Improving the Efficiency and Attractiveness of Vocational Education/Training of Electricians

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Web-based VET modules in the energy efficiency of intelligent buildings for electricians: EE-VET

Module 1 - Checking, maintaining, and adjusting the energy efficient modes of operation of modern automated BMS (Building Management Systems)

SOCIAL CRM RESEARCH CENTER

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1. Introduction

1.1. About this module

This module focuses on defining what a Building Management System is, its main parts, and how to configure and install it. Additionally, it highlights the economic and ecological benefits of the implementation of these systems. An overview of energy management principles and systems is also presented. Topics are organized into five main blocks, titled:

- Energy Management and Building Management Systems
- Structure of a Building Management System (BMS)
- Implementation of a Building Management System
- Potentials of a Building Management System
- Risks and challenges

2. Energy Management and Building Management Systems

2.1. About this unit

2.2. Goals / Objectives

After this module, participants should be able to define energy management, its main objectives, and the measures taken to achieve them. They will describe, compare, and discuss the differences between energy efficiency and quality management, and structure its key aspects and benefits.

The ones who take this course will analyze the importance of monitoring energy efficiency and debate the monitoring and functionality of a Building Management System (BMS). They will differentiate between the several types of messages from the system as well as the configuring operating modes of the system.

The ability to criticize and evaluate the pertinent maintenance to implement on a BMS will also be a strong ability that will be obtained by the end of the module.

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Attendants will also be able to give examples of the benefits that BMS give to energy management. Finally, they will explain the economic and ecological aspects of energy consumption and efficiency and the way to engineer a method or system to reduce costs.

2.3. Introduction

Buildings today are responsible for about 40% of energy consumption in developed countries, and a considerable percentage of this energy (5-20%) is wasted due to inefficiencies and faults in HVAC, lighting, and water heating systems. This energy waste represents a huge loss of $100bn per year, added to the costs of maintenance and operating expenses represented by 80% of the costs of a building's lifetime. Besides, this energy consumption makes buildings responsible for 36% of greenhouse gas emissions.

However, there is potential for reducing energy waste and managing consumption more effectively, which could lead to economic benefits.[1]

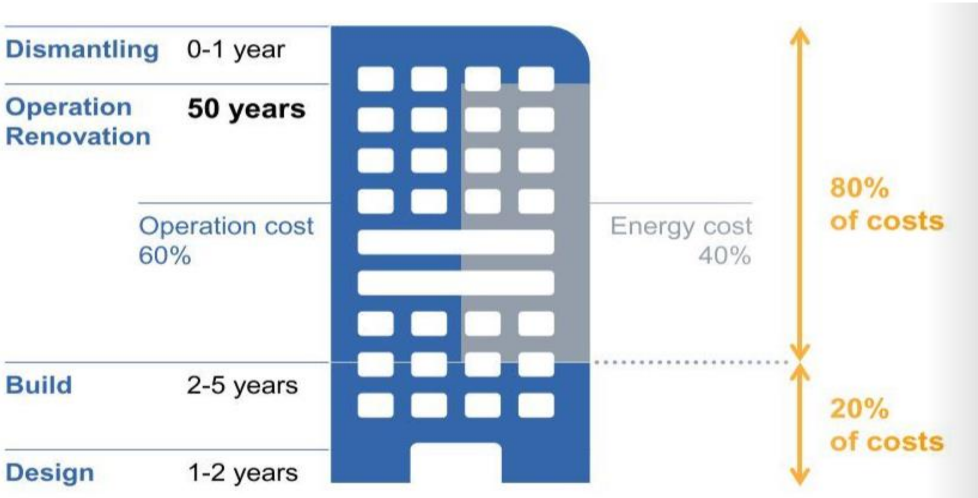

Figure 1 Diagram showing the main aspects during a building´s timelapse.

Source: https://www.yumpu.com/en/document/view/46234681/siemens-gst

EU Directive EPDB 2018[2] calls for energy-efficient, smart buildings. The main goals of the directive are:

- Creation of a clear approach to a low-carbon building stock in the EU by 2050.
- The use of information and communication technology (ICT) and smart technologies to ensure the efficient operation of buildings will be promoted.
- The deployment of e-mobility infrastructure will be supported.
- Implement an indicator that measures the ability of buildings to use modern technologies and electronic systems to adapt to the needs of the consumer, perfect its functioning, and interact with the electricity grid's "smart readiness."
- Develop long-term strategies for building retrofits and their financing.

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[1] *https://commission.europa.eu/news/focus-energy-efficiency-buildings-2020-02-17_en#:~:text=Collectively%2C%20buildings%20in%20the%20EU,%2C%20usage%2C%20renovation%20and%20demolition.*

[2] *https://enev-online.de/epbd/2018/text.htm*

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- Encourage public and private financing and investment.
- Reduce energy use and energy costs for households by renovating older buildings.

Targeted measures to improve energy efficiency and the economic and ecological aspects in the building sector require plans tailored to the building itself, the technical systems, and their use. Modern BMS (Building Management Systems) helps to identify and implement potential protocols and routines which ease the optimization of the buildings. What is needed, is the development of an energy efficiency concept, a sustainable and consistent implementation, and the adjustment of measures and strategies to improve the conditions in which the buildings are found and at the same time the living conditions of its occupants. Furthermore, by implementing energy efficiency measures, it should be possible to reduce energy consumption by 60% by 2050.

This unit consists of five parts in which the energy management and the building management systems will be described, starting by remarking its goals and aims in part 1.1, then in part 1.2 the problems that BMS pretends to solve are mentioned. Energy management and its benefits along with its challenges will be described in part 1. 3. Reaching part 1.4, the economic and ecological benefits from a normative point of view are reviewed. All these ideas find their common point and converge on part 1.5 where all that is reviewed on this unit is enclosed.

2.4. Energy Management

It is a combination of measures to minimize energy consumption without significantly affecting system performance.[3] The measures are to be reviewed continuously and adjusted if necessary. To achieve the expected results an Energy Efficiency (EE) and a Quality Management (QM) system should also be proven. Thus, energy management influences the entire building management from technical processes to the behavior of people.

Energy efficiency and management are becoming more important against the background of climate protection. Climate change and predicted changes require the most efficient way of working in the energy sector.

By reducing unnecessary use of equipment, energy management systems can prolong the life of your building's mechanical and lighting systems and reduce maintenance costs. Relating this to society in general, applying energy management helps in the distribution and saving of energy which results in less energy waste, less energy production, fewer greenhouse gases, and less costs. Additional benefits also include:

- Systematic energy management supports the efficient use of energy in buildings.
  Energy management systems allow your facility to power equipment only when needed. For many facilities, this cuts the waste of lighting, heating, and cooling portions of the building that are not used around the clock.[4]
- An efficient energy management system reduces the emission of greenhouse gases.
  Optimized controls enhance your building's current mechanical systems and increase your ability to manage comfort and air quality throughout the building. Timing the equipment's usage, either electric or mechanical, reduces energy consumption and greenhouse gases generated by producing it.

[3] *https://www.ibm.com/topics/energy-management*
[4] *https://www.researchgate.net/publication/326083652_Building_Energy_Management_Systems_BEMS*

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- Reducing greenhouse gases lowers costs (both in building management and for society).

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2.4.1. Establishment of energy efficiency and quality management (QM)

The establishment of an energy efficiency concept and quality management refers to the implementation of strategies and processes aimed at improving energy efficiency and ensuring high-quality standards within an organization or industry. This concept involves a systematic approach to finding, checking, and perfecting energy usage while supporting or enhancing the quality of services.

Some key aspects and benefits associated with energy efficiency and QM are:

- Specification of the energy efficiency requirements in the BMS planning.
- Complete control of the verifiable functions.
- Continuous control and verification of whether the requirements are met in operation.
- Continuous verification through documentation.

More specifically, energy efficiency management involves the systematic planning, implementation, and monitoring of measures and practices aimed at optimizing energy use and reducing waste within an organization or system. Figure 2 outlines the key components of the Energy Efficiency and Quality Management system, described in detail in subsections 1.3.3 to 1.3.5.

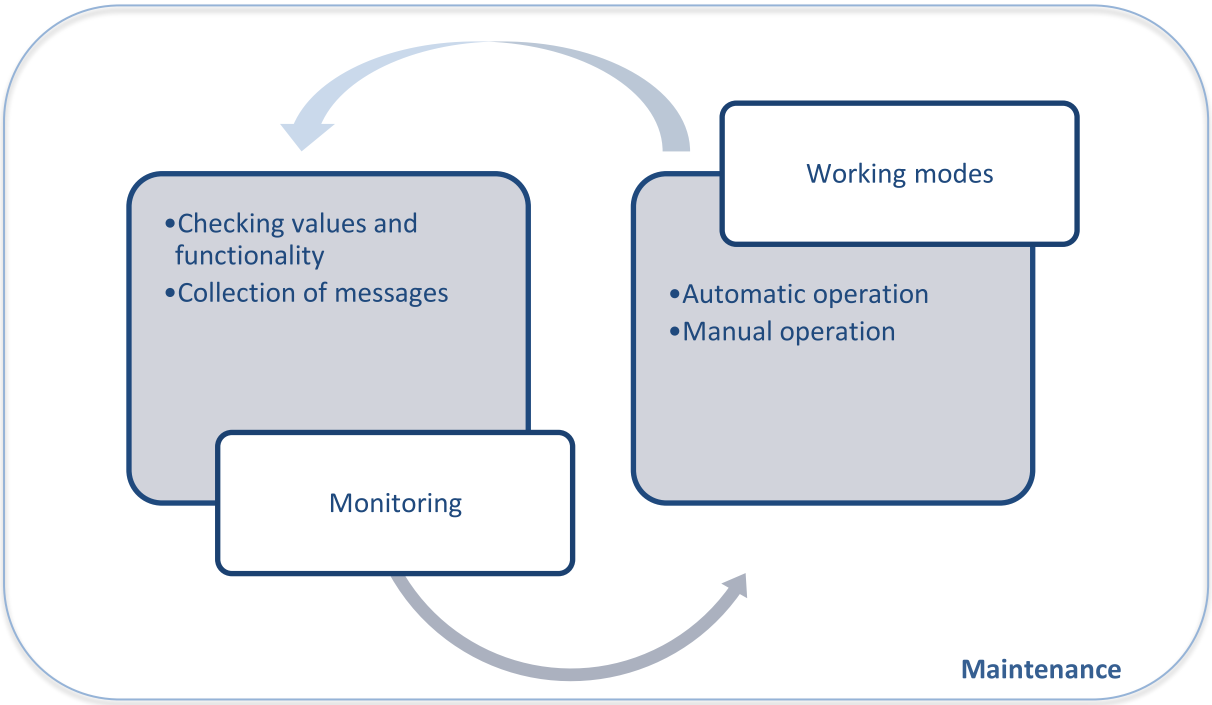

Figure 2 Diagram explaining the parts that include an energy-efficient system.

2.4.2. Monitoring in energy efficiency

This is a key part of energy efficiency success, it entails the ongoing measurement and assessment of energy consumption, energy savings, and related factors to ensure that the energy efficiency initiatives

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are effective and achieving the desired outcomes. It supplies valuable insights into energy usage patterns, finds areas for improvement, and helps perfect energy efficiency further.

Monitoring or supervision is the first step in improving and optimizing energy efficiency. A distinction is made between:

- Commissioning monitoring
- Adjustment monitoring
- Long-term monitoring

Quantitative recording of consumption values, operating hours, measured values, etc. makes it possible to compare consumption and measured values at various stages of operation or after certain measures have been taken. This involves the collection, analysis, and presentation of information in a visual format to gain insights, track performance, and make informed decisions. It is a process that combines data monitoring and visualization in a near-real-time mode.

2.4.2.1. Checking the values and functionality of the BMS

Monitoring the technical building installations is important to ensure efficient operation of them and their availability.

Through monitoring, deviations in regular operation and the exceeding of threshold values can be detected.

- On the one hand, the values must be monitored manually regularly and documented if necessary.
- On the other hand, modern BMSs automatically report deviations from target values.

Through monitoring, the total energy consumption of an object can be distributed proportionally to energy consumption and compared with other buildings of this type of use and analyzed to derive standardized measures and regulations.

2.4.2.2. Collecting messages

In building automation, messages can be divided into five areas which will be named and defined in section 2. These messages mean different things, from emergency messages or maintenance messages.

These messages are a consequence of readings and information collected by sensors of the system which take this information to the system's brain, analyze it, and decide what kind of message should be delivered to the operator. The information from the monitoring of building systems is also used to derive and develop system-specific optimization concepts. Depending on the message and incident, standardized or individual measures are to be derived so that the system continues working optimally.

2.4.3. Configuring operating modes

This model is designed to minimize energy consumption by adjusting the operation of devices, systems, or processes to reduce unnecessary energy usage. The specific mechanisms of how operating modes work to avoid energy waste vary depending on the context and the type of devices or systems involved. In this unit, automatic and manual operating modes are explained.

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2.4.3.1. Automatic operation

Implementing the use of BMS and automatic controls means giving the system the capability to function without continuous human intervention or manual control. With this kind of operation, tasks or functions are performed automatically and typically based on pre-defined settings, programming, or inputs from sensors and other automated components.

Some examples of processes that can be automated on a BMS are:

- Plant schedules.
- Time programs for temperatures.
- Setpoint specifications.

The manual operation should be made recognizable via feedback signals to the BMS (message function, alarm function, documentation)

Energy should only be supplied when there is an actual demand. The demand should be determined as far as possible with the help of sensors.

- Supply without demand is a waste of energy.
- Over-supply is a waste of energy.
- Do not heat or cool unused rooms in comfort mode if this is not necessary.
- Do not ventilate rooms if the actual load does not require active ventilation. This can be done, for example, by measuring CO2 emissions to investigate air quality using sensors.
- Automatic reset of manual settings to comfort conditions.

2.4.3.2. Manual operation

In a manual operation, tasks are done manually without automation or technology-driven systems. The control and execution of the operation rely entirely on human effort and decision-making. Manual operation is to be used exclusively for temporary tasks, such as:

- Commissioning.
- Maintenance.
- Repair.
- Diagnosis and investigation of malfunctions.
- Short-term implementation of priority conditions or comfort conditions for an event or exceptional situation.

Manual operation is not suitable for bridge malfunctions permanently or for postponing repair and maintenance measures for cost reasons.

The manual setting of comfort or priority conditions in the room automation system may also only be enabled for a brief period. These settings by users have only a temporary need and lead to energy waste if they have a permanent effect.

- User settings should be automatically resettable.
- Permanent manual operation should be technically excluded.

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There are some examples of tasks that at first glance appear to be better executed automatically, but in terms of energy efficiency must be done by a human operator. The most preferred are the cooling and heating systems. These systems cannot be a hundred percent automated because of their huge energy consumption.

If cooling and heating were to be automatic the entire building would be consuming energy all day and all night only for these two tasks. This would lead to a great increase in energy consumption and costs.

The solution that most of the building managements have found is a shading system that activates only when the user wants it to be deployed, this replaces both heating and cooling system automation by activating the shading when cooling is needed and deactivating it when the opposite.

2.4.3.3. Maintenance

The main goal of maintenance is to reduce costs and prolong the lifetime of all the devices within a building and the building itself. This could be achieved, as a first step, by supplying maintenance schedules based on wear and tear parameters given by the manufacturer of the devices.

