

WHITE PAPER

Selecting Effective Lighting Control

Bulletin 500 Lighting Contactors

This paper examines different types of lighting controls and provides guidelines that may help in selecting the controls to suit individual needs with particular emphasis on lighting contactors.



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Bulletin 500 Lighting Contactors

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Introduction

In the past decade, there have been many improvements in the control of lighting, for residential, commercial, institutional, and industrial facilities. This has resulted in more efficient use of electricity, greater utilization of daylight, and more versatile, automated, and convenient controls. Such control devices include contactors, relays, timers, sensors, operator interface graphic terminals, programmable controllers, and industrial computer-based control systems that may be utilized in diverse on-off and variable level control schemes. This white paper discusses different types of lighting controls and provides guidelines that may help in selecting the controls to suit individual needs, with particular emphasis on lighting contactors.

Categories of Lighting Contactors

In its simplest form, on-off lighting control can be a manually operated switch located on a wall, a timer, a relay mounted in a lighting fixture, separately mounted lighting contactors, or panelboards containing lighting contactors. Manually operated switches are often used in residential, commercial, and institutional facilities. However, the trend is toward the use of remote electrically-operated lighting contactors, programmable controllers, and wall mounted operator interface graphic terminals (e.g., Allen-Bradley PanelView™) to facilitate better energy management and supervisory control. To enhance ease of field conversions and servicing, many lighting contactors are designed to a modular platform with interchangeable contact blocks and coils.

Lighting contactors can be divided into three general categories: feeder disconnect type 2-, 3-, and 4-pole lighting contactors rated up to 2250 A to control large blocks of load, multi-pole lighting contactors with as many as 12 poles rated 20...30 A for multi-branch circuit control, and industrial relays rated 20...35 A with low-voltage control for individual branch circuit or luminaire control. Lighting contactors are typically electrically held, mechanically held, or permanent magnet latch type, thus lending themselves to many forms of automatic control.

Feeder Disconnect Type and Combination Lighting Contactors

Feeder disconnect type lighting contactors are used for turning large blocks of lights on and off. They are available in both NEMA and Definite Purpose type designs. Though available in sizes up to 2250 A, the more popular sizes range from 30...225 A because the trend has been to use them to control full-bus and split-bus lighting panelboards. See Figure 1.

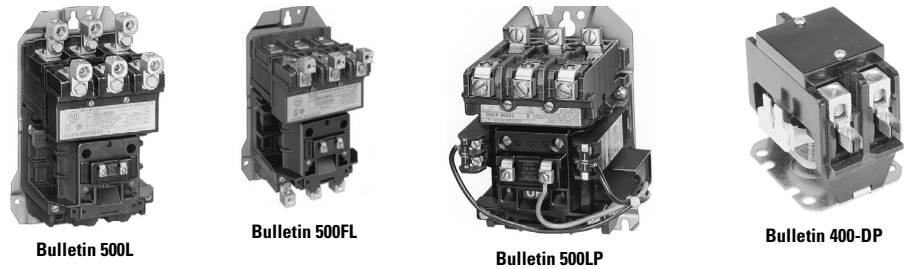


Figure 1. Allen-Bradley Bulletin 500L (10...2250 A top wiring electrically-held), 500FL (20...300 A feed-through wiring electrically-held), 500LP (20...300 A top wiring permanent magnet latching), and 400 Definite Purpose Contactor

Whenever lighting is being distributed over a wide area, two-pole, three-pole, and four-pole lighting contactors can help provide safety, economy, and convenience. Since small conductors can be used for control stations, and an almost unlimited number of stations can be used to control each lighting contactor, the electrical designer can be liberal with the number of multiple control stations used.

Shown in Figure 2 is a typical illustration of a three-wire control installation. In this instance a three-pole Lighting Contactor is being controlled from three (3) remotely located (three-position, momentary center off) control stations. Typically applied for switching large blocks of lights at the panelboard these types of lighting contactors can have ratings from 30...225 A.

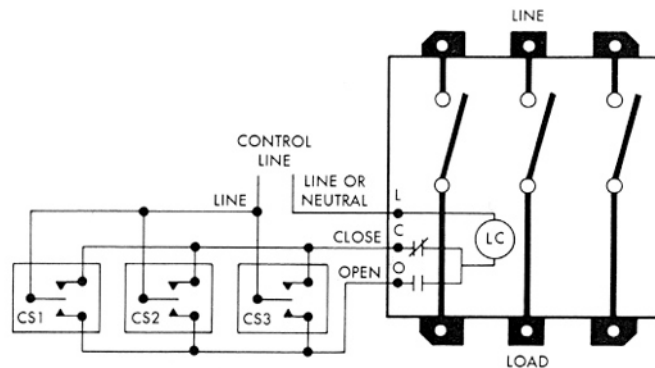


Figure 2. Typical Illustration of a Three-Wire Control Installation

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Typical of the previous installation in Figure 2, feeder disconnect type lighting contactors might be a large high-rise office building. As an example, four 225 A lighting contactors could provide on-off switching of the four zones of lighting on each floor of a high-rise building. The lighting contactors could, in turn, be controlled by one or more master controllers. Feeder disconnect type lighting contactors can be provided as open type or enclosed.

