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Home/Building Management Systems (HMS/BMS) to Protect Environment by Control Modern Lighting Installations

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Abstract. The paper presents the possibilities of using home/building management systems (HMS/BMS) to protect environment by control modern lighting installations. Through the use of HMS/BMS every user can significantly influence the energy usage and thus contribute to environment protection. The main criterion for designing and making a lighting installation is the safety of people who are in a building. The remaining two factors that determine the type of lighting are energy conservation and the comfort of facility users. Relatively low investment expenditures allow to save up to 40% of energy. The aim of this paper is to present energy saving possibilities on the examples of realized lighting modernization projects in the office building and the residential building in Warsaw. Moreover, the benefits resulting from the modernization are analysed. Thanks to the lighting control through the BMS it was possible to reduce the energy usage by a dozen or so percent.

Keywords: Building Management System (BMS); energy-efficient lighting

1. Introduction

An intelligent building is equipped with a system of monitoring devices and an integrated system for managing all installations inside. Thanks to information coming from different components of the system, the building can react to changes in the internal and external environment, which leads to an increase in functionality, the comfort and safety of users, as well as the minimization of maintenance costs.

During two decades (1984-2004), the use of primary energy increased by 49%, whereas CO_2 emission rose by 43%, which, on average, equals 2% and 1.8% per year, respectively. By the year 2020, the use of energy in developing countries (South-East Asia, the Middle East, South America and Africa) will increase, on average, by 3.2% per year, whereas in developed countries it will rise, on average, by 1.1%. As far as total energy consumption is concerned, buildings use, depending on a country, from 20 to 40% of all energy, which makes them the third largest consumer of energy after industry and transport [1].

The statistics [2] show that in 1999, 3.66 kWh, 110 kWh and 13366 kWh of energy daily, monthly and yearly respectively was used for lighting of one household. Keeping in mind, that decreasing energy usage by 1 kWh allows for avoiding CO_2 emission by 1 kg [3], environment protection possibilities per individual recipient exist.

It is estimated that an improvement in energy efficiency of buildings may lead to a decrease in energy consumption in present buildings in the European Union by 20%, which would make it possible to save €60 billion per year [4].

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The research conducted [4, 5] towards improving the energy efficiency of buildings is based on a detailed analysis and models of controlling home/building management systems (HMS/BMS). Present HMS/BMS solutions make it possible to save up to 40% of energy in new facilities [5].

2. Costs of Using a Facility/Building

The main resources within a facility are electric and thermal energy. Apart from them, there should be mentioned resources such as hot tap water, cold tap water, air of appropriate parameters, the safety of the facility, the safety of users, access to rooms, information, data links and facility space. It should be noted how diverse facility resources are – they comprise everything that is controlled and requires expenditure within a facility.

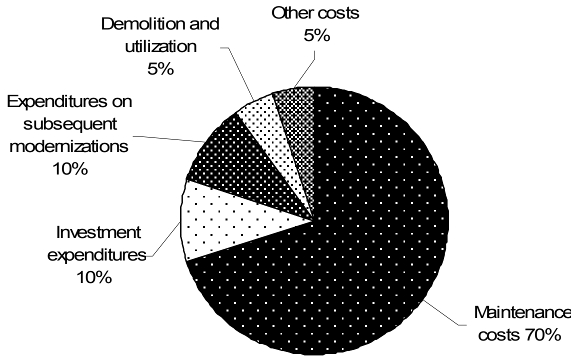

Fig. 1: The percentage share of costs during a facility's life cycle [6]

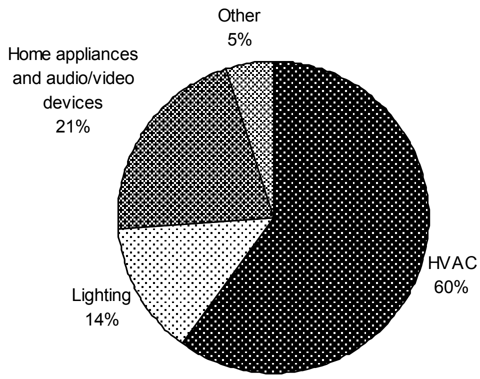

Fig. 2: The percentage share of facility maintenance costs [6]

Owing to the high costs of facility maintenance, both investors and users are paying more and more attention to energy-efficient and reliable facility operating systems. For many years, the focus had been on lowering investment expenditures on facilities – that is, on building at a low cost. However, as time passed, it appeared that expenditures on building constitute only a very small amount of total costs connected with a facility's life cycle. It appeared that facility maintenance costs comprise only ca. 70% of a facility's life cycle costs (Fig. 1). Fig. 2 presents a breakdown of facility maintenance costs [6]. In apartment buildings the costs of lighting constitute a several percent of total maintenance costs. It appears from statistical data [2] that 3.66 kWh, 110 kWh and 1336 kWh of energy were used per day, month and year, respectively, to illuminate one household in 1999. It is possible to save ca. 70% of energy by replacing traditional light bulbs (luminous efficiency: 10 ÷ 15 lm/W) with compact fluorescent lamps (luminous efficiency: 60 ÷ 75 lm/W). Theoretically, in such a case, energy consumption per household would fall by ca. 935 kWh. On the national level, with nearly 11 million of households, that would make it possible to save ca. 10.3 TWh of energy. The data are averaged and therefore it is necessary to highlight the problem of diversity of buildings and the technologies of lighting used in them, as well as the fact that in the majority of newly built facilities there are already implemented energy-efficient lighting installations.

