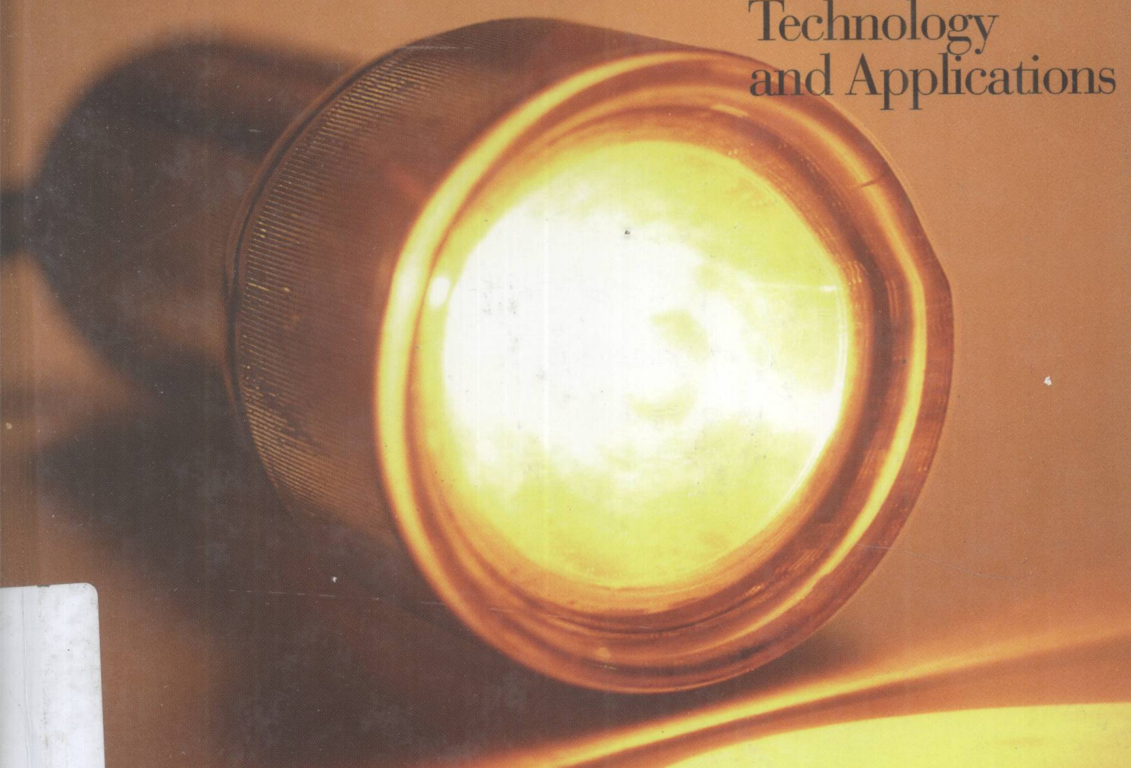
Craig DiLouie

ADVANCED LIGHTING CONTROLS

Energy Savings, Productivity, Technology and Applications



Advanced Lighting Controls:

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Edited by Craig DiLouie

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Preface

Lighting controls are an essential part of every lighting system and a major frontier in building and energy management.

An estimated 30-45 percent of a building's electricity bill is typically represented by the cost of operating lighting systems. And 30 percent to 35 percent of the cost of a building is for the mechanical systems and envelope architecture. Automated lighting controls can contribute significantly to cost savings in these areas.

According to the New Buildings Institute, which developed the *2001 Advanced Lighting Guidelines*, automatic lighting controls can reduce lighting energy consumption by 50 percent in existing buildings and at least 35 percent in new construction. In addition, lighting automation has proven effective in load shedding and peak demand reduction, resulting in additional direct cost savings in addition to potential incentives from utilities with demand response programs. Numerous strategies and technologies are available so that a proper combination can be matched to individual application needs.

Besides energy management, benefits of lighting automation include mood setting via the ability to alter a space through dimming or color changing; flexibility by allowing users to instantly adapt a space to different uses; ability to establish a responsive lighting system that can be globally and locally controlled, with automatic operation; ability to adapt electric lighting systems to daylighting strategies; decrease "light pollution" (skyglow, light trespass and glare) by dimming or switching lights based on time of night or occupancy; enhancement of workspaces with a technology that has visible effects; and potential increased worker satisfaction by enabling users to control their own light levels. The list goes on.

