Application Guidance

When selecting a BAS, consider the following application guidance.

This guide includes the following contents:

Introduction

A Building Automation System (BAS) requires many details to select, install, commission, and operate. Professionals looking to replace their BAS or purchase a BAS for a new building must start by collecting information about the building that they plan to implement the BAS. Next, they should contact a BAS manufacturer representative or integrator to complete an audit, create system drawings, create a sequence of operations for each system, and specify the BAS. This information is then used to solicit quotes for the BAS including hardware, software, installation, commissioning, training, testing, maintenance, and data management costs.

The business model for BAS manufacturers varies. Some BAS manufacturers provide full services that include audits, system drawings, sequence of operations for each system, system specification, sales, installation, commissioning, training courses, testing, maintenance, and data management; while others partner with a building integrator to provide these services. Alternatively, an experienced building engineer can complete some or all these tasks.

Gather Project Information

Selecting a Building Automation System for a building depends on many variables. The list below provides a series of questions to help gather project information, guide your audit, and develop a specification for your BAS. This section is based on the “Defining Project Scope” section of the ASHRAE 13-2015 Guideline for Specifying Building Automation Systems.

- What type of building is it? How big is the building?
- How old is the building?
- Is this a new construction project (labeled “expected” in the remaining questions) or a retrofit project (labeled “existing” in the remaining questions)?
- Do you own the building or are you leasing it?
- What are the existing energy saving control measures (if any)?
- What energy saving control measures are expected to be deployed with the new BAS?
    - Note: Some control measures may require additional sensors.

- Do you want any additional features for your BAS? (ex. ADR, application programming interfaces (APIs), local displays, energy meters, etc.)
    - Check state requirements for energy efficiency control measures (changes may trigger you to meet those requirements)
    - Review LEED's Green Building certifications
- What systems do you want to monitor/control in addition to HVAC? (ex. fire, security, surveillance, lighting, blinds, hot water heaters, solar, energy meters, etc.)
- Will you connect with multiple buildings? Is this a campus implementation?
- What is the quantity and type of HVAC systems in the building?
- What is your existing/expected HVAC configuration (consider system types, sizes, quantity, and age for electric/hydronic, stages, pumps, fans, single/multizone, heat and cool or only one, air or water source, controller(s), actuators, valves, dampers, thermostats, and sensor types)?
- What is your existing/expected BAS/control configuration (consider the existing controllers, existing actuators, thermostats and determine whether they are pneumatic or electronic and note their age)?
- How many existing/expected points are part of your system?
    - Do you have a system drawing and control point labeling scheme defined?
        - Points include the physical I/O connections points and values like temperature, humidity, and occupancy from devices like thermostats that communicate with a data cable rather than a direct wire connection to an I/O terminal.
    - The number of points will need to be verified with an audit. The audit can be done here or after considering the remaining questions below.
- What are the existing/expected communication protocols for HVAC control or other systems?
- What signal types are used by the existing/expected sensors?
- What is the project budget including BAS, HVAC, and other systems?
- What are the cyber security requirements (passwords, encryption, connection types, etc.)?
- What are the IT requirements for being connected to the network?
- What are the wall types and ceiling types?
    - These details may influence installation of wires (wired vs wireless), electrician and/or integrator costs.
- Will you have a staff engineer to program and monitor the system or do you want someone to do this for you (integrator or manufacturer representative)?
- What type of user interface do you want (multiple levels of user interface for viewing or programing rights) and how many of each type?
- Do you want displays/graphics on laptops or on local tablets?
- Do you want your BAS to have an application programming interface (API)?
- Do you want the new BAS controllers or have a router/gateway communicate with existing controllers?
- Are you planning to replace/add new thermostats?
- Are you planning to replace/add actuators/dampers?
- Do you want the digital output relays to be built-in for 24 VAC 0.5A control or 3rd party relays that accept 0-10 Volt direct current inputs for controlling 24VAC loads?
- Have you talked to an integrator and/or manufacturer representative?

