A SYSTEMS INTEGRATION APPROACH TO LIGHTING CONTROL SYSTEMS

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ABSTRACT

Today, the lighting industry is experiencing renewed development and implementation of advanced technologies. One of the most striking advances is the implementation of system solutions in lighting control. This approach promises to contribute to efficient building operations in several innovative ways. One trend, best illustrated by the emerging use of daylighting techniques, integrates lighting control systems with the building itself, complementing design decisions about skylighting, fenestration and office placement with control tools to harvest natural light. Other technologies under development seek to achieve the seamless integration of lighting controls with other building systems. Here, the rewards can be rich, with increased energy savings through linking high energy use systems like lighting and HVAC with unified controls. Finally, the industry is identifying an often overlooked beneficiary—the office worker using the lights—and seeking to integrate control capabilities with the worker's needs. This stems from the recognition that environmental influences can boost productivity, benefiting both the enterprise and the bottom line. As a consequence, controls manufacturers are exploring ways in which to turn some measure of environmental control over to the occupant.

INTRODUCTION

Traditionally, building systems such as HVAC, security/access control, electrical, and datacom have been viewed as isolated, independent systems. Only recently is this attitude changing to recognize that while each system represents a unique discipline, there are ways and reasons for linking these systems together. This is the concept expressed in the "whole building" approach, which views the facility/structure as a dynamic infrastructure whose functioning can be optimized by the integration of its systems. In the contemporary business environment, this approach reflects the rapidly evolving needs of facility occupants as well as the increasing incentive to slash energy costs by reducing consumption.

As a unique sub-set of building electrical systems, lighting and lighting control systems, too, are moving toward greater integration with the building structure itself, with other building systems, and on the level of the individual occupant with their unique control needs over personal work environments. Design and development approaches that recognize and incorporate these integration perspectives will be able to include control capabilities and flexibility in products beyond those of any isolated control component. In the future, these capabilities may simply continue to expand.

In the case of lighting control, the focus of emerging tools and technologies is on the following key factors:

- **Integration with building structures by facilitating use of artificial and natural light sources efficiently and effectively**
- **Integration with building systems by functioning in a coordinated relationship with other building control systems**
- **Integration with building occupants by satisfying growing demands for increased control, convenience, and productivity**

Broad-based industry support is underway to support the design and development of such tools and technologies. Perhaps most visible is the current industry roadmapping effort, Vision 2020, the Lighting Technology Roadmap, fostered by a number of industry organizations as well as the Department of Energy (DOE). Other efforts include the organization of a new industry organization, the Lighting Control Association, and the Light Right Consortium.

INDUSTRY INITIATIVES

As the new century and millennium open, there is a heightened awareness in the lighting control industry of the evolution of control technologies and the opportunities for further achievements. Part of this awareness has been demonstrated by a renewed commitment to supporting technological design and development. Expressing this commitment, industry participants have undertaken several industry-wide initiatives in the past few years that focus on lighting and lighting control issues.

A Map for the Future: Vision 2020, The Lighting Technology Roadmap

In the fall of 1998, the DOE initiated a roadmapping process, facilitated by its Office of Building Technology, State and Community Programs (BTS). The project is one of a series of technology roadmaps focusing on various aspects of the building industry. For the Lighting Technology Roadmap, known as Vision 2020, sixty companies and more than one hundred lighting professionals have participated in a series of forums and workshops. To date, the project has developed a vision statement:

Vision 2020
THE LIGHTING TECHNOLOGY ROADMAP

In 2020, lighting systems in buildings and other applications will:

- **Enhance the performance and well being of people,**
- **Adapt easily to the changing needs of the user,**
- **Function as true systems, rather than collections of independent components, fully integrated with other systems,**
- **Create minimal impacts on the environment during its manufacturing, installation, maintenance, operation, and disposal.**[1]

In addition, the project identifies some of the short, middle, and long term needs to be met in order to achieve this vision. It also recognizes that there are existing barriers to reaching the ultimate goals, such as lighting and controls decision making based solely on the lowest first cost.

