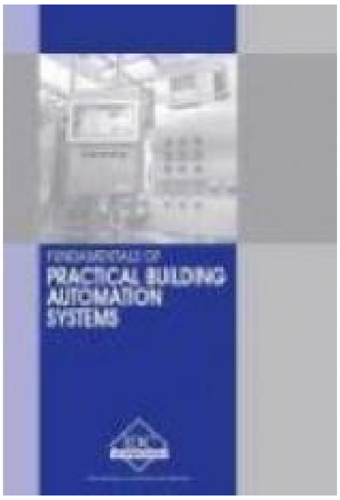
BS-E - Fundamentals of Practical Building Automation Systems



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Short Description

This book will teach you the essentials in installing, commissioning and troubleshooting individual components and systems.

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A Building Automation System (BAS) is a computerised intelligent network of electronic devices that is used to control and monitor the mechanical, lighting and security systems in a building. It is sometimes referred to as an intelligent building system. It is most often used for control of heating, ventilation and air conditioning (HVAC) systems. A BAS can result in a dramatic reduction in building energy and maintenance costs. Building automation systems can also monitor other parameters such as temperature, air pollution levels, fire alarm status and building integrity.

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1 Introduction to a Building Automation System

This chapter begins with a detailed overview of the fundamentals of Building Automation System (BAS). The concepts related to direct digital control and its predecessor controls are clearly explained. A significant part of the discussion is devoted to discussing the topology and building blocks of BAS systems. The underlying principles of the various industrial networks are dealt with, in sufficient detail.

Learning objectives

- Appreciate the importance of Building Automation Systems (BAS).
- Evaluate the principles of DDC and other controls.
- Get a clear idea of the overall topology.
- Obtain a good understanding of the key building blocks.
- Get an overall perspective of industrial networks.

1.1 What is Building Automation?

Building Automation System (BAS) is a data acquisition and control system. BAS is also known as energy management system. It is an automated, computer-controlled method of controlling and managing the energy use in a building. It helps reduce and optimize energy expenses while also ensuring a comfortable environment.

BAS incorporates various functionalities provided by the control system of a building. Modern BAS systems comprise of a computerized, intelligent network of electronic devices that are designed to monitor and control the lighting, internal climate and other systems in a building. This results in optimized energy usage, safety, security, information, communication and entertainment facilities.

The primary components of the BAS system include sensors, controllers, actuators and software. These components work together to reduce energy consumption while maintaining comfortable conditions in a building facility. By implementing the basic control strategies correctly, Building Automation Systems can perform basic and effective functions to use energy more efficiently. The graphic below is an illustration of how systems are linked together in a BAS. It can be seen how the systems are connected through a network of sensors, controllers, actuators, and software. The system interface is through a central BAS workstation, which can be connected to other BAS workstations via the internet.

Figure 1.1

Linking of systems in BAS

BAS maintains the internal climate of building within a specified range. This is achieved by

- Regulating temperature and humidity.
- Regulating lighting based on parameters such as occupancy, ambient light and timing schedule.
- Monitoring system performance and device failures.
- Generating useful data/notifications to building operations and maintenance staff.

The main benefits of building automation include:

- Lower energy usage.
- Optimization of energy usage.
- Security and privacy.
- Control over energy resources.
- Control of operating conditions such as humidity, air volume and temperature.

A typical building will have multiple technology systems that are traditionally designed, installed and operated separately. Although such systems share several common features such as communication network, cabling, equipment rooms and system databases, they are deployed and run separately.

A building design with multiple proprietary designs would resemble the following.

Figure 1.2

Multiple proprietary designs

An essential feature of smart buildings is to integrate these systems from a physical and logical perspective, resulting in enhanced functionality and lower costs. Smart buildings are comprised of advanced and integrated systems for building automation, safety and communication systems. In smart buildings, the various systems are integrated from a physical and logical perspective. This results in more functionality and lower costs. Smart buildings leverage IT infrastructure benefits by taking advantage of existing and emerging mainstream technology. The convergence of systems in a smart building is illustrated in the following diagram.

