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BULLETIN OF THE POLISH ACADEMY OF SCIENCES
TECHNICAL SCIENCES, Vol. 67, No. 6, 2019
DOI: 10.24425/bpasts.2019.130893

POWER SYSTEMS AND POWER ELECTRONICS

# Concept and implementation of adaptive road lighting concurrent with vehicles

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**Abstract.** The paper presents the authors' concept of an adaptive road lighting that is concurrent with vehicles moving on roads. The lighting system is based on luminaires with light emitting diodes. The authors describe the operation of the adaptive road lighting system and point out benefits and limitations of the solution. The theoretical considerations are supported by an analysis of the installed and working system that was implemented at Bożeny street in Poznan, Poland. The system was also evaluated by the residents living near the street.

**Key words:** lighting technology, road lighting, lighting control, light emitting diodes.

## 1. Introduction

Saving energy is a challenging issue for the contemporary world. This need is caused by increasing prices of energy and concern for the natural environment. New technologies should be efficient and their use effective to meet high requirements corresponding not only to energy efficiency but, above all, to comfort and well-being of people.

Lighting is important and necessary for our life, applied commonly in all interiors and many exteriors and roads. Lighting systems use substantial part of produced electric energy [1]. Searching for high quality and energy efficiency in lighting has been noticed and reported for many years [2–4] and still it drives development of new lighting technologies and techniques [5–7].

One of the cheapest and quickest way to improve energy-efficiency is better use of accessible energy [8]. In lighting field there are many ways of saving energy from the end user point of view. These ways correspond to minimising the power installed of lighting as well as time of use of the power [9]. It must be kept in mind that new lighting technologies and solutions that concentrate on energy efficiency should always meet the users' needs [10, 11]. A promising way to meet both the users' needs and save energy gives adaptive lighting.

Development and price decrease of control systems enable their broader use, also in lighting field. The application of lighting control, that gives many opportunities for the realisation of well-known and new concepts, may provide effective tools and systems for humans regarding energy savings. Control systems are the heart of adaptive lighting systems that have started entering our life. Also in road lighting the adaptive systems have been developing recently [12–16]. This opportunity is also connected with the broader use of LED light sources nowadays [17–21].

Rapid development of LED technology and also control systems in recent years allows implementing new solutions but also the ones that used to be unprofitable or unfeasible so far. Moreover, old ideas that have never been used in practice are now being combined with modern technologies and give unexpectedly positive effects. This is how the LED technology and advanced control systems give a new life to the almost forgotten idea of adaptive road lighting that is concurrent with vehicles.

In the late 1980s in Japan, a system of monitoring traffic was created, the logical consequence of which was developing an automatic lighting control system [22]. In those times the idea could not find a practical implementation, as an appropriate source of light did not exist. Although the incandescent lamps back then had an adequate speed of response to force, their low luminous efficacy, as compared to the high pressure sodium lamps that were just being introduced in the markets, did not give them any chance. Discharge lamps, on the other hand, are characterized by too long stabilization time. It was only when LEDs appeared that it finally became possible to fill the gap and open the way to put the ideas from over 30 years into practice. The authors' development of this idea, a new concept and its implementation are presented in this paper.

## 2. Concept of adaptive road lighting

The main objective of road lighting is to provide safety and comfort for any road user [23, 24]. For motorized traffic on roads the lighting requirements are formulated taking into account the drivers first of all. Any driver is the subject of lighting, while a road is the object. In such context, the lighting does not exist without drivers. The conclusion that follows is that the road does not have to be illuminated while it is not being used. In consequence, when the road is not being used by any driver, the lighting may be turned off. Our concept of adaptive road lighting is based on this assumption.

The adaptive road lighting system concurrent with vehicles combines an electronic monitoring and control system with the

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Manuscript submitted 2019-07-11, initially accepted for publication 2019-09-08, published in December 2019

effectiveness of LEDs. Such lighting system is the simplest way of saving energy that provides all conditions required by the standards [25, 26] for roads while the road user is performing a visual task on the road effectively and comfortably. The system switches off the unnecessary light sources while they are not being used to provide anyone appropriate conditions for visual tasks. Its main functionality is to turn on the lighting on the road whenever it is needed (there is a user on the road) and turn off or dim considerably the lighting when its function has been carried out and is no longer necessary (the user has left the given road section). Moreover, only some luminaires are turned on, these that are necessary to provide adequate conditions for the road user to perform the visual task effectively. In any time, the operation of the system should not disturb or bother anyone either. In order to meet the mentioned needs, its functioning must follow certain rules.

