Demand Response And Light Control

By Scott Ziegenfus, Member ASHRAE

In basic terms, demand response (DR) is a strategy for managing customer electricity consumption in response to fluctuations in the electrical supply. The overarching goal of DR is to keep electricity supply at a steady and controllable state, but the impetus for DR implementation can vary significantly. Facilities can be driven by a temporary need to avoid outages resulting from environmental factors (environmental DR), or a more permanent need to manage daily electricity usage for economic considerations. Because electricity is a traded commodity, its price is set by basic supply and demand, and managing daily peaks has an economic advantage (economic DR).

As legislated DR becomes more prevalent in building codes, companies will benefit from installing DR-ready technologies that can be integrated into building management systems (BMS). Intelligent control strategies that manage all light in a space including electric lighting, HVAC, and even fenestration systems will ultimately enhance a facility's responsiveness and help support an active, rather than passive, DR strategy. Intelligent controls that use higher-order logic and analytics will best meet DR goals without compromising comfort and productivity.

Ways to Participate in DR Programs

Companies are motivated to participate in DR programs based on a variety of factors including how much of their own electricity they produce and the on-site systems that enable them to control, generate, and/or store regulated power. Depending on the area of the country, a customer may deal directly with the utility bulk supplier (like the manufacturer), or with a third party—either a Regional Transmissions Operator (RTO) or Independent Systems Operator (ISO)—who then coordinates, controls, and monitors grid operation with the use of Curtailment Service Providers (CSP) who interface with the facility. Any or all of these entities may be involved in the setup, administration, and control of the DR programs in a given area. Participation requirements, program flexibility, and the existence of non-participation penalties vary by location, creating a smorgasbord of programs from which to choose.

Regardless of which program it puts together, the faster a facility reacts to a demand event, the more attractive the economic payback. Incentive to participate may be even greater if the facility produces much of its own power, as in a micro-grid. In a micro-grid, the facility has the responsibility to balance its own power requirements with the building demand independent of the utility. Micro-grids do not have

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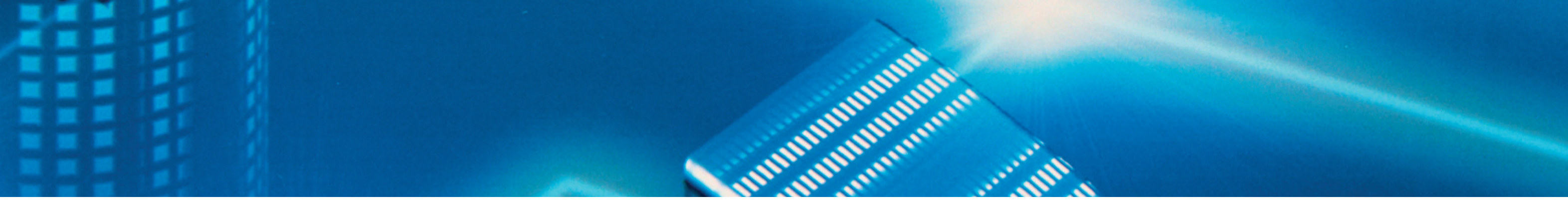


the benefit of gross aggregation to provide a cushion against fluctuations in demand of single buildings; therefore, a predictive state and quick reaction to demand events are critical goals.

DR and Energy Savings

DR can often get confused with energy savings. The two can be linked, but they are not necessarily interchangeable. The goal of DR is to keep the electrical supply at a steady and controllable state, not specifically to save energy, but it is not unusual for some of the temporary strategies put in place as a means of achieving DR goals to become permanent strategies to save energy. A strategic customer will continue to evaluate curtailment opportunities, becoming more efficient as a benefit of reaching DR goals.

Strategies for handling DR fall into two basic categories: standby generation and load curtailment (also known as load shed). We will start with a discussion about load curtailment. According to a 2003 Department of Energy (DOE) survey[1], lighting and HVAC together account for two-thirds of the electrical power usage in a typical office building. That is good news, since lighting and HVAC also offer the best options for control by a responsive and programmable DR system; lighting and HVAC should be first and second on a facility's list of curtailment strategies. Even better news is that lighting and HVAC systems can be integrated under the same BMS management umbrella, presenting an opportunity to coordinate curtailment strategies. Each system contributes different, but complementary benefits to demand response events.

