Dampers
Energy Efficiency

- Key Performance Indicators (KPIs)
  - These will present themselves upon reviewing BAS data and filling out the screen check forms.
  - They can be anomalies in the data or deviations from what you’d expect to see.
  - They may indicate a problem with the system and should be investigated!
  - The following two case studies provide examples.
KPI Case Study: AHU

Case Study #1

<table>
<thead>
<tr>
<th>Point</th>
<th>Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit #</td>
<td>AC3-3</td>
</tr>
<tr>
<td>DAT (discharge air)</td>
<td>60.3°F</td>
</tr>
<tr>
<td>DAT setpt</td>
<td>62.1°F</td>
</tr>
<tr>
<td>MAT (mixed air)</td>
<td>55.8°F</td>
</tr>
<tr>
<td>OSAT (outside air)</td>
<td>60.8°F</td>
</tr>
<tr>
<td>RAT (return air)</td>
<td>61.7°F</td>
</tr>
<tr>
<td>Avg Zone Temp</td>
<td>70.3°F</td>
</tr>
<tr>
<td>OSA damper command, %</td>
<td>10%</td>
</tr>
<tr>
<td>Heating Valve %</td>
<td>58%</td>
</tr>
<tr>
<td>SF VFD % speed</td>
<td>82%</td>
</tr>
<tr>
<td>DX Stages</td>
<td>0</td>
</tr>
<tr>
<td>ALARMS?</td>
<td>None</td>
</tr>
<tr>
<td>Zone temperatures near setpoint?</td>
<td>Yes</td>
</tr>
<tr>
<td>OKAY?</td>
<td>No; MAT and RAT low</td>
</tr>
<tr>
<td>Date/Time/Initials</td>
<td>4/19/07; 17:40; MBK</td>
</tr>
</tbody>
</table>
KPI Case Study: Chiller

Case Study #2

<table>
<thead>
<tr>
<th>AHU-2</th>
<th>Data</th>
<th>Chilled Water System</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAT (discharge air)</td>
<td>65.6°F</td>
<td>Chilled Water Supply Temp</td>
<td>55.3°F</td>
</tr>
<tr>
<td>DAT setpt</td>
<td>55.0°F</td>
<td>CHWST Setpoint</td>
<td>44.0°F</td>
</tr>
<tr>
<td>MAT (mixed air)</td>
<td>80.4°F</td>
<td>CHW Pump-1 Status</td>
<td>On</td>
</tr>
<tr>
<td>OSAT (outside air)</td>
<td>83.6°F</td>
<td>CHW Pump-2 Status</td>
<td>On</td>
</tr>
<tr>
<td>RAT (return air)</td>
<td>73.8°F</td>
<td>Chilled Water Flow, GPM</td>
<td>34 GPM</td>
</tr>
<tr>
<td>Avg Zone Temp</td>
<td>74.6°F</td>
<td>Chiller #1 Enable</td>
<td>False</td>
</tr>
<tr>
<td>OSA damper %</td>
<td>30% (min)</td>
<td>Chiller #2 Enable</td>
<td>True</td>
</tr>
<tr>
<td>Cooling Valve %</td>
<td>100%</td>
<td>Chiller #1 Isolation Valve Status</td>
<td>Open</td>
</tr>
<tr>
<td>Heating Valve %</td>
<td>0%</td>
<td>Chiller #1 Flow Switch Status</td>
<td>Off</td>
</tr>
<tr>
<td>Alarms?</td>
<td>None</td>
<td>Chiller #2 Isolation Valve Status</td>
<td>Open</td>
</tr>
<tr>
<td>Zone temps near setpoint?</td>
<td>No; up to 77.5°F</td>
<td>Chiller #2 Flow Switch Status</td>
<td>On</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alarms?</td>
<td>No</td>
</tr>
<tr>
<td>OKAY?</td>
<td>No; High DAT &amp; zn temps</td>
<td>OKAY?</td>
<td>No; High CHWST, CH-1 should be on, low CHW flow.</td>
</tr>
<tr>
<td>Date/Time/Initials</td>
<td>9/5/08;14:30;MK</td>
<td>Date/Time/Initials</td>
<td>9/5/08;14:00;MK</td>
</tr>
</tbody>
</table>
Controls Service Contract

Annual Training?

Updated Training?

Updated Software?

Alarm Troubleshooting?

What are you getting for your $?
QUESTIONS ?