Optimization Design of Campus Lighting Energy Saving System based on PLC

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Abstract: The continuous enrichment of campus life and the continuous improvement of campus planning and design have put forward higher requirements for the campus lighting system. Especially in the university campus, the proportion of lighting electricity consumption is as high as 75%.Campus lighting has many features such as large number of lamps, long lighting time, wide range and dispersion. It adopts manual control method, which is complicated in procedure and wastes electric energy. If PLC is selected as the main controller, according to the lighting requirements of different ranges and different time periods, in the campus the lighting system is optimized to save energy and reduce maintenance costs.

Keywords: Programmable controller (PLC0); Lighting system; Energy saving; Optimization

1. Introduction

As global industry enters a high-speed development model, energy issues have become the focus of public attention. Energy consumption will not only increase the unit's additional operating costs, but also increase carbon emissions, causing environmental degradation and increasing greenhouse effect, so saving energy consumption is imperative. Many university campuses are now built in university towns on the outskirts of the city. The building utilization capacity is low, and there are no tall and dense buildings around the school. This requires more lighting facilities on campus. The campus lighting facilities are mainly distributed in the teaching building, on the campus roads and in the green landscape of the campus. The circuit has many loops, long working hours, wide distribution and dispersion. If the management and control of these public lighting facilities can be optimized and upgraded, School energy conservation will take a big step. This paper discusses the scheme of optimizing and upgrading the campus lighting energy-saving system with PLC as the controller. It can realize the intelligent control of the lighting equipment, which not only reduces the manual intervention, but also makes the campus lighting electricity use a reasonable and scientific application. The consumption has been greatly reduced.

2. The Advantages of PLC Lighting Energy-Saving System

2.1. Simple operation method

Most of the control systems now use manual switches, which must be operated one by one. Manual control is required, which has high requirements for the professional quality and responsibility of the control personnel. The PLC lighting system can realize the automation of lighting management, with strong control ability, wide range and many ways. It can be pre-set through multiple scenes. Just press a button on the control panel, and each lighting loop can be changed to corresponding the lighting mode is simpler and easier to operate, and the requirements for the operator are lowered.

2.2. Diversified lighting methods

Nowadays, the lighting control system on campus has a single style, only open or closed. The PLC lighting system can adjust the brightness of the light, produce different lighting effects in different occasions and time points, and can save energy. In terms of maximum efficiency, the lighting requirements are met.

2.3. The energy saving effect is more significant

The PLC lighting system can be distributed and managed centrally. The operator can turn off the lighting of the unmanned room by operating the keyboard or remote control, avoiding the phenomenon of “long light”; at the same time, it can sense indoor light and natural light, and control the brightness of the indoor light according to actual needs. Maximize the use of natural light to achieve energy savings.

3. Design Steps and Methods

Classify the public lighting range of the campus, clearly dividing the indoor lighting area, road lighting area and landscape lighting area.
In terms of circuit design, ensure that the lamps on the same circuit are of the same type, that is, all incandescent lamps or all energy-saving lamps, preventing different types of lamps from being placed on one circuit, which is convenient for operation and management.

Be sure to operate each circuit below its rated power to ensure electrical and personal safety.
In terms of visual beauty, it is reasonable to control the difference in brightness between the lighting area and the landscape area to create a sense of beauty.

4. System Design and Function

4.1. System structure

The PLC lighting system consists of a system unit, an input unit and an output unit, each unit corresponding to a unique address to control the lighting system.
System unit: The connection between the main system and the subsystem is realized. The main system performs the same control commands and signal collection for each area, and the subsystem executes the network system of different commands in each partition. The data transfer between the main system and the subsystem must be done through a combination of different information elements.
Input unit: The externally transmitted control signal is converted into a digital signal recognizable by the controller through corresponding processing, such as a multi-function control panel, an infrared remote control with a switch light or adjusting the brightness, on/off, and the like. The PLC multi-function input control device can perform corresponding control on multiple nodes, and according to the preset requirements, the light intensity of the illumination is adjusted correspondingly by the information transmitted by the illuminance sensor to achieve the purpose of saving electric energy consumption.
Output unit: The output terminal is a variety of relays. The brightness of the lamps on the circuit is controlled by the signal output from the PLC controller. The control principle is designed to be centralized and controlled. At the same time, the programmable controller box should be equipped with automatic switch and manual switch, so that the automatic switch can be used in daily lighting work to save manpower. In abnormal situations, emergency control measures can also be taken by manually controlling the switch.

