City Outdoor Lighting System Control. Problems and Prospects

Andrei Bachurin
Perm National Research Polytechnic University – Electrotechnical Department
Komsomolsky Ave, 29, 614990, Perm, Russia
E-mail: bachurin@ellips.ru

***Abstract*—This review describes current problems, trends and prospects of the quasi-automatic light control system. The lighting systems of million cities.**

***Keywords*: control system, lighting system, management problems, prospects for control systems, control in lighting trends.**

I. Object of Study

a. Cities

The objects of study are the largest cities in Russia: Ekaterinburg, Kazan, Perm. These cities are administrative, industrial and cultural centers of large areas and they have developed network of outdoor lighting (Table 1).

TABLE I
MAIN CHARACTERISTICS OF CITIES

City	Square, sq.km.	Official number of residents	Official number of light points
Perm	800	1026000	29000
Ekaterinburg	468	1428000	41000
Kazan	614	1206000	65000

Cities are characterized by a large area, considerable extent in latitude and large difference in weather conditions at one and the same time (Fig. 1).

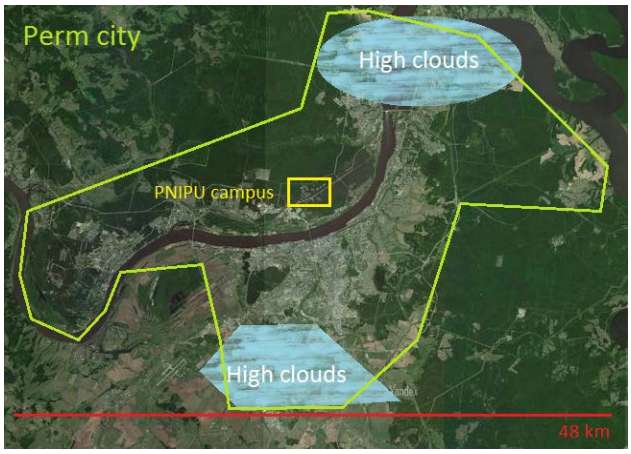

Fig. 1. Perm city from satellite photo.

Lighting systems of these cities are characterized by the presence of all types of lamps (Fig. 5), different types of lighting control systems, illuminated objects of all possible types (Table 2) and modes (Table 3) of illumination, a single lighting control center, a small number of service personnel, high demands on energy-efficient lighting.

b. Classification of illuminated objects

Street lighting can be divided by illuminated objects into 3 main categories and some subcategories (Table 2), each of them can be characterized by the following common features:

- Illumination is regulated by standards (STD);
- Illumination of the object is normalized (NORM);
- Illumination of the object can be changed depending on external conditions (VAR NORM);
- There is a standardized schedule of the object illumination (SHED);
- Schedule of the object illumination can be changed depending on external conditions (VAR SHED).

TABLE II
CATEGORIES AND OBJECTS

Category	Object	STD	NORM	VAR NORM	SHED	VAR SHED
Street lighting	Highways	*	*	*	*	*
	Streets	*	*	*	*	*
	Car parking	-	-	*	*	*
	Tunnels	*	*	-	*	-
	Road signs	-	-	-	-	*
	Road markings	-	-	-	-	*
	Pedestrian crossings	*	*	-	-	*
	Crossroads	*	*	-	-	*
Pedestrian lighting	Pedestrian areas	*	*	*	*	*
	Yards	*	*	*	*	*
	Pedestrian paths	*	*	*	*	*
	Athletic facilities	*	*	-	-	*
Decorative lighting	Parks and gardens	-	-	*	*	*
	Architectural lighting	-	-	*	*	*
	Outdoor advertising	-	-	*	*	*
	House numbers	-	-	*	*	*

It should be noted that the existing standards for most objects are very flexible and lack of base building nouns and other standards concerning lighting of there is a certain objects [5][6].

Lamps of different categories are located near each other and have to work synchronously. Ideally, the lamps must insure each other in case of failure.

The approximate ratio of the objects in city lighting categories is shown on Figure 2.