To control these schedules, it is imperative to monitor all equipment and devices, this helps to have runtime monitoring reports that help us manage less used equipment and when the maintenance must be done or not.

At the same time said schedules lead to energy saving by not using equipment or devices excessively but just the right amount of time and power. It is also imperative to mention the huge amount of energy that old equipment consumes due to its deterioration, which maintenance helps prolong.

As a brief overview, giving equipment and device maintenance, at a proper time and way, gives it a longer lifetime and therefore less energy waste.

2.5. Economic and ecological aspects of energy consumption and efficiency.

Nowadays the world is changing at an enormous speed, including people's concern about climate change and environmental sustainability. At the same time, energy efficiency has appeared as a crucial topic of discussion; because of its ability to use energy resources, minimize waste, and maximize results.

It is well known the significant role that energy efficiency plays regarding climate change mitigation and greenhouse gas emissions reduction, as well as in the promotion of a sustainable future. Adopting innovative technologies, practices, and systems is essential to reduce energy consumption without compromising the desired level of performance or comfort in a building.

One of the significant benefits of energy efficiency is its potential to conserve natural resources. Fossil fuel reserves are finite, and their extraction and consumption have a disastrous impact on the environment. By employing energy-efficient technologies and practices, we can decrease our reliance on these limited resources, thereby preserving them for future generations.

Talking about the economic side of energy efficiency, its profound impact on cost savings must be mentioned as well as its promotion of job creation and competitiveness. This translates into improved profitability for businesses, increased disposable income for households, and reduced expenses for governments, stimulating economic growth.

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2.6. Reducing costs

The cost of energy has been rising in many areas of the world in recent years. This price increase is not expected to reverse in the coming years. Advantages of implementing energy management measures include:

- Lower energy costs increase profits.
- Lower energy costs also reduce production costs and lead to competitive advantages.
- Lower costs help safeguard jobs.

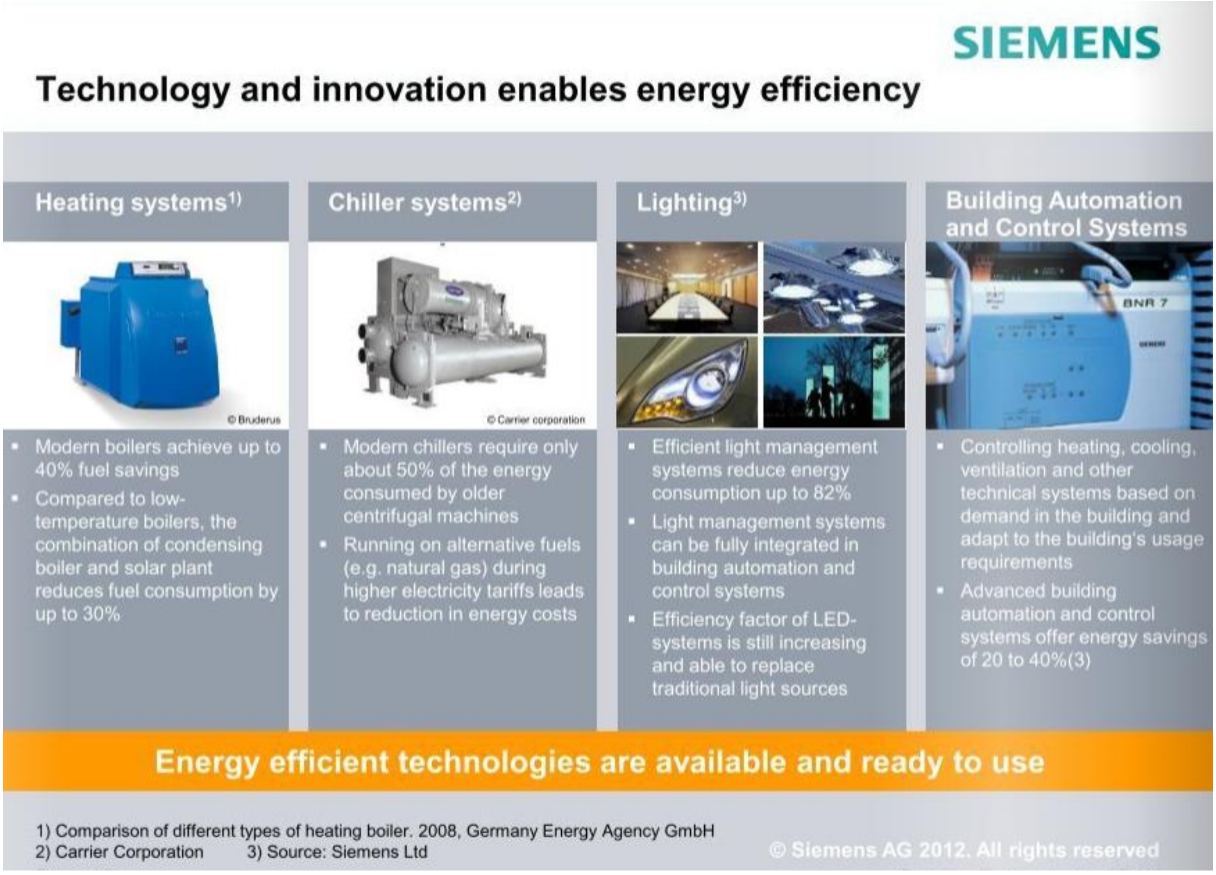

Figure 3 SIEMENS equipment that enables energy efficiency practically and straightforwardly. [5]

2.7. Environmental and climate protection

Investing in environmentally and climate-friendly measures addresses economic and ecological aspects in equal measure.

An environment- and climate-friendly policy has indirect effects on costs, e.g., in the context of CO2 pricing. Furthermore, it has positive effects on the external image of a company and can thus improve its image and attractiveness.

5 Source: https://www.yumpu.com/en/document/view/46234681/siemens-gst Environmental and climate protection

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An overriding goal is to reduce CO2 emissions directly or indirectly.

Climate protection focuses on taking care of climate change, mainly caused by the accumulation of greenhouse gases in the Earth's atmosphere. It promotes policies and regulations in the industrial and transportation sectors. It also promotes the transition to renewable energy.

Sustainable use of raw materials helps to reduce the alteration or destruction of the environment.

Sustainable raw materials extraction and processing improve and promote efficient energy use and support climate change mitigation and adaptation measures.

All these efforts and plans aim to create a balance between human needs and the integrity of our environment, ensuring future generations can enjoy a healthy planet with abundant natural resources and a stable climate system.

2.8. Summary

Buildings play an important role in energy consumption in developed countries all around the world, they represent about 40% of this rate. Most of this consumption is related to its HVAC (Heating, ventilation, and air conditioning) system which wastes about 5% to 20% due to inefficiency or faults proper of this system.

This amount of waste represents a $100bn loss per year, without adding the costs of maintenance and operating expenses represented by 80% of the costs of a building's lifetime. However, there is a way to reduce energy waste and manage consumption more efficiently, which could lead to economic benefits.

The tool that helps solve this problem is energy management, which helps minimize energy consumption without significantly affecting the performance of the system. All the measures that the energy management checks and analyses are adjusted if necessary to achieve a better usage of energy.

How energy management reaches its objectives is by reducing unnecessary use of equipment, this helps prolong the life of a building's mechanical and lighting systems and at the same time reduces maintenance costs.

Establishing an energy efficiency and quality management system requires the implementation of strategies and processes that improve energy efficiency and help reach high-quality standards. This involves finding, checking, and perfecting energy usage while enhancing the quality of services.

The key part to success in energy efficiency is the ongoing measurement of energy consumption, energy savings, and related factors that help ensure that its initiatives are being achieved.

The building manager has access to this information through messages provided by the system itself, as will be seen in section 2. These messages provide data regarding the state and functioning of the system. They also provide an emergency message or maintenance message which means the manager must take place on it.

The operating modes of an energy management system are configured to reach their maximum efficiency depending on which tasks can be done by an automated system or a manual system. In this

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way, there would be no waste of energy performing activities using equipment when a person can control the situation.

At the same time, an important aspect is the maintenance of the building, which goal is to reduce costs and prolong the lifetime of the devices found within the facility. This is proposed to be accomplished by setting schedules based on wear and tear parameters given by the manufacturer of the devices.

Having these changes and control of the energy waste in buildings will impact positively and significantly on the environment as well as job creation and competitiveness. This translates into improved profitability for businesses, increased disposable income for households, and reduced expenses for governments, stimulating economic growth.

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3. Structure of a Building Management System (BMS)

3.1. About this unit

3.2. Goals / Objectives

After this module, participants will overview the most important terms and components of a BMS. They will discuss what the main definition of a BMS is and the functionality of it. Those who take this course will understand the way BMS operates and the benefits it brings to energy efficiency.

Attendants will analyze and discuss the main parts of a BMS and differentiate between the type of networks that must be used and their communication protocols. They will explain what use the sensors and actuators have within a BMS.

Finally, finishing this module, participants will be able to analyze and discuss protection goals a BMS must carry out.

3.3. Introduction

Building Management System (BMS) is a high technology system installed on buildings that collect data, controls, and monitors the building's mechanical and electrical equipment such as HVAC (Heating, Ventilation, Air Conditioning systems), lighting, power systems, fire systems, hydraulics, and security systems.

Building management systems are also known as Building Automation Systems (BAS), Building Management and Control Systems (BMCS), Direct Digital Controls (DDC), and Building Controls. Regardless of its denomination, these systems are used to create improvements through automation:

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- Achieve energy efficiency in the building.
- Informing facility managers of the parameters of the building’s operation and state.
- Improved facility uses such as heating and cooling systems, improved light distribution, and security.

BMS are composed of three parts: software, hardware, and Networking protocols. Software programs are usually configured in a hierarchical manner, which is a control system that assembles software and hardware in a hierarchical tree, a structure in a graphic form.

Two of the most important and well-known types of software programs are:

- Proprietary, whose author owns all rights to use, change and copy. Such types of software can be implemented using communication protocols such as C-bus, Profibus, etc.
- Integrated, which incorporates word processing, database management, graphics, and communications into one product. This software must be implemented using internet protocols and open standards like SOAP, XML, BACnet, LonWorks, and ModBus (communication protocols).

Typical user interfaces can range from a simple LCD display to a full-fledged graphical operator workstation. However, it must allow the operator to see what is happening in the building and what is scheduled to happen next, as well as give him access to equipment control. It must also allow to integrate parameters into the system to adjust for seasonal events and phases.

3.3.1. What does it do?

Modern buildings have some form of mechanical and electrical services to provide the necessary facilities for keeping a comfortable working environment. Basic controls take the form of manual switching, time clocks, or temperature switches that provide the on and off signals for enabling pumps, fans, valves, etc. The task of a building management system (BMS) is to monitor these processes and to control them automatically and as energy-efficiently as possible.

3.3.2. How does it work?

The BMS is a "stand-alone" computer system that can check the building's connected equipment as well as calculate and monitor compliance with the building's preset requirements.

Connected sensors are used to record and monitor the equipment's status in the BMS. Using control signals, the BMS can switch the building's equipment on and off or control it gradually. For example, temperatures are detected via sensors, and heating or cooling systems are switched on accordingly to reach the required temperature per room.

Modern BMS are now based on open communication protocols and are WEB-enabled, allowing integration of systems from multiple system vendors and remote access.

The functions that can be monitored and controlled by the BMS depend on two factors: the building systems, and the system providers (software and hardware).

Modern BMS not only allow a precise degree of control over building systems, but they can also trigger alarms when thresholds and parameters change or are exceeded, threatening the failure of the building system.

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The building management system can therefore control building services equipment in an automated way based on environmental factors and parameters, creating energy-efficient and economic benefits.

3.4. Layers and functions of a BMS

The major aim of the BMS is to guarantee the safety of facility operation, while also monitoring and optimizing the use and efficiency of its supervised subsystems to allow more efficient operation.

To achieve optimal monitoring and optimization, it is crucial to thoroughly analyze, develop, and enhance the various layers that constitute a Building Management System (BMS). These layers serve as the pathway through which information flows, starting from sensor readings and culminating in the system's central control unit. To create a successful BMS, three key layers, illustrated in **Error! Reference source not found.**, must be set up and refined:

- Field is the lowest level and the closer to interacting with the clients. This level refers to sensors, instruments, valves, actuators, thermostats, and on/off modules. This level is particularly important as the actions taken by the BMS system are purely based on the inputs received from it.
- Automation can be considered as the brain of the BMS, it consists of compact or modular DDC (Direct digital control) controllers. Its job is to process all the inputs from the field and provide comfort to the building occupants and safety for the building's equipment.
- Management level supplies an interactable user interface to the building operator. Its job is to display all the information the controllers take from the field level in a graphical user interface format. The management level can be either a PC or an HMI (Human Machine Interface). In case of any critical alarms, the management level can communicate via e-mail or text message.

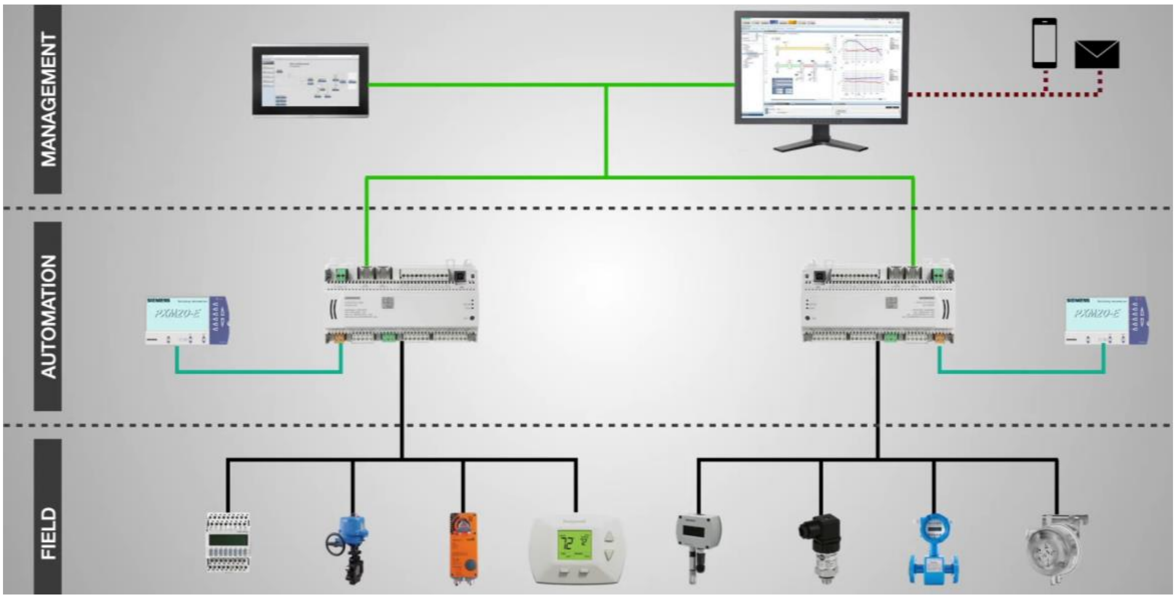

Figure 4 Diagram of a BMS, its three levels, and its hierarchy.

3.4.1. Field level

Description of layer

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At the field level, the various technical systems of the building field devices, sensors, and actuators, are run. Some examples are shown in Figure 5, including:

- Sensors that collect data (e.g., temperature; brightness, motion detectors, etc.).
- Data flows via the bus system (e.g., LONworks, etc.) to the actuators.
- Actuators receive data and output switching signals (e.g., HVAC, lighting).

