Design and Application of Intelligent Lighting Control System for Classrooms Based on PLC

Fengxia Shi[1], Zhiwei Kou*[2], Jie Chen[3], Wenjun Li[3]

1. Jin Yubaoling bio-pharmaceutical Co., LTD, Hohhot 010051, China
2. College of Electric Power, Inner Mongolia University of Technology, Hohhot 010051, China
3. Inner Mongolia University of Technology, Hohhot 010051, China
shifengxia@jinyubaoling.com.cn，kouzhiwei@imut.edu.cn, liwenjun@imut.edu.cn, chenjie@imut.edu.cn

***Abstract*—The matter of energy waste has always been an unavoidable problem in the sustainable development of human beings. Because of poor awareness and weakness technology of environmental conservation, many classrooms and laboratories are very wasteful of power resources due to the use of traditional lighting systems. Focus on the problem that the traditional lighting control technology is used in the classroom lighting system. In this paper, a new intelligent lighting control system for the classroom is designed, based on PLC and industrial touch-sensitive screen. Firstly, a new intelligent lighting control system for the classroom based on PLC is presented according to the design ideas and the composition principle of typical electrical control system. There are three control modes: automatic, timing and manual, according to the needs of the classroom lighting system, Secondly, the lighting circuit and PLC control circuit are designed, in addition, the control principle of each component in the circuit is described in detail. Based on this, the control program of PLC is developed. The test results show that the system design is affordable, which can solve the above problems well.**

Keywords—*intelligent lighting system; PLC control; Industrial touch-sensitive screen*

I. INTRODUCTION

Energy issues have always been the focus of attention. However, due to the backwardness of the traditional lighting system, a large amount of unnecessary electricity is wasted. At this time, an intelligent lighting system is urgently needed to replace the traditional lighting system, which can reduce waste of energy and better serve people.

At present, Chinese lighting electricity consumption makes up 12% of the total electricity consumption in society. Colleges and universities are a densely populated area that integrates teaching, research, and living [1,2]. They are also large energy consumers, and the school's power consumption is required to be huge. Except for the electricity required for normal life, work, and study, artificial energy waste is also serious, especially for the lighting of many classrooms.

Most colleges and universities, because of their weak energy saving consciousness, also turn on the lights when the light intensity is sufficient [3,4]. After the classroom is empty, the students may forget or don't care, the lights in the room are turned on and remain on until the administrator finds it is turned off. It is exactly because of this phenomenon that unnecessary energy waste and economic loss are caused. Therefore, a new intelligent lighting system is urgently needed to change this situation.

In view of this, most colleges and universities have begun to attach importance to energy conservation and environmental protection, and have launched corresponding actions and adopted appropriate measures [2,5]. Many researchers have also turned to the field of lighting energy conservation in colleges and universities, and have achieved numerous research results.

Intelligent lighting technology is developed with the computer technology, automatic control technology and network communication technology. Intelligent lighting control system is an electrical control system which can achieve the best lighting effect according to the site requirements, environmental changes and user predetermined conditions [4,6]. It can automatically collect the illumination, natural light and lighting demand data of the lighting site, and then carry out logical analysis, processing and judgment on the collected information, and then transmit, store, display and feedback the results to achieve control Intelligent control of illuminance [7,8].

The industrial programmable language controller (PLC) is a new type of industrial controlling device based on microprocessor, and so is called the Industrial computer, which adopts modular structure, and the automatic control system composed of which has the advantages of convenient networking, high reliability, strong anti-interference ability, and can adapt to various harsh working environments. The Industrial touch-sensitive screen is a bridge between operator and computer control equipment, which is used to realize the dialogue and interaction between operator and PLC, to receive commands and set parameters issued by operator, and to monitor the I/O status of PLC and the running process of the system in real time. Based on the above advantages, in this paper, the industrial programmable language controller and industrial touch-sensitive screen are selected as the central processor and the central computer's monitoring and controlling of the intelligent lighting system respectively.