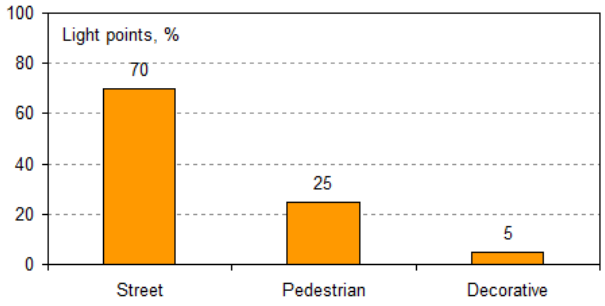

Fig. 2. The ratio of the urban lighting categories.

Objects (categories) can be grouped by lighting modes (Table 3) [5][6].

TABLE III
TYPICAL LIGHTING MODES OF OBJECTS

Objects	Lighting mode
Highways, Streets, Pedestrian areas	The lights are switched on and off according to the schedule with adjustment for the current value of illumination, at night by low traffic density, the luminous flux can be reduced by 30% while decreasing traffic to 33% and by 50% while decreasing traffic to 20%. Depending on the object, there are different rates of light and illumination should not be reduced at least 4 lux.
Road markings, Pedestrian crossings, Crossroads	Lighting should switch on and off simultaneously with the appropriate lighting of streets, but the change of the luminous flux at night is not allowed.
Tunnels, Road signs	Lighting should work around the clock without changing the luminous flux.
Pedestrian paths, Car parking	Lighting should switch on selectively (some light points), if it is necessary, according to presence and light sensors data.
Parks and gardens, Yards	Lighting should switch on and off simultaneously with the street lighting, at night the luminous flux should be reduced to a minimum, but the switching on of some light points at full power is allowed on the basis of presence, sensor data.
Architectural lighting, Advertising, House numbers	Lighting should switch on and off together with street lighting and work without changing the luminous flux.

Let's consider the classification of illumination objects by the example of PNIPU campus (Fig. 3):

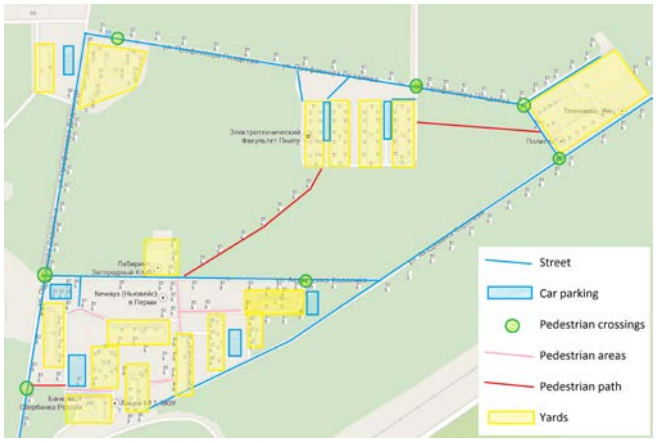

Fig. 3. Outdoor lighting of PNIPU campus.

We can see that control object is very diverse and complicated. Its automatic control system (ACS) must have more than one level of control and some not-trivial algorithms of control for effective energy usage [2].

As shown on fig. 4, energy consumption by city lighting systems makes up 25% from all city energy consumption.

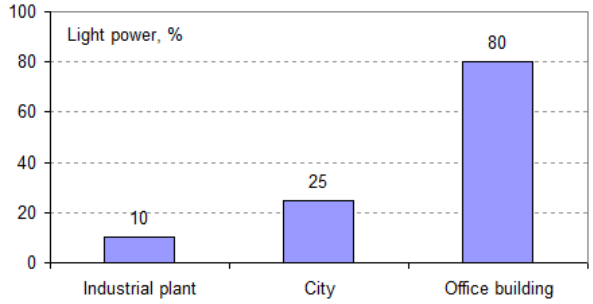

Fig. 4. Lighting share in energy consumption of object.

