Building Automation Systems After 11th September

Course Content

BUILDING AUTOMATION SYSTEMS

The shocked incident of 11th September has redefined the ways the buildings are built. Pressures of high cost of energy, maintenance costs, along with increased cost of labor have pushed up the expectations from the operating personnel. Growing expectations for comfort, security and service levels has re-enforced the importance of 'Intelligent Buildings".

Building Automation System (BAS) is typically one area that contributes to building intelligence; brings efficiency and safety. The BAS incorporates sophisticated controls and monitoring devices that integrates the building functions, mechanical and electrical services including security at one location.

Conventional Systems

The conventional monitoring systems include the pneumatic or electrical controls. Because of growing sophistication of the equipment and technology, these are being replaced with microprocessor-based controls, which offer advantages of integration at one location.

To turn fans on/off, conventional systems use time clocks. The main drawback is the amount of time it took to go around to all of the various time clocks to prepare for holidays and whenever occupancy schedule changes occurred, and so many times clocks were placed in the "always on" mode.

For temperature control, conventional system use pneumatic controllers. Their principal drawback is that they tend to drift out of calibration, and the vast majority suffers from "offset", which is the inability to keep the desired conditions at set point under changing load conditions. They are still in use today in some smaller systems, but most have been replaced with microprocessor-based control, and more are being replaced when there is a reasonable payback for doing so.

Other main limitations of conventional system:

1. The electric or pneumatic proportional controls fail to provide narrow bands of control. These results in 'offset', which means a loss of energy and also discomfort.
2. Separate sensors are required for controlling, recording and indicating functions.

3. Except in very few control schemes, electrical or pneumatic controls generally resort to 'one sensor – one equipment' combination. This results in uncoordinated operation of various equipments. For instance, heating and cooling could take place simultaneously during dehumidification process, whereas it can be avoided.
4. To monitor status of system in different zones separate mimic panels are required which take up a lot of space.
5. Each parameter to be monitored or recorded needs a separate instrument and cabling.
6. Increased quantum, cost and space requirements for cabling, panels
7. Maintenance of logbooks is tedious; accuracy of the observations is heavily dependent on the human judgment factor. Analysis of data in the logbooks is difficult.
8. Efficient operation and sequencing of equipment is dependent on judgment of the operator.
9. Managing and monitoring the dispersed or large buildings is difficult and time consuming. If there is a problem, diagnosis takes more time as plant rooms had to be accessed and equipment checked.
10. Operators are required to start and stop various equipments at fixed time and keep a detailed record of readings.

Building Automation System (BAS) - ' An answer'

A BAS makes use of computers and microprocessor hardware to help overcome the problems listed above. BAS has " proportional and integral" capability, which ensures better comfort and energy saving by maintaining close tolerances on the control parameters. The conventional On/Off or proportional control maintains a condition lower or higher than the desired condition (for e.g. temperature) depending on the load. The higher conditions lead to discomfort whereas lower conditions lead to energy waste.

A BAS supervises, monitors and integrates any or all of the building utilities like:

- Heating, Ventilation and Air-conditioning (HVAC)
- Indoor air quality (IAQ)
- Water supply, hydro-pneumatic equipment and pumping
- Telecommunication and workplace automation
- Vertical transportation monitoring (escalators, elevators and parking)
- Lighting and electric distribution

- Security and closed circuit TV (CCTV)
- Fire suppression and alarm

BAS & HVAC

It has been conclusively proven that controlled environmental conditions help in improving the efficiency of human occupants. The efficiency of machines and process also depend on the environment around.

It is seen that the HVAC systems are major energy consumers in any building that typically exceeds more than 30% of total power consumption. The high cost of power, the emphasis on energy conservation, security and the vulnerability of buildings to fire, smoke and threats lean the trend in favor of HVAC automation.

