THE NEWSLETTER OF THE E SOURCE CORPORATE ENERGY MANAGERS' CONSORTIUM

ENERGY MANAGERS' QUARTERLY

Third Quarter ■ September 2007

E SOURCE
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FEATURE

Saving Energy with a Building Automation System

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Advancements in computers, information technology, and communications protocols have made building automation systems (BASs) an effective technology for controlling heating, ventilation, and air conditioning (HVAC) systems in most new commercial and institutional buildings. BASs can also link lighting, security, fire-safety, and other systems together to make a building operate even more efficiently and effectively (see **Figure 1**, page 2).[1] Implementing BASs, which are now used in more than half of all buildings in the U.S. larger than 100,000 square feet, can be a hefty expense for the building owner of an existing building but can save an average of 10 percent of overall building energy consumption.[2] However, energy savings can vary depending on the age and maintenance record of the building as well as the implementation of the BAS.

Unfortunately, many of these BASs save less energy than they are capable of saving. For example, a study in New England that surveyed 11 buildings with BASs found that 5 of the buildings were underachievers, producing less than 55 percent of the expected savings. One site produced no savings at all. The main reason that contributed to the buildings' poor performance was that the intended BAS control strategies were never implemented correctly.[3] To improve the likelihood that BASs achieve their expected benefits, energy managers should properly document the system design and adopt a commissioning plan over the lifetime of the system.

BAS Basic Functions

The primary components of the BAS system include sensors, controllers, actuators, and software. These components work together to reduce energy consumption while maintaining comfortable conditions in a building. By implementing the basic BAS control strategies correctly, BASs can perform basic and effective functions to use energy more efficiently.

Inside EMQ

Corporate Energy Managers' Consortium

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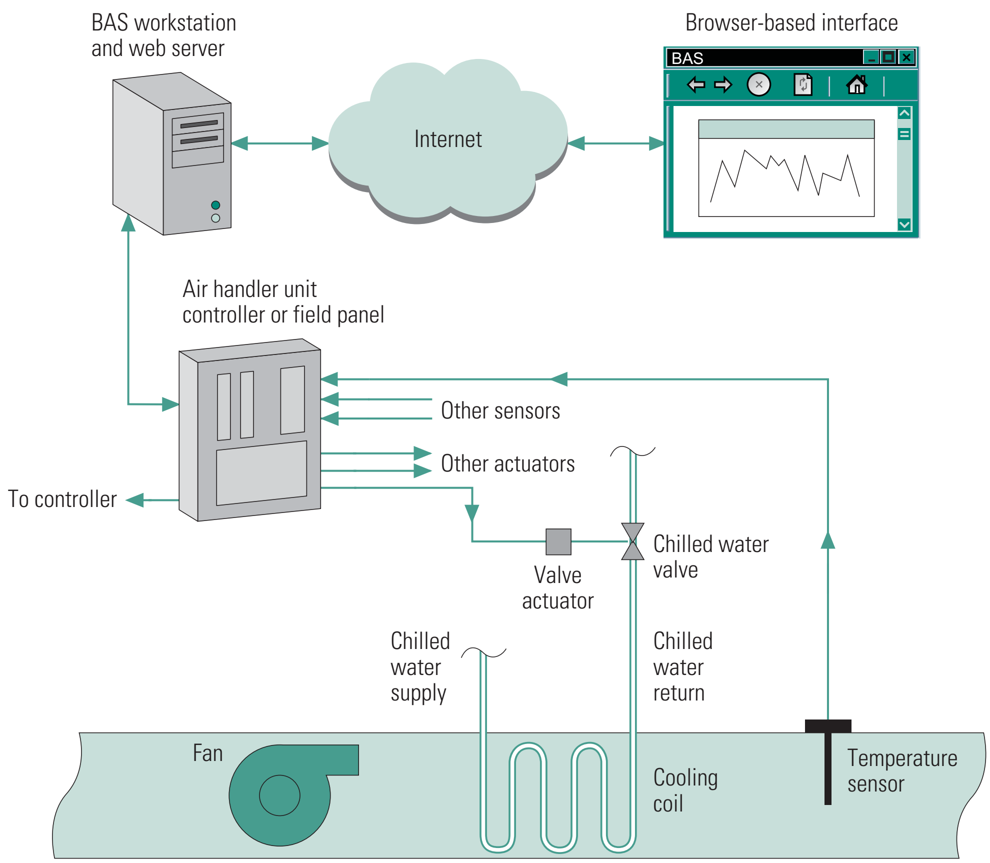
Run equipment only as needed. There is no easier way to save energy than turning off equipment when it is not needed or operating equipment at the minimum capacity required. Two of the most common strategies that can be employed in order to use less energy are scheduling and lockouts.

