The control system of energy efficiency of the LED lighting

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***Abstract* – The article considers the modern state energy consumption in Kazakhstan and Russia, an analysis of the prospects for the introduction of energy efficiency LED lighting technology. The paper presents LED lighting control system based on programmable counters and an information system for monitoring energy consumption. Designed LED lighting system has been introduced in the educational building of the University. A comparative analysis of the two lighting technology - LED lighting and compact fluorescent lamps.**

I. INTRODUCTION

The problem of rational use of energy the conditions of limited resources and the growth of consumption is one of the most important for the world community, and its decision to become a strategic priority for many countries. Prolonged global economic crisis, increase in prices of natural energy resources, environmental issues, emissions reduction of harmful substances and greenhouse gases into the atmosphere dictate the need to address energy conservation and efficiency.

Energy costs are rising in proportion to the needs of the world's population and is predicted doubling of electricity demand by 2025 [1]. The introduction of modern technologies ensuring efficient use of energy resources will avoid the electricity deficit.

Lighting is among the directions with great potential for energy savings. On lighting consumed 110 billion kW/h in Russia and almost 10 billion kW/h in Kazakhstan annually. The total potential for reducing energy consumption is estimated at 40% for Russia and 30% for Kazakhstan [2, 3]. In this regard, one of the priorities to reduce energy consumption is to reduce energy consumption for lighting.

Modern LED lighting systems allow for energy savings in relation to the lighting systems that use halogen and fluorescent lamps.

II. CURRENT STATUS AND ANALYSIS OF ENERGY CONSUMPTION OF KAZAKHSTAN

Efficient energy consumption provides 40% of the contribution to the reduction of fossil fuel consumption, which is equivalent to 106 billion euro savings per year on a global scale. From an environmental point of view this corresponds to a reduction of carbon dioxide emissions by 555 million tons per year, an annual saving of 2 terawatts of electricity, saving 1.5 billion barrels of oil [4]. The energy consumption for lighting is responsible for 6-8% of greenhouse gas emissions [5].

According to the International Energy Agency (IEA), 20% of global electricity production is consumed on the network electric lighting. Consumption of total energy produced in the World by sector is shown in Fig. 1.

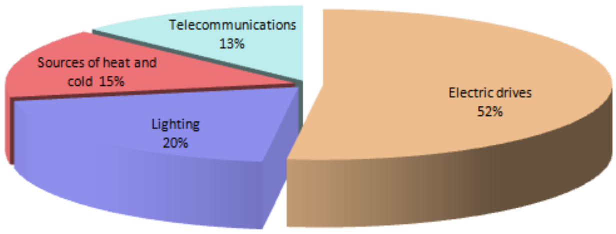

Figure 1. Consumption of electricity generated in the world [6]

Artificial lighting is 12-14% of total energy consumption for Kazakhstan [7]. This indicator is an average of 13-15% for Russia [8].

Energy consumption data by economic sectors Kazakhstan indicate that a major consumer of electricity is industry to 70%. Industrial facilities spend on illumination of 10% of the total electricity consumption. Second place for the consumption of electric energy takes the housing and communal services - 12.5%. An average statistical electricity consumption branch of the economy is shown in Fig. 2.

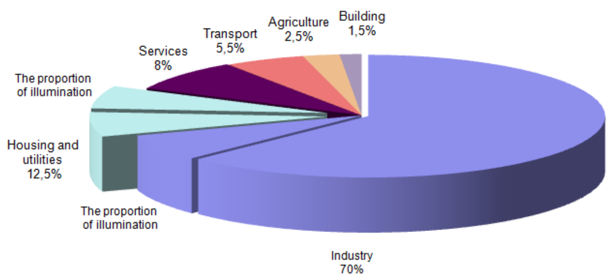

Figure 2. Average statistical electricity consumption branches of the economy in Kazakhstan [9]

The proportion of electricity consumption by lighting in public and residential buildings is 40% -60%, which is 2-3 times higher than in Europe [10].

