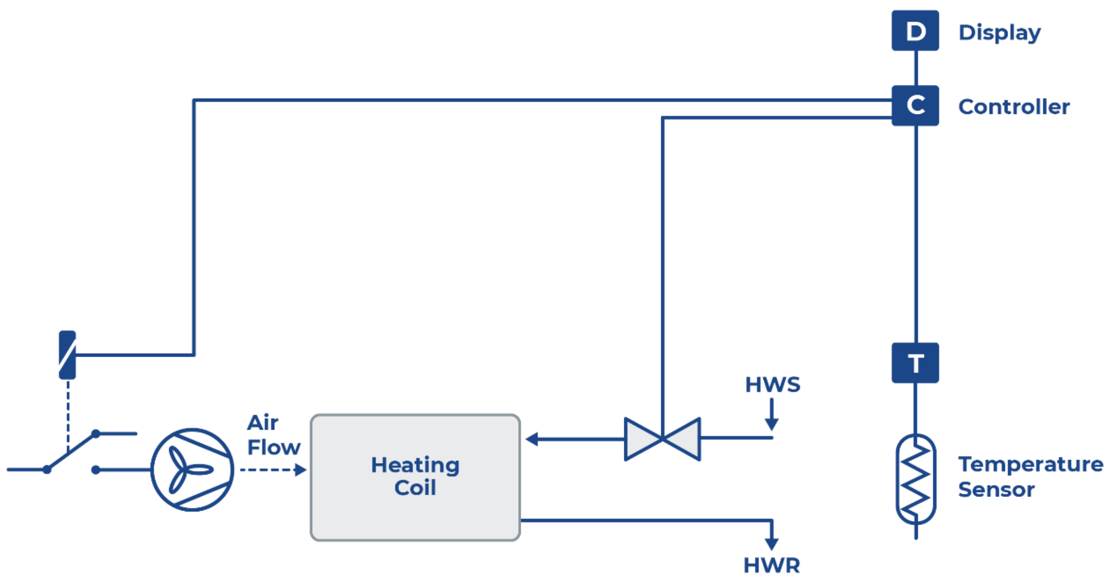
A basic automation system consists of a controller reading inputs from sensors and outputting commands to the equipment being controlled (e.g., a boiler for comfort heating or a chiller for air conditioning). Usually, the controller displays sensor readings and operating conditions in a connected or integrated display unit that allows operators to make selections or enter parameters.

Figure 1 shows a simple control system automation. The controller reads the zone temperature from the sensor and adjusts the control valve and fan to warm the zone until the space temperature reaches the set point entered by the operator. To save energy, the operator can program the controller to keep the fan running for a brief period after shutting off the hot water valve to extract all the thermal energy stored in the heating coil.

