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Energy Efficient Lighting Control System Design For Corridor illumination

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ABSRACT: Energy efficient corridor illumination in commercial and residential buildings is becoming increasingly important in the energy conservation era. Lighting control systems with adequate algorithms are basically used for energy saving. The integration of daylight with electric light in building corridors during daytime hours is a key element in designing the lighting control system.

The most common form of electric lighting control is the on/off "toggle" switch. Other forms of lighting control include occupancy sensors, daylight sensors, clock switches, a variety of manual and automatic dimming devices, and centralized controls. The selection of sensor and type of lighting control depends on the application and the area where it is used. Mostly, occupancy sensor and photosensors are used in corridors. The corridor is not always occupied with people, rather people are moving continuously in a corridor. So, required illumination in a corridor is less as compared with a room or a hall. The twilight and night time illumination requirements are different and have additional behavioral and security issues associated. For corridors, required illumination or light intensity usually ranges from 50 to 100 lux [1].

The main aim of this paper includes the study and analysis of the good practice of energy-efficient lighting for corridor. The major findings in this study are that the energy-efficient lighting design could still be achieved without sacrificing the visual comfort and aesthetic requirement of the building, which is always a major issue of the owner. However, Energy-efficient lighting could be more easily implemented if it is considered right from the early design stage.

The proposed lighting control system is based on microcontroller and uses LED based luminaries as light source. The system includes patterning of luminaries for e in day and at night. This system uses photosensor and controls the illumination in a corridor depending upon the light intensity.

Indexed Terms: LED (Light Emitting Diode), Microcontroller, energy efficiency, Corridor illumination, patterning of luminaries, photosensors, energy saving, light intensity.

1. Introduction:

The use of energy in buildings has increased in recent years because of the growing demand in energy used for heating, ventilating and air conditioning (HVAC) and lighting in buildings. Owing to the consistently growing demand, much effort has now been put towards reducing the demand for energy through energy efficiency in design. Energy efficiency is energy intensity, which, in simple terms, refers to the use of less energy to provide the same level of energy service or to do more work with the same unit of energy (EIA1 IEA2 Fickett et al, 1990). This objective can be achieved primarily by using a more efficient technology or process rather than by changes in individual behavior (Diesendorf, 2007).

Many studies have revealed that proper use of sustainable technology in lighting, such as the use of daylighting controls and low energy lighting, has a strong potential for reducing the demand for energy in commercial and industrial buildings (Busch et al, 1993; Nilsson and Aronsson, 1993; Min et al, 1997; Knight, 1999; Kim and Mistrick, 2001) and there is potential for improving the energy efficiency of lighting systems throughout the world (Mills and Piette, 1993). A recent survey of several companies has found that 23 per cent of all energy-saving opportunities could be achieved by improving the energy efficiency of lighting systems (BIE, 1996).

It has been reported that around 30–40 per cent of the total building electricity energy used in many commercial buildings is consumed by the lighting systems (Swisher et al, 1994; Yarnell, 1995; Li et al, 2002). Research shows that a fair number of newly built buildings are still not designed in the way that the energy is used efficiently (Littlefair, 1996; Li and Lam, 2001). There are several instances in which lighting energy in the building has not been used efficiently. This could be because daylight is not efficiently integrated with the artificial lighting system, or in cases where integration does exist, energy savings using energy-efficient lighting technology have not been fully explored.

Enormous energy savings are possible using energy efficient equipment, effective controls, and proper selection of light source. Electric lighting design also strongly affects visual performance and visual comfort by aiming to maintain adequate and appropriate illumination while controlling reflection and glare. The Problem of energy saving and the achievement of visual comfort conditions in the interior environment of a building is multidimensional. Scientists from a variety of fields have been working on it for quite few decades, but it still remains an open problem. People spend about 80% of their lives inside buildings. So, achieving lighting comfort conditions in a building is very important and has direct implication to the energy efficiency of the building [2].The achievement of the lighting controller depends on its efficiency and properness in light level controlled illumination systems as well as types of light source used.

There are varieties of light sources such as Incandescent lamps, Reflector lamps, and Gas discharge lamps which includes Fluorescent tube lamps (FTL), Compact Fluorescent Lamps (CFL), Mercury Vapour Lamps, Sodium Vapour Lamps, Metal Halide Lamps

Tube lights/CFLs on average contain 4 mg of mercury, which has to be disposed by land filling. If a CFL is disposed off improperly the 4 mg contained within the lamp can get back into the normal ecosystem. Traditional 50-watt incandescent uses 438 kWh, which creates around 300KGs of carbon dioxide emissions per year. LED (Light Emitting Diodes) panel at 10watt consumes 5 times less power and hence will reduce CO_2 emission to 1/5th.