- It is time to complete a full site audit, develop system drawings, and sequences of operation. ASHRAE Guideline 36-2018[1] provides guidance on developing high performing sequences of operations, so consider whether you want these to be incorporated in your building.
- Compile drawings, sequences of operation, I/O list, and specification to open a bid.

BAS Implementation Considerations

Once you have reviewed and compiled the information above, consider the following criteria when selecting a BAS:

- Integration Capabilities
- User Interface and User Experience
- Installation
- Remote Access
- Security and Encryption
- Grid Service Capabilities

Each BAS implementation consideration category is described below.

Integration Capabilities

BAS integration capabilities are separated into four categories:

- **Application** – Controller connection options for new construction, legacy mechanical systems, or both, with either a standalone BAS controllers or BAS building controllers with expansion modules.
- **Communication** – The protocol with which a BAS controller exchanges data with a network of BAS components and I/O terminals used to exchange data with sensors. This also includes the compatible software for controlling the BAS building controller.
- **Data intake & utilization** – The specific data and signals from connected components that a BAS controller can accept in real-time and act upon to modify its operation including analog voltage and current signals, digital voltage, and demand response (DR) signals.
- **Data output & usefulness** – The specific data and signals a BAS controller can offer in real-time to control the operation of BAS components.

Each integration capability is described below.

Application

BAS are designed to integrate with both new construction and legacy HVAC systems. Some manufacturers offer freely programmable building controllers in their catalog while others have general controllers, application specific controllers, and sensors. It is important to understand the communication requirements for all systems, controllers, and sensors in the building before selecting a BAS. A BAS controller's application can vary by communication type and physical attributes.

[1] https://www.techstreet.com/ashrae/standards/guideline-36-2018-high-performance-sequences-of-operation-for-hvac-systems?product_id=2016214

Controller Types

There are three general categories for BAS controllers:

- Building controllers
- General controllers
- Application specific controllers

The BAS implementation considerations for each controller type are described below.

Building Controllers

There are two primary differences between BAS building controllers that affect their application.

1) Whether it has built-in I/O terminals, and

2) How the I/O terminal quantity can be increased.

Other differences include physical dimensions, connection types, I/O terminal labels and whether there are built-in displays.

Some BAS building controllers have built-In I/O terminals, while others are modular. Modular building controllers require a power supply module (normally 24 V AC/DC), the control module which includes the communication ports to the central computer/network, and other BAS controllers and accessory expansion modules. The accessory expansion modules have eight or more I/O terminals of varying types (Analog Inputs, Digital Inputs, Analog Outputs and Digital Outputs), but some accessory modules may provide an additional connection port (RS-232, RS-485, RJ-45) to allow more communication or some other type for a specific application, like security. Several expansion modules may be needed to control large systems. ASHRAE 13-2015 recommends having 15% extra I/O terminals for each point type to allow for future use.

Different manufacturers label these I/O terminals in different ways, but the terminals are generally used for Analog Inputs (AIs), Digital Inputs (DIs), Analog Outputs (AOs), and Digital Outputs (DOs).

Common signal types for AI, DI, AO and/or DO terminals include:

- 4-20 mA
- 0-10 V
- 24 V AC
- Pulse
- Thermocouples (resistance)

Contact closures (open/closed connection)

A building controller is a general controller that acts as a gateway/router to convert communication protocols from connected components (central computer/network, general/application-specific controllers, sensors, etc.) to allow system-wide read and write functions. Building controllers are the link between the central computer or network and the building systems, general controllers, application specific controllers, thermostats, sensors, actuators, dampers, and other building components.

The central computer is a laptop, desktop or sever with specifications that meet the demands of the BAS installed in the building. Building controllers can also operate without being connected to a central

computer. Programs will run and control the building, but the storage capabilities are smaller on BAS controllers than the central computer so the BAS controller storage may fill and cause the oldest data to be lost to make space for new data.

