Intelligent Building Automation: A Demand Response management perspective

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ABSTRACT
In recent years intelligent Building Automation Systems, based on best-practice open technology, have succeeded in helping facilities reduce their infrastructure, installation and operating costs. The idea was – "the less the human intervention and the more automated the system then the more efficient the building".

With that in mind a question may arise as to whether this philosophy has been successful in educating the consumer on the importance of energy efficiency or has it actually alienated him? Would it be more effective if the consumer were to be part of the efficiency process? What about if the energy savings could be passed on to the consumer directly depending on how efficient he was?

Demand response is a mechanism by which consumers change the energy consumption in response to energy price fluctuations, demand charges, or a direct request to reduce demand when the power grid reaches critical levels.

However, in order for a demand response regime to be effective the building will need to have a number of "pre-requisites" in place.

MOVING BEYOND BASIC ENERGY CONTROL

Many commercial buildings today have the original building automation system (BAS) system in operation. It is also not uncommon for facilities to have no controls or automation at all, and instead use simple programmable thermostats installed by the HVAC equipment provider. Of course, there are many variations of control depending on the building size, design, configuration, and use factors.

So what kind of control is necessary for optimal energy performance and reasonable return-on-investment? The answer depends largely on the building, how it is currently used and planned for use, and the desired cost-savings timeframe.

It is inexpensive to implement basic controls. However, while initial costs are lowest, the building owner's ability to more aggressively manage energy is compromised by these low-cost, fixed-function solutions. This means there is limited or no capacity to do more with the system. Hence, when energy costs rise, there is no easy or cost-effective way to respond because all of the systems' energy saving features are already being applied. Additional costs must then be incurred to implement control strategies that could have been designed from the start in a more scalable BAS.

Today's BASs can be expanded to control every piece of equipment in the building, including pumps, fans, valves, dampers, compressors, lighting, and more. Integrated systems can link disparate functions such as card access to lighting and climate control in any number of divided zones of a building. If a new application of control is necessary, choosing a good BAS results in a flexible and scalable system that protects the building owner's initial investment in controls. This makes it possible for the system to be expanded in the future should the need arise. Where existing controls are already in place, the building owner should evaluate whether software can be modified or upgraded to achieve the desired results.

BEST PRACTICE CONTROL STRATEGIES

If a BAS is either being considered or already in place, the building owner's options for taking greater control of energy demand increase dramatically. Well designed building automation can save a property owner 5% to 20% annually[1] in energy costs; more if the office currently runs climate and lighting around the clock.

The following are a few best practice control strategies commonly implemented by BASs and proven financially justifiable by commercial property owners.

Fundamental Control Applications

This is the starting point for the building owner who wants to move beyond programmable thermostats or sensor-activated lighting controls. Techniques for fundamental control include: occupants are in the facility.

Zone Scheduling – Permits defined sections of a building to have HVAC and lighting reduced or shut down on a schedule. Zone scheduling means that a whole building does not need to run at a 100% comfort setting if on only a few occupants are in the facility.

Night/Unoccupied Setback – Changes the comfort settings (setpoints) of HVAC so that space temperature decreases in winter and increases in summer, thereby reducing demand for heating and cooling during unoccupied hours. This feature can also be done using a programmable thermostat, but with only a few schedules and no flexibility to more aggressively change setback temperatures.

After-Hours Override – Allows temporary changes to comfort settings after-hours. This eliminates the need to modify schedules, which can sometimes become permanent by accident. This also avoids having the entire building run in occupied mode to meet the needs of a small group.

Occupancy Sensors – Detect motion or infrared signatures in the space, and trigger lights or HVAC accordingly. The BAS also enables scheduled overrides or triggers based on card access to an area of the building.

Holiday Scheduling – A calendar defines HVAC and lighting control for an entire calendar year, saving staff time implementing special schedules and ensuring holiday weekdays do not run in occupied mode.

Advanced Control Applications

In most cases, the same BAS put in place for fundamental controls is also capable of more advanced control applications, often with only software changes. Techniques for advanced control include:

Follow Sunrise & Sunset – Permits lighting schedules (such as parking lots, signs, and outdoor access lighting) to vary throughout the year as the length of daylight changes. This prevents lights from being on during the daytime. The BAS automatically computes sunrise and sunset based on the latitude and longitude of the building's location.

