Indoor LED lighting control based on embedded systems

Bolatova Anar
Faculty of Information Technology
D.Serikbayev East Kazakhstan Technical University
Ust-Kamenogorsk, Kazakhstan
bolatova.anar@mail.ru

Svetlana Grigoryeva
Faculty of Information Technology
D.Serikbayev East Kazakhstan State Technical University
Ust-Kamenogorsk, Kazakhstan
SGrigorieva@mail.ru

***Abstract*—This article describes a specific approach in designing an office lighting system. An intelligent lighting control system based on LED lighting devices with built-in microcontrollers is considered. A portable small-sized sensor is proposed to use in order to control the light level and color spectrum emitted by the LED lighting device in real time. The system for monitoring and controlling lighting parameters is built using Wi-Fi wireless data transmission technology. The proposed organization of the lighting system allows for detailed and individual adjustment, taking into account the specified operating parameters and user requirements.**

Keywords— smart system, LED lighting, wireless technology, embedded systems

I. Introduction

Interest in the design and promotion of intelligent lighting systems is based on the development of electronic information processing devices, info-communication technologies, and is also stimulated by energy conservation programs at the international and national levels [1,2].

Statistical data show an increase in the production and consumption of electricity in Kazakhstan. Almost 10 billion kW are spent annually on lighting needs, which is 12-14% of all electricity generated in the country [3]. It should be noted that in Kazakhstan this consumption indicator is less than the world one, which is 19% [4]. However, this is not due to the use of energy-efficient lighting devices and the introduction of modern lighting control systems, but to the high consumption of energy resources in the industry and the energy sector itself.

The total potential for reducing energy consumption for Kazakhstan is estimated at 30% [5]. The lighting industry is one of the areas with great energy-saving potential. The share of electricity consumption by lighting fixtures in public and residential buildings in Kazakhstan is 40% - 60%, which is much higher than in European countries. The costs of these key resources are constantly growing and an understanding of how these resources are spent is needed. This requires managing them and optimizing their use. At the same time, one of the possibilities to "take" resources under control is associated with lighting systems, which can be made not only much more cost-effective but also can be turned into an intelligent infrastructure. Therefore, one of the priority areas for reducing energy consumption is to reduce energy consumption for lighting in this sector.

Saving electricity consumption for lighting can be achieved through the use of energy-saving lighting lamps, as well as through the introduction of intelligent control systems.

The development of semiconductor lighting technology has made it possible to use LEDs in lighting devices for lighting systems. Powerful white LEDs used as light sources are distinguished by a long service life, high luminous flux with low power consumption, high-quality lighting, the ability to control the luminous flux without compromising technical and operational characteristics. The high cost of LED lighting, which was initially a negative indicator and strongly influenced user demand, is steadily declining. In combination with improved reliability and uninterrupted operation indicators, solution of operational problems in connection and installation, as well as real financial savings due to reduced energy consumption, the price factor fades into the background. Energy-saving LED luminaires are used to solve problems of lighting a workspace in an office. They provide the required level of illumination, the necessary color rendition, and contrast for comfortable work throughout the entire declared service life.

Up to 40% of the electricity spent on lighting can be saved by taking into account natural light, disconnecting the load without the direct presence of people in the room, and planning various scenarios of the lighting environment [6]. Thanks to their technical and operational characteristics, LED light sources provide the opportunity to design intelligent lighting control systems for the workspace.

The main design criteria for modern lighting systems are energy savings and satisfaction of consumer demands. Open office layouts are the most used type of office space, where the illumination of each work area is the result of co-lighting from multiple ceiling lights. Existing commercial projects of lighting systems for office premises are aimed at reducing the cost of consumed energy and show good results through the use of different approaches in control systems [6-9]. It should be noted that the creation of a comfortable light environment, taking into account the specifics of work and user preferences, is most often overlooked or not considered at all. In addition, the installation of a control system in existing buildings with an established engineering infrastructure requires large financial investments due to the need for a global modernization.

The intelligent lighting optimization algorithm formulates lighting control as a linear programming problem, i.e. minimize energy consumption and satisfy user preferences. Currently, much less attention is paid to individual visual comfort than energy conservation. Studies conducted in standard office spaces show a positive correlation between satisfaction with the quality of the lighting environment and employee productivity. The data on the differences in the requirements for lighting for the implementation of tasks that differ in function are given [10]. More often than not, satisfying personal visual comfort is seen as a counterbalance to energy conservation. However, if the user is provided with the ability to independently adjust the lighting environment settings in accordance with his preferences in addition to the existing lighting scenario management system, then user satisfaction can be increased without increasing energy costs.

