Energy Efficient Lighting Controls and a Sample Application

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Abstract: - In order to assess the energy efficiency of an indoor lighting installation, a criterion for the installed electrical power is proposed which is broadly applicable and easy to use. Introducing target values for lamps and gear and taking into account some basic lighting comfort requirements, the maximum electrical power to be installed can be predicted for any kind of application. Herewith, one or more task areas with appropriate target illuminance values may be defined. The key parameter of the criterion is the analytical expression for the target utilance as a function of common lighting design parameters. Improved system is provided automatically controlling a light level of an interior space. The system includes a light sensor, motion sensors, electronic control cards, and a PC for fuzzy controller. Fuzzy Controller is determined turning on or turning off lamp groups according to information of light level and motion sensors.

Key-Words: Lighting, Energy, Efficiency, Controls, Fuzzy Logic, Sensors

1 Introduction

Electricity is the most versatile form of energy we have. It is what allows citizens of the developed countries to have nearly universal lighting on demand, refrigeration, hygiene, interior climate control in their homes, businesses and schools, and widespread access to various electronic and electromagnetic media [1]. Energy flows through the building envelope are present all the time. The properties of the building envelope have significant influence on the interaction between the inner and the outer energy conditions in the sense of thermal and lighting flows. Optical and thermal responses of the building correspond mostly to the solar radiation and the outside temperature. The development of the technology increases the positive aspect of thermal and illuminance energy flow through the building envelope with its automatically active response [2],[3].

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 [4].

The achievement of the lighting controller depends on its efficiency and properness in light level controlled illumination systems. In parameters of the controllers, which will lead to minimum time response are tuned manually by running extensive simulations using computer software. Here in this work, the controller is optimized by an optimization process, which will lead to minimum response time for different initial conditions [5].

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. It also increases the psychological benefit that is impossible to achieve with electrical lighting. Daylight can be used to reduce the lighting energy consumption and the heat gains associated with the electrical lighting. Daylight in spaces has been shown to increase occupant satisfaction and improve worker productivity [6],**Error! Reference source not found.**.

In this study, system is designed considering energy saving and lighting comfort together. Lighting armatures and ballasts are chosen from new generation products for energy saving purpose. System is controlled by fuzzy logic algorithms controller. Fuzzy inputs are determined by day light level, human motion information in. Light level is kept at standard light level by the fuzzy logic controller using this input values at the work environment [8],[9].

1.1 Lighting Controls

Lighting controls help conserve energy and make a lighting system more flexible. The most common light control is the on/off switch. Other types of lighting control technologies include:

- Manual dimming
- Photosensors
- Occupancy sensors
- Clock switches or timers
- Centralized controls

1.2 Manual dimming

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.

Slider switches allow the occupant to change the lighting over the complete output range. They are the simplest of the manual controls. Preset scene controls change the dimming settings for various lights all at once with the press of a button. It is possible to have different settings for the morning, afternoon, and evening. Remote control dimming is also available. This type of technology is well suited for retrofit projects, where it is useful to minimize rewiring [10],[11].

1.2.1 Photosensors

Photosensors automatically adjust the light output of a lighting system based on detected illuminance. The technology behind photosensors is the photocell. A photocell is a light-responding silicon chip that converts incident radiant energy into electrical current.

While some photosensors just turn lights off and on, others can also dim lights. Automatic dimming can help with lumen maintenance. Lumen maintenance involves dimming luminaires when they are new, which minimizes the wasteful effects of over-design. The power supplied to them is gradually increased to compensate for light loss over the life of the lamp [10],[11].

1.2.2 Occupancy sensors

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. This control scheme may be appropriate when occupancy sensors control separate zones in a large space, such as in a laboratory or in an open office area. In these situations, the lights can be dimmed to a predetermined level when the space is unoccupied. 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 after hours [10],[12].

