Dorota TYPAŃSKA,Tomasz JARMUDA

Poznan University of Technology

Improving the energy efficiency of lighting through the use of KNX system

***Abstract**. The purpose of this paper is the comparison of the conventional and controlled illumination systems in an intelligent building. Studies in the past have shown that when applying conventional illumination based on incandescent and halogen light sources reduces the energy efficiency of the illuminations inside buildings below the permissible value, which is listed in the standards DIN 18599 and PN EN 15193. A solution to this problem is the application of illumination control systems.*

***Streszczenie.** Celem artykułu jest porównanie systemów oświetlenia konwencjonalnego oraz sterowanego w budynku inteligentnym. Jak dowodzą wyniki badań – stosowanie konwencjonalnego oświetlenia opartego na żarowych oraz halogenowych źródłach światła powoduje zmniejszenie wydajności energetycznej oświetlenia w budynkach poniżej wartości dopuszczalnej ujętej w normach DIN 18599 oraz PN EN 15193. Rozwiązaniem problemu jest zastosowanie systemów sterowania oświetleniem. (**Poprawa wydajności energetycznej oświetlenia poprzez wykorzystanie systemu KNX**).*

Keywords: KNX system, intelligent building, energy efficiency, illuminations
Słowa kluczowe: system KNX, budynek inteligentny, wydajność energetyczna, oświetlenie

doi:10.12915/pe.2014.07.15

Introduction

The energy efficiency in the so called intelligent building is a value that consists of several components i.e.: the energy consumed for heating, ventilation, air conditioning and illumination. This paper discusses energy efficiency in terms of the energy consumption for illumination.

An energy-efficient illumination is a term, which appeared not long ago i.e. in the 1980s following in response to the global energy crisis. At the time the Illuminating Engineering Society of North America recommended the minimization of the energy consumption for illumination. An energy-efficient illumination is one that consumes less energy yet keeps the quantitative and qualitative attributes of conventional lighting [1, 8].

An application of conventional illumination basing on incandescent and halogen light sources leads to the reduction of the energy efficiency below the value permitted by the standard DIN 15899. Of course there exists a possibility of an exchange of light fixtures or sources to more energy-efficient alternatives but often – for the need of visual comfort – users select non-energy-efficient illumination [2,9]. However, for the purpose of the optimization of energy consumption one can apply illumination control systems.

In the subsequent paragraphs a performed comparison is presented for conventional and controlled illumination systems. A model is presented, which has been created with ReluxPro and ReluxEnergy and simulations are performed for two cases:

- without illumination control (non-energy-efficient),
- with an application of the KNX technology with a control system (which is energy-efficient and fulfills the requirements of the standards given in [5, 6].

Parameters used in the standards

The standards describing the permissible values for energy consumption for illumination give a series of parameters, which need to be taken into account during the design and inspection of the energy efficiency of an object [5, 6].

The first one that needs to be described is the total energy used for lighting. It is one of the most important coefficients taken into account during the evaluation of the illumination's energy efficiency. It can be defined by the formula [1, 6, 8]:

(1) $$W_t = W_{L,t}\, W_{P,t}\, [\mathrm{kWh}]$$

where: $W_{L,t}$ – annual energy utilized by the installed light fixtures, $W_{P,t}$ – the annual parasitic energy that is produced during deactivated light sources (e.g. for loading the batteries of emergency fixtures or maintenance of illumination control systems).

The next coefficient worth describing is the occupancy dependency factor Fo, which depicts the use of the installed power of light fixtures in reference to the period of actual human presence. It is dependent on the illumination control system. The factor Fo is taken into account in analyses concerning the minimization of the illumination time and, what follows, the reduction of power consumption [6, 8].

Another parameter which influences the energy efficiency of the analyzed object is the constant illuminance factor Fc. It is dependent on the project's assumed maintenance factor, the structure of the light fixtures and the type of installed light sources. Over time more and more of the installed power is used. The upkeep should end at the time of a full consumption of the installed power [6].

Maintain a constant ratio of light intensity Fc is another parameter influencing the energy efficiency of the analyzed object. It depends on the adopted design lighting maintenance factor dependent on the period of maintenance of lighting fixtures, their construction and type of light sources mounted in the cover [6].

(2) $$F_C = \frac{1 + MF}{2}[-]$$

where MF is the maintenance factor.

A very important issue when considering the energy efficiency of an illumination is the possibility to use daylight during a support of artificial lighting. The intensity of an artificial lighting on the work plane is regulated in order to maintain the required level of the entire light intensity (to which both the natural and artificial light sources contribute). In practice a control of the light level only relies on the regulation of the fixtures' light flux [5, 6].