A commonly used large HVAC system would comprise:

- Central refrigeration plant to produce chilled water (or brine) using one or more chilling units.
- Zonal air-conditioning units such as air-handling units and fan coil units conditioning the air in the particular zone by re-circulating it over cooling coils use the chilled water (or brine) produced at central chiller plant.
- Zonal air-distribution systems comprising ducts, dampers, grilles, diffusers mixing chambers and volume control terminal boxes.
- Chilled and condenser water circulating systems.
- Electrical power system for driving various motors, power cabling starters switches etc
- Instrumentation control system

BAS for HVAC system is most useful in monitoring the status of various equipments and is vital for *energy conservation*.

BAS for HVAC system is useful in initiating emergency response measures to the fire and smoke evacuation and is vital for *life safety.*

What does BAS control in HVAC ?

- BAS is typically used to control fan systems, namely the supply and return fan speeds, fresh-air mixing dampers, heating and cooling coils and humidification systems, all to maintain the desired fan discharge temperature and humidity and ultimately the occupied spaces of buildings.

- BAS may control and/or monitor fume hood exhaust fan and energy recovery controls (using the available heating/cooling from the exhaust air to heat/cool the outside air that's being drawn into the building by the supply fans).
- BAS maintains the indoor air quality. CO_2 monitoring systems provide for controls that adjust fresh air in large public places as the occupancy level changes.
- BAS also controls complex chilled water systems, including primary/secondary/tertiary chilled water loops, cooling towers start/stop, variable-speed controls, free-cooling systems and boilers for heating.

HVAC Energy management and BAS

The goal is to reduce energy use to the bare minimum without sacrificing occupant comfort.

The major advantage of BAS is the ability to consider all the inputs to determine the various control outputs. For example a common program for temperature and humidity would ensure that the re-heating coil is made use of only when the cooling coil is in dehumidification mode. In conventional system most of time, the air is first sub-cooled and than re-heated to achieve de-humidification. This wastes lot of energy, which occurs due to non-coordination between various outputs for cooling, heating and dehumidification.

Strategies used by facilities management systems to reduce energy consumption in intelligent buildings comprises of six major factors:

1) Scheduling
2) Duty cycling/set point reset
3) Demand Limiting
4) Load cycle
5) Optimization start/stop time
6) Record and analysis of history data

Scheduling: This function is to schedule the events before hand according to users requirements. The air-conditioning requirement in different zones may be different; the operating hours in various areas could also be different. The building occupants determine the schedules. Generally each building has a representative for building scheduling who collects schedule information from various departments before passing it along to BAS. Scheduling in BAS is programmed to initiate turn on/off equipment according to pre-defined information. The benefits are energy savings and control flexibility.

Duty Cycling/Set point reset: The BAS processor self-learns to provide unloading or stopping of plant and work on certain cycles such as ‘night’, ’duty’ and ‘zero energy band’. During nighttime, when the outside temperature is low, it can used to directly purge the building. Alternate switching to main and standby equipment reduces the maintenance by allowing both the main and standby equipment to run evenly for equal hours. The benefits are energy savings and reduced maintenance.

Demand Limiting: This function reduces peak demand consumption by automatically shedding loads. Maximum demand program enable to put off certain pre-defined non-critical equipment when the power consumption is on the rise. This ensures less consumption and avoids power penalties. Utility supply companies discourage use of electricity during peak hours and provide incentive on restrictive drawing of electric load during peak hours. The benefit is energy savings.

Load Cycling: Optimum starting and stopping of air-conditioning equipment based on the occupancy, time and outside/room temperatures lead to energy saving. This function reduces energy consumption by cycling operating facilities. Enthalpy programs like enthalpy control can be used for large energy savings. The program automatically results in repeated turning off designated equipments sensing the load elements. The benefit is energy savings

Optimization (Start/stop): Considering the transition of staging on/off, this function is to determine the appropriate time to start/stop major components. According to optimization results, major components are started or stopped at the appropriate time with the changing cooling load. The benefits are energy saving and reduction of equipment life-cycle cost

Record & Analysis: This function is to monitor and save log data for operation, maintenance, energy consumption and diagnostic errors. The system records power consumption of whole facility and each component. It could be programmed to provide analysis of the energy usage & costs and its comparison with outdoor changing weather. The benefits are periodic energy audit and analysis

BAS & LIFE-SAFETY

In wake of tragedies of Sept. 11, 2001, the occupants and tenants are more concerned about the safety features. Insurance companies specifically for high-rise and vulnerable buildings are demanding reliable and dedicated life-safety security systems to adjust their premiums. Obviously the building equipped with advanced safety system shall command lower premiums.