LED has its advantages such as a very low energy consumption level which directly contributes to savings on the light bill. LED has much longer life than traditional lighting (up to 50,000 hours). There is no infrared lighting, UV radiation from LED lights and also it doesn't contain mercury making it safer. Also LED has high luminous efficiency (at least 90-100lm/W), lower losses in the distribution of the controlled luminous flux compared to traditional lamps (emitting only a beam of 120°, whilst traditional have about 360°). LED is fully dimmable without color variation. However, LED lighting is not nearly as immediately affordable as traditional lighting. The cost problem becomes worse to change the existing lights as opposed to starting new.

2. Lighting Controls:

Lighting controls help conserve energy and make a lighting system more flexible. The most common light control is the on/off switch, Manual dimming, Photosensors, Occupancy sensors, Clock switches or timers and Centralized controls. Manual dimming controls allow occupants of a space to adjust the light output or illuminance. This can result in energy savings through reductions in input power, as well as reductions in peak power demand, and enhanced lighting flexibility. This type of technology is well suited for retrofit projects, where it is useful to minimize rewiring [3], [4]. Photosensors automatically adjust the light output of a lighting system based on detected illuminance.

Occupancy sensors turn lights on and off based on their detection of motion within a space. Some sensors can be also be used in conjunction with dimming controls to keep the lights from turning completely off when a space is unoccupied. These sensors can also be used to enhance the efficiency of centralized controls by switching off lights in unoccupied areas during normal working hours as well as afterhours [4], [5].

3. Control System:

Lighting controls can be grouped into two general categories: centralized controls and local controls. Centralized controls are used in buildings where it is desirable to control large areas of the building on the same schedule. For example in the morning the system can turn on lights a few minutes before the arrival of the employees. After the end of the working day the system can turn off lights again. During the day the lighting system can be adjusted in order to avoid peak demands (for example during noon at summer months). Localized controls are designed to affect only specific areas. There are various ways to control the lighting system for energy saving purpose. On-Off" switch is the simplest and the most widely used form of controlling a lighting installation. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required. Hence, a flexible lighting system has to be provided, which will offer switch-off or reduction in lighting level, when not needed. Grouping of light sources is also a way of lighting control systems for energy efficiency which can control light sources manually or by timer control. It can provide greater flexibility in lighting control.

Another modern method is usage of microprocessor/ infrared controlled dimming or switching circuits. The lighting control can be obtained by using logic units located in the ceiling, which can take pre-programme commands and activate specified lighting circuits. Advanced lighting control system uses movement detectors or lighting sensors, to feed signals to the controllers.

Whenever the orientation of a building permits, day lighting can be used in combination with electric lighting. This should not introduce glare or a severe imbalance of brightness in visual environment.

Additionally, sensor technology influences how well it detects occupants. Some sensors use infrared technology, some use ultrasonic technology, while others use a combination. There is a concern that some lamps have a shortened life if they are switched off and on frequently. Programmed start ballasts offer the softest and smoothest lamp start and are intended to improve lamp life if a frequent on and off occurs. [6]

The use of daylight in buildings is an important and useful strategy in replacing the need for high level of conventional energy for inside illumination. In this study, system is designed considering energy saving and lighting comfort together.

4. Study of the workspace:

The lighting control system for corridors uses daylight and electric lighting jointly to provide task, background or general luminance. The design of control system depends upon sky condition and solar location. In order to establish the lighting controls, luminance measurements are needed for a minimum of three different seasons representing winter, rainy and summer.

Here, illuminated indoor environment is the Corridor of Electronic Science Department, University of Pune. The area is first studied for deciding the optimum illumination level. For this study, the corridor in which the light control system has to be installed is divided into four sections A, B, C and D as shown in figure 1.1.

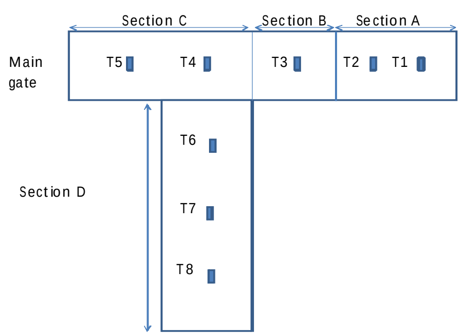

Fig1.1.Design of Corridor of Electronic Science Dept.

