Introduction to Building Automation Systems

An Online Continuing Education Course for Engineers

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Introduction to Building Automation Systems

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1.0 Introduction to Building Automation Systems

Building automation systems (BAS) are centralized systems that manage and automate various building systems, such as HVAC, refrigeration, plumbing, electrical power, lighting, fire protection, life safety, and other building systems. The integration of these building systems through BAS allows for automated control, management, and real-time monitoring, enabling greater operational efficiency as well as improved occupancy comfort. The automation of the operation of multiple building systems under BAS allowed achieving complex functionalities and sequences of operation that were not possible prior to older pneumatic control systems, for example.

1.1 Importance of BAS

- BAS helps in minimizing energy consumption by automating certain building systems, such as HVAC and lighting systems, based on real-time data from sensors. For example, HVAC systems can modulate their heating/cooling/ventilation output capacities based on occupancy levels or outdoor air temperature, ensuring that energy is only used when necessary.
- By automating parameters in certain building systems, BAS ensures optimal comfort for building occupants. For example, lighting systems can adjust to provide the ideal illumination based on occupancy and daylight levels.
- By integrating life safety and fire protection systems into the BAS, building operators can monitor and control the safety and security of buildings through their operator interface. For example, in the event of a fire, the BAS can send automated notifications (automated alarms, calls, text messages, and emails) to building operators and automatically shut down HVAC systems to prevent smoke from circulating. Furthermore, the BAS can be programmed to automatically open emergency exits, making it easier for occupants to evacuate safely.
- Modern BAS can collect vast amounts of data from a variety of sensors. This data can be analyzed to provide insights about the building performance, energy usage, and system maintenance status. Building managers can use this information to optimize building operations, perform predictive maintenance, and make data-driven decisions for future building improvements.

1.2 Historical Evolution of BAS

BAS have undergone significant advancements over the past few decades, evolving from basic pneumatic controls to modern Direct Digital Controls (DDC), allowing for real-time data collection from various systems, remote monitoring, and automated control, therefore optimizing the operation of building systems and providing valuable insights into the overall performance of buildings.

1.2.1 Pneumatic Control Systems (1950s-1970s)

- Pneumatic controls marked a significant advancement, especially for HVAC system controls. Pneumatic control systems rely on compressed air to send signals to various control components, such as damper and valve actuators. Typical system components include air compressors, air dryers, filters, and control devices that regulate the pressure of the air delivered to the system. The control signals adjust the operation of HVAC components based on control inputs (space temperature, outside air temperature, etc.), which are transmitted through the pneumatic tubing.

- Pneumatic controls were limited to individual building systems without interoperability. Since these systems lacked interoperability, different building systems could not communicate or work together to achieve certain sequences of operation. Furthermore, the fact that they rely on air pressure makes them less responsive and accurate compared to modern digital controls. In addition, they require regular maintenance to ensure that air compressors, filters, and other components are working effectively to avoid potential leaks and inefficiencies. Figure 1 below indicates the basic components of pneumatic control systems.

