ENERGY CONSUMPTION SAVING SOLUTIONS BASED ON INTELLIGENT STREET LIGHTING CONTROL SYSTEM

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Energia electrică pentru sistemul public de iluminat constituie partea cea mai importantă a consumului de energie dintr-o localitate, iar operarea şi mentenanța sistemului de iluminat este costisitoare pentru comunitatea locală. Lucrarea studiază produsele şi elementele inovative din domeniul iluminatului stradal şi propune o soluție economică bazată pe un sistem inteligent de telemăsurare şi control ce are implementată funcția de diminuare a consumului. Rezultatele indică o considerabilă economie de energie electrică şi o creştere a duratei de viață a lămpilor.

Energy consumption in the public lighting system represents the largest part of the energy usage of a community, while the maintenance and operation of the system is a considerable expense for every city. The paper focuses on products and innovative components for street lighting, proposing a consumption reducing solution based on an intelligent system for remote measurements and control with dimming technologies for HID lamps. The results indicate that considerable energy savings are achieved and the service life of the lamps is extended.

Keywords: street lighting control, intelligent management system, dimming

1. Introduction

Public lighting systems are a major source of electricity consumption, in present 3.19% of global electricity generation is used for lighting. This amount is greater than production of all hydro or nuclear plants and equals with the production from natural gas [1].

The carbon dioxide produced to generate this electrical energy represents about 70% of global emissions from passenger cars and three times the emissions from aviation. This is the reason why reducing power consumption for street lighting brings benefits on a global scale, not only for individual cities [2].

Street lighting can be defined as the artificial illumination of streets when available natural light drops below a pre-determined level.

This public service provides a safer environment to its users, including: facilitation of traffic flow and reduction of night accidents, enhanced sense of

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personal security and promotion of business/public facilities during the night hours [3].

The majority of existing public lighting systems still uses obsolete technology - some as old as the 1960's high pressure mercury lamp systems.

By switching to modern and more efficient systems like the ones utilizing dimming technology, the energy bills can be drastically reduced and carbon emissions minimized [4].

Various solutions to control the street lighting are met in practice.

Manual control is prone to errors and leads to energy wastages and manually dimming during mid night is impracticable. Also, dynamically tracking the light level is manually impracticable.

The current trend is the introduction of automation and remote management solutions to control street lighting [5]. Remote management systems with automation technology allow control of lamps, adjustment of light levels, and lamp or components fault reports.

In addition to the energy saving advantages, the adjustment of light levels contributes to the reduction of light pollution [7].

The light levels in remote management lighting control systems can be adjusted adaptively, dynamically or intelligently. When the light levels can be adjusted in real time or according to a predefined time schedule, the lighting system is called adaptive or dynamic.

An adaptive or dynamic lighting control system can be intelligent when light levels are adjusted in real time based on predefined parameters [7] [10].

For an intelligent lighting control system the usual list of features includes:

- Reporting the faults and conditions: failed lamps, faulty power factor, etc.;
- Reporting the faults and conditions at the street cabinet level;
- Ensure switching on–off of lighting plant;
- Ensure a dimming facility and energy metering;
- Ensure other operational information, such access and traffic detection, etc.

In addition, the system must be able to withstand the expected environmental conditions, as well as being suitable for installation using normal methods of working [9].

Our study is focused on lighting products and innovations for street lighting and proposes a consumption saving solution based on an intelligent system for remote measurements and control with dimming technologies for HID lamps.

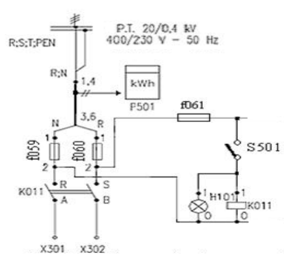
2. Street lighting –Technical status

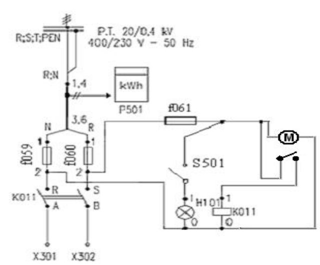
In Europe, the recommended average road surface luminance are between 0.3 – 2 cd/m^2, while in the US the range is between 0.3 – 1.2 cd/m^2 [6]. Currently, the street lighting calculations and measurements in Europe follow the European standard EN 13201-3.

