Grade 5 Thesis

The practical use of building management systems for the commissioning of building services installations

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1. Précis

Since the need for buildings to be energy efficient in both design and operation has become a higher priority, design teams and clients are now looking to install more sophisticated BMS systems to allow control, monitoring and reporting of efficiencies and faults to be easily undertaken.

The design of BMS systems together with the vast array of available sensors and controllers now available; gives a significant opportunity for commissioning engineers to “sensibly” break down large projects into smaller pieces. This in turn allows commissioning activities to be undertaken in parallel with construction activities and can give significant programme advantages if managed responsibly.

This Thesis will identify potential gains and opportunities within the design and construction of BMS systems to assist system commissioning as well as identifying areas of possible problems.

2. Introduction to Building Management Systems (BMS)

Building management systems (BMS) have been implemented in one form or another since the concept of commercial buildings has existed. The early forms of BMS initially comprised of manually initiated reaction to alarm events such as the need look at a piece of plant that had failed.

The main function of early BMS systems was predominantly to provide a “monitoring only” capability of building services, with any undesired changes in state of equipment being identified and signalled to an appropriate point within the building. This would allow the building engineering / management team to carry out any required actions manually. These early systems relied upon vast amounts of hard wired cabling and large cumbersome control / indication panels in order to provide only very basic functions. These early systems did not provide any specific form of control.

Control systems within buildings have greatly developed since the invention and implementation of micro-processor based plant controllers in the early 1970’s, the development of which has given rise to the ability to provide fully functional control, monitoring and optimization of all elements of mechanical and electrical plant.

Further advances in technology and the ease of availability of networking communications equipment has now given rise to the ability to provide large scale building control networks, operating over Internet Protocol (IP) networks allowing multiple user access from numerous locations.
Since the concept of micro-processor based building control systems, many manufacturers have developed their own individual forms of communications networks and protocols.

Initially, many manufacturers developed equipment that would only be compatible with their own form of communications network (closed protocol systems) however in recent years there has been a growing trend across the industry to standardised controls protocols in order to provide “open” systems allowing third party equipment to be integrated onto the base communications network without the need for complex interfaces.

The establishment of these open protocol systems such as BACnet, LonWorks, Modbus, KNX, etc, has provided standard device communication variables (In essence this means that devices that are all compliant to the same open protocol standards will “speak the same language”).

These standard network variables allow information to be easily collected by one manufacturer’s controller; this information can then be transmitted across the controls network backbone and read by a different manufacturer’s controller in order to perform a relevant task. This gives great flexibility to the building operator as field devices can be changed for any manufacturer (as long as the chosen device can communicate with the same standard network variables as the controller / device being replaced).

A key function of the modern day BMS control system is to provide a fully optimized and adaptive plant control system that can react to changes in a systems performance and provide the appropriate automatic response without the need for user intervention. These underlying control processes can be utilised as a valuable tool in the assistance of setting up and commissioning of mechanical (air and water) plant systems.

Other than rudimentary turning on and off of plant system and opening and closing of valves, dampers, etc the stability of plant operation i.e. variable pump speed or fan pressure control can be used to greatly help a commissioning engineer undertake his day to day commissioning tasks. Great attention however must be paid to the process of ensuring that control loops are tuned correctly as incorrect tuning can give rise to very undesirable outcomes.

Control loops are tuned for three specific independent functions, these being, proportional, integral and derivative (PID).

Proportional control relates to the effect on a control loop based on the present error or deviation from the desired setpoint. Integral control relates to the effect on a control loop based on the accumulation of past errors or deviations from the desired setpoint and Derivative control relates to the effect on a control loop based on predicted outcomes related to the current rate of change towards or away from the desired setpoint. It is not a necessity to use all three functions of a PID control loop in order to achieve the desired outcome as for commissioning purposes a control loop that is drastically hunting up and down if far less desirable than a loop that is slow to respond but eventually reaches its setpoint.