Raising Awareness: The Lighting Control Association

A private collaborative effort sponsored by lighting controls manufacturers, the Lighting Control Association is committed to raising the awareness of the benefits of lighting controls and dimming products among the design and building communities. One of the most noteworthy achievements of LCA (and its predecessor, the National Dimming Initiative) has been the development of an educational CD-ROM that includes interactive components such as a lighting controls tutorial, a controls project estimator, and a comprehensive controls product catalog. To date, more than two thousand copies of this CD have been distributed, with a target goal of 20,000. Continuing industry and public relations efforts reinforce the message that lighting control systems offer numerous benefits. To date, at least 14 controls manufacturers have contributed to the organization of this new entity.

Light Right Consortium

A third industry effort is focusing on documenting the benefits of lighting controls through scientific and market research. In the past, little attention has been given to the relationship between lighting control and personal productivity and environmental satisfaction beyond widespread belief and anecdotal evidence. The mission of the Light Right Consortium is to explore this issue.

THE EVOLVING ROLE OF LIGHTING CONTROL

As these industry initiatives have recognized, the role of lighting control is evolving in recent years. More sophisticated lighting systems, such as T8 lamps, electronic ballasts, and a host of specialized high intensity discharge technologies are gaining rapid acceptance. Furthermore, facilities managers, energy management professionals, and lighting professionals are recognizing the positive impact that well-designed lighting systems—and their control—can have on the overall operation of commercial buildings.

[1] Vision 2020, The Lighting Technology Roadmap Progress Report, August 20, 1999, p. 10.

Letting the Sun Shine In

Perhaps the emerging trend most likely to dominate the landscape in the years ahead is the attitude of integrating lighting controls with the building structure in order to facilitate the efficient and effective use of natural and artificial light sources. Traditionally, the industry has viewed its mission in a rather "defensive" mode, focusing on controlling the use of artificial lighting wherever and whenever possible. The emerging attitude, however, goes on the "offensive," seeking to utilize all light sources to achieve optimal lighting. Key in this approach is the role of daylighting, the use of natural light to supplement or supplant artificial lighting.

As a lighting control strategy, daylighting is different from other strategies and technologies. Rather than relying primarily on technological devices to control lighting, it combines control devices with architectural and engineering work to craft a solution that is integral to the building itself. Critical elements of successful daylighting, therefore, include both the development of appropriate technological devices and advancing the knowledge of building design practitioners.

Currently, daylighting technology is less common in the United States than in Europe, where it has been implemented for decades. Likewise, the development of building envelope design—the walls, roof, windows, and shading materials—to harvest this "free light" has been the focus of institutions and businesses in Europe far more than in the United States. This is beginning to change, as more data on the beneficial effects of daylighting becomes available and both controls manufacturers and end users recognize the potential for enhanced visual comfort and energy savings. For instance, studies sponsored by the California Board for Energy Efficiency and conducted by Pacific Gas and Electric have focused on the effects of daylighting on human performance.[2]

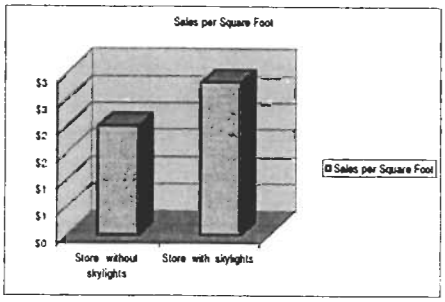
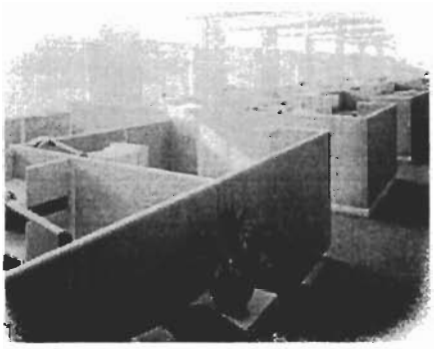


Figure 2. The retail study sponsored by the California Board for Energy Efficiency concluded that skylighting was likely to result in improved sales performance with gains up to 40%.

The studies, which explored these issues in educational and retail settings, found positive results in both cases. In elementary schools, student performance improved dramatically when the physical setting included daylighting elements. In retail settings, the use of daylighting had a beneficial effect on sales, boosting them by 30-50%. While there are no studies on other types of human performance, the implications of these studies raise interest in implementing daylighting control strategies. Other benefits include potential energy savings, which the Environmental Protection Agency (EPA) estimates could be as great as 40%.[3] In addition to these lighting-based energy savings, users could realize further savings through reduced HVAC requirements as well as decreased demand charges.



