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Advances in building automation

Building automation has seen a tremendous amount of advancement and is changing not only how buildings are managed and operated, but also how they interact with the grid

Learning OBJECTIVES

- Understand the core function and basics of building automation systems.
- Be able to discuss advanced automation for energy efficiency and occupant health and wellness.
- Appreciate how modern BAS are business integrators.
- Recognize the relationship between smart buildings and smart grids.

The original functionality of a building automation system was to keep a building climate within a specified range. With advances in technology, the BAS can now control temperature, control building pressurization, regulate humidity, optimize lighting, monitor performance, indicate device failures, provide access control, control shading devices and provide alarms in the event of malfunction. As technology advances, the BAS of old is now more agile and intelligent and capable of managing business success factors beyond energy consumption and comfort.

Buildings built in 2020 and beyond will be built to building codes that are up to 50% more efficient than when ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings was first issued in 1975; they will operate with computing performance that has increased 1 trillionfold since 1956 and they will have technology that can virtually ensure the No. 1 complaint of building occupants (comfort) will be nonexistent. New buildings will be smart, connected, healthy and secure. Smart buildings are the way of the future and without modern BAS, this would not be feasible.

Modern advances in building automation, digital technology and the "internet of things" have made it easy for new and remodeled buildings to be smart, energy efficient and healthy. It can be difficult for new and existing buildings to capitalize on these opportunities as BAS technology is changing rapidly and requires today's engineers to understand the basic capabilities and functions of a BAS, become technically savvy and incorporate data analytics into BAS designs and think beyond buildings to harness possibilities from utility providers.

Functionality upgrades

In the early 1900s, a BAS was simple. If you scour the internet looking for the beginning of BAS, you'll find some great stories of the potential first BAS installations. All in all, the basics are as simple as a lightbulb connected to a thermostat. The lightbulb would turn on when the temperature registered below a setpoint, signaling workers to shovel more coal into a boiler. The original intent was to make life easier for the person operating the building.

Around the 1960s, engineers progressed to pneumatic controls and in the 21st century to direct digital and wireless controls. Energy codes, sustainability rating systems and sustainability commitments have increased the demand for better BAS.

Even with need for better systems, the items a BAS controls have largely remained unchanged. The core function of the BAS has typically been to control heating, ventilation and air conditioning equipment to maintain temperature control in buildings. These traditional systems control heating and cooling plants, air side systems for fresh air delivery and space temperature and humidity. Many BAS also can integrate with lighting controls, security and fire alarm systems, but many times these systems remain separate. What is controlled and how it is controlled can largely depend on when the systems were installed.

Older buildings are limited by the technology and design drivers of the age they were built. Depending on when they were built, the building may have had control only at the equipment level. In these buildings, there are controls available that only control individual pieces of equipment and they may not be able to be seen by a centralized

Figure 1: Froedtert & Medical College of Wisconsin Center for Advanced Care maximizes efficiency and expandability while simultaneously supporting cutting-edge medicine. Having integrated and energy-efficient buildings are a priority. Building automation advancements and integrations were extensively studied and incorporated within the facilities to provide healthy and energy-efficient spaces. Courtesy: Steinkamp Photography

control system or BAS. Additionally, these buildings may have pneumatic or analog controls, which lack the ability to provide tight control of comfort conditions.

As older buildings continue to age, their functionality may be unable to meet the needs of a tenant and they can develop problems that are difficult to solve due to difficulty in acquiring parts. If an older building does have some level of automation, it may still have a significant problem in the fact that an older BAS operates off proprietary protocols making modifications, expansion or integration into a newer system difficult.

In buildings built during the late 1980s and beyond, the improvements in central computing gave way to distributed digital computers (essentially process controllers) located on equipment (equipment controllers), allowing communication back to a central system. By 1995, the central controller began to communicate with the internet, allowing for remote or web-based control of systems.

