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Choose the correct building controls

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Most buildings are designed to provide comfortable conditions to the occupants in an energy-efficient manner. To achieve functionality and comfort requires careful control and trade off in order to maintain efficient operation of the systems in the building.

Smaller buildings may have localised independent controls for energy systems, whereas larger or more complex buildings employ integrated building energy management systems (BEMS), that allow for the control of varied multiple lighting, heating, ventilation and air conditioning (HVAC) plant with automation.

The global buildings automation market was estimated to be worth $10bn in 2019 and is expected to grow rapidly due to the rise of wireless sensor technology, internet backed software, and security requirements. The growing deployment of building automation systems in large shopping complexes, sports facilities, office buildings, airports and railway stations are key to driving the market growth for commercial applications. Some of the key players in this industry include Siemens, Schneider Electric, Trend, Honeywell, ABB and Johnson Controls.

Individual isolated lighting, heating, ventilation and air-conditioning controls dominate much of the commercial buildings space. They typically include:

- time switches that turn services on and off in response to programmed time settings; these include 24-hour or seven-day timers;
- room thermostats that are switches operated by sensors, such as thermometers and thermistors, the electrical resistance of which changes in response to temperature, thus causing the thermostat to switch an HVAC unit on or off;
- photocell control is a resistor that changes resistance depending on the amount of light incident on it. They are commonly used for lighting control;
- passive infrared sensors (PIRs) detect occupancy and at a basic level will switch artificial lighting on/off. Where luminaires are dimmable, they can offer greater control by dimming lighting down to pre-set background levels;
- optimum start controls switch HVAC systems on at the right time, to bring a building to the correct temperature for occupancy. They provide around 10 per cent energy savings; and
- weather compensation heating systems use an outdoor sensor to automatically adjust heating systems by compensating for changes in outdoor temperature. They enable heating plant to run consistently which is more efficient, as energy is fed into the building gradually.

Key target of a BEMS

For larger and more complex buildings BEMS are often found. However, the presence of a BEMS does not mean that a building will operate efficiently. The purpose of BEMS is to collect information, understand energy use and effect control of equipment for efficient energy consumption. As the name suggests, energy management is the key target of a BEMS, as opposed to building management systems (BMS) that can be used to control a wide range of building systems.

BEMS ensure that a comfortable building environment is maintained, energy consumption is reduced and equipment can operate without interruption.

A well-specified and comprehensive BEMS will typically have the following functional requirements:

- gather information from multiple sources such as sensors, meters, submeters and external data sources (e.g. weather forecast);
- integrate and store data to allow a common analysis, presentation and control medium;
- analyse data to optimise control of the building for internal comfort and energy efficiency; and make real time corrective changes to control strategies and equipment operation;
- generate control strategies from gathered data;
- facility to prioritise load balancing between multiple energy sources if present such as local generation and

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grid supplied;
- provide alerts on out of range operation, energy waste, failed inputs or failed components;
- have the facility to switch between automatic and manual operation;
- have a user-friendly display interface for interaction with real time data, energy use profiles, historical data, energy use charts and graphs, alarms and alerts;
- provide details of conflict within the building operation, i.e. heating and cooling operating simultaneously and be able to implement changes to prevent this; and
- include software for data and sensor output gathering, sensors, network (hard wired or wireless), communications protocol, and output devices that carry out commands from the controller.

Controls standard

The principle controls standards include CIBSE publications and BS EN 15232.