Figure 1.3

Convergence of systems in a smart building

Smart buildings result in enormous savings, both in terms of initial costs as well as overall operational costs. Integration of the various systems provides more functionality and allows the information from one technology system to affect the actions of the others. The systems communicate and share data, provide more functionality and permit information from one system to influence the actions of other systems.

Considering an example; on activation of a smoke alarm, the access control system changes to emergency mode, adjustments are made to the HVAC system and the video surveillance camera begins monitoring the affected area. Smart buildings also leverage IT infrastructure benefits by taking advantage of existing and emerging technology.

The following graphics show installations where building automation technology has been successfully deployed.

Figure 1.4

Building automation in a commercial building

Figure 1.5

Building automation in an apartment building.

Economics of a Smart Building

Buildings have long life cycles that typically range between 25-40 years. Building life cycle costs include the initial cost of the facility comprising concept, design, financing and construction as well as the long term operational costs.

Figure 1.6

Life cycle building costs

Smart buildings can help significantly reduce these costs as seen by the lower capital (CAPEX) and operational (OPEX) expenses.

Figure 1.7

Added value of smart building systems

Considerable construction cost savings are obtained in smart buildings by adopting efficient methods related to cabling, labor, project management and equipment. Smart buildings also eliminate significant overheads that result from having separate contractors and workforce that must be managed, controlled and coordinated. The number of contractors/workforce in a smart building are considerably reduced leading to lower labor, management and engineering costs. The savings in terms of long-term operational costs are related to the following factors:

- Standardized infrastructure permits easier changes during the operational life of the facility for automation system devices, lighting and communication systems, networking systems etc.
- Energy savings that result from increased building efficiency.
- Effective interaction between various systems during emergency situations.
- Reduced training costs through the implementation of standardized management tools.
- Improved information management and overall staff productivity.
- Ability to procure systems with open protocols and generic cabling

requirements.
- Standardized databases that enable easy integration with additional systems of the likes of Human Resources and Procurement management.

1.2 Why Building Automation is needed?

Building Automation is needed because of the following reasons:

- Easy and centralized management of operations.
- Simplicity, future expandability and interoperability.
- Lower costs.
- Reduced scope for human error.
- High-quality building maintenance.
- Responsive building management.
- Ability to meet tenant needs.
- Effective noise control, comfortable temperatures, good indoor air quality and controlled humidity levels.
- Ability to create schedules of operation for the equipment, lighting systems, etc. so that energy savings can be earned when the facility or offices are not occupied.
- Reduced energy costs through scheduling, lockouts and resets.
- Lower operating costs.
- Creation of more productive and flexible workplaces using scalable tools that enable improved collaboration, mobility, and remote connectivity.
- Enhanced health, safety and security for occupants.
- Simple and user-friendly Human Machine Interface (HMI).
- Ability to provide remote monitoring and alerting capabilities that can warn operators of a failure or abnormal condition in a building.
- Access to a central digital entertainment library.
- Connectivity to the Internet to meet information, e-services and communication needs of the residents.

1.3 Direct Digital Control (DDC)

In a basic control loop; a sensor, controller and controlled device interact to control a medium. Here, the controller is a distinct piece of hardware. In a Direct Digital Control (DDC) system, controller function takes place in software. DDC refers to the application of microprocessor technology to building environmental controls. Heating and cooling functions can be controlled using software that takes into consideration a wide range of variables. This leads to greater efficiency.

Figure 1.8

DDC control loop

The definition for DDC as per ASHRAE Guideline 13-2000 is as follows:

"A DDC system is composed of both hardware and software combined to produce a seamless architecture that provides complete integration of a building's HVAC systems and may include control over or monitoring of lighting, security and fire systems in the building. The DDC can continuously and automatically monitor and- through control of the HVAC mechanical and refrigeration systems-maintain desired ambient temperature, static pressure, relative humidity, indoor air quality, and energy management".

