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REVIEW OF LIGHTING CONTROL EQUIPMENT AND APPLICATIONS

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ABSTRACT

Lighting control equipment is reviewed with respect to its role in the building application. The elements of a control system include the light controller, sensor, and communicator. Each type of equipment has a best use that depends on the specific control strategies and application. The applications discussed are retrofit, renovation, and new construction. The simplest controls are best used in retrofits where installation costs must be minimized. In new construction the most sophisticated controls can be cost-effective.

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INTRODUCTION

Many types of lighting control equipment permit the automatic management of lighting systems. Lighting control equipment can be used to lower light levels, turn lights on and off on a schedule, and respond to the availability of natural light or the presence of occupants. Each of these operations minimizes the energy consumed while providing the proper illumination for occupants′ use of the space.

The choice of lighting control system depends on its particular application (retrofit, renovation, or new construction). This presentation will attempt to provide a basis for selecting the control equipment and the control strategies (light reduction, scheduling, tuning, lumen depreciation, daylighting, load-shedding) most apropos to an application, and presenting the important cost factors (initial, operating, installation, supply circuit layout, building design) that one must consider for each application.

LIGHTING CONTROL EQUIPMENT

Table 1 lists various types of equipment that can be components of a lighting control system. The predominant characteristic of each type of equipment is described. Static equipment can alter light levels semi-permanently. Dynamic equipment can alter light levels automatically over short intervals to correspond to the activities in a space. Different sets of components can be used to form various lighting control systems in order to accomplish different combinations of control strategies.

Static Controls

These controls can decrease light levels by a discrete amount (usually 30 or 50%). They are a rapid, economical way to reduce energy consumption in an over-illuminated area. The method can be as simple as removing two lamps from a four-lamp fixture (delamping), or installing impedance-modifying lamps or devices. Some impedance-modifying devices must be placed in the fixture and hard-wired to the supply power, adding to installation costs.

Dynamic Controls

Automatic dynamic lighting control systems can consist of a combination of lighting devices: (i) controllers, which dim or switch lamps on and off; (ii) sensors, which measure light levels or sense the presence of occupants in a space; and (iii) communications, which process information from sensors and pass instructions to the light controllers.

Light Controllers

Fluorescent lamps can be switched on and off via switches or relays. Because switches or relays must be hard-wired into power lines, they are most economical when they control one phase of a circuit or a large bank of lamps.

There are devices that can vary the amplitude of line voltage or duty cycle to standard core-coil ballasted fluorescent lamps. These devices can vary the light output of the lamps continuously from full to about 50%. Because they operate by conditioning the supply power, they are best suited for controlling large banks of lamps. The systems are relatively economical to install, since they involve a central control. However, their flexibility is limited by the supply circuit layout.

Solid-state dimming ballasts are designed to continuously control the light output of fluorescent lamps down to 10% of full light output. The command to the ballast is via low-voltage signals (0 to 12 volts). Groups of lamps can connect on the same communication link with low-voltage wire. Thus, the flexibility of this method is not limited by the supply circuit layout. Each ballast has a manual adjustment so that the supply circuit layout. Each ballast has a manual adjustment so that maximum light output of each fixture can be achieved. The above advantage permits one to employ all the lighting control strategies.

Sensors

The sensors in a control system are used to obtain information about occupancy, time, or available daylight. Some sensors can relay commands directly to lighting controllers to operate lamps in a prescribed manner, or they can pass information to a control processor.

a) Clocks

Clocks provide instructions to a lighting system in real time. The equipment can be as simple as a spring-loaded switch that will turn the lights off at a prescribed time. It can also be incorporated in a control processor that will control the lighting system according to a prescribed daily routine for an entire year.

b) Personnel

Personnel sensors determine the occupancy of a given space by detecting motion. They are most effective for spaces that have only one occupant, since the greater the number of occupants, the less chance that the space will be unoccupied.

Personnel sensors on the market are self-contained systems that include a sensor and a light controller. Because they must be hard-wired into the supply power, installation costs are involved. They are most effective when used by occupants who spend large portions of their time away from their stations, or at stations that are intermittantly used by several occupants. That is, the controlled area must be occupied infrequently and unpredictably for personnel sensors to be most effective.

c) Photocell

Photocells are used to measure the illumination levels in a space. If there is a change in the prescribed illumination level (because of lumen depreciation or daylighting, for instance), photocells signal the electric lights to maintain the prescribed level. The photocell outputs can be sent to a lighting controller that can alter the light levels, or can be sent to a central processor. The photocell requires low-voltage wiring that creates some installation costs. Photocell lighting control systems that need to be hardwired to the supply power incur additional installation costs.

