BACnet® for Utilities And Metering

By **David G. Holmberg, Ph.D.,** Member ASHRAE; **Steven T. Bushby,** Member ASHRAE; and **James F. Butler,** Associate Member ASHRAE

Energy consumption in residential and commercial buildings accounts for approximately 40% (22% residential and 18% commercial) of total energy consumption in the United States, which is more than any other energy end-use sector. By comparison, the industrial sector accounts for about 32% and transportation accounts for about 28% of primary energy consumption.[1] Utility costs and the environmental impact of this energy consumption are important to facility managers and building owners. Building automation systems in general, and BACnet systems in particular, are important tools for managing energy consumption in commercial buildings.

Recently added features of BACnet can be used to better manage electrical consumption in commercial buildings. *Figure 1* shows how electricity typically is consumed in commercial buildings. The largest component is HVAC systems. Cooling is the most significant contributor to electrical consumption in HVAC systems (heating is mostly done using natural gas). After HVAC, the next largest component of electrical consumption in commercial buildings is lighting. The Lighting Applications Working Group of the BACnet committee has recently submitted for public review a generic lighting-output object that meets direct architectural switching and dimming needs.[3]

Managing electrical consumption in commercial buildings is a combination

About the Authors

David G. Holmberg, Ph.D., is a mechanical engineer in the Building Environment Division at the National Institute of Standards and Technology (NIST), Gaithersburg, Md. He is convener of ASHRAE Standing Standards Project Committee 135 (BACnet), Utility Integration Working Group. **Steven T. Bushby** is leader of the mechanical systems and controls group at the NIST Building and Fire Research Laboratory in Gaithersburg, Md. He is a past chair of the BACnet committee. **James F. Butler** is CTO of Cimetrics, Boston.

of finding ways to operate more efficiently, and managing peak loads to avoid or reduce demand charges. These goals are sometimes conflicting because peak load reduction may be accomplished through energy storage or other actions that shift the load to a different time at the expense of increased total energy consumption. This article focuses on BACnet features that can be used to measure electric loads (including submetering), control peak loads through shedding applications, and communicate with utilities to exchange real-time or near real-time information about loads and prices.

Measuring Electric Loads Using BACnet Objects

BACnet defines several standard object types that can be used to provide valuable information to facility managers about electric loads and trends in electrical consumption (*Table 1*). Analog Input objects can be used to represent instantaneous measurements of electrical consumption. Analog Value objects can represent calculated instantaneous consumption based on indirect measurements or other input. Measured or calculated energy consumption values can be trended and stored for analysis or historical comparisons, as with any other value in a BACnet system. The Averaging object type provides a convenient way to process electrical consumption data to determine minimums, maximums, or average values using a fixed or sliding window technique.

As with all BACnet objects, these objects are used in a building automation system as building blocks that can be combined and linked to the control and monitoring logic in completely flexible ways. This allows facility-specific measurement and management of electrical loads in the same way that other BACnet objects are used to represent custom sequences of operation for mechanical equipment control.

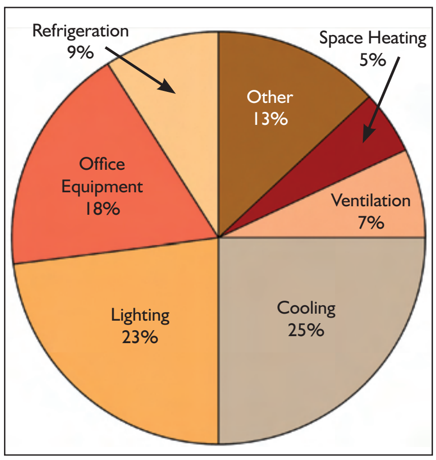

Figure 1: Commercial building sector electrical consumption by end-use, 1999 estimates.[2]

Submetering Applications

Submetering refers to the practice of using meters in addition to those installed by a utility company. Submeters typically measure the electricity consumption of a building space or the consumption of a particular form of energy by a building system. Submeters may be connected to the building automation system, but sometimes they are part of an independent system that includes a database and special software for metering applications.

Utility cost allocation is a common submetering application. For example, a university might install meters in every university-owned building to allocate utility costs to different departments or laboratories. Owners of multitenant buildings sometimes install submeters to enable them to bill tenants for their electrical consumption.