Lighting automation can be completely automated or contain elements of manual operation; can be localized, global or both; can be hardwired or wireless; and can be used for automatic switching or dimming. A wide variety of proven and developing technologies is now available to achieve a wide variety of building and energy management goals. New approaches, such as the Digital Addressable Lighting Interface (DALI), light fixtures integrating automatic controls, and control of LED lighting systems, offer new opportunities while existing technologies continue to develop in capabilities, interoperability, ease of specification and use, and reliability. New developments such as LEED, demand response programs, changing workplace goals, rising energy costs and the ASHRAE/IES 90.1-1999 (or later) energy code continue to stimulate demand for lighting automation. Research indicates that lighting automation is becoming the norm, not the exception. Both the use of automatic switching controls and dimming controls are increasing.

Advanced Lighting Controls was developed to help construction and building management professionals view lighting automation from a number of angles. It is intended as an introduction to the technology and surrounding technical, legislative and related issues and opportunities. A majority of the content for this book was written by the editor with input from the members of the Lighting Controls Association, a non-profit organization dedicated to educating the industry about the benefits, operation, technology and application of lighting automation. Members of the Lighting Controls Association include Advance Transformer, HUNT Dimming, Leviton Manufacturing, Lightolier Controls, Lithonia Lighting, Lutron Electronics, OSRAM SYLVANIA, PCI, Square D, The Watt Stopper, Tridonic and Universal Lighting Technologies.

Advanced Lighting Controls provides significant background to help construction and building management professionals consider lighting automation as an effective energy and building management strategy.

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Section I

LIGHTING CONTROL

Chapter 1

Introduction to Lighting Control

By the National Electrical Manufacturers Association, Lighting Controls Council

Lighting controls have gained an extraordinary degree of popularity in recent years because they pay for themselves so quickly due to the energy savings and other benefits they can provide.

The demand for controls created by their rapidly growing popularity has encouraged manufacturers to invest millions of dollars in research and development, to bring to the market new controls that are even more versatile, more reliable, and more cost-effective than ever before. In fact, modern lighting controls tend to create clear and convincing evidence that a building is up to date, by relying on technology that has been expressly designed to enhance the flexibility of lighting while at the same time avoiding waste.

It is particularly interesting to see what has happened to the cost of lighting controls over the years. While the price of so many other products has increased, the cost of modern lighting controls has come down, due in large part to the twin impacts of mass production of electronic components and competition. At the same time, the value of the benefits associated with lighting controls—energy savings, demand reduction, increased productivity, and more retail sales, to mention a few—has risen steadily.

LIGHTING CONTROL FUNCTIONS

Lighting controls perform seven discrete functions: on/off, occupancy recognition, scheduling, task tuning, daylight harvesting, lumen depreciation compensation, and demand control. Some lighting controls perform only one function; many perform more than one, typically on an automated basis. The following discussion provides more detail about each of these functions.

On/Off

The basic control function, typified by the common wall switch, is turning lighting on or off. The degree to which this function is performed depends on other variables or control functions such as occupancy recognition and scheduling, which are described below.

Occupancy Recognition

Occupancy recognition is commonly used in intermittently occupied areas or rooms, typically to turn lights on when people are present and off automatically after a certain amount of time when they are no longer present. Experience indicates that occupancy detection can save significant amounts of energy and money by preventing the waste caused by keeping lights on when they are not needed.

Contemporary occupancy recognition devices rely on one of two principal technologies: *ultrasonic* or *passive infrared.*

Ultrasonic systems transmit an inaudible sound in the frequency of 20,000 to 40,000 Hz to a receiver. Any movement alters the transmitted sound waves and is recognized by the receiver, causing it to initiate control action.

Passive infrared sensors use a pyroelectric detector and a fresnel lens to sense the radiation emitted naturally by people. Movement of the "heat source" is transmitted through the lens to the detector, triggering a control event.

Occupancy recognition is "packaged" into a variety of systems. In some, they serve only to turn lights off, in case the individual leaving the room forgets to. In others, they are used in combination with dimming equipment, to raise illuminance when a person approaches—e.g., at a display case in a lightly traveled area of a store, and, later to lower illuminance to the predetermined point

Scheduling

When scheduling is applied, electric illumination in given areas is activated, extinguished, or adjusted according to a predetermined schedule. In some cases, the systems control may be vested in a different device. For example, the system indicated in Figure 1-1 would be under the direction of daylight harvesting controls from 9:00 am through 4:00 pm and, from 11:00 am to noon, and 2:00 pm to 4:00 pm, demand management controls would have precedence.

Scheduling is a time-based function and, as a consequence, it is most suited for facilities or spaces where certain things happen at certain times. Because "off-normal" conditions inevitably arise, local overrides usually are provided.