Existing lighting system contains 2 tubes in section A, 1 in section B, 2 in section C and 3 in section D. The corridor has Conventional Fluorescent Lamps/tubes/tube lights (T8) of 40 W. Fluorescent lamps are categorized according to their diameter. The requirements of illumination levels at different times in the corridor depend on the people working in that area. So a survey about the working hours of the people in that building has done which is given in table 1.1. To find out the minimum intensity levels in the corridor, several observations are taken at different timing of the day. Lux meter is used to take the observations.

Zone	Timing	No.of luminaires required
Fringe Hours	8 am – 10 am (in morning)	8
Working Hours	10 am – 6 pm	6
Fringe Hours	6 pm – 7 pm (in evening)	8
Non working Hours	7 pm – 8 am	4

Table 1.1

5. Control system design:

As the cost of energy has continued to rise, increasing effort has gone into minimizing the energy consumption of lighting installation. This effort has evolved along three major directions:

1. The development of new energy efficient lighting equipment
2. The utilization of improved lighting design practice
3. The improvement in lighting control systems.

While saving energy is of a great importance, there are some other associated benefits which should be considered. These are productivity and quality. However is quite difficult to quantify their influence. Lighting controls perform functions like on-off, time scheduling, dimming, and dimming due to presence of daylighting, lumen depreciation and demand control.

Lighting controls is an integral part of a lighting system. These controls must be responsive to the functional and aesthetic requirements placed upon it, and should perform these duties in an energy efficient manner. In general, there do not appear to be any general rules or guidelines that congenitally lead one to select specific controls. Energy savings due to daylight depends on climate conditions, building form and design and the activities within the building. In addition this factor is directly linked with the operating schedule of the building.

Providing daylight in a building does not by itself lead to energy efficiency. Even a well daylit building may have a high level of lighting energy use if the lighting controls are inappropriate. Case studies [7] have shown that in a conventionally daylit commercial building the choice of control can make 30-40% difference to the resulting lighting use. Wireless protocol such as ZigBee technology is also widely used in various areas for its excellent performance in reliability, power consumption,

flexibility and cost for lighting control[8]. Lighting control could be performed by using fuzzy logic controller also [9]. Using motion sensors, lamp groups are turned on when motion is detected. Thus, energy consumption was prevented by turning off the lamp groups when there is no motion.

In order to assess the energy efficiency of lighting installation especially in corridor of a building, a criterion for the installed electrical power is proposed which is broadly applicable and easy to use.

6. Description of developed system:

The developed Lighting control system is basically based on energy efficiency of an indoor lighting installation for corridors which mainly includes use of daylight. The system is designed using 80S52 microcontroller. The block diagram of the developed control system is shown in figure 1.2.

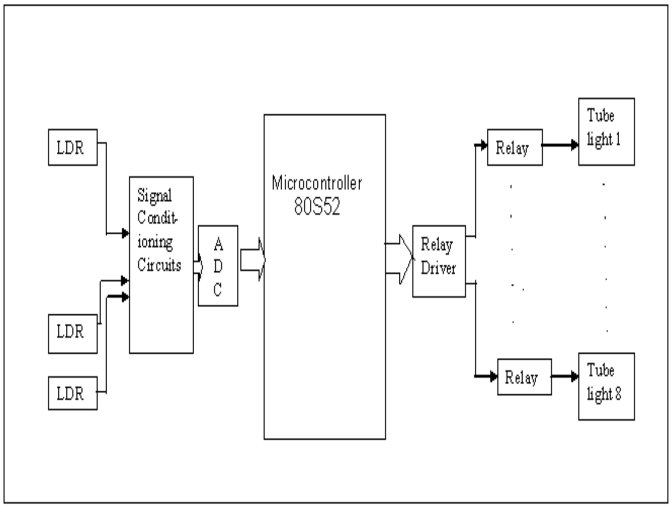

Fig 1.2 Block diagram of developed lighting control system

As shown in figure 1.2, the lighting control system uses microcontroller 80S52/80C52 microcontroller. The system has two modes. In mode 1, the inputs from the LDRs are considered. The resistance of the LDR is varying according to the light intensity in the corridor. The signal conditioning circuit converts it into voltage which is given as an input to the ADC (Analog to digital Converter). The output of the ADC is given to the microcontroller and depending upon the light intensity, the tube lights will be turn ON or OFF.
In mode 2, different options of patterning of tube lights are given to user. User can select any one of them and then accordingly tube lights will be On or OFF. User can also change or design the patterning of luminaires by making a particular tube light on or off just by setting it to 1 to turn ON or 0 to off the tube light. There are total five options are given in the system. However, they can be increased by changing the programming of microcontroller. The system uses relays which actually turn on or off the tube lights.