Also during this period, proprietary protocols evolved to open protocols such as BACnet. The incorporation of BACnet into BAS allows for the open communication between multiple pieces of equipment on a centralized or head end system. By allowing all the communication between individual pieces of equipment, temperature control is improved, energy efficiency is increased, operating and maintenance costs are lowered and indoor air quality is improved. At a minimum, the controls are web-based, have graphics that are easy for the user to understand and allow for data analytics and fault detection.

Current BAS options

With the increase in computing performance, advancements in technology and increased demand for energy-efficient and healthy buildings, most new buildings now employ state-of-the-art BAS technologies and leverage analytics platforms that ride on top of the equipment and BAS. These systems can perform complex analytics by integrating multiple automation systems, metering systems,

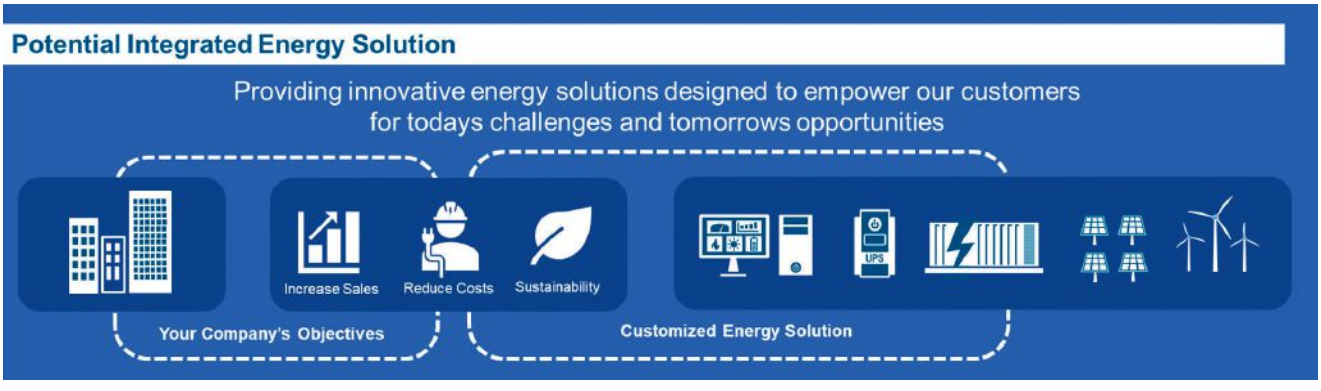

Figure 2: This shows the business case for integrated, smart solutions. Smart grids connected to smart buildings to increase sales, reduce costs and meet sustainability goals. Courtesy: Mortenson

lighting controls, process controls, security, access control and other app-based smart devices.

The biggest challenge in designing new buildings is being educated about new advancements and being able to scrutinize the different systems available for clients. New buildings should be designed as future thinking, with flexibility built in. This allows for future adoption of new technology and expandability of systems.

Future of buildings

50%
Reduction in energy consumption since 1975

1 trillion
Increase in computing performance since 1956

Zero
Occupant complaints about comfort

Figure 3: Expectations of building performance for the future of buildings includes the integration of smart building automation system technologies and internet of things integrators. Courtesy: Mortenson

Energy/cost conservation along with occupant comfort and productivity are two of the largest drivers of advancement in modern BAS. By providing improved equipment control, real-time monitoring, trend logging and fault detection building operators are better equipped to control how the buildings are operated, which decreases energy use and increases occupant satisfaction. These systems, coupled with strategic metering and data analytics, can further generate success stories around energy, carbon or climate goals, as well as wellness goals (such as air quality or quality of daylighting) that a company may have.

Climate and comfort

Reducing cost or saving money via energy conservation is a benefit of an optimized BAS. It is typically used to help justify the increased costs associated with a more complex system. However, there are other reasons for a company to track energy usage and reduce consumption. Many companies have strategic goals around energy conservation, carbon reduction and/or climate impacts.

To track and validate consumption and conservation it is helpful to have automated systems to perform and track complex calculations. Further, the analytics provided by an analytics platform can identify potential areas for improvement that otherwise may not have been found.