c. Historical, current and forecast data on the main indicators

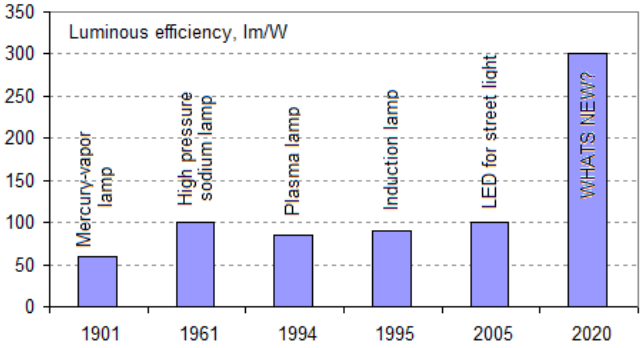

Fig. 5. Types of lamps used in outdoor lighting.

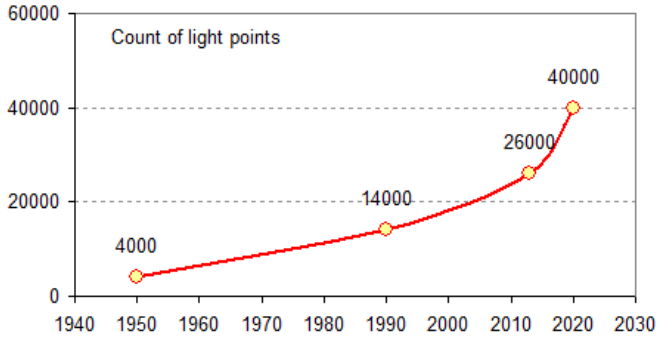

Fig. 6. Count of light points in different years in Perm city.

Number of light points used in outdoor lighting of the city increases with growth rate. The reasons for this - increase of light sources light output, growth of city territory, growth of illuminated city area, growing need for different types of lighting.

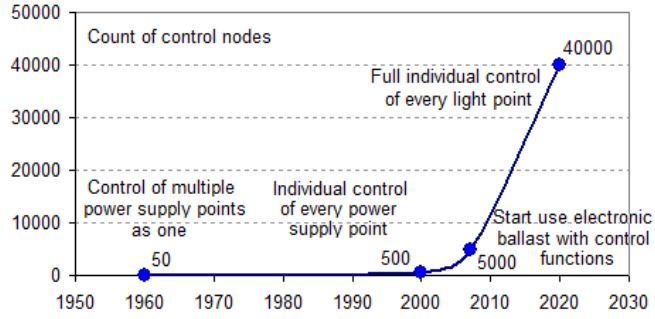

Fig. 7. Growing number of control nodes in the lighting system.

The number of levels in the ACS and the number of managed nodes grow exponentially, it is connected with the need for management and energy efficiency.

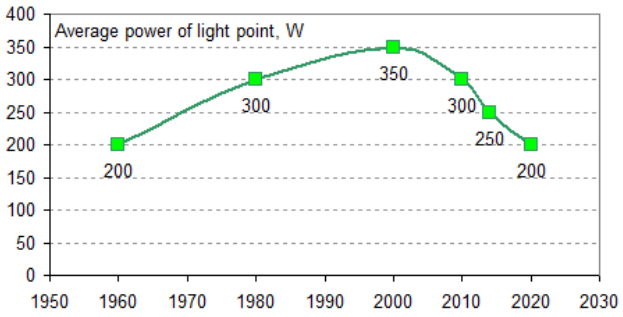

Fig. 8. Average power of light point by years.

Today and in the future the average power of one light point will decrease, thanks to the introduction of modern types of lamps with high luminous efficiency (HPS, LED, plasma, induction) and further improvement of the light sources [1].