In Romania, besides the big and medium size cities (Bucharest, Cluj, Timisoara) where the systems are controlled by large firms (such as LUXTEN) based on some long period contracts, the small cities relies only on local control systems with timers, street lighting switched on/off by photocell and even manually command.

At present, in roadway lighting applications, high pressure sodium (HPS) and metal halide (MH) lamps are the most widely used light sources. HPS lamps are used because of long lamp life time and high luminous efficacy and MH lamps offer high luminous efficacy, good color rendering properties and better peripheral visibility at low illumination levels [6]. LEDs are not ready for road lighting applications, since the luminous output of LEDs is not high enough.

Traditionally, street lighting is switched on/off manually. An example is presented in fig. 1a. Automatically, street lighting can be switched on/off by timers (fig. 1b) or photocells (fig. 2a). Our constructive solution with photocell is presented in fig. 2b.





a) b)

Fig.1. Street lighting switched on/off: a) manually; b) by timer

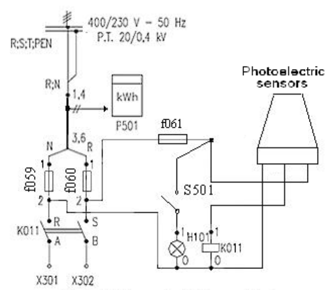


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Fig.2. Street lighting switched on/off by photocell

For energy saving reasons, intelligent street lighting control systems are increasingly used. The system architecture consists of control center, remote terminal units, light control units ballasts and lamps.

The control center (hardware and software) collects and processes information received from the lamps, makes decisions according to control parameters, and saves the processed data.

The remote terminal units collect field information from light control units and send the information to the control center, receive the commands from the control center and transmit them to light control units.

Light control units receive commands from remote terminal unit and execute the command. Also they transmit the status information of lamps to the remote terminal unit.

Although the structures of intelligent road lighting control systems are similar, the control parameters and control strategies are variable, depending on the specific case, budget and decision makers.

Time-schedule-based step dimming is a commonly used control strategy nowadays in street lighting control systems [10], [14].

The time schedule is based on the experiences and analysis of previous traffic densities. The lamp light output is controlled centrally and can be adjusted to two up to four dimming levels according to preset time schedules.

In North America, several installations of remote management street lighting control systems with time-schedule dimming were built after 2000 [9]. Remote management lighting control systems based on a time schedule have become more widely used in China since 2000 [10].

So far, there are no internationally accepted guidelines concerning dynamic changing of light levels in road lighting and the dimming strategies are made on the basis of experiences of lighting designers [11].

3. Architecture elements of intelligent lighting system

3.1. Control Center

Control Center performs the following functions:

- Monitor individual nodes and report lamp faults;
- Measure/record data;
- Control (via contactor group-switching) the on/off times of the lighting;
- Record switching times;
- Record manual interventions.

The software used is made in Visual C, C ++ or Assembly format and the configuration of areal dispatcher is set through a graphical user interface (fig. 3). The software is offered by the Company which produces the specific elements.

Fig. 3. Graphical user interface

In our experimental system a tree type network made by ten start points can be used, each of it having elements for light reducing level.

To determine street traffic presence sensors can be placed in two networks informing in this way the dispatcher about the registered traffic. Into a point of maximum importance a video camera is placed in order to store images in real time.