7. Results and Discussions:

After studying the illumination levels in all sections of the corridor (section A, B, C and D) and considering the comfort level of the occupants, it was found that minimum light intensity requirement in the corridor is about 60 lux. In section A, B, and D very less daylight reaches as these sections are interior part of the building. However, in section C sufficient day light is present because the main door of the department is open during the day time which is in section C. So, accordingly, the patterning of the luminaires in the corridor is designed.

Energy saving due to LED tubes:

The eight existing light sources (T8 tube light of 40W) were replaced by 12W LED tube (which gives about 60 lux light intensity). Energy consumed by traditional T8 (40W) tube and by LED tube were compared. The calculations for both were done for 24 hours including day and night. Day is considered from 9am to 7 pm (10hours) and night is considered from 7pm to 9am (14hours) in the next morning. The formula used for calculation is as follows:

$$\underset{\text{(in kW-Hrs)}}{\text{Total Energy utilized}} = \frac{\text{Total wattage of Luminaries}}{1000} \text{ X number of hours} \qquad \ldots(1)$$

The calculations of energy consumed by T8(40W) tube light and LED tube light are done using formula (1) and is given in table 1.2.

	Energy consumed by 8 T8(40W) tube light	Energy consumed by 8 LED (12W) tube lights	Total energy saved by LED tube lights
Per day or for 24 hours	7.68 kWhr	2.304 kWhr	5.376 kWhr
Per Year or for 365 days	2803.2 kWhr	840 kWhr	1963.2 kWhr

Table 1.2

According to table 1.2, due to the use of LED tube lights 70% energy is saved compared to traditional T8(40W) tube light.

Energy saving due to Lighting Control System:

Further, the calculations of energy consumption with developed lighting control system are done. Considering the day light, patterning of luminaires are designed. The calculations of energy consumed in summer season, winter season and rainy season is performed and then total energy consumed for one year is calculated. According to season the day light varies. In summer season sufficient day light is present throughout the day till 6pm. However, in winter season because of cloudy climate less day light is present as compared to summer. In rainy season, assuming 56 days similar to winter season and 56 days similar to summer season and 20% days (that is 9 days) will be cloudy days. So the calculations for rainy season are different from summer and winter season. The chart of all the seasons with number

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of days and availability of daylight in a year is given in table 1.3.

Season	No. of days in a year	Availability of light		
		Daylight	Twilight	No light
Summer	122 days	10 am – 6pm	6 pm – 7 pm	7 pm – 7 am
Winter	122 days	10 am – 6pm	6 pm – 7 pm	7 pm – 7 am
Rainy	56 days (similar to summer)	10 am – 6pm	6 pm – 7 pm	7 pm – 7 am
Rainy1	56 days (similar to winter)	10 am – 6pm	6 pm – 7 pm	7 pm – 7 am
Rainy2	9 days (cloudy days)	No sufficient daylight 10am – 7 p m		7 pm – 7 am

Table 1.3

According to the availability of daylight/twilight required number of luminaires varies which is given in table 1.1. Further, calculations of energy consumption as per seasons are calculated using the equation (1) and it is given in table 1.4.

Season	Energy consumed In Working Hours (kW-Hrs)	Energy consumed In Fringe hours (kW-Hrs)	Energy consumed In Night Hours (kW-Hrs)
Summer	70.272	29.280	76.128
Winter	70.272	29.280	76.128
Rainy1	69.696	29.04	75.505
Rainy2	6.912	29.184	5.616
Total	217.152	116.784	105.249

Table 1.4

As per table 1.2, the total energy consumption for one year without any lighting control system is 2803.2 units and using developed lighting control system is 439.185 units. So, total energy saving is about 84% per year by using developed lighting control system.

Conclusions:

There are several instances in which lighting energy in the building has not been used efficiently. This could be because daylight is not efficiently integrated with the artificial lighting system, or in cases where integration does exist, energy savings using energy-efficient lighting technology have not been fully explored. The major issues of the owners for installing the lighting control system is the initial investment, visual comfort of the people and aesthetic requirement of the building.

The main advantage of the developed lighting control system is that it can fitted in existing wiring setup and thus saved the initial installation cost of a system. The developed system is simple and cost effective as it is based on basic microcontroller. The daylight is integrated with the artificial light system which saves energy and LED tube light gives the aesthetic look to the building.

LED tube light which is known as the "green light source", saves energy up to 70%. In addition to it, LED lighting control system based on the microcontroller is the "Secondary energy saving" on the basis of LED light source which again saves energy and suggests many pattering options to the user.

Considering the comfort of the people and reducing the installation cost of the system, the developed system gives the simple and good design of a lighting control system for energy saving.

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