NHS National Services Scotland

Scottish Health Technical Memorandum 08-05:

Specialist services
Building management systems
Part B
Design considerations

Health Facilities Scotland
Engineering and Environment

April 2012

Contents

Acknowledgements

This new SHTM 08-05 Part B: 'Design considerations' has been developed, updated and expanded from SHTM 2005 which it replaces. SHTM 2005 was originally published in June 2001 by NHSScotland Property and Environment Forum Executive. The contributions from the National Ventilation Advisory Group and Stuart Robertson of Enterprise Control Engineers Ltd. are gratefully acknowledged.

Preface

About Scottish Health Technical Memoranda

Engineering Scottish Health Technical Memoranda (SHTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

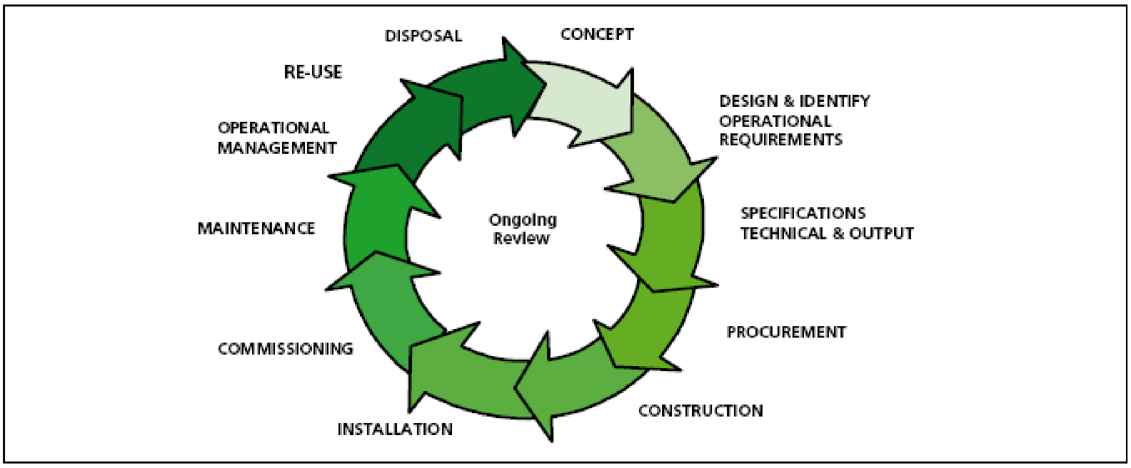
The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle. Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Engineering Scottish Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to repeat unnecessarily international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Scottish Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The core suite of eight subject areas provides access to guidance which:

- is more streamlined and accessible;
- encapsulates the latest standards and best practice in healthcare engineering;
- provides a structured reference for healthcare engineering.



Healthcare building life-cycle

Structure of the Scottish Health Technical Memorandum suite

The series of engineering-specific guidance contains a suite of eight core subjects:

Scottish Health Technical Memorandum 00: Policies and principles (applicable to all Scottish Health Technical Memoranda in this series)

Scottish Health Technical Memorandum 01: Decontamination

Scottish Health Technical Memorandum 02: Medical gases

Scottish Health Technical Memorandum 03: Heating and ventilation systems

Scottish Health Technical Memorandum 04: Water systems

Scottish Health Technical Memorandum 05: Reserved for future use

Scottish Health Technical Memorandum 06: Electrical services

Scottish Health Technical Memorandum 07: Environment and sustainability

Scottish Health Technical Memorandum 08: Specialist services

Some subject areas have been further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc.

Example: Scottish Health Technical Memorandum 06-02 Part A represents: Electrical safety guidance for low voltage systems

In a similar way Scottish Health Technical Memorandum 07-02 simply represents: Environment and Sustainability – EnCO$_2$de.

All Scottish Health Technical Memoranda are supported by the initial document Scottish Health Technical Memorandum 00 which embraces the management and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.

Health Facilities Scotland wishes to acknowledge the contribution made by professional bodies, engineering consultants, healthcare specialists and NHS staff who have contributed to the review.

Engineering guidance structure

Executive summary

A Building Management System (BMS) or Building and Energy Management System (BEMS) is a computer-based centralised procedure that helps to manage, control and monitor certain engineering services within a building or a group of buildings. Such a system ensures efficiency and cost-effectiveness in terms of labour and energy costs, and provides a safe and more comfortable environment for building occupants.

The BMS has evolved from being a simple supervisory control to a totally integrated computerised control and monitoring system.

Some of the advantages of a BMS are as follows:

- simple operation with routine and repetitive functions programmed for automatic response;
- reduced operator training time through on-screen instructions and supporting graphic display;
- faster and better response to occupant needs;
- reduced carbon usage and energy costs through centralised control and energy management programmes;
- better management of the facility through historical records, maintenance programmes and automatic alarm reporting;
- improved operation through software and hardware integration of multiple sub-systems, for example direct digital control, security and access and lighting controls.

This part, 'Design considerations', considers general BMS technology and details the requirements and considerations that should be applied to the selection, design, tendering and installation stages of a project.

Management responsibilities in terms of compliance with statutory instruments are summarised in Section 2. The technology and potential benefits of a BMS are described in Section 3, 'Functional overview'. The fundamentals of BMS architecture are described in Section 4. Section 5 describes key BMS functions, including:

- monitoring routines such as digital, analogue and pulsed inputs and trend logs;
- control of environment, energy, lighting, plant and machinery.

Section 6 covers BMS inputs and outputs. Software applications in monitoring and targeting energy or consumption, and providing the basis of a planned preventive maintenance programme, are discussed in Section 7.

Section 8 covers communications and Section 9 deals with aspects of integrating the BMS with other systems such as fire detection, security, lifts etc.

Sections 10, 11 and 12 provide guidance on project procurement, such as:

- initial feasibility studies;
- the briefing process;
- planning;
- assembling the specifications;
- the tendering procedure;
- presentation of information.

Definitions of selected staff functions and a glossary of terms are provided in Sections 13 and 14 respectively.

1. Scope

1.1 A building management system (BMS) is a management tool for the effective control of building engineering services, and can be applied equally to new and existing buildings.

1.2 A BMS can be used to manage the environmental conditions of all types of building. In healthcare premises, increasing energy efficiency, reducing CO_2 emissions and saving costs are a mandatory daily task. A BMS is particularly valuable in maintaining climate control and suitable conditions in critical areas, for example operating departments, intensive care units, isolation suites, pharmacies and sterile supply departments. BMS provide alarm communication networks for the building services plant and equipment.

1.3 A properly installed and maintained BMS operated by fully trained staff offers considerable opportunities for 'energy and carbon management'. A BMS can support separate software packages for energy monitoring and targeting and also data evaluation and reporting. Consideration should also be given to web-based energy performance monitoring, reporting and analysis tools.

> **Note:** Other areas that can be monitored and targeted include water consumption, sewage and waste disposal. As energy management is an important tool, installations are often described as 'Building and energy management systems' (BEMS). However, the abbreviation 'BMS' is used throughout this document. Section 14:'Definitions' also refers.

1.4 A further use of the BMS is to help to establish the basis of the site's planned preventive maintenance operations.

1.5 A BMS should be specified with care and detail, focusing on the functionality and required performance of the systems under control, optimising the workflows and service processes to be more efficient. The specification should detail the commissioning and handover requirements. When a BMS is specified, especially if it is replacing existing controls, consideration should be given to the appropriate level of user control.

> **Note:** When a BMS is specified, the NHS Model Engineering Specifications with appropriate supplements for Scotland should be considered.

1.6 The commissioning of a BMS should be fully documented to ensure that all aspects of the system meet the specification. Adequate resources should be allocated to ensure satisfactory commissioning procedures are met.

1.7 To continue to meet specified environmental conditions and increase energy efficiency, a BMS should be regularly maintained and its performance tested.

1.8 It is important that BMS operators and maintenance staff receive adequate training as technical malfunctions have to be detected on time and reported so that appropriate measures can be immediately carried out.

1.9 The sophistication of building services in healthcare premises is increasing, with the task of combining energy efficiency and carbon usage reduction with comfort and secure energy supply. The BMS controls should be designed, installed, operated and maintained to standards that will enable the controls to fulfil the desired functions reliably, safely, economically and efficiently.

1.10 BMS controls should be designed to standards for the full spectrum of today's building services applications in keeping up with new energy-efficient technologies, with system functions such as alarm management, time scheduling, and trend logging, combined with sophisticated control functions, Intelligent networking of information and communication technology as well as web technology and open communications making a financially wise investment for the future.

1.11 The design of the BMS controls should be consistent in its support of open communications, making it easy to connect a wide variety of building services equipment on the basis of standard open data interfaces;

- BACnet;
- LONWORKS®;
- Konnex (KNX);
- M-bus;
- Modbus;
- OPC;
- TCP/IP network protocol.

Note: 1. BMS controls should allow access to systems from any (remote) site.

2. The use of 'virtual servers' offers a greater degree of protections from systems crashing, impact of IT updates etc., relating to system security

2. Management responsibilities

2.1 It is incumbent on management to ensure that their BMS installations comply with all the statutory regulations applicable to a BMS on their premises. Other functional guidance in terms of standards and codes of practice should also be noted.

Statutory requirements

2.2 Safety regulations are as laid down in the:

- Health and Safety at Work etc (HSW) Act 1974;
- Electricity at Work Regulations 1989;
- The Building (Scotland) Regulations 2004;
- Management of Health and Safety at Work Regulations 1999;
- Provision and Use of Work Equipment Regulations 1998;
- Manual Handling Operations Regulations 1992;
- Workplace (Health, Safety and Welfare) Regulations 1992;
- Personal Protective Equipment at Work (PPE) Regulations 1992;
- Health and Safety (Display Screen Equipment) Regulations 1992;
- Construction (Design and Management) Regulations 2007;
- Electromagnetic Compatibility Regulations 2005.

Functional guidance

2.3 Guidance is as laid down in:

- British Standards and Codes of Practice;
- Health and Safety Executive Guidance;
- Model Engineering Specifications;
- Scottish Health Technical Memoranda (SHTM);
- Scottish Hospital Planning Notes (SHPN);
- Scottish Hospital Technical Notes (SHTN);
- NHS in Scotland – Firecode;
- Health Building Notes still applicable in Scotland;

For further details please refer to the 'References' section at the end of this document.