Information is collected at the field level, processed, and made available to higher levels.

Functions

The tasks of the field devices and field level are:

- Switching involves changing the state of equipment between on and off.
- Measuring, this task is developed by sensors that can measure temperature, humidity, water level, and energy consumption.
- Counting consists of tracking the number of devices that are in use or functioning.
- Reporting consists of taking the information collected by the equipment and sending it to the automation level.
- A set is commonly used to activate certain devices that must remain in a state until something disables them. (e.g., an alarm that is set when an emergency happens and is not disabled until someone fixes the problem).

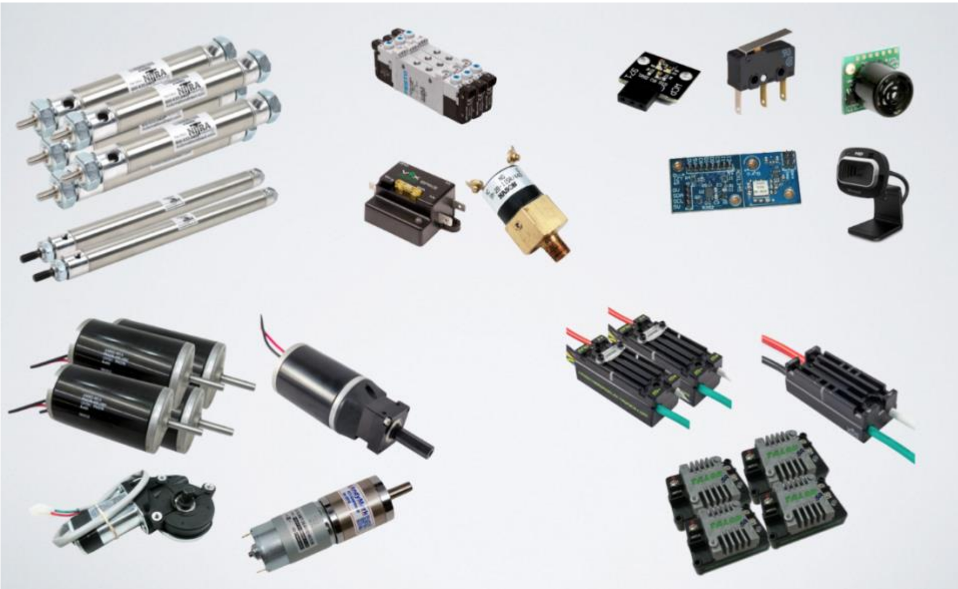

Figure 5, Sensors, and actuators used in the field layer of a BMS.

Modern field devices are increasingly equipped with communication systems. They can be connected via a computer bus system and take over tasks from the automation level. At the field level, only low data transmission rates are usually needed for processing data.

3.4.2. Automation level

Description of layer

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The building systems are controlled and regulated via the automation level. The connection to the input and output modules of the field level is made via DDC (Direct Digital Control).

Functions

The field level supplies the data for this level, while the management level supplies the parameters and specifications.

Some of the main characteristics and components of a complete automation level are listed forward and shown in Figure 6:

- DDC control, automation.
- Communication and standardization between field and management level.
- Digital networking and technical control.
- Control and regulation of technical systems.
- Monitoring of parameters (threshold values, limit values, switching states, meter readings).
- Alarm, fault, maintenance, and operating information.
- Energy consumption and operation optimization.
- Automatic and manual control.
- Data for statistics and analysis of values and states.

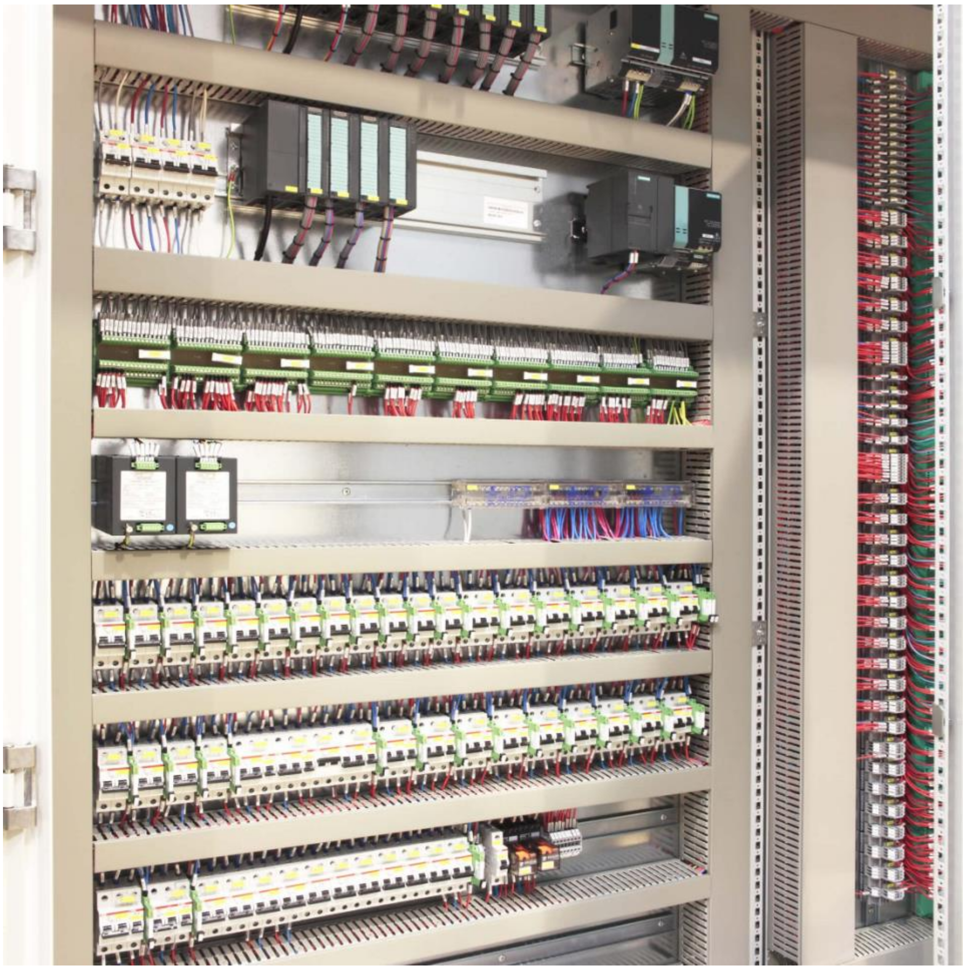

Figure 6, Control panel and its components: PLC's and relays.

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3.4.3. Management level

Description of layer

The management level enables targeted monitoring and influence on process flows. This monitoring is possible thanks to HMI (Human Machine Interfaces) depicted in Figure 7, which are screens that help the manager interact with and supervise all parameters of a BMS.

The management level is the interface for:

- Maintenance and repair management.
- Analysis of real-time data or long-term event records.
- Analysis of archived historical data from databases.
- Paging systems.
- Hazard alarms.

Cross-system and higher-level control and optimization algorithms are implemented via the management level, such as:

- Central dashboard and control center.
- Distributed systems with several operator stations (client-server architecture).

Functions

At the management level, all information of the building systems converges and is visualized and run via dashboards. Users can interact with the BMS and perform the functions listed:

- Observe the parameters and state of the building, its devices, and equipment (temperature, humidity, airflow).
- Monitor.
- Control and regulation of the technical building systems.
- Alarm functions in case of limit values being exceeded.
- Logging, which is the way of tracking and reporting errors and relating the data in a centralized way.
- Balance the use of resources depending on the data collected from the field.

Figure 7, Human Machine Interfaces used to monitor and supervise the processes of a BMS

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3.4.4. Structure of BMS levels and facilities

BMS were mentioned to have three main layers: Field, Automation, and Management. These three layers are the most important and the ones that structure the whole architecture of a BMS and at the same time are divided into different sub-layers depending on the functionality and purpose of each BMS.

As it is shown in Figure 8, each layer has its components, some of them are even shared or have the same kind of purpose.

These components consist in:

- Operating station is the part that has direct communication between the equipment and the operator.
- Programming unit, is where the operator can analyze, correct, or re-write the programming code of the system.
- Data interface unit is where the data is shown or read by the operator.
- System for special applications, this depends on what kind of equipment is used for the system.
- Data processing equipment/server station consists of servers that transport data all around the system, from its outer layers to its inner layers.
- The operating unit consists of every equipment or actuator the operator can interact with.
- Communication unit, this is every unit that sends information between layers of the system.
- Room control unit is the room where the operator supervises the well-functioning of the entire system and checks every piece of equipment.
- Controller/automation, this is the part of the system that controls every automated process.
- Local override control unit is one of the most important parts of a BMS, it is the part that helps to activate all emergency protocols in case of an extreme malfunction of the system.

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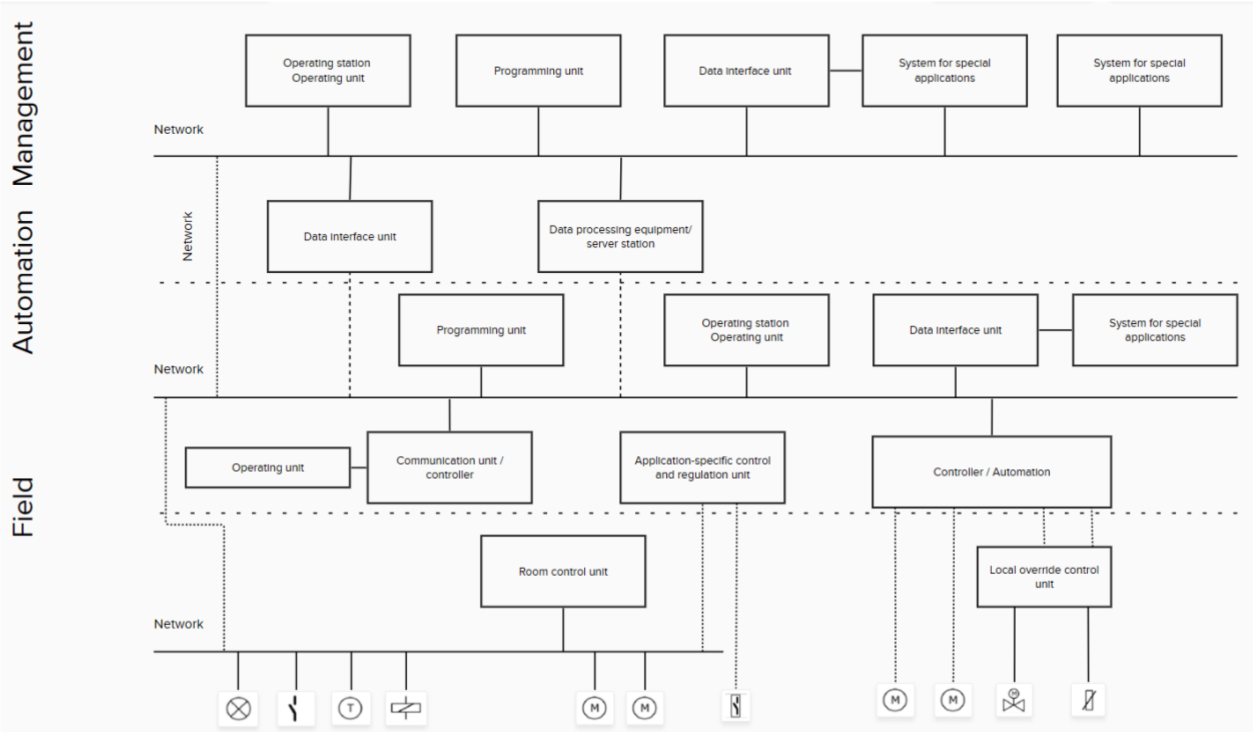

Figure 8, Guideline on building automation in public buildings for energy optimization and efficiency enhancement of building services installations Source: https://gebaeudeautomation.htw-berlin.de/index.php

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3.5. Components of a BMS (sensors, actuators, control units, communication infrastructure, security)

A BMS is a complex network that combines hardware and software to control and manage different systems within a building as can be seen in Figure 9. Said components can be categorized into four main types: sensors, actuators, control units, and communication systems.

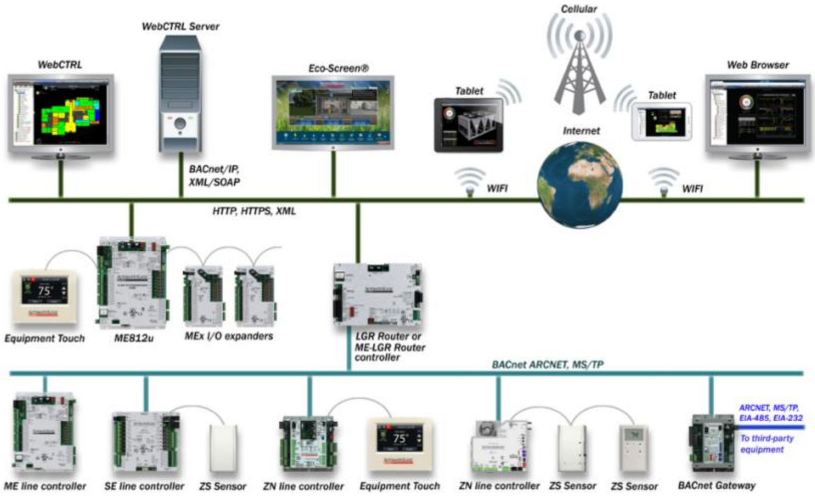

Figure 9, representation of a BMS network and its component in different layers

3.5.1. Sensors

They could be defined as the eyes and ears of a BMS. Being the direct connection between the system and the real world. Their function is to continuously monitor parameters and collect data within the building such as temperature, humidity, light levels, occupancy, and energy usage. All the data collected is then sent to the controllers for processing.

Figure 10, Aqara temperature sensor and humidity sensor

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Figure 11 Movement sensor

3.5.2. Actuators

Every equipment, device, or machine that receives a signal from the controller system to move or make an action is called an actuator. They could be valves, switches, motors, cooling systems, or heating systems.

Figure 12 Festo electro-pneumatic valve.

Figure 13 Ambaheat cooling system.

Figure 14 Heating system of a small building.

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Figure 15 Leeson industrial motor

3.5.3. Control units

A control unit, shown in Figure 16, is the brain of the BMS resulting in the part of the system that takes all decisions based on the information and data recollected from the sensors. Its main job is to gather the data and send instructions to the actuators to develop tasks with the building with as much efficiency as possible.

Figure 16 Control unit of a Building Management System

3.5.4. Communication systems

It is the main base for a BMS for it to be communicated with the occupants, the operator, and the building itself. It consists of the exchange of data between two stations, transmitter and receiver. Signals or information pass through what is called a channel for it to reach all components and control systems.

Communication network

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It is a system that enables the exchange of information and data between multiple devices, locations, or individuals. They are crucial for enabling collaboration and the sharing of resources in today's interconnected world. They employ various protocols, standards, and technologies to ensure efficient and secure data transmission.

The BMS is controlled remotely by cable or wirelessly. Decisive for the choice of the communication network is the type and size of the equipment.

While many networks are available with various applications, when setting up a Building Management System (BMS), it is essential to focus on four indispensable networks. These networks play a critical role in ensuring the effective functioning of a BMS: LAN, MAN, WAN, and Terminal Network, as shown in Figure 17.

There are a significant number of networks and diverse kinds of use they have, but to set up a BMS there are only four that must be applied.