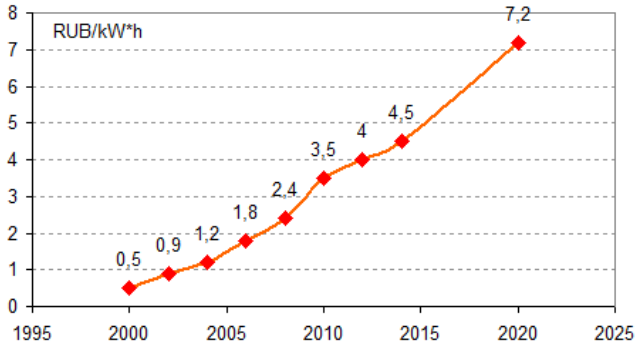

Fig. 9. Cost of electricity in Moscow by years.

The cost of electricity in Russia is growing steadily and this trend will continue in the near term.

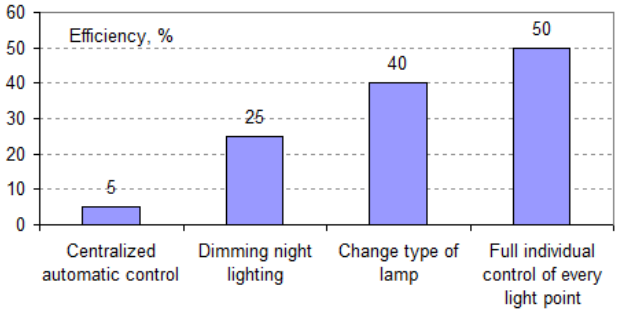

Fig. 10. Measures to improve lighting energy efficiency.

At the moment, not all MVL lamps are replaced by HPS or LED and a very small number of lamps equipped with electronic ballast. There is practically no individual control of light points.

As we can see and calculate from fig. 10, in the near future the efficiency of lighting can be increased up to 30-80% from current level.

II. Current Trends of Lighting Control Systems

a. Current state and trends of lighting control.

The use of light points with individual control is the basis for the construction of "smart" outdoor lighting system, when the operation mode of each light point changes depending on the outdoor light, traffic density or pedestrians and others.

In the area of light points is the trend in the implementation of individual lighting control systems (electronic ballasts), which have their own controller, provide the switching on / off actions of illumination and control the level of lighting. Entry level electronic ballasts can change level of lighting by two steps: full level (100%) and low level (50% or 70% or other predefined value), changing initiated by internal timer. Middle level electronic ballasts can change level of lighting by three steps by analogy. Osram named this algorithm – AstroDIM (Fig. 11) [8].

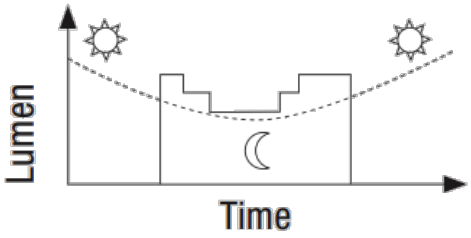

Fig. 11. AstroDIM algorithm by Osram [8].

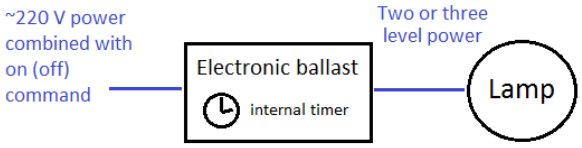

Fig. 12. Middle level electronic ballast connections.

Advanced level electronic ballasts can change level of lighting variously (Fig. 13) and equipped with network interfaces (RS485, DALI, 0-10V, etc.), allowing to integrate them in the local control system and gradually increasing their share, also their can connect some sensors (Illumination, presence).

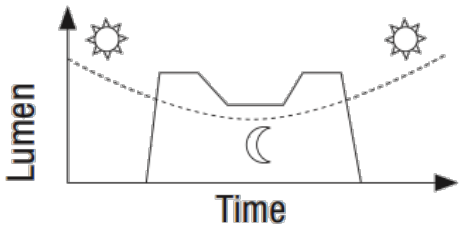

Fig. 13. Variously changing level of lighting [8].