Apart from the previously described parameters, the coefficient of an illumination's energy efficiency depends also on the values of installed power and daytime and nighttime usage of light sources [1, 5, 6, 8]. It is described by the formula:

$$LENI = \{F_C \cdot \frac{P_N}{1000} \cdot [(t_d \cdot F_d \cdot F_O) + (t_N \cdot F_O)]\} + \\ + 1 + \{\frac{5}{t_y} \cdot [t_y - (t_d + t_N)]\} \quad (3)$$

where: F_c – constant illuminance factor, P_N – power density of the illumination installed in the building [W/m^2], F_d – daylight dependency factor, F_o – occupancy dependency factor, t_d – annual time of illumination usage at daytime [h], t_y – time period assumed to represent a year, 8760 h, t_N - annual time of illumination usage at nighttime [h].

Illumination control in a KNX system

A KNX system is one which consists of illumination control devices. They can be divided into two groups:
a) Control sensors,
b) Executive elements – so called actors [3].

The job of the sensors is to send commands, which are then executed by the actors in the form of activation, deactivation or light flux regulation of light fixtures [4 ,7].

Sensors

Sensors in the electric installation of an intelligent building are, above all, sensors of motion, light intensity and reed relay etc. Their task is to send orders or prepared values, which should be set in the executive elements. Additionally there exists a possibility to control with a remote through built-in infrared sensors [4, 7]. Sensors in the form of light intensity sensors have the task to maintain its constant level in certain conditions. When the light intensity is insufficient, the sensor sends an order of brightening or vice versa – if the light intensity is excessive then it should instruct dimming. In this way it is possible to maintain an appropriate light intensity for a type of work that is being performed in the studied space [4, 7].

Fig. 1 An exemplary 2 channel sensor of presence in the Tebis system of the Hager company [10]

Motion sensors have the task to check the presence of people in a given space. They exhibit a reaction on heat sources i.e. human beings, animals and some objects. Additionally, they often possess a built-in light intensity sensor.

In conclusion – a KNX sensor turns on a light source only when motion is detected or when the light intensity value drops beneath an imposed value [7]. In Figure 1 the Tebis presence sensor of the Hager company is presented.

Actors

An actor is a device whose purpose is the connection of receiver circuits. It is connected to the system's main line through a built-in main port. It additionally contains a switching element, in most cases – an electromagnetic relay. The drive of such a relay is supplied by a DC voltage send trough the main line [4].

Two kinds of actors are used in the KNX system for the purpose of illumination control:

A. switching actors, whose tasks are:
   a) the connection or disconnection of electric circuits and the control of their current;
   b) to cause delays in connections and disconnections after a given time.

B. dimmer-actors, whose tasks are: first of – to perform connections and disconnections of electric circuits, secondly – to perform smooth regulation of the intensity of light fixtures. The choice of a dimmer-actor is made through the selection of an illumination type, which they ought to control. Hence there are:
   a) dimmer-actors for halogen light sources,
   b) dimmer-actors for linear and compact fluorescent light sources,
   c) dimmer-actors for LED diodes.

Apart from dimmer-actors for individual types of light sources, there also exist universal dimmers that cooperate with standard control signals [7]:
a) Standard 1-10V,
b) Standard DALI.

a)

b)

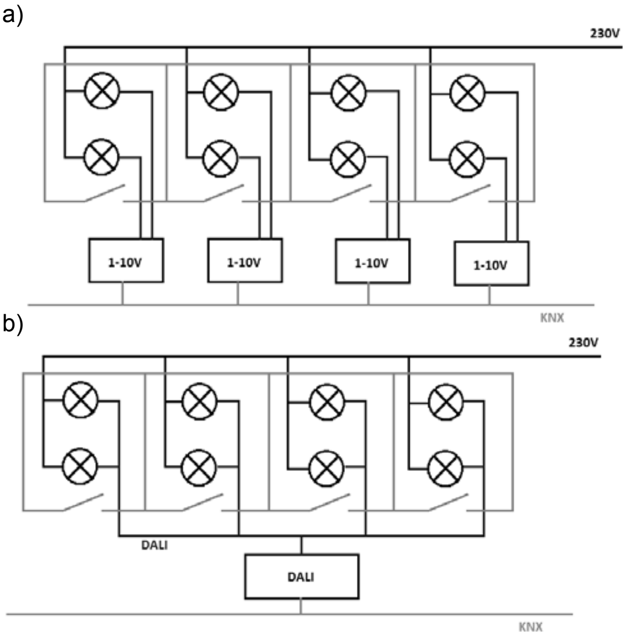

Fig. 2. Outline of the connection of dimmers for light fixtures in the standard: a) 1-10V, b) DALI

Fig. 3 The Tebis 600W 1-channel dimmer-actor manufactured by the Hager company [10]

Figure 2 presents the diagram of the connection of dimmers for light-fixtures in the 1-10V standard and the DALI standard. Also, an exemplary 1-channel 600W dimmer (Tebis) of the Hager company is presented in Figure 3.