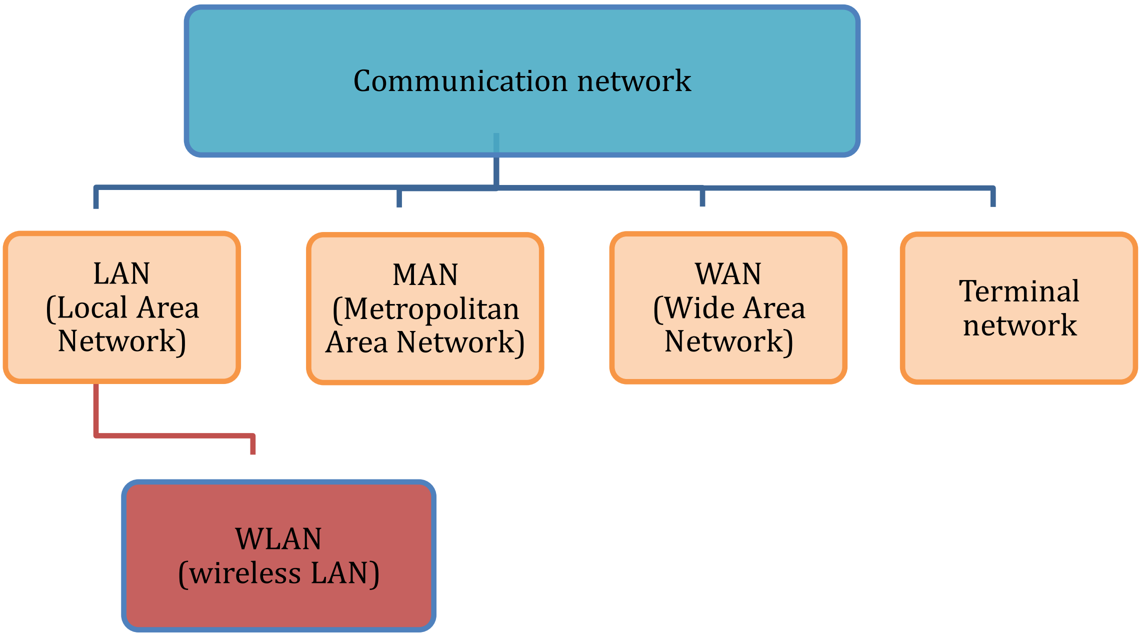

Figure 17 Different types of networks and their derivatives.

Communication protocols

The group of rules and conventions that define how data is transmitted, received, and processed is called a communication protocol. In practical words they could be compared to a language that standardizes format for communication, ensuring that devices can understand and interpret the data exchange. Such is the case for a BMS to create fluid and quick communication between all the interconnected devices. When the communication is precise and of high quality, the response of the entire system improves along with the response to emergencies. These communication protocols are shown in Figure 18.
Communication protocols such as BACnet, LON, and KNX/EIB are used in BMS.

- BACnet is a manufacturer-independent international standard ("Building Automation and Control Networks").
- LON and KNX/EIB are European standards (Local Operating Network; KONNEX / European installation bus).

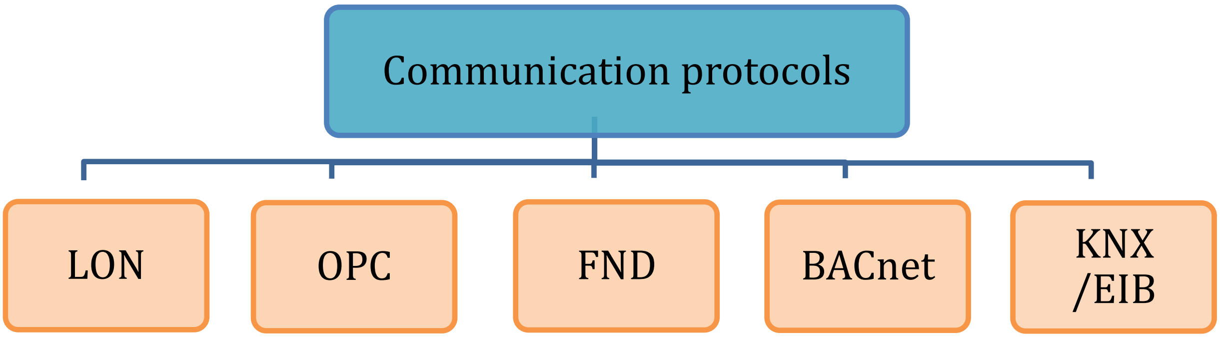

Figure 18 Different communication protocols used to communicate within the BMS.

3.5.5. Hardware and Software

Each BMS is specifically configured to a building. Functionality is determined by hardware and software components.

Hardware components

- Field devices.
- Automation equipment.
- Cabling.
- Communication equipment.
- Computing equipment.

Software components

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The software components are specific programs for the execution of the functions and services needed to run efficiently the whole BMS. They manage and gather information to be displayed to the operator graphically. In other words, they are the programs that give life to the controller system, which is the brain of the BMS.

Some of the software that is commonly used for BMS are:

- Supervisory Control and Data Acquisition.
- Energy Management Software.
- Building Automation Software.
- Integration Middleware.
- Data Analytics and Reporting Software.

3.5.5.1. IT Security

For the operation of BMS, individual systems must be interconnected and "networked" to achieve effective interaction. Therefore, integration into an IT security concept is necessary to prevent manipulation or attack on the system.

Security is the most important aspect when it comes to BMS to protect critical infrastructure, sensitive data, and occupant safety. Some of the practices that can be taken in place are:

- Implemented Access Control.
- Network segmentation.
- Regular system updates and patching.
- Intrusion detection and prevention.
- Secure remote access.

By following these practices, organizations can enhance the security of their BMS and mitigate potential risks associated with unauthorized access.

Here it is necessary to clarify:

- Which data/systems are available?
- Which data/systems can be manipulated?
- What effect can these manipulations have (loss of data, endangerment of people and/or systems)?

Protection goals and their dependencies

BMS have several protection goals that are interconnected and dependent on each other. These protection goals aim to ensure the security and reliability of the system and its components. Some common protection goals for BMS and their dependencies are shown in Figure 19

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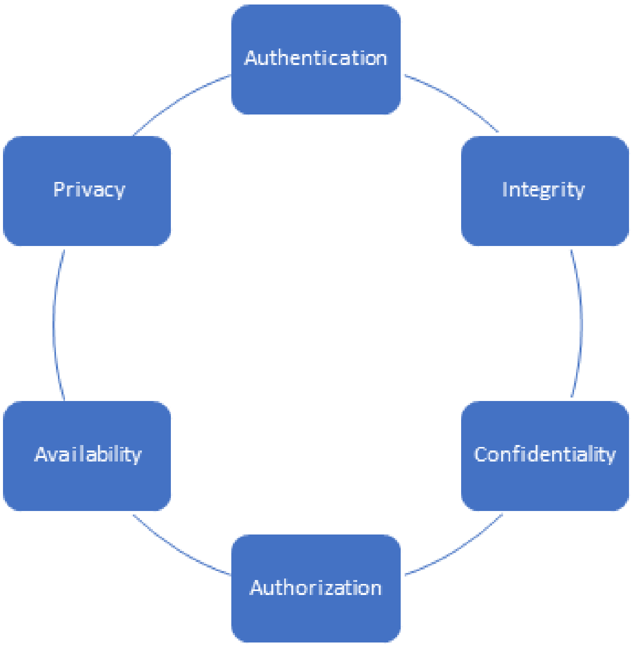

Figure 19 Characteristics and goals of a strong and secure BMS.

- Authentication depends on the implementation of strong and reliable mechanisms to verify the identity of the users and devices accessing the system.
- Integrity guarantees the accuracy, reliability, and consistency of data and information by preventing unauthorized modifications, tampering, or corruption.
- Confidentiality ensures that critical and sensitive information is accessible only to authorized individuals or entities and remains protected from unauthorized access or disclosure.
- Authorization defines and enforces appropriate access controls to ensure users can only access resources and data they are authorized to use.
- Availability ensures that IT resources, services, and data are available and accessible to authorized users when needed and protected against disruptions and downtime.
- Privacy protects personally identifiable information (PII) and other sensitive data, adhering to relevant data protection regulations and safeguarding user privacy. [6]

3.6. Summary

BMS is a system that is installed on buildings that helps collect data, controls, and monitors specific actions of the building that lead to the comfort of the client and residents of it. Its main objective is to control HVAC, lighting, power systems, fire systems, hydraulics, and security systems.

The reasons this system was created are to achieve energy efficiency in the building along with keeping facility managers informed every minute about the parameters and state of the building's operation system. This is meant to be reached using hardware and software elements of the system. On the side of software, we have two main types which are the proprietary and the integrated software.

[6] https://www.techtarget.com/searchsecurity/tip/8-ways-to-protect-building-management-systems

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The proprietary software can be changed and copied only by its author and the integrated incorporates word processing and database management.

Software and hardware are found within the layers of a BMS, which simultaneously contain equipment that helps each one reach its objectives. These three layers are Field, Automation, and Management level. These three layers play different roles within the BMS, Field layer is in direct contact with the clients; it contains the sensors and actuators that will make every action and pick all data from the out world. The automation layer will be the connection between the field and management level, it is the layer that commands the field layer based on the decisions made by the management level. The higher layer is the management level, it picks and analyses the information collected from the field and calculates every possible decision to determine the best and command the field layer to act.

BMS's connection to the outer world is found in some of its most important components which are the sensors and actuators. These can be found all around the facility, for they are the connection between the world and the system. Sensors can measure light, temperature, moisture, or movement. At the same time, actuators can be represented as motors, valves, cooling systems, or heating systems. Everything is connected to the control unit which is the brain of the BMS and contains all information and where all data is transported between layers using communication systems and communication networks such as LAN, MAN, WAN, or a terminal network. To use this network is essential to utilize communication protocols, a group of rules that define how data will be transmitted, received, and processed not to lose information necessary for the ell-functioning of the system. The communication protocols that can be used are LON, OPC, FND, BACnet, and KNX/EIB.

Recently BMS have had some modifications along with improvements, one of them is the implementation of digital security, which is to prevent manipulation or attack on the system. Security must be the most important aspect when talking about the qualities of a BMS. Some practices recommended are Access Control, Network segmentation, and Regular system updates and patching.

In the following video, you can see a summary of BMS in general, components in each level of BMS, and communication standards.

- https://youtu.be/ReEp0HH91ZU

The following video summarizes the definition of a BMS, its main characteristics, as well as its functions and benefits.

- https://www.youtube.com/watch?v=bhhagWXO5V0&list=PLu0ZfvM3i6VmMR85jaX5Enh5D32-p_d9k&index=1

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4. Implementation of a Building Management System

4.1. About this unit

4.2 Goals / Objectives
4.3 Introduction
4.4 Planning and Conceptualization
- 4.4.1 Types of Building Management Systems
- 4.4.2 Factors that influence the design of a BMS
- 4.4.3 Steps to design a BMS
  - 4.4.3.1 Identify goals and objectives of the system
  - 4.4.3.2 Conduct a building assessment
  - 4.4.3.3 Determine the type of BMS
  - 4.4.3.4 Select the components
  - 4.4.3.5 Develop control algorithms
  - 4.4.3.6 Install and commission the BMS

4.5 Installation and commissioning
- 4.5.1 Pre-Installation preparation
- 4.5.2 Physical installation
- 4.5.3 Software configuration and programming
- 4.5.4 Integration and interfacing
- 4.5.5 Functional testing
- 4.5.6 System integration testing
- 4.5.7 User training
- 4.5.8 Commissioning and handover

4.6 Maintenance and upkeep
4.7 Summary

4.2. Goals / Objectives

After this lesson, the attendants will be able to plan and correctly conceptualize the steps that lead to the creation of a well-integrated and completely functional BMS. They will analyse and discuss the diverse types of BMS and decide which one adapts better for the facility it is going to be applied to.

Attendants will differentiate the most crucial factors that influence the design of a BMS and at the same time will plan strategies on how to install correctly a BMS into a facility previously analysed and thoroughly reviewed. Assistants will determine the best type of installation that is going to be applied and will follow the pertinent steps to reach the objectives and goals of the installation and configuration of a BMS.

Finally, attendants will review and discuss the benefits of implementing a maintenance schedule based on a template of a BMS maintenance schedule.

4.3. Introduction

The management of large building projects requires workforce, coordination, planning and conceptualization of the system. There are several devices that must be installed and synchronized to accomplish the objectives of a BMS, such as light control, water management and temperature

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management. To achieve it, the systems must implement specific regulations to the building, based on the sections of the edifice that are under consideration to be automated.

The selection of the BMS type is crucial as it directly affects economic and energy efficiency possibilities. The project should allow for future improvements aligned with potential changes in building purposes. This highlights the significance of considering scalability right from the project's start to ensure the right BMS type is chosen from the start.

One of the most notorious improvements a BMS has to offer to a building is the ability to be connected to an online network using IoT (Internet of Things) tools, allowing it to be checked from any part of the world if it is desired.

After completion, a management system supplies comfort and safety to the occupants and owners of the buildings.

4.4. Planning and conceptualization

Planning Building Management Systems (BMS) is a complex process influenced by several factors, particularly the type of building it will be applied to. This consideration is crucial in deciding the most suitable and effective BMS for the specific building.[7]

4.4.1. Types of Building Management Systems

BMS have different purposes depending on the type of building they are installed at. These changes depend on the components that they manage or the building type. The type of BMS best suited for a particular building depends on the size and complexity of the building, the type of systems it already has, and the specific needs of the building’s occupants.[8]

The variety of BMS types arises from the combination of three main categories[9], which include:

- Standalone BMS, it controls only a single building. It typically consists of a central control panel connected to various sensors and actuators throughout the building.
  It mainly uses pre-programmed rules and setpoints to adjust the operation of the building’s system in real time. This type of system is better suited for small (less than 400 square feet) to medium sized (from 800 to 5,000 square feet) buildings.
- Integrated BMS, it is the type that controls multiple buildings or an entire campus. It consists of a central control panel and actuators and sensors throughout the facility.
  It is suitable for large, complex facilities, such as universities, hospitals, or corporate campuses.
- IoT-based BMS is hosted on a remote server and accessed via the internet rather than on-site. It can be used to control a single building, multiple buildings, or an entire campus.
  It is the most advanced and versatile building management system suitable for all kinds of buildings and infrastructures like retail stores, hotels, industrial plants, offices, warehouses, data centers, etc.

[7] https://ieeexplore.ieee.org/document/7501100
[8] https://www.zenatix.com/building-management-system-bms/#Evolution_of_Building_Management_Systems_BMS_technology_over_time
[9] https://www.sciencedirect.com/topics/engineering/building-management-system

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4.4.2. Factors that influence the design of a BMS

There are six main factors that are key to an effective design of a BMS, this helps adequate the system to the needs of the clients, these factors are:

- Goals and objectives, this is a factor that must be present to start the planning process of a BMS. Goals and objectives should drive the system's design and define the type of BMS that will be used, components to be installed and the control algorithms to be programmed.
- Building type and size, this is a factor influencing the economic aspects of the project and the energy efficiency aspects. It is imperative to know the type and purpose of the building that is going to be perfected; a small retail store will have diverse needs than a large hotel.
- Building assets & equipment, in this factor the designer must take in count systems such as HVAC (Heating, Ventilation, Air Conditioning), lighting, refrigeration systems, power systems, etc. The BMS must be able to check and control these systems in an optimal manner to reach the goals and objectives previously defined.[10]
- Occupant needs, this factor depends entirely on the purposes the building will perform, it is important to choose the components and the equipment according to their needs.
- Budget is one of the bases of every project, it is imperative to choose cost-effective components and prioritize features and functionalities that are more important to reach the goals and objectives in a shorter period.
- Scalability, this factor depends on the wishes of future modifications for the system. These modifications usually include the addition of new sensors, actuators, or other components to

[10] https://artpoint.org/how-to-design-building-management-system/

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integrate with other systems or devices.