This paper presents an intelligent lighting control system for classrooms based on industrial programmable language controller and industrial touch-sensitive screen, which solves the problems existing in traditional lighting system for classrooms and improve the automation performance of the lighting control system.

*Corresponding author: Zhiwei Kou, kouzhiwei@imut.edu.cn

978-1-7281-4323-1/20/$31.00 ©2020 IEEE

II. SYSTEM SCHEME

A. Design concepts

According to the control requirements of the classroom lighting, this control system needs three operation modes, which are automatic mode, timing mode and manual mode, the design concepts are as follows:

(1) Automatic mode is a working pattern without manual operation. In this mode, the system automatically measures the illumination and number of people by sensors in the classroom, and then sends this information to the CPU of PLC. After the CPU processing and calculation, the system automatically turns on or off the lighting group in the classroom.

(2) Timing mode is a working pattern that operates according to the preset-time. This mode is similar to the working mode of a street lamp. It is built on different seasons, and the time of turning on and off the lamp is different. When the system works in this mode, the preset-time has to be set in advance, and then the system automatically turns on or off the lighting group of the classroom according to the set time mode, without manual operation.

(3) Manual mode is a manual operation pattern, which is a supplementary mode, in order to meet the other two modes can not be achieved. When working in this mode, the switch of the lighting groups is controlled by way of manual operation button. Although it needs manual operation, it has the advantages of simple operation and convenient control.

In general, we can choose automatic mode or timing mode to control the lighting groups in the classroom. But in some special cases, we have to choose the manual mode to adapt to the special changes in the environment, as shown in Fig.1.

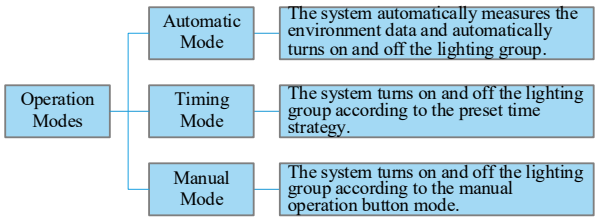

Fig. 1. The operation modes of the the control system

B. System scheme

This paper presents an intelligent lighting control system for classrooms based on industrial programmable language controller and industrial touch-sensitive screen according to the above design concepts and the composition principle of typical electrical control system, which is composed of a PLC control unit, an industrial touch-sensitive screen, the sensor groups and lighting groups, as shown in Fig.2.

In Fig.2, the industrial touch-sensitive screen is used as the human-machine interface of the control system, which human-computer interface and monitoring screen is developed by MCGS configuration software. It can accept control commands and parameter settings of the operator, and display the I/O status of the PLC, and monitor the running information of the control system. The central controller unit of this system chooses SIEMENS S7-200 PLC, including CPU224XP and EM235 modules, to complete the operation and processing of sensor signals, and to control the opening and closing of the lighting groups according to the control command by the operator.

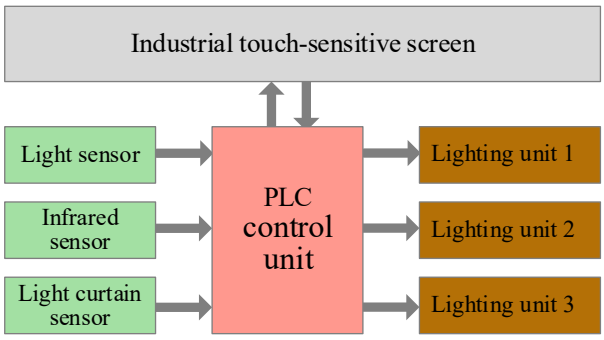

Fig. 2. The system scheme of the the control system

III. CIRCUIT DESIGN

A. The lighting groups circuit

The lighting circuit is the load of this control system, which is mainly composed of four lighting groups controlled by the AC contactor, as illustrated in Fig.3.

