Building Management System

Part 5

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Supervisory Controllers and User Interface

Introduction

In Part 4 of this series we discussed field controllers (DDC) that control field devices throughout the facility. Field controllers (tier-3) report their current values to and receive supervisory commands from supervisory controllers (tier-2). Supervisory controllers are web-based network engines that use open communication protocols like BACnet, LONWORKS and N2 protocols to connect a variety of field controller networks into a single seamless system. They support and perform the full set of building automation features, such as scheduling, trending, alarm detection, data sharing, energy management, totalization and customized control routines, which are specifically built for commercial facilities applications.

Supervisory controller also includes a graphical system user interface (UI) and configuration tool that can be accessed with a web browser. Remote access is easily achieved from an internet or intranet connection. Multiple users can concurrently connect to the supervisory controller. The security and presentation preferences can be managed by setting up user profiles, login IDs and passwords.

Simply put, the supervisory controllers manage facilities using information and internet technology. Let us understand more about the supervisory controllers and UI in the following pages.

Supervisory Controllers

Figure 1 shows the architecture of a typical BMS with three sample supervisory controllers linked to a host of field controllers – which are all stand-alone, application-specific DDCs like VAV controller, chiller controller, etc. We still need a higher level controller that will coordinate the functions of all the field controllers simultaneously, to deliver the intended HVAC system performance. The supervisory controller fits in here for overall coordination and integration. (In case of IBMS, field controllers for access systems, fire and safety system, basement ventilation system, security system, lighting system, etc. are integrated and coordinated by the supervisory controllers).

The network automation engine is a powerful computing platform that leverages IT standards to deliver optimum performance as both a supervisory controller, a user interface server, and a programming device. The automation engine has a number of information technology components on board. Its operating system is the embedded version of Microsoft XP. The user interface uses Java virtual machine. Please note that BMS of different makes could use different operating systems.
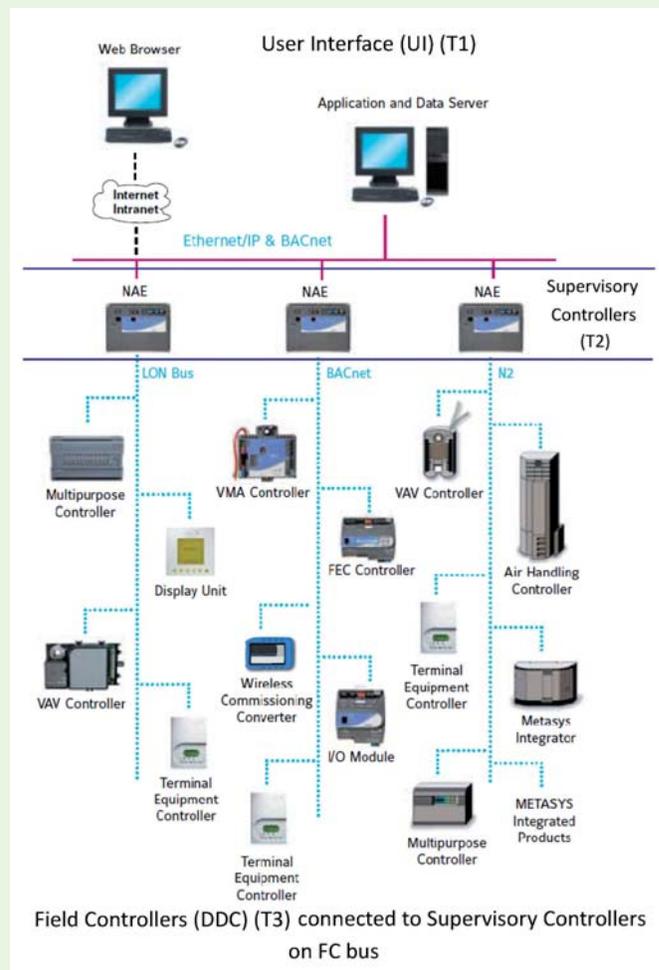