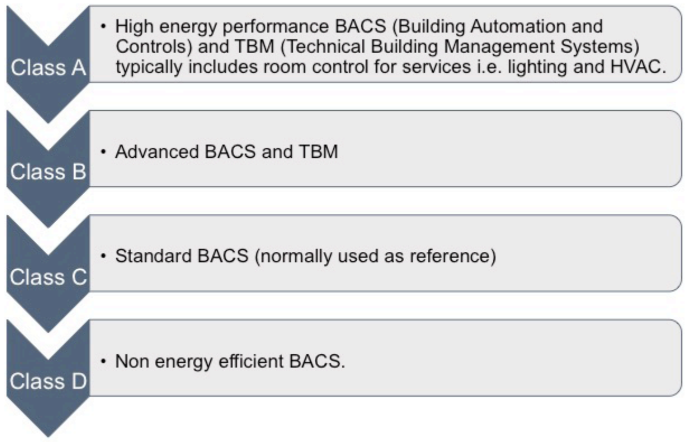
CIBSE Guide H, Building Control Systems, discusses the controls that are essential for the safe and efficient operation of a modern building and is a useful guidance for setting up a control strategy.

BS EN 15232:2017: Energy Performance of Buildings – Impact of Building Automation, Controls, and Building Management sets out energy performance classes for building automation and control as seen in Fig. 1.

To meet an A Class rating, the installation would typically have to include:
- heating / cooling - individual room control with communication between controllers, indoor temperature control of distribution network water temperature, and total interlock between heating and cooling;
- ventilation/air conditioning – demand or presence dependent airflow control at room level, variable set point with load dependent compensation of supply temperature control, room or exhaust or supply air humidity control;
- lighting – automatic daylight control, automatic occupancy detection manual on/auto off; manual on/dimmed, auto on/auto off; auto on/dimmed; and
- sun protection - combined light, blind, and HVAC control.

Class D installation describes those with no automatic control of heating, whereas Class C incorporates

Fig 1 : BS EN 15232:2017 BACS Energy Performance Classes



individual room control by thermostats/electronic controllers, but partial interlock between heating and cooling systems.

BS EN 15232 recommends demand control as an important strategy for managing use of building services, which in effect means controls are set up to run building services only when occupants require it.

An aspect of BEMS is the concept of 'open protocols'. These are the most common 'languages' used in programming building controls and they allow different types of equipment to communicate more efficiently.

There are several open protocols in use, including BACnet, LonWorks, KNX, Modbus and MBus. BACnet was developed specifically for buildings with a focus on HVAC, fire control panels and security access. LonWorks is similar to BACnet whereas Modbus enables communication between devices connected to the same network, for example, a system that measures temperature and humidity and communicates the results to a

Fig 2 : IoT allows data exchange

computer. KNX is focused on lighting systems, shading (automated blinds), room climate, security and BMS. Meters-Bus (MBus) – MBus was developed specifically for remote reading of meters.

It is important to verify if equipment can communicate with one of the open protocols; as the BEMS should be able to manage these protocols concurrently, enabling a seamless and joined-up approach towards operating the full complement of the building services. These protocols are now more or less interoperable, particularly BACnet, LonWorks and Modbus, using gateways. An example is the Anybus Modbus to BACnet gateway which allows Modbus slave devices to communicate on a BACnet network.

Collect and exchange data

Systems within buildings are traditionally independently maintained and run with attendant cost. However, web technology has enabled the internet of things (IoT), which is a network of physical objects that are embedded with electronics, software, sensors and network connectivity, which allows these objects to collect and exchange data. IoT allows devices on closed private internet connections (i.e. at building level) to communicate with others, bringing those networks together (see Fig. 2). It gives the opportunity for devices to communicate not only within close silos, but also across different networking types and creates a much more connected environment.

IoT enables interconnecting of systems and controls via the internet, reducing hard wiring thus creating an efficient network. This works well with BEMS, allowing single individuals to manage and control systems covering multiple buildings, from a single location. It also enables demand management, which is where less critical plant can be quickly shut down at periods of stress i.e. when exceeding mains grid capacity.

IoT technology is instinctive and compliments BEMS, as it can bring visibility to data and provide an insight into performance and operation.

There is now greater integration of HVAC controls with other building controls, particularly advanced lighting. For example, a sensor in an office might be used to control the lighting in that space, as well as operation of the room's unit ventilator.