A selected luminaire is turned on smoothly at an appropriate distance ahead of the user in motion and remains on until a certain moment, specified by the accepted requirements. Then, if a next road user is not approaching, the luminaire is smoothly dimmed or turned off. The length of the road section illuminated ahead of the vehicle depends mainly on the speed of the vehicles in motion. It is adjusted to the speed limit in the given location. The length of the road illuminated ahead of the user may also depend on the user's actual speed when overtaking another vehicle. In such case, a motionless vehicle should be in the center of the illuminated zone, while a vehicle moving at the maximum permitted speed should be at the end of the zone illuminated in front of it. The turning on and dimming the luminaire take place smoothly, to create the impression of continuity. The gap time between the subsequent illumination cycles must not be shorter than a certain specified value, expressed in a multiple of the minimal illumination period. If the distance between the subsequent vehicles is too small to perform such gap, the luminaire is not turned off until the distance between the subsequent vehicles is long enough. It was also assumed that conflict zones, such as intersections or pedestrian crossings should be illuminated continuously at an appropriately high level.

Implementing the above rules causes certain limitations to the system. It is not possible to apply such system anywhere and anytime. Installing such system is economically unjustified in places where the traffic density at night does not fall to an appropriately low level for a long time. The system will not be also effective if the road illuminated is not long enough or has too many junctions. Additionally, it was assumed not to install the system in places where there are residential buildings in close proximity of the road, as the light from the luminaires, being turned on and off or dimmed, may disturb the residents. A good condition for implementing the system is the existence of natural or artificial objects between the road and the houses that would limit the negative impact in the interiors of the households in the nearest area. These objects may include considerable distance itself, high or low greenery, sound screens or a combination of these elements. It seems that such function may also be fulfilled by a continuous illumination of different traffic lanes, such as a sidewalk or a local road located between the road with the adaptive lighting system and the buildings in question. Another contraindication for implementing the adaptive road lighting system may also be a perspective increase in traffic density expected in the near future, for example being predicted on the urban development plans in the given area.

For our reference road, where the distance between the single sided luminaires is 30.3 m, it is assumed that 5 luminaires are turned on ahead of each moving vehicle. The economic calculations consider a constant number of luminaires that are turned on at a time, which is possible because while a subsequent luminaire is being turned on ahead of a vehicle, another one is being turned off behind it. Assuming an appropriate pace of changes in the luminous flux over time, the power of the two luminaires mentioned sums up to the full power of one luminaire (Fig. 1.). It was assumed that the time of each lamp turning on and off is predefined, equal for all luminaries and independent on the actual speed of the vehicles.

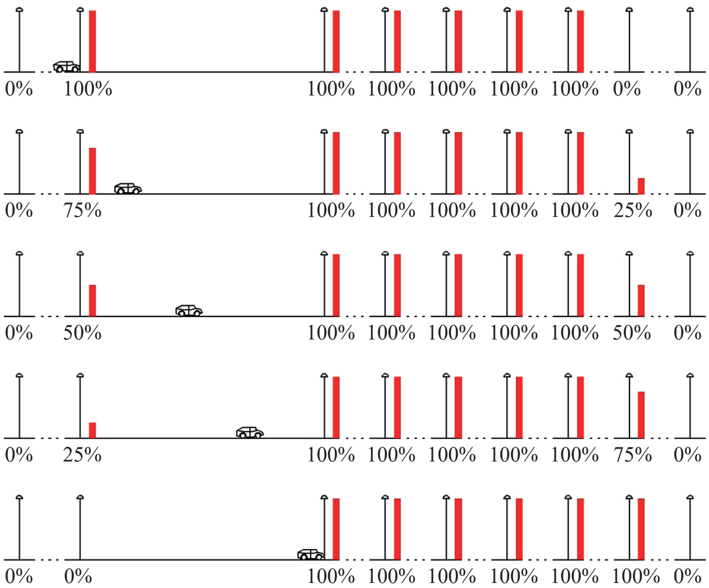


Fig. 1. The scheme of the adaptive road lighting system operation. Red column represents a percentage of luminaire power that is necessary for driver comfort