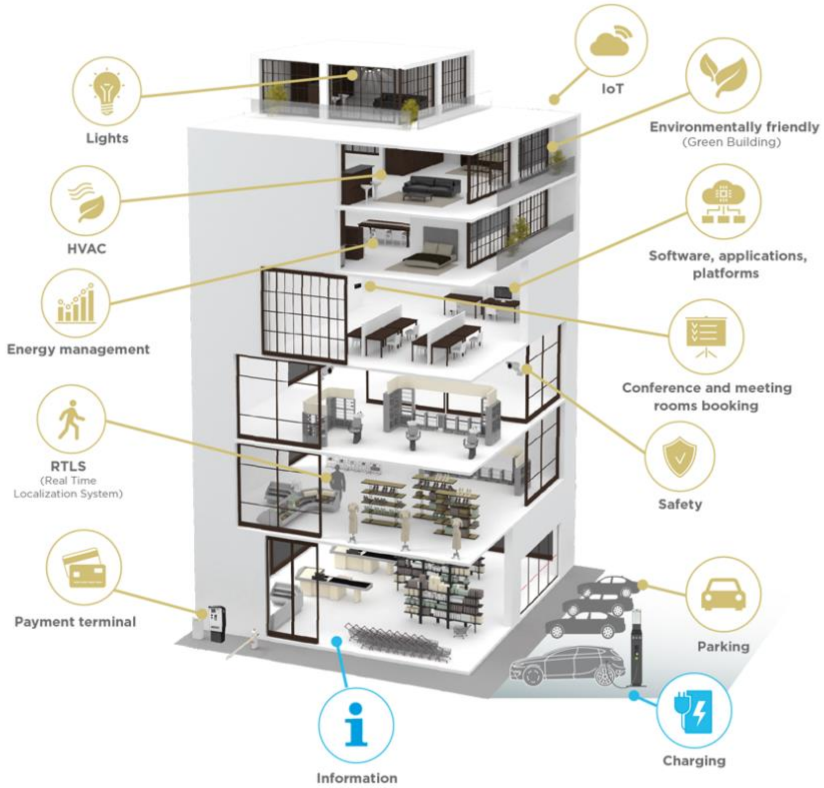

Figure 20 Representation of the needs a BMS controls.

Source: https://www.elkoep.com/bmsko

4.4.3. Steps to design a BMS.

Designing a comprehensive and coherent BMS requires adhering to six crucial steps, which are instrumental in achieving the system's primary objectives and meeting the needs of clients and users. These steps encompass the entire process of creating a BMS, starting from identifying the system's goals and culminating in its successful installation and commissioning. The six essential steps are as follows:

4.4.3.1. Identify goals and objectives of the system

These goals could be reducing energy consumption, improving users' comfort, or enhancing security. The process involves gathering information, conducting assessments, and collaborating with relevant parties to establish clear and well-defined goals for the BMS implementation.[11]

[11] http://property.mq.edu.au/__data/assets/pdf_file/0019/364114/MUP-BMS-Services-Design-Guidelines-V2.2-Jan-2018.pdf

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4.4.3.2. Conduct a building assessment

This helps to analyse the actual state of the building. This might include the evaluation of the HVAC, lighting, power, and water systems. The assessment is typically carried out by professionals, such as engineers, architects, energy auditors, or building inspectors. Based on the findings of the building assessment, a detailed report or assessment document is usually generated, outlining the current state of the building, recommendations for improvements, and potential actions to address identified issues.

4.4.3.3. Determine the type of BMS

Based on the two previous steps the selection of the best suited BMS is relatively easy. Deciding the type of BMS to use requires careful consideration of many factors related to the building's requirements, objectives, budget, and existing infrastructure.

The following factors can be taken in consideration:

- Needs assessment.
- Building size and complexity
- Existing systems and compatibility
- Budget and cost considerations
- Vendor selection
- Scalability and future needs
- User-friendly interface
- Data analytics and reporting
- Remote access and control

By carefully assessing these factors, it is possible to

determine the most suitable type of BMS that aligns with your building's needs, enhances its performance, and meets your goals for efficiency, comfort, and sustainability.

4.4.3.4. Select the components

This depends entirely on which type of BMS is going to be installed, the selection includes checking the best suited sensors, actuators, control panels, communication networks, and user interfaces. It involves a systematic process of identifying the specific requirements of the building and matching them with appropriate BMS components.

4.4.3.5. Develop control algorithms

These are the rules that will control the entire system by adjusting the operations of the facility. These algorithms must be tested before their implementation to prevent a major malfunctioning.

Developing control algorithms for a BMS involves a systematic approach that combines engineering expertise, domain knowledge, and data-driven analysis.

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Throughout the development process, collaboration with domain experts, building operators, and stakeholders is essential to ensure that the control algorithms align with the building's specific needs and supply effective and efficient control of its systems.[12]

4.4.3.6. Install and commission the BMS

This is the last step, and it requires to install all the equipment, sensors, and actuators as well as the connections between devices within the entire building. On Figure 21 is the representation of a BMS installation within a building. It is imperative to configure the control panel and the user interface. The BMS should be tested and calibrated to ensure its well-functioning.

Figure 21 Layout of a building showing the interconnection of a BMS

Source: https://www.coralair.com.au/building-management-systems/

4.5. Installation and commissioning

The installation and commissioning of a Building Management System (BMS) involves several key steps to ensure the system is properly set up, configured, and fully functional. There are steps that must be followed before and after the physical installation of the system. These steps are described in the forward sections.

4.5.1. Pre-Installation preparation

The reviewing of a building's infrastructure ensures it can fit the BMS components and wiring. It also identifies suitable locations for the collocation of the BMS controllers and panels. It helps arrange the necessary power supply and networking connections. The next steps should be followed to ensure a successful implementation and smooth operation:

- Needs Assessment and planning this helps identify the goals and objectives of implementing the BMS. It determines the scope of the system and the areas it will cover (HVAC, lighting,

[12] https://www.researchgate.net/publication/313909550_Building_Management_System

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security, etc.). It also conducts a thorough energy audit and performance analysis to understand the current building's energy consumption.

- Budgeting and resource allocation stablishes a budget for the BMS project and considers both initial installation costs and ongoing maintenance expenses. At the same time, it allocates necessary resources including personnel, time, and equipment.
- System design and architecture engages with qualified BMS vendors or consultants to design the system architecture based on the building's specific requirements and determines the types and number of sensors, actuators, and other equipment needed for optimal performance.
- Infrastructure and readiness mean to ensure that the building has a reliable and robust IT infrastructure capable of supporting the BMS communication protocols (wired or wireless) and if the building's electrical system can handle the load from BMS components.[13]
- Data connectivity and integration this determines how the BMS will integrate with existing building systems, such as HVAC, lighting, fire alarms, etc. This considers protocols and communication standards for seamless data exchange between different subsystems.
- Coordination with contractors and construction this verifies if the building is under construction, coordinate with contractors to ensure the prompt installation of required infrastructure and conduits for BMS components.
- Vendor selection and contracts, it is imperative to choose reputable BMS vendors with a proven record of accomplishment and reliable customer support to negotiate and complete contracts.

4.5.2. Physical installation

It refers to the installation of all components at their designated locations within the building. The montage of the controllers and panels in control rooms or equipment rooms. The main goal is to connect all devices and components, ensure proper wiring and cabling.[14]

Some steps that must be followed to achieve a good installation are:

- Equipment installation
- Sensor placement
- Controller integration
- Wiring and communication
- Data communication protocols
- Power supply
- Testing and calibration
- Integration with existing systems
- System commissioning
- User training

Equipment Installation involves placing hardware components like controllers, sensors, actuators, and communication devices in designated locations. Sensor Placement strategically positions sensors such as temperature, humidity, and occupancy sensors throughout the building to collect relevant data. Controller Integration integrates building system management controllers into the BMS network.

[13] https://bmscontrols.co.uk/blog/what-is-building-management-system-installation/
[14] https://safeworkmethodofstatement.com/method-statement-for-installation-of-building-management-system-bms-including-field-devices/

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Wiring and Communication establish a robust network through proper wiring and communication infrastructure.

Data Communication Protocols configure the BMS components to communicate seamlessly using specific protocols. Power Supply ensures continuous operation by installing adequate power supply and backup systems. Testing and Calibration verify the functionality and accuracy of all components, including sensor calibration. Integration with Existing Systems is undertaken when implementing the BMS in existing buildings, connecting with pre-existing systems. System Commissioning ensures the entire BMS operates as intended after successful testing and calibration. User Training provides building operators and maintenance staff with comprehensive training on using the BMS effectively and understanding its functionalities.

4.5.3. Software configuration and programming

It is to configure the BMS software on the central servers or controllers. It is also a task to program set up control strategies and schedules or alarms. The BMS software is responsible for collecting data from sensors, analysing it, and coordinating the operation of building systems, such as HVAC, lighting, security, and more.[15]

Some key aspects of a correct software configuration and programming are:

- Configuration of BMS software helps integrate sensors and its configurations which includes calibrating the sensors to the BMS software and enable data collection from different points in the building. At the same time BMS software needs to integrate with various devices. This configuration ensures that these devices can communicate and be controlled through the BMS.
- Programming logic and control include the implementation of control algorithms to regulate and optimize building systems. For example, it might adjust HVAC settings based on occupancy patterns and weather forecasts to save energy while maintaining comfort. Programming also helps the BMS to follow predefined schedules for HVAC operation, lighting, and other systems, optimizing resource usage throughout the day.
- User interface and visualization. The BMS software is often equipped with a user-friendly dashboard that presents real-time data and system status. Configuring the dashboard layout and visualizations is essential for ease of use. BMS software can generate reports and provide data analytics to track energy consumption, system performance, and comfort levels.
- Security and data management applies data storage configuration which includes decisions about how and where data from sensors and building systems will be stored securely. It also applies data encryption and its security measures like access controls which are configured to protect sensitive data from unauthorized access.

4.5.4. Integration and interfacing

This ensures seamless communication and data exchange between different subsystems and the integration of all the building's systems such as HVAC, lighting, etc.

Integration in a BMS refers to the process of combining and interconnecting different building systems, such as HVAC, lighting, security, access control, fire alarms, and more, into a single, centralized management system. The primary goal of integration is to allow these systems to

[15] https://bms-system.com/understand-the-basic-concept-of-bms-system/

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communicate and share information with each other, supplying a holistic view of the building's operation.

For example, by integrating the HVAC system with the lighting system, the BMS can adjust the lighting based on occupancy and natural light levels, contributing to energy efficiency.

Interfacing in a BMS refers to the connections and communication protocols used to enable data exchange between the BMS software and various building devices and sensors. The interfacing components act as bridges between the BMS and individual systems or devices, allowing them to interact and share data seamlessly.

Interfacing protocols can vary depending on the types of devices and systems being connected. Common protocols used in BMS interfacing include BACnet, Modbus, LonWorks, KNX, and OPC (Open Platform Communications). These protocols facilitate the exchange of data, control commands, and status information between the BMS and the connected devices.

For example, a BMS might interface with an HVAC controller using the BACnet protocol to gather temperature and occupancy data and adjust heating or cooling settings accordingly. In another case, the BMS could interface with a lighting control system using Modbus to adjust lighting levels based on user preferences or daylight conditions. [16]

4.5.5. Functional testing

This verifies that sensors, actuators, and controllers provide accurate data and respond correctly to commands. It involves evaluating its performance and capabilities to ensure that it functions according to its specified requirements. During this testing phase, the BMS is examined in a real or simulated environment to verify that it operates as intended and produces the expected outputs. Functional testing helps identify and rectify any defects, errors, or discrepancies in the BMS's functionalities, ensuring that it effectively controls and monitors building systems such as HVAC, lighting, security, and more. The goal is to validate that the BMS can successfully respond to various inputs, execute predefined actions, and generate accurate and desired results in managing the building's infrastructure.

4.5.6. System integration testing

This tests the integration and communication between all the BMS’s components, it performs a comprehensive testing of the entire BMS and its data exchange. It is a critical phase of testing that focuses on validating the interactions between different subsystems and their ability to work together seamlessly. Its primary objective is to resolve any issues that may arise due to the integration of different components, such as sensors, controllers, actuators, and communication protocols, within the BMS.[17]

The key aspects of the System integration testing are:

- Integration of subsystems
- Data flow and communication
- Interoperability
- Functionality across subsystems

[16] https://aosmithinternational.com/building-management-system/
[17] https://electricalengineering123.com/bms-building-management-system-testing-commissioning-method/

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- Error handling
- Performance and load testing
- Compatibility testing

By conducting System Integration Testing in a BMS, potential issues related to data exchange, communication, and interoperability between subsystems are identified and addressed early in the development process.

4.5.7. User training

It is one of the most important tasks to complete the process of installation of the BMS, this provides training to building operators, facility managers, and maintenance personal on how to use and interpret the BMS interface. The training is typically conducted by experienced trainers or BMS vendors and can take place before or after the BMS is deployed in the building.

During user training for a Building Management System (BMS), participants receive an overview of the system's purpose and benefits in managing building operations. They become familiar with the BMS user interface, learning how to navigate screens, menus, and dashboards. Users are taught real-time monitoring of sensor data, including temperature, humidity, occupancy, and energy consumption, through the BMS.

Additionally, they gain expertise in controlling building systems, adjusting HVAC settings, managing lighting, and changing schedules. Training encompasses alarm handling for abnormal conditions, equipment failures, and security incidents. Participants also acquire skills in data analysis and reporting to make data-driven decisions for energy efficiency and building performance improvement. Troubleshooting techniques are covered to address common issues users may encounter while operating the BMS.

Understanding security measures, access control, and user permissions to safeguard the BMS and sensitive building data is emphasized. In some cases, scenario-based training helps users practice and build confidence in handling real-life situations. Ongoing support is available, allowing users to seek assistance or additional training if needed.

User training is a crucial aspect of successful BMS implementation as it empowers building personnel to use the system effectively, optimize building operations, and ensure occupant comfort.

4.5.8. Commissioning and handover

This commissions the BMS after successful testing and optimization. The BMS is then hand over to the building owner or facility management team for ongoing operation and maintenance. [18]

Commissioning involves a comprehensive process of testing, verifying, and fine-tuning the system to ensure that it operates correctly and efficiently. The commissioning process typically includes the following steps:

- Installation verification
- Functional testing
- System integration testing

[18] https://www.betterbuildingspartnership.co.uk/sustainable-fit-out-toolkit/works/commissioning

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- Performance testing
- Alarm testing
- Data validation
- User training

On the other hand, Handover refers to the final stage of the BMS implementation, where the responsibility for the system is transferred from the installation team or contractors to the building owner or facility management team. This involves providing all necessary documentation, manuals, and access to the BMS software. The handover process typically includes:

- Documentation
- Operation and maintenance manuals
- Training
- Warranty and support information
- Testing and verification records

The successful commissioning and handover of a BMS are critical to its effective operation and long-term performance in managing and optimizing building systems.