The correct controls philosophy is a function of the building type, occupancy and critical variables. For example, a building with periodic occupancy such as offices, or variable activity levels such as leisure centres create operating conditions which run the risk of high levels of wasted energy due to services running when not occupied. BEMS within such buildings may offer greater potential for savings than buildings requiring more constant 24/7 activity or occupancy levels such as care homes or hospital wards.

Whether an entirely new installation or upgrade of an existing system, it is likely that a significant financial commitment is required to implement a BEMS project. It is therefore important to ensure that the BEMS is properly designed and specified. The design and specification should consider existing controls, irrespective of how basic, to avoid conflict.

The accuracy of controls is critical to achieving energy savings, as it is inappropriate to provide systems that operate with a degree of accuracy i.e. temperatures or Lux settings, to which plant in the building are unable to respond to. Doing so will not achieve desired energy savings. In several cases, BEMS in buildings fail because the designers are too optimistic, systems are complicated, and have limited consideration for the operators.

According to BSEN 15232, energy reductions of up to 30 per cent in heating energy consumption can be realised for a well-designed BEMS, maintained to specification and optimally operated, compared with

Fig 3 : Control principles

a poorly performing system using basic radiator thermostatic valves.

The commissioning of buildings is important for safe and energy-efficient operation of services. Commissioning is the process of bringing equipment into operation and ensuring that it works correctly and to its specified requirements. Building owners must ensure compliance with the requirements of the Building Regulations, one of which is the commissioning of mechanical plant.

Correct commissioning

CIBSE has published a set of guides for those who commission buildings, outlining what steps must be followed in the process, to ensure that services are commissioned in a proper and timely manner.

Activities that take place during commissioning tend to include pre-commissioning, testing and checking equipment performance, the components and electronics, balancing and regulating equipment. Other equally important activities include setting equipment to work which means switching them on to check their operation, obtaining statutory and insurance approvals, ensuring clients receive appropriate training and demonstrations and the preparation of reports and documentation of the commissioning process.

Commissioning is deemed as complete when the final report is issued to the building owner, on completion of all the necessary checks, tests and regulatory requirements.

Once commissioning is complete, site handover to the client takes place, which is when works defined in the contract are complete. During handover, the client or occupant is issued with all the relevant information and documentation from the commissioning process to ensure that they understand the purpose of the mechanical plant, how its control systems work and how it should be operated.

The handover documents should provide a record for operation and maintenance, and create a benchmark for future testing, maintenance as well as re-commissioning.

Existing system audit

For existing buildings, prior to considering a BEMS retrofit project, an existing systems audit should be commissioned, which should seek to establish the following:

• location and characteristics of existing controls such as sensor and actuator integrity;
• installed plant and are they connected, providing feedback and have there been software updates against manufacturers recommended schedules?;
• is there central control to any aspects?;
• are the controls suitable for the building/room use?;
• have there been changes in operations since installation/commissioning?;
• are there current communication links and protocols, for example, Ethernet or dedicated wired transmission?;

Financial payback of less than two years is common for retrofit projects. However, there are key considerations prior to committing to an investment which include:

• can the investment be justified compared to the energy saving potential?;
• are existing standalone controls able to integrate with the BEMS? Establish age, condition and reliability to help prioritising which systems are redundant.
• is the technology likely to affect the customer experience? This is important for retail and leisure buildings;
• can the installation fit into the background, to avoid distraction or disruption?;
• will it be a wireless or wired solution, as challenging building fabric and distance could impact on quality of wireless signals?;
• if adopting a wireless system, could the frequency interfere with office or retail equipment?;
• will the building undergo significant changes in the short to medium term, resulting in a redesign? Will the BEMS be robust enough to manage redesign of spaces? and
• system standardisation: where an organisation already occupies buildings with a model, multiple systems could result in higher operating costs, therefore consider standardising.