For optimal application as a control method, daylighting will integrate actual control devices with the design decisions involving building fenestration, skylighting choices, and office placement. Obviously, this will be easiest to achieve in new construction scenarios, and may be a longer term objective. In fact, the Vision 2020 Roadmap recognizes that the short-term developments in this area involve

[2] Skylighting and Retail Sales, An Investigation into the Relationship Between Daylighting and Human Performance, August 20, 1999. Daylighting in Schools, An Investigation into the Relationship Between Daylighting and Human Performance, August 20, 1999.

[3] "Daylight Dimming in Retail Facilities," EPA Application Profile, EPA 430-F-96-062, October 1996.

improving education on daylighting for the design community. This does not mean there are no practical daylighting control options in the near term. Technological solutions will be quite effective in providing significant energy savings and implementing daylighting solutions in existing buildings in parallel with the longer term development of educating the building design community.

In the short term, daylighting solutions will take advantage of emerging products that measure incoming ambient daylight and either dim controlled lighting or switch it on or off. Features such as deadband capability enhance the potential for energy savings. Other key capabilities focus on the control device's compatibility with other control devices or systems, such as occupancy sensors, building automation systems, or time clocks. In addition, control manufacturers, utilities and ESCOs are becoming involved in educational programs or in assisting their customers in implementing daylighting applications. For instance, Pacific Gas & Electric (PG&E) has launched a daylighting initiative and offers a range of information on its web site.

Early adopters of the technology are strong supporters. In one daylighting application documented through the EPA's Green Lights program, a McDonald's restaurant in Fair Haven, Vermont implemented a dimming system that controlled 14 fluorescent fixtures in the facility's dining section. Following the installation, customers and employees alike found the new lighting controls acceptable; neither group even being aware of the changing light sources. Project participants estimated the facility's energy savings from the dimming system were 29%, with a simple payback of 2.4 years.

Integrated Lighting Control

A second trend involves the interplay between all lighting control systems and other types of building systems. Differing perspectives advocate various levels of systems integration, with some championing the evolution of innovative comprehensive systems that will control all building operations, and others recognizing the intrinsic differences between system types and advocating a more coordinated approach. All agree, however, that a key development is forging a closer relationship between the systems that will manage building operations in the years ahead.

One impetus for such technological solutions is to optimize overall building operation to meet the changing needs of today's businesses. As the economy continues its shift from an industrial base to an informational one, workers require information technology at the workplace. Moreover, organizational structures are shifting toward team-based, shared resource attitudes that are not met by traditional, hierarchical building design and layout. Rather, work environments are becoming adaptable workplace "laboratories." To support these emerging characteristics, building systems such as lighting controls must be correspondingly flexible.

Currently, the industry is just beginning to develop flexible centralized and distributed lighting control systems that are capable of responding to rapidly changing needs. One of the most promising solutions, we believe, is the development of modular control devices. These control devices offer distributed intelligent control and can be installed near a junction box, virtually anywhere in a facility. From there, they share information with other devices via network communication wiring rather than traditional and costly electrical wiring back to a centralized location. When a facility's floor plan changes, or different build-out elements are introduced, lighting control can easily adapt without the expense and time-consuming labor used to implement conventional control systems. For instance, when the University of California San Francisco installed nearly 300 distributed control modules in 1998, it estimated installation savings of nearly 30% over the proposed cost of installing a conventional control system.

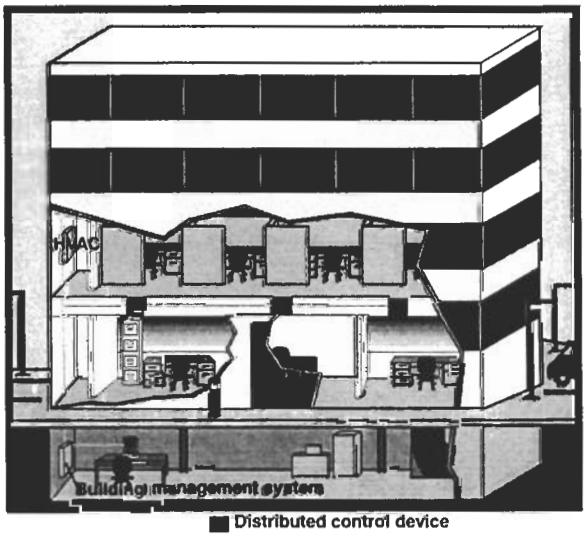


Figure 3. Distributed lighting controls interface with HVAC and building management systems.

