Primera

BUILDING AUTOMATION:

Helping to Improve the Performance of Buildings

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INTRODUCTION

For a building to perform exceptionally well, the systems within the building must be controlled. The lighting, HVAC (heating, ventilation, and air-conditioning), security, and other systems must be running at a certain time, and they have to hit certain setpoints or goals. For example, the lighting system must provide adequate lighting when the building is in use. Controlling the systems within a building is essential for numerous reasons, which leads building engineers to become increasingly interested in "building automation."

Building automation systems (BAS) are used to control many systems throughout the building which include HVAC, lighting, fire/life safety, security, energy metering, etc. Another phrase used to describe BAS is "building controls." Building automation systems rely on sensors, controllers, and control devices to control and monitor different systems.

Definitions:

Sensor – measures the controlled variable and transmits a signal (pneumatic, electric, or electronic), to the controller.

Controller – Compares the input signal to the setpoint and signals to the control device for corrective action.

Control Device – The piece of equipment being changed by the controller (typically a valve, damper, heating element, or variable speed drive).

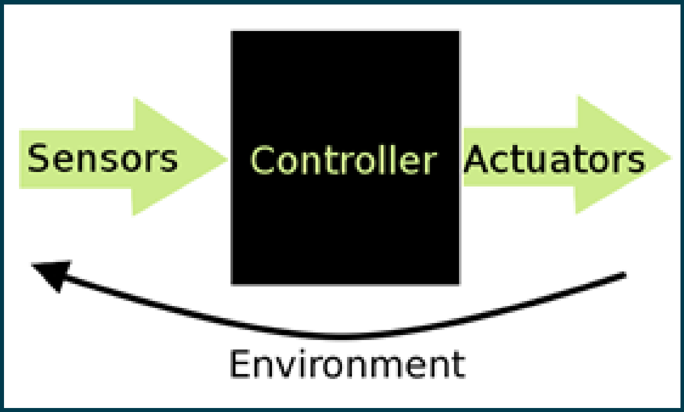


Figure demonstrating the links between the sensor, controller, actuator, and environment.
commons.wikimedia.org/wiki/File:Sensors_to_actuators_loop.png

These devices are controlled through two types of control systems: open-loop and closed-loop. An open-loop system does not have direct feedback between the value of the controlled variable and the controller, whereas the closed-loop system does. Since there is a direct link in a closed-loop system, the BAS can provide a higher level of control.

After specifying the type of control system, the next step in automating a system is writing the sequences of operation (SOO). These sequences specify setpoints, signals, error messages, etc. SOO are like coding; they tell the BAS how to respond given sensor inputs or control modes. For example, when incorporating daylight harvesting in a project, a common sequence would be "IF the daylighting sensor reads above a certain threshold value, dim the lights in the daylighting zone to 30% output." SOO are written for all system types, and this is the route of all efficiencies and performance that building automation provides.

The centralized control of building systems can use direct digital control (DDC) to share information. The information is shared over communication networks and it allows the controllers to coordinate action. Some of the standard protocols used in BAS are: BACnet, LonTalk, Konnex, MODBUS, and PROFIBUS FMS. ASHRAE Standard 135 is used to help design data communication in building automation and control networks.

From the perspective of the owner, building automation systems are often equipped with computer hardware. On the computer, there can be a graphical user interface (GUI) which is used to control, monitor, and track the building automation system. One example of this software is Honeywell's WEBs-N4 Software which includes advanced integration, visualization, and control as seen in Figure 1. The computers can be accessed remotely through a secure VPN, which allows for complete control of building systems regardless of physical location.

Figure 1: Example of a graphical user interface for a building automation system.

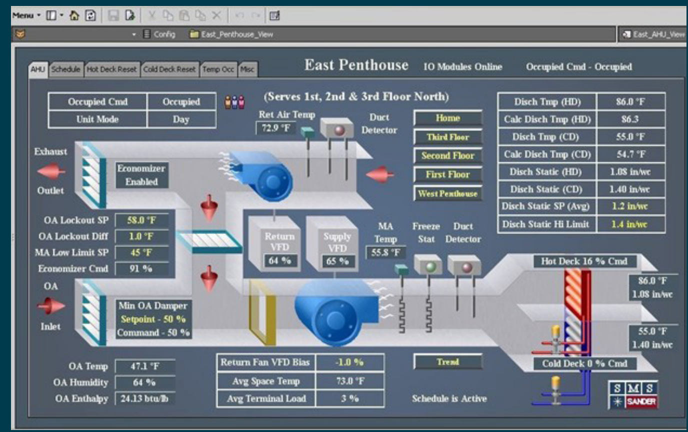


Figure 2: BAS Tier Architecture Diagram
https://sandermechanical.com/graphical-user-interface/

When a building automation system is designed by engineers, they can draw a "BAS Tier Architecture Diagram," as shown in Figure 2. The BAS is split into four tiers.