3. Functional overview

Introduction

3.1 A BMS controls the plant and equipment creating the internal environment in healthcare premises. It typically consists of a central station connected via a communications network to a number of outstations (see Figure 1). Control actions can be determined by either the central station or outstations. The latter can operate independently of the network if necessary; hence the term "distributed intelligence". Provision should be made for system expansion capacity to be provided as a base requirement, or the ability to allow additions at a later date without incurring radical system upgrades of changes.

Note: The extent and geography of the site will determine the choice of the equipment and communications network to be used. Links from the central station to remote outstations can be achieved by, for example, hard wire, modem or radio communication. However, it is critical to ensure that sensitive medical electrical equipment is not affected by radio communication interference (refer to MHRA Report ref: DB9702: Electromagnetic Compatibility of Medical Devices with Mobile Communications, 1997).

3.2 It is recommended that uninterruptable power supplies (UPS) are included for the central station, outstations and any communications network.

BMS technology

Central station

3.3 The central station of a BMS is usually a personal computer-based system to provide a graphical, real-time, user interface for the building control system. It enables the user to monitor plant or building services, and make changes to the way the building is controlled from a graphical display. All pages and actions are accessible using a mouse. The security system ensures that the user is only presented with information and functions that are relevant to their authority or task.

3.4 The central station of a BMS provides:

- the ability to establish trend logs of various monitored parameters such as sensor values or control outputs. This feature can be invaluable when investigating the performance of plant;
- the ability to receive plant alarms and abnormal conditions warnings which can be graded by degree of severity and required response;
- the ability to alter control parameters such as programmed occupancy times or control set-points;

- the ability to configure the system, including the outstations;
- the use of management software for energy monitoring and targeting and for maintenance planning;
- the ability to monitor all connected plant. Hard copy reports can be generated and printed.

Note: The technical specification of the central station is of vital importance to enable it to operate additional management software for monitoring and targeting purposes.

Outstation

3.5 An outstation is a microprocessor device which uses programmable software to perform control functions. The outstation software provides control 'blocks' which can be arranged (configured) to provide a control strategy. Once configured, the outstation is able to hold the control logic.

3.6 A number of inputs and outputs are connected to each outstation. Inputs include on/off status of plant, and data from sensors measuring temperature, humidity, pressure, velocity etc. Outputs include on/off signals to plant, along with control signals to actuators for valves and dampers etc.

Note: One or more outstations may be used to control the engineering services plant in a particular building.

3.7 Outstations are connected to a communications network. This enables data to be shared between outstations and provides a means of accessing and monitoring the system from a single point.

Unitary controllers

3.8 Unitary controllers are small outstations generally dedicated to one item of plant (i.e. fan coil units, VAV units, etc) and are connected to the communications network. Unitary controllers should be 'freely programmable' and totally flexible allowing reconfiguration of software loops/applications to be completely reprogrammed by the operators from the central (BMS).

Control functions

3.9 Control functions available for configuration depend on the make of outstation and typically include:

- time/event schedules;
- optimisers;
- compensators;
- proportional, integral and derivative control;
- logic functions.

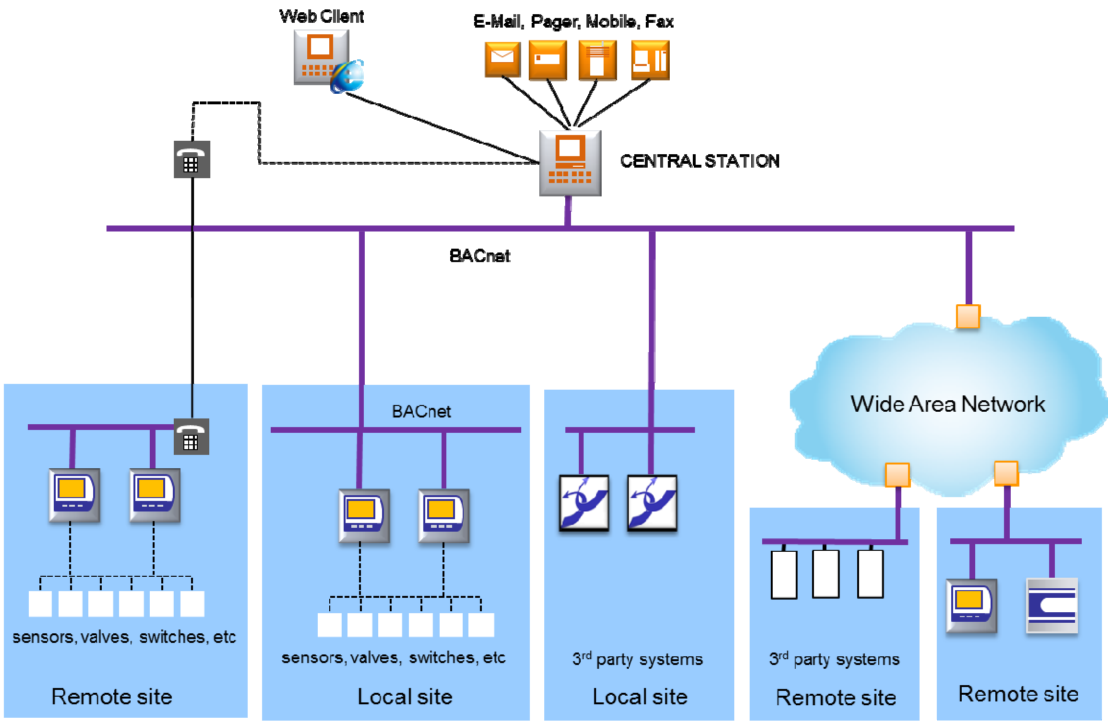


Figure 1: Building management system with remote access schematic

3.10 These various functions can be configured together to provide a tailored control strategy to suit the plant in question. Typical control applications include:

- heating;
- ventilation;
- mechanical cooling /air-conditioning;
- lighting;
- duty cycling;
- load shedding.

Potential benefits of a BMS

3.11 To reduce the carbon usage and maximise the energy-saving potential of a BMS, its ability to control plant and associated systems should be fully exploited.

Note: Improved monitoring alone may not necessarily save energy.

3.12 A BMS can provide enhanced control of environmental conditions. This is achieved by the flexibility in configuration of programmes which can be tailored to provide optimum control solutions. The ability to record or log measured or calculated parameters over time provides a powerful auditing tool which can be used to check and refine the control settings.

3.13 The logging facility is invaluable for energy auditing and checking the control of an item of plant or space condition. A permanent record can be made of environmental conditions through the use of logs.

3.14 A BMS can be configured such that any monitored parameter can signal an alarm once a predetermined value has been exceeded. The type of abnormal condition can be specified, as can the nature of the associated alarm and required response. This facility gives the BMS a fault detection capability, which can be extended to other hospital systems and equipment, for example incoming and distributed domestic hot and cold water temperatures, fume cupboards, freezers and lifts.

Note: It is essential to ensure that the BMS interface with 'lifts' processors is restricted to monitoring only. Any possibility of the BMS influencing the lift controls must be eliminated.

3.15 A BMS can be configured to log the hours run of a particular item of plant and the number of starts. This data and other information collected by a maintenance management software package can be used to schedule plant maintenance. Messages from the BMS can also be used to initiate repair and maintenance instructions.

3.16 Improved monitoring and control of plant with a BMS improves the life of the plant, reduces maintenance costs and enables better use of existing engineering labour resources.

3.17 Proprietary software for monitoring and targeting can be installed at the central station. This software can be a powerful tool in an energy-saving campaign, as it not only provides an analysis of energy use, but also highlights energy wastage and deviations from set targets.

3.18 A BMS can provide a central monitoring facility for a range of related systems such as:

- fire detection;
- security detection systems, including burglar alarms, closed circuit television (CCTV) and access control systems;
- telephone systems;
- vertical transport systems (lifts).

3.19 At present a BMS performs no control role when integrated with any of the above; it merely acts as a single user interface, monitoring autonomous systems. There needs to be a clear technical break (isolation) between fire alarm/protection systems and the BMS to ensure the absolute integrity of the fire alarm systems. This level of integration is restricted at present due to the current standards and the advice of fire prevention and building control officers. It is also essential that the BMS interface with 'lifts' processors is restricted to monitoring only. Any possibility of the BMS influencing the lift controls must be eliminated.

3.20 In healthcare premises procured by means of Public Private Partnership or Private Finance Initiative (PPP/PFI) the responsibility for the BMS and maintenance of plant being controlled or monitored will rest with the Facilities

Management Provider. In these situations the NHS Board's own estates management should still have access to all BMS information albeit on a 'read-only' basis.

4. BMS architecture

Introduction

4.1 The architecture of a distributed intelligence BMS is illustrated in Figure 1. Outstations, the central station and other operator interfaces are linked together via a communications network.

4.2 The advantages of this type of architecture over a centralised system are:

- improved reliability: outstation failure will affect only a small part of the technical installation;
- a reduction in cable costs, as the field devices are wired only to the local outstations;
- information processing functions are distributed, hence a PC or laptop can be used as a central station, which lowers initial costs. The system response time is reduced;
- the system can be expanded easily by the addition of extra outstations, I/O modules or central stations.

Central station

4.3 The requirements placed on building service plant are becoming more complex and there is an increased demand for standardised communication. As a result most BMS now communicate from their central station to a network of outstations using international standards and state of the art technologies such as BACnet and KNX.

For practical or financial reasons other methods can be used, for example:

- telephone modem;
- mains-borne signalling;
- radio or microwave.

Note: It is critical to ensure that sensitive medical electrical equipment is not affected by radio communication interference.

4.4 Each of the various BMS manufacturers implements different communications protocols at the various levels (field devices, outstation and central station), therefore special gateways are required to enable systems from different manufacturers to communicate with each other. This is described in more detail in Section 9.

Network Communications Protocols

4.5 The BMS network shall operate through standard open architecture communication protocols for transferring the information. Proprietary 'Locked-in' BMS Networks should not be accepted. The Network should use industry-recognised communication methods and standard IT network protocols. Direct interoperability between control products from different manufacturers shall be provided with the same objects and attributes specifically intended for building services defining the data throughout.