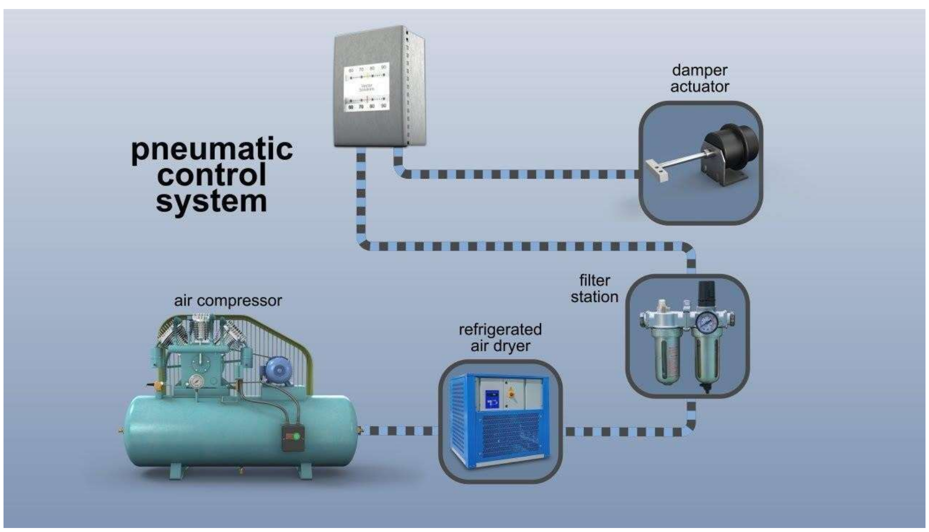


Figure 1: Basic Pneumatic Control System Schematic

1.2.2 Electric Control Systems (1970s - 1980s)

- Electric control systems gained popularity in the 1970s and 1980s and started replacing pneumatic control systems in buildings. These systems utilize relays, time delays, clocks, thermostats, electric actuators, and various other electric devices to control HVAC systems. These systems required less calibration (compared to pneumatic control systems), and it was easier to modify the sequence of operation for electric control systems, compared to pneumatic control systems.

1.2.3 Direct Digital Control (DDC) Systems (1980s - Present)

- DDC systems presented a major advancement by replacing analog electric controls with digital programmable systems. A defining feature of DDC systems is the adoption of open communication protocols such as BACnet, which allows interoperability between various systems and third-party equipment like chillers and boilers, enabling the customization of sequences of operations involving multiple building systems and equipment manufacturers.
- DDC systems can monitor and control multiple building functions from a single location, supporting facility operators in real-time remote management of different building systems. Furthermore, DDC systems leverage sophisticated supervisory controls, which not only provide advanced operational capabilities but can also integrate with the electric grid, enabling better energy management and load response.
- With the advancement of the internet, BAS adopted web-based interfaces and cloud storage, allowing operators to manage buildings and access data remotely.

Figure 2: Direct Digital Control (DDC) System Panel

1.2.4 The future of BAS

The Internet of Things (IoT) has enabled devices within BAS to communicate and share data in real time, further enhancing the adaptability of these systems to respond to conditions in real time. Furthermore, modern BAS use machine learning for predictive maintenance and fault detection, minimizing operational costs of buildings, resulting in improved energy efficiency and operational longevity of building systems. The next frontier in BAS is achieving fully autonomous operations. Such systems will continuously monitor and adjust to optimize energy efficiency, occupant comfort, and system performance without human intervention.

1.3 Components of the Modern BAS

The core components of BAS are sensors, field devices, controllers, communication networks, and user interfaces, each playing a specific role within the system to ensure intended functionalities are achieved.

1.3.1 Sensors

Sensors are the fundamental components of BAS and are responsible for collecting data from various environments within the building. They measure parameters like temperature, humidity, occupancy levels, light intensity, and air quality. The information gathered by sensors is crucial for the BAS to maintain system controls within parameters and respond to changes effectively.

1.3.2. Field devices:

Field devices include components like airflow monitors and differential pressure sensors. Field devices typically respond to signals from BAS controllers to achieve the intended function or sequence of operation. For example, control valves and dampers regulate fluid and air flows within HVAC systems and respond to commands from BAS controllers to adjust their position based on certain conditions.

1.3.3. Controllers

Controllers are the brain of BAS. They receive data from sensors, process it, and send commands to other system components, such as field devices, HVAC units, lighting systems, etc. Controllers use algorithms and predefined rules to make decisions, ensuring that building operations are aligned with the desired set of parameters to achieve the intended functions of occupancy comfort, energy efficiency, and safety.

1.3.4. Communication Protocols

Communication protocols allow different components of BAS to communicate effectively. These protocols standardize communication between devices, enabling seamless integration and interoperability among diverse systems. BACnet and Modbus are two widely used protocols.