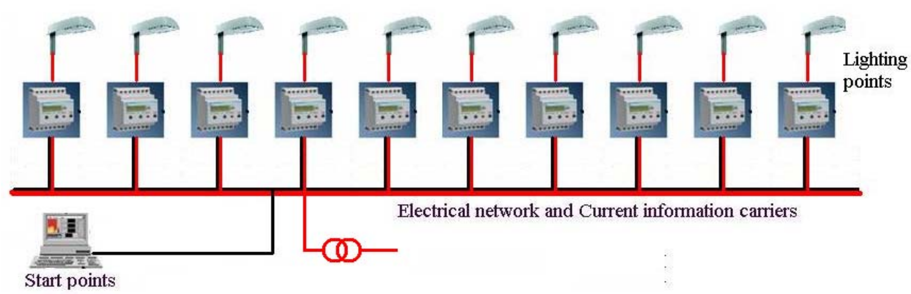
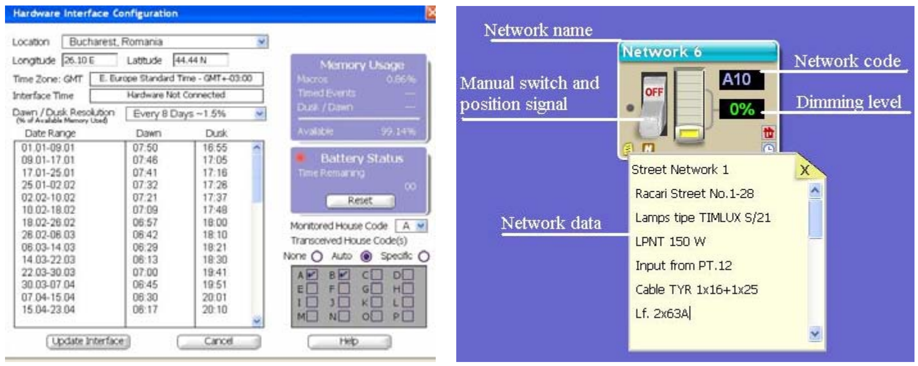


Fig.4. Block diagram

In fig. 4, is presented the block diagram for a ten system lighting points and one dispatcher for start points. With black line is indicated the information flow and with red line the energy flow, both being overlapped on the same physical network.

The ten lighting points can be made to function according to the daily program. An on/off program can be programmed, based on the astronomic clock.

For example, for a specific application, the operator introduces in the software the area longitude and latitude (in our case Bucharest), including the offset after the first meridian (fig. 5a). According to location, the hour of sunrise and sunset are automatically extracted from the hour base, and there is no need for correction (fig. 5b).



a) b)

Fig.5. General programming of the dispatcher and particularity on each light point

Each lighting point is symbolized by graphic elements that show the name and the network code, the current state of the system, the identification data and the dimming level.

Every network can be individually automated by introducing corresponding data. In the area where crime risk is bigger, the operator can choose a longer time working installation with shorter dimming periods.

More restrictions can be chosen also, depending on the hour, week day, sunrise or sunset delay and the dimming level.

For a strict control of the network, there is also the possibility to generate a report which includes the presentation elements and resulting errors.

3.2.Communications and commands

The control center utilizes a server to maintain the database of street light. Individual street light networks can communicate with the data centre via a wide number of technologies such as GPRS, GSM and Ethernet.

The experimental system utilizes GSM technologies, with 4 inputs and 8 digital outputs. The structure of the light point which is using GSM modem is represented in fig. 6.

The input and output configurations are (fig. 7):

- Input 1 – remote transmission of lighting network activation;
- Input 2 – transmission of an information regarding the lighting point deterioration;
- Input 3,4 – transmission of network information.

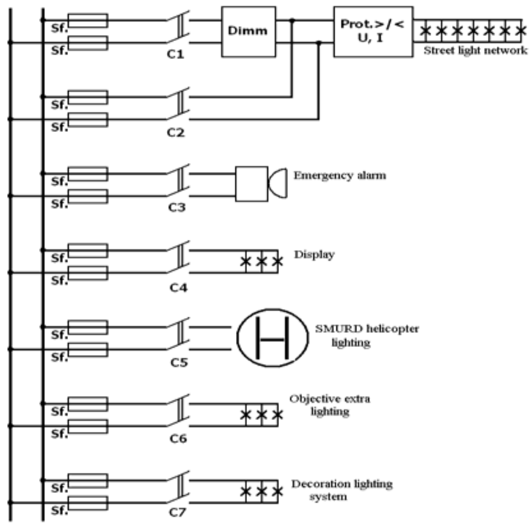


Fig.6. The structure of the light point which is using GSM modem

The output can be adapted to the following functions:

- Output 1- forced connection of lighting according to the maintenance team activity;
- Output 2- deactivation of the sensor for protection against vandalism;
- Output 3 - deactivation of protection elements for maximum voltage activation of the sensors from that point;
- Output 4 - activation of a civil protection alarm;
- Output 5 – activation of the lighting for special occasions;
- Output 6 – activation of the special installation for seasons timer (winter);
- Output 7 – activation of a lighting signal for warning on dangers;
- Output 8 - the lighting mark of a helicopter landing for intervention.

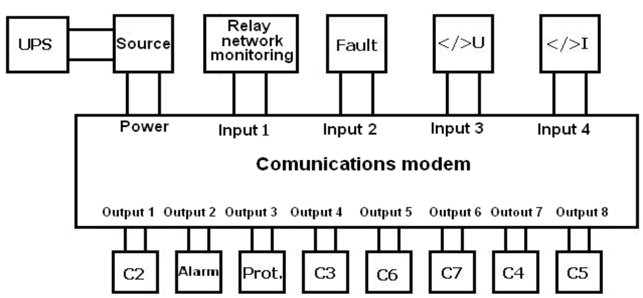


Fig 7. The input and output configuration

4. Experimental system and measurement results

To monitor the network parameters (maximal or minimal values) a network analyzer type MF-7 (made by Schrack) can be used which can provide a digital, settable signal, taken by the communication modem and transmitted to the dispatcher.

To monitor the traffic, photoelectrical sensors can be used, which by electronically counting systems (for example SLB-94 counting system by Simex) give information about exceeding the threshold set.

The experimental system contains three light sources with 250 W high pressure sodium lamps, connected by various automation equipments (fig.8).

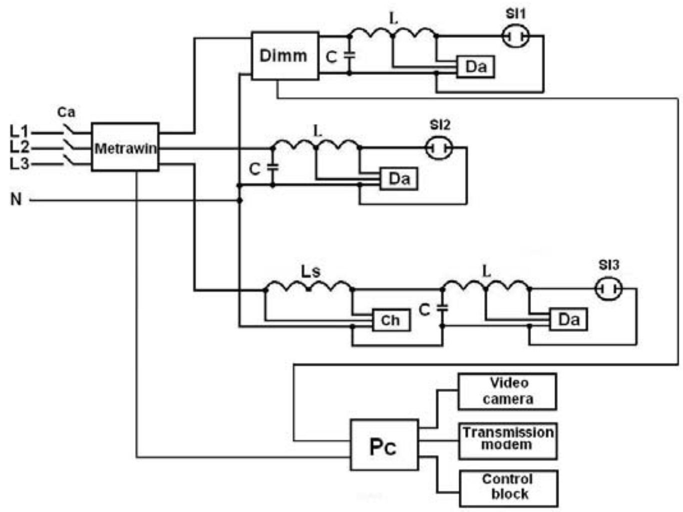


Fig.8. The experimental system scheme

The first light source is controlled by a dimming device, formed from static circuit elements, the second is connected by a twilight sensor, and the last source is equipped with a device which reduces the light intensity through extra ballast (which is by-passed according to the implemented curve).

The evolution of network parameters is monitor by a digital energy meter.

The transmission medium is Internet or GSM and the process computer has all the programs used in this application installed.

In the first phase the monitored parameters are determined, from which: the active power, reactive power, harmonics and the network frequency.

The colors blue, red and green indicate the active power to the light source ordered with dimming directly and with the device that reduce the extra ballast consumption; the colors pink, yellow and white blue indicate the reactive power and the colors brown, grey and violet – the harmonics and the dark green color indicates the network frequency.

In Fig. 9 you can see the tabular results (fig. 9a) and the variation graphics of the active and reactive power (fig. 9 b) between the hours 22 and 24.