3. Lighting in an Intelligent Building

Maintaining appropriate lighting parameters makes it possible to limit the probability of accidents at work, university and home. A very significant issue at especially hazardous work places is the psycho-physical condition of a worker, which is directly influenced by lighting. An appropriate lighting installation mainly ensures better visibility, protection against glare, but also an improvement in work ergonomics. People who are in well-illuminated rooms feel better, work more effectively and safely.

Energy savings in new lighting installations are achieved simultaneously in two ways. The first source of savings are energy-efficient light sources, e.g. fluorescent lamps or LED diodes characterized by higher luminous efficiency than traditional light bulbs. The other source is using intelligent lighting control systems. When reducing energy consumption, it is very important not to lower the level of two parameters of lightning design discussed earlier: safety and comfort. An important element which makes it possible to reduce the costs of lighting is efficient use of daylight. The installation of illumination sensors makes it possible to switch on a specified number of lighting fittings, so that illumination is at a predefined level. On the other hand, when daylight is too intensive, it is possible to pull down window blinds thanks to the integration of a lighting system with a building management system. It is an example of how to use the same sensor to achieve all the above-mentioned objectives: energy savings, comfort and safety. Presence sensors make it possible to reduce lighting in unused rooms, but may also have influence on their temperature. That is why it is very important to properly integrate energy resources management systems within a building. In case of sensors' failure, a building management system may be able to control a building according to programmed algorithms, for example to control window blinds with consideration of the movement of the Earth around the Sun and the illumination of a specific location on the Earth in a given season and on a specified day of the year.

4. HMS/BMS Systems in Lighting – Case Studies

4.1. Control Lighting System in the Office Building

Below there is presented an analysis of savings obtained thanks to using devices of building automation, as compared to the expenditures incurred in connection with an investment carried out in the year 2008 [6].

The LCN[1] system was selected by the management of the Technical Department of a multi-storey office building in Warsaw and it was to control the lighting of its reception hall. It was necessary to replace an older, over ten-year-old system of controlling light sources installed in the reception hall with newer generation devices including computer-programmed dimmers of LCN-LD and LCN-HU type.

The lighting system of the reception hall consisted of the following lamps:

- 230V/230W halogen lamps that constituted the main lighting of the hall, placed in the luminaries on the ceiling (QT32),
- 12V/90W halogen lamps that provides lighting in the lifts (QT12),
- 58W 3-band fluorescent lamps in luminaries installed on the walls and ceiling (TL-D).

As dimmers in the old control system stopped functioning properly, the staff of the building was forced to set the supply control of light sources in the reception hall to maximum power voltage (230V). Some light sources operating at maximum power voltage have much shorter life than those supplied with lowered voltage, e.g. 195V. Therefore, at voltage of 230V the staff of the Technical Department of the building was much more frequently engaged to replace burnt-out lamps than in the past, when the originally installed system of dimmers worked properly. Moreover, the more frequent replacement of lamps was connected with incurring considerable additional costs of servicing the lighting installation of the reception hall.

Before the LCN devices were purchased, there was conducted an analysis of savings that would be possible to gain after installing new dimmers and other necessary apparatus. Table I presents an analysis regarding only one type of lamps which are most problematic for the staff of the building – that is QT32 halogen lamps.

[1] LCN – Local Control Network. Other popular HMS/BMS systems are: KNX/EIB, LonWorks, BACnet, X-Comfort.

As required illumination of the surface of the reception hall is obtained at 85% of the value of rated power voltage, power consumption by the system decreases and the life of lighting sources is prolonged. Thus, savings are obtained due to a drop in payments for power consumption by QT32 light sources, QT12 halogen lamps and TL-D fluorescent lamps. Additional savings result from lowering the frequency of replacing burnt-out lamps. Therefore, the costs of buying and replacing new light sources are reduced. Savings obtained in this way compensate the investment expenditures incurred to purchase and install a new dimming system. As it results from data obtained from the investor in the building automation system, in the described office building, the value of purchased LCN devices and the costs of installing and running a new lighting installation equalled together 12 000.00 EUR (gross). Therefore, the expenses incurred, resulting from running a new, intelligent electrical installation in the hall of the office building are comparable with savings gained throughout the first two years. It means that in the case of the described investment the expenditures incurred paid off in a period of no more than thirty months.

