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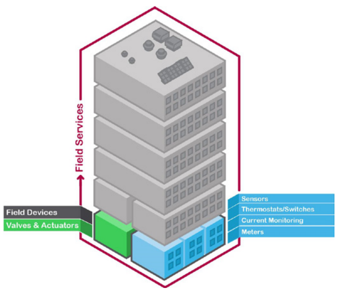
The Role of Device Level Control in a Building Management System: Trends in Education

by Mark Sarna and Brent Bernardi

Executive summary

Although often unheralded, device level controls—or field devices—are in many ways the foundational elements that make the myriad benefits of a BMS possible. While these workhorses operate similarly in all types of buildings, many parts of the education sector are often early adapters of the latest technologies and applications, helping to reclaim energy expenses and optimize the learning environment in their buildings. This paper will examine the role of field level devices, the trends associated with them, and how innovative institutions can benefit now and in the future.

Introduction



Smart Starts at the Foundation of the BMS

HVAC related costs account for upwards of 40% of operating expenses for many college campuses and K-12 school districts—for most, the largest expense they face except perhaps for that of staff and personnel. Many institutions today strategically invest in Building Management Systems—also called Building Automation Systems—to deliver technologically sophisticated control of heating and cooling to optimize comfort, reduce energy waste and decrease this expense, reclaiming dollars that can be redirected to learning initiatives and the optimization of student development.

Device level control, smaller BMS components that work remotely in individual rooms and buildings, rarely get the attention afforded to the more flashy centralized components of a Building Management System solution such as graphic dashboards and control software, or to the larger and more costly mechanical components of the HVAC system such as chillers and heat pumps. Yet, it is these modest components that make the efficient and effective operation of all the others possible. These often invisible workhorses include:

- *Valves,* which are opened and closed to precisely control the flow of water, fresh air, gas or other element impacting the space;
- *Actuators,* which physically adjust the valves through electric or mechanical means; and
- *Sensors,* which measure aspects of the environment such as air or water temperature, carbon dioxide levels and relative humidity, and direct the actuators to adjust the valves to compensate in order to get the variable back into a pre-determined comfort range.

There may be several thousand of each of these field level devices across a multi-building campus or district, associated with equipment and infrastructure such as dampers, fan coils, air handling units, chillers, furnaces and more.

Operating quietly in the individual buildings and classrooms, these foundational field devices substantially enable many of the benefits delivered by a Building Management System solution. They feed vital information back to the centralized controller, reducing energy usage and optimizing the classroom comfort that boosts the concentration and attention levels and enhances the productivity and effectiveness of students and staff alike. Indeed, experience shows that student attendance levels as well as test scores and class performance can be positively impacted by an effective Building Management System. For example, an Illinois school found that indoor air quality improvements resulted in a 5% increase in student attendance[1]. In another study, schools in Chicago and Washington, D.C., added 3 to 4 percentage points to standardized test scores as a result of building improvements[2].

Although valves, actuators and sensors operate similarly in many building environments including retail stores, hospitals and office buildings, it is the education sector, especially colleges and universities, as well as K-12 school districts, that are often early adapters of the latest associated technologies and applications to help improve their learning environments in this way. This paper will examine some of the current and predicted trends in field level devices and Building Management Systems and how even greater numbers of innovative colleges and schools can benefit.

[1] Illinois Healthy Schools Campaign, "Apparently Size Doesn't Matter: Two Illinois School Districts Show Successful IAQ Management." School Health Watch, Summer 2003

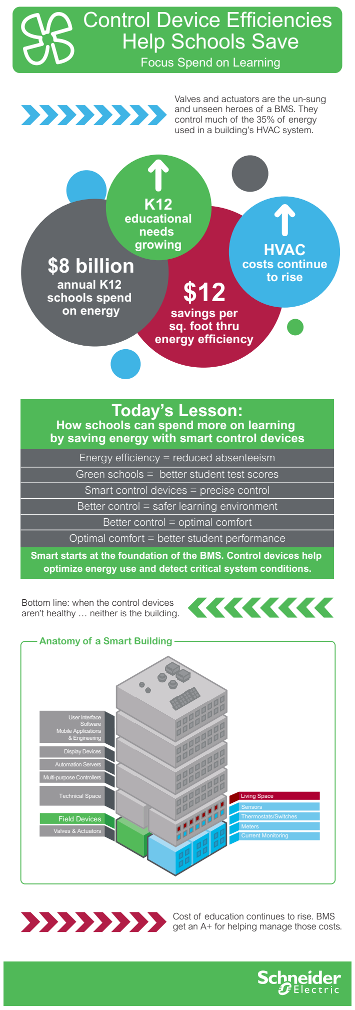
[2] Schneider, Mark. "Public School Facilities and Teaching: Washington, DC and Chicago," November 2002