Throughout the year in a typical commercial building, lighting and HVAC electricity use is virtually equal, but HVAC curtailment is often the only DR strategy used in a building. Theoretically, this makes sense as demand peaks are usually associated with outside climate conditions that closely mirror the HVAC demand—the warmer the outside air temperature, the more electricity it takes to cool the building, and the cooler the outside temperature the more electricity it takes to heat the building. During peak demand HVAC typically accounts for a large share of power usage, and is an obvious target for DR strategies. It is possible the BMS used to manage DR might not be integrated with the lighting system, limiting the opportunity to use lighting DR to its greatest advantage. The additional benefit of incorporating lighting as a contributing factor to achieving energy curtailment goals may not be as obvious, but its advantages can be easily demonstrated by revisiting the idea that a faster reaction time equals greater economic reward.

HVAC accounts for the larger share in a demand event, but with that comes multiple DR management considerations including predictability and responsiveness. HVAC is weather dependent, resulting in limited predictability. How well can one predict the temperature next April 3rd? And, HVAC has to manage the relationship between three variables: temperature, ventilation, and humidity. HVAC does not respond either immediately or proportionately when you change temperature settings. The thermal mass of the building is highly complex and has tremendous inertia; there is an extensive lag time between a change to the HVAC setting and the desired result. Reversing HVAC is like trying to reverse a moving train, it is a gradual process. HVAC also has a recovery time to deal with. Radical adjustments can produce unintended peaks, which may be worse than no load shed at all.

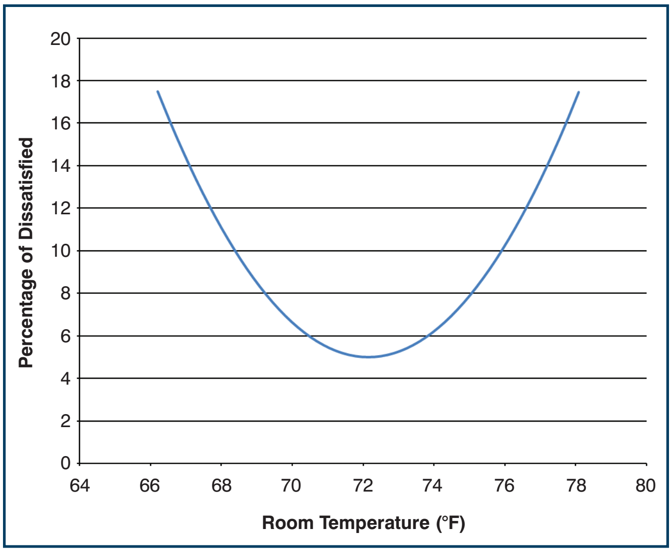
Lighting Control Provides a Linear, Responsive DR Strategy

So what about lighting? As we mentioned before, lighting and HVAC are almost equal in yearly power usage but lighting use is not climate driven. Day-to-day, lighting is essentially constant, much the same at 9 a.m. as it is at 3 p.m. with only slight deviations. Even with daylight harvesting strategies, algorithms can effectively calculate and account for the angle and arc of the sun in respect to your building's exact location, enabling lighting levels to be more predictive. As opposed to HVAC, lighting is linear and highly responsive. Lighting power is simply the product of voltage and current, and since the voltage is steady there is only one variable: current. Reduce current and lights go down; increase current and lights go up. The speed at which you take current away or put it back is the speed at which the lights change, making lighting easier to manage than HVAC. It is the predictive nature of lighting, along with its linear response, that makes it such a useful and complementary demand response strategy, especially as a means of quickly contributing to response levels that HVAC can only achieve over time.