Ahead of each moving vehicle on the road, a light wave should appear of a length not less than about 100 m, moving with the vehicle along the road. The subsequent luminaires should have their time of turning on adjusted to the maximum speed limit on the given road. The time to reach the nominal luminous flux should be equal to the minimum time spent by the vehicle under the luminaire, that is, the time that a vehicle moving at the maximum permitted speed travels a distance equal to the length of the module. Such time should be set as identical to the time of turning off the luminaire that the vehicle has passed. In such situation, a vehicle travelling at the maximum speed permitted will cause the subsequent luminaires to be turning on and off in a smooth manner. Each subsequent luminaire will initiate its operation exactly at the moment when the previous one has reached its nominal luminous flux. If another vehicle enters the controlled area after a time shorter than the sum of the full illumination cycle and the pre-set minimal turning off time, it will prevent the luminaires from turning off after the previous vehicle has passed, and make them wait for the next vehicle to pass.

In the case of dual carriageway roads it is assumed that an independent system works on each carriageway. On two-way single carriageway roads the system must analyze the traffic in both directions and take into account the place and time when two vehicles travelling in opposite directions will pass each other. Specific principles for controlling the luminaires in concurrent lighting systems have been presented in previous work [27].

The designed system might disturb the visual guidance. It has not been investigated if the visibility of only a few nearest luminaires operating is sufficient to properly distinguish the shape of the road ahead. If it turns out that for such orientation it is necessary that the driver sees the luminaires on a longer section of the road, an extra condition may be introduced that if there is a vehicle on the road, all luminaires visible for the driver should be turned on with a specified minimum power, or the luminaires may be equipped with additional diodes to provide visual guidance with a minimum power. The present theoretical analyses, however, assume that these luminaires are turned off.

All the earlier considerations assume an even distribution of vehicles within the given time period. This assumption does not cause any significant distortions, as for a certain traffic density two vehicles moving at a time interval that is much shorter than the average one cause an extension of the interval between other vehicles accordingly.

Three modes of operation of the system control cycles are considered here: immediate – when each possible moment is used to turn off the luminaires, fast – when the time that the luminaires are turned off may not be shorter than the minimum time of illumination, and slow – when the minimum interval period between the illumination is twice as long as in the fast cycle mode. Introducing the fast and slow cycle modes results from the desire not to create an impression of chaos in a potential observer and not to cause anxiety or irritation by the luminaires being constantly turned on and off.

## 3. Models of the system

The study that started from theoretical considerations is aimed then at developing how the adaptive road lighting system should function at night, determining the level of traffic density at which implementing such system may be appropriate, as well as showing the potential savings that might result from implementing the system. It was assumed that the streets considered in the analysis are within a built-up area, and thus the maximum speed limit was assumed at 50 km/h.

Because the actual street length, as long as it is greater than the minimal one that provides the functionality of the system, does not influence significantly the analysis results, all the parameters in the calculations are converted to 1 km of the street length. Single carriageway roads are considered: one-way and two-way ones, and it is only for such roads that the analyses were carried out. Dual carriageway roads may be treated as a combination of two one-way single carriageway roads, so the analysis of such cases is not presented in this paper. For each analysed road, a single sided lighting system is taken into account. The analyses consider a changing traffic density, at a level from 10 to 200 vehicles per hour in each direction. The bottom level of traffic density represents cases of very low traffic density occurring at late night, while the top level stands for high traffic density.

The first case analyzed is a one-way single carriageway road. In the beginning of the street there is an initial section that is permanently illuminated by 5, 10 or 15 luminaires, of a length of 121.2, 242.4 or 363.6 m accordingly, depending on the control mode selected. Controlling the remaining luminaires depends on the traffic conditions. In the case when there are no vehicles on the road, the luminaires remain turned off. A luminaire is turned on when a vehicle is 150 m ahead of it and turned off when the vehicle passes it and another vehicle is not approaching.