Daylight Harvesting[2] – In zones of the building near exterior walls and windows, lighting can be dimmed or shut off based on specified minimum lighting levels detected by photocells. Controlled use of motorised shades can also optimise the availability of natural light without compromising energy efficiency.

Optimum Start – Starts HVAC equipment only as early as required to bring the building setpoints to comfort levels for occupancy. Control routines take into account outside air temperature and inside space temperatures when initiating the morning warm-up or cool-down cycles. Optimum start takes the guess-work out of scheduled.

Optimum Stop – Determines the earliest possible time to initiate setback temperatures before unoccupied periods while still maintaining occupant comfort. Also known as "coasting." Space temperature drifts gradually beyond comfort levels in anticipation of the unoccupied period.

Ventilation On Demand – CO2 levels in the occupied space are used as an indicator of the number of occupants in a room. Calculations are then performed that relate the CO2 level to the fresh air intake damper, indicating when more outdoor air is needed. CO2 levels also assist heating and cooling anticipation in thermostatic control to optimise comfort and air circulation.

Variable Air Volume (VAV) Supply Air Temperature Reset – The supply air temperature (SAT) of variable volume air handlers can be reset upwards when full cooling is not required. The SAT setpoint is increased on cooler days based upon the actual building load. Then when terminal boxes reach 100% open, the SAT is decreased. This minimises the need for mechanical cooling, optimises the use of economisers, and improves tenant comfort by reducing drafts due to the movement of excessively cold air.

Demand Limiting or Load Shedding – Monitors electric meters and current draw on high-demand equipment, then relaxes setpoints to immediately reduce demand. This technique can, for example, prevent a chiller from further loading, but can also globally change setpoints throughout the building to shed electric load to avoid peak utility charges. Non-critical equipment and lighting loads can also be shut off. Discussion and planning usually occur with the customer in advance so the right strategies are implemented that fit the business.

Chiller Optimisation – The chilled water loop temperature can be raised as the cooling requirements for the building are reduced, increasing chiller efficiency. A technique known as "load reset" raises the chilled water temperature setpoint until one of the chilled water valves is 100% open.

Cooling Tower Optimisation – The condenser water supply to the chiller can be decreased to a minimum setpoint, as defined by the manufacturer. Then an optimal water supply setpoint can be calculated using a combination of the outside air wet-bulb temperature and the cooling tower approach temperature. The reduced water temperature improves the chiller's partial load efficiency and also optimises the cooling tower's operation.

Hot Water Reset – Hot water system temperatures can be reset based on outside air temperature, decreasing heat losses in supply piping. This saves energy and also makes the office space more comfortable because it reduces localised heating caused by excessively hot pipes.

Integrated Control Applications

The concept of integrated control is an extension of fundamental and advanced control, but with links to more diverse parts of the commercial office. Integrated control provides a high level of potential business benefits, plus the flexibility to expand control, at least cost, for future energy savings objectives.

Variable Speed Drives (VSDs) – VSDs optimise the power consumed by HVAC fans, speeding up or slowing down the fan based on climate demands of the space under control. A 20% reduction in fan speed (and air flow) results in a 49% decrease in electrical consumption[3]. Integrated control of VSDs can also be part of a load shedding strategy.

Card Access Triggers HVAC and Lighting – Card readers used for entry into the building trigger lighting and climate control for the specific area where the card-holder works. Lights turn off on a schedule or based on occupancy sensors. This is especially useful to save energy at properties with multiple tenants and unpredictable occupancy periods.

Reporting and Billing – The BAS logs data from HVAC operation, utility meters, indoor and outdoor temperature trends, and other devices. This data is then used to view weekly, monthly, or annual trends in energy consumption. Proper reporting provides early warning when energy efficiency begins to "drift." Leased space can also be billed for actual energy consumption.

Smart Circuit Breakers – The BAS runs software that can switch on and off electrical circuit breakers (known as "smart breakers"). This enables integrated control of lighting and electrical consumption, which reduces the need for a separate lighting control system installation, training, and maintenance.