Data from submeters also can be used to improve building operations and detect possible equipment faults. Building operators can use energy consumption trends to identify unusual energy consumption patterns and measure the effect of energy conservation measures. Frequently, it is necessary to normalize meter data to account for the impact of variations in weather on energy consumption.

Control algorithms for HVAC systems also may benefit from real-time submeter data. At least one patent[5] describes a method for improving the efficiency of an air-conditioning system using a power consumption setpoint for the heat rejection devices. One can conceive of power demand management algorithms for building HVAC systems that involve the active adjustment of system setpoints and rely on real-time measurement of power consumed by chillers, pumps, and fans.

Managing Electrical Loads

One recent addition to the BACnet standard is the Load Control object type,[6] which is designed to provide a general, high-level interface used to manage shedding of electrical loads to reduce peak consumption or when responding to real-time price or utility load shed signals. Load Control objects can be linked in a distributed, hierarchical fashion for controlling arbitrarily complex combinations of electrical loads found throughout the facility.

The Load Control object's interface accepts commands that specify how much and when load reduction is required. Four specific parameters may be written: Requested_Shed_Level, Start_Time, Shed_Duration, and Duty_Window. The Requested_Shed_Level parameter may be specified as a "1, 2, 3" level, as a percentage of baseline, or as an amount (kW) to shed. The Load Control object can be in one of four states: inactive, shed request pending, shed compliant, or shed noncompliant, and the state is indicated in the Present_Value property.

The definition of the Load Control object does not specify how the electrical consumption is to be reduced or how consumption baselines should be determined. Whatever load reduction strategy is used, the building control system will require configuration and/or programming to implement the chosen strategy. The Load Control object provides an interface to execute predetermined control actions and to view the current load shed status of a facility.

Let's consider an example of how a Load Control object could help reduce a building's HVAC system electrical consumption. First, a mechanical engineer designs a sequence of operation for electrical demand reduction. That sequence is programmed into a supervisory controller in the building control system,

BACnet Object Types Used to Measure Electrical Consumption	
Accumulator	This object represents the characteristics of a meter that indicates measurements by counting pulses. It is used for peak load management and account billing applications where accurate representation of the measured value is critical.
Analog Input Analog Value	These object types are used for a wide range of control and monitoring applications. They are well suited for representing instantaneous electrical consumption and are often used in submetering applications. Common implementations of these object types are constrained to a precision of approximately six digits. This can make them unsuitable for representing cumulative consumption with high accuracy over long periods of time.
Averaging	This object type is used to calculate the minimum, maximum, and average values of a numeric property value in another BACnet object using a sliding-window technique. Averaging objects can be configured to mimic the electrical demand calculation done by some electric meters.
Load Control	See discussion in article text.
Pulse Converter	This object represents the characteristics of a measurement process where the value being measured is represented by pulses or counts. It is used for peak load management and account billing applications. A Pulse Converter object does not have a guarantee of accuracy found in an Accumulator object, e.g., some pulses or counts can be lost.
Trend Log; Trend Log Multiple*	These object types are used to collect and store time-series data. The data can be retrieved for display or other processing using the ReadRange service. Objects of these types are used to collect and manage utility consumption trends.

*This object type is still in public review and is not yet officially part of the BACnet standard.[4]

Table 1: *BACnet object types that may be used to track electric loads and trends in electrical consumption.*

and a new Load Control object in that controller is configured to trigger the demand reduction sequence. A building energy management application can write to properties of the Load Control object in a way that is equivalent to saying, "reduce

Advertisement formerly in this space.

Advertisement formerly in this space.

demand to 90% of baseline for 180 minutes starting at 3 p.m." Processing this request triggers a preprogrammed sequence of steps to reduce electrical load. Properties of the object show the progress in complying with the requested load reduction.

It is expected that the Load Control object will become an important component of future automated demand response systems because it standardizes one communication interface between utility energy management systems and electrical loads.