With a constant speed limit (50 km/h, as assumed before), the time of traveling a distance of 1 km is 72 s. The time period spent by a vehicle within one spacing is thus 2.18 s. The time when each luminaire is on while a single vehicle passes lasts 10.9 s. The minimum time of the immediate cycle mode is equal to the time that the luminaire is on; with the fast cycle mode it is twice that time, that is, 21.8 s, while with the slow cycle mode it is three times that time, that is, 32.7 s. The system is working if the distances between the subsequent vehicles are greater than 150, 270 and 390 m, according to the mode of selected operation system. These times correspond to the traffic density at the level of 330, 150, and 103 vehicles per hour. The time when each luminaire on the road is turned on during one hour was determined as a function of the number of vehicles passing. The results are presented in Table 1.

Table 1
Time when each luminaire is turned on and the energy savings with dynamic lighting of a one-way single carriageway road operating in the immediate mode

| Number of vehicles per one hour | Operation time of each luminaire in the initial section [s/h] | Operation time of each luminaire in the controlled section [s/h] | Energy saving for the whole road [%] | Energy saving for the controlled section of the road [%] |
|---|---|---|---|---|
| 10 | 3600 | 131 | 82 | 96 |
| 25 | 3600 | 327 | 78 | 91 |
| 50 | 3600 | 655 | 70 | 82 |
| 100 | 3600 | 1309 | 54 | 64 |
| 200 | 3600 | 2618 | 23 | 27 |

A very common road situation is two-way traffic on a single carriageway road. As in every case of using the adaptive road lighting, the illumination of the beginning and the end of the street (the intermediate sections) is constant – the lighting conditions meet the requirements for the greatest traffic density – the luminaires are working with a nominal power during the whole period analyzed here. In the situation considered here, there are 5, 10 or 15 luminaires on each end of the street marking the initial section that is 121.2, 242.4 or 363.6 m long respectively, depending on the operation mode of system selected. The temporary setting of the 24 remaining luminaires depends on the traffic present there. The operating of the controlled section is the same as in the case of a one-way road, except for the situation when vehicles moving in opposite directions pass each other. At the site of the expected passing, 12 luminaires stay on for an extended time period. The analyses considered a symmetry in traffic, that is, an identical number of vehicles moving in both directions. For a proper functioning of the immediate operation mode, the traffic density for each direction must be half the density of one-way roads and it must not exceed 165 vehicles per hour in each direction. Above this density the lighting system works permanently with full power.

As in the previous case, for a constant permitted speed the time periods of operation of each single luminaire on the road were calculated as a function of the number of vehicles passing. The results are presented in Table 2.

Table 2
Time when each luminaire is turned on and the energy savings with dynamic lighting of a two-way single carriageway road operating in the immediate mode

| Number of vehicles per one hour | Operation time of each luminaire in the initial section [s/h] | Operation time of each luminaire in the controlled section [s/h] | Energy saving for the whole road [%] | Energy saving for the controlled section of the road [%] |
|---|---|---|---|---|
| 10 | 3600 | 152 | 68 | 96 |
| 25 | 3600 | 462 | 62 | 87 |
| 50 | 3600 | 1191 | 47 | 67 |
| 100 | 3600 | 3456 | 3 | 4 |
| 200 | 3600 | 3600 | 0 | 0 |

## 4. Operation of the system

The proper operation of the system is based strictly on adequate detection of the road users and an assessment of their movement parameters. This requires using a system that is able to identify the presence of each vehicle, determine the direction of their movement and assess their speed [28, 29]. From the data obtained, the system must calculate the momentary control parameters and give a command to turn on the respective luminaires.

Another factor that needs to be considered is the speed of the vehicles. It rarely happens that someone is travelling at exactly the maximum permitted speed. The users are to adjust the speed to the given conditions and drive a bit slower than allowed by the regulations. It may, however, happen that someone is travelling significantly slower, or on the contrary, is breaking the rules by exceeding the speed limit. Nevertheless, the system should adjust the speed of the illumination wave to the speed of each user individually. In the case of slower driving, the subsequent luminaire will not start turning on until the vehicle appears at a specified road section. In the case of vehicles exceeding the speed limit, the subsequent luminaire will turn on before the previous one reaches full power. The fully illuminated zone will be shorter by maximum one spacing. With the vehicle's speed exceeded by 100%, the length of the illuminated section will be shorter by half spacing, however, the number of the luminaires turned on simultaneously will not be changed.