Third-party Equipment – Systems such as HVAC equipment, fire detection systems, alarm systems, smoke evacuation systems, and elevators are integrated into a single BAS. This type of integration brings total control of the facility to a single graphical interface.

Central Monitoring and Control – Maintenance staff or the energy manager can monitor and control the whole building from a single console, either on-site or remotely over the Internet. Alarms defined by the user can appear at the console, or be sent to an email address or cell phone. The energy service provider can also perform remote monitoring.

These are examples of best practices in control operations, though not an exhaustive list. There are many techniques that apply to the specific equipment of a commercial office in a design-to-suit offer. No matter what level of automation or control is present, a building owner should be inquiring with their supplier about whether any of these techniques can be achieved with modifications to an installed BAS.

ENERGY LIFECYCLE SERVICES

We have discussed the business motivators around energy relating to owner-occupied and tenant-occupied commercial buildings. And we have outlined best practice techniques that apply a BAS toward solving the costs related to energy demand. This section now discusses energy services, and how ongoing review of energy practices can ensure energy management objectives are continuously being met.

COMPLETE BUILDING ENVELOPE

Unless a BAS is maintained and upgraded regularly, it is likely there are energy inefficiencies. Buildings are known to "drift" out of control over time due to reconfiguration, changes in use, staffing changes, lack of training, and relaxed operations and maintenance (O&M) practices.

Energy conservation measures should not be looked at individually without considering how they interact and impact other planned steps toward energy efficiency. So an important aspect of energy conservation is to manage demand with control systems combined with energy services that apply to the complete building envelope, including windows, walls, foundation, basement slab, ceiling, roof, and insulation. Looking at the building envelope broadens energy management beyond just smart BAS techniques. It considers non-control facets of the building that can affect energy demand. Energy services, usually part of an energy program, are designed to maintain optimum energy efficiency after initial efforts to establish energy conservation are put in place.

Figure 1 illustrates the typical energy consumption over the course of time in a building.

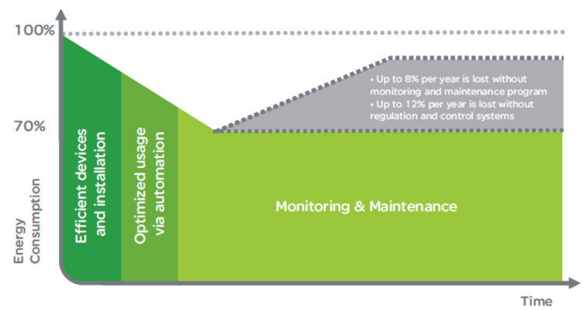

Figure 1. Energy Consumption Analysis

TYPES OF ENERGY SERVICES

Experience tells us that early identification of excessive energy expenses can often be corrected for very little cost with regular service to controller software, schedules, and economiser operation, and by practicing simple and inexpensive maintenance procedures. Ignoring, or not even seeing spikes in energy costs can consume many times what the remedy would have cost had it been implemented in a timely manner. Energy services that look at the complete building envelope include:

i. Outsourced remote monitoring and reporting
ii. Outsourced operations & maintenance, including controls
iii. Alarm notification and mechanical service response
iv. Building automation system fine-tuning
v. Periodic energy audits and reports of recommendations
vi. Evaluations of infrastructure that relate to energy consumption, such as roofing, glass, airlocks, insulation, etc.

vii. Assistance finding government rebates and financing

viii. Comprehensive energy efficiency programs

Once initial steps are taken to maximise energy efficiency, periodic reviews ensure office configuration, equipment, controls, or other systems have not been altered by users or maintenance staff. Energy efficiency “drift” can defeat the best intended energy program. A trained and qualified energy specialist understands the complete building envelope. Expert services, combined with effective knowledge of controls help commercial building owners maximise savings, not just once, but on an annual basis.

DEMAND RESPONSE

Occasional storms and heat waves, as well as periodic shut down for maintenance can affect the supply/demand for electricity. When demand is high and supply is short, the price of kWh can be multiplied by more than 10.

In this critical context, it is essential to lower the demand on one side (Demand) to be able to respond for peak demand periods on the other side (Response).

