Priority Lighting Control

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Abstract:

In Hong Kong lighting systems contribute around 20% of the total energy use in buildings, while intelligent lighting control has been considered as an important tool to reduce the lighting energy use and thus to improve building energy efficiency. To demonstrate the effectiveness of intelligent light control, this study presents a development of Arduino based priority lighting control strategy. A test rig with two zones was used to develop this strategy, where these two zones have a similar lighting design but suffers different daylighting environments. The energy and transient control performance of the proposed strategy were analyzed under different scenarios with different requirement for illuminance levels. Experiments were carried out to demonstrate the efficiency of the proposed strategy.

Keywords:

1. Priority Lighting Control
2. Energy Efficiency
3. Zoning System
4. Extra Lighting Source
5. Energy Consumption

1. Introduction:

In the past decades, concerns over the energy crisis have risen due to the continuous increase in energy consumption around the globe. Scientists and engineers are looking into various ways to provide greener energy and reduce energy use at the same time. According to the Electrical & Mechanical Services Department (EMSD), electricity accounts for 55% of the Hong Kong total energy end-use in which commercial and residential buildings attribute 64% of the total electricity use (EMSD, 2018). It can be seen from the data that there is an immense potential for energy reduction in commercial and residential buildings.

The energy end-use of buildings includes air conditioning, lighting, hot water & refrigeration, office equipment cooing and others. For commercial buildings, lighting constitutes 12% (EMSD, 2018) and 9% (US DOE, 2011) of the total energy used in Hong Kong and the U.S respectively. For residential buildings, lighting amounts to 9% (EMSD, 2018) and 6% (US DOE, 2011) of the total energy used for Hong Kong and the U.S respectively.

Multiple researches have shown that integrated smart lighting control could save 17% to 60% of energy when compared with the traditional lighting control method. (Kalavally, Tan, Parkkinen, 2016) The lighting control system can also aid in reducing the peak load. (Doulos et al, 2005) Therefore, lighting is one of the aspects which has the potential of reducing energy consumption.

In the construction industry, professional software is used to create computer simulation both to select the most appropriate type of luminaire and to design their arrangement. Usage of the room, architectural design, openings, relevant government legislations and codes of practices, requirements of end-users, etc. are the parameters of creating the model.

The idea of this project is to adopt daylighting as an alternative method to supply lighting for the indoor environment with the aim of cutting energy consumption with the smart lighting control system.

In order to find out the characteristics of the priority lighting control system, an experiment has been developed for simulating an actual indoor environment with the following objectives:

a) To test different strategies of adopting artificial light with dimming to find the ideal strategy which can both minimize the energy consumption and meet the illuminance level requirement.
b) To compare the energy performance between one zone and two zones lighting system setting.

2. Methodology

2.1 Basic idea of priority lighting control

The controlled area is divided into multiple zones and each zone has its own sensor and luminaires. The sensors first measure the illuminance level of a specific area and then transfer the feedback back to the summing point to compare the result with other data. After the calculation, a control signal will be sent to the appropriate dimmer to control the supply current to the corresponding LED lamp for adjusting its luminous output. Besides, the signal may not be sent to the dimmer which is located in the same zone as the sensor, by doing so, the required illuminance level can be maintained. (Ference et al., 2000)

2.2 Experiment design

A model box is formed for simulating an indoor environment. The dimension of the box is 840mm (length) x 510mm (width) x 780mm (height). (Cheung, 2016) It is placed on the corridor of a laboratory. The artificial lighting from the laboratory will be classified as a natural lighting source for this experiment.

There are three openings for the model box, two of which are windows with the dimension of 330mm (length) x 150 mm (height). The windows are located at the front and at the back of the box with brown tinted glass. Another opening with a size of 840mm (length) x 510mm (width) is on the top of the box. A white board is used to the cover the opening since it is not designed to let the light get inside the box.

The model box is separated into two zones, each zone contains a set of LED lamps, a illuminance level sensor and a controller. There is a partition (10mm width, 840mm length) ,which is placed 255mm along the width 520mm above the ground of the model box, for spacing and for limiting the amount of illuminance passing through between the zones. In this paper, the zone next to the opening is classified as zone A. Another zone is classified as zone B.

Windows allows the daylight to enter the model. LED lamps are the artificial light source for the model box. Illuminance level sensor measures the illuminance level of the respective zone. The dimmer is for controlling the supply current to the lamp. The Arduino board compares the feedback, which is sent by the sensors, with the input and the required output. The illuminance level sensors would record the data of the experiment and retransmit them back to the Arduino Board so that the record can be examined.