Figure 1: Typical BMS architecture

The role of supervisory control is to provide integrated control supervision and network management services for one or more local networks of field controllers, and provide direct control over inputs and outputs. Supervisory controllers use these interfaces to monitor and control HVAC, lighting, and other electrical systems to provide system-wide coordination, improve occupant comfort,

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annunciate off, normal and alarm conditions, reduce energy usage and optimize operating efficiencies. Supervisory controllers organize system information into displays, reports, and graphics that can be accessed by using a web browser.
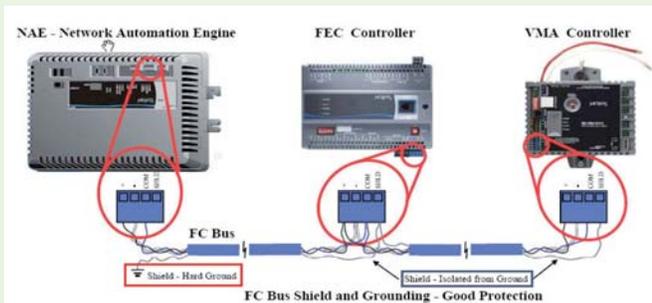

Figure 2: Field controllers connected to supervisory controller

All the field controllers are connected to the supervisory controller on the FC bus in a daisy-chain fashion, while using the MS/TP trunk (RS485). Refer *Figure 2*. One function of the FC bus is to provide a two-way communication between field controllers and supervisory controllers. The most common protocol used today to share information on the FC bus between building automation devices is the BACnet MS/TP. The MS/TP applications are sensitive to 'noise', which requires certain FC bus cabling guidelines to be followed.
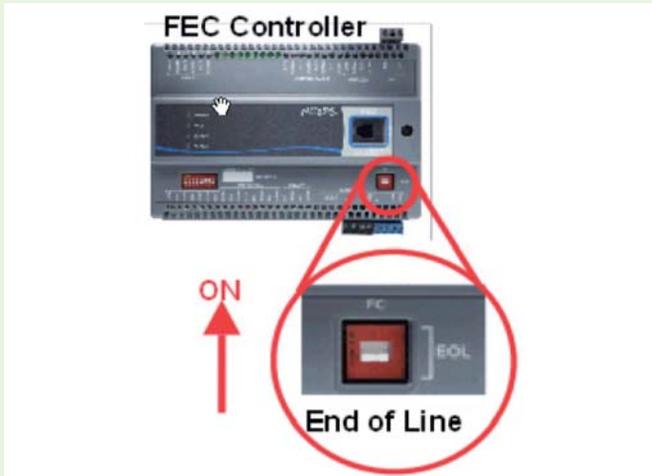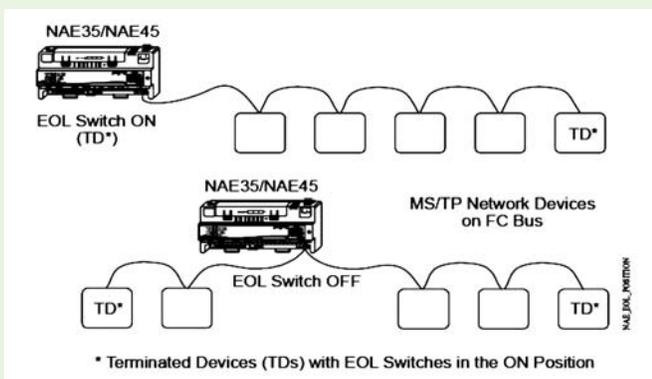

Figure 3: Field controllers showing EOL switch

Figure 4: NAEs, network devices and EOL switch positions

End-of-line (EOL) termination is used on FC buses. This helps to eliminate network interference caused by signal reflection, which occurs when data transmissions reach the ends of a bus segment and bounce back on the segment. Most of the new BACnet MS/TP products have a built-in EOL termination switch (*Figure 3*). If the product does not have one, a stand-alone EOL switch is added at the end of the FC bus.