The impact of appropriate, responsive and dynamic controls systems cannot be underestimated in the quest for achieving energy efficiency savings and drive carbon reductions. Advances in technology, particularly via web connected systems and IoT will support the growth of BEMS. As systems become easier and more cost effective to deploy, sustained growth of BEMS will require technically skilled personnel, to install, service and maintain, otherwise the life span of systems may be impaired and energy savings not achieved.

Table 1 Some common issues and failure scenarios with BEMS

BEMS Issue	Consequences	Avoidance/Corrective Measures
Complex building services/controls	Misunderstanding, misuse, abuse and system conflict	Keep designs simple, train operators and develop a building logbook
Poor operator understanding of BEMS capability	Energy wasted in poor control	Re-train operational staff
Over-reliance on maintenance contractor	Energy wasted as systems operating in manual mode 24/7, pending contractor attendance	Re-commission BEMS and include on-site operators
Over-centralisation of controls through BEMS	Poor comfort and in-turn energy waste	Provide more user input with simple interfaces
Poorly set-up BEMS	Energy wasted in poor control	Re-commission BEMS. Check settings against occupant requirements
Lack of monitoring.	Energy waste not being picked up.	Introduce monitoring procedures with regular summary reporting
Out of range sensor feedback	Energy waste and occupant discomfort	Review sensors accuracy and re-commissions BEMS. Avoid rushed commissioning
Systems mismatch 'tail wags dog' effect i.e. large plant for small load	Large central systems operating to supply a small local need, with possible energy waste	Supply small load separately or introduce good zone controls
Partial handover and no test trials	System operates poorly from start and may never recover. Unlikely to deliver intended energy savings	Avoid rushed commissioning or handover & involve designers in trials
BEMS disconnected or by-passed out of frustration	Heating, cooling and ventilation systems in conflict, significant energy waste	Review with operators and designer, then re-commission BEMS

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BUILDING CONTROLS

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. What is a recognised standard for building automation and controls?
- ☐ ISO90001
- ☐ BS EN 16247
- ☐ ISO50001
- ☐ BS EN 15232

2. What would be recognised as an open protocol in relation to BEMS?
- ☐ Modbus
- ☐ Microsoft 365
- ☐ VOIP
- ☐ Skype

3. Which of the following are steps taken during BEMS commissioning?
- ☐ Screen fitting
- ☐ Client training
- ☐ Infra-red sensor procurement
- ☐ Weather Protection

4. What happens after commissioning is complete?
- ☐ Client Handover
- ☐ Balancing and regulation
- ☐ Equipment can be set up
- ☐ Initiation of fire drill

5. The BS EN 15232:2017 standard sets out energy performance classes for?
- ☐ Building automation and control on an A+ basis
- ☐ Building automation and control on an A to G basis
- ☐ Building automation and control on an A to D basis
- ☐ Building automation and control on an ad hoc basis

6. What does IoT mean in relation to BEMS?
- ☐ Internet of Technologies
- ☐ Internal operating Techniques
- ☐ Intuitive over Time
- ☐ Internet of Things

7. Which of the following issues should inform the planning stages of a retrofit BEMS project?
- ☐ Rising utility prices
- ☐ Poor weather
- ☐ Systems conflict
- ☐ Energy conversion factors

8. Which of the following is not a critical function of a well specific building energy management system?
- ☐ Able to gather information from multiple sources and sensors
- ☐ Integrate & store data to allow a common analysis, presentation and control
- ☐ Provide alerts on out of range operation, energy waste and failed inputs
- ☐ Convert energy use into real time cost

9. Which of the following parameter may not be measured within a BEMS?
- ☐ Time
- ☐ Electromagnetic compatibility
- ☐ Temperature
- ☐ Humidity

Q10. What could lead to failure of a BEMS?
- ☐ Annual software updates
- ☐ Installer only training
- ☐ Temperature exceeding 30ºC
- ☐ Incomplete commissioning

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