General Controllers

There are two primary differences between general controllers that affect their application:

1) the total quantity of built-in I/O terminals, and

2) the type of connection terminals.

Since general controllers are typically not compatible with expansion modules, the built-in controller I/O quantities and types affect what HVAC system or other building system that controller can control. Some manufacturers list applications (HVAC systems: Air handling unit, roof top unit, chiller, etc.) on specification sheets for general controllers to helps guide selection. Also, consider that ASHRAE 13-2015 recommends having 15% extra I/O terminals for each point type to allow for future use.

General controllers are BAS controllers that are freely programable. The controller can have a completely customized program or there may be pre-defined programs that can be loaded onto the general controller for it to control a specific HVAC systems or other system.

Application Specific Controllers

Application specific controllers are BAS controllers that are designed for a specific application, such as:

- Specific HVAC system controllers (i.e., fan coil unit, chiller, boiler, etc.)
- Thermostats
- VAV controllers/actuators controllers
- Security
- Lighting
- Blinds
- Others

Some controllers may be shipped with a control program for your application, while others may come with a library of programs to choose from in the software user interface. Communicate with the manufacturer representative/integrator to ensure you receive the proper configuration.

Thermostats come with varying features. Some thermostats can function as a FCU controller while others only provide temperature measurement and setpoint control. Thermostats often have add-on features which allow for occupancy sensing, humidity measurment, carbon dioxide measurement and digital/analog outputs that could be used for fan, remote heater, or other controls. Thermostats also come with different interface styles, some are touch screen, while others have physical buttons or sliders.

Communication

It is important to understand the communication requirements for each controller type and any connected sensors. Some BAS manufacturers offer different versions of BAS controllers that use specific communication protocols, while others provide a driver to be installed which allows them to use a different communication protocol.

Building Controllers

The router/gateway functionality of the building controller allows the building controller to connect to general/application-specific controllers using wired or wireless connection types. Generally, the wired connection types are RJ45 or RS485 connections. The RJ45 connections allow for the following protocols: BACnet (Ethernet or IP), Modbus (TCP/IP) and LonMark (IP). The RS485 connection allows for BACnet (MS/TP) or Modbus (RTU) communication protocols. Zigbee, Bluetooth and EnOcean are some of the common wireless connection types achieved by adding a wireless dongle to some manufacturers BAS controllers. Proprietary communication protocols vary by manufacturer.

Legacy BAS, HVAC, or other building systems with proprietary communication protocols may require an additional router/gateway to convert the signal to an open communication protocol that the BAS building controller can interpret.

During the BAS market assessment it was found that BACnet was the most common communication protocol offered by BAS controllers, and that most manufacturers were planning to move to IP communication rather than MS/TP if they did not already have IP communication capabilities.

The connection topology of BAS controllers varies between manufacturers. Controllers are often connected as a daisy chain that starts at the building controller and expands throughout the building to the other controllers, actuators, dampers, and sensors. Other manufacturers allow for this daisy chain to reconnect on itself as a loop. This connection approach allows the system to continue to operate if one controller malfunctions and stops data transmission.

For large buildings, manufacturer representatives often recommend an ethernet switch to provide a star style connection topology. This ethernet switch allows for six or more RJ-45 output connections. The ethernet switch has the potential to decrease the total daisy-chain communication length and improve system reliability. BAC controllers connected to the ethernet switch may be daisy chained or looped depending on the manufacturer. These ethernet switches require additional power and have some alarm features via output I/O terminals.

Building controllers communicate with expansion modules or I/O modules using either a proprietary built-in plug connection on the controller chassis and the I/O module or a separate wired connection to the I/O expansion module. The number of expansion modules and the type of signals varies for each BAS controller and expansion module. Review product specification sheets or call a manufacturer representative to verify options.