There may also appear two road users moving in the same direction, but at different speeds, which will result in overtaking. These vehicles will be covered by separate light waves as long as the interval between them is longer than the cycle in the selected mode. As they approach each other, the waves will automatically merge. The time of the elongated wave will be decreasing as the vehicles approach each other, until it reaches the standard length at the moment when the vehicles are leveled. After the overtaking, the wave will be increasing in length again, until it splits again into two separate waves ahead of each vehicle.

## 5. Implementation of the system

The authors' idea of adaptive lighting system concurrent with vehicles was implemented by the Micromex Company and is now offered as LEDMICON [30]. In its construction OLC-230DALI/MD controllers [31], placed in all LED luminaires, and a LIS-UNI, PLC LonWorks controller [32], with a built-in astronomical clock that regulates the time of turning on the lighting system at night and shutting it off in the morning, were used. The LIS-UNI, PLC LonWorks controller supervises the system operation and is located in a control cabinet. A traffic sensor was installed on each lighting post to collect information on the current position of each road user.

The system was installed in Bozeny Street in Poznan, Poland. The length of the straight road covered by the system is 1300 m. In the test section 56 luminaires were installed, with a power of 73 W each. The total lighting power installed was 4088 W. This street meets the standard lighting requirements and is sufficient for local community. The traffic on this road may be described as very low. There are a few houses located on one side of the road and a short distance from it.

During one calendar year (from 1st January to 31st December) the energy consumed by the system was monitored. Data including the energy consumption, average effective voltage, the current and the power factor of each phase of the power line were integrated in one-minute intervals and stored in the memory of an energy meter installed by the power supply company. These data were used to assess the electric energy savings by comparing the power consumption of the adaptive lighting system with a lighting system operating with a constant power, equal to the nominal power of the system, and with a lighting system operating with a 50% power reduction at late night hours, when the traffic on the road decreases completely. The time period of power reduction in the latter system compared here was adopted based on real data concerning the reduction of traffic in the middle of the night, obtained from the operation of the analyzed system. The one-minute power consumption values for every of the three phases were summed up as the whole system's one-minute demand for electricity.

To illustrate the energy consumption of the analysed lighting systems four characteristic days in a year were selected: 21st March (Fig. 2a), 22nd June (Fig. 2b), 23 September (Fig. 2c) and 22 December (Fig. 2d). The changes patterns are similar and fall under the same envelope, regardless of the season of the year. The greatest differences result mainly from the changes in the time the system was working – depending on the daily time of sunrise and sunset. Analysing the charts one may notice traffic decrease at about 9 PM and traffic increase at about 1–2 AM. It means that about 4.5 h at nights the traffic on this road is very low.

The one-minute energy consumption values were summed up for each day, giving the daily energy consumption. The com-