Model of the studied object

The studied object is a bedroom of a single-family house. Its dimensions are: 6.5x3.6 m and 2.5 m in height (Figure 4). The installed light sources are:
1) two incandescent lamps (100 and 60 W respectively),
2) four halogen lamps of 50 W,
3) two fluorescent lamps (12 and 23 W respectively).

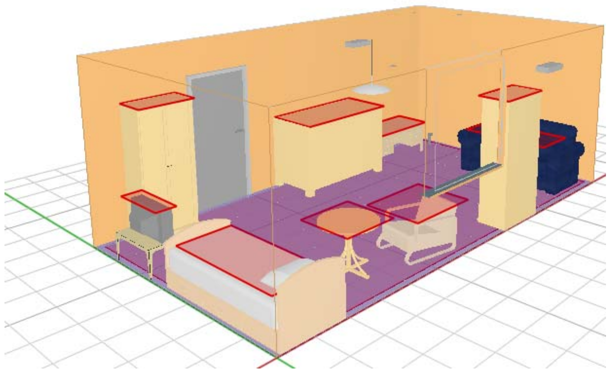

Fig. 4. A view of the modeled room

Fig 5. A view of the modeled illumination in the studied space

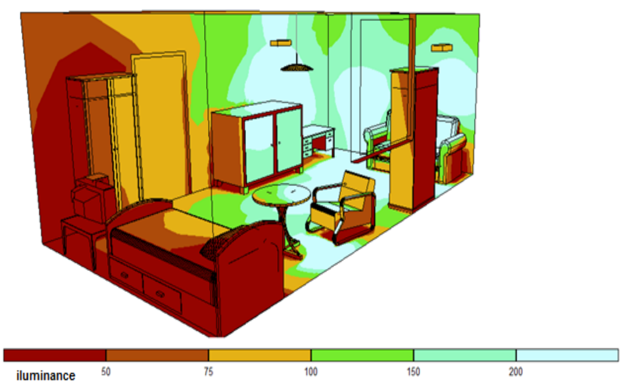

Fig. 6. Light intensity distribution at the boundaries of the studied space

Figures 5 and 6 represent (respectively): a view at the room's modeled illumination and a distribution of light intensity obtained with the Relux Pro software. The intensity varies in the range 20-300 lx.

Comparative analysis of the studied object with a modeled object in KNX technology

The previous paragraph presented the studied room and its model, which have been created in ReluxPro software in Polish language. The total power of the light fixtures was 395 W, which gives 17.17 W/m2. A comparative analysis of the system with and without control has been made in the ReluxEnergy software and presented in the subsequent paragraphs. Figure 7 presents the values assumed for the computations of the illumination's energy efficiency.

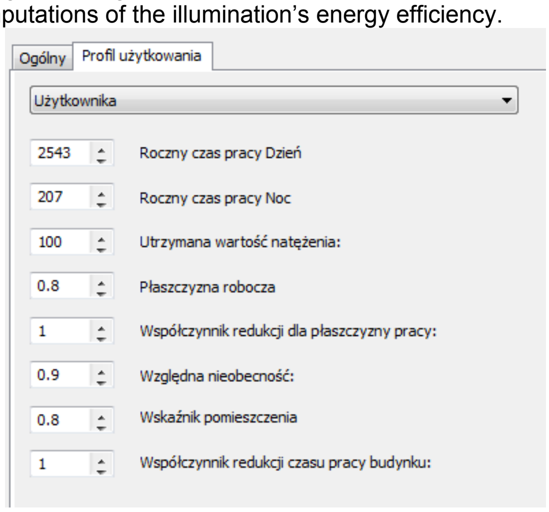

Fig. 7 View at the data, required to perform computations of the energy efficiency, which has been entered to the ReluxEnergy software

The total assumed annual work at daytime hours is 2543 h, while at nighttime hours it is 207 h. The maintained light intensity is assumed to be 100 lx. The work plane on the desk and table is at the height of 0.8 m.

Results for no illumination control

Currently the studied space does not possess any illumination control system. The total energy consumption obtained with the ReluxEnergy software is 597 kWh/year, which is more than three times the permitted value of 176 kWh/a (Fig. 8).