Combination lighting contactors are available for applications that require combining switching and overcurrent protection in the same enclosure. Combination lighting contactors may be applied for industrial, highway and area lighting applications or where a lighting circuit may have to be disconnected for periodic maintenance. See Figure 3.

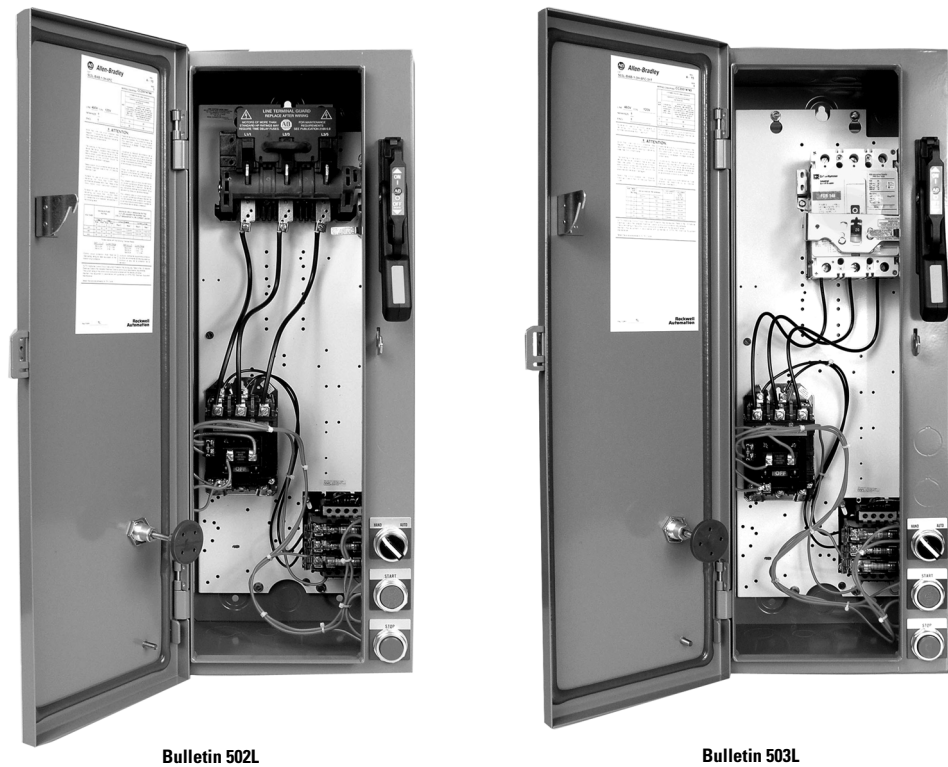


Figure 3. Allen-Bradley Bulletin 502L (with disconnect switch) & 503L (with circuit breaker) Combination Lighting Contactors

Multi-Pole Lighting Contactors for Branch Circuits

Today's compact, multi-pole, lighting contactors are available up to 12 poles, with contacts rated at 20...30 A for branch circuits. See Figure 4.

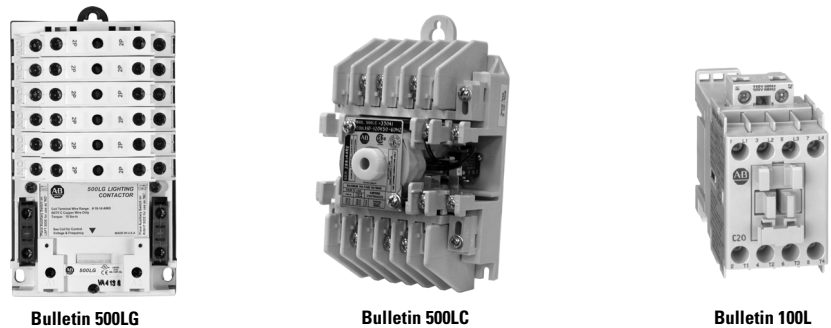


Figure 4. Allen-Bradley Bulletin 500LG Lighting Contactor (electrically held), 500LC Lighting Contactor (mechanically held), and 100L Lighting Contactor (electrically held)

The compact multi-pole lighting contactors that are electrically held require a continuous control voltage to maintain their position. Electrically held lighting contactors change position and disconnect power to lights and/or general loads during sustained reduction or complete loss of control voltage. This change of state during loss of power is critical for applications or processes that require inspection prior to start up. Thus, electrically held lighting contactors are well suited where protection is needed against automatic restart after a power failure or where reliability to a control function is critical to safety.