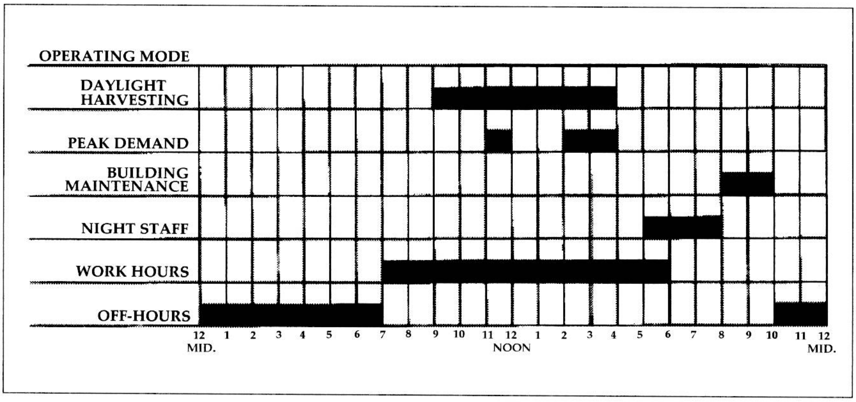

Figure 1-1. Typical weekday lighting schedule.

Tuning

Tuning means adjusting the light output of a luminaire or a system of luminaires to the specific level needed for the task or other purpose, such as aesthetics. It is most commonly done through dimming. It can also be accomplished through switching, as when ballasts of a four-lamp luminaire are wired in such a way that the two inboard and two outboard lamps are separately switched, permitting full light output or 50 percent light output.

Tuning can create significant monetary benefits through energy use reduction. In essence, it helps assure that only the amount of light needed is actually provided. The more flexible and easily controlled the system is, of course, the more benefits that can flow. For example, when a given worker is able to adjust electric illumination to optimal levels for that specific person, productivity will be higher. Long-term benefits are also apparent, as when tasks change or are relocated. Rather than having to move luminaires or replace them altogether, it often is possible to meet new needs simply by changing light output.

In retail areas, the ability to provide tuning creates the ability to define spaces with light, to create a mood or atmosphere most suited to the nature of the display, and to highlight impulse purchase items or seasonable goods.

Tuning is also used for aesthetic purposes, when light output is adjusted to create dramatic effects of one type or another.

Virtually any type of lighting system can be tuned, and particular advances have been made in the field of fluorescent and high-intensity discharge (HID) lighting. While dimmable fluorescents have been available for many years, new control modules and electronic ballasts now help assure high-quality effects and new levels of cost savings. Similarly, new HID fixtures and auxiliary equipment enable light levels to be varied, which was not possible a few years ago.

Daylight Harvesting

Daylight harvesting is applied when daylight entering a space can't be put to positive use. The systems involved use strategically located photocells to determine the ambient light level. This information is fed to a control device that then raises or lowers luminaire output or turns off selected luminaires to maintain the amount of light (illuminance, measured in footcandles) set for the space. The adjustment occurs gradually, so occupants in a space are not aware of it. Response delays are also used to prevent frequent adjustments due to passing clouds or similar phenomena.

Some buildings are designed to take advantage of daylight. Others have daylight available to them and using that daylight may or may not be worthwhile, depending on factors such as the tasks being performed and/or the orientation of workstations with respect to windows. Daylight also brings heat with it, which, in summer, might necessitate cooling unless appropriate window films are installed. In other words, if a building has not been designed to use daylight, some study is needed to help assure it can be put to positive use and to establish exactly what needs to be done in order to realize that gain.

Lumen depreciation compensation. The output of electric illumination systems diminishes over time, due particularly to a phenomenon called lamp lumen depreciation (LLD). As shown in Figure 1-2, most commonly used lamps produce less light the longer they are in service. Light also is lost due to the build-up of dust and dirt on lamps and the reflective surfaces of luminaires, as well as other reflective surfaces in the illuminated spaces, including walls and ceiling.

Lumen depreciation compensation is essentially the same as daylight harvesting. It senses ambient luminance and increases light output to maintain whatever is desired. At such time as the desired illuminance cannot be provided, lighting system maintenance is called for, and probably is overdue.

Although effective controls can help compensate for inadequate maintenance, they should not serve as an excuse for poor maintenance. In fact, regular maintenance of electric illumination systems can often be a major source of energy and cost savings, as well as improved lighting quality.