1.3.5. User Interface and Operator Workstation

The user interface, often a terminal or dashboard, is where facility managers or operators interact with BAS. It provides a centralized platform for monitoring system performance, adjusting settings, and receiving alerts and alarms about potential operational issues. The interface is designed to present information in an intuitive way, allowing operators to manage the BAS easily and respond to system needs in real time.

1.3.6. Network Infrastructure

BAS networks typically use Ethernet and BACnet protocols for data communication throughout a structured network of routers, switches, and cables. There are also wireless communication protocols like Zigbee for added flexibility. While some systems incorporate internet connections for remote monitoring and control, other systems focus on local networks for security and reliability.

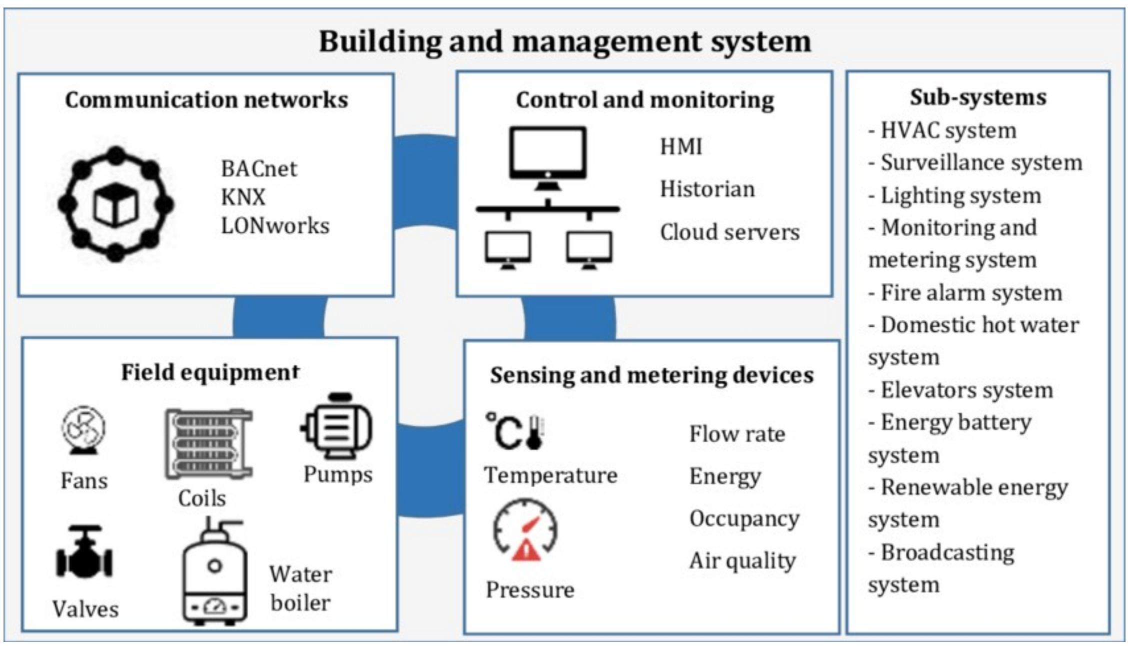


Figure 3: Building Automation System Components

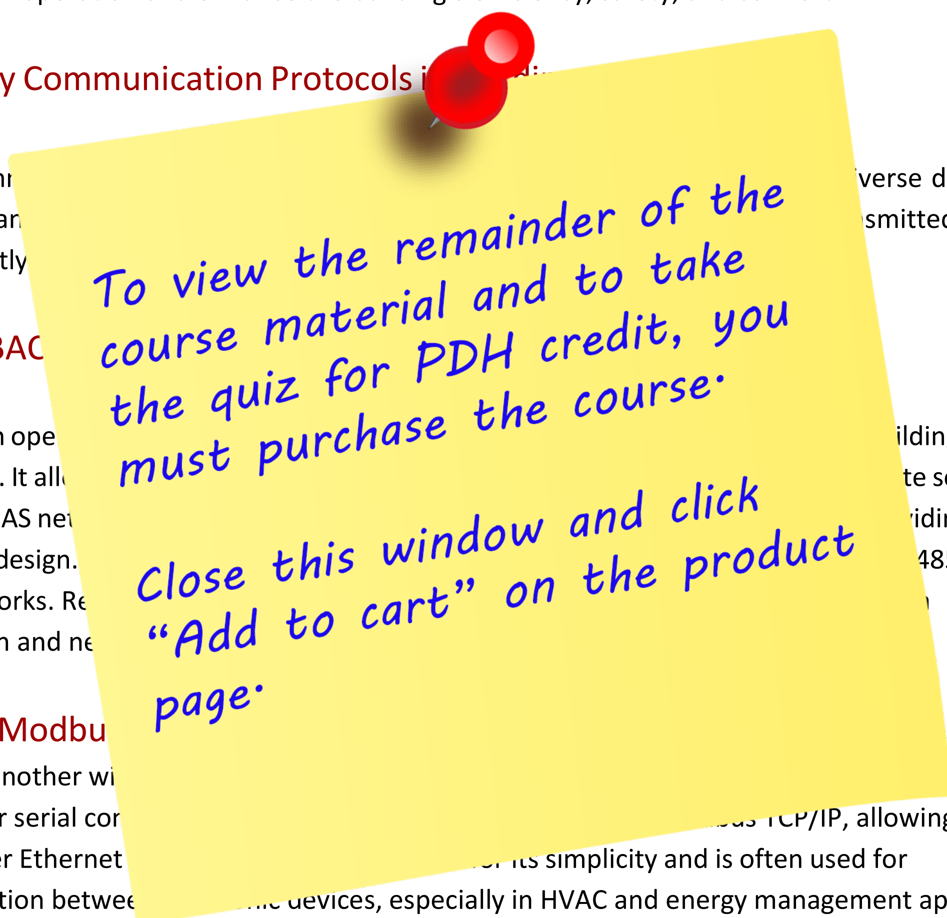
1.4. Networks and Communication Protocols of BAS

BAS relies heavily on network communications to manage, monitor, and control various systems within buildings. Effective network communication ensures that HVAC, lighting, security, and other building systems operate to achieve the intended function and the programmed sequence of operation. This section explores the fundamental aspects of network communications in building automation, including key communication protocols that enable interoperability between different devices and systems.

1.4.1. Building Automation Networks