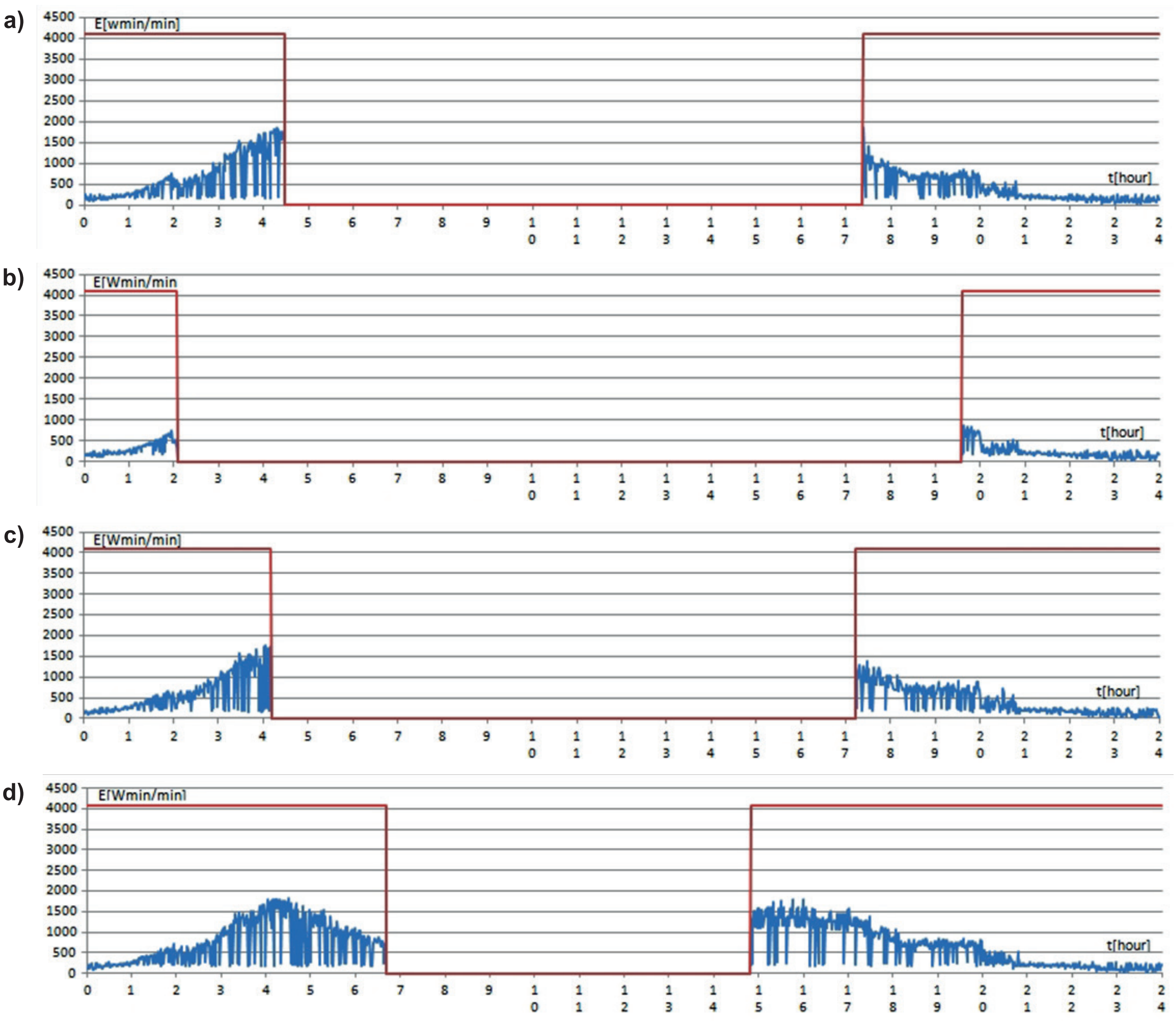


Fig. 2. Daily, one-minute energy consumption charts: a) March 21st b) June 22nd c) September 23rd d) December 22nd. The red line signifies the constant, full power mode, the blue line stands for the adaptive lighting mode

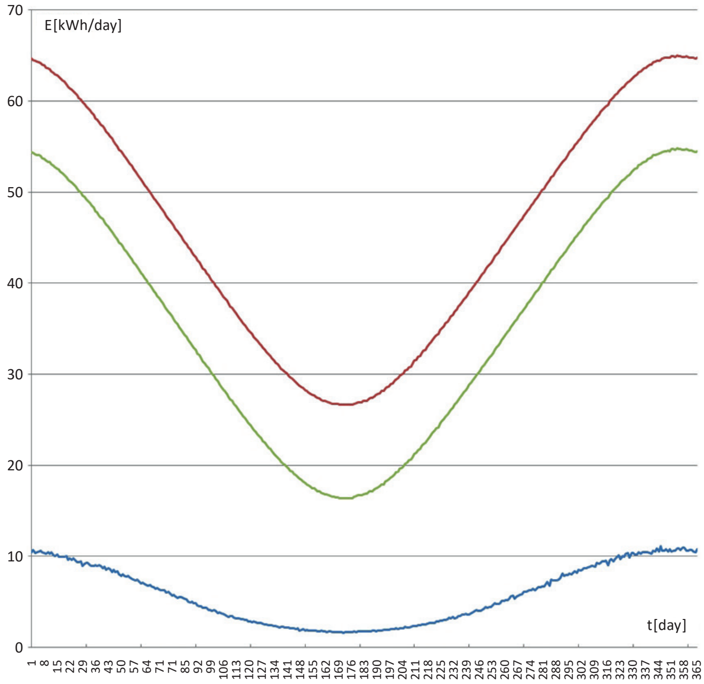


Fig. 3. The three systems annual energy consumption. The red line represents constant power; the green line signifies 50% power reduction at low traffic at night, the blue line represents the adaptive lighting system

mon diagram (Fig. 3) presents the variability of the system's daily energy consumption for three cases: the system running constantly with constant full power, according to the sunrise and sunset tables (red line), the system taking into account a 4.5-hour power reduction by 50% (green line), and the system operating according to the principles of adaptive lighting (blue line). The first and second curves were determined theoretically based on the time of switching on and off, based on the examined system's one-minute energy consumption data.