The compact multi-pole lighting contactors that are mechanically held require only a momentarily applied current to either close or open. This enables the lighting contactor to be controlled by:

1. Manually operated, three-position, momentary contact switches with the center off positions.
2. Auxiliary relays or solid-state modules that operate as a function of photoelectric and occupancy sensors.
3. Timers with a single-pole, double-throw contact. Single-throw contacts can be utilized if a two-wire control module is furnished.
4. Energy management systems.

Mechanically held lighting contactors do not change position and disconnect the lights during a momentary drop, sustained reduction or complete loss of control voltage. Such contactors do not require a continuous control voltage to maintain their position. Because the operating coil is not continuously energized, coil hum and continuous coil power consumption are eliminated, thus avoiding background noise and saving energy at the same time.

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Magnetically held, 20 A, multi-pole, lighting contactors are also used for lighting control. To provide fail-safe lighting in the event of loss of control power, Form C relays with normally closed contacts that carry the lighting load can be used. However, contact configuration and reduced contact pressure of normally closed contacts often limit the ability to carry fault currents or meet UL requirements.

Multi-pole, double-throw, lighting contactors are also available. These can be used to select either of two lighting levels, e.g., day lighting or night lighting, from a common power source.

From an energy conservation point-of-view, controlling a specific number of branch circuits or luminaires (2...12) rather than large blocks of lighting allows more design flexibility and customizing for the application. The latest multi-pole lighting contactors are available with optional solid-state control modules that provide convenient interfacing with various control systems. These will be discussed later.

Today's multi-pole lighting contactors are of shallow construction to accommodate mounting in panelboards or separate mounting in 4-inch stud-construction walls. They can be designed to withstand fault currents up to 22,000 A, symmetrical rms.

Low-Voltage Relays for Selective Lighting Control

Low-voltage relays are usually single pole and used for individual branch circuit or luminaire control. These single-pole low-voltage relays are available with contacts rated for 20 A at 120 and 277V AC. They are typically mechanically latched, requiring only a momentary 24V rectified AC switch circuit pulse to either open or close the load contacts. However, it should be noted that an open or failed unlatch control circuit will fail to unlatch the relay. For this reason, a mechanical latch unit should not be used where protection is needed against automatic restart after a power failure or where reliability to a control function is critical to safety.

There are also low-voltage industrial relays (containing no mechanical latch) available. These 1-...12-pole low-voltage industrial relays are available with contacts rated for 20...35 A for tungsten lamp loads to 480V AC. These industrial relays are modular and generally contain contacts that can easily be replaced or converted from normally open to normally closed (and visa versa) in the field. See Figure 5.

A step-down transformer is required to provide low-voltage control power for relay actuation. One transformer can typically supply power for up to 15 relays, provided properly sized wiring and transformer is used. Low-voltage control wiring must be segregated from other lighting circuit conductors. See Figure 5.



Figure 5. Allen-Bradley Bulletin 700-PK Relay, 700-PH Relay, and 1497 Control Transformer

Low-voltage relays are most often used in installations where a very high degree of selective lighting control is desired as they can control individual lighting fixtures.

Application Considerations for UL 67 Listed Panelboards and UL 508

When applying a lighting contactor to a UL 67 listed panelboard, the mechanically held type has certain advantages. The fact that the mechanically held version can be supplied with a single pulse-operated coil assures greater contact pressure, essential for withstanding short circuit fault currents. For example, a typical mechanically held, 20 A lighting contactor can withstand an available 22,000 A fault current when used with a 30 A molded case circuit breaker. Thus, they are satisfactory for use with UL 67 listed panelboards.

In addition to withstand current rating, consideration should be given to the type of lighting load. UL lists lighting contactors for general use loads, ballast (fluorescent) loads and tungsten (incandescent) loads. UL 508 requirements for ballast loads are more stringent than those for a general-use load, because UL requires ballast testing at a lower power factor and twice the nominal current rating. The requirements for a tungsten load are more stringent because they have to be tested for high inrush currents. A UL listed lighting contactor suitable for all three classes of load will have its nameplate so marked. The number of poles required for single-phase and three-phase applications also have a bearing on the continuous duty rating. Typical ratings for a small AC lighting contactor are shown in Tables 1 and 2.