General/Application Specific Controllers

Communication between the general/application specific controllers and the thermostat is typically proprietary, but the general/application specific controllers also have built-in I/O terminals which could be used to read in temperature or other sensor data and/or user overrides for that zone with analog or digital inputs instead of using the thermostat.

Data Intake and Utilization

Once you have determined what control strategies you would like to implement, recorded the HVAC system configuration details, identified other systems you would like to control, and compiled the number of existing sensors and control points after the system audit, you can develop the sequence of operation for each system. The sequence of operation is the basis for the control programs that will be implemented during commissioning of the BAS.

The sequence of operations provides a written description of the following:

- The system being controlled (HVAC or otherwise)
- What the program will entail (control loops based on a sensor inputs, among others)
- The various operation modes (normal – day/night, vacant – day/night, freeze prevention, among others)
- Alarms with general use ranges for variables
- Variables for trending and the sampling rate

Data Output & Usefulness

BAS and the associated BAS software have data logging and reporting capabilities. Generally, BASs store data and reports to the central computer, networked storage, or the cloud. Data reports typically have the following file output types: CSV, XLSX, JSON, ASCII, PDF or SQL compatible types.

Some BAS require an SQL server to run the BAS software. This SQL server can be purchased through the BAS manufacturer or from a 3rd party vendor. SQL servers work well for storing large amounts of data due to the compression and encryption capabilities.

Alarms, trends, and reports can help identify system malfunctions while also providing the benefits of program and setpoint changes. Some BAS have additional options such as email or text alerts.

User Interface and User Experience

The user interface for BAS can vary across manufacturers. There are often multiple programs, user interface types, programming types, and multiple layers of access for each program.

Multiple Programs

BAS manufacturers often have separate programs for their BAS that focus on commissioning new controllers, programming/operation, monitoring, and energy management. Licensing is bound to a computers Host ID and is managed via a web hosted license or a downloadable license file.

User interface Types

The user interface style varies from manufacturer to manufacturer and software application to application within the manufacturer's offerings. Some user interface styles include text based and graphical programing.

- Text based programming involves identifying input/output variables with text and writing text-based expressions to interpret inputs and use math/logic to control outputs.
- Graphical programing involves identifying input/output variables using pictures or symbols and connecting these with other pictures or symbols with built-in math/logic to control outputs.

Graphical programming can be present in multiple layers of the BAS including the programming user interfaces and/or the monitor user interface.

- The programming user interface involves identifying input/output variables inside of blocks, tables, pictures, symbols, or graphics that have built-in math/logic or can be connected to other blocks, tables, pictures or symbols or graphics with built-in math/logic to control outputs.
- The monitor user interface is higher level programming that displays input/output variables with text boxes, plots, or charts. The math/logic is generally performed in another level of

programming that this user does not interact with. Although, some inputs/outputs may be overridable in the monitor/graphic based program. This simplified user interface is generally developed by a manufacturer representative or an integrator as an additional feature. The monitor user interfaces have specific changes that can be made by the user (setpoint changes, schedule, setback etc.), while programming user interface listed above, and the line-based programming are used to control a wider variety of variables in the system.

Installation

Typically, BAS building controllers are mounted in an existing controls cabinet on a din-rail or new control cabinet with communication cables/wires that extend to other sections of the building for communication with application specific controllers and or sensors. General/application-specific controllers may be mounted directly to the HVAC system that is indented to be controlled. Two examples of controllers mounted directly to the HVAC system include 1) VAV controller/actuators mounted directly to dampers and 2) thermostats are mounted on the wall in the place of existing thermostats to capture zone level space occupancy, temperature, humidity, and CO2 measurement.