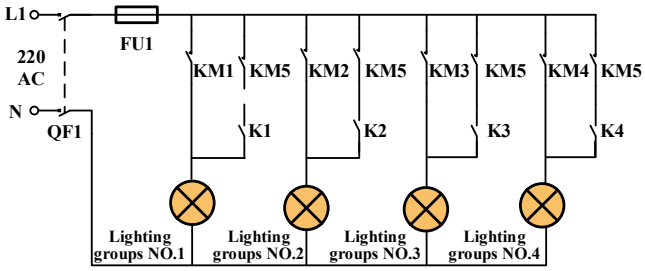

Fig. 3. The lighting groups circuit

The main devices and their applications of the lighting groups circuit are given in Table 1.

TABLE I. THE MAIN DEVICES OF THE LIGHTING GROUPS CIRCUIT

Devices	Applications	Notes
QF1	System power supply	Breaker
FU3	Power protection	Fuse
KM1	Lighting groups NO.1 control	Contactor
KM2	Lighting groups NO.2 control	Contactor
KM3	Lighting groups NO.3 control	Contactor
KM4	Lighting groups NO.4 control	Contactor
KM5	Manual mode control	Contactor
K1~ K4	Manual mode control	Button
Lighting groups NO.1~ Lighting groups NO.4	System load	Lighting groups

The lighting circuit is powered by AC 220V power and controlled by the system power supply breaker QF1. There are four Lighting groups numbered No.1, No.2, No.3 and No.4 respectively, which are the load of this intelligent lighting control system, and it is controlled by AC contactor KM1, KM2, KM3 and KM4 respectively. When this intelligent lighting control system works, it needs to select the control mode manually, and then drive the corresponding lighting group according to the command by man or the controller to provide lighting for students to attend classes or study.

B. The PLC circuit

This system chooses PLC to control and realize all functions of the system. As a controller, PLC holds the characteristics of high reliability, rich I/O interface, simple installation and easy maintenance. Fig.4 is the circuit diagram made with PLC as the core.

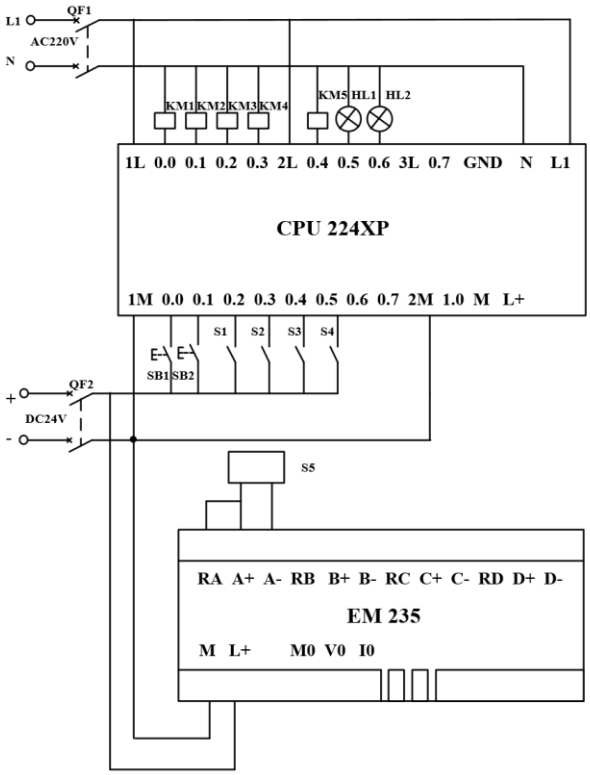

Fig. 4. The PLC control circuit

In the Fig.4, the analog module EM235, and the input interface of PLC are powered by DC 24V, and the PLC power supply and AC contactor are powered by AC 220V. Devices and its parameters of this circuit are selected as showed in Table 2.