A general DDC system block diagram is shown.

Figure 1.9

DDC block diagram

DDC uses control or monitoring points, each connected to a computer (or interconnected computers) which reads the value of each input and transmits commands to each output. The control strategies are implemented by computer programs that can be changed by the operator at will. Each strategy has the value of every system input available to it, instead of a very limited local set. Thus, the entire building operates as one integrated system rather than as independent small systems.

A DDC application can be readily identified by the graphical user interface.

The DDC controller is essentially an Input/output device. While it gets inputs from sensors and equipment such as temperature and water levels, the outputs are sent to equipment such as HVAC and pumps. A logical bridging of the systems with the programming results in an automated sequence of operations for controlling the building system.

Example: Based on the reservoir level, the DDC controller may switch on the auxiliary pumps to top up the reservoir or, as in the case of a fire in the ventilation system, shut the system blowers down to prevent smoke from blowing throughout the building.

1.4 Predecessors to DDC Control

Early controls were pneumatic or air-based systems and were generally restricted to controlling various aspects of the HVAC system. Common pneumatic devices included controllers, sensors, actuators, valves, positioners, and regulators. Due to the large base of installation of these systems through the 1960s and 1970s, pneumatic control systems can still be found to exist in a significant number of buildings.

Pneumatic controllers used compressed air to operate the dampers and valve actuators, in order to control space conditions such as temperature, humidity and fresh-air circulation. One building would have several such systems which were controlled independently. For example, an air-handling system comprising two fans, three dampers and three valves would be controlled by local pneumatic controllers which operated as independent units, as shown in the figure.

Figure 1.10

Pneumatic controllers

Each controller had to maintain a constant set point, (for example, supply air temperature) by monitoring and controlling a limited number of variables connected to it by means of compressed air lines, whose pressures represented the values of the variables. The control was adjusted manually and as calibration of the pneumatic components was rarely carried out, these systems often did not control the building efficiently. Because the pneumatic controllers were purely electromechanical devices, their sophistication and accuracy of control were extremely limited.

A later variant of pneumatic control came with the addition of a computer system. This system monitored some additional points such as space temperatures and either calculated new set points for each pneumatic controller or allowed an operator at a computer terminal to transmit manual set-points to the pneumatic controllers. Although this arrangement provided more information about building conditions and performance, overall effective building control was still compromised by the local pneumatic controllers. Each controlled point was still operated by a pneumatic controller with limited capabilities and virtually no flexibility. These limitations became more important as ways to manage energy became more sophisticated.

Analog electronic control devices became popular throughout the 1980s. They provided faster response and higher precision than pneumatics. However, it was not until digital control arrived that a true automation system was possible. But since there were no established standards for this digital communication, various manufacturers created their own proprietary communication protocols. The automation system was therefore not interoperable or capable of mixing products from various manufacturers. It was towards establishing a standard open communication system that ASHRAE developed the BACnet communication protocol that eventually became the industry open standard.

1.5 System Topology

Most building automation networks consist of a primary and secondary level. The function of the primary level is to mainly gather data from the secondary level devices and send out commands for managing the controls inside the building. Several kinds of buses can be used to set up the entire network, including serial (RS-232/485), optical fiber, Ethernet, or even a wireless interface. In view of the modern day demands of video streams in surveillance systems for strong bandwidth, gigabit Ethernet switches and wireless LAN devices are more ideal for Building Automation Systems than serial devices.

Building automation systems rely on standardized network protocols, the most commonly used of which are:

- BAC-net
- LonWorks
- KNX/EIB
- Internet based–wired and wireless

Most building automation networks consist of a primary and secondary bus, as shown in the graphic below. These connect high-level controllers with lower-level controllers, input/output devices and a user interface (also known as a human interface device). The high level controllers used in BAS are generally specialized controllers, but may be generic Programmable Logic Controllers or PLCs. The primary and secondary bus can either be a wired or a wireless network.

