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# Exploring Challenges In Existing Building Automation Systems

INTERVIEWS BY MARY KATE MCGOWAN, MANAGING EDITOR

Often, engineers design with a focus on the “peaks and valleys” when working on building automation systems (BAS), said James Del Monaco, P.E., Member ASHRAE, chair of ASHRAE Technical Committee 1.4, Control Theory and Application. But, he says, “to properly design the system, we need to also understand all the points in-between.”

From designing BAS to work properly from the start or troubleshooting issues after construction, engineers need to know common system challenges and misapplications when working with existing BAS. Del Monaco and other engineers dive into accessible tips to diagnose problems efficiently and provide recommendations and best practices for assessment tools and techniques.

## Most Common Issues

### Right Component, Right Place

“Make sure you’ve got the right component for the job and that it’s put in the right place,” said Chris Benson, P.E., Member ASHRAE, member of TC 1.4. For instance, Benson, an associate director of sustainability and energy at the University of Utah, said building pressure sensors are often poorly located, which can result in issues with stability and personal comfort. If you see leaves blowing in or that people by exterior doors can’t stay warm, pressure sensor location could be an issue.

“Make sure manufacturer recommendations for height and recommended distance from walls and

doors are understood and followed. For big buildings, consider use of multiple sensors, including [one on] the lowest floor with an entrance (where pressure is most negative),” he said.

Another issue is also tied to location. Hydronic flow sensors, like those used in energy meters, are too often placed where inadequate lengths of straight pipe exist, which reduces accuracy—sometimes significantly, said Benson. “If we can’t get reasonably accurate measurements, it may not be worth the investment to have the equipment in the first place. Find a better location, alternate technology choice or supplement with flow straighteners to ensure manufacturer recommendations are met,” he said.

Too often Benson said he sees probe-style temperature sensors selected for air-handling units' (AHU) mixed air sections. Systems don't always control with this, but if you see a need for active heating or cooling from the AHU when an economizer should be able to do all the work, this may be part of the issue. Stratification is likely to occur and mixing sensors can be a much better fit for control logic to maximize efficiency for climates in which outside air temperature widely varies.

Outdoor air temperature sensors are often installed where they are exposed to direct sunlight or where nearby thermal mass, such as concrete slabs, can create microclimates, according to Benson. This can cause the temperature to swing by several degrees. The locations can reduce the number of hours when outdoor air is used and unnecessarily increase loads, he said.

"A comparison between the values of site and local weather sensors can sometimes identify issues or confirm where microclimates are notable. When referenced by an AHU, consider placing these sensors within outdoor air intakes so you have a more accurate representation of the actual air temperature available for economizing," Benson said.

### Overloaded Subnetworks

For Joseph Kilcoyne, P.E., Member ASHRAE, vice chair of TC 1.4, most performance issues are due to overloaded subnetworks. In existing facilities—particularly larger buildings or campuses—new controllers are frequently added to existing networks, rather than running new communication cable back to a supervisory controller in an IT closet, he said. Every manufacturer has different recommendations on the maximum number of field controllers to be located on each subnetwork. Usually, fewer than 50 controllers is acceptable, while fewer than 30 is best practice, according to Kilcoyne.

"We've found individual subnetworks containing over 100 controllers. It took over five minutes for information on this network to pass from the controller to the main BAS server," said Kilcoyne, a principal at SC Engineers.

To remedy overloaded subnetworks, Kilcoyne advises adding additional supervisory controllers. "If you've got an overloaded subnetwork, the only fundamental fix is to split it into smaller subnetworks. You will have to add supervisory controller(s) somewhere, and just make sure you don't exceed the length limitation on the subnetwork cabling," he said.

Most challenges Kilcoyne encounters are in the supervisory level—the network supervisors that host one or more serial subnetworks of field controllers and report directly to the BAS server usually over an IP connection. These may also act as an advanced application controller for a plant or AHU, he said.

"The challenges are found here because these controllers are frequently the bottlenecks for communication. All communication points and trend points pass through these supervisory controllers," Kilcoyne said. "They usually have limited memory and can easily become overwhelmed. These controllers are also where most of the network configuration settings are programmed."

### Accurate As-Builts and Sequences of Operations

Del Monaco, an associate principal at P2S Inc., said the most common issues he sees when diagnosing issues in an existing BAS are having accurate as-builts and sequences of operations.

