CONTINUOUS CONTROLS: LIGHTING ENERGY MANAGEMENT FOR RETROFIT AND NEW CONSTRUCTION PROJECTS

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ABSTRACT

The rising interest of specifiers and end-users in Lighting Energy Management (LEM) control equipment has led to an increased need for further education in the selection, capabilities and applications of such equipment.

This paper addresses these and related points for a particular type of LEM equipment referred to as “continuous controls.” More specifically, the need for such equipment and its performance are reviewed. The remainder of the paper discusses the capabilities and applications of continuous control equipment for retrofit and new construction projects. Particular attention is drawn to the need for specifiers and end-users to become more control conscious as continuous controls become more fully integrated into building design.

INTRODUCTION

Lighting is responsible for a significant portion of the total energy bill for an office building, typically constituting thirty-five to sixty percent of the electrical load. Lighting costs will continue to rise as electrical rates and demand charges escalate. A recent survey of energy users revealed an expected average electricity rate increase of 6% for the next year. (1) This is consistent with data from previous years; since 1969, electricity costs on a national average basis have always increased from year-to-year, peaking in 1974 and 1979 with 29.92 and 20.5% increases respectively. (2)

From a building owner's point of view, Lighting Energy Management (LEM) equipment is necessary in order to control present and future energy expenditures as well as to minimize the sudden damaging effects of a dramatic price increase; those which occurred in 1974 and 1979 are good examples. Specifiers then, must become proficient at understanding the capabilities and applications of LEM equipment. They must gain the attention of building owners who expect energy-efficient buildings and realize that properly designed, high-quality LEM equipment will help ensure long-term satisfaction. Conversely, building owners will seek out specifiers with a thorough understanding of LEM as well as a proven track record. It will then be to the advantage of architects, engineers and lighting designers to become knowledgeable about the various LEM controls that are available so that the optimum control system can be selected for each client.

CONTINUOUS CONTROLS

There are several types of LEM control equipment that a specifier can choose from. One of the most technically innovative and economically justifiable of these is “continuous control”, often referred to as dimming. In its truest sense, however, dimming involves reducing the light output of a lamp for aesthetic purposes, to modify the ambiance and help define the mood of a space. Dimming fluorescent and H.I.D. sources require the use of special dimming ballasts and while energy is saved during the dimming process, it is not the prime consideration.

With continuous controls, the prime motivating factor is proper energy management. Energy consumption is reduced proportionately to lighting levels. As an alternative to using rather expensive dimming ballasts, cost-effective continuous control equipment used conventional magnetic core ballasts to reduce the power consumption of fluorescent and H.I.D. fixtures. This is quite significant, because one of the primary objectives in any project is to minimize costs while providing maximum benefits. These two important project objectives make every existing or future building an excellent candidate for a continuous control system, since it will be shown that tremendous energy savings and other associated benefits will result. Costs will also be minimized because the first half of the system, conventional ballasted luminaires, is already in place or soon will be.

EQUIPMENT

The other half of a continuous control system is the equipment itself. There are four major classifications of continuous control equipment by capacity: sub-circuit, circuit, multi-circuit and panel control.

SUB-CIRCUIT

Sub-circuit control is used when the lighting level requirements or working schedules vary within a small area, typically less than 1,000 square feet. Sub-circuit control would be considered for areas less than 500 square feet for some older buildings with 120 volt lighting systems. The equipment is generally located above the ceiling in the plenum or in the fixture itself.
CONTROL

Circuit control is the most common strategy in an office building whereby a continuous control unit adjusts the lighting consumption of an entire circuit of lighting. The control equipment typically is mounted in or near the electrical closet.

MULTI-CIRCUIT

Multi-circuit control involves combining several lighting circuits on the same lighting phase to one control unit. The unit is fed with a higher amperage breaker, typically 30 or 40 amp, and the load is then reduced to 20 amp lighting circuits (15 amp in some cities) via secondary breakers on the equipment. Multi-circuit control equipment is used in larger areas where lighting load requirements and schedules are similar. The control equipment again is installed typically in or near the electrical closet.

Panel control involves controlling all the lighting on a distribution panel as one zone (a zone of lighting being defined as a group of luminaires which are controlled simultaneously and identically). The control equipment is of high amperage capacity and instalts between the main distribution panel and the lighting distribution panel, either in the electrical closet or where the main feeders enter the building.