Life-safety and HVAC system integration

- Life-safety systems and HVAC-system controls must work together to minimize the danger to building occupants and provide an opportunity to escape. For instance, fire alarms need to be interfaced with HVAC controls to shut down systems (to prevent spread of fire) or place them in a smoke-control or a purge mode.
- BAS are typically programmed to automatically respond to fire emergencies and smoke control. The smoke control components for e.g. the fire dampers are the primary means of effecting the compartmentalization of a building. Most designs would require the fire dampers and HVAC to completely shut down while others may require bringing the affected area in negative pressure for smoke removal.
- Commercial ventilation systems are seen as a potential means of chemical and biological threat (CBT). A properly designed HVAC system however offers potential defense as these have the capability of isolating areas from CBT with space differential pressure control. The BAS can be considered a means of using the capabilities of the ventilation system to quickly respond and mitigate an attack.

Life-safety and Security System Integration

- Life-safety and control systems are being integrated with emergency-response plans. BAS- life-safety systems module provide the data necessary for building operators to make correct decisions regarding how to handle the emergency using contingency plans.
- End users could adjust the way they're using a BAS to accommodate an emergency situation by allowing a manual "panic button" approach.
- Security control requires restricting unauthorized access to the building. The entry and exit through the building could be monitored using smart cards using simple magnetic strip or an embedded wire, a proximity card reader, an occupancy sensor such as those used in lighting, or voice, finger, hand, or retina readers. The last four remain very expensive and are only used in special installations.
- BAS makes the count of persons present in the building any time. This is important to track the number of people inside the building particularly during fire emergency and initiate a corrective action.
- The closed-circuit television with cameras and intrusion alarms located at strategic location provide monitoring and audio-visual alarm at one centralized location.

Life –safety and Telecommunication Integration

- Telecommunication service is a lifeline to an emergency response. One of the lessons learnt on world trade tower incident was the need for a reliable and redundant communication capability. Had the communication services worked under unpredictable situation, the expected loss of life could have been minimized.

BAS & ELECTRICAL SYSTEMS

Lighting control can provide significant savings. There are three basic approaches to automated lighting control: programmable, dimming, and occupancy sensors. These can present savings of 30% and 50% of the energy used for lighting.

Time operated controls like auto-timers or advanced illumination sensors can ensure that the lights are not working during the daytime. Similarly the outdoor streetlights are programmed to switch on automatically on dark settings.

BAS could be integrated to the various appliances in the building, such as coffee and vending machines.

The BAS system monitors the overall energy consumption of the facility. The system could be programmed to restrict the peak demand of electrical distribution system. The demand limiting is switching off the excess non-critical load.

BAS can monitor the UPS system charging and provide an alarm indication on low output or insufficient charging.

BAS & INFORMATION SYSTEMS

Information systems include telecommunications and workplace automation. The occupants of the building shall have an access to advanced information system features at a considerably reduced cost as equipment is shared by many users. Some of the telecom features involved in intelligent buildings are:

- private telephone exchange systems
- cablevision
- audio-visual and videoconferencing
- signage and graphics
- satellite communications

- local and wide area networks
- electronic mail and internet access
- cetralized data processing
- document control, scanning , xerox etc.

BAS & TRANSPORTATION

The BAS system can regulate the building transportation system from one centralized location and can efficiently respond to emergency situation.

BAS could be programmed to optimize service, prevent crowding, save energy and provide efficient coverage for the building.

With fuzzy logic programming, the BAS control software tries to anticipate demand based upon the calls received and a high probability floors. It also allows the system to anticipate traffic patterns such as the morning up peak and evening down peak and to park lift cars at strategic locations when not needed.