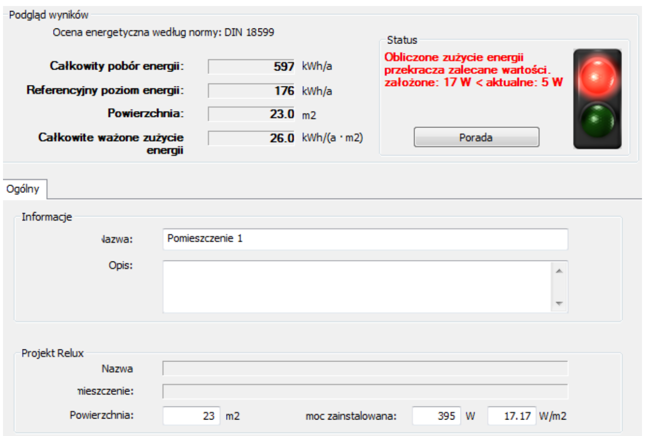

Fig. 8. Energy consumption for the studied object without illumination control

In order to minimize the energy consumption for illumination per year one of the following solutions can be applied:
- a change of light fixtures,
- a change of entire light fixtures,
- an application of an illumination control system.

An exemplary control system created with the KNX technology is presented in the next paragraph.

Results after applying a KNX technology control system

The previous results show that so far the illumination is not energy-efficient. Hence computations have been performed (Fig.9) with an assumption that a KNX illumination control system has been installed in the room. The control system contains presence sensors and dimmer-actors.

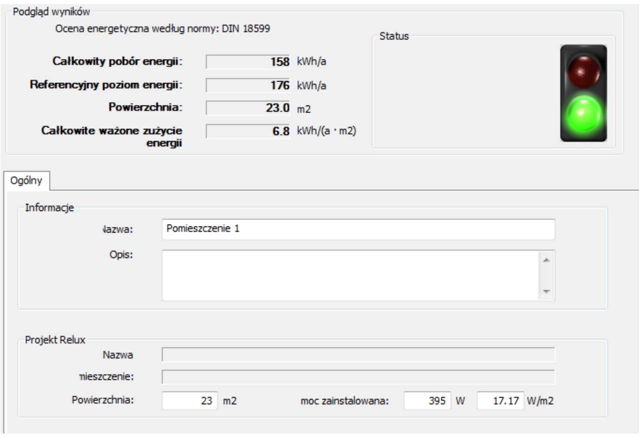

Fig. 9. Energy consumption values for an object with illumination control

The computations indicate that the application of the illumination control system fulfils its role, which results in the improvement of the energy efficiency. The annual energy used is 158 kWh/a, which is below the value given in the standards (176 kWh/a).

Summary

The application of incandescent or halogen light sources, especially in living spaces, can have positive influence on a person’s well-being. It is because these kinds of sources emit a warm light color emit and have a high color rendering index Ra>90. However, an application of these light sources leads to a high energy consumption. The performed studies prove that the KNX control systems can significantly decrease the energy consumption below the maximum values given in the norm [5]. Thus it is not necessary to abandon this kind of illumination.

The application of the ReluxPro and ReluxEnergy software software allows to model objects in terms of appropriate light intensities and their uniformity. It also allows to perform a rating of an illumination’s energy-efficiency. The energy efficiency becomes faster in comparison to when analytical computations are performed basing on the equations given in paragraph 2.

REFERENCES

[1] Bąk J.: “Energy-efficient indoor illumination” (in Polish), Warszawa, 2009
[2] Grzonkowski J:" Light sources - development and current state" (in Polish), Przegląd Elektrotechniczny, 6/2002, 153-163
[3] Hiroyasu T., Nakamura A., Yoshimi M., Miki M.: " Lighting Control System using an Actor ", IEEE, Nature and Biologycally Inspired Computing, 2010 Second World Congres on, 2010,140-145
[4] Kamińska A., Muszyński L., Boruta Z., Radajewski R.: “Modern techniques in the design of energy-efficient building installations in a KNX system” (in Polish), Medium Publishing House, Warszawa, 2011.
[5] Norma DIN 18599: “Energy efficiency of a building” (in Polish).
[6] Norma PN-EN 15193: “Energy performance of buildings – requirements concerning illumination” (in Polish).
[7] Stachno A.: “Illumination control in a KNX system” (in Polish), Fachowy Elektryk, 2/2013.
[8] Typańska D: “Energy efficiency rating of illumination inside sports facilities basing on the PN-EN 15193 standard: Energy performance of buildings – requirements concerning illumination” (in Polish), Poznan University of Technology Academic Journals, Issue 69, Poznan 2012.
[9] Żagan W.: "Theoretical considerations of luminous efficacy and color rendering by light sources" (in Polish), Przegląd Elektrotechniczny, 10/2013, 284-287
[10] Hager company products katalog 2013

***Authors**: mgr inż. Dorota Typańska, Politechnika Poznańska, Instytut Elektrotechniki i Elektroniki Przemysłowej, ul. Piotrowo 3a, 60-965 Poznań, E-mail: dorota.typanska@put.poznan.pl; mgr inż. Tomasz Jarmuda, Politechnika Poznańska, Instytut Elektrotechniki i Elektroniki Przemysłowej, ul. Piotrowo 3a, 60-965 Poznań, E-mail: tomasz.jarmuda@put.poznan.pl*