There are trade-offs between the different control capabilities; for example, as the equipment size increases, the installed cost per watt controlled decreases, but so does the flexibility and with it the potential to maximize energy savings. Careful consideration must be given to the performance capabilities of the control equipment for each project. Manufacturers are usually willing to provide applications assistance however, it may be best to work with the manufacturers that offer a wide choice of equipment to ensure that the client’s needs are best met and not the manufacturer’s.

PERFORMANCE

A properly designed continuous control system that performs well is an invaluable asset to a building owner; the equipment will provide tremendous energy savings while creating an extremely flexible lighting system. On the other hand, a continuous control lighting system which performs poorly will result in lower energy savings, negative employee/worker reactions and an extremely unsatisfactory lighting system. It is the responsibility of the specifier to seek out such control systems, verify the economic justification of a control system may not longer apply and the specifier will end up with a potentially unhappy client.

A high quality continuous control lighting system will provide a wide control range, excellent lamp aesthetics and uphold the integrity of the lighting system. It is the responsibility of the specifier to seek out such control systems, verify all performance criteria are met as well as the client’s short and long-term needs.

APPLICATIONS AND DESIGN CONSIDERATION

There are three continuous control strategies which may be employed, either independently or in combinations with each other, in order to maximize savings. Lighting energy savings are possible by:

1. Maintaining a given light level using photo-sensor control.
2. Eliminating lighting energy wastes when and where appropriate.
3. Reducing lighting peak demand usage.

PHOTOSENSOR CONTROL

Two options are possible using photosensor control.

Daylighting - DAC

Daylight Automatic Control is probably the easiest control strategy to understand as well as justify. A photosensor is used to monitor daylight levels and interface with continuous control equipment, signaling the equipment to reduce lighting/power levels when any daylight is present in the controlled space. With DAC it is not necessary to reduce the maintained light level to incur savings (figures 1A and 1B). Of course, the savings resulting from maintaining 70 footcandles will be greater than a system which maintains 123 FC. Data obtained from detailed analysis, experimentation, and test installations (3, 4, 5) show that DAC can reduce lighting energy costs from 8% to 10% on a building’s basis. This is quite substantial.
When one considers that potential daylight con-
trollable perimeter zones may account for only 15% to 25% of the total floor area; actual annual savings in the controlled zones will range between 25% to 70%. These studies have been further co-
corporated with post installation monitoring of acti-
cut projects which show lighting energy savings of 45%, 55% and 63%, respectively. (6, 7, 8) In ad-
tion to those points already mentioned, a DAC con-
trol system should meet the following perfor-
mance criteria: 1. Be easy to adjust and calibrate. 2. Utilize an accurate photosensor that does not drift with time or temperature. 3. Provide a slow fade rate (20-30 seconds) between levels to ensure that occupants are not subjected to rapidly fluctuating lighting levels, thus minimizing awareness of a control system. Sub-circuit and circuit control capacity equipment is generally equipped due to the size of the perimeter areas as well as their orientation (maximum savings are achieved if different building facades are controlled independently). Larger perimeter areas or areas that see uniform daylight levels should be translated into additional peak demand savings. Savings associated with reduced peak demand and lower cooling loads may be realized as well. The greatest seasonal peak demand period for many commercial buildings occurs in the mid to late afternoon during the summer, primarily due to increased cooling load requirements. Concurrently, with DAC the perimeter lighting load will be sub-
stantially reduced providing built-in demand re-
duction capabilities as the lighting power (KW) decreases in response to daylight. Cooling re-
quirements will also be reduced during these periods, 0.15 to 0.60 fewer watts of cooling per watt of lighting reduction are required, de-
pending on the total building design and location. The majority of commercial office buildings may be able to achieve traditional peak demand and consumption savings after accounting for all thermal considerations. The same building might also enjoy potential capital savings: downgrading the tons of refrigeration required in new con-
struction (a savings of $600 to $800 per KW expected lighting reduction, assuming $1500 to $3000 per ton of refrigeration installed). (9)

Lumen Maintenance - ILC*. Interior Lighting Compensation may be used in any new construction or renovation project, or in retrofit applications where group relamping is practiced. All lighting sources depreciate in light output as the lamps age, necessitating the lighting designers and engineers to provide more light initially than is actually required to ensure that enough light re-
mains at a later date. Luminaires also tend to accumulate dirt and dust, further reducing the ef-
ciciency of the lighting system. To overcome this and LEA provides a means of pro-
ducing uniform lighting at a lower energy cost.