Specialized needs of educational buildings

Although education-related buildings and complexes share many of the same needs with other types of campuses, such as those related to businesses or hospitals, many colleges, large school districts and similar institutions find that meeting many of these needs are even more urgent due to the unique functions of educational environments.

Take class and student meetings and related room scheduling, for example. While many businesses might have built a reputation for calling personnel meetings throughout the business day, the meeting room demands of even the most active office environments would likely pale in comparison to the meeting and occupancy schedules of the multitude of classes, lecture halls, labs, dining locations, libraries, department meetings, sports practices, clubs, tests, residence hall events and other gatherings that are likely to go on nearly around the clock in a busy campus environment.

Further, colleges and K-12 schools stand out from other sectors in the sheer diversity and fast-changing nature of their schedules. For example, a business building, apart from the occasional holiday, might be said to have a fairly steady population flow from 8-5 or during other basic business hours, five days a week. Main areas of a hospital building might be occupied unchanged around the clock by patients and various shifts of doctors, nurses and support personnel. School buildings, on the other hand, might go from packed to sporadically populated for weeks or months at a time several times a year, during winter break, fall break, spring break and summer. And the regular occupants of individual rooms or buildings might be absent due to a one-time field trip, snow day, or other school event, suddenly emptying the space unexpectedly.



Occupancy sensors

It's no wonder then, with their complicated and ever-changing scheduling, that many schools have been the earliest and most proactive adopters of occupancy sensor technology. Emerging in the past few years, HVAC occupancy sensors are a relatively recent addition to Building Management System capabilities. These devices allow buildings and individual rooms to respond on the fly—without human intervention and outside of rigid pre-set timing—and dynamically adjust cooling and heating to more accurately reflect the actual rather than the "expected" population.

Obviously, this capability provides a significant improvement in energy efficacy and occupant comfort, providing optimization not just during breaks but also during every single class every single day. No more conditioning air to the "right" temperature and humidity, with the specified number of air exchanges per hour, keeping no one but desks and chairs comfortable. No more wastefully chilling a lecture hall down to 55 degrees in anticipation of the 200 warm bodies about to enter—and then not having them enter. Indeed, the capability even helps ensure interim attendee comfort as early arrivers file in, avoiding the need to overcool in advance—and maintaining comfort more steadily even if the lecture is not as fully attended as expected.

Relying upon a chosen tracking variable, most occupancy sensors today work by detecting fluctuations in room temperature, or sampling the air for carbon dioxide levels to get an estimate of the population of the room, and then directing the actuators to adjust the valves to increase or decrease the cooling or heating elements as required. Based on their readings, the CO_2 monitors can also call for an influx of fresh air to more precisely align air volume with demand and alleviate "stuffiness" of the environment to improve the comfort and attention levels of the attendees.

The future of occupancy sensors

Many experts feel that this technology is only the beginning, and visionary companies are thinking about what other variables could be read by the sensors to provide even faster

"HVAC can account for up to 40% of energy costs in a building. Smart buildings enable efficiency with device level controls that help lower energy use."

interaction and response times between people entering the space and room reaction. Measurements of temperature and CO_2 drive relatively fast responses, but what if, for example, seat occupancy at the start of a class could be measured and sent to the system as well, or Wi-Fi or other mobile device related signals could be counted as occupants entered the space to get an instant estimate of population. This would allow adjustments to be made well before the instructor began speaking, even further optimizing comfort, and even more precisely aligning energy output with needs. These incremental energy savings multiplied by the potentially hundreds or even thousands of rooms on a campus or in a school district, could generate significant additional savings over time.