The following communication protocols are acceptable;

- TCP/IP – Internet Protocol;
- BACnet – American (ASHRAE) Building Automation and Control Network;
- EIBus - European Installation Bus Standard administered by EIBA;
- LonWorks® - Communication protocol developed by Echelon®;
- Ethernet 10Base-T – ISO 8802-3 Data transmission of 10 Mbit/s;
- Ethernet 100Base-T – ISO 8802-3 Data transmission of 100 Mbit/s;
- Konnex (KNX).

Outstations

4.6 The development of technology has enabled BMS manufacturers to design systems that integrate using Internet protocols and open standards such as BACnet, LonWorks, Modbus and KNX, etc. Outstations have been manufactured to incorporate web servers which can deliver user-specific web pages to a PC or mobile device running internet browser software. BMS field devices (analogue/digital inputs and outputs) are normally wired directly to outstations, but other forms of communication can be used as mentioned above.

4.7 Analogue input and output devices would include resistance thermometers, potentiometers and voltage- or current-operated devices, normally functioning in the range of 0-10V or 4-20mA.

Stand-alone controllers

4.8 These controllers are not linked to a communications network. They are normally provided with strategies appropriate to their applications. An outstation can be used to switch a stand-alone controller (for example compensator or PID control, as described in paragraph 5.8) on and off according to a time schedule and input set-points. The outstation’s digital outputs can enable the operation of the stand-alone units.

System expansion

4.9 BMS should be modular in construction and designed to be flexible. Outstation configuration software should enable control strategies to be modified as required. To enable outstations to expand provision should be made to incorporate additional input/output points in each outstation and to enable additional modules to be installed.

4.10 Expansion of an existing system may be inhibited by the existing capacity of outstations and some outstations may require to be replaced. In replacing these, the possible need for further expansion in the future should be considered.

5. BMS functions - typical system description

Monitoring routines

5.1 BMS outstations can be configured for several different types of monitoring routine, for example:

- digital inputs;
- analogue inputs;
- pulsed inputs;
- positive feedback;
- run time totalisation;
- trend data logging.

Digital inputs

5.2 BMS outstation software recognises the status of digital inputs and also enables associated events as defined by any logical relationships. The BMS also recognises the status of soft or internal points.

Analogue inputs

5.3 The outstation software processes analogue inputs (voltage or current signals). The software assigns scaling factors and upper and lower limits to each analogue input.

Pulsed inputs

5.4 Inputs from meters (for example gas, electricity or water) are pulsed. The outstation stores the pulsed input signals as cumulative totals, and the operator has the facility to reset the counter. The software scales the pulse rate to display totals in the required units.

Positive feedback

5.5 The outstation software provides positive feedback of plant operation by monitoring physically separate but functionally related sensors, transducers or internal ‘soft’ points. The feedback strategy raises an alarm and operates standby plant if the expected response has not been established within a pre-set time.

Run-time totalisation

5.6 Run-time totalisation routines in the outstation software record the cumulative run-time for each item of plant. The outstation software signals an alarm when pre-set maximum levels are attained.

Trend data logging

5.7 Logging routines in the software record any real or 'soft' point in the system at regular specified time intervals. These can be set up to operate continuously or for predetermined periods.

> **Note:** Management systems should be in place to analyse the recorded data and initiate any follow-up action.

Available control functions

Control modes

5.8 The outstations provide proportional control (P) or proportional and integral control (P+I) or proportional and integral and derivative control (P+I+D) modes individually for each controlled device. The proportional band, integral action time and derivative action time are adjustable for each control algorithm. Closed loop PID control, often called feedback control, is the control mode most often associated with temperature control.

Time control

5.9 The BMS controls plant by switching it on or off according to multiple pre-set times or time intervals. The programmes usually allow for several operating periods per 24 hours.

5.10 The time programmes can accommodate variations such as:

- day/night;
- weekends;
- holidays;
- seasonal;
- clock changes, for example British Summer Time;
- manual override, for example extended occupancy periods.

5.11 The time programmes can also be subject to pre-defined conditional parameters, for example minimum/maximum ambient conditions.

Event control

5.12 Control software can start and stop plant according to sequences or events detailed in the specification, including any conditional requirements for status of plant items, valves or dampers. For example, standby plant is required to operate automatically on the failure of duty plant. Starting routines can be delayed to provide sequential plant operations.

Note: Minimum on/off cycle times and/or the maximum number of starts per hour can be programmed to prolong plant life.

Plant protection during shut-down

5.13 During plant shut-down a plant protection routine can be used to run items of plant automatically for short periods. The normal seasonal sequence of plant operation overrides this routine.

Sequence control

5.14 Plant operations can be sequenced by monitoring load parameters and efficiently matching the plant to the load. Control options include:

- choice of different control strategies;
- operator facility to override programmed sequence;
- operator facility to vary and adjust the set-point values for each control action;
- operator adjustment for switching control differentials to prevent short cycling;
- automatic modification of schedule when maximum number of start/stop cycles is reached for a particular plant.

In the case of high cost plant such as large boilers, chillers, and CHP units it is especially important to maintain optimum performance in order to release maximum energy savings. This requires a very detailed assessment of plant efficiency and places heavy demands on the BMS. In this instance consideration should be given to using an open, serial RS-232 or RS-485 protocol (i.e. Modbus) as it allows a higher volume of data to be transferred and continuously logged allowing efficiency to be calculated over a shorter time period.

Keyboard control

5.15 This facility allows the BMS operator to control the plant directly. This operation usually overrides the programmes.

Boiler management

5.16 Separate boiler controls supplied by the boiler manufacturer normally supervise the safety and firing of boilers. However, the BMS provides the following boiler management routines:

- on/off command signal to the boiler controller;
- selection of fuel in multi-fuel installations;
- signalling of faults and alarms;
- monitoring of the following parameters:
  - burner status;
  - fuel consumption;
  - heating flow/return temperatures and the ability for remote adjustment;
  - hours run.

Note: Reference should be made to INDG436 HSE Guidance Note, Safe management of industrial steam and hot water boilers and BG01HSE Guidance Note, Guidance on safe operation of boilers.

Chiller management

5.17 Separate controls supplied by a chiller manufacturer normally supervise the operation of packaged chiller plant. However, the BMS provides the following chiller management routines:

- on/off command to the chiller controller;
- signalling of faults and alarms;
- monitoring of the following parameters:
  - electrical load;
  - chilled water flow/return temperatures and the ability for remote adjustment;
  - hours run.

Combined Heat and Power management (CHP)

5.18 Separate controls supplied by a CHP manufacturer normally supervise and control the operation of packaged CHP plant. However, the BMS provides the following interface:

- 0-10V input to vary engine load (typically 30-100 % of full engine duty);
- 0-10V output to provide engine load / performance feedback;
- Interface for start/stop function;
- Volt-Free Contact (VFC) to monitor engine faults;
- signalling of faults and alarms.

Machinery management

5.19 Machinery installations, such as air compressors, lifts or pumping sets, can be supervised or monitored by the BMS providing the following routines:

- recording start/stop times;
- counting number of starts in a predetermined period;
- issuing test commands to demonstrate the operation;
- fault and alarm monitoring
- hours run.

Optimum start/stop

5.20 Optimum start routines for heating and cooling systems compute the optimum daily minimum 'on' period necessary to achieve target comfort conditions at occupation start time.

5.21 Optimum stop routines compute the earliest 'off' time in order to retain minimum target comfort conditions in the space at the end of occupation. The control routines have a self-learning process which will seek to reduce any error in achieving the target conditions at the required time. The optimum start/stop routines include the following facilities:

- independent adjustment of the start and stop times;
- overriding compensation controls during pre-heat periods;
- application to both individual zone and overall operation.

5.22 The following parameters can be adjusted by the operator:

- target temperature for optimum start to achieve comfort conditions;
- maximum pre-heat/pre-cool period;
- target temperature for optimum stop;
- minimum space temperature for out-of-hours periods;
- separate time/temperature limits for optimum start and optimum stop;
- enable/disable the self-learning function;
- default time limit for handover to the weather compensation routines after the start of occupation.

Weather compensation

5.23 These routines control the heating/cooling systems in relation to the internal and external temperature. There is often the option to adjust the temperature and flow-rate settings for the system to redefine the weather compensation.

5.24 The weather compensation automatically adjusts the temperature when a significant difference occurs between the measured and required space temperatures.

Note: Care should be exercised in the location of the sensors recording internal and external temperatures to ensure that external influences (for example air extract discharges) do not cause any misrepresentation of the environment.

Frost protection

5.24 Frost protection software routines operate plant and pumps to protect building services systems and their components from frost damage. The protection must be provided in two stages:

- when the outside air temperature falls to the operator-set minimum frost protection temperature, the outstation software starts selected pumps;
- when the system temperature falls below the operator-preset minimum, the control routine initiates the full frost protection facility. For heating systems the control routine activates the heat source and maintains a minimum return temperature. For other liquid systems the BMS activates specified protective devices.

Building/plant protection

5.25 Building/plant protection routines operate the plant to protect the building fabric and its contents against the effects of low internal temperatures and condensation. If the room temperature falls below the pre-set protection temperature, the control routine activates the heating system and related plant.

5.26 The building/plant protection routine overrides other operating programmes unless otherwise specified. The routine operates whenever the normal heating is switched off.

Load cycling

5.27 A load cycling routine intermittently disconnects selected plant to make electrical energy savings. The periods of disconnection and the control limits are adjustable.

Electrical load and gas management

5.28 The BMS can manage electrical and gas demands using load-shedding or diversification routines which include the following features:

- monitoring of demand during a set interval which coincides with the supply authority's metering tariffs;
- predicting whether cumulative demand by the end of the metering interval is likely to exceed a definable limit;

- shedding of loads and/or transfer to alternative energy sources to reduce cumulative demand during the metering interval to avoid exceeding the demand limit;
- restoring loads which have previously been shed/transferred when the predicted cumulative demand falls sufficiently below the demand limit;
- a two-stage alarm to indicate whether the demand limit is likely to be exceeded and whether it is exceeded.

Note: Adaptation of main and sub-metering would contribute to effective control of energy consumption. This in turn would greatly enhance savings.

5.29 The maximum demand limit and load shedding routines can be adjusted according to the supply authority's tariffs.

5.30 The BMS operator can allocate the loads to be shed into a number of priority groups, and can assign to each load or group a maximum off-time and/or a minimum on-time.