Figure 22 Illustration of a Building's control room

Source: http://dsqidong.com/index.php/solutions/control-room

4.6. Maintenance and upkeep

Maintenance of BMS is a critical aspect to ensure the system's continuous good functioning. Proper maintenance helps prevent system failures, optimizes performance, and extends its lifespan.

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There are five main aspects that need to be followed to manage a good maintenance:

- Regular inspections mean conducting routine inspections of the components of the system and to check for any physical damage, loose connections, or signs of wear and tear.
- Calibration, this is important to all the components to ensure accurate measurements and control actions. This adjusts control settings as needed to optimize building performance and energy efficiency.
- Data monitoring, this helps monitor all data from the system to identify anomalies or deviations from normal operation. It analyses trends or patterns to identify potential issues.
- Firmware and Software updates, its task is to keep the software up to date by installing the latest patches provided by the manufacturer. It is imperative to check for security updates to protect against vulnerabilities.
- Preventive maintenance is the most important aspect to follow, its task is to follow a schedule, shown in figure 23, which may include cleaning, lubrication, and replacement of parts of the equipment. It helps reduce the possibility of an unexpected failure and ensures the system runs optimally.

The following video describes the steps to develop correctly and accurately a preventive maintenance plan and its benefits: https://www.youtube.com/watch?v=cnsFV2FxQmo

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Building Maintenance

Year :
Location:

Exterior - Building

	January	February	March	April	May	June	July	August	September	October	November	December
Exterior Walls												
-Clean												
-Flashings/Secure												
-Good Condition												
-No Pest, Wasp, etc.												
-other												
Doors												
-Good Condition												
-Secure Hardware/Handles												
-Locks Working												
-Glass Good Condition												
-other												
Windows												
-Good Condition												
-Latches in place												
-Weather-stripping Good												
-Hinges secure												
Roof												
-Good Condition												
-Flashings Secure												
-Vents Clear												
-Access Clear												
-No Evident Leaks												
-other												
Electric Panels/Receptacles												
-Covers in place												
-Nothing left plugged in												
Water Faucets												
-Not Leaking												
-Winterized												
Seats/Tables												
-Good Condition												
-Clean												
-Securely Mounted												
Ash Cans/ Waste Cans												
-Secured												
-Emptied												
Shelter												
-Good condition												
-Clean												
-Secure												

H:\safety\Copy of MASTER. Building Maintenance Check list.xls

Figure 23Template of a Building Maintenance Schedule

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Source: https://www.sampletemplates.com/business-templates/maintenance-checklist-template.html

4.7. Summary

Managing large building projects requires workforce coordination, meticulous planning, and conceptualization of the system, which must adhere to specific building regulations. An important consideration is the selection of the Building Management System (BMS) type, ensuring it allows for future scalability and improvements. By incorporating Internet of Things tools, the BMS can be connected to an online network, enhancing occupant comfort and safety.

The BMS's purpose varies depending on the building type and occupants' specific needs. There are three main types of BMS: Standalone BMS that controls a single building, Integrated BMS that manages multiple buildings or an entire campus, and IoT-based BMS hosted on a remote server and accessed through the internet.

To design a comprehensive BMS, several crucial steps must be followed, starting with identifying the system's goals and culminating in its successful installation and commissioning. These steps include conducting a building assessment, developing control algorithms, and performing the installation and commissioning process.

Before the physical installation, thorough pre-installation preparation is necessary. This involves reviewing the building's infrastructure, conducting a needs assessment, and planning, and determining the system design and architecture.

During the physical installation, all devices and components are connected, ensuring proper wiring, and cabling, and placing hardware components like controllers, sensors, and actuators in designated locations. Data communication protocols are established, ensuring a robust network and continuous operation with reliable power supply.

The software configuration and programming task involves configuring the BMS software on central servers or controllers and programming control strategies, schedules, and alarms. Additionally, it creates a user-friendly dashboard for real-time data and system status visualization.

Integration and interfacing enable the BMS to adjust the building's systems based on occupancy and natural light levels, contributing to energy efficiency. This involves data exchange between the BMS software and various building devices and sensors, which can use protocols like BACnet, Modbus, LonWorks, KNX, and OPC.

Functional testing ensures that the BMS operates as intended and produces the expected outputs, rectifying any defects or errors that may be detected during testing.

System integration testing focuses on testing the communication between all BMS components, resolving any issues that may arise from integrating different systems.

User training is vital for building operators, facility managers, and maintenance personnel. It equips them with the necessary skills to navigate the BMS user interface, monitor sensor data, manage HVAC settings and lighting, modify schedules, and make data-driven decisions for energy efficiency and building performance improvement.

The commissioning and handover process involves providing all necessary documentation, manuals, and access to the BMS software to ensure a smooth transition and efficient operation.

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Maintaining the BMS includes regular inspections, calibration, data monitoring, firmware and software updates, preventive maintenance, and security updates. These practices are essential to ensure the BMS's optimal performance and reduce the risk of unexpected failures.

5. Potentials of a Building Management System

5.1. About this unit

5.2 Goals / Objectives

5.3 Introduction

5.4 Energy savings and cost efficiency

5.5 Improvement of indoor climate and comfort

5.6 Sustainability and green building compliance

5.7 Integration with IoT devices

5.8 Optimization of operations and resource management

5.9 Summary

5.2. Goals / Objectives

At the end of this module, participants should be able to define energy savings and cost efficiency, they will compare the costs and benefits before and after the installation of a BMS on a facility. Attendants will be able to give examples of the strong points that a BMS reinforces within the comfort in a facility that is given to the attendants and clients.

Finally, they will explain the environmental impact of the energy consumption and reduced waste of a building that has a BMS installed, they will also name the important points to achieve a sustainable BSM along with the integration of IoT systems and their job making automation and monitoring tasks easier for the building manager.

5.3. Introduction

The creation, installation and development of a Building Management System are important steps to achieve the automation of a desired facility. On the other hand, it must be known that applying the BMS brings benefits to the building, the owner and to the people who will make use of the installations.

The benefits of a BMS can go from energy saving and economic savings. In this unit both points will be reviewed deeply understanding and comparing both an automated building and one that has not a BMS. The benefits a management system brings to the facility it is being applied to is not only reduced to these two examples, but this unit also explains the benefits that it develops for the users within the building such as the improvement of indoor climate and the comfort it brings.

Applying a BMS brings sustainability and ecological benefits to the environment with help of the newly applied IoT system that improves the automatization of a BMS beyond its capacities. This also

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helps to optimize all the operations throughout the facility and manage the resources it brings to its clients.

5.4. Energy savings and cost efficiency

Improving building performance and energy efficiency is a key priority for any Facilities Manager. The economic potential of BMS, costs and savings opportunities, usually depends on the functionality, number, and interconnection of building systems. However, there are many benefits to build or turn a building into an energy efficient building:

- Reduced energy costs due to improved energy efficiency.
- Improved energy management and control, with the ability to monitor energy usage in real time.
- Improved comfort for occupants due to better temperature regulation.
- Increased environmental sustainability due to reduced energy consumption.
- Reduced maintenance costs due to reduced equipment operating.

The BMS facilitates the control of the building's comfort equipment. For example, you can control the lighting to adapt it to the needs of the occupants. In the same way, the system allows intelligent management of heating, ventilation, or air conditioning.[19] This allows to have a better management of the energy, because the system decides the best time to make use of the equipment, not wasting energy. Just by automating HVAC and lighting systems, for example, it is estimated that overall energy consumption could be reduced by up to 30%.[20]

The centralized control of the building's technical equipment and the regulation of systems according to the needs of the occupants contribute to limiting waste and reducing the operating costs of the building. From this point of view, as well as for maintenance issues, BMS appears as a profitability lever for operators.

At the same time, a BMS can help reduce maintenance costs using detection methods to analyse the state of equipment and data on building systems to identify potential issues before they lead to equipment failure or energy waste.

BMS can do both things: reduce maintenance costs and extend the life of the building systems and equipment.

5.5. Improvement of indoor climate and comfort

Another essential benefit of a Building Management System is the potential to improve occupants' comfort. By monitoring and adjusting environmental factors such as temperature and humidity, BMS can help ensure a comfortable and healthy indoor environment for building occupants.

For example, a BMS can adjust HVAC settings to maintain a consistent temperature throughout the building or adjust lighting levels to optimize visibility and reduce eye strain. By providing a

[19] https://energisme.com/how-to-exploit-the-potential-of-bms-to-improve-the-energy-performance-of-buildings/#:~:text=The%20BMS%20facilitates%20the%20control,heating%2C%20ventilation%20or%20air%20conditioning.

[20] https://www.cubecontrols.co.uk/2023/02/28/why-a-bms-should-be-part-of-your-energy-saving-journey/

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comfortable and healthy indoor environment, BMS can help improve productivity and well-being among building occupants.[21]

Some key improvements that a BMS can bring are:

- Temperature control, a BMS allows for precise control of heating, ventilation, and air conditioning (HVAC) systems. It can maintain a consistent and comfortable temperature throughout the building, avoiding fluctuations that could lead to discomfort.
- Humidity regulation, to maintain an optimal humidity level is important for indoor comfort. A BMS can monitor and control humidity, preventing issues like dry air in winter or excess moisture during humid periods.
- Air Quality Management, it is the integration of air quality sensors to monitor pollutants, such as CO2, VOCs (volatile organic compounds), and particulate matter. The system can then adjust ventilation rates, accordingly, ensuring a constant supply of fresh air and reducing the risk of indoor air quality-related health problems.
- Zoning and individual control, this means to divide the building into areas with separate climate control settings. Additionally, occupants may have individual control over the temperature and ventilation in their immediate workspace, allowing for personalized comfort.
- Daylight harvesting, it comprehends the integration of lighting systems to take advantage of natural light. By dimming or turning off artificial lights when sufficient daylight is available, it enhances the indoor environment and reduces energy consumption.
- Occupancy sensing, the integration of occupancy sensors so the system can adjust heating, cooling, and lighting based on occupancy patterns, ensuring resources are utilized efficiently.
- Seasonal adaptation, this comprehends the programming of the system's software to adjust HVAC settings seasonally, considering the changing outdoor conditions and occupancy patterns, to maintain optimal indoor comfort.

5.6. Sustainability and green building compliance

By optimizing energy consumption and reducing waste, BMS contributes to sustainability goals and may help buildings achieve green building certifications, such as LEED (Leadership in Energy and Environmental Design).[22] Some important points to achieve sustainability for BMS are:

- Demand management, during peak demand periods, when energy costs are high or the grid is strained, BMS can automatically adjust energy usage in non-critical areas of the building. This helps to reduce energy consumption during expensive peak hours and contributes to more stable grid operation.[23]
- Resource management, BMS can also help manage other resources like water. It can monitor water usage, detect leaks, and control irrigation systems to ensure efficient water use and reduce wastage.
- Waste reduction, by minimizing unnecessary usage, BMS helps reduce the amount of waste generated, promoting a more sustainable approach.
- Green building certifications, many sustainable buildings seek to obtain green building certifications, such as LEED (Leadership in Energy and Environmental Design). BMS plays a

[21] https://www.zenatix.com/building-management-system-benefits-and-importance-for-optimizing-building-performance/
[22] https://www.mdpi.com/2076-3417/12/7/3271/html
[23] https://www.sciencedirect.com/science/article/pii/S2667259622000029

vital role in achieving these certifications as it provides the necessary data and automation to meet the strict criteria for energy efficiency, IAQ, water conservation, and overall sustainability.

- Carbon emission reduction, through its energy optimization and efficiency measures, BMS helps reduce the building's carbon emissions. This aligns with global efforts to combat climate change and supports organizations' sustainability goals.

5.7. Integration with IoT devices

Efficient energy utilization and IoT based smart energy management in buildings has become a trending research area by now. With urbanization, the number of buildings increases rapidly, leading to a shortfall of demand and energy supply across the globe. Along with this exponential growth of demand, a better energy management system for the buildings is needed due to the increasing number of buildings. Otherwise, there will be more power curtailments unnecessarily without proper control. [24]

BMS can integrate with a wide range of IoT devices, such as occupancy sensors, smart thermostats, smart lighting, occupancy trackers, and other intelligent sensors and actuators, these devices are connected through a network and communicate to make the most optimal decision as shown in Figure 24. These IoT devices are equipped with sensors that collect data and communicate with the BMS through the building's network.[25]

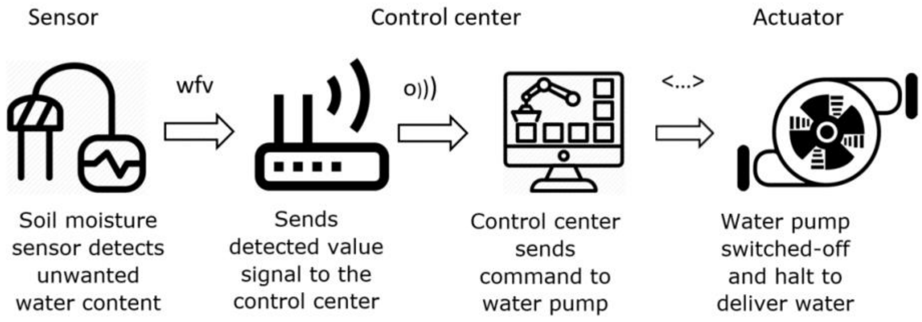

Figure 24 Diagram showing the decision-making steps of an IoT device from the reception of information to the action of the actuator

Source: https://www.novatec-gmbh.de/blog/sensors-and-actuators-of-the-iot/

At the same time IoT devices provide real-time data on various aspects of the building, such as occupancy levels, temperature, humidity, and equipment status. By integrating with IoT devices, BMS can enable advanced automation and control capabilities. For example, occupancy sensors can detect the presence of people in a room and automatically adjust lighting and HVAC settings based on occupancy, ensuring energy is not wasted in unoccupied spaces.

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[24] https://ieeexplore.ieee.org/document/9580866

[25] https://time24tech.com/building-management-systems/#:~:text=IoT%20brings%20automation%20to%20traditional%20building%20management%20systems.,the%20place%20of%20a%20%E2%80%98dumb%E2%80%99%20building%20management%20system.

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5.8. Optimization of operations and resource management

Building Management Systems can help enhance building operations and management. By providing centralized control and monitoring of various building systems and processes, BMS can help building managers streamline operations and optimize building performance.

The ability of a BMS to provide real time data on energy usage is useful to track occupancy patterns and other factors that affect the building's performance. This data can be used to identify areas for improvement and to develop strategies for optimizing building performance.[26]

A BMS can provide automated reporting on building systems and performance, which can help building managers stay informed and make data-driven decisions. By providing a centralized platform for building operations and management, BMS can help streamline communication and collaboration among building management teams.

5.9. Summary

The primary objective of a BMS is to enhance the energy efficiency, savings, and cost-effectiveness of the facility where it is implemented. Achieving this goal is a top priority and largely relies on the number, interconnection, and functionality of the building systems. By installing a BMS, several benefits can be attained, including the reduction of energy costs, improved energy management and control, enhanced occupant comfort, and lower maintenance expenses.

One example of this is the control of lighting adapting it to the needs of the occupants via BMS control. This can also mean that the system's intelligent management allows the manager to control parameters of the heating, ventilation, and air conditioning equipment. As an obvious consequence, when applied correctly, this leads to a great energy efficiency.