There are three basic types of occupancy sensors:

- Passive infrared
- Ultrasonic
- Dual-technology (hybrid)

1.2.3 Clock switches or timers

Clock switches or timers control lighting for a preset period of time. They come equipped with an internal mechanical or digital clock, which will automatically adjust for the time of year. The user determines when the lights should be turned on and when they should be turned off. Clock switches can be used in conjunction with photosensors [10].

1.2.4 Centralized controls

Centralized building controls or building automation systems can be used to automatically turn on, turn off, or dim electric lights around a building. In the morning, the centralized control system can be used to turn on the lights before employees arrive. During the day, a central control system can be used to dim the lights during periods of high power demand. And, at the end of the day, the lights can be turned off automatically. A centralized lighting control system can significantly reduce energy use in buildings where lights are left on when not needed [10].

1.3 Daylighting Controls

A building designed for daylighting but without an integrated electric lighting system will be a net energy loser because of the increased thermal loads. Only when the electric lighting load is reduced will there be more than offsetting savings in electrical and cooling loads. The benefits from daylighting are maximized when both occupancy and lighting sensors are used to control the electric lighting system.

Occupancy sensors detect when a space is occupied by using passive infrared, ultrasonic, or a combination of the two technologies. Once the heat or movement of the occupant is no longer detected, and after a preset delay time, the sensor will emit a signal to extinguish the lights. Occupancy sensors used alone are good for low or intermittent use areas such as storage rooms, restrooms, and even corridors.

Light level sensors have a photoelectric "eye" that measures the illumination in a room. Threshold on and off values can be set to respond to specific lighting conditions. These sensors can operate on/off switching of various luminaires or lamps within luminaires and they can also operate a continuous dimming system. Continuous dimming system will obviously cost more than switching systems but they have greater user satisfaction because the change in light levels is not as noticeable.

Fluorescent lighting systems are the most common daylight control lamp source because of the availability of step switching and dimming systems. HID sources are typically not a good choice for daylight switching because of the extended strike and re-strike times. There are now two-step HID sources available that may be useful in some stepswitching applications where the "off" mode is not desired during a typical day. A daylighting design will use both occupancy and light sensors. With these two control strategies the lights will come on only when the room is occupied and only if there is insufficient daylight. In most designs a manual override is provided for user convenience [10],[11],[12].

2 System Description

In this study, Illuminated indoor environment is the laboratory where approximately 50 m^2. System has sensors, ISA data acquisition card, PC, twelve high efficiency fluorescent lamps and designed electronic cards.

2.1 Designed Electronic Cards

These cards are designed for controlling lamp groups, measuring light level and providing isolation between PC and System.

Relay control card is designed with five single pole double throw (SPDT) relays which can be drived digitally. Electric energy controlled by first two relays and other three relays are used for controlling lamp groups. Optic isolation card provides electrical isolation between PC and system, using optocoupler.

Luxmeter circuit is designed for measuring outside light level. Si photo diodes are used as light sensor. Sensor is isolated optically in order not to be affected from interior lighting. Depending to the light level, the circuit is producing 0-5 volt analogue output signal against 0-300 lux light levels. Calibration of circuit is made by using two digital luxmeter.

Luxmeter circuit is sensing outside light level. The sensors at the working plane produce faulty outputs because of the people movements in indoor area. During the lesson hours students are always made movements for doing their experiments. For that reason, light level at the working plane could not be measured properly. According to the results of the experiments, interior light level is measured depending on the outside illumination level and light sensing circuit is calibrated accordingly.

2.2 Designed Fuzzy Controller

Optimization of fuzzy logic system is of interest to researchers in past and will remain in future as new applications are emerging. The important factor in optimization of fuzzy logic controller is to determine which parameter is to be tuned.

Due to the results of this experiment, to stabilizing light level at 300 lux on the working plane depending on the natural light level, lamp group on-off period is determined at the diagram shown in Fig. 1 for one day (24 hours).

