Simulation of daily, artificial and combined lighting in the software DIALux

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Abstract. *This article deals with the simulation of daily, artificial and combined lighting in a room. Simulation is performed within the software DIALux. With usage of the simulation software DIALux it is possible to simulate the intensity of light changes during the day, month and year. It can also be used to simulate combined lighting. With performed simulation it's possible to estimate economical and energy savings of combined lightning. Each simulation should be performed in a way that provides the minimum luminous intensity according to standard EN 12464-1. After evaluating the simulated data, these data can be used as a reference to calculate the savings when combined lighting is realized in real conditions. The main goal of this article is comparison between uncontrolled and controlled artificial lighting shown on an example of one room. The results are showing possible economical and energy savings that would be incurred with case of using the combined light instead of purely artificial light.*

Keywords

DIALux, artificial lighting, energy saving, sensor.

1. Introduction

Lighting plays an important role in human live. When a person is outside, in nature or when he is in a room, the light is always present. The only element constantly changing is the type of lightning used. During office work, the most common type of lighting is artificial lighting. We are using luminaires to create artificial lighting. It is very important that to have sufficient amount of indoor lighting, to perform out daily tasks effectively. If the lighting is not sufficient, e.g. there is not enough illumination in the room, the worker will be tired which also affects his work performance. Other factors that are decreasing work performance are for example the incorrect placement of a desk, an unsuitable office chair, insufficient hydration, lack of fresh air in the room or insufficient ambient temperature. The article will be dealing with artificial lighting of one room and there will be carried out of simulation of possible energy consumption and economical savings with deployment of combined lighting instead of solely artificial one. Reducing electricity consumption will not affect the minimum light intensity that needs to be achieved according to EN 12 464-1.

2. Lighting types

Lighting can generally be divided into 3 types:

- daily,
- artificial,
- combined.

2.1 Daily lighting

Daylight is the lighting that comes directly from the sun. The sun is a source of daylight, so it can also be called natural lighting. In general, it can be divided into 3 parts, depending on how the light comes into the room.

- *Direct lighting* - it comes directly from the sun and enters the room without reflecting.
- *Diffuse illumination* - is lighting that comes from the sun and is reflected from the object. (e.g. table, chair, ...).
- *Reflected illumination* - is lighting that is reflected before entering the room [1] [2].

Daylight intensity is not the same all day; it is constantly changing throughout the day. The greatest intensity values can be measured at around 12:00, the smallest in the morning or in the evening. In the night there is no daylight. Time is not the only parameter, on which the intensity of lighting depends. It depends on several factors:

- *Sky Status* - clear, partly cloudy or overcast.
- *Latitude* - maximum hours per year the sun is shining around the equator and the daytime light is reduced when the equator is moved to the north or to the south.
- *Seasons* - in the winter months are the shortest days, in the summer months are the longest, so the amount of daylight depends

on the season. In the summer months, daylight can be used more efficiently because it is available for a longer time [3].

2.2 Artificial lightning

Artificial lighting is generated by artificial sources, by luminaires. Light from luminaires strikes directly and after reflection from surrounding surfaces to a place, to a room, where we need [2]. Artificial lighting is required for us to work during hours, when daylight is very low, for example in night, in mornings or evenings.

The requirements for artificial lighting in the room are described in the standard EN 12 464-1 and parameters, which are in the standard we needs to be considered, when are designing lighting.

2.3 Combined lighting

Daylight is not sufficient in any case because its value changes during the day. In those periods when there is not enough of daylight, it is necessary to supplement it with artificial lighting and then a combined lighting will be created [3]. The best solution for combined lighting is to use a sensor that will monitor the amount of daylight in the room. Based on sensor data, artificial lighting is controlled to reduce room energy consumption.

3. Simulation software

For carrying out necessary simulation the software DIALux in version 4.13 was. Using the software you can design and visualize the room, and based on this input data calculates the distribution of light intensity in the room. The program is freeware, even though is frequently used in practice [4]. Recently, designers have also started using the program in designing various projects such as designing a room, building, road, public lighting or sport stadiums. The reason for his popularity is that the software is easy to use.

When the proposed project will be built in real life, for example, a stadium will be built or there will be realized reconstruction of the lighting system in the room is necessary to design the project to the smallest details to ensure that the results calculated by the program will correspond to the results in reality. In the program, there are various objects that are predefined. In addition, we have the ability to correct these objects to specify object parameters such as length, width, height or color.

4. The simulation of different types of lighting in the software DIALux

The first step is to design the analyzed room. It is necessary to set the correct room parameters such as:

- width,
- length,
- height.