- **Tier 1** – Enterprise Level – BAS workstation,control center
- **Tier 2** – Building Level – Building BAS Panels and Routers
- **Tier 3** – Equipment Level – Main equipment of systems
- **Tier 4** – Sensors and Control Devices

A BAS tier diagram helps designers and owners visualize the connections for the building control system. Devices can be hard-wired or use IP-based technology to communicate with each other. Figure 3 shows a clear diagram on how everything is connected and controlled in the building automation system.

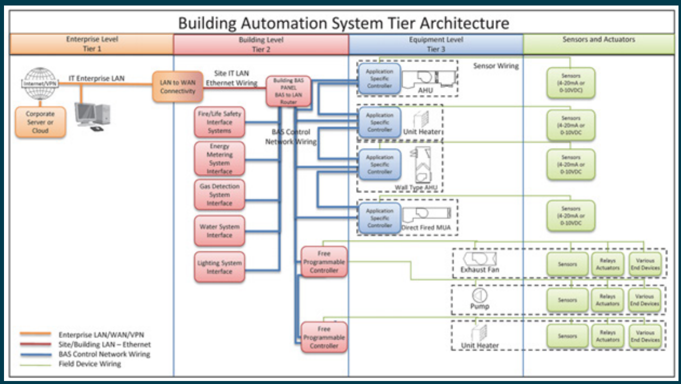


Figure 3: schematic diagram of a typical BAS
ASHRAE Guideline 13-2015

The HVAC and lighting are major sources of energy consumption within a typical building, and building automation provides a solution to reduce the energy consumption. Building automation systems also provide a unique way to protect the health and safety of building occupants.

Energy Efficiency

Building automation systems are a very effective way to save energy within a building project. Without building controls, a system would run continuously within a building without changing. The lights would remain 100% on, and the HVAC would run continuously. In order to reduce the operational energy within the building, a properly designed building automation system is required. HVAC and lighting controls offer a high potential energy savings within a building project

HVAC

Despite a multitude of different options for **HVAC** Systems, all these systems can incorporate building automation to increase the energy efficiency.

The plant loop of a central HVAC system typically has a cooling coil supplied by a fluid, and a heating coil supplied by a fluid or electric resistance. Common sensors and actuators in a plant loop include:

- Fluid flow stations
- Temperature sensors at inlet/outlet of coil
- Control valves with actuator
- Electric resistance control
- Boiler temperature sensor and control actuator
- Chiller controls

In addition to the coil and fluid control, the airflow in the plant loop must be controlled. Common sensors and actuators on the airside include:

- Dampers: outdoor, return, exhaust, and supply air
- Variable speed drive fan
- Airflow station
- Differential pressure sensors across filters, coils
- Air temperature sensors: outdoor, return, supply
- $CO2$ sensor: return air

When the environment requires less heating or cooling, the BAS can send signals to the plant loop to reduce the output of the system. In turn, the operational energy of the system decreases. When the plant loop of the system is tracked over time, inefficiencies can be targeted to increase the performance of the system. When using different setbacks and operational modes in the sequences of operation, owners can see a decrease in energy consumption. In addition, SOO's can detect possible failures within a system early and provide instant information to the building owner.

ASHRAE Guideline 36 provides an extensive look at sequences of operations for HVAC systems, and helps designers with high-performance buildings.