To estimate the cost of a BAS, it is recommended to collaborate with a contractor or sales representative. Ensure that the following information is specified in the quote for the system:

- Required BAS components
    - Building controller(s)
    - General/application specific controllers which may include:
        - RTU
        - Chiller
        - Boiler
        - FCU
        - Cooling Tower
        - Thermostats (optional CO2, humidity, occupancy sensing and I/O ports)
        - VAV actuator/damper
        - Others as needed
    - Other electrical components which may include:
        - 24 Volt AC or DC power supply(ies) to power the controllers
        - Ethernet switch (may be necessary when using many IP connection)
        - Valves
        - Actuators
        - Dampers
        - Others as needed
    - Sensors, which may include:
        - Flow
        - Temperature
        - Humidity
        - CO2
        - Pressure
        - Others as needed
- Electrical enclosure for controls
- Specialized electrical cables/conduit as needed by the control system

    - Cable for connecting central computer or network to BAS building controllers
    - Cable for connecting BAS building controllers to general/Application-specific controllers
    - Cable from thermostats to BAS controllers
    - Cable from BAS building controllers to expansion modules and/or I/O modules
    - Wires form BAS controllers to sensors
    - Conduit for wire protection
- Necessary software licenses – some software licenses are charged based on the following:
    - Number of points, both
        - Physical I/O terminal connections, and
        - Virtual points, which are one that are defined in the buildings program and can be monitored
    - Number of connections (communication wires) between the building controller and other building controllers, general controllers, and application specific controllers from that same manufacturer used in the building
    - Number of buildings being monitored (may need the enterprise level software)
    - SQL server to store settings, variables, and data (can be purchased through the BAS manufacturer or a 3rd party, and payments can be annual or onetime)
- Typical maintenance contract
    - Software Maintenance Agreement (SMA) for computer software, where applicable. Sometimes an expired license will still allow control, but outdated software versions may not be able to communicate with products that have a newer software version. Some manufacturers offer an optional software upgrade for a period of one year, while other manufacturers may require payment for backdated SMA fees in addition to the new SMA.
    - Controller SMA, where applicable.
- Commissioning of devices
- Startup training
- System Testing
- Maintenance
- Service contract (if desired)

Make sure to keep this information and the information compiled in the "Gather Project Information" section of the application guidance in mind when communicating with the contractor or sales representative to estimate the cost for the system in your building.

Remote Access

Remote access and reporting capabilities are related to the remote terminal, such as the web portal, provided for a BAS.

BAS are typically accessed with a computer either directly or through a network, but in some cases can also be accessed through remote terminals and smart phones. Accessing the BAS controls, trends and reports may require an additional software package. Some software applications are proprietary and additional features must be requested, purchased, commissioned, evaluated by the manufacturer, and users likely need to be trained. Other software applications are open source which allows for additional

control features to be added by downloading drivers online but still need to be commissioned and evaluated by an integrator. Users will also likely need to be trained on these features.

The user interfaces for different devices depend on the user account that is defined for that user and on the device being used. Users can be assigned different levels of access like read-only or full access with programming abilities. Some BASs access the internet and pull information from the other computers, applications, or systems through an application programming interface (API).

Security and Encryption

Security features are not widely advertised for BAS. Although BAS have a variety of security features, like password requirements, for logging into the system for each different user type and some BAS have more specific security features like encryption, complying with FIPS 140.2, complying with FIPS 201, having adjustable automatic logout times when no activity is sensed.

Grid-service Capabilities

Some BAS manufacturers mention demand response (DR) capabilities, but generally do not mention energy storage, renewable energy, or microgrids in their product literature. Some BASs have integrated Automated Demand Response (ADR) features, while others require third-party drivers to enable ADR capabilities.

Although controlling energy storage devices, renewable energy systems, and participating as part of a microgrid is not often listed in BAS product documentation, most BAS are programmable and use open communication protocols so they can integrate with nearly any other system. It is important to note that communication with systems that allow these grid-service capabilities may require additional costs beyond implementing a BAS to control HVAC only. Additional costs for these features may include component labor, installation labor, commissioning and/or training to ensure proper functionality.