Automation in Construction 43 (2014) 10–22

Contents lists available at ScienceDirect

Automation in Construction

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

Building automation and control systems: A case study to evaluate the energy and environmental performances of a lighting control system in offices

C. Aghemo *, L. Blaso, A. Pellegrino

Energy Department, TEBE Research Group, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

ARTICLE INFO

Article history:
Received 15 May 2013
Revised 9 November 2013
Accepted 22 February 2014
Available online 18 March 2014

Keywords:
BACS
Lighting control system
Energy consumption
LENI
Experimental study

ABSTRACT

Building automation and control systems (BACs) allow plants in buildings to be controlled and managed, thus increasing the users' comfort and reducing the operation and maintenance costs. As far as the lighting services are concerned, control systems offer an important opportunity of managing lighting systems and reducing energy consumption, due to the use of integration strategies between daylight and electric lighting and strategies based on the occupancy of spaces. The results of an experimental case study of ten offices in Torino (Italy), in which a custom-design building automation and control system has been designed to control both the lighting plants and the air conditioning system, are presented in this paper. The study was carried out in order to evaluate the energy efficiency of the lighting control system and to analyse the environmental luminous conditions obtained through the application of this technology to a real case. The environmental and energy performances, together with the degree of users' satisfaction and acceptance of this control system, were analysed after a year of activity to verify the potentiality and operation of this lighting control system. The obtained results regarding the potential energy savings (from 17% to 32%) were evaluated taking into account both the monitored annual electric energy consumption (for operation) and the parasitic energy consumption due to the installed devices (luminaire ballasts, sensors and controllers), and were compared with the estimated energy consumption calculated applying the method proposed in the European standard EN 15193:2007.

Published by Elsevier B.V.

1. Introduction

Over the last decade, a great evolution has taken place in the field of lighting technologies, in both light source segments and in lighting control systems. The potential energy savings that can now be obtained using lighting control systems in commercial and residential buildings have led to an increase in interest in these technologies. Lighting control systems offer an important opportunity of managing lighting systems and reducing energy consumption, thanks to integration strategies between daylight and electric lighting and strategies based on the occupancy of spaces [1–8]. These technologies, when correctly programmed and calibrated, can in fact provide the right amount of light for the environmental requirements and reduce energy waste. Lighting control systems are now mentioned in European standards as possible ways of reducing lighting energy consumption in buildings. The European Directive on Energy Performance of Buildings (2002) [9] and the 20-20-20 Renewable Energy Directive (2010) [10] have identified a saving potential in buildings, and consequently stressed the necessity of adopting effective strategies and technologies to reduce energy consumption. Accordingly, the Directives dictate that the integrated energy performances of buildings should be certified and they define minimum performance values in order to help designers in the planning of more energy efficient buildings. An important contribution can be made by adopting specific strategies to reduce electric consumption for artificial lighting, especially in commercial buildings [11–13]. The role played by electric lighting on building energy consumption is well known [14,15], and lighting installations are responsible for a significant part of building energy consumption in Europe [16,17].

Control systems and daylight and electric light integration techniques for offices and residential buildings have been in use since the eighties. Nevertheless, the lack of technical knowledge, the high costs associated to the difficulties in calculating the actual energy benefits, and the technical management problems of these systems have determined a lack of use of these systems. The estimation of the energy efficiency of lighting control systems is an important goal, since an accurate evaluation could help and guide designers to make the most appropriate choice [18]. Generally speaking, the information available to designers to assess a control system's performance in saving energy is based purely on advertising material from manufacturers. Catalogues and technical literature frequently publish information on the energy savings that can be achieved by adopting these systems with respect

* Corresponding author. Tel.: +39 0110904410; fax: +390110904499.
E-mail address: chiara.aghemo@polito.it (C. Aghemo).

http://dx.doi.org/10.1016/j.autcon.2014.02.015
0926-5805/Published by Elsevier B.V.

to a base-case with a lighting plant tuned on for the whole working time. This information concerning the chance of saving energy through the use of control systems is very general, and it is not sufficient to estimate the real performances of applying the system to a specific case.

An accurate estimation of energy performance, and therefore of the efficiency of a lighting control system, depends on several factors that are linked to the specific characteristics of the building, as well as to the characteristics of the system itself (architecture of the control system, control strategies, type of control devices, etc.) [19].

For this reason, both theoretical and experimental research activities have been carried out at the Politecnico of Torino (Italy) over the last few years, with the aim of obtaining more information on the consequences of introducing lighting control systems in already existing or new buildings. This paper focuses on an experimental research activity that was carried out in a group of offices in which a custom designed control system was installed and monitored over a year. The first year of monitoring, although too short to make generalizations, has allowed a first assessment to be made regarding the energy consumption and environmental conditions that arise from the use of a custom designed control system.