Moreover, Demand Response solutions allow much more efficient use of generation and T&D network capacity.
It helps protecting the environment avoiding start up of huge CO2 emitters like gas, coal or oil generation units.

Demand and supply on the electricity grid need to be in balance at all times. Therefore, system operators meticulously monitor and forecast energy demand in order to provide the matching amount of supply throughout the day and year. When the matching amount of supply is either unavailable or expensive to acquire, demand response plays a key role. Without demand response, electricity would be less reliable and more expensive.

Demand Response Types

There are two types of demand response[4]:

Emergency demand response: When electricity demand peaks during the middle of a day with unusually hot or cold weather conditions, the matching amount of supply may not be available. In order to avoid a power outage, electric utilities call upon their emergency demand response programs.

For example, some utilities have a program where large commercial and industrial customers reduce their electric load to a previously agreed upon level during emergencies. Although this program is only called upon once every two or three years, it has helped avoid costly power outages.

Economic demand response: As electricity demand increases, the cost to acquire supply increases. When demand is low, supply comes from relatively inexpensive base load generation, such as coal or nuclear power. When demand is high and base load generation is exhausted, supply comes from relatively expensive peaking generators. Although residential customers pay a flat rate, the price their utility pays for electricity generation constantly changes. The flat rate you pay reflects the average cost to deliver the electricity throughout the year.

Economic demand response lowers that average cost by providing incentives for customers to use electricity off-peak. For example, many utilities offer time-of-use electric rates, which are higher during the day and lower at night.

Electricity is more reliable with emergency demand response, and less expensive with economic demand response.

Figure 2 demonstrates the relationship between electricity consumption and price.

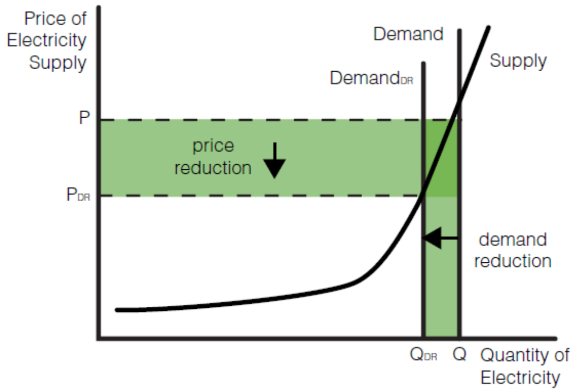

Figure 2. Demand Response mechanism

Demand Response Effectiveness

Demand response program participants can earn back 5-25% of their annual energy costs[5]. Typically, facilities also find demand response as a means for better integration into their business processes and way to begin treating electricity as manageable cost. The revenue generated from demand response participation is often used for capital improvements such as equipment upgrades. The savings values vary based on speed, location, and willingness to participate. These factors can mean the difference in hundreds of thousands versus tens of thousands of dollars.

Examples of participation strategies are depicted in Figure 3.

Demand Response Participation Strategies					
Activity	Office Buildings	Retail	Data Center	Healthcare	Industrials
Turn off non-essential lighting, fountains and decoration	•	•		•	
Raise air conditioning set points	•	•	•	•	•
Reduce use of elevators and escalators		•		•	
Delay dishwashing, laundry and ice machines	•	•			
Delay battery chargers, scrap compactors and bailing machines	•			•	•
Delay batch processes and non-essential pumping machines					•
Turn on allowable on-site generation	•	•	•	•	•
Shift load to alternative locations			•		

Figure 3. Demand Response Participation Strategies

Demand response monitoring and control systems programs make it possible for the participant to initiate control actions to shed a pre-defined amount of load. There is no walking around to make adjustments when the reduction request is received. Plus automatic participation provides better payback via improved participation levels and therefore greater financial benefit.

Demand Response Cycle

The cycle, Figure 4, begins with a notification being sent by the demand response provider.

Following its receipt, the consumer determines when and if he can curtail his energy usage based on the energy and demand profile.

Upon acknowledgement, a load control schedule is performed with predefined curtailment scripts.

This in turn allows the consumer to accept or reject the curtailment response, thus potentially creating the cost savings.