Communication

a) Computer/Micro-Processor

A single, central processor can store information and satisfy the communication needs for very large areas. The relatively high cost of a unit means it is generally not cost-effective for controlling a small amount of floor space. The computer/micro-processor is centrally located and involves relatively small installation costs.

b) Power-Line Carrier

A power-line carrier is a technically feasible device for transmitting input and output signals to and from a central processor. A carrier is particularly attractive in retrofit applications because it does not require distribution of signal wire. For other applications one must consider the relative costs and advantages of using a power-line carrier or distributing low-voltage signal wire.

LIGHTING CONTROL EQUIPMENT AND STRATEGIES

Table II lists the lighting control strategies that can make use of the various types of control equipment. Note that several groups of strategies are listed for some equipment. The number of strategies in which a control is most effective depends on the application, as will be discussed later (see Table III).

Static Controls

The static controls, delamping and impedance monitors, can be used to reduce the light levels throughout a space or in selected areas (i.e., by tuning). These strategies are most effective in spaces that are over-illuminated, so they are best used in retrofit applications.

Dynamic Controls

The dynamic lighting controls include the use of various control components to create a system that executes the types of control strategies that are apropos depending on the application.

Light Controllers

a) Switches/Relays

In retrofit applications, relay-type controls are best limited to a single strategy, scheduling. A central processor with a clock can control an entire floor or building. If the power supply distribution can be altered, as in renovations, two control strategies can be accomplished. For appropriate buildings designed to exploit natural light, relay-type controls can employ three strategies (see Table II).

b) Voltage/Phase Control

These devices condition the input power to standard core-coil ballasts, which permits the dimming of fluorescent lamps over a continuous range. Because these devices dim lamps over a continuous range, these systems can accomplish two strategies in retrofit applications (see Table II). If photocells are used, three strategies can be accomplished, including lumen depreciation.

In buildings designed to be employ natural illumination, and with the proper wiring of the supply power, daylighting can be used.

c) Solid-State Dimming Ballasts

Dimmable solid-state ballasts are best used in renovation and new construction because a ballast must be installed in each fixture. In addition to the efficacious operation of the fluorescent lamp system, ballasts allow four major lighting control strategies. The advantages, as compared to the other controllers, are increased dimming range and the control of light levels via low-voltage signals.

For buildings designed to exploit natural light, five strategies can be accomplished with solid-state dimming ballasts.

Sensors

a) Clocks and Photocells

Clocks are required to indicate real time for employing the predictable scheduling strategy.

Photocells are needed to measure ambient illumination levels for accomplishing lumen depreciation or the daylighting strategy. For lumen depreciation, only a few photocells are required. Considerably more photocells must be used for daylighting because the dynamic nature of natural illumination requires measuring illumination levels over smaller areas.

b) Personnel Sensors

These sensors are most applicable to retrofit situations in spaces that are occupied intermittently during the day. They are the only devices that can automatically respond to unpredictable occupancy of a space.

Communications

The communications central information processors and power-line carriers are auxiliary controls used in conjunction with lighting controllers and sensors. They connect the instructions with the commands. The central processors are most effective with the scheduling, load shedding, and lumen depreciation strategies.

Transmitting information over power lines eliminates the need to string wire. In retrofit applications, rewiring could make the control technique too costly, so power-line communication is most attractive. In renovation and new construction, where rewiring will be done, power-line carrier methods are less attractive because of installation costs.

APPLICATIONS AND COST FACTORS

Decision-makers may be faced with one of three types of applications (retrofit, renovation, or new construction) for a lighting control system. Table III shows the five major cost factors they may have to consider for each type of application.

Retrofit

A retrofit replaces or adds to an existing lighting system that already is operating adequately. The primary objective of a retrofit is to reduce operating costs. It is unlikely that a retrofit application would be economically sound if the supply circuit layout or the building design would have to be altered. The ideal retrofit requires no hard-wiring to the supply line. The above arguments are the reasons all five major cost factors must be considered for a retrofit.

Renovation

When a building is renovated, the entire lighting system is replaced as well as all the supply circuit wiring. Thus, for renovation applications, installation costs and supply circuit layout are no longer major factors. That is, they would have been replaced at some cost in any case. The three major cost factors for a renovation are the initial and operating costs and the maintainance of the building design. This means the lighting control system can employ more control strategies since there are fewer application constraints.

New Construction

This is an application where the lighting control system can influence the building design. For example, many new buildings are designed to optimize the use of natural illumination. The building structure, position, and fenestration system are designed to accommodate the lighting control technique. Thus, the building design is not a major cost factor in new construction applications. This permits the use of daylighting.

As shown in Table II, a greater number of lighting control strategies are feasible in new construction.

