Energy and Buildings 66 (2013) 329–337

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Lighting control strategy for energy efficient office lighting system design

Prashant Kumar Soori[a,*], Moheet Vishwas[b]

[a] School of Engineering and Physical Sciences, Heriot Watt University Dubai Campus, Dubai, United Arab Emirates
[b] Lead Systems Specialist, Infratech Controls, Dubai, United Arab Emirates

ARTICLE INFO

Article history:
Received 30 November 2012
Received in revised form 24 February 2013
Accepted 12 July 2013

Keywords:
Artificial lighting
Compact fluorescent lamp (CFL)
Lighting control
Light emitting diode (LED)
Thermal loads

ABSTRACT

Lighting is the highest consumer of electrical energy in office buildings and it is one of the areas that offer many opportunities for improving the energy efficiency thereby reducing the energy consumption. This paper presents control strategy for energy efficient office lighting system design. The energy efficiency of a typical office building lighting system in Dubai is examined in this paper. The impact of use of natural lighting and artificial lighting on the HVAC system is assessed and highlighted. Lighting control algorithm is developed with the ultimate goal of achieving energy efficiency and health aspects of occupants into consideration. It is simulated using control systems simulation software functional explorer (FX) tools and recommendations are forwarded. The proposed control algorithm can be used as a reference to other new buildings to be built in Dubai or Middle East in general.

1. Introduction

Lighting represents approximately one-third of electricity used in commercial buildings [1,2]. It is of significant interest to every building owner to bring down lighting energy consumption to save money. It also benefits the environment through lower fuel consumption. As a result, building owners are inclined to use efficient lighting controls to reduce their lighting energy use.

A table of lighting energy savings has been reported by space type (private office, open office and classroom) and controls type (multilevel switching, manual dimming, daylight harvesting and occupancy sensors) [3]. Their findings say that the lighting energy savings ranges from 6% to 70% across eleven categories of space types and controls types [3]. It has been reported that integration of artificial lighting with the use of energy efficient luminaires and daylight harvesting schemes can help reduce the electrical energy demand and improve vision efficiency of the occupants [4]. It is extremely difficult to have exact estimation of artificial lighting and overall energy savings with daylight linked lighting controls due to the complex relations between artificial lighting, day lighting and solar heat gain [5].

A comprehensive literature review and analysis of energy savings from all types of lighting controls used in commercial buildings has been investigated [6]. The study found that simulations appear to overestimate savings achievable in the field, especially for day lighting. This result is not surprising, as daylight in a building is affected by so many factors such as building orientation, location, weather, type of occupancy, blinds, reflectance, commissioning and so on. This indicates that energy policy and saving estimation should not be based on simulations alone, but should include filed measurements or at least conservative estimates of savings predicted from simulations. Their findings has shown that individual control strategies can on an average save between one-quarter to one-third of lighting energy and multiple control strategies do even better by capturing up to nearly 40% savings on average [6].

Most people prefer to live, work and play in spaces where they have a degree of control over the indoor environment, are thermally comfortable, have access to daylight and views, and can communicate effectively due to good acoustics. Buildings that provide these comforts are ideal as centers for the community they serve. Over illumination within buildings have adverse impacts on the occupants' health. These health effects vary from migraine headaches to stress and anxiety. In addition to the adverse health effects the people working in such environments are susceptible to low productivity or decreased worker efficiency [7].

Influence of shading control patterns on the energy assessment of office spaces was reported. Four different types of shading alternatives were analyzed and concluded that shading control strategy has direct impact on visual comfort of office occupants [8]. It has been reported that proper design of daylight integrated

* Corresponding author. Teaching Fellow, School of Engineering and Physical Sciences, Heriot-Watt University Dubai Campus, Academic City, P.O. Box 294345, Dubai, United Arab Emirates. Tel.: +971 555458639.
E-mail addresses: pksoori@yahoo.com, p.k.soori@hw.ac.uk (P.K. Soori), daywalkermohit@gmail.com (M. Vishwas).