Another advantage of LEA is "tuning." Tuning re-


dents with time as additional power is required to main-
tain the designed light level (figures 2A and 2B). Maximizing the ability to fine tune the lighting system to proper levels. Only after the age of those working in an area and the nature of the task being performed (importance, required accuracy and speed, and other factors) have been considered, can one effectively determine and set the appropriate light level. The value of flexi-

bility is overemphasized until one considers a typical office building where a specifier is asked to design a lighting system. In many instances the building owner cannot predict what specific tasks will be performed at the new building, let alone the other factors mentioned. He cer-
tainly cannot predict what each area will be used for in two, three or four years.

The ability to fine tune the lighting system over time using continuous controls is one solution to this design dilemma. One study (10) indicated that building owners could have saved an additional 12% on lighting energy costs if the lighting system could have been fine tuned as described. Energy savings might also be realized in areas where constraints due to space-saving-focus-point requirements may be performed. Grid patterns or selected fixture types
provide maintained light levels higher than
desired. LEA can be used to lower the lighting/
power levels to reach the design levels. The
"flexibility" feature of continuous controls, both
for existing facilities and new construction
provides more control as well as on/off capability when used in conjunction with pro-
grammable time clocks or energy management equip-
ment. TODS control can provide tremendous building
wide energy savings due to the fact that lighting
requirements not only change over a long period of
time, but in fact change in many instances in a predictable manner within a
day. Take for example a typical weekday. If the "official" start of the workday is 8:00 a.m.,
there will be some workers who will arrive prior
to that time to take care of small matters —
cleaning up a desk, setting up the day's schedule,
etc. In short, preparing for the upcoming day.
The majority of these tasks would be classified as
non-critical in comparison to those during normal
work hours, so it is reasonable to expect that
lighting levels might be lowered as much as 20% during these non-critical periods. Once the normal
work schedule has been resumed, lighting levels
would be brought up to 100% of the desired level.
During lunch or other break periods, lighting levels
could again be reduced and then finally
shut off after the cleaning crew has arrived.
Lighting/power levels could again be reduced and then finally
shut off after the cleaning crew has arrived
building up the Figure 3).

TODS offers perhaps the greatest building
wide energy savings potential of any continuous controls and long term benefits for a building owner. The TODS system can provide building owners high quality
lighting, tremendous energy expenditure reductions
to incorporate demand limiting strategies. PDR
should be evaluated as carefully as any other
demand control, and will be found to be applicable
in many instances.

**CONCLUSION**

LEA equipment will play an increasingly im-
portant role in the design of the total building
system. Continuous control is one LEA strategy
that when properly integrated into the lighting
system can provide building owners high quality
lighting, tremendous energy expenditure reductions
and unsurpassed lighting system flexibility. Furthermore, associated with these benefits are
tremendous building wide energy savings due to the fact that lighting
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specifier. This support may take the form of:

- "toll-free technical assistance "hotlines"
- Applications and system layout assistance
- "Technical and sales presentations"
- "Free computerized energy analysis"

These support services will foster a good working relationship between a control manufacturer and a specifying firm; this can only serve to enhance both the short and long term satisfaction of that firm’s clients.

An electrical energy costs escalate, it will become more difficult to hold building operational costs in line. Many owners and specifiers will view this situation as a tremendous problem. Others will translate this problem into an opportunity by using energy management equipment such as continuous controls.

REFERENCES

11. Ibid.
12. Rubinstein, Measured Savings.
DAYLIGHT LEVELS 15' FROM WINDOW (TYPICAL) VS. TIME OF DAY.

Figure 1A

DAYLIGHT LEVELS 15' FROM WINDOW (TYPICAL) VS. TIME OF DAY.

Figure 1B

ENERGY CONSUMPTION VS. TIME USING FIGURE 1A USING CONTINUOUS CONTROL (100%-40% Range, Target Level 50 FC).

Figure 2A

LIGHT LEVEL IN INTERIOR OFFICE SPACE VS. TIME.

Figure 2B

ENERGY CONSUMPTION VS. TIME USING FIGURE 2A.

Figure 3

ENERGY CONSUMPTION VS. TIME FOR TYPICAL OFFICE AREA.
TIME OF DAY SCHEDULING VIA CONTACTOR SWITCHING

TIME OF DAY SCHEDULING VIA CONTINUOUS CONTROL

DEMAND PROFILE FOR TYPICAL OFFICE AREA