Free heating and cooling

5.31 A control routine should maximise the potential for free cooling from the fresh air stream and free heating from the return air stream, taking into account the very limited applications in healthcare facilities for recirculation.

Air quality

5.32 The operation of the ventilating plant and the intake of fresh air are controlled in response to measured air quality, for example CO_2. If the air quality control is used in conjunction with the fresh air control, the demand for fresh air should have priority.

Lighting

5.33 Control routines for lighting can include the following:

- on/off switching of external and internal lights according to a time schedule;
- dimming and switching of internal lights based on signals from external and internal photo-sensors, incorporating a user-adjustable delay;
- switching off internal lights according to occupancy detectors;
- on/off switching of external lighting based on the signals from an external photo-sensor.

5.34 Local switches and the central station operator can override the BMS lighting control. In the event of BMS failure the lighting system can be controlled manually. The BMS monitors the emergency lighting but performs no control function.

Occupancy

5.35 These routines enable the ventilation, temperature, lighting etc. to be controlled in response to the level of occupancy. The level of occupancy is determined by the level of carbon dioxide (CO_2) or access control data.

Note: Typically, signals from infra-red detectors indicate whether the space is occupied, but not the level of occupancy.

Other site alarms

5.36 The BMS can be used to monitor the status of other system alarms.

6. BMS inputs and outputs

General

6.1 The effectiveness of a BMS relies on the performance of the inputs and outputs. Sensors, detectors and associated meters should comply with relevant British Standards, and should also have a proven record of long-term precision and reliability.

Digital inputs

6.2 Digital inputs include plant status switches and inputs from other control, monitoring and alarm systems. The inputs should be compatible with the BMS outstation input interface.

Digital outputs

6.3 Digital outputs in BMS outstations are used to switch equipment on or off, usually via relays or contactors.

Actuators

6.4 The analogue outputs of a BMS are often connected to actuators to convert the electrical signal to a physical movement. To achieve good control, the control device (for example valve or damper) must be correctly sized for its application. The actuator must be matched to the control device.

Valve actuators

6.5 Control valves should have authorities relevant to the required application: diverting and throttling, mixing or on/off, and they should be sized accordingly.

Damper actuators

6.6 Control dampers should be sized to give the required control authority; failure to do so may lead to a system being uncontrollable.

6.7 Actuators can incorporate position feedback devices. BMS use this feedback either to provide closed loop control of position or to give independent information on achieved positioning.

Sensors

6.8 Many different sensors can be connected to a BMS. Suitable values of range and accuracy are shown in Table 1.

Sensor	Range	Accuracy
Temperature Air Flue gas Chilled water Water	 -10 to +40°C +30 to +850°C -10 to +30°C -10 to +150°C	 ±0.5°C ±3.0°C (0.75% of FSD > 450°C) ±0.5°C ±2.0°C
Humidity	10 to 90% RH	±5% RH
Pressure	-	±5%
Air flow	-	±5%
Fuel flow	0 to 10Hz	±3%
Water flow	> 5:1	±2%
Electricity	-	±1.5%
Light Internal External daylight External security	 0 to 1,000 lux 1,000 to 30,000 lux 0 to 100 lux	 - - -

Table 1: Range and accuracy of sensors

6.9 Sensor location is critical to the operation of the BMS. A BMS is only as good as the sensor used to measure the controlled variable (temperature, humidity, pressure etc.) and transmit it as a measured value to the outstation. It is crucial that the sensor should provide an accurate measurement of the controlled variable at the reference point in the control loop. The following should be used as a guide for the benefit of engineers and installers on site.

Immersion sensors for water:

- ensure that the full active length of the sensor is immersed in the medium;
- install sensors against the direction of flow.

Duct mounted sensors:

- ensure that the full length of the sensor probes is exposed to the airflow;
- probe-type sensors should not be used in areas where stratification can occur, such as downstream of mixing dampers, heating coils, cooling coils or heat recovery equipment.

Room sensors: Room sensors should be installed at a height of 1.5m in occupied spaces, and at least 500mm from the adjacent wall. The sensor must not be exposed to direct solar radiation.

External sensors: The façade on which the sensor should be located is determined by the system design. They should not be:

- exposed to direct solar radiation;
- installed on facades affected by significant rising heat (e.g. metal);
- installed on facades which will be heated by solar radiation.

Surfaces mounted/Strap-on sensors: The surface must be clean and smooth removing any paint. The sensor must be fixed firmly to the surface using a heat compound.

Note: The application of these sensors should be one of last resort although they be suitable as part of trouble-shooting or investigation procedures.

7. Software

Application software (outstation)

7.1 The control, monitoring and alarm functions of a BMS are undertaken via the application software within a BMS outstation. The application software is configured to provide the required control routines or algorithms.

7.2 The control routines are created by linking together separate control function 'building blocks'. Larger outstations have more inputs and outputs and hence a greater number of each of the different 'building blocks' used to write the control routines.

7.3 Outstations have the ability to store logged data for subsequent analysis. Outstations can be connected together to expand the number of control functions available for a particular application.

Management software (central station)

7.4 Operator access to a BMS is normally via the central station running management software. The software is normally a Windows® based software package designed to provide a complete management interface for the supervision of buildings.

7.5 The primary functions of the central station software are to allow the operator to view the operation of the plant and building under control, to alter the control settings and algorithms, and to provide manual override.

7.6 Software can include a package for handling mathematical formulae. These will include the full range of algebraic functions such as:

- addition;
- subtraction;
- multiplication;
- division;
- powers and root extraction;
- maximums, minimums and means;
- calculation of enthalpy;
- trigonometrical functions;
- functions of Boolean algebra, that is, NOT, AND, NAND, NOR, XNOR, as well as relational operators.

Automatic operation

7.7 The central operator facility should automatically:

- monitor system status and report faults;
- allow the execution of commands issued by an operator whose authority has been confirmed in accordance with security codes;
- process and store data received;
- annunciate alarms;
- maintain a real-time clock and calendar;
- operate an adjustable 'time out' facility to log off the operator between 1 and 10 minutes after use of the facility ceases.

Operator actions

7.8 Suitably authorised operators should be able to undertake the following from the central station:

- acknowledge alarms;
- add or delete points from the system;
- inhibit alarms;
- alter alarm level limits;
- re-schedule plant operation times;
- adjust and synchronise all real-time clocks on the BMS;
- prepare a calendar for plant operation;
- alter plant control parameters;
- obtain and display data from the BMS on command or at selected time intervals;
- set up trend logging facilities;
- archive, condense and/or delete logged data;
- interrogate system protocols.

7.9 The management software should have a clearly accessible help facility which is comprehensive for all routine operations.

Data handling

7.10 The central station software should be equipped for the on-line storage, retrieval, processing and display of logged data. The format of the data should be such that it can be exported into other software packages.

Alarm handling

7.11 The alarm handling facilities shall be able to process incoming alarms and decides what action needs to be taken, ensuring immediate notification of alarm conditions. Alarms shall be able to be displayed in an alarm viewer, filtered, categorised, logged, and retransmitted e.g. using email, pager, or SMS.

Operator alarm handling facilities should include the following:

- alarm status should include a high priority level that is annunciated regardless of any other activity, and a low priority or information status that is only annunciated on demand;
- a visual, audible and printed annunciation of the alarm or any combination of these as selected by the operator;
- a requirement for all alarms to be acknowledged;
- a time programme for annunciation of alarms to different destinations;
- operator-supplied text message associated with alarm condition.

Note: The extent and provision of alarms will be project-specific.

7.12 The alarm handling system should provide for:

- alarm processing and annunciation of priority alarms to take precedence over other activities;
- distinction between active alarms whose condition is not yet cleared and unacknowledged alarms;
- an alarm review facility;
- storage of alarm data in order that alarms can be analysed together with other data either by the BMS software or by other software;
- alarm data which should include:
  - condition identity;
  - condition value;
  - alarm time and date;
  - acknowledgement status.

Note: Where alarms are sent to a printer, any printer malfunction should not inhibit the operation of the BMS.

Third-party management software

7.13 The computer which hosts the BMS central station management software should have the capacity to run third-party management software. This third-party software uses the data collected by the BMS sensors to provide additional management information.

7.14 Energy monitoring and targeting (M&T) and planned preventive maintenance (PPM) are the two major types of third-party program associated with the BMS central station, others include;

- frequency inverters;
- generators and LV switchgear electric meters;
- fire alarm system;
- stand alone electronic metering systems.

Full liaison and co-operation is essential between trades to obtain all the necessary technical information in developing the software interface. The integration should allow the central workstation to interact directly with third party software operating other packaged plant. Seamless integration of a true bi-directional nature should be achieved with the other building control systems. The communication shall be gathered and transmitted through the local area network (LAN) or direct data ports on the equipment. The (BMS) facility shall share the control data and inter-operate between separate systems.

7.15 Management packages that have the necessary protocols can communicate with the BMS and load data directly from the outstations. For packages lacking the protocols the data has to be transferred within files created by the BMS. The former type of package operates faster and more efficiently because of its direct link with the BMS.

7.16 The compatibility of management packages and BMS should be examined carefully to ensure the optimum solution is provided. It also follows that there may be difficulties in transferring data between different packages. This implies that suitable interfaces may be required for third-party software.

Note: Details of the Works Information Management System (WIMS) interface is given in Model Engineering Specification (MES) C54 (Building management systems).

Energy monitoring and targeting software

7.17 Energy monitoring and targeting systems have been promoted as an effective means of achieving reductions in the annual energy cost. The software is usually spreadsheet-based, and actual energy consumption figures are recorded and compared with pre-defined targets. The system should be fully scalable and be used to gather data and create reports from various utilities. Other information can also be taken into account for analysis purposes. Analysis data may include;

- electricity;
- gas;

- water;
- steam;
- oil;
- temperature;
- compressed air.

7.18 The algorithms within the software can normalise the energy consumption data with respect to degree days, units of production or other figures. Energy consumption data, targets and savings can be displayed graphically using the M&T software.

7.19 Typically, M&T packages read energy meter data on a regular basis (from half-hourly to monthly), and possibly degree-day or temperature data from the BMS outstations.

7.20 BMS operators are a key element of any M&T system. Without actions from the operators, reducing the energy consumption is not a reality.