Building–Utility Communication Standards

Because buildings represent such a large portion of a utility's electrical load, they can play an important role in promoting a more reliable electrical grid and an energy-efficient future. This has important financial implications for the building owner and utility. Buildings can act as a resource to provide power for peak control, whether by bringing distributed generation on-line, shedding loads, or by reshaping the load profile using energy storage. Considering that the average cost of electricity at peak can be 10 times off-peak rates,[7] a strong incentive exists for building owners to cooperate in reducing peaks. Utilities benefit by reducing the need to build and operate expensive peaking power plants and by gaining more tools to use for improving the stability and reliability of the electric power supply. Effective, automated communication between utilities and building energy management systems will be a critical component of realizing this potential.

Until now, utilities' efforts toward automated demand reduction have primarily focused on residential customers because of the direct access they have to loads versus commercial customers where every building is different and the utility cannot shut down equipment. The commercial market has traditionally required either custom system integration to allow automated load shedding, or manual communications to request a load shed.

California is at the forefront of automated demand response (DR) efforts, working to fulfill a state agenda driven by constraints on power resources. An electricity demand response activity has been defined as, "an action taken to reduce electricity demand in response to price, monetary incentives, or utility directives so as to maintain reliable electric service or avoid high electricity prices."[8] Leaders in DR efforts include the Demand Response Research Center (DRRC), OpenAMI (a user community developing the Advanced Metering Infrastructure), investor-owned utilities, and the Electric Power Research Institute. The DRRC has produced an initial draft standard interface for automated demand response for use in communicating with commercial customers. Their "Demand Response Automation Server" uses Web services to send simple

Advertisement formerly in this space.

Advertisement formerly in this space.

event shed information to demand response clients at customer facilities, who then act upon the shed request. The current draft discusses three generic types of utility–building communications: load shed event notifications, demand bidding, and real-time pricing. The BACnet Utility Integration Working Group (UIWG) is supporting this effort by providing the perspective of the commercial facility energy manager and the BACnet committee.

California is not the only state with DR programs. The U.S. Department of Energy reports that 45 states have demand response/load management programs, which provide incentives to curtail demand and reduce load during peak periods in response to system reliability or market conditions.[9] On the federal level, the Federal Energy Regulatory Commission sees DR as a tool for improving grid reliability and encourages measures leading to a healthy electric market allowing demand bidding of load sheds and distributed generation. The BACnet UIWG desires to work with any program that focuses on commercial buildings to promote BACnet and develop and demonstrate the best ways for achieving demand response.

Another important player in the drive toward standard communication interfaces between buildings and utilities is the Department of Energy's GridWise Initiative.[10] GridWise advocates for advanced communications and up-to-date information technology to improve coordination between supply and demand, and enable a smarter, more efficient, secure and reliable electric power system. GridWise is serving as a platform where many stakeholders can meet, including utilities, energy companies, and governmental organizations.

BACnet serves as an increasingly important standard in commercial building automation systems. As described in this article, it has features already being used to implement electrical load management in commercial buildings. Representatives of the BACnet committee are part of the utility-driven activities to develop building–utility interfaces. The recent addition of BACnet Web Services provides a tool that may play a key role in a future building–utility communication interface.

Role of BACnet Web Services

Web services have become a hot technology in the mainstream IT world because Web services can make it easier to integrate computer applications over a network. An increasing number of popular business applications can function as Web services clients, and modern software development tools make it easy to add Web services functionality to custom software applications. As defined by the World Wide Web Consortium (W3C), Web services are typically implemented using Extensible Markup Language (XML) and the Simple Object Access Protocol (SOAP). Because SOAP and XML are relatively verbose compared to most network protocols used for control applications, Web services are most appropriate for high-speed networks in which bandwidth is not a major concern. Web services are unlikely to be the basis for new control protocols anytime soon, but they can play an important role in facilitating the flow of information between control systems and other systems.

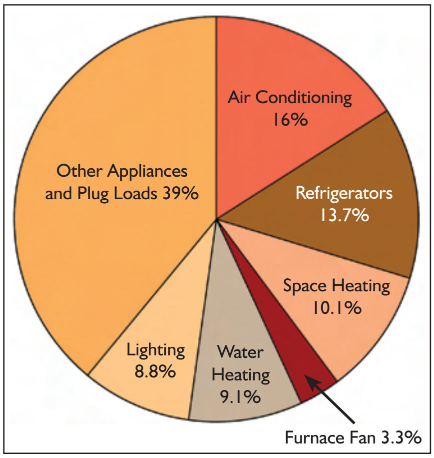

Figure 2: Residential end-use consumption of electricity, 2001.[12]

The BACnet Web services specification[11] was designed to make it easy for business applications to access data in building control systems. The data model was intentionally designed to be generic, allowing BACnet Web services to be used with a wide variety of data sources, including control systems that do not communicate using BACnet. The data access services are also generic, allowing the Web services client to read and write simple data values (integers, real numbers, strings, dates, etc.) and to retrieve trend data.