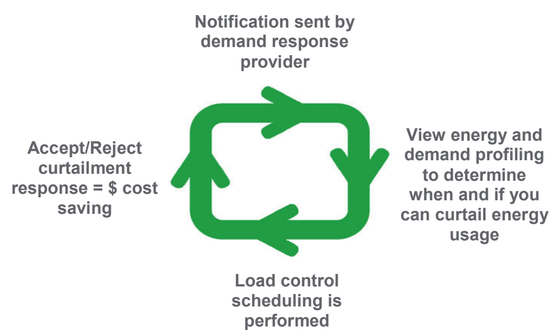

Figure 4. Demand Response Cycle

PLANNING FOR DEMAND RESPONSE PROJECTS

The planning of a demand response programme is vital. A project being executed in the United States is one of many of such initiatives, the details of which are shared as follows.

The Building Owners and Management Association (BOMA) of Chicago Smart Grid programme objective is to:

i. Deliver a utility scale, green "virtual generator" to 263 member buildings
ii. Reduce the peak load by 20%, or 200 MW
iii. Cut participants' implementation costs by 50%
iv. Provide innovative new financing for participants' cost share

The initiative is one of the largest aggregation and integration of commercial buildings programmes designed to provide demand response, operating reserves, and frequency regulation from demand side resources.

BOMA/Chicago represents 263 buildings housing private, institutional and government/public uses in the City of Chicago.

In aggregate, member buildings total over 150 million square feet of office space, and comprise an estimated 5% of the largest Illinois electric utility (ComEd) system load.

The benefits to participants of the programme included:

i. 50% cost share from stimulus funds for qualified projects
ii. Optional financing with no additional out-of-pocket expense
iii. Creation of new building revenue streams from wholesale market revenues
iv. Reduced operating expense & upgraded building systems
v. Enhanced asset value

Equally as important, the benefits to society of the programme included:

i. Annual energy cost reductions of $82 million
ii. Reduced carbon emissions of 300 million pounds annually
iii. Demonstration of collaboration among private sector, government, utilities, regional transmission organisation, and private lenders
iv. Ability to measure and verify regional economic and environmental benefits in unprecedented scope, scale, and granularity
v. Creation or retention of over 2,000 jobs
vi. Opportunity for replication in other markets

The key tasks to implement the programme were as follows:

i. Identify individual building infrastructure requirements
ii. Upgrade existing building systems & devices to enable smart grid functionality
iii. Install smart meters & AMI system to communicate market price information
iv. Install Network Operating Centre to aggregate and coordinate interaction of buildings with power grid

CONCLUSION

Demand response monitoring and control system programs make it possible for the participant to play a major part in energy optimisation. However, in order for demand response to be effective it is crucial to have a strategy in place.

This begins with having an intelligent building automation system, coupled with metering and data management tools. An audit is then required to assess the best load reduction strategies for your facility. Additionally, an assessment of the financial opportunity that demand response participation will mean needs to be carried out.

Participants are also able to engage in incentive management schemes that allow savings to be traded for various regulated and non-regulated services.

ACKNOWLEDGEMENTS

Schneider Electric

Schneider Electric is a global specialist in energy management with operations in more than 100 countries, Schneider Electric offers integrated solutions across multiple market segments, including leadership positions in energy and infrastructure, industrial processes, building automation, and data centres/networks, as well as a broad presence in residential applications.

Focused on making energy safe, reliable, and efficient, the company's 100,000 employees achieved sales of more than 15.8 billion euros in 2009, through an active commitment to help individuals and organisations "make the most of their energy."

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1 *Portland Energy Conservation, Inc. (PECI) study for the U.S. Department of Energy, Fifteen O&M Best Practices for Energy-Efficient Buildings, September 1999.*

2 *According to the California Institute for Energy Efficiency and the U.S. Department of Energy, 77,000,000 MWh of electricity are consumed in the United States each year for lighting buildings' perimeter zones where daylight is already present.*

3 *Based on employed and demonstrated historical best-practices at Schneider Electric*

4 Energy DSM. *Josh Schellenberg.*

5 *Based on employed and demonstrated historical best-practices at Schneider Electric*