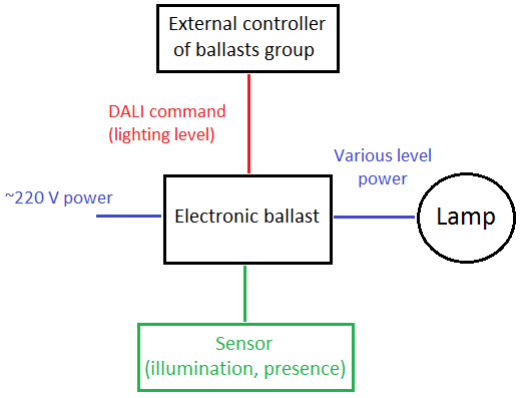

Fig. 14. Advanced level electronic ballast connections.

As we can see on Fig. 10, entry level ballasts (Fig. 12) can save only 25% of electric energy, but use of advanced level ballasts (Fig. 14) allow to save up to 50% of energy. Also we can see that entry level ballasts work autonomous and need only ~220V connection, but advanced level ballasts must have advanced connection to control network (for synchronous group work).

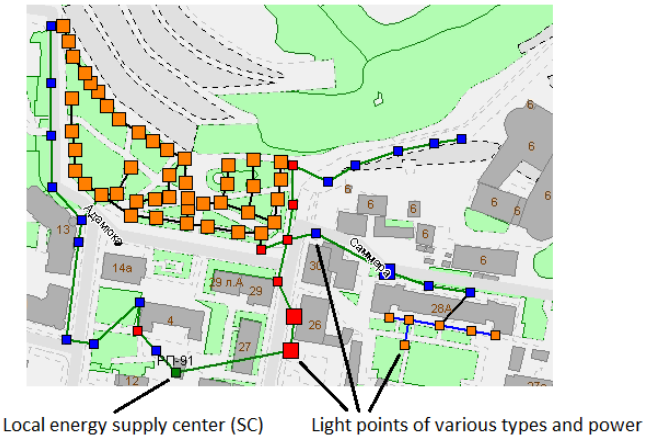

Fig. 15. Sample part of real lighting net from Kazan city.

b. Current trends of data transfer in lightning systems.

Today lighting system consists of some local energy supply centers (SC) and groups of light points which are connected to SC via power cable (Fig. 15).

External controller of ballasts group typically placed in supply center and we must connect all light points from this SC to controller via control network. Several variants are possible (Fig. 16, 17, 18) [1]-[4][7][8].

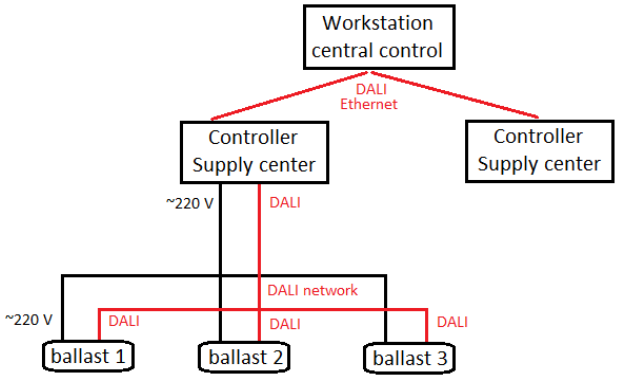

Fig. 16. Electronic ballast connections via DALI-network [8].

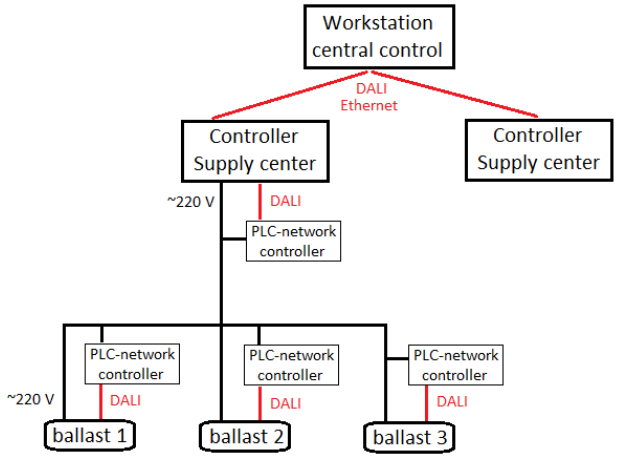

Fig. 17. Electronic ballast connections via PLC-network.