Internet in lifts and signage is also used where an intelligent server in the hotel or office building pulls the content that is addressed to that site. It is then delivered to the elevator via a wired or wireless local area network.

BAS is also useful in controlling the ground vehicle parking system. The BAS system in conjunction with CCTV system can monitor the vehicle parking status and could control the entry and exit gates. BAS has capacity to facilitate broader parking management that integrates a building's internal car park system within the framework of a citywide car park management system.

BAS & PLUMBING

BAS can check the storage status of the water tank and could provide an alarm status on overflow or low-low level.

BAS can detect an open tap and can regulate the auto flushing timing of the plumbing fixtures.

BAS can regulate water distribution pumps, softening plant and expansion tank. A significant energy saving could be achieved on proper operation.

STRUCTURE OF BAS

BAS can be built in a wide variety of capacities from a moderate size building to distributed large buildings.

Basically the system is built up in three levels:

1. Field equipment and sensors
2. Direct Digital Control (DDC) substations
3. Central application processor host computer station

Field information: is gathered by sensors that send signals to reflect status of equipments, data logging or raising alarms to the direct digital control (DDC) substation.

Direct-digital-control (DDC) substations consists of controllers, network-interface devices, operator interfaces, and software packages providing database management, communication, programming, graphics, and other user-interface tools.

"DDC", logs electronic temperature measurements and compares them to the desired settings (set-points), then calculates an appropriate response if the two aren't equal, and finally sends out new signals to correct for any difference. Start/stop control and alarm reporting are also incorporated into DDC.

Host computer is used to pool up the information status data from different substations. The color graphic terminal displays information and alarms in the form of dynamic pictures.

The hardware of BAS typically consists of:

Field Equipment and Sensors

- Starters
- Control actuators for valves and dampers
- Special motors
- Sensors for temperature, humidity, lighting, occupancy, motion sensors, differential pressure etc
- Fire & smoke alarm signals

Direct Digital Control Substations (DDC)

- The DDC substation manages the tasks of operating, monitoring, supervising the HVAC system in one zone. The substation comprises
- Programmable controller
- Input modules

- Output modules
- Communication interface

Host Computer

- The computer along with printers and other hardware collects data from various substations. Some of the hardware is
- Micro/mini computer
- Disc Drive
- Connecting interface
- Terminals
- Color Graphic Terminal
- Printers

OPERATION OF BAS

In general a BAS would perform its task with the help of its hardware as detailed above.

The software that makes the hardware run resides in the DDC station. Alarms, time functions would also be stored in the controller.

The field equipment and sensors provide input signals to the digital controller through input modules. The controller processes the input data and gives output commands based in the programs. The outputs like positioning of a modulating valve, starting/stopping of equipment are communicated to the respective field equipment by the output modules.

The total number of field equipment and the individual capacity of the substation determine the number of DDC substations.

The communication interface is used to transfer data and receive instructions directly from the operating terminal or the central station.

Various substations and the central station communicate with each other on the continuous basis. Terminals, printers, graphic monitors at the central station can record or display these as required by the operator.

The DDC substation does interaction with the field equipment and the system being controlled. Normally the substation has stand-alone capability, therefore central station acts only as supervisory station where all the dates are gathered, displayed and processed. Unless there is a need for global command or control, the central station does not have any control functions to perform.

Various DDC substations or BAS can be linked together to form a larger system with the use of telephone modems or fiber optic communication cabling or even radio link. This enables linking of BAS, which are far apart.

ADVANTAGES OF BAS

BAS comprise of microprocessors and electronic components. These are almost trouble free and require no maintenance. The components have very low failure rate that makes the system extremely reliable. Failure chip is easily replaced rather than relying on repair. Periodic checks need to be done only after long time durations.

1. **Better Overview of Installation**

   BAS enables the user to have complete overview of the various utilities and subsystems with the help of a few keys on the keyboard. One does not require sending people all around to find out information like temperature, tank water level, compressor pressure, AHU stop/run status etc. Observing the various sub systems in a short span enables the user to make proper and quick decisions.