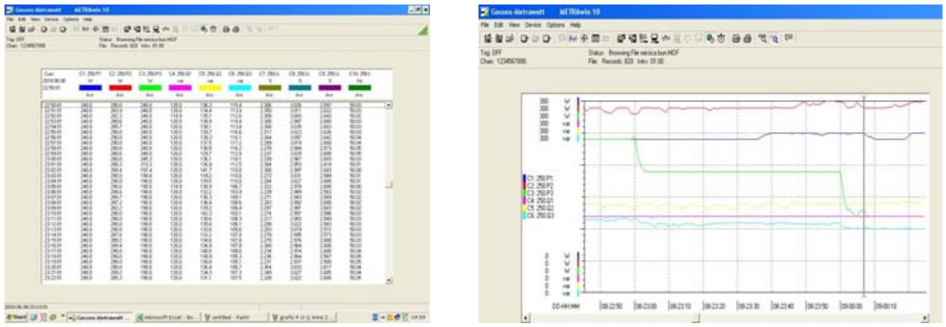


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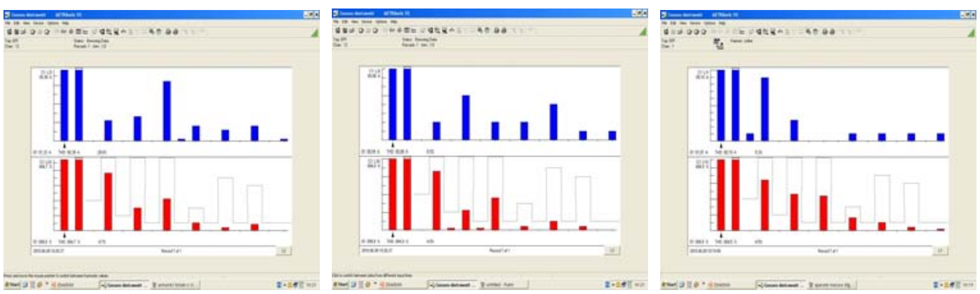
Fig. 9. Monitoring results- graphics and tabular

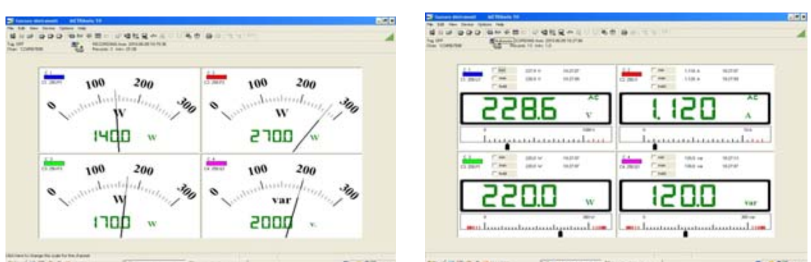
Fig. 10 shows the total harmonics of the voltage and the current intensity in the 3 phases network.



a) b) c)

Fig.10. The harmonics analysis in the 3 phases network

The monitoring system allows the visualization of the chosen parameters in analogic (fig. 11 a) and digital (fig. 11 b) modules.



a) b)

Fig.11. Analogical and digital display of the results

The video monitoring takes place in real time, the quality being determined by the camera parameters (fig. 12).

Video monitoring is extremely useful to visualize in real time the different points of the installation. The operator from the lighting dispatcher, usually in the local municipality, can also monitor the points that are possible generators of unwanted events.