The PID control loops are software algorithms hosted within the field mounted controllers. Field mounted controllers can have generic software programs for specific items of equipment already pre-loaded or can be of a universal type which require configuration prior to use. The Fieldbus controllers are normally connected by hard wired cabling to the field sensor and control devices (temperature sensors, pressure sensors, inverter drives, etc) however the use of wireless field sensors is becoming more common.

On larger systems, field controllers are normally located within larger control panel cubicles and connected together to form a “Fieldbus” network to allow information exchange between relevant devices (for example the use of a common pressure sensor to controlling two independent air handling plants feeding the same space). The fieldbus network allows data to be transferred quickly between specific plant controllers and sensors over a dedicated control network whilst minimising potential risks that can be caused by delays in communications due to network traffic and routing on local area networks.

Once connected and configured the fieldbus controllers are now normally connected to a main system server via either a dedicated Local Area Network (LAN) or as a Virtual Local Area Network (VLAN) if installed as part of an integrated internet protocol (IP) data network system. The use of IP is now commonly used as a base platform for communications for devices above the fieldbus level.
A head end graphical display computer (supervisor) is usually provided and connected to the bms server again using an IP communications network.

3. Typical BMS system architecture

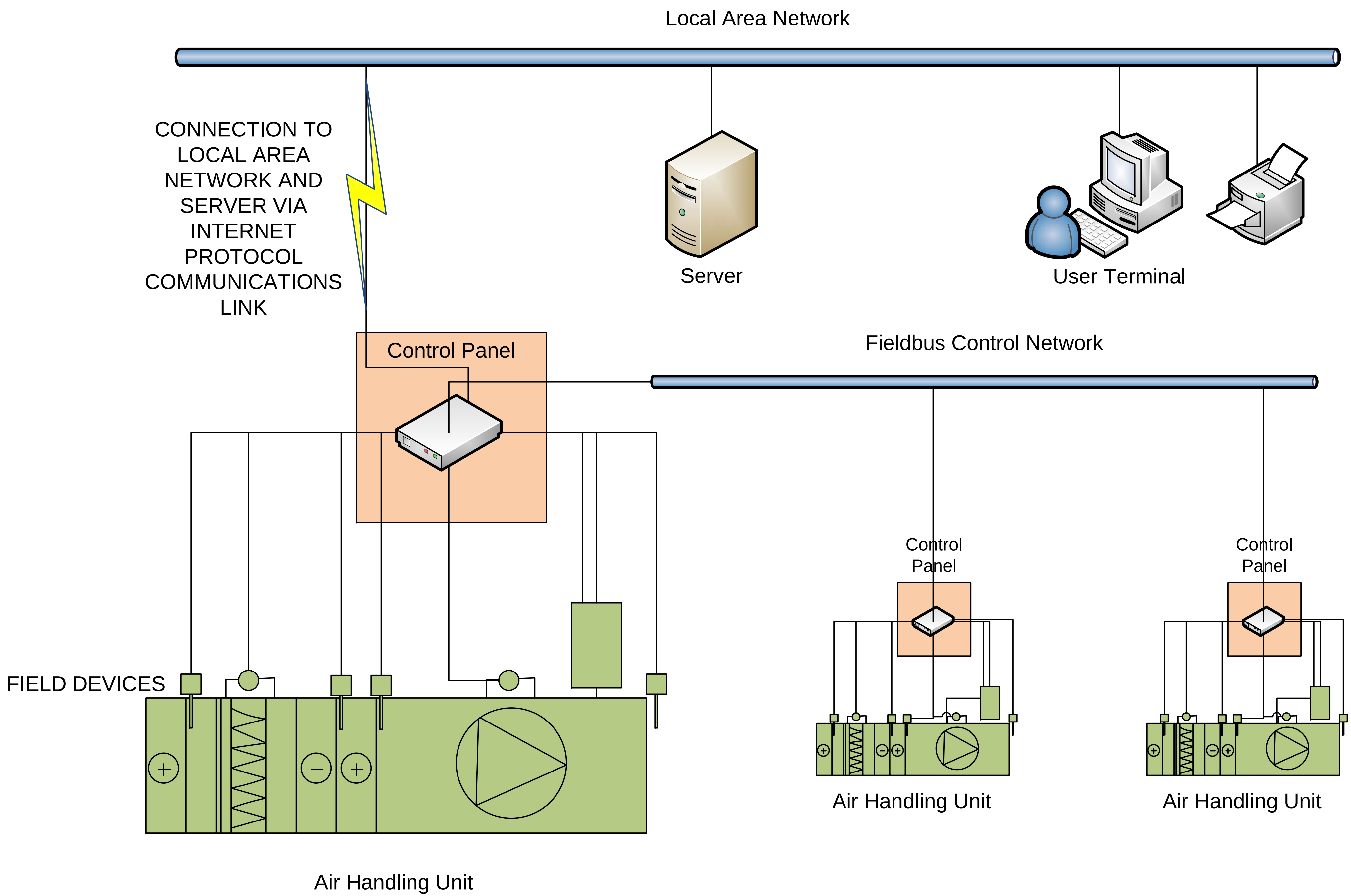
The system architecture schematic overleaf details a typical arrangement of networked BMS control panels interconnecting a number of air handling plants. This typical setup can be used to connect many different kinds of plant such as pumps, fan coil units, variable air volume units, etc.