- *Scheduling.* This practice turns equipment on or off depending on time of day, day of the week, day type, or other variables such as outside air conditions. Improving equipment schedules is one of the most effective measures for saving energy in commercial buildings. For example, scheduling can prevent needless operation of equipment after hours and on weekends, eliminating one of the largest energy wasters in commercial buildings.[4] A feature called "Optimum Start," offered by all BAS manufacturers, can further increase energy savings by automatically starting a system no earlier than necessary based on daily variations in the weather.
- *Lockouts.* Lockouts ensure that equipment does not come on unless necessary and protect against glitches in the programming of the control system that may inadvertently cause equipment to turn on. For example, a chiller and its associated pumps can be locked out when a calendar date is set, when the outside air falls below a certain temperature, or when building cooling requirements are below the minimum.

Figure 1: Linking systems together with a building automation system

With a building automation system (BAS), systems can be connected through the use of sensors, controllers, actuators, and software. An operator interfaces with the system via a central BAS workstation, which can be connected to other BAS workstations via the Internet.



Source: E SOURCE; adapted from Portland Energy Conservation Inc. [1]

Optimally control equipment. Use equipment controls to accurately meet the load and to operate equipment in its optimum efficiency range:

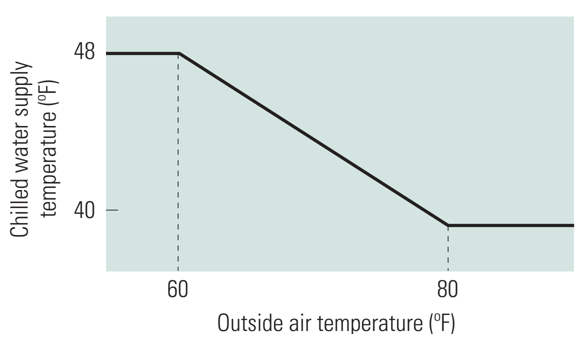
- *Direct digital control.* A standard part of any BAS, direct digital control (DDC) systems use electronic signals sent via computer to directly control valves, dampers, and so forth for building temperature control (as shown in Figure 1). They also typically provide feedback information from the building. The advantage of this approach (as opposed to using older conventional pneumatic or electronic controls) is that a more advanced control algorithm called proportional-integral-derivative (PID) control can be implemented in the BAS's computer code. Due to the complexity of this algorithm, older pneumatic or electronic controls used only the proportional form of this control technique, which is known for its inability to reliably maintain the temperature setpoint. If applied properly, PID control can both save energy and provide improved comfort. Proper implementation of a PID control algorithm is a complex process that is best left to experienced professionals.

- *Resets.* HVAC systems typically use less energy when their operating parameters are adjusted to meet the building load. Because this load varies with the weather, a BAS can help equipment to operate at greater efficiency levels by automatically varying these operating parameters. The simplest approach is to use a proportional reset schedule based on outdoor temperature (see **Figure 2**). Although that method works reasonably well, a more effective method is to base resets directly on building loads (see **Figure 3**, page 4). Examples of building control parameters that can be reset include supply-air and discharge-air temperature for fan systems that use terminal reheat, hot-deck and cold-deck temperatures for multizone HVAC systems, and heating water supply temperature.

Limit demand. Because electrical demand charges can make up 40 percent or more of a utility bill, many BASs have demand-limiting or load-shedding functions.[5] For example, when the demand on a building meter or piece of equipment, such as a chiller, approaches a predetermined setpoint, the BAS can be set to not allow the equipment to load up any further. In buildings with electric heat, electrical

Figure 2: Proportional reset schedule

As the outside temperature decreases, the chilled water temperature is reset to a higher value.



Notes: F = Fahrenheit.