While wellness and human comfort can be difficult to track and monetize, standards like ASHRAE 55: Thermal Environmental Conditions for Human Occupancy and ASHRAE 62.1: Ventilation for Acceptable Indoor Air Quality set a baseline. With the increase in wellness standards that companies use to attract and retain employees, it is increasingly important to be able to verify that occupied buildings are healthy buildings.

Using a BAS to maintain a healthy building and trend and verify wellness metrics is common for new buildings. This is most important in hospital designs. In an article on BAS in hospitals, Neil Lorenzi writes "With patient satisfaction and healthy outcomes more closely tied to reimbursement, hospitals are seeking ways to improve the overall patient experience and building performance is critical to that mission." High patient satisfaction doesn't happen without a state-of-the-art BAS.

Equipment control

By integrating equipment controllers into a centralized BAS building, operators can optimize HVAC efficiency and improve control. Examples of this include using economizers for free cooling, resetting boiler temperature setpoints based on outdoor air temperature and optimizing building start/stop times, which allows for night and weekend setbacks. Occupancy sensors can be integrated into ventilation systems to optimized ventilation rates, further reducing energy and improving IAQ, as well as control lighting. Carbon dioxide and volatile organic compound sensors can further optimize ventilation rates and occupant health.

By providing improved equipment control and visualization into system operations, facilities can see lower maintenance costs and potentially lengthen equipment life. Alarms and trend logs can signal facility operators before they cause discomfort to building occupants and escalate into bigger, more costly problems that could result in equipment failure.

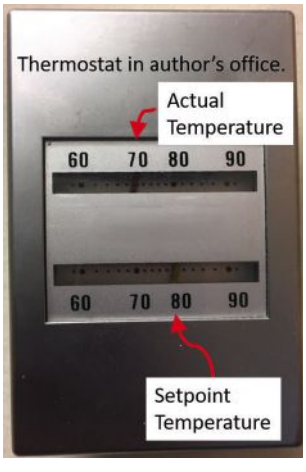

Figure 4: There are limitations of pneumatic control systems. On this 1980s thermostat, the setpoint temperature is 80°F. The actual room temperature is 70°F. The current systems cannot meet the desired setpoints. Courtesy: Mortenson

Metering and submetering

Metering and submetering equipment that uses energy and integrating the data into a BAS can provide additional insight into

optimizing a building. To really get into energy conservation, the old saying "you can't manage what you don't measure" applies. Typically, metering is done in two ways — whole building and/or end use. Whole building metering is helpful when utilities haven't provided smart meters. They can measure whole building use in real-time and in user specified intervals (each second, minute, 15 minutes, etc.). End-use meters get into real-time use of energy on a break-out level such as lighting, fans, water heaters and plug loads. Many buildings that have employed end-use meters have used the data to impact tenant behavior through energy conservation competitions.

At Mortenson, the competition was on a floor-by-floor level in the headquarters campus. Every electrical panel on every floor was analyzed and submetered to most accurately calculate the energy consumption on each floor of the building. Each floor was then provided with educational materials similar to the Energy Star Bring Your Green to Work program.

The end result was a 12.9% reduction in energy use over a three-month period. All savings were attributed to the behavioral changed made by the occupants. An important part of metering and submetering is to understand the purpose of the data collection before you start to collect it. This avoids installing equipment and gathering data that you can't or won't use. Information that is accurate and useful will improve operations, cut costs and provide the best experience for occupants.

One of the things that happens when data are gathered and analyzed is that additional data are generated and one can end up with "paralysis by analysis." Harnessing data and generating meaningful analytics is complicated. Data can be expensive to acquire and use, and data have little value on their own. It is only as good as the insight it delivers.

There are companies that specialize in providing data analytics platforms for buildings. These companies design easy-to-use automation software that can visualize and analyze real-time information for multiple applications and can provide metrics on energy, maintenance, productivity and even product quality. These systems are intended to integrate beyond the BAS and can tie into manufacturing, product quality, financial tracking, etc. Successful analytics uncover new business insights capable of driving real value and greater business performance. Equipment controls and a BAS are just two things that an analytics platform can use.