4.2. Software overall structure design

4.2.1. Indoor lighting control design

Today, the school's management of the lighting system of the teaching building is mostly extensive management, that is, when the students come, the people go, and then the building management staff turns off the lighting power of the entire teaching building at the time specified at night. Such a form of management will result in a large amount of electrical energy consumption, because the sensitivity of the human eye to low light is reduced under strong light, which makes it difficult for people to perceive the existence of light when the natural light is greater than the illumination of the lamp. This creates a phenomenon of day lighting lights, which wastes a lot of energy.
The PLC lighting system can realize the intelligence of the control system, use the principle of infrared to make a dynamic sensor, automatically identify whether there is someone in the classroom, and then send the signal to the controller. When there is no one in the classroom, the power is automatically turned off and all the lights are off; When there are people in the classroom, compare the actual illumination level in the room with the standard illumination value of the international classroom, and intelligently control the opening and closing of the lamps and the number and mode of turning on the lamps. PLC lighting system can not only make lighting scientific, save energy, but also reduce students' visual fatigue and protect students' vision. Table 1 shows the international standards for various room illuminations.

Table 1. International standard for room illumination

Campus location	Depending on plane and height	Lighting intensity(Lx)
Classroom	Class desktop	500
Experimental classroom	Experimental desk desktop	300
Art classroom	Desktop	500
Multimedia teaching classroom	0.75 Horizontal plane	300
Classroom blackboard	Blackboard	500

In addition, it is also necessary to consider the factors of campus winter and summer vacation. The annual summer and summer vacation time is about 3 months. During the winter and summer vacations, the number of students staying on campus is small. The school can control the number of open classrooms and manually control the lighting system to enable students to study. Relatively concentrated, reducing the range of illumination, in order to save energy.

4.2.2. Road lighting control design

4.2.2.1. Lighting layout planning and design

There are a wide range of colored light spots on campus. Because the roads on the campus are mainly pedestrians, including teachers, students and staff, there are also very few vehicles. The functional division of the lanes on the campus is not as clear as the highways. Pedestrians and vehicles are active in the same range of roads. Therefore, the design standards for the road lighting facilities on the campus are slightly higher than those in the residential areas, slightly lower than the commercial areas, and the light intensity is Greater than or equal to 15Lx. Considering the lighting energy-saving problem, on the basis of convenient time-sharing control, the road lamp road can be staggered on both sides, the pole distance is set to 25m, which is slightly smaller than the standard pole distance.

This can expand the range of illumination and reduce the dead angle of the light when controlling the lighting in time sharing. By measuring the length and width of the road surface, the luminous flux and the light source power can be calculated. The luminous flux ϕ is calculated as:

$$\phi = EKBD/(UN)$$

Where: E is the brightness of the road lighting, taking 15Lx; N is a double-sided staggered arrangement, taking 1;
U is the utilization factor, which is 0.8;
K is the asphalt pavement, take 2;
B is the width of the road, taking 12m;
D is the pole spacing, take 25m.
Substituting the data into the above formula gives:

$$\phi = EKBD/(UN) = (15*2*12*25)/0.8 = 11250Lm$$

By consulting the light source manual, a 150W metal halide lamp should be used. Through the campus area, total length of the road and other data, you can calculate the number of street lights and power consumption that the school needs to install. In the same way, the amount of electricity consumed by the landscape lighting facilities on campus can be calculated.