The flowchart shows the logical process of the Arduino programme. It demonstrates the data flow and the control process of the lighting control system.

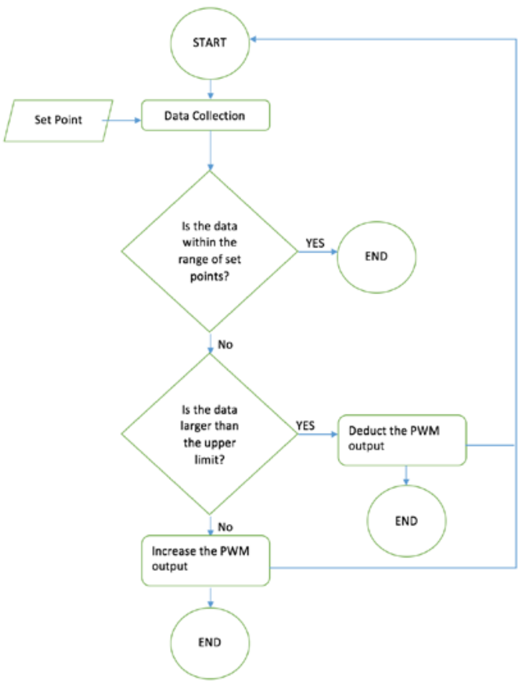


Figure 1. Flowchart of the Arduino Programme

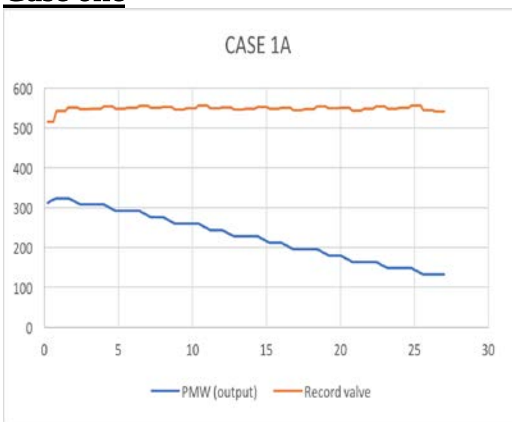
3. Result and Discussion

The arrangements of the two zones lighting design are as follow. The default Lux level of zone A is 400 Lux while the set point around 400 Lux is from 530 to 550. The default lumen level of zone B is 500 Lux. The set point for zone B around 500 Lux is from 950 to 930. The luminaire of each zone is controlled by its own lumen sensor. The compare example is a one zone lighting design. Only one zone is contained in the model box. The default lumen level is 500 Lux. The set point for zone A at 500 Lux is from 830 to 840 and from 940 to 950 for zone B. The two luminaires are controlled by its corresponding sensor. The energy consumption performance and transient response will be discussed below. There are nine scenarios for the two settings.

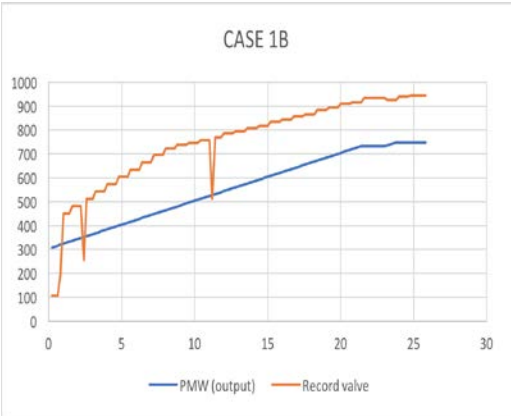
Two zones	Case 1 all opening closed			
Zone A [Lux]	Zone B [Lux]	Volt[V]	Current [A]	Power[W]
400		5.6	0.11	0.616
	500	5.5	0.64	3.52
Two zones	case 2 open window A only			
394		5.6	0.07	0.392
	506	5.5	0.68	3.74
Two zones	case 3 open window B only			
401		5.6	0.09	0.504
	503	5.5	0.65	3.575
Two zones	case 4 open window A& B			
399		5.6	0.06	0.336
	501	5.6	0.62	3.472
Two zones	case 5 open roof only 1			
393		5.6	0.08	0.448
	497	5.6	0.65	3.64
Two zones	case 6 open roof only 2			
389		5.6	0.03	0.168
	488	5.6	0.61	3.416
Two zones	case 7 open roof only 3			
391		5.6	0	0
	488	5.6	0.56	3.136
Two zones	case 8 open roof only 4			
432·		5.6	0	0
	495	5.6	0.45	2.52
Two zones	case 9 open roof only 5			
440		5.5	0	0
	495	5.6	0.4	2.24
Two zones	case 10 open roof only 6			
430		5.5	0	0
	484	5.6	0.48	2.688

