ABSTRACT

of the dissertation for the degree of Doctor of Philosophy (PhD) specialty 6D070200 - Automation and Control

GRIGORYEVA SVETLANA VLADIMIROVNA

OPTIMIZATION OF LED LIGHTING SYSTEMS BY ELEMENTS OF ROBUST CONTROL

Thesis relevance. The problem of rational use of electricity in the conditions of limited resources and the growth of consumption is one of the most pressing, and the solution becomes a strategic priority for many countries. Prolonged global economic crisis, rising energy prices, environmental protection, reduction of harmful emissions and greenhouse gases into the atmosphere dictate the need to address energy conservation and efficiency.

President of Kazakhstan Nursultan Nazarbayev in Address to the Nation said: «We must make every effort to implement Global energy and ecological strategy in Kazakhstan» those pose the task of reducing energy consumption and of saving energy consumed by the population of Kazakhstan. This idea is emphasized in the book of the Head of State «Global Energy and Sustainable Development Strategy in the XXI century».

Energy costs are rising in proportion to the needs of the population. In Kazakhstan GDP growth of 1% matched against increase in electricity consumption about 0.5%. According to the calculations of the Ministry of Industry and New Technologies of Kazakhstan for the period from 2010 to 2020 the consumption of electricity in Kazakhstan will increase by 50%. These data show that the issue of energy efficiency is becoming more relevant. For Kazakhstan, the combined potential to reduce energy consumption is estimated at 30% -35%. The electric lighting is among the areas with the greatest potential for energy savings. One-ninth of the total energy is used for lighting each year in Kazakhstan, therefore one of the priorities is to reduce energy consumption for lighting.

If we consider the power consumption for the 1st quarter 2016 according to the Energy Service Energyprom.kz consumption amounted to 24.4 billion kWh. When calculating the cost of electricity for lighting would be about 3.2 billion kWh. For the ecology, this means that the amount of emissions of CO produced approximately 1.6 million tons. This amount of carbon monoxide leads to many diseases, as well as climate change. Obviously, the reduction of energy consumption for lighting will significantly improve the environmental situation on greenhouse gas emissions. In this context becomes relevant task of improving the efficiency of lighting systems. In general, it will positively affect the energy balance of the country and the environmental situation created by power plants work. The introduction of modern technologies for efficient use of energy resources will avoid power shortage.

46 countries, including Kazakhstan, have approved programs stimulating energy savings, as well as the transition to energy-efficient lighting technology. Currently, law «On energy saving and energy efficiency» and program «Energy – 2020» were approved for the introduction of energy-efficient lighting in Kazakhstan. The relevance of energy efficiency and energy saving are constantly highlighted in the annual message of the President of the Republic of Kazakhstan to the people of Kazakhstan and the State program for accelerated industrial-innovative development of Kazakhstan. The implementation of these programs stimulates the development of energy-efficient lighting systems.

Substantial savings of lighting can be achieved through the use of new semiconductor (LED) light sources and the development of lighting devices based on them. World experience shows that street lighting and intra-based LED technology automation improves quality of life, while ensuring energy efficiency that is economic benefits and environmental safety. Philips Lighting Company which is a leader in the field of LED technology intends to sell 2 billion LED units by 2020. The company has implemented LED technology in a 15-storey building The Edge in Amsterdam, where 6.5 thousand lamps were fitted. The economic effect amounted to 100 thousand euros per year. Also introduced LED technology for street lighting in Los Angeles. The annual economic effect amounted to USD10 million.

The main element of the semiconductor lighting is LED. LEDs have high technical and economic parameters (high luminous efficiency, long service life, high reliability, easy maintenance, economic efficiency), have a wide range of colors, configurations and capacities. Unlike traditional light sources, semiconductor lighting has some of advantages in terms of application: environmentally friendly, has high mechanical strength and vibration resistance, no ultraviolet radiation emitted by the light and stroboscopic effect, inertia with lamps turned on and works well at low temperatures. Separately it is necessary distinguish the possibility of controlling of the luminous flux of LED in a wide band. It is because of these qualities, the LED lighting is one of the promising directions.

Existing energy efficiency LED lighting systems have some disadvantages - mismatch claimed lifetime due primarily overheating LEDs and imperfections of designs of LED lamps.

Therefore, the problem posed in the dissertation of optimization work of integrated LED lighting technology eliminates the deficiencies noted by the mode control automation of LED lamps using the robustness of the elements in managing to give a significant economic impact, which is undoubtedly relevant.

The idea of work – combine in "integrated" system lighting, new LED lighting installations taking into account their thermal mode and automated control systems with elements of robustness.

Thesis objective. Development of an automated energy-efficient system of LED lighting with elements of robust control.

Object of the research – the LED lighting system.

Subject of the research – technology to optimize operating modes and control LED lighting system.

Research objectives. To achieve this purpose, the following tasks:

1) To analyze the current state of functioning and development of LED lighting technology.

2) To investigate heat and mass transfer in a typical high-power white LEDs.

3) Simulate the LED lighting system to obtain the optimal parameters.

4) To develop a pilot installation of automated control LED lighting with elements of robustness.

5) To conduct field experiments automated LED lighting control system to analyze the results and estimation of its efficiency.