4.2.2.2. Time-division control of road lighting design

The student's activity time and activity area are clear, so the humanized design of the lighting system according to the student's work schedule can effectively control the consumption of electric energy. Before the system is optimized, the school can conduct research and statistics on the activities and activities of the students, so as to scientifically design the brightness and time of the lighting. For example, most students choose to study in a library or teaching building after class, or perform outdoor sports on basketball courts, football fields, and playgrounds. These activities are basically concentrated before 21:00, and most of the students have returned after 21:00. The bedroom, 23:00 is the school's blackout time, between 21:00 and 23:00, only a small number of students are outdoors, after 23:00, the bedroom building is closed. Therefore, the first time point of road lighting can be set at 21:00. Before 21:00k, the traffic volume on the campus is large, and the lighting facilities are all turned on; The second road lighting time point is set at 23:00, between 21:00 and 23:00, the number of activities is reduced, and the lighting facilities can be closed half; After 23:00, there are almost no people outside, only the minimum lighting is required, and basic lighting protection is provided for only a few pedestrians and night workers. Choose to turn off 3/4 of the road lights, so that the road surface illumination is higher than the minimum requirements of road lighting, that is, no less than 3Lx. By flexibly adjusting the brightness of road lighting, it not only ensures the safety of pedestrians on campus, but also achieves effective energy conservation.
Secondly, it is necessary to adjust the lighting duration according to seasonal factors. In the summer, when the night is short, the lighting time should be delayed, and the light-off time should be earlier; In the winter, when the night is long and short, the time for turning on the lights should be relatively advanced, and the time for extinguishing the lights should be relatively pushed back to ensure the safety of the students.

4.2.3. Landscape lighting control design

The time point for landscape lighting control can be set to 23:00, all open before 23:00, and 3/4 after 23:00. During holidays and winter and summer vacations, open or a small amount of time during the specified time period to meet the minimum lighting requirements. This control method is simple and easy to operate, and has significant energy saving effects, which greatly saves campus operating expenses.

4.3. Control principle design

4.3.1. Indoor lighting control design

The specific working method is: when the classroom is no one, the power is automatically turned off, and all the lamps are extinguished. When there are people in the room, there are three situations: If the classroom illumination degree $X \leq X1$, the lamps are all turned on; if the classroom illumination degree $X1 < X < X2$, the lamps are only half open or the mode of turning on the lamps according to the actual situation; if the indoor illumination degree $X \geq X2$, all the lamps do not open. Among them, the values of X1 and X2 can be calculated according to the average illuminance formula.

$$E = NUK/A$$

Where: Φ is the luminous flux;
N is the number of lamps;
U is the utilization factor of the luminaire;
K is the maintenance factor;
A is the indoor area.