Occupant productivity is always an issue with demand events. A small decrease in productivity can effectively negate any advantage gained from DR. *Figure 1* illustrates how changes in thermal environment as a result of HVAC demand response can create dissatisfaction, which may ultimately decrease productivity. This is probably the biggest reason onsite generation is used more then curtailment. Onsite generation consumes resources and contributes to faster equipment degradation but will not negatively impact productivity. Lighting, on the other hand, works in conjunction with the innate qualities of the human eye; the pupil naturally expands to counter a decrease in light. Studies have shown that most occupants will not detect a gradual change in light level such as a 15% to 20% decrease in light output.[2] Gradual, slow and steady changes over a few seconds are offset by the natural capabilities of the eye, and will have no impact on productivity for the majority of office tasks (*Figure 2*). Demand responsive lighting can be zoned such that the level of curtailment can be increased or decreased based on the criticality of the visual task.

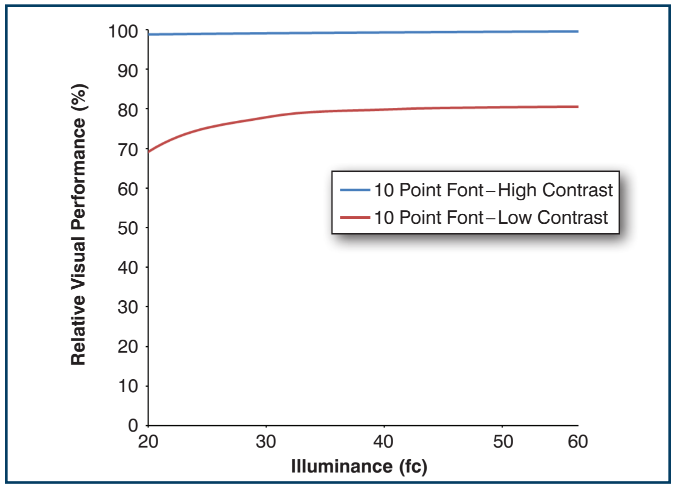
BMS Managed DR that Integrates Lighting and HVAC

By integrating both lighting and HVAC in a DR strategy, a facility has greater ability to fine-tune the environmental systems.



This graph shows how dissatisfaction with the thermal environment changes as the room and room surface temperatures change. This plot is based on typical air movement, business attire, and a typical office work activity level. Dissatisfaction estimated from the predicted mean vote (PMV). (Source: Fanger, P.O. 1973. *Thermal Comfort*. New York: McGraw Hill Book Company).

Figure 1: HVAC demand response requires recovery time, which may affect occupant comfort and decrease productivity.



The relative visual performance is a percentage expected performance while reading 10 point font under 100 fc. Ten point font is the lower limit for most printed office material. High contrast is similar to black print on white paper. Low contrast is similar to a newspaper article. Most offices and classrooms are designed to provide 50 fc at the desk level. As you can see, the illuminance can be dramatically decreased before a considerable decrease in visual acuity is expected. Adapted from: Rea MS. 2000. *The IESNA Handbook.* Ninth Edition. Illuminating Engineering Society of North America. New York.

Figure 2: Lighting demand response requires no recovery time and results in little change in comfort or productivity.

In particular, making small adjustments to the lighting levels can result in optimal performance and system efficacy. For example, assume that a DR event relying strictly on HVAC curtailment does not go far enough to achieving energy goals or to realizing the facility's requirement to generate an additional 100 kW in power reductions. The lighting system can deliver a 10% to 20% reduction over the course of 60 seconds to immediately deliver the required savings in a manner that is less intrusive and virtually undetectable to employees and other occupants in the space. This can be particularly important for buildings that attempt to generate 100% of their energy needs through renewable on-site generation, which is known to have inconsistent energy output.

In another scenario, HVAC demand response may be so aggressive that the building environment becomes too uncomfortable, and the system is required to react equally aggressively to recover from the demand event, which elevates the potential for peak charges. An integrated strategy would enable the responsive nature of the lighting system to quickly offset the HVAC, and help to avoid peak charges. Using a single BMS with the ability to manage both lighting and HVAC allows the HVAC to provide the main adjustment and lighting to accomplish the fine-tuning.