Analysis carried out by the IEA of economic development and energy efficiency of existing trends in the world allowed to predict the increase in demand for artificial lighting by 60% over the next 20 years. Without improvement of technology and the implementation of energy efficiency policies such rates of increase of electricity production will lead to an increase in energy consumption, most of which are non-renewable and environmental degradation associated with the increase in hydrocarbon fuel emissions.

Thus the task of improving the efficiency of lighting becomes relevant. In general, this will positively affect the country's energy balance and global climate processes (reduction of greenhouse gas emissions)

Introduction of modern energy-saving technologies is possible only through the establishment of new standards for artificial lighting therefore many countries have a systematic policy to develop such standards. For example, in the United States entered into force on regulatory act, which establishes a complete rejection of inefficient light sources with 2014, in this case the costs will be reduced by more than 20 billion dollars. The European Union banned the sale of incandescent light bulbs 100W in September 2009, and all the light bulbs in 2012.

Not only North America and the EU declared the adoption of measures aimed at energy conservation and promoting the use of energy-saving light sources. New legislation in the field of energy efficiency, including the phasing out of incandescent lamps operates in Australia, New Zealand, Russia, Japan, South Korea, Brazil, Argentina and other countries.

Kazakhstan is also moving in this direction. However, it may be noted that the replacement of a very small amount undergoes light points in different segments and lamps only, but not the full lighting system. However, a complete replacement of obsolete lighting in homes, offices, shopping squares and streets can lead to 57-80% energy savings with a return on investment in the period from 2 to 5 years [1].

46 countries, including Kazakhstan and Russia, approved the program stimulating energy savings, as well as the transition to energy-efficient lighting technology. Implementation of the lighting market transformation program allowed to change structure of consumption lamps in favor of energy efficient luminaries in Kazakhstan.

Substantial savings of lighting can be achieved through the use of new semiconductor light sources. The main element of the semiconductor lighting is light-emitting diode (LED). LEDs have high technical and economic parameters (high luminous efficiency, long lifetime, high reliability, easy maintenance, economic efficiency), have a wide range of colors, configurations and capacities.

Solid-state lighting has advantages under application conditions: environmentally friendly, a higher mechanical strength and vibration resistance, in the emitted light is not harmful ultraviolet radiation and stroboscopic effect, inertia with lamps turned on and working at a lower temperature. Of special note is the ability controlling the luminous flux of the LED of a wide frequency band. It is because of these qualities, the LED semiconductor lighting is one of the promising directions of development of lighting.

Segment LED lamps will grow from 170 thousand pieces in 2013 to 10 million pieces in 2018, and in monetary terms from 2.2 million in 2013 to 42 million USD in 2018 (Fig. 3). The growth market of lamps in 2016 will be due to increased consumption of the LED lamps in the professional segment, especially in offices, retail outlets, hotel and restaurant businesses.

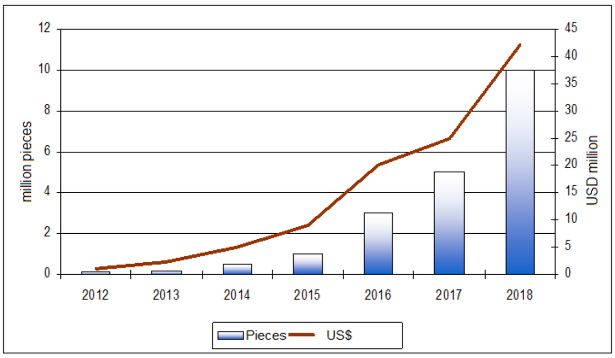

Figure 3. The forecast of LED lamps in Kazakhstan [11]

This increase is explained by a decrease in production costs, and, as a consequence, the price of LED lamps to a level where the total cost of ownership of this type of lamp is more attractive than the total cost of ownership of other types of energy-efficient lamps. The retail price of this type of lamps will be $ 6.57 in 2016 and $ 4.20 per share in 2018 (Fig. 4).