Speaking of mobile devices, this level of real-time occupancy information could also ultimately drive additional benefits, such as improved real-time room scheduling information on a busy campus. Suppose, for example, the campus scheduling system has double booked classes in Lecture Hall A, while mistakenly listing Lecture Hall B as occupied when it is in fact vacant. Occupancy sensors feeding back into the Building Management System and into the scheduling system could potentially flag Lecture Hall B as vacant or other criteria, and deliver this information in time to allow the professor to get students to the alternate room in time, hopefully salvaging the class.

These are just a few examples, and clear indications that occupancy sensors and the other field devices they drive are increasing in sophistication and will become an even more vital part of an effective Building Management System in the coming years.

Smarter devices feeding more information

Today's actuators, are more intelligently designed and contain more sophisticated onboard software. They capture more real-time detail about the actions of the system and feed it back to the Building Management System, delivering many benefits to facilities managers, as well as the ultimate users they serve, such as students and faculty.

Continuous vs. ad hoc monitoring

The ability to monitor the health of an HVAC system remotely through a laptop had an immense "wow" factor when it first emerged almost a decade ago. Building on the enormous value of this real-time monitoring capability, smarter field devices can now provide more and more information that can spot issues automatically, without a user having to call and say "the room is too hot," or even having to rely upon a proactive operator identifying an issue on the screen and taking manual action. Devices can detect problems such as loss of control signal or valve blockage and alert the operator automatically, whether or not the operator is logged in to the system at that particular moment in time. Additionally, they can provide more capabilities to make "repairs" remotely without rolling out a truck or sending a technician. For example, smart sensors controls can send a signal electronically to initiate a safety reset after a power failure, rather than demanding physical intervention. While the era of a fully "push button" repair person might never emerge when it comes to heavily mechanical-based systems, smart device vendors continue to realize and incorporate the expectations of the next generations of repair technicians, who are often more than comfortable with using a laptop vs. swinging a hammer when the situation calls for it.

Identifying hidden—but expensive—problems

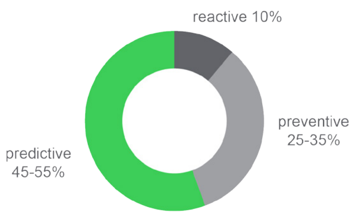
Further, with the power of today's field devices, problems can be identified and alleviated without an occupant—or even an operator— ever knowing that a problem exists. Take the case of a system where a hot water valve is stuck open in a lecture hall and the chiller is compensating, so that the room maintains its desired comfortable 70 degree Fahrenheit temperature so that no complaint call ever comes in, and no warning of out of specification temperature is ever flagged. However, meanwhile, the temperature is being maintained in a costly, inefficient fashion, and the cause of the malfunction, as yet unknown, might point to other issues detrimental to the HVAC system. Today's field devices, perhaps with the help of building data analytics software and similar tools, can spot the patterns that show these types of unusual, inefficient operations, even in the absence of outside evidence, and warn operators accordingly.

Reactive vs. Preventative vs. Predictive Maintenance

In conjunction with building data analytics software, the amount of data generated by field devices can deliver even greater returns over time, giving more insight into what isn't right or can be improved upon at present, as well as identifying longer term energy efficiency opportunities.

For example, reactive maintenance—or "fighting fires"—is still an extremely common maintenance scheme among buildings of all kinds worldwide. This is an expensive approach, leading to higher repair costs and the greater threat of dealing with unusable buildings and classrooms until a situation can be fixed.

Types of maintenance programs used in top-performing facilities



More proactive, value-conscious operators have long since adapted a *preventative* maintenance scheme, which, in this context, would call for a subset of field devices and other BMS components and equipment to be examined and serviced on a regular recurring schedule, catching and alleviating problems before they can occur, saving repair costs and reducing the chance of sudden, unanticipated failures that can make spaces uninhabitable. It is estimated that a well-conceived preventative maintenance program can deliver 5x the ROI of a reactive maintenance program[3]. Still, the fact that there can be thousands of individual field devices on a campus—coupled with the fact that field devices are robust devices that tend to "keep on working"— can still make maintaining a highly effective preventative maintenance program for them more challenging.