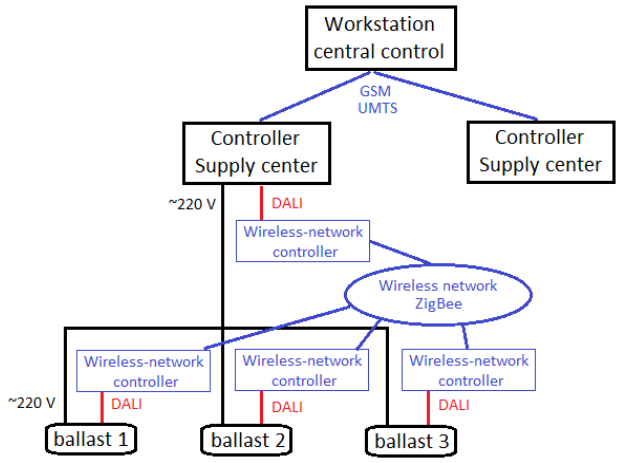

Fig. 18. Electronic ballast connections via ZigBee-network [4].

The surroundings, the methods and data transfer protocols evolve. Over long distances (supply center – central control) die slow and expensive ones - modem connection over a telephone pair, radio, SMS, Ethernet. And rapidly gain popularity those that become cheaper and expand geographically - GSM, UMTS. At close distances (light point – supply center) wire ones - PLC, DALI, RS485 are superseded by cheaper wireless ZigBee and WiFi.

In the field of wireless communication we can see a rapid growth of the so-called M2M devices (smart sensors that are connected to the Internet)/ That's due to the reduced cost of electronic components providing connection to networks (WiFi, GSM, UMTS, ZigBee), increasing network coverage and range of devices, reduction of tariffs for connection to the grid.

In the future these trends will intensify and that will lead to a serious displacement other data channels by cellular networks and it will be possible to connect to the Internet practically "each pen".

Also it is likely that advanced electronic ballast will be separated into more simple electronic ballast and controller light point [7]. Simple ballast will be more unified and cost effective. Controller light point will take following functions: sensor connection, link with central control workstation, link with other near light points, control of electronic ballast via simple unified interface (0-10V) by typical algorithms (Fig. 19).

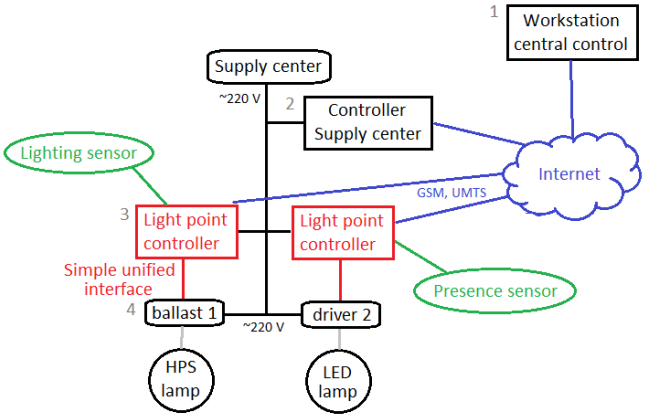

Fig. 19. Structure of future lighting control system.

c. Current corporate trends.

In the area of corporate management continues unabated trend towards outsourcing usage. It is gradual applies to the production functions, including power supply, telecommunication services and data transmission.

We can suppose that in the field of lighting will increase the number of energy service contracts, increase the number of light points of light transmitted to the specialized service organizations. Energy service organization will be integrated and their number will be reduced and the load for a specific electrician will increase.

Giants of lighting industry (General Electric, Philips, Osram) for several years develop and implement projects of "smart" light systems for the city [8]-[10]. But the cost of such systems is rather great for mass distribution, and also the used technology (Fig. 12-18), design technology and equipment setup technology – are already out of date today. All that do not allow you to create quickly and inexpensively large lighting systems, that are simple and inexpensive to operation.