Source: E SOURCE; adapted from Portland Energy Conservation Inc. [1]

demand charges can be reduced if the heat is staged on in the morning over a several-hour period starting with the coldest spaces first. Other demand-limiting strategies are expected to be developed as utilities implement time-of-day or real-time electrical pricing into their rate structures.

Use the BAS for diagnostics. Energy managers who use a BAS to monitor information such as temperatures, flows, pressures, and actuator positions may also use those data to determine whether equipment is operating incorrectly or inefficiently and to troubleshoot problems. In the past, this functionality was seldom used by energy managers largely because most buildings have an insufficient number of monitored points.[6] A thorough job of building diagnostics typically requires the building operator to monitor more points than the minimal number needed to simply control a building, but a modern BAS gives users a good head start on a recommissioning or an ongoing commissioning program.

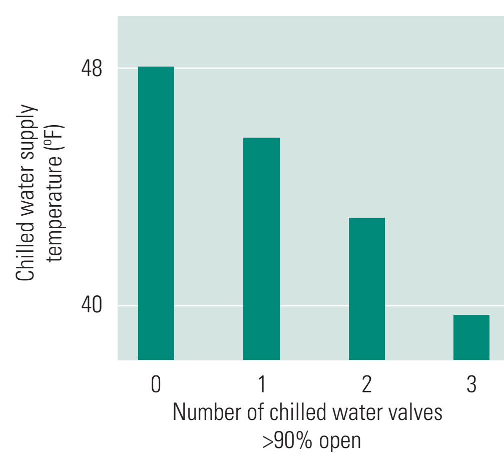
The Latest Trends

A couple of new BAS developments that are starting to emerge on the market come at a higher cost than a conventional system but allow for easier implementation and more effective controls.

Wireless devices. Although wireless communication devices are still being developed and are relatively expensive, they are now used in some applications because they are becoming more affordable and reliable with the development of new manufacturing techniques. They are not commonly used in buildings yet, but wireless technology may become a cost-effective choice in applications where it is difficult to install wiring.[7] For example, a wireless installation can add new capabilities quickly and with minimal disruption of operations, as opposed to running wires from fixtures and sensors back to a control unit, which could require ripping into and then repairing walls. The BAS application that wireless communications may possibly dominate in future installations is the field-level controller (that is, variable air volume box controllers). In this case, the cost of adding wireless communications to the controller will quite possibly be less than the labor and material costs currently required by the wire-based communications technologies used.

Figure 3: Direct load information reset

In this reset schedule, the cooling load is based on the number of chilled water valves that are greater than 90 percent open.



Notes: F = Fahrenheit.

Source: E SOURCE; adapted from Portland Energy Conservation Inc. [1]

One type of wireless network, called a mesh network, is a decentralized set of wireless nodes that are linked to one another to form a self-organizing, self-healing network. To provide multiple, redundant paths through the network, control is split among the different nodes. This network enables bidirectional communication between sensors and controllers at all times and can also cover larger distances with low levels of transmitting power.

Also, the ZigBee, a new open wireless communication standard, is enabling the development of wirelessly networked products that are reliable and low power and that provide much more flexibility than proprietary wireless systems. However, because buildings typically require a large number of sensor nodes (which drives up the cost), designing wireless systems is currently a balance of functionality and cost-effectiveness, with designers cutting costs by removing functions and limiting compatibility with external systems. As costs continue to come down, wireless networks will likely become much more prevalent in BASs.

XML and web services. Most companies involved in data exchange over the Internet have developed custom Internet applications using the Internet protocol called XML (Extensible Markup Language). XML (along with "web services," an Internet-based system for setting up XML applications) has emerged as the standard protocol for data exchange in many business sectors and has gained attention in the field of building automation. ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) recently published an extension to the BACnet standard—a data communications protocol standard for BASs—which defines how BACnet protocol information can be communicated using XML and web services. Concurrently, an organization known as CABA (Continental Automated Building Association) has developed a building automation–oriented protocol called oBIX (open building information exchange) that also utilizes XML. As these new standards see wider use, more aspects of building automation communications will undoubtedly migrate to the Internet. Further, the use of XML may allow BASs to seamlessly communicate with business enterprise software, such as accounting and business scheduling (for example, Microsoft Outlook) packages.