0378-7788/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2013.07.039

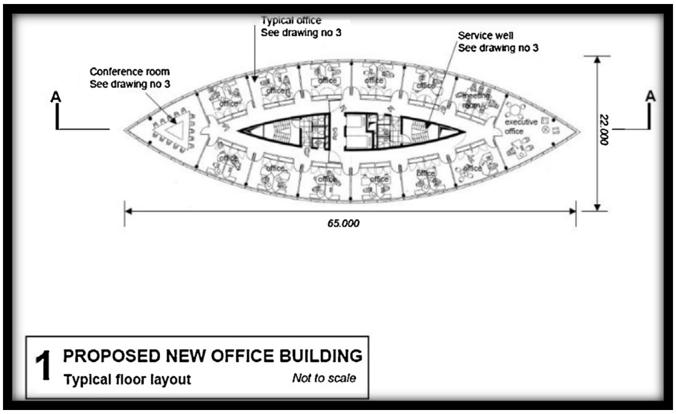

Fig. 1. Floor layout.

electrical lighting design strategy to be implemented in the building under construction in Abu Dhabi (United Arab Emirates) is expected to have 103% net positive energy use [9]. The design of the system required a great effort to adapting the building architecture to the local climate of Abu Dhabi while determining the opportunities for daylight harvesting.

The purpose of our study is to take into account the various conclusions of the above literature to justify the need for efficient lighting controls. The novel aspects of present study is to examine the impact of use of natural lighting and artificial lighting on space cooling system in the typical office building in Dubai, develop control algorithm using control systems simulation software FX tools which takes care of harvesting day lighting by adjusting the blinds, determines the required artificial illuminance taking into account the visual comfort of the occupant and adjust the space cooling loads with the ultimate goal of achieving energy efficiency. The various strategies adopted are:

i) *Day lighting*: Offices should be designed to allow ample natural light into the space while given that glare control devices can minimize the unwanted effects of diffused sunlight. The space should be designed to take advantage of better access to the windows.
ii) *Integration of lighting control and space cooling systems*: Lighting at each workstations and common lighting control for shared spaces should be incorporated into the building to permit occupants to alter the light levels to go with their needs and preferences. And finally implement an algorithm for lighting systems coupled with space cooling.
iii) *Conduct occupant surveys*: Surveying occupants about their comfort within the office space to address thermal conditions, lighting and other elements that contribute to their satisfaction, allows the building owner to identify areas for betterment and enhance work productivity.

2. Methodology

The structural layout of the office building considered for the analysis is shown in Fig. 1. The building has six floors. Each floor has twelve office rooms. Fig. 2 shows the typical office room layout. Building characteristics are specified in Table 1.The 3D view of the office space is shown in Fig. 3.

In our study, it is confirmed from simulation using VELUX Daylight Visualizer 2 software that an ideal office space in Dubai has sufficient potential to harvest natural light [10]. The VELUX simulation showed us that daylight alone could provide necessary interior illuminance during the office hours from 9 AM to 5 PM. But in reality it is not true as the daylight factor (DF) is not uniform throughout

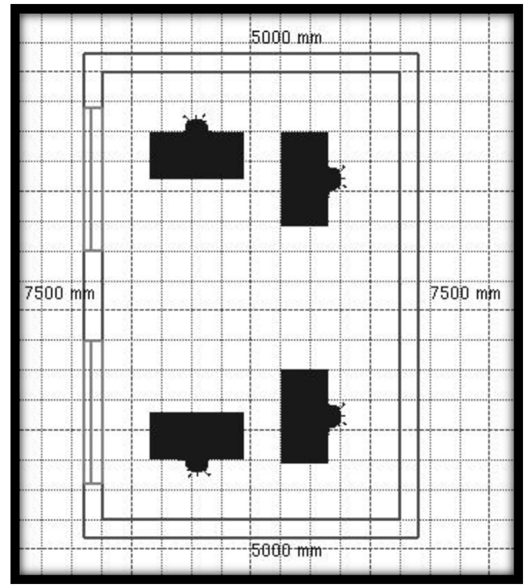

Fig. 2. Typical office layout.

Table 1
Building characteristics.

Parameter	Description	Unit
Office space dimensions	Length	7.5 m
	Height	4 m
	Width	5 m
	Floor area	37.5 m^2
	Wall area	30 m^2
Windows: two windows on the façade of the building	Height	1.8 m
	Width	2.4 m
	Total window area	8.64 m^2
	Visual transmittance (Tvis)	0.78
	Window to wall area ratio	0.288
	Window to floor area ratio	0.2304
	Height above the floor	0.85 m
Location: Dubai	Longitude	55.31°
	Latitude	28.35°
Building orientation	Orientation	250° Clockwise (CW)

Fig. 3. 3D view of the office space layout.