Figure 4 indicates how EOL devices are added on an FC bus. When in doubt, check with the BMS OEM, to avoid poor network performance on the bus.

Figure 5: Supervisory controller (indicative example)

Figure 6: Hybrid IP Controller (indicative example)

A close-up view of a typical supervisory controller is shown in *Figure 5*. It has computer serial ports to connect to a computer or VTU, USB ports to connect to a modem, an Ethernet 8-pin RJ45 port to connect the supervisory controller to the network, two FC bus ports to connect the FC bus, a 24VAC power supply terminal, a battery for data protection and a set of LEDs for status indications. Hybrid IP controllers (*Figure 6*) provide both IP and supervisory control in a single IP-connected device. NAEs have multiple connection port options that enable building an extremely flexible network at the automation and enterprise level of the system, as well as at the field controller and data acquisition levels.

Supervisory controllers communicate internal system data using peer-to-peer messaging over the IP Ethernet network (*Figure 1*). Thus each NAE device shares data and has access to information on all other NAE nodes on the network to coordinate the overall functions of the building controls.

Supervisory controllers are selected based on the number of hardware points and field devices that it can support. A sample selection table is shown in *Figure 7*.

Supervisory Controller Model	NAE85	NAE55	NAE45	NAE35
No. of BACnet/IP trunks	1	1	1	1
No. of BACnet MS/TP trunks	0	2	1	1
No. of field devices that can be supported				
BACnet MS/TP	275	50	50	50
BACnet IP	0	100 – 200	100	50
Total no. of hardware points supported	25,000	2,000	1,000	1,000

Figure 7: Selection of supervisory controllers (indicative example)

Communication Interfaces

Supervisory controllers support multiple embedded and optional communication interfaces. This facilitates integration of many different types of field controllers, and also provides different ways of remote user access. The available embedded and optional communication interfaces include the following:

- 10/100 Mbps or 1 Gbps Ethernet
- RS-485
- RS-232 (up to 115, 200 baud rate)
- LONWORKS (78 Kbps FTT-10A)
- Wireless TEC communications (Release 6.1 and earlier)
- GPRS Modem

This list could differ slightly for various makes of supervisory controllers. Please refer the OEM's product brochures.

Supported Networking Protocols

Current day supervisory controllers use open network protocols like BACnet MS/TP, BACnet IP, N2 Open, LONWORKS, web services and ZigBee wireless. Different makes and models may also include optional client-server drivers, where we can add the required protocol drivers.

The NAE supports integration of BACnet objects and services on both the IP level and on the RS485 selectable field bus inputs. When integrating third party systems equipment, it is much more feasible to provide seamless integration at the IP level as many BACnet vendors include proprietary objects and attributes on their MS/TP connected devices that may not have full functionality on systems of other make.

Supervisory controllers' hardware and software design is modular. The system designer can add accessories, such as communications cards, input and output modules (IOM) and software options, if needed. The IOM, when added on the FC bus, works as a point multiplexer. This modular add-on design allows selection of the most appropriate controller for the size of facility and the options best needed to control it.

On-board Tools of Supervisory Controllers

Network engines have an on-board user interface, on-board tools, and a standard suite of building management systems applications that equal the power of typical dedicated system workstations. Also on-board are tools that let the designers build their own databases and create their own graphics.

The on-board user interface does not change regardless of the engines being used in a simple or a complex installation. In addition, the network engine carries out all the traditional building automation functions. It has a real-time clock to perform *scheduling* of field controllers. It retrieves historical information from field controllers and stores them in its memory for *trending*. It creates *alarms* for critical system conditions. It provides a graphical user interface. It also carries out totalization, optimal start, demand limiting (load rolling, e.g. plan a 10 minute shutdown every hour or so) and custom control applications. In fact, the automation engine will often be the only component installed in many buildings. Mount it in the appropriate location, connect the network, and not only is the building automated, it is accessible from any Internet Explorer browser on that network.