Table 1 Continuous Duty Rating

Load Type	Amperes Continuous	Pole to Load	
		1 for 1ø	2 for 1ø 3 for 3ø
Tungsten	20	250V AC	250V AC
Ballast	20	277V AC	480V AC
General	30	347V AC	600V AC

Table 2 Available Symmetrical Amperes RMS

Service Voltage	When Used with Molded Case Circuit Breakers	
	Withstand Current Rating (Amps)	Max. Breaker Size (Amps)
250V AC	22,000	30
480V AC	14,000	
600V AC	10,000	

The Allen-Bradley Bulletin 500LC mechanically held lighting contactor is suited for UL 67 listed panelboards; however, it should be noted that many motor starter contactors, general-purpose relays, electrically operated circuit breakers, and some lighting contactors are not suited for UL 67 listed panelboards. Furthermore, they are not usually rated as per above nor listed per UL 508 requirements. Furthermore, use of a circuit breaker with trip elements for repetitive switching can alter the breaker's ability as an overcurrent protective device. Manufacturers' catalogs and technical literature should be consulted to ensure that the equipment is properly rated for the application.

UL 508 requires:

Tungsten Loads

Endurance: 6,000 cycles of operation of tungsten filament lamps at rated current (20 A), 250V AC at a duty cycle of one second on, 59 seconds off. This duty cycle allows enough off time for the tungsten filament to cool so that the next time that is energized, the switch must close on approximately 20 times rated current for up to 14 cycles which is characteristic of tungsten loads. This duty cycle assures the worst test conditions.

Overload: 50 cycles of operation at 1.5 times rated current (30 A), 0.75...0.80 power factor, 600V AC.

Ballast (electric discharge lamps)

Endurance: 6,000 cycles of operation at two times rated current (40 A), 0.4...0.5 power factor, 480V AC.

Overload: 50 cycles of operation at three times rated current (60 A), 0.4...0.5 power factor, 480V AC.

General Use

Endurance: 6,000 cycles of operation at rated current (20 A), 0.75...0.80 power factor, 600V AC.

Overload: 50 cycles of operation at 1.5 times rated current (30 A), 0.75...0.80 power factor, 600V AC.

Power Factor Corrected Ballast ❶

The Allen-Bradley Bulletin 500LC Lighting Contactor is suitable for power factor corrected ballast far in excess of 6,000 cycles of operation.

❶ Important: UL does not test for this requirement. However, we believe that this additional endurance test is a valuable, and unique, feature that illustrates the lighting contactors high reliability.

Lighting Control Methods and Sensors

Control Modules

The versatility of controlling lighting contactors is illustrated by the availability of optimal control accessories that can be provided to interface with various control schemes such as energy management systems, microprocessors, photoelectric cells and timers. These accessories may be in the form of discrete auxiliary relays or combined with solid-state modules, with the trend towards the latter. Three control methods are two-wire control, three-wire control, and start-stop control.

Figure 6 shows a typical wiring diagram of a 20 A multi-pole lighting contactor being controlled from two (2) remotely located (three-position, momentary, center off) control stations. The control stations in this figure are shown with signal lamps to indicate open or closed status of the lighting contactors' main contacts. Lighting contactors of this type typically can control from two to twelve 20 A branch lighting circuits.

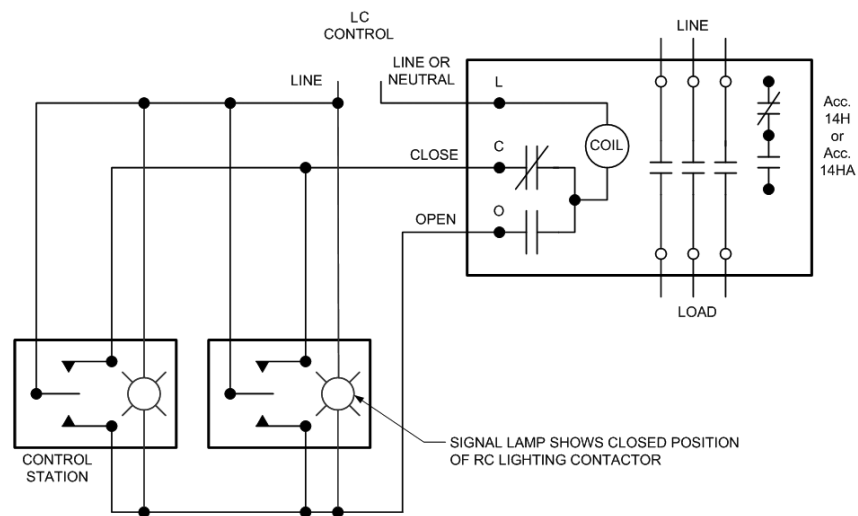


Figure 6. Typical Wiring Diagram

Two-Wire Control

If the lighting contactor is being operated from a programmable source, logic controller, or any control device providing control voltage to the lighting contactor by closing a set of single-pole maintained contacts, it would be necessary to provide an intermediate control device or a two-wire control module. Solid-state control modules provide control voltage to the contactor by responding to the opening and the closing single-pole single-throw (SPST) maintained output contacts in the primary control device. Therefore, different control voltages can be applied to operate the lighting contactor (i.e., 12V AC/DC, 24V AC/DC, 120V AC, 240V AC, 277 V AC). When utilizing a mechanically held design (e.g., the Allen-Bradley 500LC Lighting Contactor), such lighting contactors only require a momentary pulse of current to operate, the maintained current from the primary control device is converted to a momentary on/off pulse to the coil. Therefore, the coil only experiences a momentary pulse of current to open and close the lighting contactor's main contacts. See Figure 7.