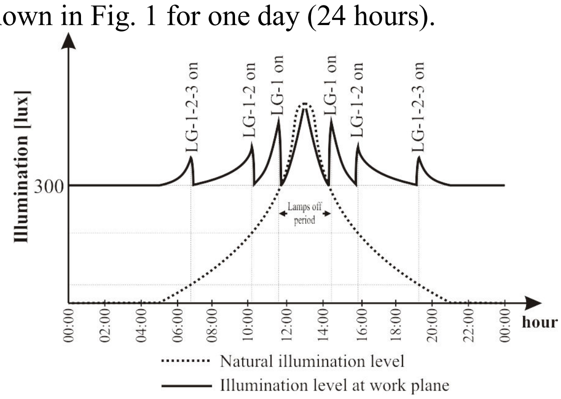

Fig. 1 Lighting control system diagram

Fuzzy logic based controller is designed for the system. It is aimed that to stabilize light level at the 300 lux in the lighting controlling environment. Experiments were performed for designing fuzzy logic controller to recognize system working conditions. Fuzzy logic rules are shown in Table 1.

Table 1 Fuzzy logic rules

Rule No	Motion	Illumination Information	Lamp Group 1	Lamp Group 2	Lamp Group 3
1	No	Dark	Off	Off	Off
2	No	Fair Bright	Off	Off	Off
3	No	Medium Bright	Off	Off	Off
4	No	Bright	Off	Off	Off
5	Yes	Dark	On	On	On
6	Yes	Fair Bright	On	On	Off
7	Yes	Medium Bright	On	Off	Off
8	Yes	Bright	Off	Off	Off

3 Experimental Results

System whole day tests were performed after determining fuzzy logic controller rules. In these tests, system behaviors are examined for different atmospheric conditions. (Clear Sky, Partly Cloudy, Foggy, Mostly cloudy) One of the results, which are found by using designed fuzzy logic controller, is shown in **Fig. 2** as an example.

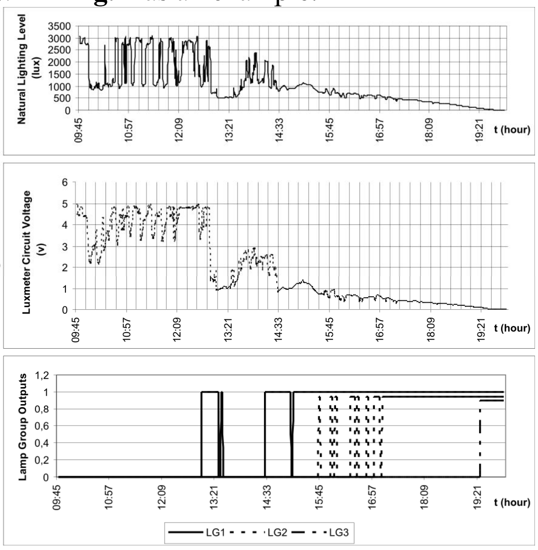

Fig. 2 Luxmeter, luxmeter circuit and lamp groups comparison graphics.

Natural light level was decreased under the limit value, determined for working plane around the time 14:10, so, LG1 was turned on as shown in **Fig. 2**. LG2 was turned on at 15:45 when the light level has decreased again. The last group, LG3 was turned on at 19:21 and maximum light level has been reached with three lamp group. These results show that fuzzy logic controller could control system as aimed.

4 Conclusions

After installation of the system, measurements were done in 3 months period, which cover spring term. During the one week usage period in normal conditions at the experiment laboratory, after calculations and measurements it was determined that designed system used ¼ of conventional lighting system energy.

As a result; lighting control could be performed by using fuzzy logic controller at the laboratory during the lesson hours with providing required light level in the lighting system controlled by fuzzy logic study. Lamp groups are turned on using motion sensors when motion is detected at the laboratory. Thus, energy consumption was prevented by turning off the lamp groups when laboratory was not in use.

It is provided that, lighting system was operated with stabilizing total lighting of 300 lux value at working plane, depending on the natural light level. Lamp groups turned on and off in three steps, so over-lighting was prevented. Lamp groups were turned off gradually when light level exceeds 300 lux; in this way maximum benefit from natural light level is gained.

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