Figure 1.11

Building automation network

Most controllers are proprietary in nature, in that companies have their own controllers for specific applications. While some controllers like Packaged Root Top Units are designed with limited controls, others are designed to be flexible. Sensor inputs are used to read variable measurements, examples being temperature, humidity and pressure sensors. A digital input indicates if a device is turned on or not. Analog outputs control specific actuators that effect changes on the air temperature of a building and on its energy management system (EMS). Digital outputs are used to open and close relays and switches.

1.6 Key Building Blocks

The components of a BAS system essentially create an independent network in which communication can be conducted through wired or wireless signals. The most common smart building components are devices and controllers. Devices may be typical electrical or electronic components such as lights, appliances, fans, locks, etc. that can be controlled remotely. They're designed to specifically receive signals and react to them accordingly by turning on, dimming, opening, or performing some other useful function. On the other hand controllers are used to control these devices in that they send signals to these devices to trigger various functions. Controllers come in many forms such as switches, keypads, touchscreens, remotes etc.

Interfaces create a bridge between the smart building network and other household systems like security systems, water systems etc. A smart building system helps customize the lifestyle and habits of its inhabitants. It consists of typical hardware/software that monitors environmental, electrical, and other inputs and activities and consequently controls the various building devices and systems based on these inputs. Automation systems can range from custom-installed and configured servers to freely-available software. Smart building systems help provide a high level of control, through a diverse set of interfaces.

In a standard building automation model, the system functionality is divided into three levels that are ordered hierarchically. While environmental data are measured and parameters of the environment physically controlled at the field level, automatic control is performed at the automation level and global configuration and management tasks are realized at the management level.

Figure 1.12

Hierarchic levels in building automation

Over the years, BAS implementation involved mapping the levels of the functional model to separate networks, with the sensors and actuators being interconnected via field networks. Controllers like DDCs responsible for dedicated process-oriented and time-dependent sequential control, were combined via automation networks. Finally, servers and workstations hosting applications for trend logging and visualization were linked by a management network. This model also entails providing vertical access for data exchange from the lowest to the highest level.

This standard three level functional hierarchy model can be implemented as a flatter, two-level architecture to enable the so called intelligent field devices to incorporate more functionality than ordinary ones and to also make information technology (IT) and its infrastructure became accepted not only at the management, but also at the automation level. A two-layered hierarchical approach for Building Automation Systems is shown.

Figure 1.13

Two-level hierarchy in building automation

This architecture comprises a control network level and a common backbone which together form the building automation network (BAN). The control network is home to field devices and has typical bandwidths in the order of a few KBits/s. But, this control network cannot fulfill the requirements of management devices because of the need for higher data rates and therefore control networks are interconnected via a high-bandwidth (MBits/s) backbone network. At the intersection point between the networks, interconnection devices are used.

1.7 Industrial Networks

Modern building facilities use sensors and control devices that are linked to a central control system. These sensors and control devices are installed throughout the facility. In the past, each individual system would have its own set of cables that would allow it to communicate with the central control system.

Although this arrangement still exists in many facilities, newer buildings are implementing converged networks that act as a single communications backbone for multiple systems.

Internet Protocol (IP)-based network systems are becoming an increasingly common option as a communications backbone for building facilities. Many buildings are now starting to deploy multiple Intelligent Building systems as well as administrative Local Area Networks on a single IP-based network. Most manufacturers of BAS and related sensors and controls are currently designing their products to operate on an IP network. Such networks have major benefits associated with them such as cost efficiency, greater flexibility, higher data capacity and multiple vendor options.

Intelligent Buildings communicate with their devices by sending signals in communication protocols through data networks. To put it in simple words, the protocol may be considered as the language spoken by the system, while the network is the phone line that carries the conversation. Building systems communicate by sending signals through networks to and from sensors, actuators, and control software. The information sent is in the form of packets. Each packet contains information written in a protocol, a language that both the sender and receiver understand. Two of the most popular open source protocols are BACnet and LonWorks and these networks will be discussed in detail, in the chapters to follow.