This network topology indicates the 3 fundamental stages of a bms wiring strategy. The first stage is field wiring which is used to connect specific sensors and devices back to a field controller. The second stage is an interconnecting fieldbus control network cable which can be used to interlink a number of field controllers with the third stage being the local area network providing interconnectivity between the field controllers, main server and user terminals.

The main advantage for the use of this standard arrangement is that with the use of distributed system intelligence it is possible to setup and configure each element of plant individually without the need for completion of the entire network infrastructure. This can allow many simple control algorithms to be implemented early on within the construction phase of a project instead of waiting until the nearing project completion in order to configure these control loops (an example of this would be to control a fan to a fixed discharge pressure).

BMS system architecture will vary considerably dependent upon the constraints of a project however, if early attention is paid to the proposed commissioning strategy, it is possible to arrange the system architecture to ensure individual systems can be operated on a standalone basis without reliance upon a fully completed infrastructure. An example of this would be to ensure that Variable air volume units connected to an air handling plant system are all connected to the same bms fieldbus and controller to ensure that all devices can be viewed and operated from one location.

TYPICAL BUILDING MANAGEMENT SYSTEM ARCHITECTURE



4. Designing of BMS systems to aid commissioning (Air / Water / Environmental)

During the design stages of a BMS project it is a significant benefit to engage with the system end users and commissioning specialist to enable simple and cost effective additions to the design that can, in the long run, add value to the systems operation and "usability".

Below is listed a number of cost effective solutions that can be implemented to speed up the commissioning process and allow the end user to understand the true operation of a system.

Water systems

The design of water systems for larger buildings can lead to the requirements of sectional commissioning being undertaken in order to facilitate the completion of a project. As system pumps are selected against a total system duty, the pump duty for sectional commissioning may be greatly reduced and as a result it will benefit the commissioning engineer to have a reliable source of volumetric flow for the system at all times. This could be achieved by the use of a conventional orifice plate and differential pressure transducer being installed in order to provide a true representation of system flow. It is also possible to use the feedback from energy metering devices (provided that it has an "Instantaneous" output facility rather than a pulse) that may well already be installed as a requirement of the Building Regulations for energy consumption metering. It is possible to configure pump speed control to be directly related to system pressure and thus ensure differential pressure control valves are not subjected to system pressures that are outside their operating range.

It is possible to instigate this flow rate monitoring across system risers or even floor by floor in order to provide a system map of flow rates at any given moment in time. This not only helps the commissioning engineer to interpret system operation but can also be used in future to aid the building facilities management team to ensure water quality is maintained. Many BMS systems have good alarm reporting functions that can be engineered to identify flow problems (i.e. indicate when flow has fallen below a certain threshold for a defined amount of time).