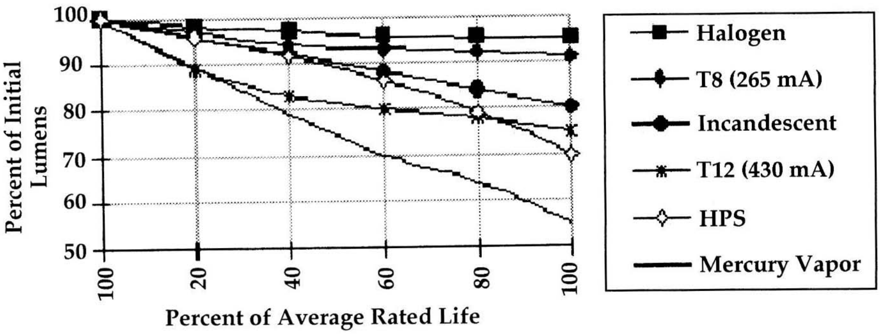

Figure 1-2. Lamp lumen depreciation of commonly used lamps. *Source: Lighting Design Lab.*

Demand Control

Most nonresidential electrical rate schedules impose a charge for energy and demand. Energy equates to the amount of kilowatt-hours consumed in any given billing period. Demand is the rate at which energy is consumed. The more energy needed at any given moment in time, the more the utility must do to provide it—i.e., more generating capacity, more distribution capacity, and so on. To illustrate by example, consider two hypothetical buildings. Both consume the same amount of electricity, but building "A" consumes it in 24 hours, building "B" in eight hours.

Even though both buildings consume the same amount of energy, the utility obviously must invest more money in generating, transmission and distribution equipment to meet the needs of building "B." The extent of this investment is defined by the highest rate at which energy is consumed, even though it may be consumed at that rate for only a very short period of time.

Energy charges alone would yield a poor rate of return on the utility's investment because the utility's equipment needed for building

"B" is used only for a relatively short period of time.

One way of obtaining a more reasonable return would be to average all generation, distribution, and transmission equipment costs among all customers. That approach would not be fair, however, because those who use the utility's equipment efficiently would be subsidizing those who do not. To be fair, therefore, the utility collects from each customer an amount proportional to the cost of meeting that customer's demand requirements. Demand requirements are measured through the use of special metering equipment which measures and averages consumption for a certain period of time. This period is called the *demand interval.*

A commonly used demand interval is 15 minutes. The typical demand meter records average energy consumption for each 15-minute interval in a day. When the first interval ends, the equipment resets and starts on the second one.

The utility reviews the demand records for the building at the end of each billing period. The maximum demand recorded is used to compute the demand charge.

Demand charges can be substantial. Demand control equipment is used to help assure that demand will not exceed a given maximum. The procedure involves identification of certain secondary loads that can be "shed" during peak periods. In some cases, it may mean that air conditioning is shut down for a given period of time, then restarted once demand ebbs somewhat. Certain lighting circuits also can be made part of the secondary loads, with some luminaires being dimmed while others may be turned off altogether. Typical candidates would be lobby lighting systems, overhead office lighting, and other electric illumination systems that can at least be dimmed for short periods without creating any adverse impact on safety or security.

Demand control becomes particularly important when a utility has what is called a "ratchet clause" in its demand schedule. In essence, a ratchet clause states that the amount of demand for which a customer is billed should reflect the maximum demand recorded at any time in the recent past, since the utility must be prepared to meet a customer's demand requirements at any time, not just during a given month.

Most utilities experience maximum demand in summer months due to the widespread use of electric cooling systems. A typical ratchet clause, therefore, may state that the amount of demand for which a building is billed during the winter period may be no less than a certain percentage of the maximum demand recorded during the previous summer season. If a 75 percent ratchet clause is in effect, and if maximum summer demand was 1,000 kW, the winter season demand bill would be based on a minimum of 750 kW (1,000 kW x 75 percent). Even if the actual winter season demand never exceeds 600 kW, the demand used for billing purposes will be 750 kW. Obviously, if demand control equipment is used to keep demand as low as possible during periods of peak use, savings will be achieved for all subsequent periods to which a ratchet clause is applied.

Electric utilities throughout the United States are encouraging more demand control, since every kilowatt of demand that is reduced adds a kilowatt of new capacity. By eliminating waste, America's utilities can continue to meet new demand requirements without having to build costly new generating plants. For this reason, many are subsidizing the cost of lowering demand by offering rebates and other financial incentives. Lighting controls can play a vital role in this important undertaking.

THE BENEFITS OF LIGHTING CONTROLS

Modern lighting controls provide an array of benefits, ranging from energy savings and electrical demand reduction to supports of the functions for which lighting is needed. The bottom-line value of some of these benefits can be significant, creating paybacks that are best measured in weeks rather than years.

Energy Savings

Controls are the only devices that can help assure optimal use of energy and elimination of energy waste. By applying controls wisely, a building owner or manager can help assure that only the specific amount of lighting actually needed, if any, is provided. No matter how much efficiency may be designed into a system through selection of lamps, luminaires, ballasts, and shielding/diffusing media, maximum energy efficiency cannot possibly be achieved without effective controls.

Utility Cost Savings

For some people, utility cost savings and energy savings mean one and the same, but that seldom is the case. Almost all electric utilities