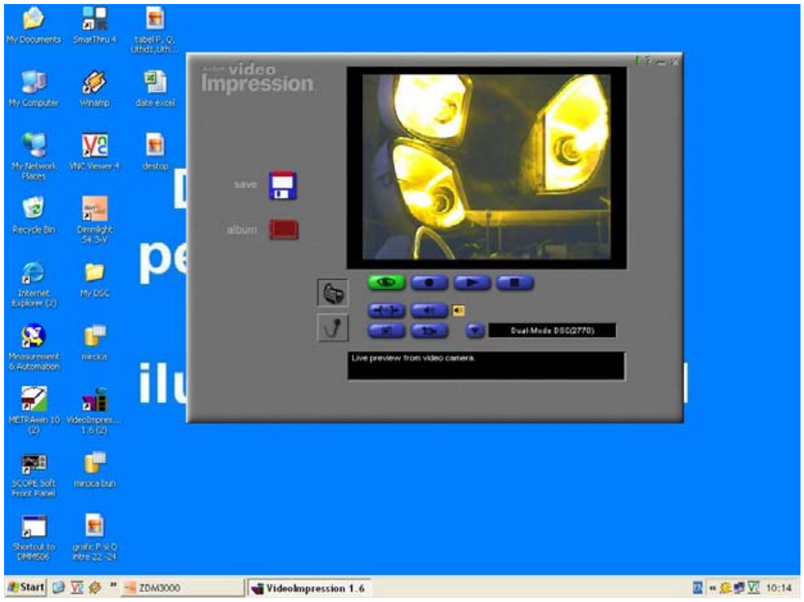


Fig.12. Online monitoring

The experimental system offers a broad view on the performance of the light control systems. The stored parameters are given in Table 1.

Table 1

Experimental parameters

t	**P1**	**P2**	**P3**	**Q1**	**Q2**	**Q3**	**U1 THD**	**U2 THD**	**U3 THD**
	w	w	w	var	var	var	%	%	%
20:58	32.7	52.7	40.8	105.1	217.3	40.3	2.30	3.05	2.54
20:59	82.5	141.9	130	260	525.8	107.5	2.30	3.11	2.51
20:58	32.7	52.7	40.8	105.1	217.3	40.3	2.30	3.05	2.54
……..	…….	…….	…….	…….	…….	…….	…….	…….	…….
5:53	302.8	301.9	240	93.06	135.6	118.1	1.99	2.50	2.06
5:57	300.8	300.6	240	86.67	143.6	119.7	2.05	2.40	2.07
	2512.19	**2677.47**	**1473.78**	**942.85**	**1282.23**	**954.96**			

The next graphics presents the differences between the three systems measured in the experiment. P3/Q3 (blue) represents the conditioning dimming system, P2/Q2 (yellow) the conventional system (lamp directly connected) and P1/ Q1 the system with extra ballast (fig. 13 a, b).

Compared with the traditional system, the experimental system with dimming has an economy of 60.50% and the system with extra ballast an economy of 32.27%.

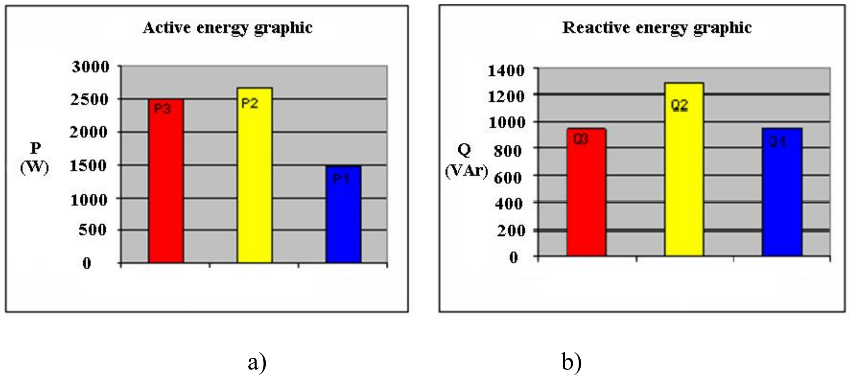


Fig.13. Consumption results: a) active energy; b) reactive energy

The graphic of current intensity variation (blue) and of the active power (yellow), depending on the way the dimming equipment works (0%, 20%, 40%, 67%) are presented in Fig. 14.

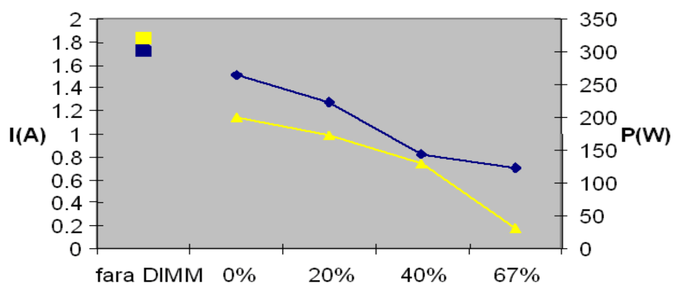


Fig.14. The variation of current intensity and of the active power

Comparing the results, it is obvious that the light source given by the dimming equipment is the most efficient.