BAS networks often involve numerous devices communicating across various protocols. These networks range from simple, single-purpose connections to complex, multi-protocol systems. BAS networks typically consist of routers, switches, and cables connected to field devices, controllers, operator workstations, and other BAS components, allowing different parts of the automation system to work together to achieve operational functionalities. Reliable network communication allows these components to exchange data, perform commands, and provide feedback to achieve intended sequences of operation and enhance the building's efficiency, safety, and comfort.

1.4.2. Key Communication Protocols i



Several comı ... iverse devices from different mar ... nsmitted accurately and efficiently

1.4.2.1 BAC

BACnet is an ope ... ilding automation. It all ... te seamlessly across the BAS ne ... iding flexibility in network design. ... 485, and IP-based networks. Re ... transmission and ne

1.4.2.2. Modbu

Modbus is another wi ... Originally designed for serial cor ... TCP/IP, allowing it to operate over Ethernet ... its simplicity and is often used for communication betwee ... devices, especially in HVAC and energy management applications.

1.4.3. Ethernet Networks

Ethernet is a networking technology that supports building automation protocols such as BACnet/IP and Modbus TCP/IP. The widespread adoption and high data transfer rates of Ethernet make it a preferred choice for network backbones. Ethernet also supports the integration of devices within IP networks, enabling remote monitoring and control over the Internet.