Table 1: An analysis of savings obtained after introducing a system of LCN dimmers, relating to QT32 halogen lamps

No.	Current state at voltage of 230V	State after installing dimmers, at voltage lowered from 230V to 195.5V (by 15%)	Gross savings per week (in EUR) resulting from lowering voltage by 15% from 230V to the level of 195.5V
1.	Power of the lighting system with QT32 lamps - 19kW	System power – 16.15kW	72,00
2.	5 items per week wear out and need replacing	Average expected use - 3.5 items per week	13,50
3.	4 man-hours per week required to replace burnt-out lamps	Number of man-hours per week necessary to replace worn-out lamps - 2.8	12.00
		Savings per week	97.50
		Savings per year	**5 070.00**

The following assumptions were used to estimate the savings:
1. Gross cost of used electrical energy – 0.127 EUR /1 kWh (2008)
2. Gross cost of 1 man-hour – 10.00 EUR

Moreover, a modern system for dimming and brightening up lamps in the office building hall makes it possible to obtain illumination that is more friendly to the eyes of employees, staff and guests of the building, as it helps to eliminate light beam reflections on the constructions of luminaries and the façade of the hall (elimination of "disrupting light").

4.2. Control Lighting System in the Residential House

The subject of case study is the design of automated electric installation, controlling the lighting, heating and controlling electro-technical devices in 2-floor apartment of the area of 412 m^2, realised with the participation of authors [7]. This is a standalone facility and it has 21 rooms.

Table 2: The analysis of savings obtained after the use of energy saving sources

After replacing the traditional lighting sources by energy saving ones:		
The difference between traditional and energy saving lighting power	Calculations [kW x h/year x EUR/kWh]	Annual savings due to exchanging part of light sources
8.9 – 4.5 = 4.4 kW	4.4 x 657 x 0.137	396.00 [EUR gross]
Savings due to light sources life		
2pcs/month x 12 months = 7.6 x 12 = 91.20 EUR/ year,		
Installed generation capacity - dimming sources with the voltage 230V	Power value after using dimming, with the voltage up to 195V	Annual savings due to voltage reduction
4.0 kW	3.4 kW	84.28 [EUR gross]
Calculations : 4.0kW – 3.4kW = (0.6 kW x 657 h/year x 0.137 EUR/kWh) = 54.00 EUR/year, ie.15%		
Calculations non dimming light sources: (4.0 kW x 657 h/year x 0.137 EUR/kWh) = 360.00 EUR/year Calculations dimming light sources: (3.4kW x 657 h/year x 0.137 EUR/kWh) = 306.00 EUR/year		
Costs due to exchanging to more expensive energy saving light sources: 440.70 EUR		
Lighting savings account for: (396.00+ 91.20+ 54.00) – 440.70 = (541.20 – 440.70) = **100.50 EUR/year**		

Five light controlling methods were used, exclusively or in different combinations, that is: local manual controlling, automatic time switches, presence sensors, lighting intensity measurement, adjusting lighting.

During designing light sources properties of dimming and frequent switching off, depending on user functionality, were taken into the consideration.

From the listing of materials used in the project, we know the share of costs of LCN devices. Table II presents the analysis of material costs related to expenditures refund on Polish market.

The preconditions were as follows:

gross cost of used electrical energy in Poland is 0.137 EUR/kWh (in 2009),

coefficients of lighting switching ΔE1:

$$\Delta E_1 = L_h \cdot C_p \cdot C_{d/n} = 8760 \times 0.3 \times 0.25 = 657\ h \quad (1)$$

where:

ΔE_1 - Coefficients of lighting switching

L_h - Hours per year: 8760

C_p - Coefficient of surface use by 6 people: 0.3

$C_{d/n}$ - Coefficient of day and night relation: 0.25

As the result of the performed analysis, 15% of electrical energy was saved after using energy saving, dimming of most lamps. Additional savings are the result of using PIR presence sensor and illumination sensor (life of lamps is extended). Modern controlling system combined with new technologies of light sources, provides lighting conditions that are user friendly.

5. Conclusions

The ongoing depletion of fossil fuels' resources leads to the increased meaning of renewable energy sources and to improve the energy efficiency of consumers Home/building management systems (HMS/BMS) allow to save up to 40 % of energy. Over 50 % of energy consumed in buildings is made up of energy used by the HVAC (Heating, Ventilation, Air-Conditioning) system. By using building automation systems in modern lighting systems it is possible to use energy more efficiently and to achieve financial savings that result both from lower energy consumption and from reduction of maintenance costs. Aside from financial benefits, individual recipient has possibility of measurable influence on environment protection improvement through the decrease in energy usage. Protection of environment is due to both, lower usage of energy directly drawn by the lighting sources (15%) and lower usage of energy required for lamp production (extending the longevity of lighting sources). In the first presented example, investment expenditures on the modernization of the currently used lighting installation paid off after less than thirty months. In the second case, 15% of electrical energy was saved after using energy saving and dimming lamps.

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