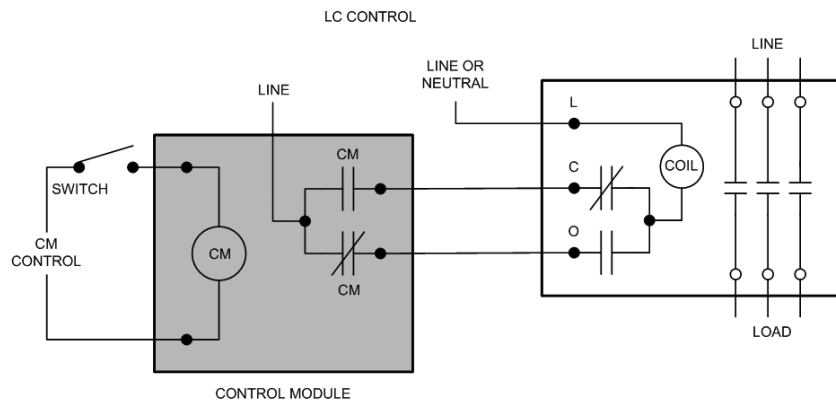


Figure 7. Two-Wire Control

Three-Wire Control

The three-wire control method permits extended control line runs. It provides three-wire control of the lighting contactor whereby one circuit is energized to close the lighting contactor and another is energized to open the lighting contactor. If neither or both circuits are energized, no operation will occur. Therefore, a single-pole, three-positioned (maintained off-momentary on position) type control station as shown in Figure 7, or two interlocked normally open push buttons, can be used with the accessory to operate the contactor. See Figure 8.

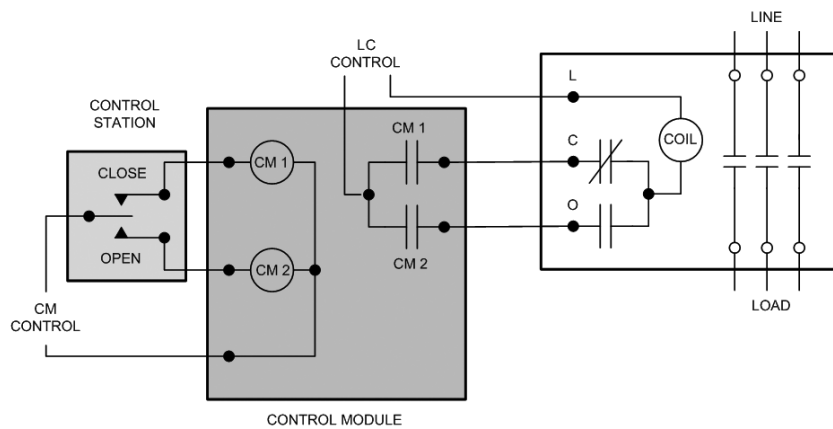


Figure 8. Three-Wire Control

Start-Stop Control

This control method provides start-stop (on/off) control of the lighting contactor. The accessory is energized to close the lighting contactor and de-energized to open the lighting contactor. Therefore, one normally closed and one normally open control station can be used with the accessory to operate the lighting contactor. See Figure 9.

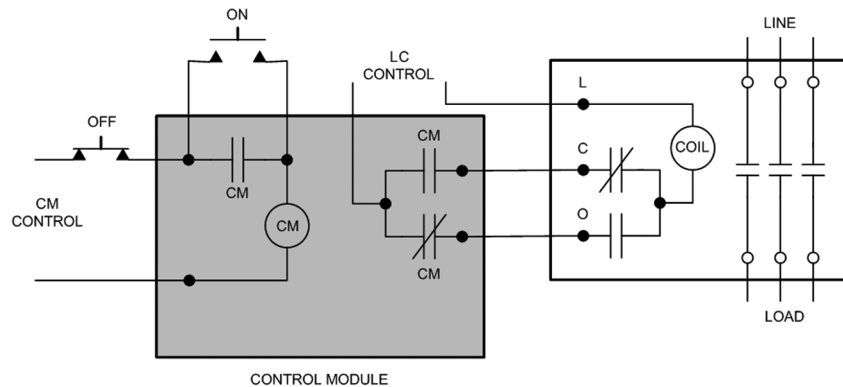


Figure 9. Stop-Start Control

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Optional control accessories can be applied at various control voltages such as 24V DC, 24V AC, 120V AC, and 277V AC. The solid-state versions are compact and can often be mounted directly on the contactor. Their power consumption is extremely low (less than 1.0 VA), thereby making them particularly suitable for energy management systems and long control wire runs. See Figure 10.