However, emerging field device and other BMS technologies have made the next stage in the evolution—*predictive* maintenance (also called continuous or monitoring-based commissioning)—a potentially more effective possibility, enabling institutions to prioritize and find the rarer "needles in the haystack" malfunctions that may need the lion's share of maintenance attention. Now, using delivered data run through building data analytics software, the "regular" preset preventative maintenance schedule can be prioritized, so that engineers can spend the most time on the highest value tasks—those promising the most positive impact on cost, comfort and other energy management goals.

For example, we can now see that actuator/valve pair #1038 might still be taking a fraction of a second longer to open and close as compared to its operation last year, even though it was just serviced a month ago. So, attention might be redirected to it at the next service even though in a preventative maintenance scheme it might not be scheduled to be looked at for another year. That particular valve could be evaluated again for excessive build-up, proper lubrication, proper sealing, hidden damage or other issue to alleviate inefficient operation or avoid a failure, while the multitude of correctly operating devices might be given lower priority. No wonder then that an effective predictive maintenance program is said to deliver a 10x ROI compared to a standard reactive maintenance program[4].

Building data analytics for long term, continuous improvement

But, today, perhaps the biggest "wow" factor related to the most intelligent BMS and device level controls is what can now be done with the data they deliver over the longer term. In conjunction with building data analytics software, highly detailed trend information can be combined with such inputs as utility costs of electricity per kW to provide very

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[3] Operations and Maintenance (O&M) Best Practices-U.S. Department of Energy

specific suggestions for the most effective changes that can be made to generate continuous, incremental energy efficiency improvements throughout the campus. How specific? On the order of “Change the control to a variable set point in Room 301 to generate an additional $30 per week in energy savings.” Thanks to this type of technology, the entire concept of the term “maintenance” may one day be redefined from “fixing things” to “creating energy savings” across the board.

Energy management as a recruitment tool?

Saving money through energy efficiency is important to every economic sector—businesses, hospitals and institutional organizations alike, but energy efficiency has aspects in an educational environment not likely to be found elsewhere. For example, while environmental impacts might be important to all organizations to a degree, one is unlikely to see office workers holding a sit-in in the CEO’s office demanding that the company reduce its carbon footprint or do more to alleviate climate change. Today’s incoming students and prospective students are perhaps even more environmentally conscious then were the older Millennials. Fortunately, with the increasing granularity of BMS data, valuable information can be shared with educational stakeholders that might be less relevant in other types of organizations.

For example, information sent by the field level devices can be analyzed and disseminated to show the community their energy use on a daily or weekly basis, helping to maintain transparency, as well as fuel conservation interest and action. Per capita energy use information can be used in friendly green competitions, between rival high schools, for example, or among community subsets such as residence halls or departments.

Improving the “user” experience

A good BMS, of course, is focused on the needs of the user, usually defined as the facility managers and others involved with the responsibility of HVAC operations. As the available information driven by field level devices gets even more granular, educational institutions might become early adapters of a new capability—delivering some controlled amount of personalized information directly to the end user, such as students themselves. For example, a student might be able to help conserve energy by turning down the heat when she leaves her dorm room in the morning, and then use an app to turn it back on a few minutes before she heads back from classes, similar to what she might do at home. Multiplied by thousands of users, these incremental reductions could present significant additional savings, as well as help position the institution as even more technologically advanced and environmentally conscious to its stakeholders.

Connectivity, standardization and cybersecurity

With field level devices collecting and disseminating more and more data, their ready connectivity—the ability to move that data quickly and accurately—goes hand in hand. No matter how sophisticated the devices get, manufacturers push proprietary communications protocols and ignore standardization at their peril. Users expect any device to be connected and work on any network “right out of the box,” so open protocols such as BACnet, LonWorks® and KNX are usually preferred for BMS in educational institutions or any other environment.

The Internet of Things

When it comes to outstanding connectivity, the Internet of Things is the “holy grail,” and its ultimate emergence will give innovative field device and BMS manufacturers the potential to expand the capabilities and enhance the performance of their systems. Devices can be connected through a cloud infrastructure, taking advantage of the reliability, redundancy

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[4] Operations and Maintenance (O&M) Best Practices-U.S. Department of Energy

and robustness of the Internet for connectivity. Whether particular devices are individually IP enabled, or just visible as part of a system, "single hop" information transfer can be more direct and nearly instantaneous.