When these settings are already constructed, the editing of the room is completed. After editing the room, it is necessary to insert windows and doors into the room, and also other objects such as cabinets, tables, chairs, plants. When everything is inserted and set, it is necessary to define the computational surfaces so that the program knows where to calculate the parameters that are important to follow. Floor plan of a room with windows, doors, tables, chairs and with calculate surfaces can be seen in the Fig. 1.

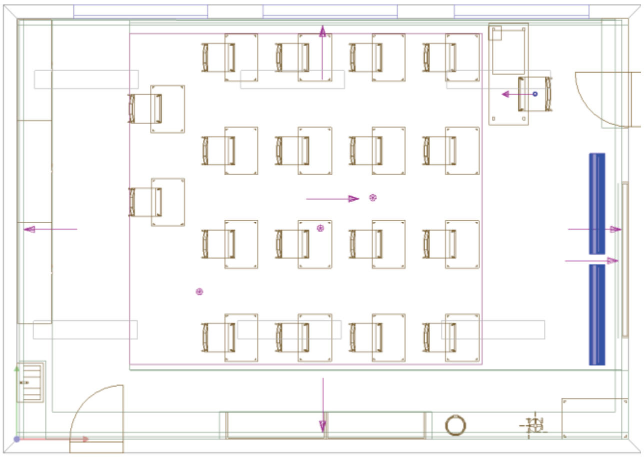

Fig. 1 Floor plan of a room with objects and with calculate surfaces

In the software we can see the room also in 3D format, which we can see in the Fig. 2. This makes it easier to understand the structure of the room.

Fig. 2 Room in 3D format

4.1 Daylight simulation

Simulation of daylight in the program is a bit complicated because other parameter needs to be taken in to consideration. This parameter is coordinates of the room. Intensity is depending on specific location. In addition, it is also necessary to set the northern orientation of the building. It is also necessary to insert light scenes so that the program knows how much time we need to count on the program. After all parameters have been set, the software calculates the lighting illuminance distribution in the room. Fig. 3 is illustrating the amount of daylight based on season, which are represented by their typical months.

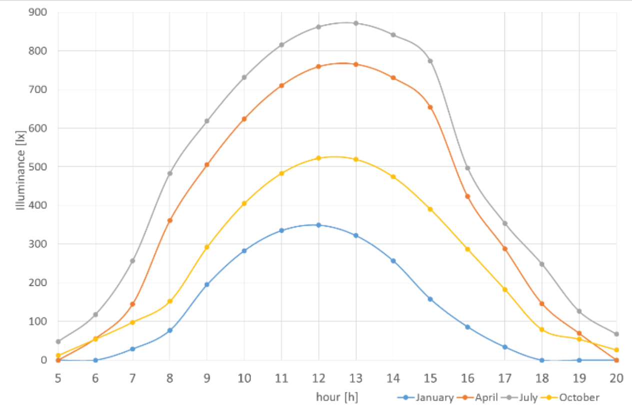

Fig. 3 Dependence of light intensity during the day in different seasons

4.2 Artificial lighting simulation

The simulation of artificial lighting is most important. The room has to be designed to meet legislative requirements. Each building, each room has different requirements which is described in standard EN 12 464-1. The room described in this article is a class, where it is important to reach a minimal value of illuminance at least 300 lx [5]. It is necessary to try different luminaires from different manufacturers, different shapes and nominal power in the simulation. Finally, the lamp from the manufacturer PHILIPS was selected. To reach the minimal value of illuminance, it was necessary to add 6 pieces of lamp to the program and to set it up to work at 100 % power.

4.3 Combined lighting simulation

The brand new room are applied and sensors that monitor the amount of daylight in the room and on the basis of measured data adjustment of the power lamps. Due to the fact that the lights do not shine at 100% power, it is possible to save part of the electricity that is used for lighting. For the simulation combined lighting is required to simulate daylight and artificial light. In the case of artificial lighting, it is also necessary to simulate the percentages of luminaires from 0 % to 100 %. This is necessary in order to calculate what energy savings would be. The combination of the results was made with the following procedures:

1. It is necessary to see in the standard the intensity of lighting we should have in the room.
2. It is necessary to evaluate the results of light intensity when daylight.
3. Will be calculate the difference between the value in the standard and achieved result.
4. Missing intensity of lighting must be illuminated with the lamps.

As an example it is possible to mention. If the daylight intensity of the room is 100 lx. The normative requirement is requiring at least 300 lx. It means that 200 lx needs to be illuminated artificially. For instance, at 70% of nominal power can luminaire achieve additional 200 lx which is required with normative. With such regulation there would be achieved 30% energy saving in comparison with case without using of regulation.