"Oftentimes, the system has evolved over time, and operators have made changes to the sequences and setpoints that deviate from the original design intent," he said. "This is usually in response to occupant complaints, or a system does not appear to be working as intended. These changes are made, and there is no formal record of it anywhere."

He suggested finding any available as-builts and sequences. Because the system may have been modified, Del Monaco suggests engineers compare the general network architecture from the as-builts to the installed conditions via field surveys, which can give the engineers a solid foundation to design around moving forward.

He said engineers should understand how they want to design the system, what parts and pieces they will need to upgrade and modify on the existing system, and know the ramifications to the upstream and downstream equipment if they replace components/controllers in-between.

"I would recommend an assessment of the equipment prior to modifications. Are the sensors, devices and controllers operating? Can we identify any failures in the current system and operation? I've worked on renovations where the owner intended to keep some of the components, and when we went to test them at the end of construction, they were not functioning. These resulted in change orders that would have been part of the base bid," he said.

### Understanding the Existing System

Del Monaco advises engineers to not solely rely on the controls vendor to inform them about the existing system and upgrades, including when trying to prevent recurring issues in existing BAS.

Engineers need to coordinate with the BAS vendor and the IT department, said Del Monaco.

When engineers are integrating new components and controllers into an existing system, they need to know the terms of licensing agreement, he said. They need to know what they have with the existing system, and what they can actually do to ensure the system is cohesive and functional. Engineers also need to know about the condition of the system, software patches and updates and if the owner has maintained the system and kept it up-to-date, said Del Monaco.

“We need to understand the existing system in detail and the future needs to appropriately select controllers and adapt the network, if needed,” he said.

Del Monaco added that another concern with existing control systems could be dealing with pneumatics. “If we’re upgrading the system from pneumatics to DDC, there will be physical restrictions in an existing building that could limit the upgrades due to the financial burden,” he said.

### Properly Diagnosing Issues

#### During the Design Process

To help prevent challenges from arising during the design process, Benson suggests using industry guidelines—such as ASHRAE Guideline 36-2018, *High-Performance Sequences of Operation for HVAC Systems*. He said it helped his team working on a campus-wide controls upgrade project to start with a well-vetted resource (the Guideline) instead of from scratch.

And, he says, “the more widely these [Guidelines] are deployed, the better our performance and the more time our designers, contractors and operations and maintenance teams can save,” he said.

Bringing those stakeholders together during the design process is also important. Once the controls contractor has thoroughly reviewed sequences and has identified where issues and other methods could be used, Benson said engineers should schedule deep-dive discussions about the controls with selected vendors and O&M teams.

“Make sure stakeholders can attend and explore questions and concerns as a group. These sessions require

an investment of time, but they pay dividends, typically resulting in better sequences and better-trained staff,” he said.

Benson said O&M teams often have feedback that designers do not know. For example, on one project, the team decided they needed to program the controls system to start building scheduling earlier than initially planned.

“There is a common sequence, called ‘optimized start,’ that starts equipment early (for as little time as possible) to make sure the air temperature is where it needs to be by the time a space is occupied. The O&M staff was adamant: ‘We still need to schedule our spaces for at least half an hour earlier than when people arrive or they are going to be uncomfortable.’ At first we didn’t understand. Why would you do this if you already knew the temperature would be at setpoint by the time people arrived? Mathematically, that’s right, but we were only looking at air temperature, and we hadn’t taken the thermal mass of furniture into account. Staff knew this in their gut,” he said.

After several conversations, the entire project team figured out the solution to ensure occupant comfort, Benson said. “One of the lessons that I’ve learned through these conversations is to really, really respect the O&M staff. They have a lot of experience and talents that our engineers can learn from,” he said.

#### Field Investigation and Diagnostic Testing

Approaching an issue with a combination of field investigation and diagnostic testing is a strong strategy, said Kilcoyne. While some BAS manufacturers’ software will provide reports with the quantity, type and protocols of field controllers on each subnetwork, others do not. This, he said, then requires engineers to perform physical inspections to determine these network characteristics.

“On one project in a large government medical center, we had to perform a hand-over-hand survey of over six miles [10 km] of communication cable in order to map out the existing BAS network. Because of infection control requirements, it all had to be done in mobile air containment units (MACUs) and took six months to complete,” said Kilcoyne.

Also, noting the type and gauge of communication and low voltage power wiring is necessary in field investigations, according to Kilcoyne.