Cybersecurity

Of course, the downside of expanding connectivity is increasing concern over cybersecurity issues. Historically, Operational Technology related databases like a BMS—where availability is the key issue as opposed to confidentiality—have been less enticing to hackers than Information Technology related databases where the goal might be to gain direct access to confidential financial information such as credit card or bank account numbers. Nevertheless, cybersecurity experts at forward thinking companies in the BMS industry and others are working hard to envision threats in advance and proactively guard against them. In the educational environment, for example, is there a way for a hacker to turn up the heat in a teacher's office to 120 degrees for fun? Or more maliciously, could hackers gain complete control of building systems and do real damage? Or even find and exploit loopholes to gain access to private admissions data or Bursar's office payment information?

So cybersecurity—previously perhaps not as top of mind in the BMS industry, has become an escalating priority for the most forward thinking BMS technology manufacturers and will become more so in the future. In general, leading companies are undertaking a holistic approach towards cybersecurity which is instituted through the entire product development lifecycle, working to ensure that there are no open spaces in the product, both in its stand-alone format or in a networked/solutions format. Additionally, they might also offer ongoing consulting or monitoring to help ensure continuous security.

The "negative" of extreme reliability

Fact is, field devices are among the most long lived and reliable of HVAC equipment, often performing well far beyond their estimated life. In fact, the majority of field level devices are often more commonly replaced as part of an overall system replacement or building overhaul rather than any major issues—even a decade or more after their "expected" useful life.

This actually works against users, as it keeps them from benefitting from new technologies that can more than pay for themselves. We've discussed many above; another of note is the huge improvements made to CO_2 sensors in recent years. Unlike 10 years ago, these sensors no longer demand regular, labor-intensive calibration, so the information they are reporting is far more trustworthy—and the influx of expensive treated air they are driving more likely to be both cost-effective and comfort-enhancing. Meanwhile, there are millions of older sensors out there—and a large percentage of them, no doubt, are providing inaccurate information. Similarly, for example, there are millions of decades old valves that may be sticking slightly, but not enough to be noticed in use or detected by preventative maintenance programs. Scenarios like these are generating high costs for educators, both in dollars and in the quality of their educational environments.

Investment in a BMS

Among capital projects, building management systems, as well as upgrades that include the latest field devices and other cutting edge components are arguably among the easier "sells" because of their fast payback in ongoing energy savings year after year. In a higher end school or collegiate environment where image and cutting edge performance is important for recruitment and retention of the highest quality students and faculty, the case may be even more compelling.

Still, if the investment dollars aren't there, they're not there, no matter what the ultimate return might be. Fortunately, there might still be a way for even resource-poor institutions to begin benefitting from a new or better building management system.

Some schools have experienced significant savings and clear increases in comfort by adding automated field level devices in individual rooms a few at a time, as budgets allow. They can get immediate benefits like the ability to set back heating and cooling levels when a room is not occupied, or optimize the flow of hot and cold water with more sophisticated valves and actuators.

And since the best systems can be infinitely scalable, institutions can add improvements to additional rooms as funds allow, with incremental savings potentially helping fund the "next round" of upgrades. Ultimately, if they so desire, they can network them together and centralize control to gain a full BMS solution—one which will likely pay for itself within just a couple of years.

Conclusion

Device level controls like valves, actuators and sensors are the foundational backbone of any building management system, working in the individual buildings and rooms to control the larger equipment and deliver the raw mechanical and operational data that makes the energy savings and comfort enhancing benefits of the BMS possible. Smart starts at the foundation of the BMS with device level valves, actuators, and sensors—if they are not functioning at optimal efficiency, neither is the BMS.

New developments in technology and application are promising to make these devices and BMS systems even more valuable to users of all kinds, and are worthy of consideration for any new building under construction, or one where a retrofit is underway. As historical early adopters of many of these technologies, many types of educational institutions may be especially interested in moving to investigate the added benefits that might be applicable to their individual situations, helping them free up more funds for mission critical projects and further improving the effectiveness of the learning environment.

About the authors

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