Planned preventive maintenance software

7.21 It is imperative that the BMS is maintained properly to ensure the on-going efficiency of the system and plant. Instead of scheduling plant maintenance on a fixed time basis, the work can be planned according to the total equipment hours run or number of starts made. Plant data on hours-run and number of starts can be recorded by the BMS and accessed by a planned preventive maintenance package. The software will then issue works maintenance orders as and when required. Plant alarm messages sent to the PPM software can be used to produce breakdown maintenance requests.

Listed below is a list of the PPM checks to be covered; this list is not exhaustive:

Outstation Check; each Input and Output associated with each outstation should be checked and verified that the correct values and statuses are being achieved.

Outstation Logic Backup; A backup of the outstation strategies should be copied for archiving. These will be called upon should the outstation require replacing.

Peripherals and Field Devices; Field-mounted equipment and devices should be inspected for validity and correct operation. Valve actuators will be driven to their limit to prove functionality.

Central Station Backup; A backup of the central stations project files and libraries should be copied for archiving. These will be called upon should the central stations or computer running the software fail or require replacing.

Data Network Communications; The validity and operation of the data network should be checked to ensure that all LAN and WAN communications are functioning correctly.

It is recommended that the BMS operator ensures that any BMS faults which occur in between maintenance visits are logged within a BMS fault log book. The maintenance contractor should ensure the BMS fault log book is checked during routine PPM visits and investigate as necessary.

8. Communications

Protocols

8.1 For a BMS to function effectively, data must be transferred around the system and in many cases, to and from other systems. To provide a means for the transfer of data, communication protocols are implemented. These protocols permit the physical connection, transfer and interpretation of data between various points in the system.

8.2 Major BMS companies implement different communication protocols, resulting in equipment from different companies being unable to communicate directly. This can result in several problems, including:

- a system provided by a single supplier may not include the most suitable features/functionality for specific applications;
- the building owner may not receive best value for money by being tied to a single supplier;
- the building owner is faced with separate user interfaces if autonomous systems are implemented.

8.3 At the sensor and actuator level, a number of control manufacturers have developed bus systems which allow a range of control devices to be connected to the same cabling circuit.

European standards on BMS communications

8.4 European standards to address the issue of communication protocols are initiated by the European Standardization Committee (CEN), technical committee (TC) 247, 'Control for Mechanical Building Services'. A working group was responsible for 'System Neutral Data Transmission for HVAC Applications'.

8.5 Building Automation Control Network (BACnet) has emerged from discussions within this committee and various working groups. It comprises a data communications standard protocol for building automation, controls and building management at each of the following 'levels': Specifications should state that all devices from various manufacturers should be BACnet compliant and able to communicate with each other, including;

- central station to central station;
- outstation to central station (and outstation to outstation);
- sensors/actuators to outstation.

Gateways

8.7 Building Management Systems are handling a growing amount of information through several standard protocols. A centralised solution is limited in term of speed, evolution and performance. A possible solution is to decentralise field data management and serve information to the central station through gateways. Gateways are used to transfer data between different systems. Essentially a gateway can be thought of as a 'black box' which is placed between dissimilar systems to give a degree of interconnection and to enable a certain amount of interaction. Currently gateways present several potential problems, for example:

- high cost of engineering the gateway;
- loss of functionality;
- gateway maintenance;
- accommodation of protocol variations;
- contractual issues, that is, determining who has ultimate responsibility for the communications.

Although in some fields there is still a requirement for the use of gateways, with the development of technology and open protocol a gateway should only be considered when there is no other option.

Modems

8.8 Modems are devices which allow the use of the telephone network for data transmission between remote devices and the BMS central station. These are particularly appropriate to remote or dispersed sites.

8.9 Modems should have auto-dialling facilities with safety features to prevent unnecessary use of the telephone network. Judicious choice of the telephone tariff structure/network circuit used for modem links can result in considerable reductions in operating costs.

Note: Modems can avoid the higher costs of using dedicated telephone lines.

9. Integration of BMS with other systems

Integrated systems

9.1 An integrated BMS can address and serve the complexity, scalability and flexibility required for healthcare buildings. The control room or facility management suite of a modern building will often house the central processors and display units for a range of non-energy related systems as well as a BMS. To reduce the number of displays monitored by the operator, separate systems can be integrated with the BMS, providing a central monitoring facility for a range of non-energy related systems, for example (this list is not exhaustive):

- fire detection systems;
- security detection systems:
- intruder alarms;
- access control systems;
- closed-circuit television (CCTV);
- watchman's rounds;
- vertical transportation systems;
- medical gas alarms;
- blood banks;
- fixed temperature storage;
- telephone systems.

9.2 At present, BMS perform no control role when integrated with any of the above; the BMS merely acts as a single user interface, linking autonomous systems. There needs to be a clear technical break (isolation) between fire alarm/protection systems and the BMS to ensure the absolute integrity of the fire alarm systems. This level of integration is usually restricted due to current standards and the advice of fire prevention and building control officers. It is also essential that the BMS interface with 'lifts' processors is restricted to monitoring only. Any possibility of the BMS influencing the lifts controls must be eliminated.

9.3 In principle, fire alarm systems can be integrated into the BMS. However, current regulations and codes of practice restrict this level of integration.

9.4 Integrated systems should comply with the relevant standards, codes of practice and guidance documents shown in the 'References' section.

Advantages of integration

9.5 Enabling interoperability between building service systems (such as HVAC, lighting, security and energy management) with industry standard open protocols, can deliver substantial savings in operational and energy costs. Integrated systems have the following potential advantages:

- single point navigation from a central BMS enables the facility management to view all systems and facilities from one workstation. Information on any system's performance and operating conditions can be viewed, analysed and processed from one common graphical interface;
- system integration is easier to standardise and co-ordinate. For each installation, alarms and controls can be effectively prioritised;
- single point central annunciator or group of annunciators allows the adoption of a rational and coherent format for the presentation of information. The operation of the entire system can be monitored by one operator, and one recording medium used to log all the system events;
- single point system for several functions is easier to administrate by the user.
- system integration allows building service systems to target occupant comfort efficiently and promptly.
- system integration extends the BMS capabilities for data collection, archiving, networking and decision making to other building service systems;
- modern BMS designs are based predominantly on open system technology, which means that the BMS can communicate as needed with a variety of other systems in a facility that communicate using different protocols. This offers the client the option to choose components and system retrofits in a price-competitive environment;
- a trained integrator can link it together and set it to work, from design and installation through commissioning and handover;
- a single point of contact when a problem arises.

Limitations of integration

9.6 Integrated systems can have a number of limitations compared with separate systems, for example:

- each installation may have different requirements despite the priorities for the various alarms and other annunciators being readily coordinated and allocated. The site specific operation configuration should be carefully prepared;
- the alarm annunciations should be effectively prioritised to avoid an operator missing critical alarms while attending to other alarm signals;

- integrated systems are dependent on their software, which tends to be more complex. During the design phase, much more skill and care is therefore needed;
- there is the possibility of potentially adverse interactions between the different functions, which will require resolution during the design of the system;
- the dependence of an integrated system on a single piece of equipment or wiring common to several functions could make it vulnerable to faults;
- engineers involved in the installation, operation and maintenance of the system may require a higher level of training and skill, and an appreciation of the interactions between the system functions;
- the user of a multi-function integrated system will require a higher level of training.

Detailed design

9.7 The detailed design of an integrated system should give careful consideration to the following:

- definition of the specific objectives of the BMS;
- how these objectives are to be achieved;
- what information is required to support the above issues;
- how this information is to be accessed, including:
  - the display/output of information at all times and for all scenarios;
  - the required priority of alarms and information;
  - the delay, storage, annunciation and subsequent display of lower-priority alarms initially masked by high-priority alarms;
  - the likely consequences of all alarm and information scenarios.

9.8 Designers with expertise in each integrated system should be employed, and one organisation should be appointed with overall responsibility to coordinate the design.

9.9 Each integrated system should meet the relevant standards with respect to design, installation, commissioning and maintenance.

9.10 The power supply requirements of each integrated system should be considered separately, and stand-by power supplies specified when necessary.

9.11 The integrated system should be designed so that a fault in one system will not affect the other systems unless it affects common equipment.

Operations

9.12 Particular attention should be given to the maintenance of integrated systems. Specialists should only work on systems for which they have been trained. If maintenance of one system affects another, maintenance specialists for both systems should attend site together.

9.13 Special care should be taken when making modifications to any part of an integrated system to ensure that the changes do not affect other systems. When changes affect more than one system, engineers responsible for the other systems should be present for testing.

10. Projects

Feasibility studies

Purpose

10.1 BMS can be beneficial for large healthcare sites, buildings or complex plant to provide a high level of control and monitoring. It may be advantageous to replace existing control systems with a BMS. This can be demonstrated by feasibility studies.

Note: Stand-alone controls may be more appropriate for smaller buildings or buildings with simple plant. For a widely dispersed estate, the BMS may offer advantages.

Objectives

10.2 A feasibility study should include:

- review of control and monitoring requirements;
- review of any existing BMS on site;
- review of the condition of any existing controls;
- required interface with existing controls;
- review of need for energy monitoring, targeting and planned preventive maintenance third-party software;
- estimate of energy savings;
- estimate of manpower savings;
- estimates of annual maintenance and support costs;
- cost estimate of new BMS;
- cost estimate of traditional control system;
- cost estimate of manpower requirements;
- cost estimates for future expansion;
- estimates of payback periods.

Potential users of BMS

10.3 Potential applications of BMS (subject to the result of a feasibility study) include:

- large hospitals or healthcare premises;
- highly serviced buildings, for example:

- laboratories;
- operating theatre suites;
- intensive care units;

- widely dispersed estate.

10.4 On sites where there is an existing BMS, the system can be extended to cover major energy users to maximise the savings potential. These include:

- boilerhouse;
- refrigeration;
- combined heat and power;
- sterile services departments;
- incinerators;
- laboratories;
- wards and clinical areas;
- offices;
- staff accommodation;
- catering departments;
- laundries.

Client's brief

Pre-tender brief

10.5 The purpose of a pre-tender brief is to introduce potential suppliers to the project and to obtain from them an interest in tendering and, via a questionnaire, company information relevant to the undertaking of the work. This information should enable a shortlist of suitable tenderers to be produced, thereby avoiding abortive tendering.

> **Note:** Where an extension to an existing BMS is being considered, a full pre-tender brief may not be appropriate.