The annual energy consumption by the lighting system was calculated by summing up the whole year's daily energy consumption for each of the operation modes. An installation working with a constant nominal power would use 16 714 kWh per year. Introducing the power limits at night as described above would reduce the energy consumption to 12 974 kWh per year, which would mean a reduction by 22.4%. The lighting installation operating in the adaptive lighting mode consumes only 2 134 kWh per year. The saving compared to operating at the constant power is 87.2% and compared to operating at the lower power in the middle of the night, it is 83.6%.

## 6. Survey assessment of the system operation

A questionnaire containing 11 questions was prepared and distributed among the residents living near the analysed street to assess the perception of the adaptive lighting system. In total, 75 questionnaires were left in mailboxes or handed over to the respondents. A brief conversation with three people was conducted. Each questionnaire was accompanied by an envelope with a return address and a stamp, and an email address for electronic response. Twenty one surveys were received by regular mail and none by email. The responses represent 28% of the surveys distributed. In two cases the respondents also added their own remarks.

The survey content with responses are presented in Table 3. The residents noticed the change of lighting on the street and perceived positively the change of the colour of light from the yellow sodium to the white LED. The lighting changes resulting from the control system operation were mostly assessed positively, however, the respondents would prefer the lighting only slightly dimmed rather than turned off. In the period under consideration no dangerous situations were recorded on the analyzed street. In the remarks, one respondent noted that

Table 3
Survey results obtained from residents of Bozeny Street in Poznan, Poland

| Question | Question content / response | Responses |
|---|---|---|
| 1 | Have you noticed a change in the way of lighting the street? | |
| | Yes | 20 |
| | No | 1 |
| 2 | Is the **colour** of light from the new luminaires: | |
| | Definitely pleasant | 8 |
| | Acceptable | 10 |
| | Insignificant | 1 |
| | Unpleasant | 1 |
| | Definitely unpleasant | 1 |
| 3 | Is the length of the road section illuminated **ahead of** the vehicle: | |
| | Definitely too long | 0 |
| | Too long | 1 |
| | Sufficient | 16 |
| | Too short | 1 |
| | Definitely too short | 0 |
| | I don't have an opinion | 3 |
| 4 | Is the length of the road section illuminated **behind** the vehicle: | |
| | Definitely too long | 0 |
| | Too long | 2 |
| | Sufficient | 12 |
| | Too short | 0 |
| | Definitely too short | 0 |
| | I don't have an opinion | 7 |
| 5 | Is the **level** of lighting **around** the vehicle: | |
| | Definitely too high | 1 |
| | Too high | 0 |
| | Sufficient | 16 |
| | Too low | 1 |
| | Definitely too low | 0 |
| | I don't have an opinion | 3 |

| Question | Question content / response | Responses |
|---|---|---|
| 6 | Is the **level** of road lighting **outside** the section illuminated around the user: | |
| | Definitely too high | 1 |
| | Too high | 0 |
| | Sufficient | 16 |
| | Too low | 2 |
| | Definitely too low | 1 |
| | I don't have an opinion | 1 |
| 7 | Is the **level** of lighting **outside** the street (roadside, driveways to the gates, backyards, etc.): | |
| | Definitely too high | 1 |
| | Too high | 0 |
| | Sufficient | 15 |
| | Too low | 3 |
| | Definitely too low | 1 |
| | I don't have an opinion | 1 |
| 8 | Does the lighting control system give the **impression** that in the street it is: | |
| | Definitely safe | 4 |
| | Sufficiently safe | 4 |
| | Relatively safe | 9 |
| | Slightly dangerous | 1 |
| | Definitely dangerous | 1 |
| | I don't have an opinion | 2 |
| 9 | Is the light from the luminaires in the street perceived **inside** the house as: | |
| | Definitely insignificant | 4 |
| | Without greater significance | 6 |
| | Indifferent | 4 |
| | Perceivable | 6 |
| | Irritating | 0 |
| | I don't have an opinion | 1 |
| 10 | In your opinion, should the street lighting while **there is no-one in it** be: | |
| | Kept at a constant high level | 5 |
| | Slightly dimmed | 14 |
| | Significantly dimmed | 1 |
| | Switched off | 1 |
| | Streets shouldn't be lighted at all | 0 |
| | I don't have an opinion | 0 |
| 11 | Have you noted any **incidents** (accidents, thefts, etc.) recently (within 1 year) at the time when the lighting was modernised in the street? | |
| | Yes | 0 |
| | No | 21 |