Specifying Lighting and HVAC to Work Together

Together, HVAC and lighting systems that are managed by a single BMS, seem to offer a DR strategy that most effectively achieves curtailment goals. Why, then, isn't this combined strategy implemented much more broadly? In large part, it is a function of habit. Building management systems traditionally have been used as a front end to the HVAC system, and only recently, with the introduction of lighting control systems made with proper BMS integration features, has there been a movement to integrate lighting into the mix. The biggest hurdle to integration may lie in different electrical expertise. Traditionally, the specifiers, contractors, and installers who work with HVAC and BMS are mechanical in nature; those who work with lighting systems are electrical in nature, and neither has been comfortable in the other discipline.

Today, this divide is less prominent, driven mostly by the changes in the specifications. Since 2004, the CSI Master Format has added "Division 25 – Integration" as the umbrella specification for all system integration requirements. Some lighting control manufacturers are embracing BMS protocols like BACnet instead of using limited third-party gateways. These manufacturers are embedding or making "native" BACnet in controls, and certifying devices to assure proper communication with independent agencies like BACnet Testing Labs (BTL).

New Opportunities in Lighting DR

Traditionally, lighting control has been about electric lighting, but there is largely untapped potential for DR strategies that control daylight in conjunction with HVAC. Integrating active fenestration systems, such as controllable window shades, controllable louvers, and dynamic glazing into the BMS management umbrella can significantly reduce or eliminate the heat contribution from solar radiation, which can be up to 93 W/ft^2 (1000 W/m^2), while controllable window shades can also provide an air barrier for additional R-value.

The interaction between these systems can greatly reduce the load on the HVAC system with minimal change to the thermal environment, but can potentially increase demand for electric light by reducing available daylight in the space. Ideally, a DR strategy will enable the user to simultaneously analyze, manage and adjust the thermal loads from daylight and electric light, as well as electric lighting power, to achieve the desired balance, meet DR goals, and maintain a productive, comfortable environment.

New lighting products offer the opportunity for DR curtailment that integrate intelligent electric lighting management, HVAC, and daylight management within the BMS. Until recently, integration protocols and capability have been limited, and most integration between active fenestration and other systems has been limited to a simple contact closure or two.

This is changing as a result of distributed, intelligent, active fenestration systems that offer advanced integration and control capability with protocols such as BACnet. Studies highlighting the energy savings and curtailment potential for this type of integration, and the availability of analytics to support energy claims, are in their infancy, but as knowledge expands, the industry is likely to embrace intelligent fenestration as another element of a sophisticated DR approach.

Legislation and the Future of Demand Response

So far, DR has been voluntary and companies are allowed to supplement power from the grid with power they generate onsite. However, newly established green codes, standards, and rating systems are moving municipalities toward legislated DR implementation. California's newly adopted CalGreen, recently released codes including ASHRAE/USGBC/IES Standard 189.1-2011, the recently finalized International Green Construction Code (IgCC), and USGBC's imminent LEED v4 update all have DR components. Furthermore, Standard 189.1-2011 and the DR credit for LEED v4 do not allow "standby power generation" or "on-site electricity generation" to be used, signaling a definite move toward pure curtailment strategies.

As DR becomes more universal, controllable systems for HVAC and lighting become more important. Today, the industry is working toward automatic demand response or AutoDR. Demand events will directly signal energy managers to curtail power through a facility control system. This trend will become more prevalent as the smart grid develops (see *Open ADR Advances*, Page B16).

The ability of lighting to be predictive, responsive and linear when operated by intelligent light control systems, makes DR simpler, and more economically beneficial. Gradual, steady changes in light levels result in immediate reductions in power usage while being completely transparent to the occupants in the building, which makes lighting and lighting control systems your best choice for DR fine-tuning adjustment.

References

1. EIA. 2008. "Overview of Commercial Buildings, 2003." Energy Information Administration. ftp://ftp.eia.doe.gov/consumption/overview.pdf.

2. Lighting Research Center, RPI. 2003. "Understanding Light Levels for Load Shedding." http://tinyurl.com/8tuj3ws. ■

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