As discussed in the system architecture section it is imperative that items of plant and sensors that are reliant upon feedback from each other for functional operation eg. A pressure sensor controlling a pump must be connected to the same control outstation as the pump controller in order to maintain the stand alone functionality of a field controller and to allow independent commissioning whilst other parts of the bms system are still being commissioned.

The installation of simple to use control panel switches can aid a commissioning engineer and prevent the need for full time attendance from a bms engineer. Panel switches could be designed to make use of many functions that would normally be done on a computer workstation e.g. switch input to command all valves open 100%,etc.

Air Systems

Air systems can be set up in similar ways to water systems with the use of constant and variable air volume units (CAV / VAV)being installed in conjunction with a main system volumetric flow device (e.g. flowgrid or velocity probe). These systems can allow larger air systems to be broken down into bite size elements that can be commissioned independently of each other allowing works to be completed in line with building zonal completion instead of having to wait for the entire system to be complete. CAV and VAV can be provided with controllers that provide a true feedback of volumetric flowrate and actual damper position, many manufacturers also allow the CAV and VAV setpoints to be adjusted remotely. These key elements of feedback and control can all be made available to a commissioning engineer via a graphical head end to allow system adjustments to be made prior to the act of actual commissioning taking place e.g. turning off a cav box feeding an unfinished area, adjusting total system flow to match the requirement of the area which is planned to be commissioned without the need to continually pitot traverse a duct.

Like water systems, pressure control of fans can be utilised to maintain a constant duct static pressure without the requirement for constant adjustment by an engineer. This can be of a significant benefit when systems have to be commissioned over longer period, which may allow inlet filters to become dirty and thus affect the downstream volumetric flows without the knowledge of the commissioning engineer.

Head End / User Interface

During the commissioning stages of the project it is advantageous to provide commissioning engineers with restricted levels of access to bms outstations via either dedicated commissioning laptops or via a specific panel mounted human interface devices (HID), such as a touch screen visual display to allow adjustments to be made to operating systems without the need for the provision of a dedicated bms engineer (specific training will be required to be given by the bms provider to ensure no interference with the remainder of the bms installation without the required authorisation).

The BMS provider could be asked to provide an engineering graphics page in order to simplify operations for a commissioning engineer. This page could feature simple global commands such as “All Chilled Water Valves 100%”, “All Low Temperature Hot Water Valve 100%”, “Pump speed manual selection Hz”, “Pump pressure control setpoint”, “Air Handling Unit pressure control setpoint”, “Air handling unit supply pressure setpoint”, etc. This list is not exhaustive and if engage early enough in the project the bms contractor can normally include such a page without much fuss.

5. Stand alone and integrated commissioning

The use of bms systems for commissioning can be very advantageous if planned and carried out in a structured manor, however, it also brings with it risks that need to be managed and the need for a close relationship between the bms provider and the commissioning engineers undertaking the commissioning works.

It is imperative that the equipment selected and installed as a function of the bms system is suitable for the required tasks being undertaken and that the feedback and responses given from such equipment can work within the expected tolerances detailed for commissioning works. In many instances this will require independent calibration of equipment or validation of the same once installed against known calibrated instruments (e.g. pressure sensors validated against a micro-manometer, etc). Factory testing can also be utilised to ensure performance of equipment prior to site installation.

Pieces of equipment that provide pressure or volumetric control must be commissioned on a stand alone basis to ensure that the control functionality provided again falls within the expected tolerances and that the control loop parameters are tuned to give the desired outputs that suit the commissioning tasks being performed (i.e. pumps controlling to a fixed volume are not hunting).

