Proposal for standardization of switsching and control profiles in public lighting

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Introduction

At the present, it is in the interest of the majority of most developed countries to reduce the power consumption. Great emphasis is placed on the use of efficient electrical equipment. The European Union started the implementation of the political and economic actions, leading to reduce the use of inefficient products and replacing them with more efficient. Lighting is one of the areas which consumes a lot of energy, but also offers a high potential for savings. Therefore, product- and system-oriented limitations are implemented through European directives into national legislation of the European countries aimed to gradually reduce the use of inefficient products. One of such system tool is the energy performance of buildings introduced several years ago, and now it is time to establish the platform for benchmarking the public lighting systems. In the new draft the standard prEN 13201-5 introduces the compound numerical indicators PDI and AECI. Examples of calculation of the PDI and AECI are in annexes of the draft standard, indicating the typical values for different road profiles, taking into consideration different lighting classes of roads and usage of different technologies available for the public lighting. In annexes are showed typical values of the lighting operation coefficient for different operational profiles. This paper deals with the typical values of AECI for different operational profiles and with calculating of the lighting operation coefficient. The main aim of the paper is to propose additional typical values of the lighting operation coefficient, taking into consideration different detection probability.

Operational profiles

The operation time of the lighting system of public lighting is determined by rising and sunset time of sun. Frequently it is used at computations and similar applications 4000 hours as year operational time of public lighting. In the reference [4] it can be found math relationships and procedure for the computation of operational time for different Earth latitudes in the Europe. Computed value is determined around 3900 hours. In the public lighting is possible to describe 4 types of functional profiles which are depicted in the pictures Fig.1 to Fig.4. They can be also found in the appendix A1 of standard prEN 13201-5.

Full range profile:

In the picture is showed full range operational time. This profile is used for simple lighting networks in public lighting for many years until nowadays. Networks are switched through fotocells or timers and so on. Full range profil is used in most of old public lighting networks in Slovakia. Such lighting networks should be used fter renovation or in new public lighting only for roads with constant traffic. [1] Full range profil represents annual operational time 400 hours of lighting system of public lighting.

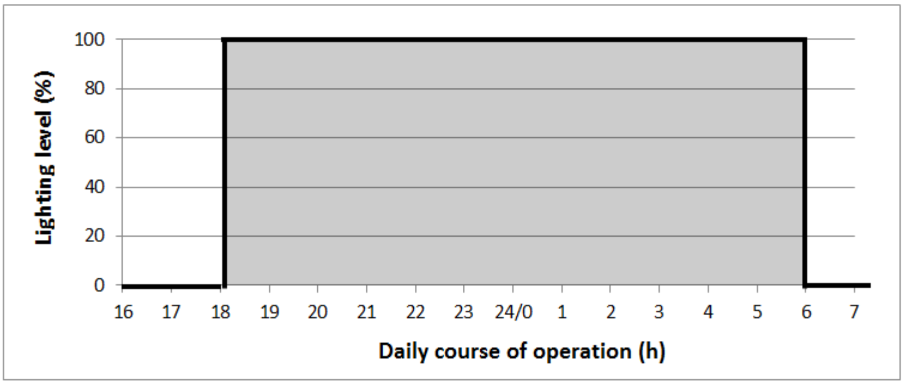

Fig.1.Full range profile

Night-time switching off regime of public lighting

Sometimes occur in small towns and villages for electric energy saving purposes. Lighting system at the night time is fully switched off. This regime is used in the lighting systems with simple switching elements where technically it is not possible install cost effective lighting control system. This profile is not recommended to use due to security reasons. Therefore it is not mentioned in the draft of the standard prEN 13201-5. However by switching off of the lighting system is achieved energy saving but in this regime purpose of lighting system is lost for purposes was designed i.e. mainly secure feeling in the town or in the city. Completely switched off lighting system brings also security risk for car drivers for whom it is very difficult to observe a barrier on the road as pedestrians, animals etc. It is acceptable around astronomic observation places where pollution light prevents quality of observations of night sky and so on. The calculation shows that switching off means 2175 hours at full power *P* and 1825 hours at zero power *P*.