10.6 The pre-tender exercise will produce qualitative judgements, whereas the tender reveals a quantitative result.

10.7 The pre-tender brief should contain the following:

- objective;
- project description;
- project management and form of contract;
- building and plant schedules;

- questionnaire.

Objective

10.8 The purpose of the pre-tender brief should be stated to allow the tenderer to both register an interest in the work and quickly decide whether they wish to be considered.

Project description

10.9 The project description should contain the following four main elements:

- a general description of the building(s) to be controlled and monitored by the BMS, for example location, building types, use, floor areas and also layout plans of the sites;
- a general description of the building services systems and plant to be controlled and monitored, and any special requirements;
- an outline of the general BMS requirements, for example the location of the control facility, control facilities required at outstations, the extent of any user programming of control algorithms, likely future extensions of the BMS etc;
- special considerations such as required interfaces to other data networks, computers and software.

Building and plant schedules

10.10 The building and plant schedules should contain the minimum essential information on the building plant which is to be controlled/monitored by the BMS, such that the supplier or installer may appreciate the scale and complexity of the proposed BMS and the suitability of their equipment.

Questionnaire

10.11 A questionnaire should be used to obtain details about the company and approximate costs and timescales for the proposed system. A sample questionnaire is provided in Appendix 1.

Planning the project

Overview

10.12 The design of the BMS should be undertaken from the top down, starting with the corporate policy of the client or end-user as expressed in the design brief, and working towards a functional specification.

10.13 The BMS installation can be a stand-alone project in its own right. For major construction work, the BMS project should be an integral part of the building scheme and not considered in isolation.

10.14 The client should produce a design brief, including any particular requirements and restrictions on the cost or scope of the BMS, which is then developed in conjunction with the design consultant. The design consultant will produce a conceptual design for the project including an economic appraisal which will be agreed by the client and form the basis of the specification process.

10.15 A pre-tendering exercise is recommended to shortlist potential suppliers; this is discussed in Section 11.

Planning considerations

10.16 In new buildings the design of the BMS should be integrated with the design of the building services plant.

10.17 Consideration should be given to the availability of the BMS when commissioning other plant.

10.18 In the retrofit case, incorporation of existing control systems may be required in the design. Plant modifications may be necessary to accommodate this.

10.19 End-users (potential operators and building occupiers) should be involved in the project from the beginning. Potential operators with 'local knowledge' can contribute to resolving problems and avoiding loose ends during commissioning and handover. The experience they gain is invaluable for the long-term maintenance and optimisation of the system.

Assembling the full specification

10.20 The full specification should describe the scope of the contract. It should state unambiguously what is to be done and the standards and performance to be achieved.

10.21 A full specification for contract documentation (as indicated in the Model Engineering Specifications (MES), inclusive of Scottish supplements) will usually contain:

Part A – Standard general conditions of contract with amendments, special conditions and preliminary clauses;

Part B – General clauses common to building services, plant and equipment;

Part C – Standard engineering specifications;

Part D – Detailed description of extent and nature of the works.

10.22 It is the designer's responsibility to provide Part D of the specification. NHS Model Engineering Specification C54: 'Building management systems' is recommended for BMS projects. The specification should be complemented by drawings and schematics.

10.23 The description, extent and nature of works are contained in Part D. This part of the specification will detail any amendments to the Model Engineering Specifications so as to customise the design. Any additional information/ requirements should be provided to enable the full design intent of the project to be realised.

11. Tendering process

Pre-tendering process

11.1 The pre-tender brief can be used in assessing the suitability of potential suppliers or installers for the project.

11.2 The pre-tendering process enables a shortlist of suitable tenderers to be selected.

Note: Reference should be made to PROCODE for additional information.

Tender documentation

11.3 Typically, documents required for the tendering process are:

- invitation to tender;
- instructions to tenderers;
- form of tender;
- full specification;
- drawings and schematics;
- tender details and summary;
- additional information required from tenderers.

Assessment of tenders

11.4 If all the tenderers meet all the requirements in the full specification, the preferred supplier may be decided on cost. Ambiguities in the specification and/or the form of tender can lead to difficulties in directly comparing tenders. Tenderers should be required to price the documentation as issued. If any deviations or optional extras are offered, they should be separately confirmed but not included within the tender price.

11.5 The options are to reject tenders which do not completely conform to or accept the tender as presented. Expert opinion may be required to assess the tenders with their discrepancies, with regard to whether they meet the functional specification for a successful and cost-effective project.

12. Collection and presentation of information

General

12.1 Using the top-down design approach, the conceptual design of the project leads on to functional statements and functional descriptions.

12.2 The clauses in this section describe the format and presentation of project information required to define the project and eventually construct the specification.

Functional statements

12.3 These define how the BMS will operate in strategic terms, for example, ‘Optimum start will be applied to the heating system’.

12.4 The level of detail employed in functional statements will vary according to the conceptual design and requirements of the buildings and plant. In general, functional statements will imply particular capabilities of the BMS and emphasise that all constituents shall be BACnet compliant

12.5 Specific low-level requirements, such as the interaction between particular items of plant, are dealt with in the operational schedules.

Note: A sample functional statement is shown in Appendix 2.

Future expansion

12.6 The need for the system to accommodate future expansion should be fully defined.

Maintenance requirements

12.7 Initial maintenance is particularly important. Responsibility for this can be effectively focused by including the initial 12 months’ maintenance in the supply contract. If maintenance is to be provided by the supplier/installer, it will be advantageous to detail the costs in the initial tenders.

Note: This approach should reduce the potential for disputes during the contract defect liability period.

Maintenance arrangements should commence at handover.

Schematics

12.8 One of the purposes of the specification is to allow the tenderer to understand fully the functional requirements of the project and its implications in terms of BMS equipment. The form of the schematics is usually some physical representation of a building services system or part of it.

12.9 Schematics communicate control and monitoring requirements, particularly the relative locations and correspondence of points, and can also be used as the basis for graphics for the eventual operator interface. A sample schematic is shown in Appendix 3.

The role of the schedules

12.10 The schedules provide the means to incorporate specific detailed requirements within the specification. They include the points schedule, which defines the physical scope of the BMS, and schedules for detailed operational requirements such as plant start-up sequences.

The points schedule

12.11 In the points schedule the requirement for a point is described in terms of its function. The parameters to be monitored or controlled are described, together with the operating range. A sample points schedule is shown in Appendix 4.

Operational schedules

12.12 The operational schedules describe the way in which the buildings and plant are to be controlled. They will determine the required BMS monitoring and control routines, its logical configuration and some of its physical characteristics.

12.13 Specific schedules may include the following areas:

- zoning;
- environmental parameters;
- alarm limits, priority and routing;
- initial time programmes;
- plant operating sequences;
- load shedding sequences;
- actions on start-up;
- actions on daily shut-down;
- actions on seasonal shut-down;
- actions on communications failure;
- actions on BMS failure;

- actions on total power failure.

12.14 These schedules may be subdivided for particular plant areas or zones as required. A sample operational schedule is shown in Appendix 5.

Equipment schedules

12.15 There will be the occasional requirement for a particular piece of equipment or capability (for example the number of operator facilities), and these should be detailed in the equipment schedules.

Report schedules

12.16 There may be a requirement for the BMS to produce reports containing very specific information, in addition to the manufacturer's standard reporting formats. This information should be detailed as a schedule or a prototype report.

Graphics schedules

12.17 The graphics schedules contain details of particular graphics to be provided, with reference to the schematics included in the specification as appropriate.

12.18 General features of the graphics such as the use of animation, real-time display of parameters, images and interactivity should be detailed as functional statements. However, there may be additional detailed operational requirements which should be presented within the graphics schedules. There may be a requirement for a flexible graphics user interface to meet the needs of different levels of staff use.

Drawings and documents

12.19 Particular requirements for drawings and documentation, numbers of copies, form of presentation etc. should be specified.

12.20 The information concerning the BMS installation to be supplied at handover should be identified. Details of this are given in the 'Validation and verification' (Part 'C') of this SHTM.

Training

12.21 The training requirements associated with the project should be identified. Details of this are given in the 'Operational management'(Part 'D') of this SHTM.

Commissioning

12.22 The commissioning requirements associated with the project should be identified. Details of this are given in the 'Validation and verification' (Part 'C') of this SHTM.

13. Designated staff functions

13.1 Only trained and competent persons should be appointed by management to operate and maintain the BMS.

13.2 **Management**: the owner, occupier, employer, general manager, chief executive or other person who is accountable for the premises and who is responsible for issuing or implementing a general policy statement under the HSW Act 1974.

13.3 **Employer**: any person or body who:

- employs one or more individuals under a contract of employment or apprenticeship;
- provides training under the schemes to which the Health and Safety (Training for Employment) Regulations 1990 (SI No 1990/1380) apply.

13.4 **Designated person (electrical)**: an individual who has overall authority and responsibility for the premises containing the electrical supply and distribution system and who has a duty under the HSW Act 1974 to prepare and issue a general policy statement on health and safety at work, including the organisation and arrangements for carrying out that policy. This person should not be the authorising engineer.

13.5 **Duty holder**: a person on whom the Electricity at Work Regulations 1989 impose a duty in connection with safety.

13.6 **Authorising engineer (low voltage)**: a Chartered Engineer or Incorporated Electrical Engineer with appropriate experience and possessing the necessary degree of independence from local management who is appointed in writing by management to advise on and monitor the safety arrangements for the low-voltage electrical supply and distribution systems of that organisation to ensure compliance with the Electricity at Work Regulations 1989, and to assess the suitability and appointment of candidates in writing to be authorised persons (see SHTM 06-02: 'Electrical safety guidance for low voltage systems').

13.7 **Authorised person (LV – electrical)**: an individual possessing adequate technical knowledge and having received appropriate training, appointed in writing by the authorising engineer (LV) to be responsible for the practical implementation and operation of management's safety policy and procedures on defined electrical systems (see SHTM 06-01, -02 and -03).

13.8 **Competent person (LV – electrical)**: an individual who in the opinion of an authorised person has sufficient technical knowledge and experience to prevent danger while carrying out work on defined electrical systems (see SHTM 06-01, -02 and -03).

13.9 **Commissioning specialist (BMS)**: an individual or organisation authorised to carry out commissioning, validation and routine testing of BMS.