2. Description of the experimental case study

In 2006, the Building Management Department at the Politecnico of Torino (Italy) started a retrofitting process of their offices with the aim of reducing the energy consumption of the air conditioning and lighting systems, while preserving environmental quality. The intervention was considered as a pilot test to evaluate the effectiveness of solutions that could be applied to the whole building in the future. A building management system was specifically developed to control the luminaires and fan coils and, in particular, the electric lighting system was completely redesigned, while the air conditioning system was only upgraded with a new automatic control system.

2.1. Description of the building and lighting system

The Building Management Department consists of 10 offices, which are situated on the ground floor of the Politecnico of Torino (Italy) at a latitude of about 45° N. The building is located in an urban area and all the offices therefore have external frontal obstructions. Fig. 1 shows the degree of obstruction caused by the surrounding buildings and gives an external view of the building itself. Five of the ten offices face the North-East, and five face the South-West.

Although the department is on the ground floor and has external obstructions, the offices receive a great deal of daylight. In the offices facing North-East, daylight is provided through a window situated on the opposite wall to the office entrance. This window has a single clear glass pane (visible transmittance of 90%), and is 2 m wide and 3 m high. The offices facing South-West have double pane windows (clear single glass plus selective glass with a visible transmittance of 54%). The dimensions of the window vary between 2.5 m^2 and 5.7 m^2, and WFR value (window-to-floor ratio) varies from 18% to 23%. All the offices are equipped with manually controllable internal vertical blinds to shade daylight.

During the retrofitting of the Department, the existing air conditioning system was equipped with control devices (thermostats, temperature sensors and actuators) to both automatically and manually control the indoor air temperature. The existing lighting system was replaced with a new one, consisting of 2 or 3 suspended luminaires per office (depending on the office size) with a direct/indirect light distribution. Each luminaire has two 35 W linear fluorescent lamps and is equipped with reflecting louvers and digital dimming ballast (DALI) with an Energy Efficiency Index (EEI) of A1. The luminaires in each office are grouped together in one single circuit.

The lighting system was designed to guarantee the lighting requirements specified in the Italian UNI EN 12464-1:2004 standard (updated in 2011 [20]) which prescribes the following parameters for office activities:

- Average Maintained Illuminance: Em = 500 lx,
- Uniformity on the working plane: U ≥ 0.7,
- Unified Glare Rating: UGR ≤ 19,
- Colour Rendering Index: CRI ≥ 80.

The positions of the offices and luminaires in the Department offices are shown in Fig. 2.

The new lighting and control systems were installed in the offices in the Department, while the previous lighting system (recessed luminaires

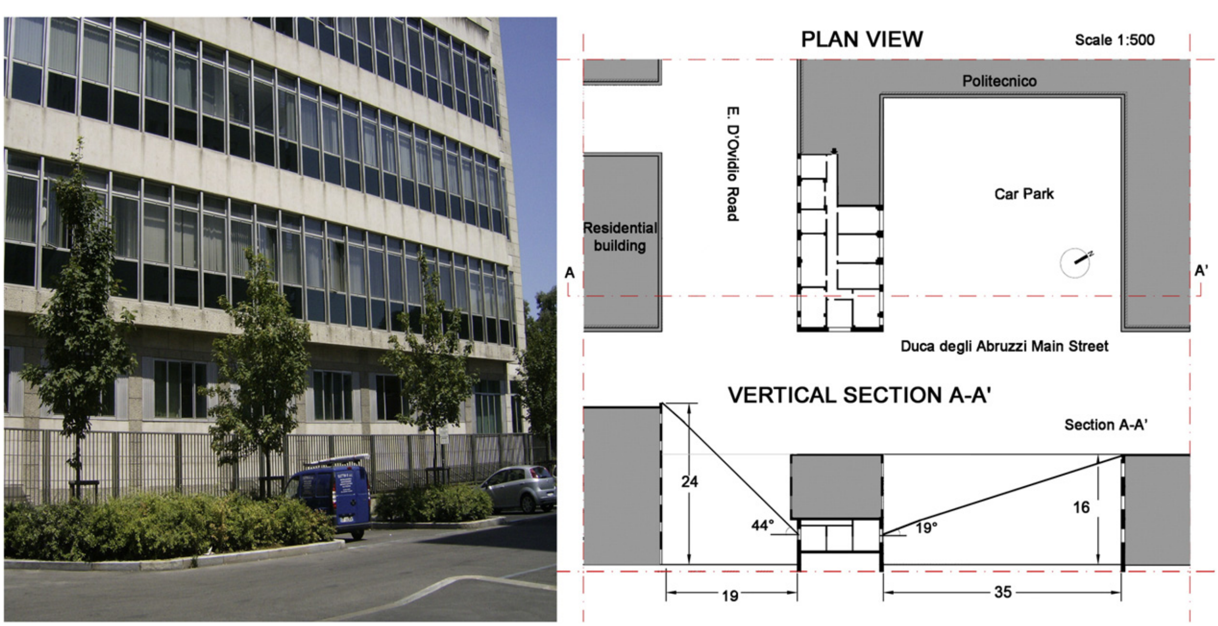

Fig. 1. Plan and vertical section of the department and view of the surrounding buildings.