The air distribution loop is another focus for the building automation system. The zone control of an HVAC system can provide superb thermal comfort and increase energy efficiency. Starting with thermal comfort, a building automation system may include a thermostat (controller) inside a specific thermal zone. Inside a

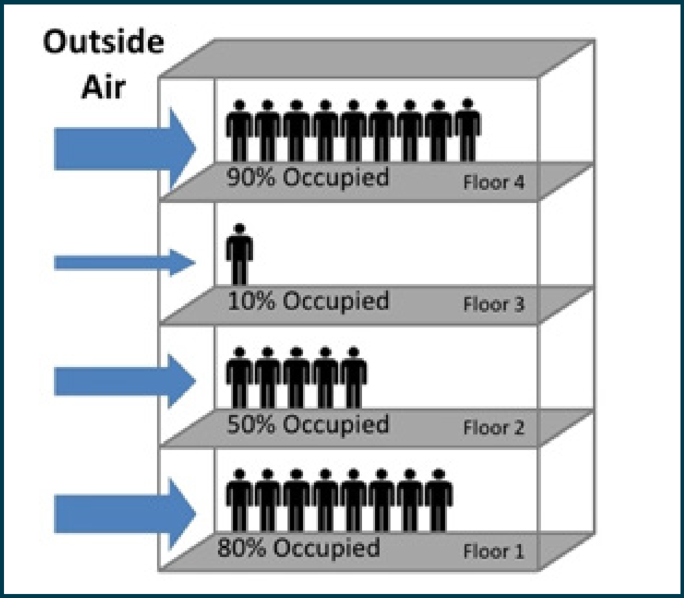
Figure 4: Picture of a Siemens Smart Valve
new.siemens.com/global/en/products/buildings/hvac/valves-actuators/intelligent-valve.html

thermostat, there is usually a temperature sensor included. The thermostat can send a signal to the supply system to modulate the heating/cooling demand depending on the need. The system may respond by:

- Opening the damper (increase airflow)
- Vary the speed of the fan
- Modulate the flow of the heating/cooling fluid (control valve actuator)

With these controls, the space is provided with the appropriate amount of conditioning, which provides occupants with a comfortable environment. These strategies may also be effective in reducing the energy consumption of the space by not over-conditioning.

Building on the energy efficiency capabilities, demand control ventilation (DCV) is a strategy to increase efficiencies within the system. DCV varies the rate at which outdoor air is delivered to a space, depending on the number of people in the space. There are a few methods to make DCV possible: time scheduling, occupancy sensors, population counters, and CO2 sensors. There are pros and cons to each type, but they all communicate with the BAS the necessary amount of outdoor air required for the space. Without any controls, the outdoor air supplied may be very high for a space, especially when it is not 100% in use. With less outdoor air requirements, the speed of the fan may be reduced, and less energy would be consumed for the HVAC system.



https://www.horizon-engineering.com/uncover-hidden-energy-savings-using-demand-control-ventilation-and-building-pressure-control

LIGHTING

Lighting controls are another great way to save energy in a building. The simplest way for control systems is implementing scheduling. Light scheduling can be implemented within the sequences of operation of the BAS. A basic sequence may be: "During hours of occupancy, turn lighting fixtures 100% on." Another sequence may be, "During unoccupied hours, turn lighting fixtures off."

Although scheduling is a great way to increase energy efficiency, modulating the lighting during hours of occupancy allows for even more energy savings. Daylight harvesting is a strategy used in architectural engineering, and it is when buildings use daylight to offset the amount of electric lighting needed at a certain time. With increased collaboration between architectural and engineering design, daylighting sensors can be incorporated into certain spaces that include daylight. If there is an abundance of daylight, the lights can be dimmed to reduce the amount of power supplied to the luminaires. Another way to increase energy savings is with occupancy sensors within spaces. The lighting fixtures (control devices) can connect with the occupancy sensors to turn on/off depending on whether there are occupants within the space. This will reduce the lighting loads within the building by turning off any lights that are in unoccupied spaces.

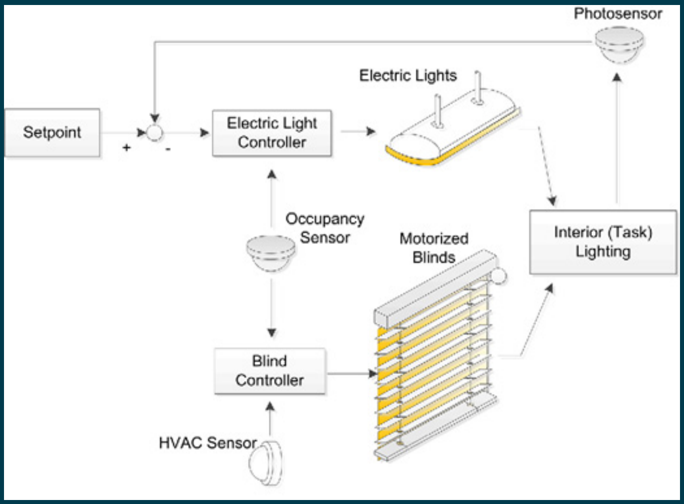


Figure 5: Demonstrating how lighting controls can link together.
https://www.semanticscholar.org/paper/Energy-and-visual-comfort-analysis-of-lighting-and-Shen-Hu/6efc11ae1155d06b4689314942205c8648bd5da9