The organization of an individual comfortable light environment is relevant in the design of lighting control systems in an office since lighting devices are usually connected and grouped into zones in which the same uniform illumination is provided. The widespread development and implementation of embedded systems based on microcontrollers allows the introduction of modern methods of automation and control to solve this problem. By leveraging the versatility of wireless networking technologies embedded in today's sensors and actuators, an intelligent lighting control system can be created that simultaneously maximizes user satisfaction and conserves energy in offices.

In this paper, the authors describe their own approach to designing an intelligent LED lighting control system in an office premise with common space. It is proposed to use wireless data transmission technology to control the level of illumination and color spectrum based on embedded systems to solve the problem of efficient management of electricity and space at the same time.

II. LIGHTING CONTROL SYSTEM USING EMBEDDED SYSTEMS

The basis for research and implementation of our own approach in the design of an intelligent lighting system for an office with a common space was the educational laboratory "Intelligent life support systems" developed on the basis of D. Serikbayev VKTU. The appearance is shown in Figure 1.

Fig. 1. Teaching laboratory: 1 - Siemens controller; 2 - Touch panel; 3 - LED lamp

All modules of the system are controlled by the Siemens Simatic S7-400 controller. The software allows the control and monitoring of parameters in the room. The resources of the program are located on the webserver and allow connection to the system remotely. Administration levels are provided. For visualization and ease of control, the system is equipped with a touch panel. When switching to manual control, it is possible to change the scenario, set new settings.

This system has the following main modules (Figure 2):

– water supply control module - controls the absence of leaks in the water supply and sewerage systems;

– access control module - controls access to the room, and also monitors the movement and presence of people in the room to execute the developed scenarios;

– temperature control module - controls the temperature in the room and controls the valves of the heating system;

– lighting control module - controls the level of lighting in the room depending on the time of day, controls the level of the luminous flux of LED lamps, taking into account natural light, and also,turns on / off all lamps in the roomdepending on the information received from the access control module.

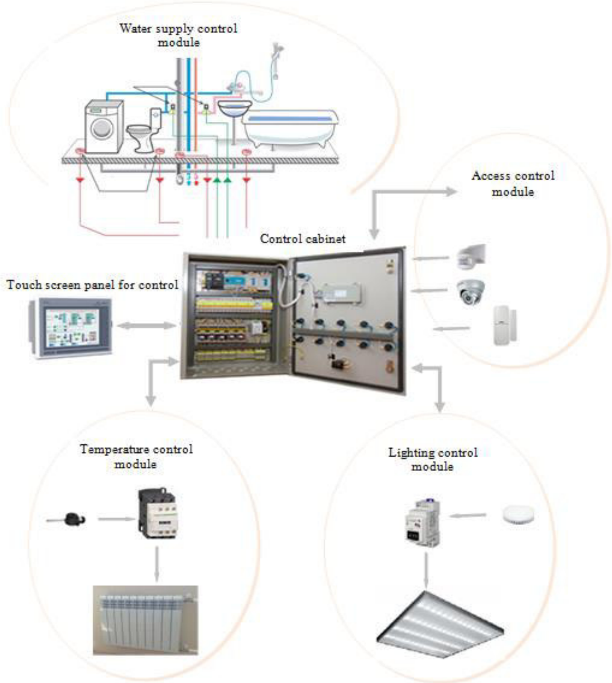

Fig. 2. Modules of the "Smart House" complex

Taking a closer look at the lighting control subsystem, it works on the basis of data received from motion sensors installed on doorways and light sensors installed in the middle of the ceiling of the room. The control algorithm takes into account the following parameters:

- motion sensors read the number of people present in the room. Upon entering the room, lighting devices are automatically turned on. In the absence of people in a given period of time, the lighting is turned off.

- light sensors take into account natural light and adjust the lighting level in the room in accordance with the specified one.

This approach is classic when designing a lighting control system.

Most of the existing projects in the "Smart Home" system implement control modules focused on the use of powerful controllers. The advantages of such systems are large computing capabilities and the integration of connecting a large number of devices to organize a comfortable environment and control life support parameters. However, the detriments are the high price, the incompletely used functionality and power of such a system, the complexity of integration into the existing engineering and informational infrastructure. To create an energy-efficient system with high functionality, this investigation proposes to integrate a lighting control module into an existing system, which includes LED lamps with built-in microcontrollers and a portable sensor.