The setup of inverter drives should be carried out as a combined exercise between the controls specialist, commissionig engineer and in some cases the inverter manufacturer may also be used. This ensures that plant is put into service with all necessary checks being carried out beforehand (e.g. removal of transit bolts / protection, alignment of belts, setting of inverter to motor / fan details, etc). Ensuring these simple checks are undertake correctly and at the right time can prevent costly damage and ensure that once the plant items are set to work, they will continue to operate effectively.

One significant area of frustration borne by many commissioning engineers relates to the operation of control valves on fan coil unit installations. The simple exercise of ensuring that the correct actuators are fitted onto the correct service and that they are fitted properly installed can save a project days, if not weeks of problems.

Stand alone commissioning must be planned properly to align with the construction programme and must be carried out in a methodical manner to ensure integrated commissioning can be undertaken and that engineers can use bms data and graphical displays with confidence that what they are indicating is a true representation of the systems operating condition. Integrated commissioning must always be undertaken as the last element of commissioning works as “trying to run before you can walk” can lead to major re-commissioning works and hours spent re-checking information that is not repeatable.

6. Safety advantages

The use of bms systems for commissioning can greatly reduce the risks envolved in the commissioning process. Any work requiring the commissioning engineer to come in contact with a piece of equipment can be a potential risk. The correct implementation of a bms system can drastically reduce the amount of time a commissioning engineer has to repeatedly visit certain items of equipment e.g. a water service flow metering device that is connected to a bms system will prevent the need for continual connection / disconnection of a poddymeter / waterbox to an orifice device. This example alone will significantly reduce working at height as well as the major reduction in the requirements for transporting bulky items of access equipment around a work area.

The table below gives further examples of installation practices that can provide safety advantages.

Device	**Safety Advantage**
Inverter drive in lieu of star delta or D.O.L starters	Running current and motor speeds can be read directly from inverter without the requirement for direct access to electrical cabling or fan chambers when the plant is operational. Plant speed / volumes can be remotely adjusted without the requirement for access to valves that may be at high levels.
Flow grids / CAV / VAV completed with test points	Reduces requirement for working at height and drilling of ductwork.
Pressure independent control valves	Simplifies the water balancing process and reduces working at height as valves do not have to be repeatedly re-visited.
Temperature sensors installed in the supply air chamber of an Fan Coil	Allows remote verification of a control valves open / closed status which prevents the requirement for checking valve operation visually at height.
Installation of end switch or positional feedback on damper / valve actuators	Once commissioned these devices give true status feedback minimising the requirement walking around congested plant areas and restricted height areas.
Head End / Remote User Interfaces	Lessens the requirements for time spent within plantrooms and within close proximity to plant / trip hazards / low head height areas.

The above list is not exhaustive.

7. Lessons learnt / possible problems and pitfalls

The use of a third party system in order to carry out commissioning works has many problems that must be addressed during the procurement phase of the project. The addition of clauses into contractual obligations will ensure that the bms contractor is aware of the obligation to provide certain levels of access and functioning plant control to the commissioning subcontractor.

Calibration and validation of plant and equipment is an absolute must and must be carried out to the satisfaction of the final witnessing authority. Failure to undertake this element could lead to vast amounts of re-work that can prove costly and have extensive programme implications.

It is fundamental that a clearly defined project flow diagram and / or programme which indicates to all parties the commissioning stages and required input from the bms team at each stage.

8. Final opinion

In summary, the use of a BMS system to allow sectional commissioning of a large building project to be made simpler is in many cases an opportunity that is overlooked at procurement stage. Early “Buy In” buy the client / facilities team can allow for some of the simple requirements to be incorporated into the project brief without the requirement for additional contract cost.

Evaluation of the mechanical systems early on in the design stages of the project by a competent commissioning specialist can help align the requirements of a bms system with the operational needs of the commissioning team and allow inclusion within the project scope.

The installation of simple devices and a system that allows easy visibility of the same can greatly speed up the commissioning process and provide valuable feedback and operation that can be of benefit to the building end user and as such it is my opinion that the use of bms systems as a commissioning tool should be undertaken on larger scale projects as a matter of course.