In order to measure the number of people in the laboratory, this system uses the infrared sensor and the plus and minus counter in PLC to achieve this function. The binary probes of infrared sensors are located at the door of the laboratory side by side at a short distance. By observing the sequence of the signals measured by the two infrared sensor probes, we can judge whether someone enters or leaves the laboratory at this time.

To determine the number of people in the laboratory, this system uses the infrared sensor and the plus and minus counter in PLC to achieve this function. The sensitive elements of the infrared sensors S1 and S2 are placed close to each other at the entrance of the classroom. By observing the sequence of the signals measured by the two infrared sensors, we can judge whether someone enters or exits the classroom at this time. When the signal is primarily measured by the infrared sensor S1 close to the door, it indicates that someone enters at this time. When the signal is first measured by the infrared sensor S2, it indicates that someone leaves at this time.

TABLE II. THE MAIN DEVICES OF THE PLC CIRCUIT

Devices	Parameters	Manufacturer
PLC	CPU224CN	SIEMENS
Analog modules	EM235	SIEMENS
SB1	Start button	Button
SB2	Stop button	Button
HL1	Operation indicator	Indicator
HL2	Alarm indicator	Indicator
S1、S2	Infrared sensor	Sensor
S3、S4	Light curtain sensor	Sensor
S5	Illuminance sensor	Sensor

On behalf of realizing intelligent lighting and measure whether the lighting light in a corner of the classroom is blocked, the system uses light curtain sensors S3 and S4 to detect the blocking signal. Two light curtain sensors are respectively connected to I0.3 and I0.4 input port of CPU. When the light curtain sensor detects that the light curtain is blocked, that is, someone is active in the corner, and the lighting light is blocked, the signal is transmitted to the CPU to judge whether the light needs to be turned on.

The light intensity is respected by the light intensity sensor S5. Because the CPU of PLC can only recognize the digital signal, the analog signal with similar light intensity can not be recognized. At this time, we are obliged to add the analog input expansion module to the CPU. The analog signal processing module maintained in this system is EM235. The light sensor transmits the measured analog signal of light intensity to the analog input expansion module, and then the analog input module and CPU carry out digital to analog conversion, so that the CPU can obtain the corresponding digital signal that can be read, and then judge according to the control program.

Signal indicators HL1, HL2 and Hl3 are operation mode selection indicators. When a certain mode is running, the corresponding indicator light up.

IV. SOFTWARE DESIGN

Three control modes is designed for the intelligent lighting control system, which are automatic mode, timing mode and manual mode. The control program of automatic control mode is the key of system software research. In the automatic

control mode, PLC is the core component of the control system, which is responsible for the signal acquisition and processing of light sensor, infrared sensor and light curtain sensor. According to the control strategy, the power on or off of the contactor coil of the lamp group is controlled, so as to realize the intelligent lighting of the classroom.

Considering the control requirements, control mode and I/O interface of the system, the control program consists of a main program, data processing and display subroutine, protection and alarm subroutine, automatic control subroutine, and timing control subroutine, the main program flow is shown in Fig.5.

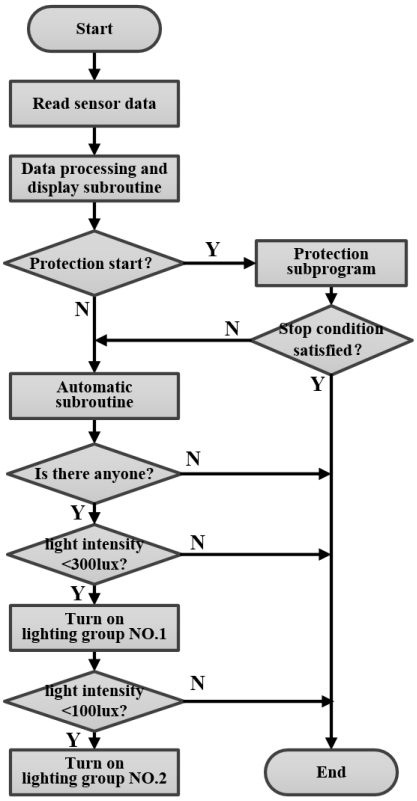

Fig. 5. The main program flow of the PLC

V. SYSTEM IMPLEMENTATION AND TEST

In the laboratory, the experimental test device of intelligent lighting control system based on PLC is built, and the automatic mode, timing mode and manual mode of the system are tested respectively.