2. **Fast reactions to Breakdown**

   The alarms can be displayed, printed and stored in the memory. The alarms can also be canalized to specific terminal, printer, and storage files. A great deal of decision making for alarm situation can be programmed. For instance in case of fire certain fans and dampers can be closed and others operated. In case of tripping of equipment standby can be put into operation.

3. **Effective Deployment of Manpower**

   BAS can be used to schedule maintenance of equipment based on parameters like operating hour's etc. This helps in reducing the down time of the various equipments.

   BAS enables user to deploy a small amount of people effectively for large installation. Since all alarms are reported at the control, regular observation trips by several maintenance personnel can be avoided. This also ensures that problems are attended to before thing go out of hand.

   BAS enables field service technicians to be dispatched via handheld PCs. From any location, the technician can call up a complete history of the equipment; diagnose the problem, and electronically record equipment readings and the

tasks he performed. The technician's notes are captured in a database and routed to the appropriate managers.

4. **Energy Efficiency & Optimization of services / equipment**

BAS has a good deal of optimization capabilities. The air conditioning plant and the air-handling units can be started and stopped at optimum time by considering parameters like room temperature and outside air temperature. Programs for sequencing and rotation of chillers etc. can also be used. With the help of performance curves the equipment can be made to operate more in the high efficiency zones. A proper operation of BAS could lead to significant energy savings.

Among other practical benefits of the BAS include the following:

- Provides precise control, accurate and timely data that would otherwise be difficult to obtain, speed in decision making, faster problem solving, and more comfortable and productive work environments.
- Provides countless system integration possibilities, such as an opportunity to share data through a network, and it contributes to energy efficiency and cost savings.
- Provides a unified 'User Interface' for all subsystems, which simplifies and lowers cost of training and operations
- Provides linkage to tenants for direct and faster feedback.
- Provides personal control enabling greater tenant satisfaction/retention
- Maintenance and Facility Management – for e.g. field service automation to manage assets across multiple buildings

DEVELOPMENT OF BAS

How the building will be operated and by whom should be identified early in the design process. The engineer must figure out how each system is going to work in all modes of operation and clearly communicate this in the sequence. The sequence of operation for each of the system designed must be complete and detailed.

Consideration should be given to developing logic diagrams during the conceptual design phase. That should be the design engineer's decision.

The Building Automation System designer should be involved early in the building design process to identify the potential benefits of BAS.

Following steps are required:

1. To begin with the user has to define all the controls, alarms, and time function to performed for the various subsystems. This is usually done through a system description or writing a sequence of operation. The user will have to ensure that all the necessary equipments like smoke evacuation systems, humidifiers, return fans, dampers etc are incorporated in design.
2. A detailed Input/Output (I/O) summary is prepared listing out the subsystems. Based on this field and signal equipment's are estimated to perform the necessary control functions.
3. After consolidating the data for all the subsystems/utilities etc. the various kinds of input/output modules are selected to meet the total requirement. Based on the capacities/capabilities of the control equipment controllers and modules are grouped together to form the various DDC substations.
4. The equipment at the central station largely depends on the point capabilities of the system software and the functions required at the central station. The user should generally opt for a monochrome terminal, printer and color terminal. Parallel terminals and printers can also be deployed depending on the needs of the building services.
5. Identification of ownership and required interaction between building sub-systems must be done to ensure successful integration. Both design presentation and construction management should be an active part of this integration.

SELECTION CONSIDERATIONS OF BAS

The 3 major elements that need to be checked are:

Inter-operability is the mutual exchange of information in a system of diverse manufacture. Owners desire to add a building to an existing network without sacrificing control and visibility of the overall building system, regardless of manufacture. *Interoperability between applications, which is user configurable, leads to lower cost in developing integrated applications*.

Inter-changeability is the ability of a BAS to utilize equipment of different manufacture at the component level. This allows, buying a replacement control component from anybody, plugging it in and going. It is important that the control and visibility from the original central operator workstation is maintained irrespective of one manufacturer.