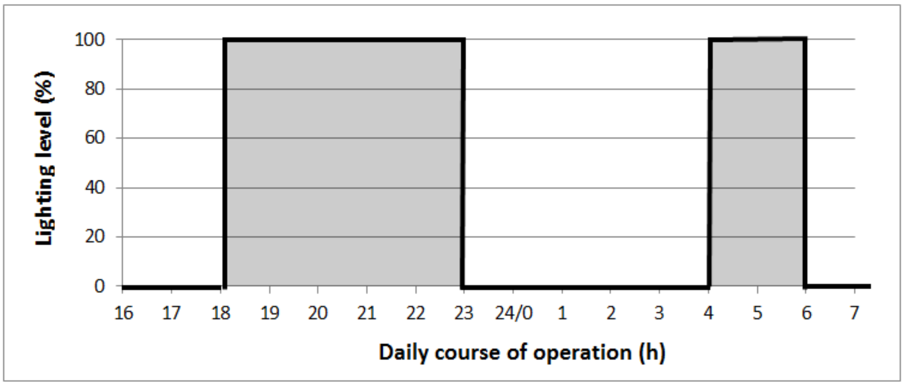

Fig.2. Profile with night switching-off

Regulated control profile: Multi level regulated control profile (for example two level profile in the picture Fig.3) consists two or more time intervals within during the day where luminaires have various input power and they can be operated at different level according to road class requirement (standard EN 13201-2) for each of the interval. This profile is suitable for roads with lower traffic density when is assumed lower frequency of cars on the road at night. For dimming control can be used various voltage regulators, phase regulators, dimmable electronic ballasts. The calculation shows that control profile means 2175 hours at full power *P* and 1825 hours at lower input power 0,7*P* at 50% of illuminance level (Fig.3).

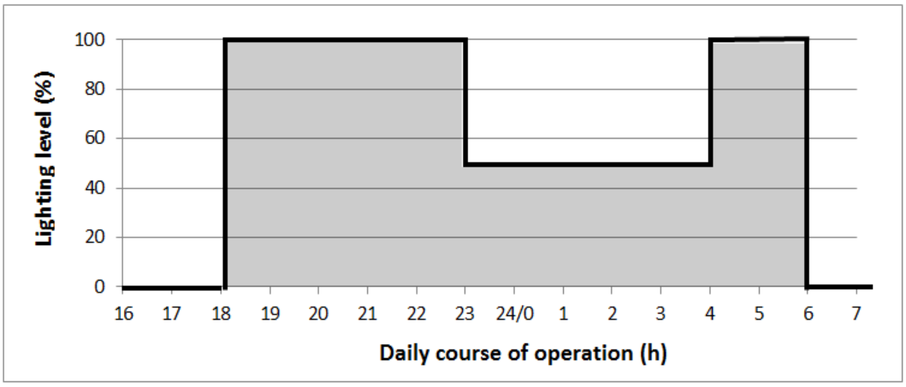

Fig.3. Bi-profile operational profile

Controlling of lighting system by multi-detection of cars and pedestrians:

If the lighting system is controlled by detectors of moving cars and persons, full or multi-level profile is switched into lower to minimum illuminance levels than usually when traffic is not detected. At night time after sunset for this purpose is defined new, third illuminance level of lighting system which represents minimum of security risk for other people which are living in area with this controlling system (secure movement of pedestriance in the case when detection system failed, minimum level for habitants of builings who looking from windows). Simultaneously this controlling system should maintain luminaires in stanby regime. Particularly it is suitable for LED luminaires which are easily controllable for various illuminance levels. Levels when traffic is not detected (Fig.4) depend on detection and they are not periodic. For the determination of AECI is therefore needed to assume with some probability of higher illuminance levels at time of detection for the each illuminance level of the lighting system. This controlling system should be used in a residential area. The calculation shows that control profile means 2175 hours at two level control system between 100% and 60% of system input power *P* with 80% probability of detection and 1825 hours two-level reduced control system between 20% and 60% of system input power with 20% probability of detection.