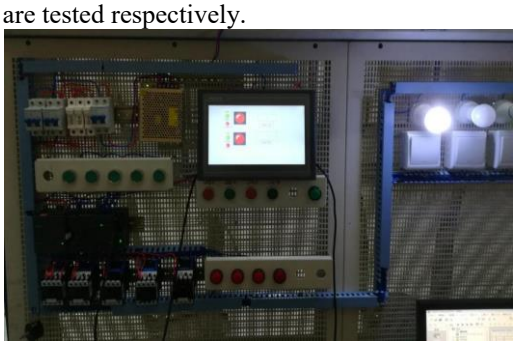

Fig. 6. The control interface in Channel 1 Experiment

The test results show that the system can solve the problem of classroom lighting and realize the intelligent lighting of the classroom. The test results of automatic mode operation is shown in Fig. 6.

VI. CONCLUSION

In this paper, a new control system for classroom intelligent lighting is proposed based on PLC, focus on the problem that the traditional lighting control technology is employed in the classroom lighting system. A control system for classroom intelligent lighting based on PLC and industrial touch-sensitive screen is developed according to the design ideas of cerebral control and control requirements of the control system. The experimental data show that the intelligent lighting control system for the classroom is stable, intelligently and reliably, and the human-machine interface is beautiful, friendly and simple. More importantly, the scheme has realized the remote monitoring of system status in real time, which can improve application performance and technology level of the classroom intelligent lighting.

REFERENCES

[1] Zhenfeng Li, Jingtao Li and Xiaofan Li. Design of Office Intelligent Lighting System Based on Arduino[J]. Procedia Computer Science,2020,166.

[2] XiaoDong Lai, MengYun Dai and Raufdeen Rameezdeen. Energy saving based lighting system optimization and smart control solutions for rail transportation: Evidence from China[J]. Results in Engineering,2020,5.

[3] David Sun, Andreas Athienitis, Katherine D'Avignon. Application of semitransparent photovoltaics in transportation infrastructure for energy savings and solar electricity production: Toward novel net - zero energy tunnel design[J]. Progress in Photovoltaics: Research and Applications,2019,27(11).

[4] Yangping Zheng, Jia Qu and Hongtao Yu. Research on energy-saving power system of office building lighting based on Internet of Things[J]. The Journal of Engineering,2020,2020(2).

[5] Mo Jianli. Research on Intelligent Indicator Lamp Control System and Its New Technology Based on Internet of Things Technology[C]. Institute of Management Science and Industrial Engineering. Proceedings of 2019 4th International Industrial Informatics and Computer Engineering Conference (IIICEC2019). Institute of Management Science and Industrial Engineering: Computer Science and Electronic Technology International Society),2019:58-63.

[6] Dominika Cupkova, Erik Kajati and Jozef Mocnej. Intelligent human-centric lighting for mental wellbeing improvement[J]. International Journal of Distributed Sensor Networks,2019,15(9).

[7] Wang Wenqing, Yan Yuan and Zhang Rundong. Multi-Attribute Fusion Algorithm Based on Improved Evidence Theory and Clustering.[J]. Sensors (Basel, Switzerland),2019,19(19).

[8] Xiaoqiang Xu, Ao Zhan and Xiaohan Li. Design and implementation of street light control system based on power line carrier communication[J]. Procedia Computer Science,2019,155.