“Frequently, clients request BAS investigations when they are looking for a plan to update, migrate or replace

their BAS systems. The communication wiring used in a network operating on a proprietary protocol will likely not be the recommended gauge for the higher speed communications used by modern BACnet networks. This requires a total rewire when replacing controllers,” he said.

Kilcoyne says other aspects to note during field investigations are the quality of installation in each control panel, proper labelling and termination of all signal wires and proper communication cable shielding splices and grounding.

“Issues with cable shielding is the most common reason for ‘network noise’ and losses in communication,” he said.

BAS network diagnostic software can be a powerful tool. Most manufacturers provide some form of diagnostic or commissioning programs as part of the main BAS network hosting software package, he said. These tools can test several aspects: communication speeds of each subnetwork, report firmware versions and point loading of individual controllers and test for proper airflow modulation of variable air volume (VAV) boxes, among other information.

“If these programs are not already present, there is also third-party software designed to perform these functions,” said Kilcoyne. “Some are free but require significant training to learn and interpret results. Others are paid and can provide intuitive reports that can quickly diagnose controllers, networks or configuration settings that are causing system issues.”

## Preventing Issues from Recurring

### Use Your Resources

Kilcoyne recommends that anyone looking to help prevent issues in BAS design start with ASHRAE Guideline 13-2015, *Specifying Building Automation Systems*.

Kilcoyne said the Guideline includes a full sample guide specification for control systems, which is helpful. “It will explain in detail in layman’s terms what exactly all those requirements mean and why you do it,” he said.

Del Monaco said Guideline 13-2015 is especially helpful for beginners in the industry. One challenge the Guideline can help with is when designers and engineering firms rely heavily on their BAS vendors and do not take the time to learn about the system in-depth, he said. Guideline 13-2015 helps engineers understand a system’s controllers, devices, etc., and how those integrate into the system architecture, said Del Monaco.

“The Guideline 13 committee is working on a reference guide (three to five pages) that designers can use as a tool to communicate with owner to understand BAS and how they might want to set their system up,” he said.

Kilcoyne agrees that the guidelines are “extremely valuable” for control engineers working with building owners and clients.

“What really helps is when you bring [Guideline 13-2015] up to a client or a controls vendor, there’s not much better room for discussion when they say we think we’ve got a better way to do it,” he said. “We say, ‘We defer back to ASHRAE’s work in [the Guideline].’”

In addition to ASHRAE Guidelines 13 and 36, three ASHRAE Handbook chapters, Chapter 7, “Fundamentals of Control” in the 2017 ASHRAE Handbook—Fundamentals; Chapter 11, “Refrigerant Control Devices” in the 2018 ASHRAE Handbook—Refrigeration; and Chapter 48, “Design and Application of Controls” in the 2019 ASHRAE Handbook—HVAC Applications are commonly referenced resources.

Del Monaco also points to ASHRAE e-Learning and technical seminars from previous ASHRAE conferences as more resources.

Del Monaco also recommends researching the individual BAS products and talking with the facilities team and operators to understand their preferences and pain points.

“They live with these systems and buildings on a daily basis and have a wealth of knowledge. It’s in all of our best interest to work together so the building meets the needs of the owner and the building occupants,” he said.

Benson recommends working closely with the owner, O&M teams and commissioning authorities. “This is your best path to tap into institutional knowledge, receive feedback, and ensure decisions meet your intent,” he said. “It isn’t easy, but you’re not going to leverage that talent without real and open conversations.”

In addition, engineers should become familiar with the specific requirements of the BAS platform they are designing, said Kilcoyne.

“Each one has small variations in their network architectures that can become important in specifying a system for issue-free operation,” he said.

### Keep in Communication

Once the design work is over, the project is ongoing. Pay attention to the commissioning process, said Benson.

“This feedback will tell you where things were misunderstood or difficult to get working,” he said.

Kilcoyne added that the commissioning report is commonly the last time a design engineer will be able to see any issues in the BAS design.

“After this, facilities engineering takes over and mitigates, works around or lives with any BAS deficiencies,” he said. “If [design engineers] have the opportunity, I suggest checking back in with the client after six or 12 months to see what is working for them and what issues have arisen.”

Benson also suggested staying in communication with customers and O&M teams as they become familiar with the building and day-to-day challenges.

“This is especially powerful for owners that use analytics and benchmarking to track performance. Don’t forget to request feedback both on where you could do better as well as what’s working well,” he said.