III. Practical results

Description of a general approach to system design.

The main computing power is taken over by the master controller. It is suggested to use a single-board computer Raspberry Pi, which is much cheaper than industrial controllers. For the convenience of user control and visualization of the system operation, a touch screen monitor can be installed additionally.

The slave device will be LED ceiling lights. In this case, it is advisable to use two or more lamps.

For monitoring and control, its own portable small-sized light and color spectrum sensor with low power consumption is used.

Wi-Fi wireless technology is used to transfer data and control signals between elements of the lighting system. With this approach, both internal (individual) system configuration and connection to a common network with the possibility of remote control are possible.

The main elements of an intelligent lighting system based on embedded systems are shown in Figure 3.

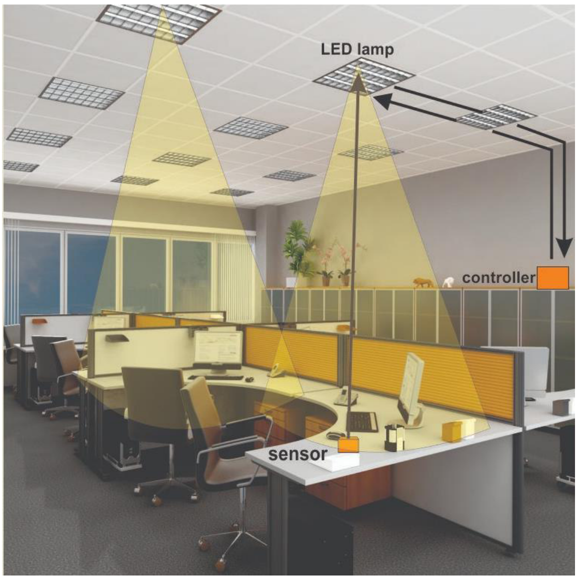

Fig. 3. General scheme

Modern microprocessor electronics allow the development of a low-cost smart lighting device with the ability to control and transmit data wirelessly. For implementation, it is proposed to use a microcontroller on the Espressif ESP8266 chip. This microcontroller has established itself at the present time due to its low cost, as well as the opportunity provided for the development of devices supporting the concept of the "Internet of Things" based on data transmission over a Wi-Fi network. An additional advantage when choosing a microcontroller is the presence of a NodeMCU development board.

Espressif offers a new line of ESP32 microcontrollers with support for wireless data transmission over two communication channels - Wi-Fi and Bluetooth, with significant computing power and data transmission security. [11].

Both chips have become the market leaders of the "Internet of Things" concept in their respective segments, providing connection to a huge number of devices around the world. However, in this project, there is no need to overpay for functionality that will not be used.

As analogy with the lighting device, the developing portable sensor will be equipped with the same ESP8266 microcontroller. The advantage of the selected microcontroller in the sensor design is its low power consumption, as well as the ability to operate in various energy-saving modes. This parameter is very important in terms of portable sensor design. In the device under development, it is suggested to use two sensitive photocells. One of them will react to the ambient light level in the room, and the second will analyze the visible light spectrum. Both parameters will be read in real-time.

Description the operation algorithm of the control system.

The user installs the handheld transducer on the work surface. To get started, it should be activated. The activation process is confirmed by a light indication on the handheld sensor and on the touchscreen of the master controller. The next step is setting the parameters. This is possible both for a group of sensors and for each sensor separately. The system can operate in two modes - user and automated. In the user mode, a person in the room parameterizes the system independently in accordance with his requirements and preferences. Using the touch screen connected to the master controller, the user can set the required parameters of the illumination in the room. To reduce energy costs and set the optimal characteristics of the working surface, an automated version of room lighting is provided.

After activating the portable sensor, the system needs to determine it in the space of the room and bind it to the LED lamp. For this purpose, the system transmits the binary sequence of each lighting fixture using visible light communication technology. The sensor photocell reads the signal and transmits it to the master controller. There is a binding of the lighting fixture and the measuring device. The next step is to compare the measured data with the setpoints for regulation.

Conclusion

The proposed lighting control system will allow real-time adjustment of the optimal or user-defined level of illumination of the working surface. Leveraging the ease of integrating wireless networking with existing lighting equipment, the fixtures are connected to a portable, small-sized sensor via a Wi-Fi link to provide individual switching and dimming. The proposed approach to the organization of the LED lighting control system will reduce the computing power in the system, avoid installing a system of stationary sensors, and provide point and individual settings, taking into account the specified operating parameters.

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