Methods of research. The research methodology is based on a systematic approach to the substantiation of complex theoretical and experimental results obtained by the methods of mathematical and statistical analysis, mathematical and physical modeling, lighting and photometric methods. As the simulation tools and software development are used modern software packages: DIALux, STATISTICA, MATLAB, Solid Works, Autodesk Inventor, SCADA TRACE MODE. Experimental studies are conducted using modern electrical and electronic devices.

Scientific position and results taken out on protection:

1) Method of the theoretical calculation heat and mass transfer in an illumination device using time-dependent differential equations describing a set of interrelated processes of heat and mass transfer.

2) Model of the thermal performance of the LED lighting devices using modern software tools «SolidWorks» for optimum thermal characteristics of the fixture.

3) Model optimization of lighting technology to provide uniform illumination of the working space.

4) Automated LED lighting control system with elements of robustness providing reliable, efficient characteristics of the lighting system.

5) Complex software that implements the developed models and algorithms for energy-efficient control of the LEDs new design.

Scientific novelty:

1) Mathematical model of heat and mass transfer taking into account features of the system «LED base - crystal - lens - the ambient air» for the LED lighting device is designed.

2) Model of temperature modes of the LED lighting device in order to obtain optimum thermal characteristics developed.

3) New approach to improve the reliability and durability of LED lighting system by automating control of the temperature mode of the LED is developed.

4) Method of increasing the stability of the LED lighting system based on the theory robustness is proposed.

Validity and reliability of scientific statements, conclusions and recommendations of the thesis is based on the integrated use of modern theoretical and experimental research methods and common approaches to the modeling of

complex systems, taking into account the uncertainties that affect the work of LED lighting control system. Comparability of the results of theoretical research, the simulation results and experimental results is quite high, which makes the results of the thesis sufficiently substantiated and reliable.

Practical value. The results of the thesis focused on the establishment of production of the controlled high-efficiency fixtures and automated systems for optimal energy-saving control.

Create adjustable LED lighting devices intended for the combined illumination of industrial, residential and other facilities housing and having improved light efficiency, reliability and durability as a result of efficient cooling systems.

The development of new energy-saving LED lighting systems will increase the working life of lamps and bring it up to 50-100 thousand hours.

Introduction of automated lighting control systems, implementing the developed models and optimal energy-saving control algorithms will reduce power consumption up to 55%.

Implementation of the results. The main scientific and practical results of the thesis were accepted for the implementation of LLP «Iron Technician», Kazakh-French enterprise LLP «The laboratory of alternative energy».

Received a certificate on state registration of rights to the object of copyright «The Automated control system the LED lighting with the robustness of the elements (a computer program)» for №2336 from 9.11.2016.

A layout of the automated LED lighting system with elements of robustness has been presented at the exhibition «Week of EKR, dedicated to EXPO-2017» (Astana, November 2016).

Link with state programs. Subject of the thesis is based on the priority areas identified in the Resolution of the Government of the Republic of Kazakhstan «On Approval of the Program « Energy Saving – 2020» from August 29, 2013 № 904, aimed at reducing energy consumption through the introduction of energy-saving technologies in lighting.

Scientific studies presented in the thesis, carried out under the grant financing of MES RK on «Optimization of energy consumption in LED lighting installations combined with automatic control: algorithms, software, demo layout at EXPO 2017» (state registration number 0113RK00822), 2013-2015, where candidate for a degree are performers.

Approbation of the work. The main results of the thesis were reported and discussed at: International Conference «Computational and Informational Technologies» (Ust-Kamenogorsk, 2013); International scientific-practical conference «Green Economy - the future of humanity» (Ust-Kamenogorsk, 2014); the Tenth International Asian school-seminar «Problems of optimization of complex systems» (Cholpon-Ata, Kyrgyz Republic, 2014); IV International scientific-practical conference «Academic science - Challenges and Achievements» (Moscow, Russia, 2014); 9th International Symposium on Applied Informatics and Related Areas (Szekesfehervar, Hungary, 2014); Asian XI international school-seminar «Problems of optimization of complex systems»

(Cholpon-Ata, Kyrgyz Republic, 2015); IX International Conference «Efficient use of resources and environmental protection - the key issues of the development of mining and metallurgical complex» and XII International Scientific Conference «Advanced technologies, equipment and analytical systems for materials and nanomaterials» (Ust-Kamenogorsk, 2015); II All-Russian Student Scientific Conference with international participation «Student: science, profession, life» (Omsk, Russia, 2015); International scientific-technical conference of students, graduate students and young scientists «Creativity young - the innovative development of Kazakhstan» (Ust-Kamenogorsk, 2015); 11th International Forum on Strategic Technology (IFOST) (Novosibirsk, Russia, 2016); VIIth International Symposium and Young Scientists School «Modern problems of laser physics» (Novosibirsk, Russia, 2016); 11th International Symposium on Applied Informatics and Related Areas (Szekesfehervar, Hungary, 2016).

Publication. According to the thesis published 17 scientific works, including 1 article in the journal indexed in the database Thomson Reuters , 1 article in the journal indexed in the database Scopus, 5 articles in journals recommended by the Committee for Control of Education and Science of the MES, 8 works in collections international conferences, including 2 articles in journals abroad (Hungary).

The structure and scope of the thesis. The thesis consists of an introduction, 5 chapters, conclusions, list of references from 189 names contained in the 139 pages of computer text, including 75 figures, 7 tables and 4 annex.