### Possible Pitfalls

#### Start with Controls in Mind

When starting to design any type of system, keep controls in mind, said Del Monaco.

“Oftentimes controls are put on the back burner, and they’re developed really late in the game,” he said.

When controls are not considered in the early stages of design, sometimes the designer does not consider all the components and/or devices to control the space or environment, he said.

“So you end up adding modifying equipment or components really late in the game. And sometimes that could be a challenge because there may be physical limitations, impacts to other trades and cost implications to doing that,” Del Monaco said.

Kilcoyne said he would like to see the industry move more toward an integrated design approach, which he said could lead to better performing and more energy-efficient systems.

“When you’re thinking about the types of controls sequences and resets that you want to incorporate into the design sequences, then you have to know where those sensors are located in your piping plans, your air distribution and ductwork,” he said.

#### Do Not Overly Rely on Others

“Young or less experienced engineers tend to rely too heavily on others,” said Del Monaco. “They do not do their due diligence to understand the existing system and new components. As the engineer of record, they

are responsible for all aspects of the design and should learn the system in detail.”

He encourages young or less experienced engineers to take the initiative to learn what they are doing, instead of being intimidated because they think someone else is the expert.

“Do your own research, ask questions, but discern what it being told to you,” he said.

Kilcoyne echoed Del Monaco. Relying on a local BAS vendor to perform the controls design on a project is the most frequent pitfall Kilcoyne sees. While BAS vendors are experienced and knowledgeable about their product and can be a valuable resource to a design engineer, the design engineer needs to be able to temper and judge their recommendations and perform their own design, said Kilcoyne.

“These vendors may have motivations other than optimal BAS performance that show up in their designs. They are also not being paid to perform the investigation into the existing network that is necessary for a proper design,” he said.

Kilcoyne advises engineers to educate themselves or work with someone within their own firm to get a “truly independent and unbiased controls design.” He also pointed to design templates that are available through ASHRAE and manufacturers.

“They’re all useful tools that you can use, but you have to have enough knowledge,” he said.

#### Do Your Due Diligence

Benson advises design engineers to do their own due diligence—especially for existing systems. He recommends engineers plan at least one site visit to ensure they understand an existing building’s components, original intent and how things are installed. He also said to always remove non-applicable sections of specs.

“Avoid the cardinal sin of redundant tag names and numbers. Multiple pieces of equipment in a building with the same tag number (ex: ‘exhaust fan 1’, ‘VAV 01’, ‘AHU 01’) is a nightmare and leads to real problems referencing designs and maintaining systems effectively. Using unique names from the start is very much appreciated,” said Benson.

#### Simplify Overly Complex or Unmanageable Strategies

“As good as their intentions are, we often have an issue when an engineer tries to squeeze out the last few

percentage points of efficiency,” Benson said. “Needs change over time, and we simply don’t get persistence [from contractors and O&M teams] when things are really difficult to understand or manage.”

Benson advises design engineers to follow a good, intuitive strategy. A simpler choice will always have higher performance in the long term than a theoretically better, but abandoned option.

“Because of how we traditionally communicate sequences, it can also be a real challenge to ensure systems get programmed as the designer intended. When there is ambiguity, we depend on creative license to fill in the gaps,” he said.

### Don't Reinvent the Wheel

Knowing and adhering to an owner’s BAS requirements and guidelines from the start is critical.

“This can affect everything from technology choices, point naming, sequences of operation and the way information is presented on a graphical interface. The more standardized a system is for an owner, the easier it is for O&M staff to get trained and utilize it effectively,” said Benson.

When an owner does not have requirements or guidelines, Benson recommends engineers use ASHRAE Guideline 13-2015 or ASHRAE Guideline 36-2018 as resources, and speak up if a owner’s references need to be revised.

“Respecting the owner’s existing plans and providing feedback is a great way to build solid trust and a path to continued partnership,” he said.

### Avoid Independent Controls for the Same Outcome

Limited budgets often require engineers to scale back a renovation’s scope, said Benson. This situation can create challenges.

Benson said common issues happen when controls of related systems can’t communicate, such as when a VAV is upgraded, but a baseboard radiator in the same space is left in place with original and independent controls.

“More often than not, these systems will eventually fight, causing discomfort and big impacts to efficiency,” he said. “Take the time to tie things together and ensure sequences remain well-coordinated.”

Benson recommends owners consider adjusting scope in ways that support this, such as renovating fewer rooms but upgrading all necessary components. ■

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