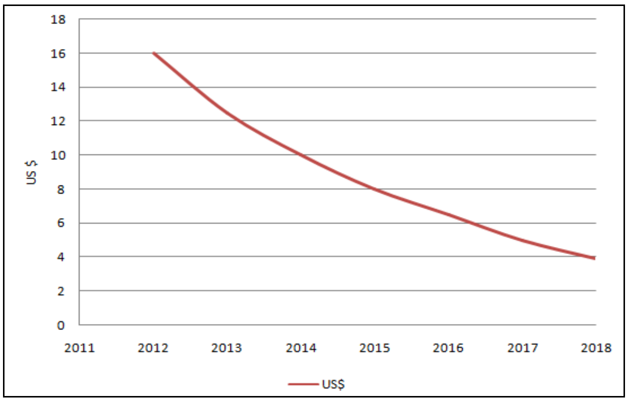

Figure 4. The forecast cost of LED lamps in Kazakhstan [11]

The ban on the production and sale of incandescent lamps 25 W and above will result in a massive shift to the first use of compact fluorescent light bulbs, and then the LED lamps. The total energy savings for the period from 2013 to 2018 will 3011 MW (Fig. 5).

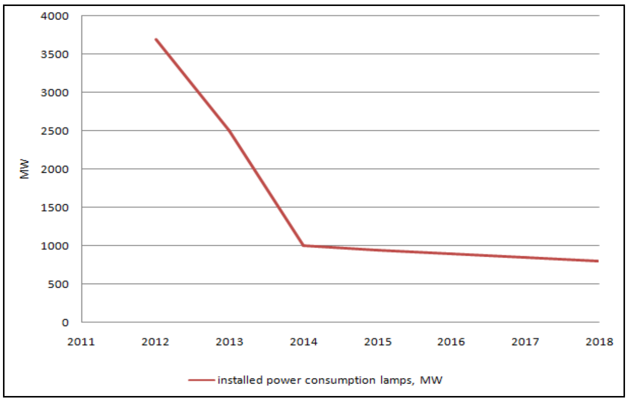

Figure 5. Reduction of installed capacity from 2013 to 2018 [11]

It is impossible not to mention one more aspect of the energy savings associated with the use of LED lamps. Their work is easily programmed and controlled to optimize lighting, adjusting its intensity. This quality extends the functionality of of lighting devices, offers the prospect of creating an ergonomic variable light environment, in contrast to today - uncontrolled and static.

2 THE AUTOMATED CONTROL SYSTEM OF LED LIGHTING

There are two directions of technological development in the field of electric lighting. The first is to improve the light-emitting components and designs lighting equipment: an increase the light output of the light source, reduction of power density; improving lighting and energy characteristics. The second trend involves the development of methods and modes of operation of lighting products: optimizing the placement of lamps depending on the purpose of visual tasks; efficient use of natural light with view of the diurnal cycle, seasonal and climatic region; implementation of lighting control systems.

The automated control system of the LED lighting was developed in East Kazakhstan State Technical University [12]. Field experiments were conducted to analyze the energy efficiency this system lighting. We measured the power consumption of lighting recreations two floors academic building.

Schematically floor with lighting fixtures and automated control system is shown in Fig. 6.

On one floor used daylight fluorescent lamps, and on another floor LED lamps which operate in two modes: normal mode without a control system and with use automated control system. In addition, motion sensors and light sensor was installed which allowed to implement the various scenarios of the lighting system in all floors. On the second floor of the fluorescent lamps were installed with a total light output equal light output of LED lamps of the first floor.

For each segment were installed electronic meters «Mercury 230» to pass data to the PC for the comparative analysis of the efficiency of the lighting technology.