All these capabilities of network engines are fully experienced and leveraged in the work station. Let us understand how this UI works.

User Interface or Work Station

In *Figure 1*, at the top portion of the BMS architecture, network engines are connected to the Ethernet. The most common protocol used today on the Ethernet LAN/WAN to share information between the engines is BACnet IP. A computer, using a standard web browser, can access the engines and tons of real-time and past-history data of the entire gamut of equipment connected to the BMS system. This is tier-1 of the BMS architecture and is referred as user interface (UI) or a work station.

The user is able to monitor, operate and control the entire facility from here. This is facilitated by realistic and simple graphics for the user to monitor different equipment and also by live trending of actual real-time data from all the mapped equipment. In large facilities having numerous equipment and devices, data size becomes large, necessitating the use of application data servers.

A terminal allows the user to communicate with the controller and, where applicable, to modify the program in the controller. Terminals can range from hand-held units with LCD display and several buttons to a full-sized console with a video monitor and keyboard. The terminal can be limited in function to allow only display of sensor and parameter values, or powerful enough to allow changing or reprogramming the control strategies. In some instances, a terminal can communicate remotely with one or more controllers, thus allowing central displays, alarms, and commands. Usually, hand-held terminals are used by technicians for troubleshooting, and full-sized, fully functional terminals are used at a fixed location to monitor the entire digital control system.

The computer does not require any special workstation software other than the browser and a standard Java® plug-in. The web browser accesses the controllers directly over the IP network, or via the internet. Standard internet browsers can be used to access system information.

Small Network System

Refer *Figure 8*. Each of the supervisory controllers on the network provides the function of a web server. A user could log into any one of them to communicate with all of its connected points and functions. But the user would have to know which

Figure 8: Site director for a small network of supervisory controllers

controller contains the user's specific points of interest. So we use the concept of a site director. Any one of the network engines can be designated the site director and it serves up the graphical user interface (GUI). Whenever the user logs in to it, it provides a connection to the data associated with all network engines on the site. This approach is adopted when the site does not require historical data storage.
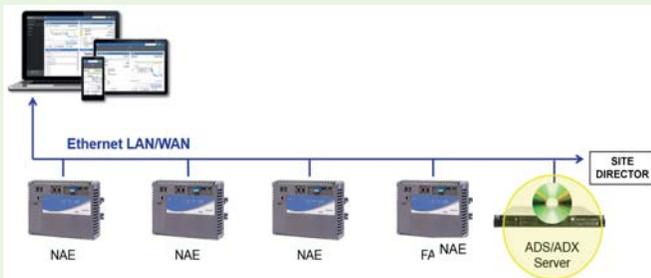
Large Network System

Figure 9: ADX server as site director when the network grows

As the BMS size grows, ADS/ADX server is used and it becomes the site director (*Figure 9*). The server communicates with the engines using *web services* and not on BACnet IP. The server allows many additional software packages to be utilized.The server increases the capacity of historical *trend data* as well as advanced GUI.

Figure 10: Graphical user interface (GUI)

The GUI (*Figure 10*) is the user's point of interaction with the building management system. It communicates directly with the system's *site director* (NAE or server) and is accessed with a standard web browser, using a PC, tablet or smart phone. It can be accessed from anywhere in the world, so long as the customer's IT department provides an external internet connection. The UI allows access to system data remotely over an intranet, the internet or virtual private network (VPN). It supports standard IT firewall technologies for protection against unauthorized access.

Figure 11: SMP – graphical tool

Refer *Figure 11*. Site management portal (SMP) is a GUI tool and also a system configuration tool, residing in the site director. Mobile access portal (MAP) is another UI tool (*Figure 12*) that facilitates site engineer accessing the FC bus and SA bus using hand-held devices for commissioning and configuration purposes.