Another benefit that BMS give to any facility is the comfort improving for its occupants, this is reached easily by monitoring important parameters such as lighting levels or temperature and humidity. This helps to optimize visibility and reduce eye strain and providing a comfortable and healthy environment within the building.

Some more complex BMS implement zoning and daylight harvesting which are new methods to provide the comfort and energy efficiency, these are based on the integration of light systems in a way that daylight can be used more than artificial lighting and zoning divides the building into areas with separate climate control to reduce the heating system waste.

By optimizing all the energy waste of a building, it contributes to sustainability goals and helps achieving green building certifications, such as LEED. To achieve this certification is necessary to manage and control the demand and waste of energy as well as reduce its waste and reduce the carbon emissions produced by a facility.

This is reached faster and easier with the implementation of IoT into a BMS which helps control and monitor more equipment and devices of the building. IoT helps integrate devices such as occupancy sensors, smart thermostats, smart lighting, occupancy trackers, and other intelligent sensors or actuators.

[26] https://www.researchgate.net/publication/235988959_Optimization_Building_Management

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By implementing a BMS all this points and benefits could be added immediately to the benefits a building offers to its occupants and owners giving a good optimization and management of resources that helps its owner not only economically but also ecologically by not being part of the facilities around the world that contribute to greenhouse gas emissions.

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6. Risks and challenges

6.1. About this unit

6.2. Goals / Objectives

By the conclusion of this unit, participants will possess the ability to engage in discussions and analyses regarding optimal strategies for safeguarding the BMS against attacks. Moreover, they will adeptly navigate the implementation of data protection measures within the system, in conjunction with IT security programs and protocols.

Attendees will acquire comprehension and engage in discussion concerning the interoperability and standardization across diverse BMS variants. Furthermore, they will identify and acknowledge each type, while also appreciating the advantages that standardization bestows upon BMS maintenance.

Lastly, participants will conduct an analysis of distinct system upgrades and the requisite conditions for their implementation within the BMS framework. Simultaneously, they will engage in discussions about the intricacies involved and the necessary training prerequisites for the personnel tasked with operating the facility's comprehensive BMS.

6.3. Introduction

The design, implementation, installation, and start-up of a BMS represents various challenges that the owner and creator of the BMS must overcome to enjoy the benefits this brings to the installation it will be implemented to.

At the same time, there are risks that are especially important to consider in protecting the integrity not only of the BMS but also of the occupants of the building. These risks comprehend the vulnerability the entire facility has to an attack coming from a third person.

It is imperative to understand, analyze and detect these risks and threats to create a plan to protect the system and to be prepared in case the system fails or is compromised.

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All BMS represent challenges to be fully developed and even upgraded, it is the job of the manager to accomplish said challenges to provide the maximum comfort to the occupants of the facility.

6.4. Data protection and security - IT Security

Like any other computer system installed in buildings and factories, building management systems are vulnerable to attackers, hackers, mistakes made by employees, etc.

One way an attacker can easily hack a building management system (BMS) is via the existing manuals and documentation available on the internet. These documents are full of information, such as passwords, that an attacker could use.[27]

The results of an attack to a BMS will result in catastrophic consequences, it could go from stealing information about the facility or the personnel that runs the facility, to sabotaging the entire building's system and make it useless.[28]

6.4.1. How to protect a BMS

The most important thing to do after the installation of a BMS is to ensure its protection against severe risks and attacks, to do this it is imperative to follow the next steps[29]:

- Ensure the BMS is not connected directly to the internet and that the BMS is separate from the enterprise network by an air gap or firewall.
- Use virtual local area networks and segregated networking practices to keep BMS subnetworks separate and isolated. That way, a problem in one subnet cannot affect the other networks.
- Always change the default passwords for the BMS system, workstation, and field devices. Do not permit the use of shared usernames and passwords. Make passwords as complex as the system permits.
- Train personnel, contractors and vendors on security expectations, policies, and procedures. Security is everyone's job, and protecting the BMS from attack or misconfiguration is important.
- Perform security assessments to locate and identify any physical or cybersecurity vulnerabilities, then correct the issues as soon as possible. In these assessments, look for easy access points, such as rogue wireless access points, open/unlocked cabinets and passwords written on cabinets.
- When terminating an employee, contractor, or vendor, ensure that their physical access is erased. It is important to make sure that card keys are deactivated, keys are collected, and that their cyber access is turned off within an hour of the firing.
- Have a security incident response plan in place. This plan should address both cyber and physical security incidents. This plan must be evaluated at least every few months and ensure it works, is up to date and that weaknesses can be corrected quickly.

[27] https://www.techtarget.com/searchsecurity/tip/An-introduction-to-building-management-system-vulnerabilities
[28] https://www.nozominetworks.com/blog/securing-building-management-systems-from-cybersecurity-threats/
[29] https://www.techtarget.com/searchsecurity/tip/8-ways-to-protect-building-management-systems

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6.5. Interoperability and standardization

Interoperability and standardization play crucial roles in the successful implementation and long-term effectiveness of a BMS. They ensure that various components and systems within a building can communicate and work together seamlessly, regardless of their manufacturers or technologies.

Interoperability allows different building systems, such as HVAC, lighting, security, and access control, to be integrated into a unified BMS. This integration enables centralized monitoring, control, and management of all building functions, leading to more efficient operations. With standardization, building owners and operators are not tied to a specific vendor's products or solutions. They can choose from a variety of compatible devices and components, promoting healthy competition, cost-effectiveness, and future flexibility.[30]

When devices and systems adhere to recognized standards, maintenance becomes more straightforward. Technicians can work with a consistent set of protocols, reducing troubleshooting time and increasing the overall reliability of the BMS.

Standardized communication protocols, such as BACnet, LonWorks, Modbus, and OPC, facilitate data exchange and interaction between devices from different manufacturers. This ensures that critical information is shared seamlessly across the BMS.

Despite the advantages, achieving complete interoperability and standardization can still be a challenge due to legacy systems, proprietary technologies, and differing priorities among vendors. To address these challenges, industry organizations and regulatory bodies play a crucial role in promoting and developing common standards for BMS technologies.

6.6. System updates and upgrades

Modern building management systems (BMS) enable superior integration between smart systems including operations technology (OT) and information technology (IT) systems. They also maintain specifications for heating, cooling, and ventilation, monitor independent power supplies, and support energy conservation and emergency response procedures.[31]

For many building owners, the prospect of retrofitting their aging BMS is stressful. There are some indicators that tell when the right time is to change or upgrade the existing BMS. To reach the maximum level of serviceability of the facility is imperative to consider these indicators.

6.6.1. Serviceability becomes problematic

This happens when the controllers installed in a facility were discontinued by the manufacturer several years ago. The possibility of acquiring new compatible controllers from the manufacturer is impossible. If the system experiences a major failure, they are likely to lose most if not all their tenants.

[30] https://www.researchgate.net/publication/38977156_Building_Information_Modeling_and_Interoperability
[31] https://blog.se.com/buildings/building-management/2022/01/04/when-to-upgrade-your-building-management-system/

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6.6.2. Availability of existing financial incentives for new BMS

Incentives are often offered to promote energy efficiency, sustainability, and the adoption of smart building technologies. However, the availability and specific details of incentives can change over time, so it is essential to check with local government agencies, utilities, and energy efficiency programs for the most up-to-date information. This helps to know if the owner of the facility has enough capital to invest in a new BMS.

6.7. Complexity and training requirements

The complexity and training requirements of a BMS can vary depending on several factors, including the size and type of the building, the scope of the BMS implementation, the level of integration desired, and the sophistication of the technology involved.

Larger and more complex buildings with multiple systems (HVAC, lighting, security, etc.) require more extensive BMS setups. Coordinating and managing various subsystems to work together seamlessly can increase complexity.

Some BMS implementations may focus on specific building functions, like HVAC optimization, while others aim for comprehensive control over multiple systems. The broader the scope, the more intricate the BMS becomes.[32]

The complexity of a BMS can be reduced if the components and systems used are interoperable and follow recognized standards. Ensuring interoperability can simplify the integration process.

To reach the full potential of the abilities a BMS can reach is imperative that BMS operators and maintenance personnel have technical expertise in managing and troubleshooting the system. This may include understanding HVAC systems, electrical systems, network protocols, and programming languages.

Operators must be proficient in using the BMS software interface to monitor and control building functions effectively. They should understand data trends, alarm systems, and reporting features.[33]

The complexity and training requirements of a BMS emphasize the importance of working with experienced professionals during the design, installation, and ongoing operation of the system. Training and ongoing support are essential to maximize the benefits and efficiency of a BMS in a building.

6.8. Summary

The risks and challenges inherent in the process of implementing a BMS encompass a broad spectrum of subjects, including data protection and security. This consideration is imperative considering the escalating instances of hacker attacks targeting diverse systems, including BMS. The repercussions of a successful breach can prove catastrophic for the system, potentially resulting in its complete failure.

[32] https://www.researchgate.net/publication/38977156_Building_Information_Modeling_and_Interoperability

[33] https://www.researchgate.net/publication/348849779_Smart_Building_Management_System_Performance_Specifications_and_Design_Requirements

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There are diverse ways to protect a BMS from said attacks, that attempt to disconnect the BMS to the internet. To prevent them, the administrator must it always change the default passwords used in the system and develop a security incident response or plan.

Another challenge is represented by the interoperability and standardization which play crucial roles in the successful implementation and effectiveness of a BMS. Interoperability allows different building systems to work and be integrated to the BMS and be operated at the same time. This leads to have more efficient and coordinated operations.

On the other hand, standardization on communication protocols facilitate data exchange and interaction between devices from different manufacturers and helps having more control on the system.

To reach the maximum potential of the BMS is imperative to continuously perform updates and upgrades depending on distinct factors, such as the time of service the equipment has achieved or the compatibility of the equipment with the software. This also depends on the financial availability to upgrade the equipment of the system.

This brings benefits to the entire system but, with the implementation of new equipment it is necessary to have a training team that supports and helps the facility team to be updated as well to be able to take the maximum potential of this new equipment to make the system work at the highest performance.

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7. Exams

Energy management and Building Management Systems

What is energy management?

- It is a combination of measures to minimize energy consumption without significantly affecting system performance. (✓)
- The manage of resources to improve a building’s look and economic incomes.
- It is a combination of measures to minimize energy consumption without caring about the system performance.

How can energy management prolong the life of the building’s equipment?

- By reducing unnecessary use of equipment. (✓)
- By reducing the use of building rooms.
- By improving the light consumption in every room of the building.

What changes represent an efficient energy management and optimized controls?

- They reduce the emission of greenhouse gases and enhance the facility’s current mechanical systems and the ability to manage comfort. (✓)
- They improve the comfort of the habitants by controlling HVAC.
- They reduce greenhouse gases by not using HVAC or by reducing energy waste.

What is the establishment of energy efficiency?

- It is the implementation of strategies and processes that improve energy efficiency and ensure high quality standards. (✓)
- It is the prohibition of energy waste by limiting the usage of systems within buildings.
- The implementation of batteries that save energy to use it for small tasks within the building operations.

What are the benefits of monitoring in energy efficiency?

- It entails the ongoing measurement and assessment of energy consumption, energy savings, and related factors. (✓)
- It tells when something is being used or not.
- It helps prevent the misuse of the equipment of the building.

What are the two main monitoring types?

- Manual and automatic monitoring. (✓)
- Field and automation monitoring.
- Short and wide range monitoring.

What are the messages sent by the system?

- They are a consequence of readings and information collected by sensors of the system. (✓)
- They are the readings taken by sensors and displayed on a screen.

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- They are a support service that helps the manager contact with the equipment.

What are some examples of processes that can be automated on a BMS?

- Plant schedules, time programs for temperatures, setpoint specifications. (✓)
- Management service and cleaning.
- Maintenance and repairs.

What are some tasks that are exclusively intended to be operated manually?

- Commissioning, maintenance, repairs, diagnosis, and investigation of malfunctions. (✓)
- Maintenance, repairs and HVAC.
- Management service, maintenance, cleaning, plant schedules.

What is the purpose of implementing maintenance in a BMS?

- To reduce costs and prolong the lifetime of all the devices within a building and the building itself. (✓)
- To repair equipment and be able to keep installing more devices.
- To prevent the misuse of the equipment.

Structure of a Building Management System (BMS)

What is the main purpose of a BMS?

- To monitor processes of the building and to control them automatically and as energy-efficiently as possible. (✓)
- To automate all the devices within a building including TV's and HVAC.
- To create a more comfort environment for occupants.

How does a BMS work?

- It is a system that can check the building's connected equipment and calculates the building's preset requirements. (✓)
- It takes the information from sensors and creates a chart with all the data.
- It receives data from the automation layer and displays a solution for a manager to implement.

How does a BMS collects information?

- It collects information from the field based on sensors that are installed throughout the facility. (✓)
- The user gives information to the system about the data of the equipment.
- The manager collects all the information by reading the information given by the sensors.

What are the three main layers of a BMS?

- Field, Automation, Management. (✓)
- Sensors, actuators, monitoring.
- Reading, analysing, calculation.

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What are the main functions of the field level?

- Switching, measuring, counting, and setting. (✓)
- Collect information and make calculations.
- Give instructions to the automation layer to control the actuators.

What is the main equipment used in field level?

- Sensors and actuators. (✓)
- Actuators, computers and sensors.
- Sensors, cameras and cables.

What are the main functions of the automation field?

- It receives data from the field level and parameters and specifications from the management level, after working with this information it gives instructions to the field level. (✓)
- Receive the data from the field level, make calculations and action the actuators.
- Give instructions to the management level to control sensors and actuators.

What are some characteristics and components of the automation level?

- DDC control, communication and standardization between field and management level, digital networking, and technical control, monitoring of parameters. (✓)
- It manages computers, software and programs related to the system.
- It controls the management system and consists of sensors and actuators.

What is the management level?

- It is the level that enables targeted monitoring and influence on process flows. It is the interface for maintenance and repair management. (✓)
- It is the level that controls sensors and actuators to reach the goal of automation.
- It consists of equipment that measures and receives data that is the calculated by the field level.

What are sensors and actuators?

- Sensors could be described as the eyes and ears of the building. They monitor parameters and collect data within the building. Actuators are defined as every equipment, device, or machine that receives a signal from the controller system to move or make an action. (✓)
- Sensors are machines that receive a signal from the controller system to move or make and action. Actuators can be described as the eyes and ears of the building. They monitor parameters and collect data within the building.

Implementation of a Building Management System

What role does planning plays in the creation of a BMS?

- It plays the most important role at the beginning of the creation of a BMS, because it defines the type of BMS that better suits the facility it is going to be applied to. (✓)

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- It designs where the system is going to be installed and the room that is going to keep all the equipment.
- It plays an important role because it proved all the information about the system and the occupants.

What is the first consideration that needs to be taken in count when designing a BMS?

- The type of building it is going to be applied to and the size of it. The goals and objectives that are needed to be accomplished and the budget. (✓)
- The size of the equipment that is going to be installed and the location of the building where it is going to be placed.
- The brand of the equipment that is going to be used including the sensors and actuators.

What are the three main type of BMS?

- Standalone, integrated, and IoT-based. (✓)
- Integrated, online, and standalone.
- Standalone, interconnected, IoT-based.

What is the factor of scalability?