Smart buildings

Smart buildings are those buildings that have leveraged data and real-time information to optimize energy consumption. They have leveraged IoT connectivity, sensors and the cloud to monitor and control multiple building systems (HVAC, lights, plug loads, elevators, etc.). They use that connectivity to communicate and automate to generate greater efficiency, security and comfort while saving money. Smart buildings have a modern BAS.

Many smart buildings are designed around the phenomena of "electrification of everything" and transition to 100% renewable energy. These buildings are better positioned for the future of the electrical grid. Incorporation of technologies such as heat pumps, electric vehicles and other electric

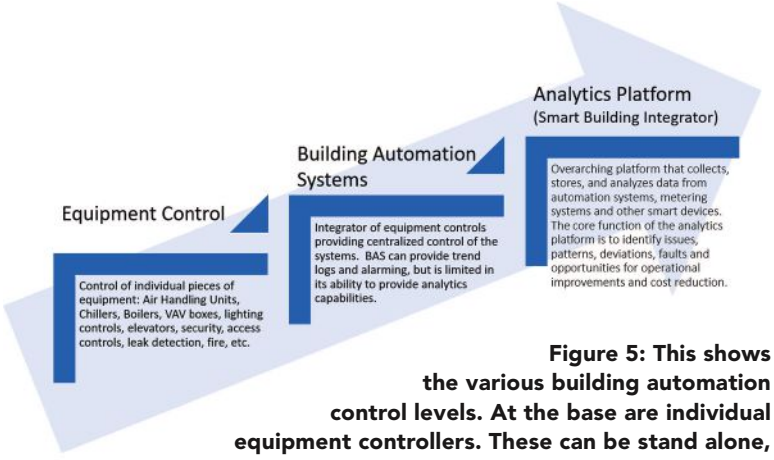

Figure 5: This shows the various building automation control levels. At the base are individual equipment controllers. These can be stand alone, smart or may need to be connected and controlled by a building automation system. The equipment controllers can be integrated into a functional head end or BAS for building level control. With strong equipment controls and BAS, an analytics platform can be used to perform complex data analytics to further optimize building performance. Courtesy: Mortenson

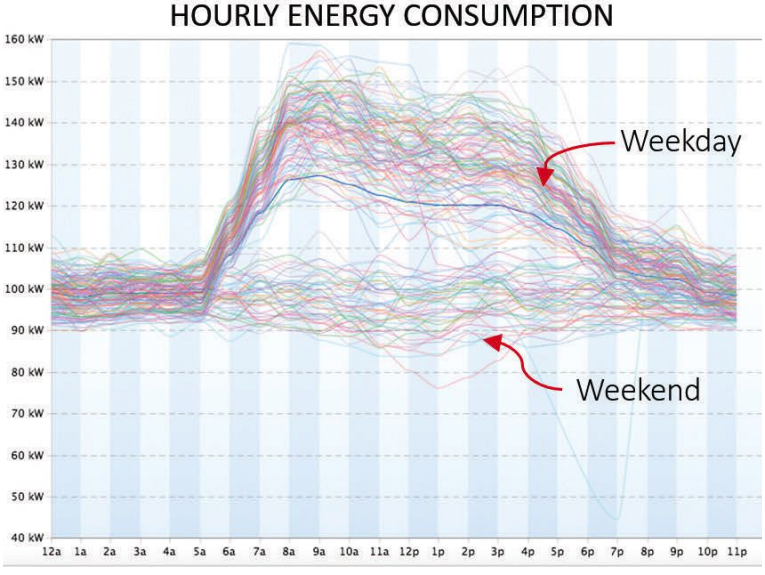

Figure 6: The example data provided by an analytics platform indicates the baseline load of the building as well as how the building is performing on weekends versus weekdays. Courtesy: Mortenson