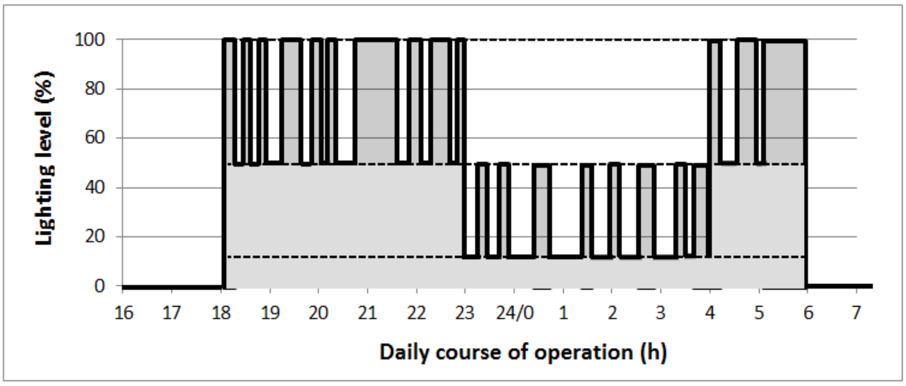

Fig.4. Tri-power detector driven operational profile

For full control profile is usually assumed annual operational time 4000 hours. At other operational time regimes it is sufficient combine annual operational time of particular illuminance level with the relevant system input power. In the case of systems with detectors combination should be assumed for probability of the detection. By this combination it can be determined *coefficient of operational time of lighting system* c_{op}. By means of multiplication of this coefficient with AECI value for whole control profile as result will be AECI value for considered control profile of the lighting system. Typical values of coefficient c_{op} are listed in the Table 1 while values in the table were determined under considerations mentioned above.

Table 1. The parameters of roads

Control profile of the lighting system	c_{op} **(%)**
Full profile	100,0
Two-level profile	86,3
Three-level profile with sensors	62,8
Switching off at night-time	54,4

Technical posibilities

So-called adaptive lighting system is described in several studies. The advent of this new technology into the practice is very slow due to significant costs and technology is not sufficiently fine-tuned yet. For lighting designs using this type of lighting system is very important return on invested funds. The particular design of adaptive lighting systems is not a simple. It is influenced by a lot of factors that they need to be considered. Currently use of this technology is limited also by technology difficulties of detect motion in addition to high costs. Detectors can be divided into groups as follows:

- PIR movement detectors
- IR barriers
- Microwave detection sensors
- Laser detectors

Each of the detector or technology has its specific features which can be used for various situations and different areas. If such project is at preparation level it shall be addressed to each individual area and simultaneously consider all the factors of this area. In Slovakia were carried out two pilot projects. In the first case it was used a simple situation with communication and corresponding sidewalk where the PIR sensors have been used to control of lighting system mounted into luminaires. According to sensor detect movement it is changing of output luminous flux of particular luminaires individually. With such solution it is necessary that the luminaires directly communicate with each other and they provide sufficient light output for the area where the user may have to move. On the other hand for cars it is necessary to ensure switching of lighting system in advance to ensure sufficient visibility for the drivers with respect to the car speed. In the village it is based on the empiric experience about 100 m ahead of the car.