Figure 1. Example of a Simple Control System/BAS

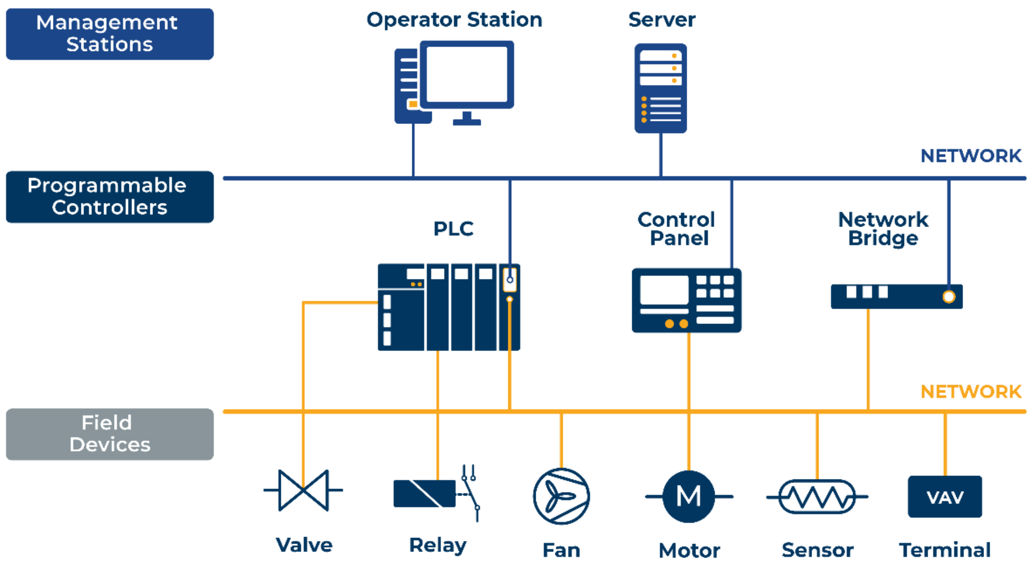


One of the simplest control systems widely used in buildings is a thermostat controlling a zone's constant air-volume box or fan-coil unit. A controller or a control system and a building automation system (BAS) are different in scale and complexity.

The term "automation" in BAS refers to the controls to operate building equipment running with little to no intervention by building operators, under normal conditions. The term "system" in BAS refers to a networked collection of controllers that react to changing conditions while maintaining the building's desired temperature conditions.

The typical BAS architecture has a hierarchy of four functional layers, as shown in Figure 2.

Figure 2. Simple BAS Architecture



- **Management Station:** A management station ranges from a simple panel display to a desktop PC and dedicated interface units. This configuration allows the operator to interact with the system, such as accessing readings (e.g., temperature values, ON/OFF status, etc.), changing set points and overriding automated actions when the situation is abnormal. Software and databases are usually hosted here, allowing for additional functionalities beyond control such as trending, alarming, reporting, and performing analytics.
- **Programmable Controller:** These specialty micro-computers are built with input and output channels to read signals from the field devices, perform computations, and send control signals to field devices. A programmable logic controller (PLC) is a common example. The inputs, computations, and output signals are read, calculated, and adjusted thousands of times per second, which is necessary to implement accurate control. PLCs communicate with the management station over a communication network using protocols such as BACnet and Ethernet to store data, display information, and receive commands.
- **Field Devices:** Sensors, relays, valves, switches, heating/cooling terminals, motor drives, and other electro-mechanical devices interface between the equipment/plant being controlled and the programmable controller. Examples of field devices are temperature sensors that read zone temperature, a control valve that adjusts the flow of chilled or hot water, a relay that operates the fan motor to move air across a heating/cooling coil, and a variable-frequency drive (VFD) that adjusts motor speed. Field devices connect to programmable controllers through dedicated input/output channels or over a separate communication network using protocols such as Modbus, FieldBus, or analog signals.

- **Networks:** Connections between field devices and the programmable controller, between the programmable controller and the management station, and between units within the same functional layer for communication. Usually, networks are hierarchical and are often a mixture of physical linkages such as RS232, RS485, and Ethernet. Both wired and wireless networks are commonly available.

BAS advanced from the early days of pneumatic control and electrical control to microprocessor-based digital control. The progression also brings sophisticated and accurate control strategies, from basic open-loop ON/OFF control to today's common "taken-for-granted" closed-loop proportional integral differential (PID) control. Taking advantage of cloud-based resources supplements and expands local functions performed by the BAS, from maintaining comfort to optimizing comfort, equipment health, and energy costs.

RTEM-Enabled BAS

Real Time Energy Management (RTEM) has the potential to achieve 15%-30% in energy savings[1] while improving occupants' comfort and wellness,[2] safeguarding compliance to codes and regulations, and ensuring proper operation for millions of dollars' worth of building assets.

Figure 3 shows the BAS architecture illustrated in Figure 2, expanded with RTEM. In the illustrated scenario, RTEM becomes an extension of the management station by internet-enabling analytics, fault detection, and fault diagnostic resources. The results of the analytics, such as adjusting set points, schedules, and operating conditions, are communicated back to the management station and dispatched to the programmable controllers and field devices.

[1] Methods for Fault Detection, Diagnostics, and Prognostics for Building Systems, International Journal of HVAC&R Research, Vol. 11, No. 2, April 2005. Srinivas Katipamula, senior research scientist, Michael R. Brambley, staff scientist at Pacific Northwest National Laboratory.

[2] Through integrating indoor air quality (IAQ) monitoring and optimization of the outdoor air exchange rate.

Figure 3: Expanding BAS Architecture with RTEM