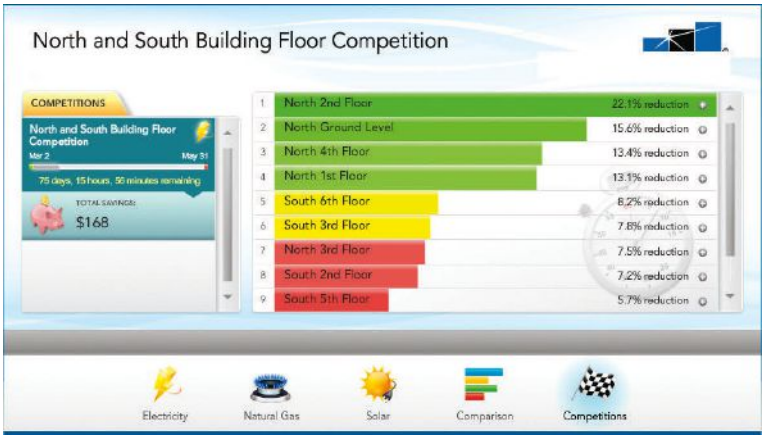

Figure 7: The use of submetered data can influence human behavior to reduce energy consumption, as shown in this example of the company headquarters floor-by-floor competition. Courtesy: Mortenson

technologies are on the rise and their increased incorporation could increase U.S. electricity consumption by nearly 40% by midcentury, according to a National Renewable Energy Laboratory report.

This need to electrify everything has complications for the electric grid and creates an increased demand for a smart grid. In a traditional grid scenario energy flows from the utility to the end user. It is a one-way transmission. A smart grid allows for many great improvements, but at a baseline one of those things is the ability to have two-way transmission.

A smart grid is on the utility side of the meter. It involves the transmission lines, substations and transformers required to deliver power from the plant to the users. Smart grids allow for real-time energy usage and real-time energy pricing and can help building operators further manage usage cost, and manage when to use energy and when to generate on their own through renewable energy. Smart grids are continually evolving and smart buildings and BAS need to evolve with it to optimize performance on both sides of the meter.

The smart grid will need smart buildings to talk to for ultimate success. Utilities have committed to being more connected to their customers, but to be truly successful, they need their customers to connect to them in a different way. Most of today's smart grid integrations end with the utility providing a smart meter. It is a start, but only a start and it needs building designs to advance. When a smart building is connected to a smart grid, there is mutual benefit for both the building owner and power provider.

What's next

The Jetsons — the 1960s TV cartoon — family lived in the future and they had amazing contraptions (smartwatches, video phones, drones, robots, autonomous vehicles) that aided in everyday living. They lived in perfectly climate controlled, healthy buildings in the sky. We are on the cusp of being in "the future" portrayed in that cartoon, but The Jetsons had robots and artificial intelligence. The automation systems used today continue to rely on human interaction and interpretation.

As an example, fault detections and alarms still rely on humans to take action and much of our data still needs human interpretation. The technology that limits or eliminates the need for human interpretation is machine learning and artificial intelligence. These technologies are rapidly evolving and some aspects are being integrated in BAS algorithms, but it is happening gradually.

In today's increasingly connected world, the IoT communicates but is not independently intelligent. Current systems typically rely on "after the fact" reporting: analyze the past, make a change and hope the test works in the future. If the results of the change don't meet expectations a different change is made and the process is repeated.

In ML and AI, a machine collects the building management system and analytics platform data and combines them into increasingly robust data sets. These data sets are large and contain more information than a human brain can process. Current ML protocols for BMS use the robust data sets and combine them in a way that allows operators to schedule equipment based on better data. This is what is known as a supervised ML system, and while it is not a fully automated system, it is more vigorous than the current "after the fact" reporting.

Additional benefits of the ML/AI integration include: the ability to use multiple data sets to forecast and operate the building off weather predictions, establishing better coordination of complex systems (combining HVAC, lighting, ventilation and occupancy) and improved fault detection (optimized continuous commissioning).

In the most succinct terms, the core function and intent for BAS is to keep humans comfortable, healthy and safe. The business purpose of the BAS is to save money and improve productivity. Using advancements at an equipment level, an automation level and at an integration level, the BAS is a business tool in addition to an energy and comfort tool.

When smart technology is applied to BAS and those advancements are in sync with smart technology from power providers, new business insights can be uncovered. These insights can drive real business and environmental value and greater business performance. cse

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