5. Conclusions

This intelligent lighting system control is intended for small towns but may be extended with additional modules for applications in large cities.

Experimental results gave some quantitative information and optimization solutions regarding the consumptions, allowing choosing the most economical way.

Telemanagement integration in street lighting networks of small cities has been very hardly developed both in conceptual and applicative way, especially due to limited economical resources of local communities which became responsible of too many new tasks, public illumination being one of them.

REFERENCES

[1]. *M. Richards, D. Carter,* Good lighting with less energy**,** Lighting Research and Technology*,* 2009, 41: 285

[2]. *D. L. Loe*, Energy efficiency in lighting**-**considerations and possibilities**,** Lighting Research and Technology, 2009, 41: 209

[3]. *PR Boyce, S Fotios, M Richards,* Road lighting and energy saving**,** Lighting Research and Technology*,* 2009, 41: 245

[4]. *Tetri, E., Halonen L.,* Future trends of energy efficient lighting, Proceedings, 26th Session of the CIE, Beijing, China, 4-11 July 2007, pp. 45-48

[5]. *Jitka Mohelnikova*, Electric Energy Savings and Light Guides, Energy& Environment (EE'08), Proceedings, 3rd IASME/WSEAS International Conference on, Cambridge, UK, February 23-25, 2008, pp.470-474

[6]. *M.S. Rea, J.D. Bullough ,Y. Akashi,* Several views of metal halide and high-pressure sodium lighting for outdoor applications**,** Lighting Research and Technology, 2009, 41: 297

[7]. *Iacob A., Alexandrescu R. M., Salceanu C., Ionescu I., Racovitan I.,* Requirements and conditions for power demand and quality parameters system deployment for public lighting in Romania, Journal of Sustainable Energy, **Vol. 1**, no. 1, March, 2010

[8]. *V. Dogaru, H. Andrei, C. Cepisca, E. Dogaru, M. Popa, T. Ivanovici,* Uncentralized systems of electric and thermal energy product using nonconventional sources*,* ISEE 2002, Proceedings, International Symposium on Electrical Engineering, June 2002, Targovişte, pp.225-231

[9]. *L. Guo, M. Eloholma, L. Halonen,* Luminance monitoring and optimization of luminance metering in intelligent road lighting control systems, Lighting Engineering, **Vol. 9**, 2007, pp. 2440

[10]. *I.L. Guo, M. Eloholma, L. Halonen,* Lighting control strategies for road lighting control systems, Journal of the Illuminating Engineering Society of North America (LEUKOS) [Online]*,* **Vol. 4,** no. 3, 2008

[11]. *E.C. Guest, M.H. Girach, S.A. Mucklejohn, U. Rast,* Effects of dimming 150 W ceramic metal halide lamps on efficacy, reliability and lifetime, Lighting Research and Technology, 2008, 40: 333

[12]. *F. Argatu, C. Cepisca,* Modeling dynamic high intensity discharge lamp characteristics, U.P.B. Sci.Bull., Series C, **Vol.72**, Iss.3, 2009

[13]. *C. Cepisca, H. Andrei, S.D. Grigorescu,* Modern solutions for reducing the lighting consumption, Proceedings, 6th International Symposium ATEE, nov. 2008, Bucharest, pp.86-91

[14]. *O. Grigore, Inge Gavat, Corina Grigore, M. Cotescu*, An Adaptive Lighting System Using the Simulated Annealing Algorithm, Simulation, Modelling and Optimization, Proceedings, 8th WSEAS International Conference on, Santander, Cantabria, Spain, Sept., 2008, pp.142-147

[15]. *** *Dimm Light,* ISLE and KD Electroniksysteme GmbH, 2008.