It is likely that BACnet Web servers will become common components of building automation systems because they provide convenient access to building automation system data through an interface that is well understood by developers of a wide range of management software. As the details of the communication needs between buildings and utilities become clearer, it is expected that BACnet Web services will be expanded and become the primary means for building–utility interactions as part of a utility industry standard.

It was previously pointed out that residential buildings account for a substantial portion of national energy consumption. *Figure 2* provides a detailed breakdown of the typical electrical loads for residences. From the perspective of the utility, it is beneficial to have a similar load management interface for all buildings. Even though BACnet technology is not generally used today in residential applications, the desire for a common, or at least similar utility interface, could provide the incentive for considering a BACnet Web services interface, that could be applied to both commercial and residential applications.

Conclusion

Building energy consumption is the largest energy end-use sector in the nation. Energy costs, environmental impacts, and the need to manage electrical grids for reliability and stability are all strong drivers for automated electrical load management in buildings that involve interaction with utilities. BACnet technology dominates new and retrofit building automation applications for commercial buildings. Support already exists in the BACnet standard for measuring electrical loads and managing sophisticated load shedding strategies, and support will soon be available for lighting control. This covers the building automation side of electrical load management well but there is a missing piece, a standard interface between building automation systems and utilities.

Members of the BACnet Utility Integration Working Group are working with the GridWise Initiative, the Demand Response Research Center, and other national efforts to standardize communication between utilities and their customers. It is expected that extensions to BACnet Web services will play a key role in the solutions that evolve. The end result will be an effective set of tools for utilities and building managers to collaborate in reducing energy consumption and managing peak loads. The solutions for commercial buildings could also play an important role in residential applications.

References

1. U.S. Energy Information Administration. 2006. "Energy Consumption by Sector." Figure 2.1a. http://tinyurl.com/7wor (or www.eia.doe.gov/emeu/aer/pdf/pages/sec2.pdf).

2. U.S. Energy Information Administration. 1999. "Commercial Buildings Energy Consumption Survey (CBECS), Preliminary End-Use Consumption Estimates." http://tinyurl.com/2d4boh (or www.eia.doe.gov/emeu/cbecs/enduse_consumption/intro.html).

3. Addendum *i* to ANSI/ASHRAE Standard 135-2004, *A Data Communication Protocol for Building Automation and Control Networks*. www.bacnet.org/Addenda/index.html.

4. Addendum *b* to ANSI/ASHRAE Standard 135-2004. www.bacnet.org/Addenda/index.html.

5. Hartman, T. 2001. U.S. Patent 6,257,007,2001.

6. Addendum *e* to ANSI/ASHRAE Standard 135-2004. www.bacnet.org/Addenda/index.html.

7. U.S. Government Accountability Office. 2004. "Electricity Markets: Customers Could Benefit from Demand Programs, But Challenges Remain." www.gao.gov/new.items/d04844.pdf.

8. U.S. Federal Energy Regulatory Commission. 2007. "Assessment of Demand Response and Advanced Metering." Staff Report. http://tinyurl.com/38ze3p (or www.ferc.gov/legal/staff-reports/09-07-demand-response.pdf).

9. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Energy-Efficiency Funds and Demand Response Programs. http://tinyurl.com/2hzdps (or www1.eere.energy.gov/femp/program/utility/utilityman_energymanage.html).

10. U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability (OE), Electric Distribution Program. www.gridwise.com.

11. Addendum *c* to ANSI/ASHRAE Standard 135-2004. www.bacnet.org/Addenda/index.html.

12. U.S. Energy Information Agency. 2001. "Residential End-Use Consumption of Electricity." http://tinyurl.com/2ap3la (or www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html).