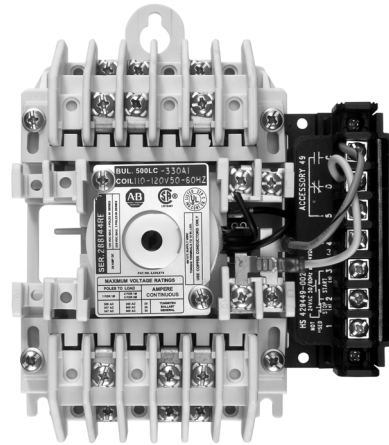


Figure 10. Bulletin 500LC Mechanically Held Lighting Contactor with Form C Start-Stop Control Module

Control Line Runs

Consideration should be given to control line runs when selecting lighting contactors and to the size of control wire between the lighting contactor and control station. The longer the line run, the larger the required wire size. Manufacturers provide line run data for lighting contactors using various wire sizes. When more than one lighting contactor is connected to the same control conductors, the data can be used in terms of "contactor feet." The allowable run for a group of lighting contactors is equal to the listed values divided by the number of lighting contactors. For example, if one lighting contactor has an allowable run of 1000 feet with #12 wire, 4 lighting contactors will be limited to 250 feet if they are operated simultaneously. Auxiliary relays and solid-state modules, as previously discussed, are often used where long control runs are required and it is desirable to limit the wire size.

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Timing Controls

A broad variety of time controls are available for direct control of lights or control of lighting contactors. They include 24-hour, 7-day calendar and astronomical dial timers. Though motor-operated timers are economical and quite suitable for many applications, the trend is toward electronic timers. Modern electronic timers use microprocessor technology and are extremely versatile and multi-functional in controlling many lighting areas. In the event of a power outage, electric timers can stagger the restoration of lighting loads to limit power surges. Internal batteries assure that the timers will retain their memory and keep timing during power outages. See Figure 11.



Figure 11. Allen-Bradley Bulletin 1760 Pico™ Controller, 700-HR52, 700-HRM, 700-FS, 700-HNK, 700-HRF, 700-HX, 700-HNC, 700-HXM

Electronic timers are used where multiple circuits, accuracy, and more sophisticated programming are required. They can be scheduled years in advance, taking into account holidays, etc., and allowing for leap years and daylight savings time changes. However, some have a limited load-carrying capacity and may require interfacing when used with lighting contactors. As previously discussed, optional solid-state control modules are available for such interfacing.

Photo-timers combine remotely mounted photoelectric switches with a 7-day timer. They can control multiple circuits, each with its own program. For example, one circuit can provide on and off by photoelectric control; a second, on by photoelectric control and off by timer; and the third, both on and off by timer. Manual bypass can maintain any circuit on or off for prolonged period without affecting the other circuits or the timer settings.

Pico is a trademark of Rockwell Automation, Inc.

Sensors

Sensors for lighting controls are either photoelectric sensing or presence detectors. Photoelectric sensors are normally set to switch lighting on at dusk and off at dawn. Adjustments can be made to change response to higher or lower levels. Built-in time delay helps to eliminate nuisance switching in response to sources other than natural ambient light, or passing shadows.

Photoelectric sensors are often combined with timers to provide a more efficient light control. Figure 12 shows such a control arrangement. Contacts on both photoelectric switch and the timer must close to cause the multi-pole lighting contactor to switch on the lights. Opening either set of contacts will open the lighting contactor, thus turning off the lights. A typical application would be an industrial parking lot where lighting is required only Monday through Friday evenings, and is turned on at dusk and shut off at midnight. The two-wire control may be a separate electromagnetic control relay or a built-in control module as shown.

A variety of presence detectors or occupancy sensors have been recently developed. These detectors automatically activate the lighting controls. They are designed to turn lights on upon sensing heat or motion caused by human occupancy within a defined space and turn them off at some preset time after the last person leaves.