13.10 **Maintenance person (BMS)**: a member of the maintenance staff, BMS manufacturer or maintenance organisation employed by management to carry out maintenance duties on BMS.

13.11 **BMS operator**: any authorised individual who operates a BMS.

14. Definitions

Actuator: an electromechanical device that positions control devices (such as valves or dampers) in relation to a supplied control signal.

Alarm: the annunciation of an event that the system operator needs to be aware of.

Analogue: pertaining to data that consists of continuously variable quantities.

BACnet: BACnet is a communication protocol for building automation and control networks, suited for the management and automation levels, especially for HVAC, lighting control, life safety, security and fire alarm systems.

BAS – building automation system: synonymous with BMS.

BEMS – building and energy management system: synonymous with BMS.

BMS – building management system: a system comprising electronic equipment and software with the prime function of controlling and monitoring the operation of building services within a building, including heating, air-conditioning, lighting, and other energy-using areas.

BMS contractor: the organisation responsible for the supply and/or installation of the BMS. The contractor may be either the manufacturer or a systems house. It is often the case that the BMS contractor will commission the BMS.

Bus: a means of connecting a number of different devices, sensors, controllers, outstations, etc. to act as a means of data exchange.

Central station: the primary point of access to a BMS; the usual point from which all operations are supervised.

Client: the individual or group of individuals ultimately responsible for paying for and using the BMS.

Commissioning: the advancement of an installed system to working order to specified requirements.

Commissioning specialist: the individual responsible for the commissioning of the BMS. He/she may be employed by the BMS contractor or a specialist commissioning company.

Communications network: a system of linking together outstations and a central station to enable the exchange of data. Usually a dedicated cable system, but radio or mains-borne signalling may be used.

Compensator: a control device whose control function is to either:

- reduce heat supply with decreasing building heat load; or

- reduce cooling energy supply with decreasing building cooling load, in response to outside and (sometimes) inside temperatures.

Completion: the state of being finished in its entirety, according to the specification, ready for use by the owner.

Configuration software: software (in the form of “building blocks”) resident in an outstation which can be configured to create different control strategies.

Control function: a term used to describe a specific, discrete form of control, for example compensation, optimisation etc. These can be linked together in a control strategy.

Control loop: proportional, or proportional + integral, or proportional + integral + derivative control strategy where the output is related to a function of the input signal.

Control strategy: a description of the engineered scheme to control a particular item of plant or perform a series of control functions.

Data: a representation of information or instruction in a formalised manner suitable for communication, interpretation, or processing by humans or computer.

Derivative control: a control algorithm in which the control output signal is proportional to the rate of change of the controlled variable.

Direct digital control (DDC): a term used to define products that are based on microprocessor control.

Distributed intelligence: a description of a system where data processing and control is carried out at outstations, not at a central point.

Duty cycling: a control function that rotates the use of items of plant so that each item undergoes equal usage.

EMS – energy management system: synonymous with BMS.

Field device: the controls that are placed in the field level, that is, switches, sensors, actuators, etc.

Gateway: software written to enable data to be exchanged between two different communications protocols.

Handover: the transfer of ownership of all or part of a building or system, usually to the client.

Integral control: a control algorithm in which the output signal is proportional to the integral of the error.

Load cycling: a control method where management of plant energy demand is achieved by means of fixed on/off periods of operation.

Load shedding: the function of switching off electrical equipment if the load exceeds a limit. This function therefore reduces the risk of maximum demand penalty charges.

LonWorks: Collective term for LON technology as a whole.

M-Bus - (Meter-Bus): Standardised field bus system (conforming to EN 1434) for the transmission of energy consumption data.

Modbus: Open standard protocol for industrial use.

OPC: Software interface defined in process automation.

Optimiser: a control device whose function is to vary the daily on and off times of heating, ventilation and air-conditioning (HVAC) plant in order to produce an acceptable environment with lowest energy usage.

Outstation: a device to which sensors and actuators are connected, capable of controlling and monitoring building services functions. It also has the facility to exchange information throughout the BMS network.

Performance tests: tests carried out to demonstrate that the system functions according to specification.

Point: a physical source or destination for data in the form of analogue or digital signals.

Pre-commissioning checks: systematic checking of a completed installation to establish its suitability for commissioning.

Proportional control: a control algorithm in which the output signal is proportional to the error in the controlled variable.

Proportional and integral control: a control algorithm in which the output signal is proportional to the error plus the integral of the error in the controlled variable.

Proportional and integral and derivative control: a control algorithm in which the output signal is proportional to the error plus the integral of the error and the rate of change of the controlled variable.

Protocol: a set of rules governing information flow in a communication system.

Sensor: a hardware device which measures, and provides to a control strategy, a value representing a physical quantity (for example temperature, pressure etc); or activates a switch to indicate that a preset value has been reached.

Soft point: a point that can be referenced as if it were a monitoring or control point in a BMS, although it has no associated physical location. It may have a set value or be the result of a given calculation or algorithm.

Stand-alone control: during normal operation, an item of equipment which can operate normally when isolated from the remainder of the system.

TCP/IP: Transmission Control Protocol/Internet Protocol

Testing: the evaluation of the performance of a commissioned installation tested against the specification.

Witnessing: the observation (by the client or his/her representative) of tests and checks of BMS hardware and operation prior to completion.

Appendix 1: Questionnaire for prospective tenderer

- company details;
- project management details;
- company history and organisation;
- financial history;
- technical history;
- order book status;
- project planning system in use;
- applications to trade and research organisations;
- supply and/or installation services offered;
- software, operational and maintenance support;
- quality control procedures;
- specific standards employed in design, manufacture and installation of equipment;
- details of installations completed;
- outline details of equipment suggested for the proposed project;
- budget cost of the system (hardware, cabling, installation and commissioning);
- provisional installation programme and completion dates;
- details and costs of standard maintenance arrangements;
- guarantees on equipment, system performance, savings etc;
- compatibility with other BMS suppliers' equipment; (BACnet)
- expansion potential of the system;
- general comments.

Appendix 2: Sample functional statements

Sample only

Functional statements describe the overall control strategy to be adopted. They are arranged in logical order by building or services system, individually numbered, and cross-referenced to drawings and other relevant documentation. Detailed parameters such as times and temperatures should be listed in the Operational Schedules.

> *'There should be three groups of selected plant and circuits available for electrical load shedding as described in the Operational Schedules.*
>
> *Heating, cooling and ventilating systems should be operated under time programme control including the use of optimum start/stop control and free cooling.*
>
> *Main boilers should be loaded in sequence to maximise efficiency and equalise operating periods for each boiler.*
>
> *The BMS should interface with packaged chiller plant in Plant Room C to provide supervisory monitoring and control.*
>
> *Lighting in corridors and open-plan offices should be operated under timed and illumination level control.*
>
> *The BMS should be capable of initiating paging of the duty engineer for out-of-hours priority alarms'.*