APPLICATION AND EQUIPMENT

Table IV lists the lighting control equipment that best suits each type of application. For each application, there are several options, which are optimum for different situations. For each application, the table lists control equipment in groups of priorities. In addition, the number of strategies that are optimum for each type of control are indicated in parenthesis. Priority I includes the equipment that meets all the conditions for the particular application. For example, delamping in a retrofit application has no initial cost, saves 50% in operating cost, has very small installation costs (removing the lamp and disconnecting the ballast from the supply), requires no change in supply circuit layout, and does not require a change in building design.

The group of retrofit equipment classified as Priority II involves significant installation costs and requires stringing wire throughout the floor. These satisfy four of the five major cost factors.

The power-line carrier is in the Priority I group for a retrofit and Priority II in renovation and new construction applications. This is because laying control lines is not required when retrofitting. In renovation or new construction, the expense of laying the control lines is much less--that is, installation costs are not a major factor.

Personnel sensors are also rated Priority II for renovation and new construction. Although installation cost is not a major factor, the uncertainty of the activity in the space affects operating costs.

The difference in the number of strategies that can be accomplished in a renovated space and in new construction is shown in Tables II and IV. The additional strategy that can be employed in new construction is daylighting. This does not imply that daylighting is impossible in renovation applications. Daylighting depends on the building design, which is a major cost factor. However, some existing buildings are suitably designed to use daylighting effectively.

SUMMARY

A general approach for selecting the lighting control equipment that best suits an application has been presented. This approach is based on the interdependence of equipment, control strategies, major cost factors, and applications. The equipment listed for each group is not exclusive; there could be circumstances in which equipment or a strategy not listed would be suitable.

More importantly, this paper shows that a decision-maker has several options for lighting control systems for any application.

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Table I Lighting Control Equipment

System	Remarks
Static	
Delamping	Method for reducing light level 50%.
Impedance Monitors	Method for reducing light level 30, 50%.
Dynamic	
Light Controllers	
Switches/Relays	Method for on-off switching of large banks of lamps.
Voltage/Phase Control	Method for controlling light level continuously 100 to 50%.
Solid-State Dimming Ballasts	Ballasts that operate fluorescent lamps efficiently and can dim them continously (100 to 10%) with low voltage.
Sensors	
Clocks	System to regulate the illumination distribution as a function of time.
Personnel	Sensor that detects whether a space is occupied by sensing the motion of an occupant.
Photocell	Sensor that measures the illumination level of a designated area.
Communication	
Computer/Microprocessor	Method for automatically communicating instructions and/or input from sensors to commands to the light controllers.
Power-Line Carrier	Method for carrying information over existing power lines rather than dedicated hard-wired communication lines.

Table II Lighting Control Equipment

System	Application	Strategy: Light Reduction	Scheduling: Predict.	Scheduling: Random	Tuning	Lumen Deprec.	Day-lighting	Load-Shedding
STATIC								
Delamp	Retrofit	x			x			
Impedance Modifier	Retrofit	x			x			
DYNAMIC								
Light Controller								
Switch/Relay	Retrofit		x					
	Renovation		x					x
	New Construction		x				x	x
Voltage/Phase	Retrofit	x	x					
Control	New Construction		x			x	x	x
Solid-State	Renovation		x		x	x		x
Dim. Ballast	New Construction		x		x	x	x	x
Sensors								
Clocks	Retrofit		x					
	Ren./New Const.		x					
Personnel	Retrofit			x				
	Ren./New Const.			x				
Photocell	Retrofit					x		
	Ren./New Const.					x	x	
Communication								
Computer/	Retrofit		x					
Microprocessor	Renovation		x			x		x
	New Construction		x			x	x	x
Power-Line	Retrofit		x					
Carrier	Ren./New Const.		x		x	x	x	x

Table III Major Cost Factors for Lighting Control Applications

Application	Initial Cost	Operating Cost	Installation Cost	Supply Circuit Layout	Building Design
Retrofit	x	x	x	x	x
Renovation	x	x			x
New Construction	x	x			

Table IV Equipment Selections for Various Applications

Priority	Retrofit	Renovation	New Construction
I	(1-2) Delamp (1-2) Impedance-Modifier (lamps) (1) Switches/Relays (1-2) Voltage/Phase Control (1) Computer/Microprocessor (1) Power-Line Carrier (1) Clocks	(2) Switches/Relays (3) Voltage/Phase Control (4) Solid-State Dimming Ballasts (3) Computer/Microprocessor (1) Clocks (1) Photocells	(2) Switches/Relays (4) Voltage/Phase Control (5) Solid-State Dimming Ballasts (4) Computer/Microprocessor (1) Clocks (2) Photocells
II	(1-2) Impedance-Modifiers (hard-wired) (1) Personnel Sensors (1) Photocells (3) Voltage/Phase Control	(5) Power-Line Carrier (1) Personnel Sensors	(5) Power-Line Carrier (1) Personnel Sensors

( ) Numbers in parentheses indicate the number of lighting control strategies that can be implemented for an application.