III. Current Problems

Here is the list of problems facing the large systems of outdoor lighting:

- A large number of light points and its constant growth;
- A large area where light points are placed;
- A wide variety of illuminated objects types, and as a consequence - wide variety of local lighting systems control modes;
- Low level of lamp types unification (MVL, HPS, LED), and as a consequence - low level of unification of electronic ballasts types and "drivers" (various ballasts and LED-drivers);
- The lack of widespread low cost universal interface for controlling electronic ballasts and "drivers" (the predominance of proprietary technologies in control systems);
- Low distribution of tools for the diagnosis of lighting lines and light points;
- Low level of management culture and operation of lighting networks, which dictate the need for a complex but unified control algorithms for typical lighting objects;
- Almost complete absence of individual control of light points which can give up to 50% additional energy savings.

IV. Projected Solutions

Try to imagine a system of outdoor lighting in the future.

Maintenance and management of the most city' outdoor lighting installations will be administered by a one service organization.

All lighting systems will be combined into a single network management using public, common, reliable communication channels provided by the operators.

All light points and power supply centers will be energized and on-line connected all the time.

Each light point will have its own individual fully functional control system that can operate completely autonomously and interact with neighboring light points, the controller of power supply center and general control center [9][10].

Future innovate changes in the lighting control system:

- From electronic ballast will be picked up functions of light point control (working with sensors, network protocol support, link with central control workstation, link with other near light points, control of light point via simple unified interface by typical algorithms) and they will be given to light point controller;
- Electronic ballast control will be organized according to a simple low-cost and reliable unified interface;
- From SC controller will be picked up functions of light points group control (switch on/off, light level adjusting), because individual control functions will be given to light point controller and functions of group control will be given to central control workstation;
- All light points all the time will be energized and on-line connected to central control workstation (not uncontrol, not undefined status of light points);
- The light points controller will have all the features which are necessary for high-grade lighting control in stand-alone mode (parameter monitoring mains and control object, light control point on the schedule, external commands, depending on the values of external sensors, and the state of the neighboring light points using standard algorithms);
- The use of standardized common communication channels;
- The use of standardized common control algorithms for typical lighting objects;
- Group work of light points (the ability to combine any point of light in any group) using communication via a higher level;
- Implementation of possible function of a single light point by an individual algorithm (one of the types, but with individual settings).

To realize all these innovations its required the creation of a new control system on the upper level, that is based on new principles of light points individual control. It is our future work.

ACKNOWLEDGMENT

I want to thank my colleague Alexei A. Shiharbeev for his support in the work. Without him the topic of this article did not take place.

REFERENCES

[1] "Handbook of Illumination", Edited by J. B. Eisenberg. - M: Energoatomizdat, 1995. (rus)
[2] Feasibility efficient installation automatic control unit outdoor lighting, Karelin A.N., Industrial ACS and controllers, 2008, № 1, pp 62-66.
[3] Decentralized wireless control system outdoor lighting, Obraztsov S.A., Panfilov D.I., Light & engineering, 2012, № 1, pp 32-36.
[4] DE102010049121 (A1) "Method for lighting e.g. road, involves switching on the lamp on detection of movement of person, and sending message to neighboring lamps through communication unit"
[5] GOST R 54305-2011 "Roads public road. Horizontal illuminance from the artificial lighting".
[6] SP 52.13330.2011 "Natural and artificial lighting - Code of Practice. The updated edition of SNIP 23-05-95"
[7] Teliko Intelligent street lighting. [Online]. Available: http://www.teliko.com
[8] Osram products. [Online]. Available: http://www.osram.com
[9] GE's LightGrid Big Data System. [Online]. Available: http://www.scientificcomputing.com/news/2013/04/lights-data-action-ge's-lightgrid-big-data-system-cut-la's-electricity-bill
[10] Philips IntelligentCity. [Online]. Available: http://www.lighting.philips.com/main/systems/public/intelligentcity.html