Smarter BASs. BASs are starting to incorporate more powerful algorithms based on artificial intelligence techniques. The first examples to appear are Optimum Start and PID controllers that have adaptive capabilities, which minimize efforts needed to tune these algorithms for the specific building and systems. More encouraging is the development of third-party software applications that detect faults and operating inefficiencies in building systems.[8] These applications can measure the performance of a building system and compare it to a modeled performance benchmark. When differences arise, the system can use these powerful algorithms to diagnose the problem and then alert the building operator. In time, these performance-monitoring capabilities may become more tightly integrated with BASs so that automatic system corrections can occur.

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Keys to Success

The success of a BAS requires commitment throughout a system's life cycle. Improper management of a BAS will likely cause the system to underperform and provide less energy savings than initially hoped.

Develop specifications for the system. Begin by talking to a variety of consultants and controls vendors. This process will provide the education you need to properly define your goals and needs and then match them with a good performance

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specification. Although most current BAS manufacturers produce equipment that will meet the needs of a typical project, each product line has different features (that is, the type of communications protocols used, the style of the graphics system, and so forth) that may or may not meet your needs. Therefore, it is important to do research into these features so that you know what you are buying. It is also important to determine which manufacturers are represented in your region and, if represented, to research the quality of service provided.[9]

Once you define your goals, it's important to make your specifications clear and understandable. Specifications are most effective when they provide complete information about the design intent, the control strategies, and the capabilities of the BAS itself, as well as the responsibilities of the project team. As a minimum, BAS specifications should include a custom-developed sequence of operation (a narrative description of how the BAS will control each of the building systems) and point list (which describes what inputs and outputs are connected to the BAS).

Unfortunately, the design intent is often underdocumented by the design team. A typical practice is to create BAS contract documents that simply state what to install, including a generic sequence of operations, and what the initial settings should be. In most situations, this does not provide sufficient information required for the programming of the system and performance verification before turnover, nor does it provide for good operations and maintenance after occupancy.

Implement commissioning. Commissioning is a systematic process that improves the likelihood that all building systems will perform interactively as intended. It includes specifications in the design phase, inspections during the installation process, tests conducted after installation is complete, and operator training. Building owners and designers can do three things to ensure a successful BAS commissioning process.

- *Select an able commissioning provider.* Hire an objective engineer with commissioning experience to review design documents, help write specifications, design tests, observe the testing phase, and assist with operator training.

- *Incorporate commissioning and recommissioning requirements into the specifications.* These specifications should be detailed and should include roles and responsibilities of the project team, installation and initial checkout procedures, functional test requirements, training procedures, and documentation requirements.

- *Ensure that the BAS is fully tested.* There are many standard functional tests that describe requirements and procedures for testing a BAS. In many cases it is necessary for a commissioning provider to customize these tests to more exactly match the technical requirements of the specific project.

As energy prices rise and improvements are made to BAS technology, BASs will likely become more commonplace in both new construction and retrofit applications in the future. With the emergence of wireless communication and complex control algorithms, they will continue to become more intricate. Addressing proper specifications from the start, however, as well as implementing a commissioning procedure, will help ensure that such powerful systems provide the promised savings to make these installations cost-effective.

Notes

1 Portland Energy Conservation Inc. (PECI), Portland, OR, 503-248-4636, contact@peci.org.

2 M.R. Brambley et al., "Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways," prepared for the U.S. Department of Energy by Pacific Northwest National Laboratory (April 2005), p. 2.7.

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4 PECI, "Energy Management Systems: A Practical Guide," prepared for U.S. Environmental Protection Agency (October 1997).

5 PECI [4].

6 Karl Stum, "Using Energy Management Control Systems for HVAC Operational Diagnostics," *Proceedings Eleventh Symposium on Improving Building Systems in Hot and Humid Climates* (June 1998), pp. 209–210.

7 Bill Lyon (July 19, 2007), Vice President of Energy Services, Federated Department Stores, bill.lyon@macys.com.

8 Kristin Heinemeier, "Fault Detection and Diagnostic Tools Ready for Prime Time," *Consulting-Specifying Engineer* (June 1, 2007), www.csemag.com/article/CA6454437.html.

9 David Clayton and Andy Chatha, "Building Automation Systems Worldwide Outlook: Market Analysis and Forecast Through 2006," ARC Advisory Group (2002), pp. 63–130.