With this procedure, all the days and all the times of the year need to be done to determine what savings would be made in the year with regulation. In real life, there are various sensors from different manufacturers that monitor daylight in the room. It is important to choose the right one because not all sensors work with all of luminaires. Since in the simulation it is used PHILIPS luminaries, so it would be appropriate to use sensors their sensor. One option is to use PHILIPS LRL1220 sensors. The price of one sensor is approximate 20 € [6].

5. Comparation of operating costs without and with sensor

In order to assess that the use of sensors is advantageous or not, the results need to be compared to operating costs. Operating costs determine how much electricity will be used to illuminate a room. Operating costs can be calculated with Equation (1):

$$OC = TLO * t * d * ep \tag{1}$$

Where:

OC - operating costs [€].
TLO - total light output of the room [kW].
t - time of day of the room lighting (t = 8 hours / day).
d - number of days. It was calculate a 190 days.
ep - electricity price [€ / kWh].

Electricity consumption vary from month to month, as shown in Fig. 4. The reason for these changes is that the amount of daylight in the room is changing. Most of the daylight is in the summer months. The least is in the winter months. This can also be seen in Fig. 4, as the biggest savings are in achieved during the months May and June, the smallest in January. However, electricity consumption also depends on how many days are workdays during month.

Financial savings are increasing with electricity price. Electricity price will increase in future; thus economical savings are expected to be greater. Therefore, is necessary to emphasize the importance of lighting control. This is shown in Fig. 5.

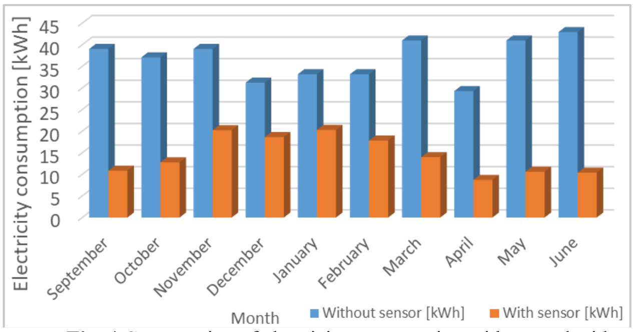

Fig. 4 Comparation of electricity consumption without and with sensor

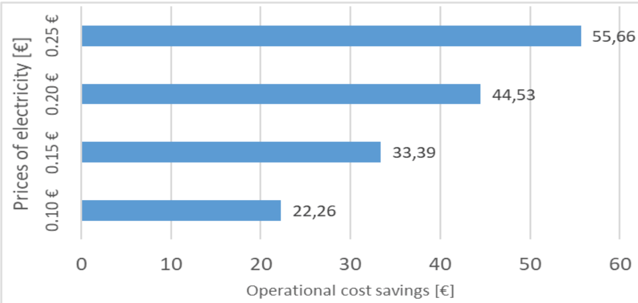

Fig. 5 Comparison of saved cash at different prices of electricity

6. Conclusion

This article deals with the simulation of daily, artificial and combined lighting in a room. It has been explained how to simulate the different types of lighting in the software Dialux. It has also dealt with pooled lighting, and it has also been shown how the intensity of lighting changes over the course of the day and what consequences it has on reducing operating costs. Information about saving energy and thus money is theoretical. The program room was made as accurately as possible in order to achieve approximately the same results if the proposal is actually implemented. The room, which was simulated in the software DIALux has a standard area of 30 m^2. It has 3 windows, from where will come the daylight. In 1 year the operational saving costs will be a 45 €, when price of electricity 0,20 €/kWh is considered. With increasing price of electricity (e.g. 0,25 - 0,3 €/kWh or greater) operational cost savings increases as well. The amount of saving also depends on how many window and luminaires are present in the room. It can be seen that it is possible to save money with the sensors. If we are seeing a larger period, for example 5 or 10 years, the savings would be greater. The return on investment depends on whether only sensors or even sensors and lights are bought. If only sensors are bought (2 – First and second sensor will control 3 - 3 luminaires) the return of investment is 1 year, because 45 € will be saved and estimated price for 2 sensors is 40 - 50 €. If sensors and luminaires are bought, then return of investment depends on the price per luminaire. Return investment for the sensors in this case 1 year as well, but return investment for the luminaires is a longer than 1 year.

Acknowledgements

Research described in the paper was supervised by doc. Ing. Ľubomír Beňa Phd., KEE FEI TUKE and supported by the Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Slovak Academy of Sciences by the projects VEGA No. 1/0372/18.

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