Integration is the combination of building systems of different makes and their universal control from a central workstation. Control manufacturers like to say their products are interoperable because they can be integrated with different OEM equipment. This muddies the waters. They may have controls that are interoperable internally, but the controls may not be interoperable with other buildings on a network. It is very important

that the building systems are integrated to have uniform, remote access to different equipment. BAS manages integrated processes for maintenance and operations of subsystems resulting in improved up time and lower maintenance and operations costs.

LEADING SUPPLIERS OF BAS

Honeywell

Johnson Controls

Landys and Gear

Staefa Controls

EVALUATION CONSIDERATIONS OF BAS

Every enterprise has a unique pattern of building management requirements. There may be several control options and control equipment, but the choice of right subsystems to meet specific needs is crucial. For instance the critical defense, nuclear or R&D installations might require sensors capable of detecting most chemical and radiation threats. To employ them in a commercial setting is difficult to justify, impractical and very expensive. Wherever buildings are mission critical - the hospital, factory, airport, hotel, financial institution or university campus, the challenge is repeated.

When choosing the option for BMS and or while selecting this for the existing facilities evaluate:

1. That the system design permits flexibility & compatibility
2. What happens to the system if the remote equipment fails?
3. That the system could be easily interrogated and programmed in-house
4. That the BMS system shall be made compatible with the existing instrumentation and control
5. That international data formats are supported for e.g. dates.
6. The ability to put a hardware or software point in a "test mode."
7. The ability to override a point or a set point
8. The ability to change a detailed tuning parameter of a PID block
9. The ability to add an offset to an input for calibration purposes
10. The ability to seamlessly and efficiently trend and archive control-system parameters

When you decide to implement a Building Automation System, you must take into consideration all cost savings and hidden costs, not just energy savings. The system with the lowest initial purchase price often is complicated and requires a larger overall investment during its lifetime. In most cases, the simpler the system is to operate, the greater the contribution engineers and technicians can make toward increasing efficiency and lowering costs on a daily basis.
Although the potential exists to integrate all facilities management activities into one monstrous system, practical and economic considerations might discourage this. It is recommended to

1. Clearly establish the mission/objective of the building,
2. Demonstrate how the building's intelligence benefits the occupants/tenants

Other important considerations:

1. A BAS system will have a capital cost of $100 - 125 per sensor or control point and usually contribute to 15 to 20% of the total HVAC costs. The payback period is usually more than 2 to 4 years but is recommended to check the economics that is unique to each project.
2. BAS doesn't guarantee savings on it's own. The mechanical and electrical systems need to be equipped with design features that introduce overall efficiency and safety. Also the savings largely depend on the operator's skill, duty hours, and the energy costs.

Course Summary

The automation system go by many names: Building Automation System (BAS), Energy Management System (EMS), Energy Management and Control System (EMCS), Central Control and Monitoring System (CCMS) and Facilities Management System (FMS). Essentially the function of each is the same.

Building Automation Systems help facility managers understand their buildings, make intelligent decisions, and respond more easily to changing conditions. Building Automation Systems are computer driven to control such HVAC-related issues as temperature, humidity, airflow, and equipment operation. In addition to helping you make more informed decisions regarding the challenges and changing conditions of your facility, a Building Automation System monitors and controls the day-to-day operation of your building's HVAC, safety, lighting, and security systems.

It is learnt that the BAS have high potential of providing benefits to the building services:

- Better and reliable operation
- Improved control, comfort and security

- Improved monitoring of building, equipment and historical analysis
- Comprehensive overview of installations
- Reduce response time or fast reaction to breakdowns
- Scheduled maintenance
- Savings in manpower costs
- Reduced equipment operating times, energy consumption (10-30% energy savings)

The cost of BAS is around 15 to 20% of the total project cost depending upon the sophistication desired. Benefits of energy saving will offset the extra cost of the BAS. The usual payback is around 2 to 4 years depending on the energy costs and operating time.

In case the facility is not geared up for BAS system for what ever reasons of capital scarcity or life cycle economics, it is strongly recommended to keep provisions in the specification to adapt BAS at a later date.