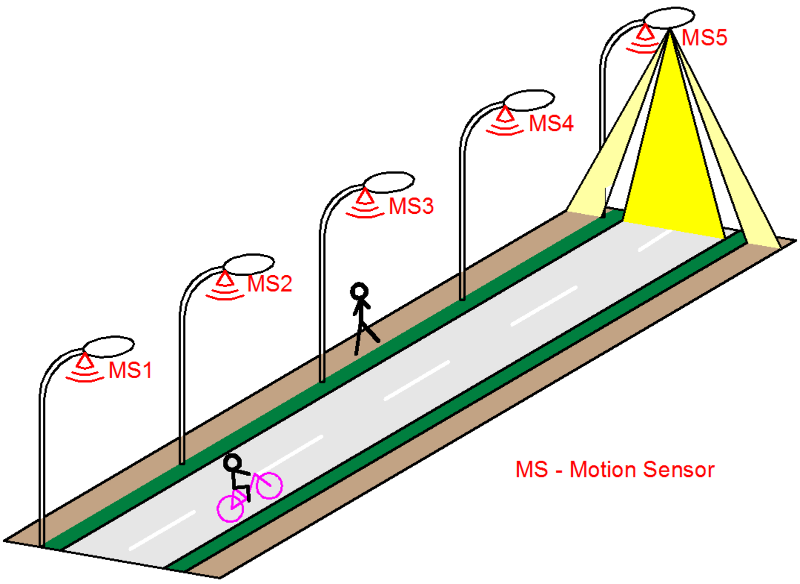

Fig.5.Example of adaptive lighting

The second pilot project aims to solve more technical problems and analyses of the impacts. As part of this project they are also involved authors of this paper. At the present analyses about possible technical solutions were carried out. Also measurements of the photometric and electrical parameters of luminaires are performed. Photometric parameters of luminaires provide information on changes in the management of lighting system. On the other hand electrical parameters give to user information on saving energy and impacts on supply power network. A major problem in the use of detectors is to eliminate disturbances and detection of unwanted objects and subjects. These can for example include detection of animal movements and green trees during strong wind and detection of moving objects (e.g. waste on the road and so on.). Effects of weather would be necessary to exclude but also to control the weather conditions could be based on other inputs. Except of effects of weather as wet roads snow-covered roads and influence of reflection on the road would be also necessary to consider at design state. This is not currently available due to lack of research work in this field. Under such conditions it would be necessary switching of luminaires with larger advance or in a different order in connection of assumption of the positive or negative contrast on the road. In addition to selecting the right sensor it is also important choosing the appropriate area on the road for adaptive lighting. In order to achieve an acceptable return of investment in appropriate time in connection with proper lighting system design it is necessary to focus on primarily on less frequented areas. The most suitable areas are small villages outside of the main transit traffic where it is expected that in the late evening and early morning the traffic density of persons and vehicles is at minimum. Other suitable road communications are eg. residential areas under construction (Fig. 6). On the contrary unsuitable areas are busy main roads, city centers with high-traffic area. It could be also difficult to apply of this system on roads with a geometrical complex shape such as a lot of turns and so on.

Fig.6.Apposite example of street situation

Conclusion

In the paper is presented possibilities of control system of public lighting in different areas by means of various controlling systems and profiles. Also particular examples from the practice are presented with possible solutions of the controlling of lighting system. In the table 1 is present three-level control system of public lighting where coefficient of operational time 62,8% was computed for particular probabilities of detection of movement. It was mentioned above probability of movement detection is very important selection of the road communication or sidewalks with respect to density of traffic on the road or density of movement on the sidewalks. It depends on appropriate selected area in the cities, towns and villages. Very often the traffic density data are not available. In the Table 2 are listed results of sample calculations of coefficient c_{op} for some model situations which can occur in the practice. In the future work it should be investigated more real road communications with respect to computation of coefficient c_{op}. Furthermore more real installations investigation in practice of lighting control systems in detail should be perform.

Table 2. Examples for AECI with different probability detection

Three level profile	Main time (..-23:00; 04:00-..)		Night time (23:00-04:00)		Cop (%)
Power consuption of system (%)	100	60	60	20	
Probability detection (%)	90	10	40	60	68,63
	80	20	30	70	64,63
	70	30	20	80	60,63
	60	40	30	70	60,28
	60	40	20	80	58,45
	60	40	10	90	56,63

Acknowledgement

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