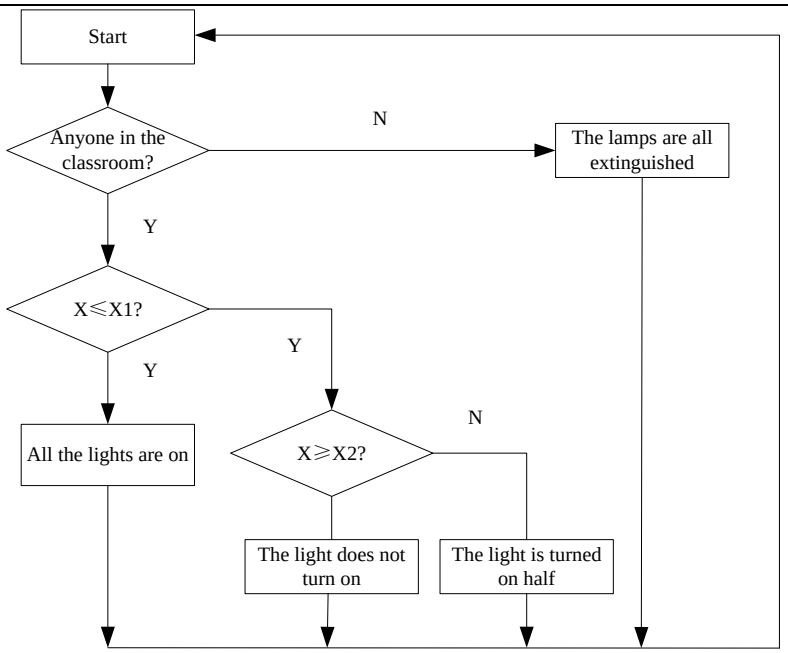

Figure 1. Indoor lighting control design

4.3.2. Road lighting and landscape lighting design

The specific working method is: 19:00-21:00, all road lighting and landscape lighting are all turned on; from 21:00 to 23:00, the road lighting facilities are opened halfway, and the landscape lighting facilities are all turned on; 23:00-the next day 6:00, road lighting and landscape lighting are all turned on 1/4.The time period is flexibly changed according to the change of the season and the holidays, the winter and the summer vacation.

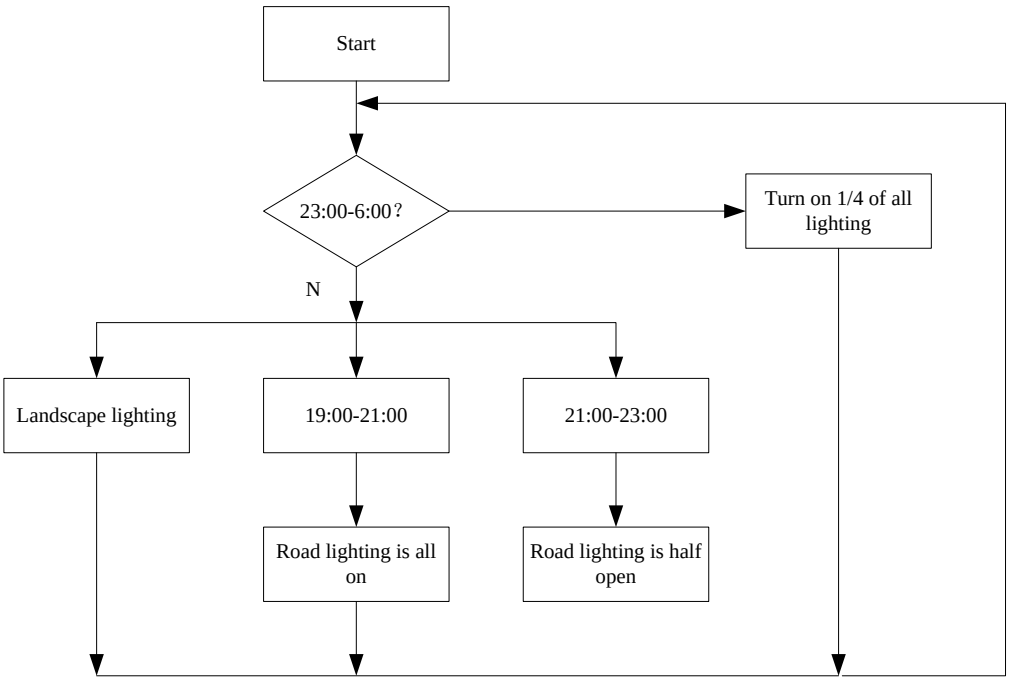

Figure 2. Road lighting and landscape lighting design

5. Conclusion

Campus lighting system based on PLC as control component is more flexible, easier to operate, low operating cost, low failure rate, bulb life can be extended by 2-4 times, direct investment can save at least 100,000 yuan. It realizes the rational and scientific adjustment of the lighting modes of campus classrooms, roads and landscape lighting facilities, can significantly reduce power loss, and efficiently achieve lighting requirements, and can provide reference for school lighting technology transformation.

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