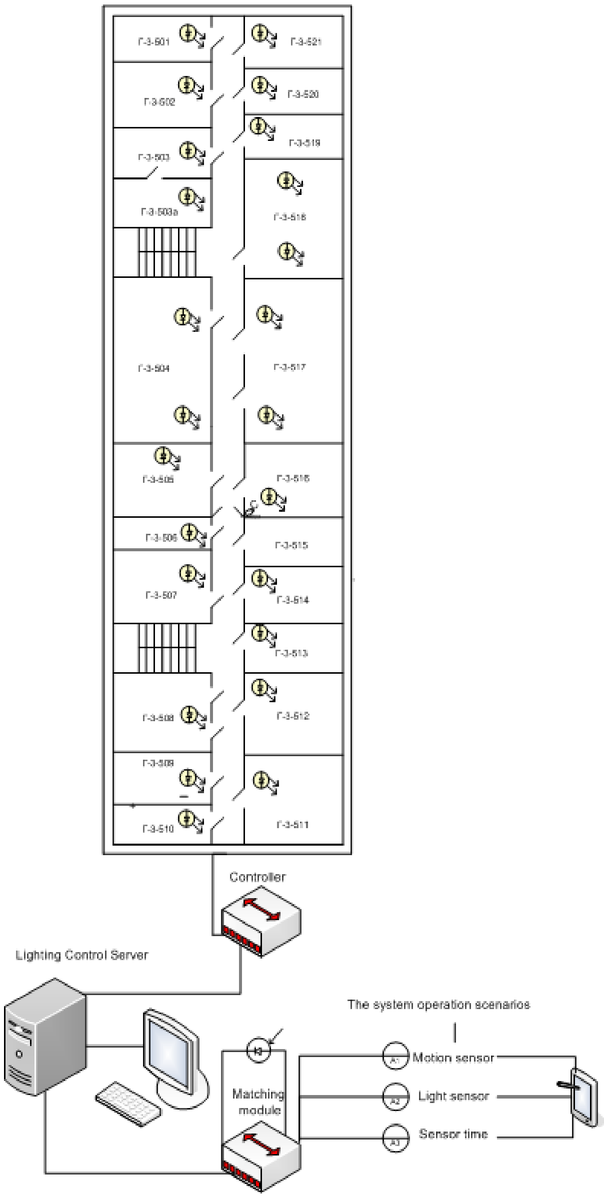

Figure 6. Scheme of automation and accommodation of LED lamps

Connection diagram counters to a computer is shown in Fig. 7.

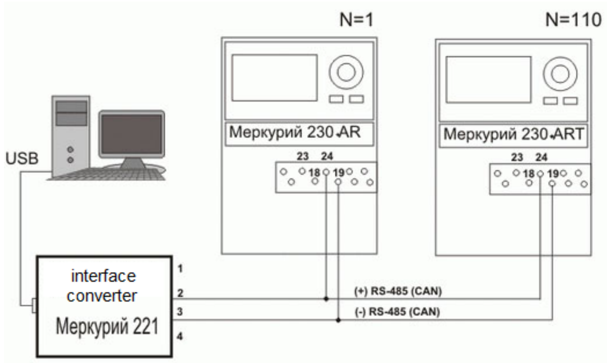

Figure 7. The connection diagram counters «Меркурий-230» to the computer

Data transmission takes place the RS-485 standard with using the interface converter which is designed to convert the USB interface CAN/RS-232/RS-485. After installing the USB driver interface converter is defined as a virtual COM-port. All interface converter terminals are galvanically isolated from the USB interface of the computer.

For visual monitoring of electricity consumption the interface was developed, showing graphs and histograms of energy efficiency both floors (Fig. 8).

Figure 8. Appearance of the connection meters with monitor

Information coming from the counters, transmitted to the server and stored in a database. This allowed for the study of energy efficiency LED lighting system automated.

3 Evaluation of LED Lighting System

The developed application provides information on electric power consumption and efficiency of lighting systems. The data is displayed on the monitor and recorded in the database (Fig. 9).