The above table indicates the collected data from the two zones experiment by the own setup. Case 1 is the sample which the lumen supply is completely relied on the artificial lighting supply. As expected, case 9 is the most effective case since the largest area of opening is provided which demonstrates that the energy consumption can be improved after adopting the priority lighting control system. The following figures would can described these two cases.

Case one



Data for zone A with 400 Lux (case one-two zones)

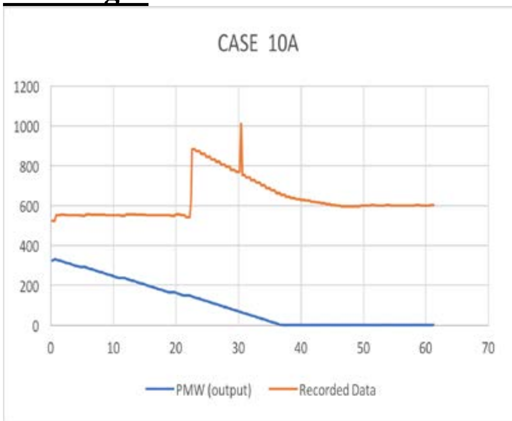


Data for zone B with 500 Lux (case one-two zones)

Zone A reached 400 Lux at around 25s and the power supplied was 0.616 W. Zone B also reached 500 Lux at around 25s and the power supplied was 3.52W. It is the benchmark which is used to compare with other scenarios.

In theory, the slope of orange line, which represents the recorded value by the sensor, and blue line, which represents the amount of PWM output, should be very similar. However, as shown on Figure 15, the slope of orange line tends to zero but that of the blue line is negative. This phenomenon happened because zone B did not achieve the designed illuminance level, so both the output of PWM and the luminosity of zone B increased simultaneously. The light penetrated from zone B to zone A. In order to maintain the illuminance level in zone A, the PWM output should be decreased until zone B reaches a steady stage.

Case night



Data for zone A with 400 Lux (case nine-two zones) *Data for zone B with 500 Lux (case nine-two zones)*

Zone A reached 440 Lux at around 36s and the power supplied was 0W. Zone B reached 495 Lux at around 48s and the power supplied was 2.24W. In case 10, the dormer windows were fully opened which allowed the largest amount of light to enter the model box. The former was opened at 24s. The relatively transient control period lasted 11s which is longer than the case eight.The power supply was reduced. It only takes 2.24W which is 88.9% of the case eight.

4. Concluding Remarks

This research studies the priority lighting control method with experiments set up for one zone and two zones system using various parameters. The one zone system requires the illuminance level for the model box to be maintained at around 500 Lux and the system is controlled by two set of controllers and LED independently. The two zones system separates the model box into two zones. The illuminance level for both zone A and B are maintained at 400 Lux and 500 Lux respectively and the systems were controlled by their own controller and LED. The energy performance and transient control performance are then recorded. Case one experiments are used as benchmark for the energy saving potential and transient control for both one zone and two zones systems.

To sum up, the one zone system has a similar energy saving performance with the two zones system and it requires a shorter time for transient control with power supply reduction ranges from 1.16% to 45.88%. The worst performance on energy saving for one zone system is case three, where only window B is opened, only 1.18% of the power supply is saved. As for two zones system, the worst performance on energy saving is case five, where a minimum level of the roof is opened, only 1.16% of power supply is saved.

The best energy performance of both zoning system are case nine where the maximum level of roof is opened and the extra light can enter the model box directly. Up to 45.88% of power supply is saved. It can be deduced that the energy saving performance is proportional to the area of openings and the orientation to extra light source by adopting priority lighting control method.

For the performance of transient control, the result shows a longer transient control period is required when the difference between the extra light source and the required illuminance level is large. It can be seen from the experiment data that the duration of transient control is increased when a larger area of opening is opened. Moreover, the percentage increase of one zone system is less than two zones system since the required illuminance level for one zone example is, in average, 50 Lux less than the two zones system.

Priority lighting control is a successful lighting control method. It can maintain the required lumen level within 50s for each zone with a higher energy efficiency when an extra light source is provided.

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