Readers may be noticing that as we discuss network automation engines and user interface, there are a lot of references to IT jargon. Actually, this is the area of convergence between IT and BMS.

Figure 12: MAP – mobile access portal

Secure IT Formats and IT Standards Used in BMS

By using standard data formats and communication protocols of the IT world, BMS is compatible with the networking infrastructure in most modern buildings and facilities. These standards include:

1. Transmission Control Protocol/Internet Protocol (TCP/IP) as the protocol between network engines, servers and web browsers.
2. Simple Network Management Protocol (SNMP) for alarm traps and object queries in the Management Information Base (MIB).
3. Simple Network Time Protocol (SNTP) for networking time synchronization.
4. Simple Mail Transfer Protocol (SMTP) for e-mail message transfer.
5. Dynamic Host Configuration Protocol (DHCP) and Domain Name System (DNS) for device naming and dynamic network addressing.

6. Simple Object Access Protocol (SOAP) and Extensible Markup Language (XML) to transfer data between system components and make it available to enterprise applications through the use of published web services.
7. Bluetooth, ZigBee and WiFi for wireless communication
8. SQL Server 2000 Desktop Engine (MSDE), Microsoft SQL Server and Microsoft SQL Server Express for historical data management

Some of the standard features of BMS include, but are not limited to:

1. *System navigation:* user views that can be authorized and assigned to different levels of users (*Figure 13*).

Figure 13: System navigation on UI

2. *Monitoring and commanding:* to access, view, analyze reports and control and modify them with user views.
3. *Time management:* synchronizing time and date across all devices, preventing errors and facilitating scheduling, trending, data collection, etc; the site director can be configured to synchronize its time from an external web site and, in turn, it will configure all devices in the BMS.
4. *Preferences:* configuring how the UI appears (sounds, colors, alarm priorities, start-up, etc.); preferences can be divided into system preferences and user preferences.
5. *Alarm and event management:* the user can configure routing of alarm messages for permanent storage, alerting the operator with a pop-up alarm and analysis of alarm history (*Figure 14* and *15*).
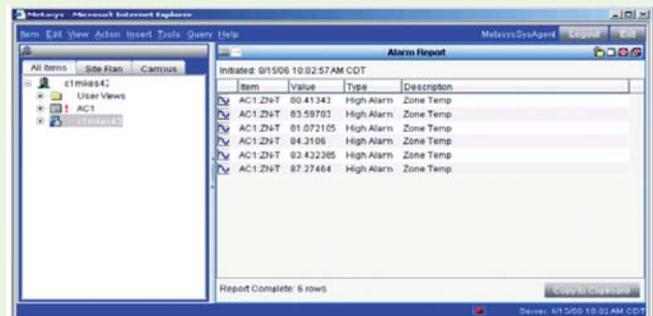