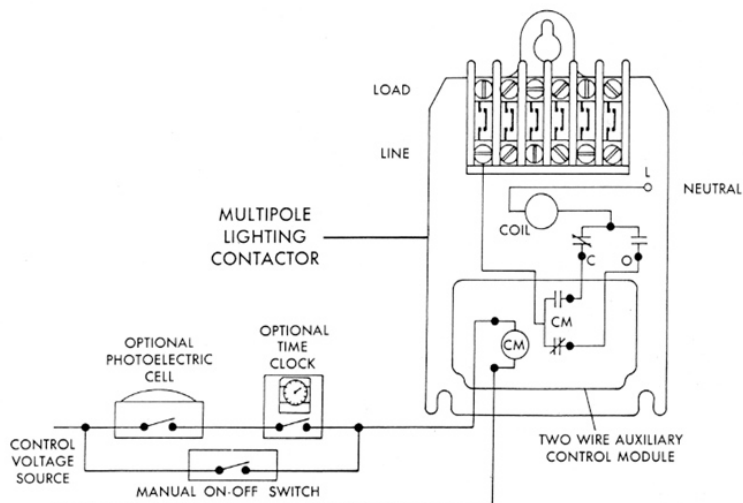


Figure 12. Photoelectric Sensor with Timer

Industrial Computer/ Programmable Controller Based Control Systems

Today's industrial computer and programmable controller (PLC) based control systems are sophisticated versions of electronic timers. The heart of such a system is an industrial computer and/or PLC-based controller that holds in memory a series of on-off instructions to the lighting circuits throughout a building. They can provide minute-by-minute control of an entire lighting scheme according to a user-determined schedule, with pulse initiation of the control signal generated from its internal clock. Photo, occupancy sensor, and manual controls are often utilized as logic inputs in determining the control decision.



Figure 13. Allen-Bradley Bulletin 1000/1761 MicroLogix™ Controller, 2711 PanelView™ Operator Interface Graphic Terminal, and VersaView® Industrial Computers

Multiplex signals from the control system can be sent throughout the building via a twisted pair of communications type wire. With other arrangements, signals can be sent via existing power wiring to the receiver control modules. Because no copper-to-copper connection exists between the primary and secondary of a conventional power transformer, couplers are available when command signals must bypass a transformer.

The codes from the controller are transmitted to the transceivers where they may be combined with other signals and, in turn, transmitted to the lighting contactors with control modules that require only a momentary electrical pulse to operate. The lighting contactors are often fitted with low-voltage control modules that can operate directly from the controller output.

Programming discretionary control and over-ride functions can be displayed on a CRT or operator interface graphic display and recorded on a hard copy printer. Figure 14 shows a conceptual scheme for an industrial computer/PLC-based lighting control system.