Appendix 3: Sample schematic diagram

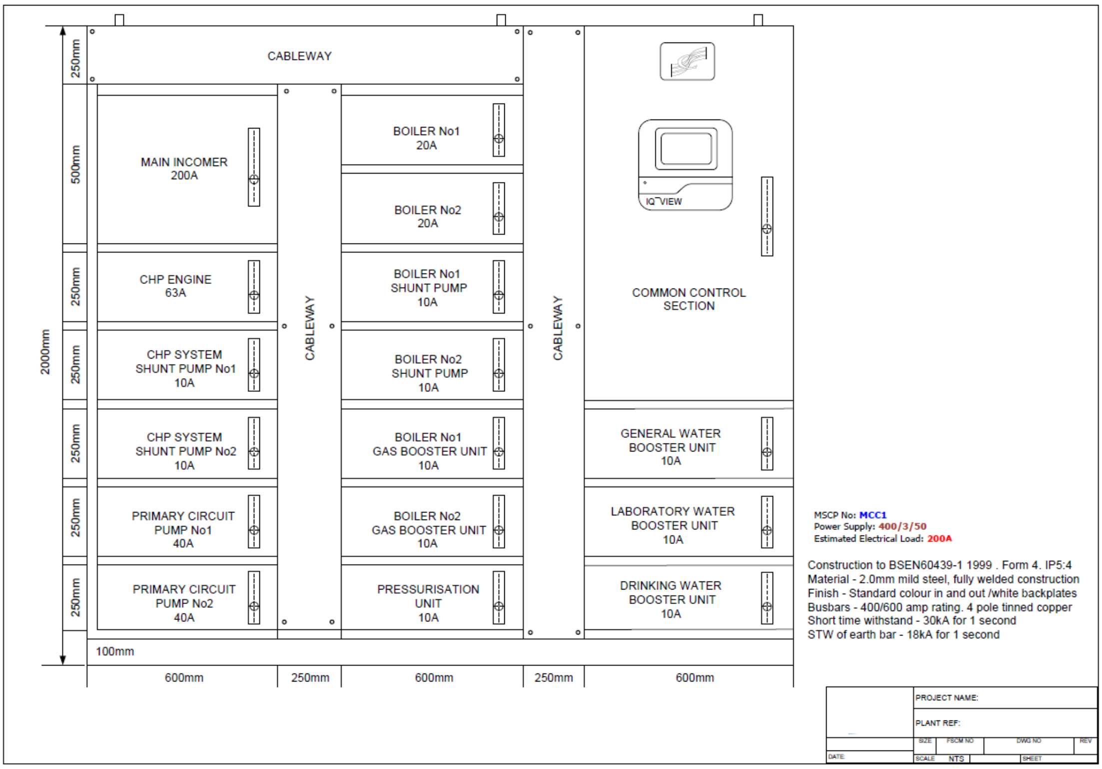


Figure 2: sample of a Form 4 motor control centre schematic – external

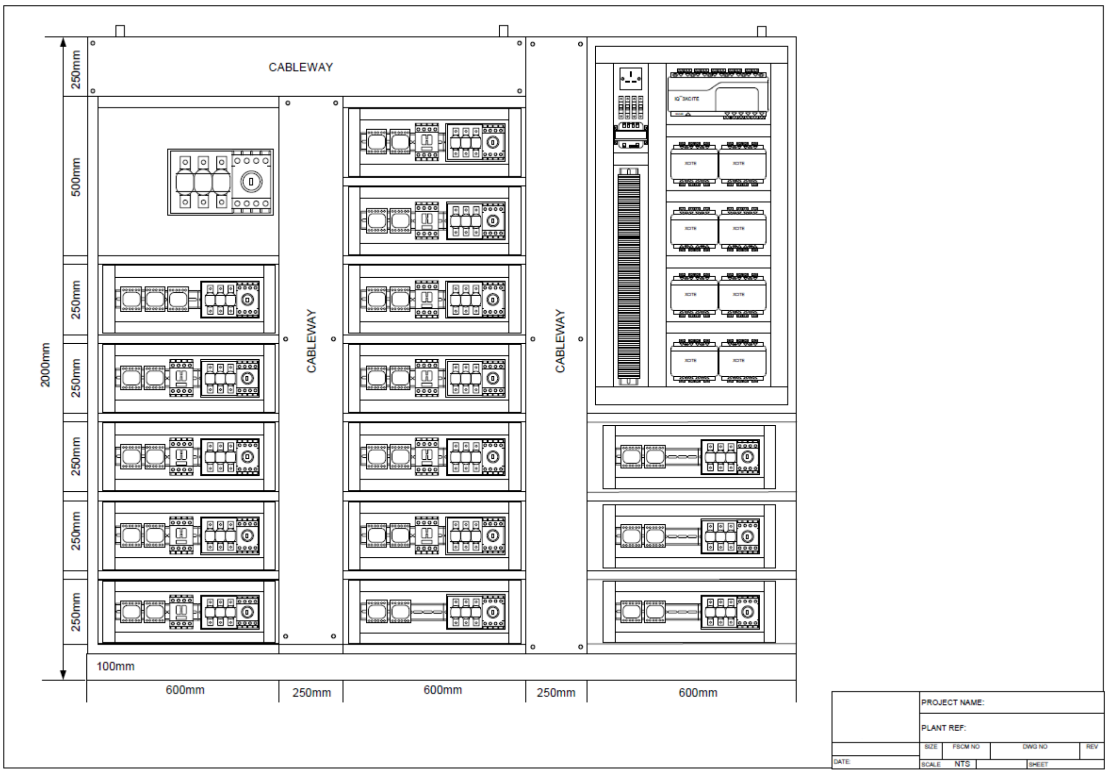


Figure 3: sample of a Form 4 motor control centre schematic – internal

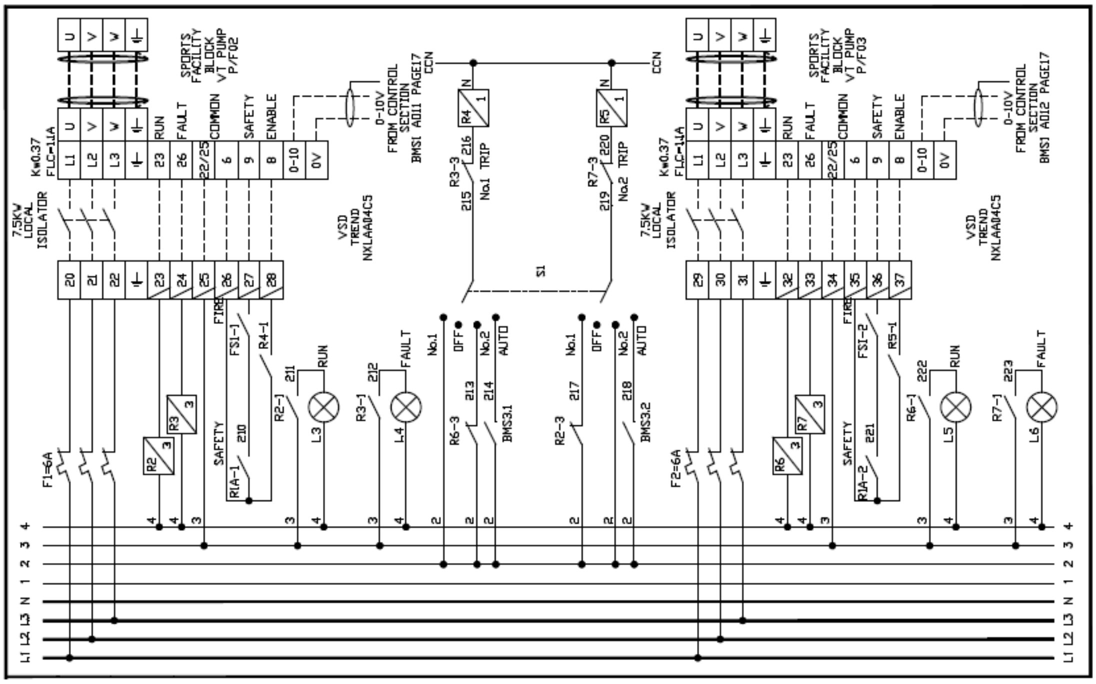


Figure 4: sample of a motor control centre wiring schematic

Appendix 4: Sample points schedule

MCC1 – Energy Centre

BMS Points Schedule

Qty	Point	DI	DO	AI	AO
	Building Fire System				
1	Fire alarm activated	1			
	Boilerhouse Plant Safety				
1	Plantroom gas solenoid valve status	1			
1	Main Building gas solenoid valve status	1			
1	Plantroom emergency shutdown activated	1			
1	Plantroom gas detection system alarm, fault	1			
	CHP System				
1	CHP enable/control/status	3	1		1
1	CHP common flow temperature			1	
1	CHP common return temperature			1	
1	CHP unit back-end protection control valve	1			1
1	CHP primary shunt pump differential pressure switch	1			
2	CHP primary shunt pump enable/status	2	2		
	Boiler Circuit - General				
1	Common flow high limit thermostat activated	1			
1	Primary circuit common flow temperature sensor			1	
1	Primary circuit common return temperature sensor			1	
1	Primary flow measuring meter input			1	
	Boiler №1 Circuit				
1	Boiler №1 enable/control/status	1	1		1
1	Boiler №1 flow temperature			1	
1	Boiler №1 return temperature			1	
1	Boiler №1 booster unit enable/status	1	1		
1	Boiler №1 shunt pump differential pressure switch	1			
1	Boiler №1 shunt pump enable/status	1	1		
	Boiler №2 Circuit				
1	Boiler №2 enable/control/status	1	1		1
1	Boiler №2 flow temperature			1	
1	Boiler №2 return temperature			1	
1	Boiler №2 booster unit enable/status	1	1		
1	Boiler №2 shunt pump differential pressure switch	1			
1	Boiler №2 shunt pump enable/status	1	1		
	LTHW Circuit				
1	LTHW circuit common flow temperature			1	
1	LTHW circuit common return temperature			1	
1	LTHW circulating pumps differential pressure sensor			1	
2	LTHW circulating pumps VSD enable/control/status	2	2		2
	Pressurisation System				
1	Pressurisation unit control panel fault/alarm	1			
1	LTHW low pressure indication	1			
1	LTHW high pressure indication	1			
		26	**11**	**12**	**6**
		DI	DO	AI	AO

Figure 5: sample of a BMS points list

Appendix 5: Sample operational schedule

Operational schedules describe the detailed control strategy, and relationships between plant items and control parameters. They are arranged in logical order by building, zone or services systems, individually numbered, and cross-referenced to drawings schematics, schedules and other relevant documentation.

Plantroom B – DHW System (example only)

General

The domestic hot water system comprises a hot water calorifier and secondary constant volume return pump. The calorifier is served from the Energy Centre CT pumps via a 2-port control valve.

Motor Control Panel Details

Control equipment associated with the pumps should be housed in Motor Control Panel MCP/1/G01.

Selector switches and indicator lamps should be incorporated on the fascia of the Motor Control Panel as follows;

Motor Control Panel MCP/1/G01		
Title	**Switch Position**	**Indication**
Calorifier High Temp	Reset (Pushbutton)	High temp cut-out
DHWS Return Pump	Hand/off/auto	Run/trip

Hand; the 'hand' position on the selector switch is provided for commissioning and maintenance purposes and should allow the drives to run out of normal automatic control provided all safety interlocks are satisfied.

Off; when the plant is selected 'off' on the selector switches the plant should stop. If the 'off' position is selected whilst the plant is running under automatic control, the plant should configure itself as described for pump failure, and the alarms raised will have to be cleared before the plant will run again under automatic control.

Auto; when the switch is selected in the 'auto' positions the following controls strategy should apply.

DHW System Start/Stop:
The DHW system should operate on a dedicated time schedule or via a manual command at the BMS central station.

On start-up the system should be configured as follows;

- secondary return pump should be enabled;
- DHW calorifier temperature control loop should be enabled.

Plant Shutdown:

The system should be disabled via its BMS time schedule or via an operator command at the BMS central station. On shutdown, the pump should be shutdown and the temperature control loop should be disabled.

Temperature Control:

A temperature sensor mounted in the calorifier at two-thirds height should act as the measured input to the DHW calorifier temperature control loop. Once enabled the 2-port control valve should be modulated via the proportional plus integral action control loop to maintain a temperature of 62°C ± 3K.

High Temperature Protection:

A manual reset high limit thermostat should be installed at the top of the calorifier. In the event that the temperature at the top of a calorifier exceeds 75°C, then the control valve should be closed and an alarm should be raised at the BMS central station. The calorifier should not be re-instated into automatic control until the high limit thermostat has been reset.

Heating Demand:

Whenever the DHW control valve is at least 10% open to the calorifier for a period of greater than 1 minute, a heating demand signal should be sent via the BMS communications network to the energy centre CT pumps.

The heating demand signal should be removed, via the BMS communications network when the control valve closes and remains closed for a period of 5minutes.

DHW Return Pump:

The common secondary return pump should operate throughout the programmed time schedule for the DHW system. The pump should be monitored for its running status via its motor starter auxiliary contact. In the event of pump failure, as detected by a mismatch between the BMS command and the pump running status, an alarm should be raised at the BMS central station and the pump should be shutdown. A failed pump should not re-enter the automatic control sequence until the alarm has been cleared at the BMS central station.

Monitoring:

Temperature sensors should be located in the DHW common flow and return pipework and should be connected to the BMS for monitoring purposes only.

References

Note: Where there is a requirement to address a listed reference, care should be taken to ensure that all amendments following the date of issue are included.

Acts and Regulations

NB: Access to information related to the following Acts and Regulations can be gained via www.legislation.gov.uk.

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