the system did not always properly react when pedestrians were present near the street. Another respondent pointed out that the branches of trees growing in the vicinity of the street interfered with the operation of the system and limited a proper street illumination.

## 7. Conclusions

The concept of adaptive road lighting concurrent with vehicles fits into the contemporary lighting trends, enabling a reduction of energy consumption and limiting the hazardous effects of road lighting on the natural environment, while maintaining the provision of road lighting that meets the standard requirements. The paper presents the concept of the system, a theoretical analysis of the benefits resulting from reducing the level of electric power for road lighting, as well as the effects of using the system for the illumination of a real street.

From a theoretical analysis that has been carried out follows that the system is able to operate giving benefits only when certain conditions are met. It will not be efficient on any street. The choice of the system location should be preceded by thorough analyses of the daily traffic volume. The electricity savings in places where such control system is useful is significant and exceeds the 50% level substantially. In places where traffic is intense all night the system will not fulfill its task. In such cases, due to the high traffic, despite the installed motion sensors, the luminaires will still be operating at full power most of the time at night. The theoretical considerations presented above were the basis for launching test installations and assessing the system operation on the real street.

An analysis of the results of the system that has been working over a year, implemented at Bozeny Street in Poznan, reveals practical value of this solution and its high potential. In the case of the street analyzed, the reduction of electricity consumption by this lighting system, as compared to a lighting system that would use full power at night, is 87% in a year.

The study clearly indicates that the presented adaptive lighting system may significantly reduce energy consumption on roads with low and very low traffic volume at night. While planning the location for installing an adaptive lighting concurrent with vehicles, the conditions of its operation at the given site should be carefully examined. The savings will depend not only on the traffic density at night, but also on the degree of dimming, that is, the difference between the basic level of illumination and the level that should be provided when the traffic on the road decreases substantially. In the theoretical analyses presented above a full reduction of lighting was used, which means switching off the luminaires when there are no users on the road. The regulations of the new standard [25] specify that the lighting should not be completely turned off. Reducing the level of lighting from class M3 to the lowest possible level described by class M6, in the case when the traffic is very low during the whole night, may give up to 70% savings, while reducing the class from M5 to M6 may give no more than 40% savings. In the latter case the profitability of investing into the adaptive lighting may be questionable.

The use of adaptive lighting installations should be regarded not only from an economic point of view, but also from the social perspective. From the survey results it follows that the changes in the road lighting caused by the appearance of vehicles and pedestrians are visible inside the homes, however, they are not uncomfortable. It seems that the lengths of the illuminated road sections ahead of and behind the vehicle have been selected correctly.

Implementing any adaptive lighting system on the roads makes it necessary to carry out a more thorough periodic assessment of the lighting conditions on site by regular measurements. It is known that in the case of LED luminaires working all night with the nominal power, all luminaires should be replaced with new ones after the lifetime period declared by the producer of the light emitting diodes used in the luminaires. For adaptive lighting, the lifetime of the luminaires will be noticeably longer, however, it is not possible to predict how much longer. With a much extended period of operation, particular attention should be paid also to the dirt on the luminaires and the durability of other luminaire components apart from the LEDs.

Since adaptive lighting systems bring economic benefits, they are gaining acceptance from local authorities. In municipalities and cities in Poland, where the system was tested, new investments are being made. The contractors of the installations inform that new units of local government are joining the group of users and the adaptive lighting systems are being implemented on increasing scale.

**Acknowledgements.** Micromex company covered the costs of testing the effects of the adaptive road lighting system at Bozeny street in Poznan.

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