HEALTH AND SAFETY: COVID-19

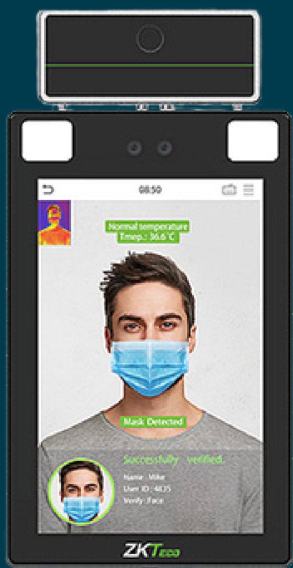
With an increased effort to provide exceptional health and safety precautions within buildings, building automation systems make it easier.

Biometric Access Control System

The first method to ensure the health/safety of buildings occupants is to eliminate the entry of a threat. Access control systems can be incorporated at the entries of buildings. ZKTeco provides a product that can use facial detection to identify a person while wearing a mask. With a database full of occupants, this prevents the entry of a potential threat. In addition, the product can measure the body temperature of an occupant, which prevents the entry of people with a fever. This automation system would work great for buildings with many continuous occupants (offices, schools, employers). This biometric sensor can be paired with an electric door strike, turnstile, or other device to allow for entry of an occupant within the system without a fever. Biometric access control systems are a great example of how building automation can increase the health and safety of building occupants.

Actuate AI Technology

Another innovative product is made by a company called Actuate. Actuate uses artificial intelligence, paired with a building's security cameras to protect against COVID-19. This software can detect social distancing rules (6 feet), identify problem areas, and track mask compliance rates. With the ability to use existing cameras, this has great potential for buildings to help comply with health and safety regulations. Building managers would be able to rearrange the space to prevent against potential spread of viruses. In addition, mask compliance rates may be very beneficial in schools, offices, hospitals, and other types of buildings. The BAS may be alerted of warnings, and notifications could be sent out to building managers.



https://www.zktecousa.com/product-page/body-temperature-mask-detection-access-control-reader-sf1008t

IP-Based Key Fob Technology

Another strategy for helping with health and safety is using key fobs to track the location of occupants. If the location of occupants can be tracked in a BAS system, social distancing measures can be enforced better. In addition, contact tracing can be performed using the BAS workstation software. With an increased knowledge of building occupants' locations, a building owner would be able to identify trends, prevent an outbreak of a virus, and make sure everyone is safe.

CONCLUSION

To conclude, building automation systems are becoming increasingly popular in building designs. It is very important to control the systems within the building, as it effects the building occupant's health, safety, and thermal comfort. From an owner's perspective, building automation systems provide the ability to reduce the energy consumption of the building, Also, the owner is able to control the systems digitally, which requires less physical work. There are many types of systems that can be used for building automation, and BAS's have the power to increase the performance of a building.

REFERENCES

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- Zkteco
- Actuate

ABOUT THE AUTHORS

Erin Lowery, PE, PMP, LEED AP BD+C
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Erin Lowery is a Certified Project Manager (PMP) and has over 15 years of experience working for Primera Engineers. Erin began her career providing mechanical engineering services, and for the last eight years has worked as a Project Manager on projects utilizing multiple disciplines as a prime and subconsultant for MEP, FP, architectural, lighting and commissioning projects. Erin has led teams that have performed studies, renovations, and new construction on complex projects in the Chicagoland Area spanning multiple sectors, including higher education, healthcare, commercial, municipalities, parks and recreation. She has extensive experience managing renovation and new construction projects from design through commissioning, as well as a strong understanding of the LEED rating system.

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Mechanical Engineering Intern

Jacob is a mechanical engineering intern in our Building's division. He is currently in his last semester at the Illinois Institute of Technology working toward a Bachelor of Science degree in Architectural Engineering, with a focus in building systems. As part of his curriculum, Jake has learned about all components of a building project, including building automation systems, energy efficiency, and sustainable design. His coursework has helped with his project work throughout his last three internships, and he continues to learn about new strategies to enhance building performance.