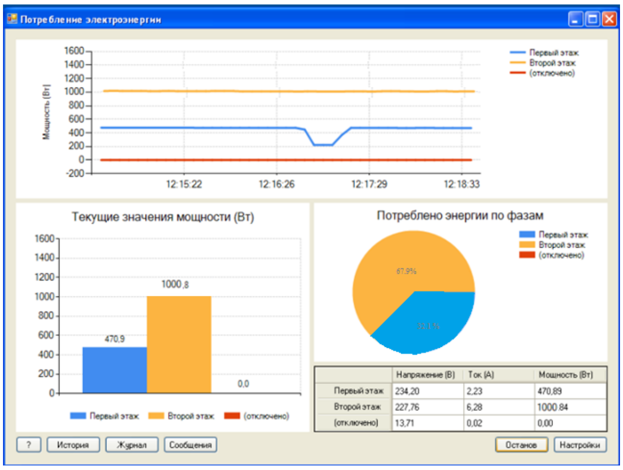

Figure 9. Interface of the power consumption control

The working field of the interface is divided into three parts. Electric power consumption is displayed at the top in real-time. The current time is plotted on the horizontal (in this case 12 hours 15 minutes). It can be seen that the energy consumption of the second floor is 1000W, and the consumption of the first floor with an automated LED lighting system is 470W. The graph shows a sharp decrease in power. This is a demonstration of the system performance (briefly off the light on the first floor at 12 o'clock 17 minutes).

In the bottom of the interface shows a histogram of power consumption. These histograms show the exact power consumption of the first and second floor, as well as the percentage of energy consumption on the floors. The values shown on the chart are average for a long time of full-scale tests (within 5 months).

On the basis of the obtained information on the power consumption of the lighting systems of the two floors have been calculated annual energy costs (Fig. 10).

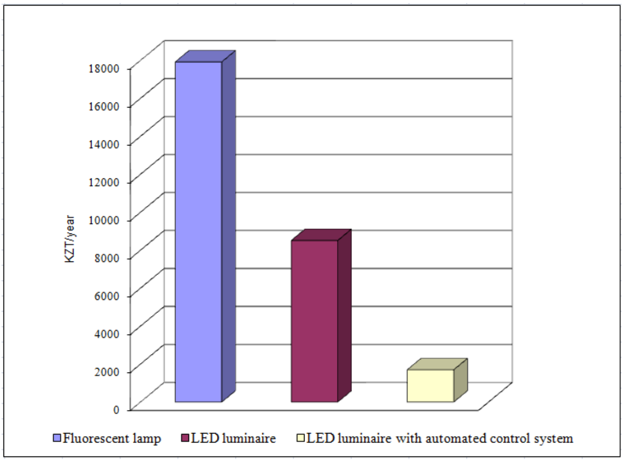

Figure 10. Chart of energy costs of the lighting systems

LED lights do not require operating costs (disposing, purchase consumables). Fluorescent lamps require constant maintenance. Cost of which is increasing by about 15% per year. Also, fluorescent lamps require a dispose that more increases maintenance costs by 5%.

Total costs with operational costs for a single lamp «Armstrong» in different segments are shown in Fig. 11.

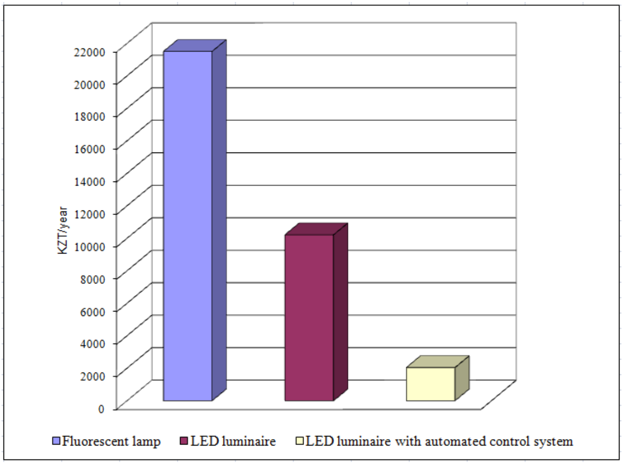

Figure 11. Chart total costs of exploitation of the lighting systems

On the basis of this data is visible to real savings the energy costs and savings of the total operating costs of LED lighting systems. Thus, in operating mode of the system LED lighting compared to fluorescent lamps energy savings is 91% with a motion sensor and 52% without.

CONCLUSION

The article presents the results of the implementation of the automated control system of LED lighting. Field tests showed the stability of the developed system.

The installed system of the control and monitoring allows us to calculate the energy efficiency of the LED lighting devices. It is demonstrated that the use of automated control system of the LED lighting saves energy almost 10-12 times as compared with currently available illumination based on fluorescent lamps.

Also, field measurements showed that the LED lighting fixtures allow you to save the electricity by 2-3 times, even without the use of automated systems.

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