Distributed controls offer a wide range of features, such as:

- networking of multiple systems
- computer interfaces
- demand control/load shedding opportunities
- interfaces with other types of lighting control devices (i.e. daylighting controls, occupancy sensors)
- integration with building management systems and other building systems (i.e. security)

In addition, these systems can produce monitoring and verification information for energy management purposes, and even bill building tenants for energy usage. Such distributed control devices can easily support the emergence of workplace laboratories and work teams that frequently change to support new project requirements.

Another aspect of integrated control addresses the capability of lighting control systems to interface with other building systems. While the development of a single,"super" system capable of controlling all of a building's operating systems remains a vision for the future, steps in systems integration are already being made. Two of the most prevalent systems integrated currently are lighting control and HVAC. Since the operation of both systems bears directly on occupied spaces, the integrated control is often achieved through occupancy-based devices. For instance, the Florissant Valley campus of the St. Louis Community College institution implemented a control system that relied on the interface between the facility's lighting controls, building automation system (BAS), and HVAC systems.[4] Occupancy sensors that controlled classroom and laboratory lighting were also used to signal the building's BAS during unoccupied periods. This then prompted a signal to reduce cooling and heating loads. The project won the 1997 ASHRAE Technology Award. Other organizations have implemented similar approaches. When it built a new corporate headquarters, Bose Corporation deployed occupancy sensors to control a state-of-the-art HVAC system.

Tools for Increased Control, Convenience, and Productivity

A third emerging integration trend, identified by the Vision 2020 process, involves the harmonious relationship between individual occupants and their work environments. Industry participants are discovering that this can be achieved via the implementation of control technologies that can be directed by the workspace occupant. While this trend supports the objective of energy efficiency, its primary objective is to increase worker comfort and productivity. And recent studies have indicated that there is a relationship between worker comfort or environmental satisfaction and productivity.[5]

One of the earliest studies to suggest a link between personal control over environmental elements such as lighting and temperature, and worker satisfaction and productivity was conducted by the Lighting Research Center at the National Center for Atmospheric Control (NCAR). The study was performed between December 1996 and March 1997 in 81 private offices at the NCAR facility in Boulder, Colorado. Its findings clearly demonstrated that occupants want and use personal control devices when they are available. ***Over the course of the study, 74% of the users operated the dimmers at least once to alter their personal work environment. They adjusted lighting two-thirds more often when desktop control were available.***[6]

Today, manufacturers are developing personal control technologies, sometimes also referred to as personal environmental modules (PEM) or environmentally responsive workstations (ERW). These systems usually feature some type of desktop controller with which the user can adjust lighting, airflow, temperature, even background noise masking parameters. One of the more innovative approaches is to team occupancy sensors with wireless desktop controllers for dimming overhead lighting and switching of controlled outlets.

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[4] Cox, Robert L., "Retrofit for a College Campus," ASHRAE Journal, November 1996, pp. 59-64.

[5] Lomonaco, Carol, "Comfort and Control in the Workplace," ASHRAE JOURNAL, September 1997, p. 50-56.

[6] "Private Office Lighting Controls," DELTA *Snapshots*, Issue 5, May 1999.

CONCLUSION

With the continued impetus for ongoing research and development, the future holds great promise for lighting control systems that are integrated with the evolving needs of commercial buildings and workspaces. As lighting controls integrate more fully with building infrastructures, the industry will witness the development of improved daylighting design tools as well as basic guidelines, or "rules of thumb," for architects and other members of the design community. It is likely we will also witness advances in window and glazing technologies to complement daylighting controls and building design advances.

Integration of lighting control systems with other building control systems will rely on newly developed open control protocols that enable seamless interfacing between control ballast components as well as with other building systems such as HVAC. In addition to optimizing lighting and HVAC loads, this systems integration will be put to use to achieve energy management strategies such as load shedding.

At the most personal level, that of the employee interacting with his or her work environment, lighting control systems will assist the individual in configuring or defining their environment to suit the range of their task needs. Ultimately, system capabilities will be integrated with the individual, rather than the work environment, enabling individual-specific accommodations as they move throughout the greater work environment.

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