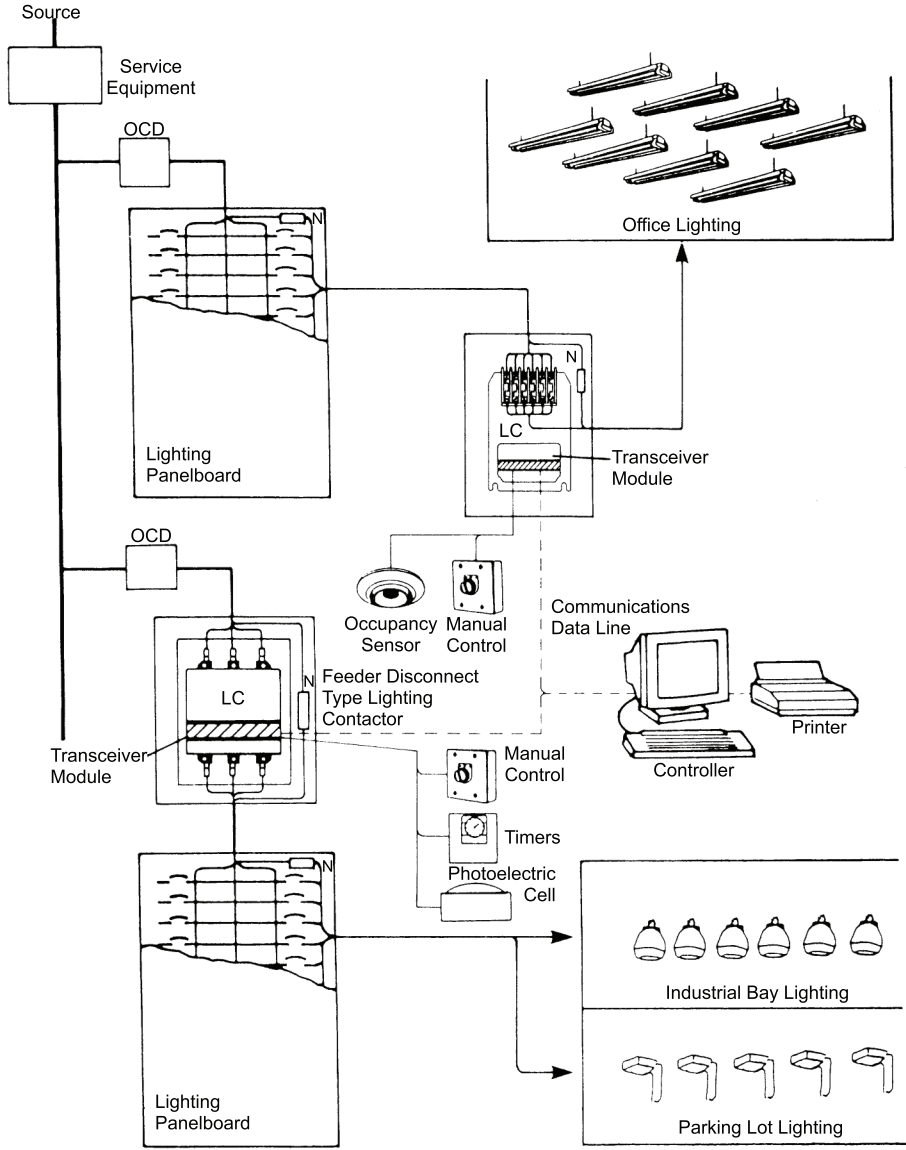


Figure 14. Conceptual Lighting Control System

Level Controls

In some energy management applications, it is desirable to provide a variable level of electronic illumination. Dimmers are the most often used means for providing lighting level control. Today's solid-state dimmers are suitable for incandescent, fluorescent, and HID lighting. Through the use of intermediate controllers, dimmers can operate as a function of available day lighting.

To fully exploit daylight as a source of illumination, it is necessary to establish an interactive link between ambient daylight conditions and the artificial lighting system. This can be achieved with a photoelectrically controlled lighting system that adjusts the output of the artificial lighting system based on the amount of prevailing daylight. Lighting control hardware that links artificial lighting to available daylight generally falls into two categories:

1. A continuously dimmable artificial lighting system that is controlled by photosensors that continually adjust the artificial lighting level in response to the amount of daylight striking the control photosensors. At the heart of the system is the controllable output ballast or dimming ballast.
2. A photo relay-based system that automatically switches off perimeter lighting when day lighting is sufficient to meet lighting needs.

The artificial lighting in daylight zones is used as fill-in lighting to provide even illumination across the occupied space. The amount of usable daylight is dependent on the window and skylight types and sizes, window and skylight treatments (drapes, glazing, etc.), building orientation and design, interior design, and furnishings.

Selection Guidelines

There is no set of specific rules that conveniently lead one to select lighting controls. However, the following factors will have a bearing and can serve as a general guide.

A large facility may economically justify a building management system or programmable controller that provides centralized lighting control. On the other hand, a small facility may obtain optimum savings by selection of a simple timer control.

Size of Individual Lighting Area

If the current drawn by an individual lighting area exceeds 30 A, feeder disconnect type or combination lighting contactors may be the choice. Small areas such as individual offices would be candidates for low-voltage relays for selective lighting control or multi-pole lighting contactors for branch circuits. In either case, these devices normally would be controlled by manual switches, operator interface graphic terminals, timers, photoelectric, and occupancy sensors, etc.

Facility Use

If the facility provides commercial rental of office space, flexibility may be a desirable design consideration. In other cases such as industrial and institutional facilities where lighting requirements are more fixed, multi-pole, and higher ampacity mechanically held, electrically held, or magnetic latch feeder disconnect type or combination lighting contactors may be the preferred choice.

Existing Facilities

Older buildings can often be upgraded using multi-pole lighting contactors. They can be mounted adjacent to the existing lighting panelboard to control only those circuits serving selected lighting loads. Extensive rewiring to existing fixtures may be avoided. Multi-pole lighting contactors used with occupancy sensors can be used to sectionalize a facility into functional work areas. This can help yield significant energy savings and possibly a short payback period.

European Common Market



Figure 15. Allen-Bradley Bulletin 500LG Electrically Held Lighting Contactor (cULus, CE-mark, RoHS compliant, IP1X, and IP2X)

The standards for lighting contactors to be used in the European Common Market are mandated by the International Electrotechnical Commission (IEC). Manufacturers of lighting contactors indicate compliance with these standards by placing a CE mark on the product.

Also, the European Common Market has the Restrictions of Hazardous Substance Directive (RoHS) that regulates the presence of heavy metals and certain flame retardants in the materials used to manufacture electrical and electronic equipment. The goal of this European Union directive is to restrict, wherever practical, the use of specific materials such as lead, mercury, and cadmium. This directive is expected to have an impact on virtually all products. Verify that lighting contactors are RoHS compliant prior to using the product in the European Common Market.

Finally, consideration should be given to IP2X (protection against access to hazardous parts with a finger) and IP1X (protection against access to hazardous parts with back of hand).

Conclusion

Recent technological advances have made available a wide choice of switching equipment and control systems for lighting. This presents opportunities to lighting designers to provide quality lighting. Regardless of the type and size of the facility a designer may deal with, there are suitable types of controls to use. Sound judgment in the selection of control schemes and equipment can achieve a quality lighting system with optimum energy savings.

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