- This factor depends on the wishes of future modifications for the system. These modifications usually include the addition of new sensors, actuators, or other components to integrate with other systems or devices. (✓)
- The ability that the building presents talking about upgrades and updates that can be applied to it.
- The number of upgrades that have been installed to a facility.

What are the steps to design a BMS?

- Identify goals and objectives of the system, conduct a building assessment, determine the type of BMS, select the components, develop control algorithms, install, and commission the BMS. (✓)
- Plan the location of the equipment, design the operation room, install the equipment in the control room, program the system and commission the BMS to the client.

What is a pre-installation preparation?

- The reviewing of a building's infrastructure the certainty that all components and wiring can fit in the facility. The identification of suitable locations for the collocation of the entire BMS. (✓)
- The reviewing of the equipment and the facility it is going to be installed to and the devices that need to be added.
- The reviewing of the software that is going to be installed to the system and to the equipment to know if it is available for start-up.

What is a physical installation?

- It is the installation of all components at their designated locations within the building. The montage of the controllers and panels in control rooms or equipment rooms. (✓)

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- The installation of the computers that control the building management system.
- The installation of the equipment that controls the BMS and the actuators with its software.

What are some steps that must be followed to achieve a good installation?

- Equipment installation, sensor placement, controller integration, wiring and communication, data communication protocols, power supply, testing and calibration, integration with existing systems, system commissioning, user training. (✓)
- Measuring the space of installation, hiring technicians to install the equipment of the system, programming the software of the system, testing without calibration.

What is maintenance and upkeep?

- It is a critical aspect to ensure the system's continuous good functioning. Proper maintenance helps prevent system failures, optimizes performance, and extends lifespan. (✓)
- It is the analysis of the causes that make an equipment fail or that make them shorten their lifespan.
- It is the tracking of the quality of the equipment and the lifespan of them to know when they are going to fail or stop working.

What is the benefit of applying a schedule to maintenance?

- It helps having a more coordinated maintenance job and helps noticing when is time to replace equipment or pieces of equipment. (✓)
- It helps knowing when the equipment fails and keep track of it.
- It helps knowing what kind of places are needed to be ordered to the fabricant.

Potentials of a Building Management System

What are the benefits of turning a building into an energy efficient facility?

- Reduced energy costs due to improved energy efficiency, improved energy management and control, improved comfort for occupants, increased environmental sustainability, reduced maintenance costs. (✓)
- It increments the comfort of the occupants and at the same time it increases the clients of the facility.
- It helps reduce energy costs and increases the green areas in the building.

How can a BMS reduce maintenance costs?

- Using detection methods to analyse the state of equipment and data on building systems to identify potential issues before they lead to equipment failure or energy waste. (✓)
- Using detection methods to analyse the parts of the equipment that need to be replaced and repairing them instead of replacing them.
- Using schedules to keep machines and equipment functioning at their maximum work range.

How can a BMS improve occupants' comfort?

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- By monitoring and adjusting environmental factors such as temperature and humidity, BMS can help ensure a comfortable and healthy indoor environment for building occupants. (✓)
- By giving them more green areas within the facility and by incrementing the amount of energy available for them.
- By reducing the energy costs and limiting the energy that they can use.

What are some improvements a BMS brings to occupants?

- Temperature control, humidity regulation, air quality management, zoning and individual control, daylight harvesting, occupancy sensing, seasonal adaptation. (✓)
- More space in the building and a more friendly environment.
- Security, low costs, air quality and a better presentation of the building.

How does a BMS contributes to sustainability goals?

- By optimizing energy consumption and reducing waste. This may help buildings achieve green building certifications. (✓)
- It helps reduce the energy costs.
- It increases the comfort level of the occupants.

What is an example of a green building certification?

- LEED (Leadership in Energy and Environmental Design). (✓)
- ISO9001.
- IPX5.

What is the advantage of implementing IoT systems to a BMS?

- The integration of a wide range of IoT devices, such as occupancy sensors, smart thermostats, smart lighting, occupancy trackers, and other intelligent sensors and actuators. (✓)
- It helps monitor all the actions that the occupants of the facility are taking in place.
- It helps control the rooms of the occupants, so they reduce their energy waste.

How does these IoT devices work?

- These devices are connected through a network and communicate to make the most optimal decision. (✓)
- The devices are connected to the internet where they can be controlled by the manager.
- The devices are interconnected to the field layer and not to the management layer.

What kind of data does IoT devices provide?

- Real-time data. (✓)
- Numerical data.
- Categorical data.

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How is real-time data useful for a BMS?

- To track occupancy patterns and other factors that affect the building's performance. This data can be used to identify areas for improvement and to develop strategies for optimizing building performance. (✓)
- It helps the system track the information in real time and helps make real-time actions.
- It allows users to compare real-time data with the data displayed on the screens.

Risks and challenges

What is the purpose of Data protection and security?

- To help owners of a BMS prevent the attacks to the system that can cause catastrophic consequences and even lead to the destruction of the system. (✓)
- To avoid the system from being connected to the internet.
- To avoid the building to be controlled by third parties.

What are some steps to follow to ensure the protection of a BMS against attacks?

- Ensure the system is not connected directly to the internet, use virtual local area networks, change default passwords, train personnel, perform security assessment. (✓)
- Disconnect the system from the internet and use virtual area networks.
- Change default passwords and re-write the programs of the entire system.

What role plays interoperability in BMS?

- It allows different building systems, such as HVAC, lighting, security, and access control, to be integrated into a unified BMS. (✓)
- It allows every device to work individually to reach own goals and objectives.
- It allows the equipment to be available for individual activities and cooperative tasks.

What enables interoperability within a BMS?

- Centralized monitoring, control, and management of all building functions, leading to more efficient operations. (✓)
- The comfort of the occupants, the automation of the system.
- The programming of the system and the software that is used.

What role plays standardization in BMS?

- With standardization, building owners and operators are not tied to a specific vendor's products or solutions. They can choose from a variety of compatible devices and components, promoting healthy competition, cost-effectiveness, and future flexibility. (✓)
- It helps the system have a single code for all the equipment that is going to be installed throughout the facility.
- It helps the system have the same planning and layout for every building it is going to be installed to.

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What are the benefits of applying standardization to a BMS?

- Maintenance becomes more straightforward. Technicians can work with a consistent set of protocols, reducing troubleshooting time and increasing the overall reliability of the BMS. (✓)
- It helps the manager to know better the equipment that is installed in the facility.
- It helps the occupants ensure the increase of comfort they will experience.

What are some standardized communication protocols?

- BACnet, LonWorks, Modbus, and OPC. (✓)
- HTTP, HTTPS, DNS.
- Bluetooth, NFC, MQTT.

What are some indicators that help identify the right time for an upgrade?

- Serviceability becomes problematic, availability of existing financial incentives for new BMS. (✓)
- The equipment is already damaged or cannot longer work.
- The system is optimal and needs maintenance to work at its maximum capacity.

What makes vary the complexity of a BMS?

- The size and type of the building, the scope of the BMS implementation, the level of integration desired, and the sophistication of the technology involved. (✓)
- The number of occupants of the facility, the costs of the equipment and the client it is going to be offered to.
- The location of the system and the kind of people that is going to use the facility.

What is necessary for a BMS to reach its full potential?

- It is imperative that BMS operators and maintenance personnel have technical expertise in managing and troubleshooting the system. This may include understanding HVAC systems, electrical systems, network protocols, and programming languages. (✓)
- A good maintenance, a good manager, and a good power source.
- A good maintenance, technical expertise, good knowledge of green areas and environmental benefits.

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8. Glossary

Actuators: Equipment or devices that receive signals from the control system and perform actions, such as valves, switches, motors, cooling systems, and heating systems.

Adjustment monitoring: Monitoring after system adjustments.

Air gap: Physical isolation of the BMS from external networks.

Attendants: Individuals participating in a training or educational session.

Authentication: Verification of the identity of users and devices accessing the system.

Automatic operation: System functions without continuous human control.

Automation level: The layer responsible for processing inputs from the field level and controlling building systems through Direct Digital Control (DDC) controllers.

Automation: The process of making systems operate automatically, without manual intervention.

BACnet, Modbus, LonWorks, KNX, OPC: Protocols used for communication and data exchange between devices in building automation systems.

Breach: A successful security compromise.

Budget: The planned allocation of financial resources for a project.

Building Automation Systems (BAS): Another term used interchangeably with Building Management System (BMS), referring to systems that automate and control building functions.

Building Management System (BMS): A system that monitors and controls building functions like HVAC, lighting, and security.

Building Retrofits: Renovations and upgrades to improve energy efficiency.

Building automation software: Software used to control and manage building systems and operations, ensuring efficient functionality.

Building management installation: Technical systems ensuring building efficiency.

Building performance: The overall efficiency and effectiveness of a building's operations.

Building scope: The extent of a building's systems covered by the BMS.

Calibration: Adjusting sensors and devices to ensure accurate measurements and operations.

Capital investment: Funds used to acquire assets or improvements.

Carbon emissions: The release of carbon dioxide and other greenhouse gases into the atmosphere, contributing to global climate change.

Centralized control: Management of various building systems from a single point.

Centralized monitoring: Monitoring from a single location.

Climate Change Mitigation: Actions to reduce the impact of climate change.

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Commissioning: The process of testing and verifying a system before it is handed over for regular operation.

Communication protocols: Set of rules and conventions that define how data is transmitted, received, and processed between devices, ensuring smooth communication and data exchange.

Confidentiality: Protecting critical and sensitive information from unauthorized access or disclosure.

Configuration: Setting up the parameters and options of the BMS software to customize its behavior.

Control algorithms: Set of rules and logic used to control and optimize the operation of building systems.

Cost efficiency: Maximizing the cost-effectiveness of building operations by minimizing energy and resource expenses.

Cybersecurity: Measures to protect computer systems from attacks.

Data analytics: The process of analyzing data to uncover trends, patterns, and insights.

Data protection measures: Strategies to safeguard data from unauthorized access or manipulation.

Data-Driven Decisions: Making choices based on information and data analysis.

Daylight harvesting: The utilization of natural light to reduce the need for artificial lighting.

Direct Digital Controls (DDC): Compact or modular controllers that process inputs from field devices and provide comfort and safety for building occupants and equipment.

E-mobility Infrastructure: Support for electric vehicle charging infrastructure.

EU Directive EPDB 2018: European Union directive calling for energy-efficient and smart buildings.

Energy Consumption Monitoring: Continual assessment of energy use patterns.

Energy Consumption: Amount of energy used for various purposes.

Energy Efficiency: The ability to achieve desired outcomes with the least energy consumption.

Energy Management: The combination of measures to minimize energy consumption while maintaining system performance.

Energy management software: Software designed to monitor and manage energy consumption, aiming to improve energy efficiency.

Energy savings: Reduction in energy consumption achieved through efficient management and control of building systems.

Environmental sustainability: Ensuring a healthy planet for the future.

Facility: A building or space used for a specific purpose.

Field level: The lowest layer of a BMS, consisting of sensors, instruments, valves, actuators, thermostats, and on/off modules that interact with the building environment.

Financial incentives: Monetary rewards for specific actions.

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Functional testing: The process of testing individual components to ensure they perform as intended.

Green building: A structure designed to have minimal negative impact on the environment, focusing on energy efficiency and sustainable practices.

Greenhouse Gas Emissions: Gases, like CO2, released into the atmosphere, contributing to climate change.

Grid: The network of electrical power transmission lines and equipment that deliver electricity from power plants to consumers.

Hackers: Individuals who gain unauthorized access to systems.

Handover: The transfer of responsibility for the system from installation teams to building owners or managers.

Heating, Ventilation, and Air Conditioning (HVAC): Systems for temperature control.

IT Security: Measures and practices implemented to protect information systems and data from unauthorized access, manipulation, and attacks.

Information Technology (IT) Systems: Computer-based systems for data processing.

Infrastructure: The underlying physical and organizational structures needed for the operation of a system.

Installation: The process of physically setting up and connecting BMS components within a building.

Integrated BMS: A type of BMS that manages multiple buildings or an entire campus through a central control panel.

Integration middleware: Software that facilitates communication between different systems and devices, enabling interoperability.

Integration: The process of combining different building systems into a unified and coordinated management system.

Integrity: Ensuring the accuracy and reliability of data by preventing unauthorized modifications.

Interconnection: The linking of different building systems and devices to work together seamlessly.

Interoperability: The ability of different systems to work together.

IoT (Internet of Things): The network of interconnected physical devices that can collect and exchange data via the internet.

IoT-based BMS: A BMS hosted on a remote server and accessed via the internet, suitable for various types of buildings.

LAN (Local Area Network): A network of interconnected devices within a limited geographical area, usually within a single building or campus.

LEED (Leadership in Energy and Environmental Design): A widely recognized green building certification program that promotes sustainable building practices.

Long-term monitoring: Ongoing assessment over an extended period.

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MAN (Metropolitan Area Network): A larger network that covers a city or metropolitan area, connecting multiple LANs.

Maintenance schedule: A planned program of activities aimed at maintaining the proper functioning of a system over time.

Management level: The top layer that provides a user interface for building operators, allowing them to monitor, control, and optimize the building's functions.

Manual operation: Tasks performed without automation.

Occupant comfort: Ensuring that building conditions are conducive to the comfort and well-being of occupants.

Occupants: Individuals using the building where the BMS is installed.

Operations technology (OT): Systems used for building operations.

Optimization: Maximizing efficiency and performance through strategic planning and control.

Password complexity: Use of complex and unique passwords.

Peak demand: Times when electricity usage is at its highest, often leading to increased energy costs.

Power curtailments: Reductions in power supply or availability due to high demand or insufficient resources.

Preventive maintenance: Scheduled maintenance activities aimed at preventing system failures and ensuring optimal performance.

Programming languages: Languages used to code software.

Public and Private Financing: Funding from government and private sources.

Quality Management: Strategies and processes to ensure high-quality standards within an organization or industry.

Resource management: Efficient utilization and control of resources such as water and energy.

Retrofitting: Upgrading or modernizing existing systems.

Runtime monitoring reports: Reports on equipment operation times.

Scalability: The ability of a system to handle increasing demands or accommodate future expansions.

Security assessments: Evaluations to identify vulnerabilities.

Security incident response: A plan to address security breaches.

Security updates: Updates to software and systems to address security vulnerabilities.

Sensors: Devices that collect data from the environment, such as temperature, humidity, light levels, occupancy, and energy consumption.

Serviceability: The ease of maintaining and repairing a system.

Shading system: Automation for controlling sunlight and temperature.

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Standalone BMS: A type of BMS that controls a single building, usually consisting of a central control panel and sensors.

Standardization: The process of establishing common standards for compatibility.

Streamline: Simplifying and improving processes to enhance efficiency.

Supervisory Control and Data Acquisition (SCADA): Software used for monitoring, controlling, and gathering data from various systems in an industrial setting.

Sustainability: The practice of using resources in a way that meets present needs without compromising the ability of future generations to meet their own needs.

Terminal network: A network that provides access points for users to connect to the central control system.

Troubleshooting: Identifying and resolving issues.

User interface: The visual interface through which users interact with the BMS.

User training: Instruction and education provided to users on how to operate and make the most of the BMS.

Virtual local area networks: Segregated networks within a larger network.

Vulnerabilities: Weak points in a system that can be exploited by attackers.

WAN (Wide Area Network): A network that spans a larger geographical area, often connecting multiple cities or countries.

Zoning: Dividing a building into different areas with separate climate control settings.

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