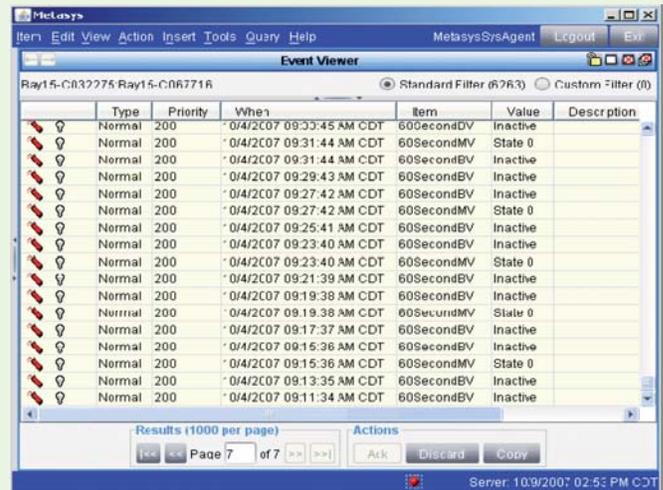*Figure 14: Alarm report on UI*

Figure 15: Event viewer on UI

6. *Destination Delivery Agents (DDA)*: method used for routing and delivering event messages to pagers, printers, e-mails, network management system, etc.
7. *Scheduling*: a graphical UI illustrating when the events are scheduled to occur and automating the routine actions (refer *Figure 16)*; each schedule consists of a weekly schedule, an exceptional schedule, list of items in the schedule and an effective period.
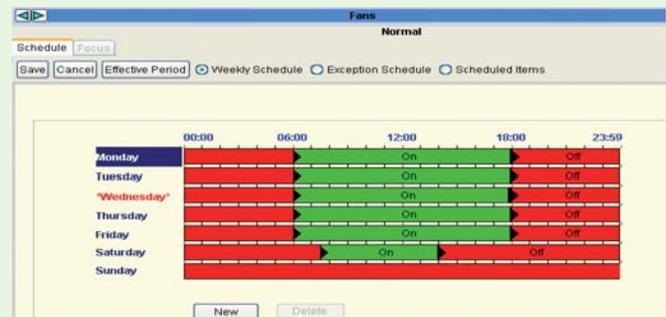

Figure 16: Scheduling screen on UI

8. *Historical data management (trend)*: allows the user to collect, store and view data, enabling the user to manage energy use, prove compliance to standards and diagnose problems (refer *Figure 17)*.

Figure 17: Data trend report

9. *Export utility software*: facilitates managers to build custom reports using historical data.

10. *System security*: user access is controlled by user account; extent of data access is pre-defined for each user and type of access like view-only or editing also; in all there are 25 categories, including HVAC, fire and security and 10 different levels of user functionality.

11. *Interlocking programs (event)*: provides conditional control, using *if..then* and *true or false* checks.

12. *Energy optimization*: the optimal start determines the correct time to start HVAC systems; it adjusts to seasonal variations.

13. *Demand limiting/load rolling (DLLR)*: helps save energy cost by limiting peak energy use, adjusting the set-point; it works to achieve user-specified energy reduction (*Figure 18*).
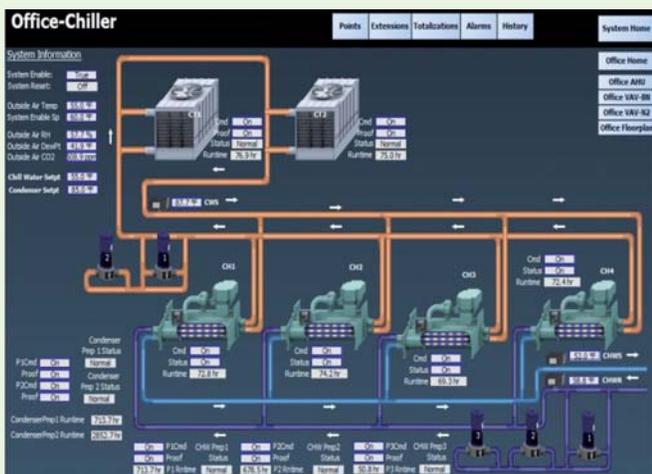

Figure 18: Load rolling on UI

14. *Audit trails (transaction data management)*: generates and delivers an audit message whenever a specified significant event is happening and is displayed in the audit viewer.

15. *System diagnostics and serviceability*: the network automation engine collects and stores this data that can be displayed in the diagnostic view.

16. *Ready access portal (RAP)*: every employee's desk has the potential to be a part of the BMS user experience.

Modern day building management systems are extremely versatile and capable of total customization for every customer's needs, helping to maintain indoor comfort and IAQ and optimize energy use.

References

1. ASHRAE Fundamentals Handbook 2013
2. *Intelligent Building Systems*, Albert Ting-pat So and Wai Lok Chan, Johnson Controls
3. Different articles and presentations on BMS by Johnson Controls ❖

> *In Part 6 of this Classroom series, in the July- August 2016 issue of the Journal, we shall discuss Control and Performance Optimization of an HVAC system by BMS.*