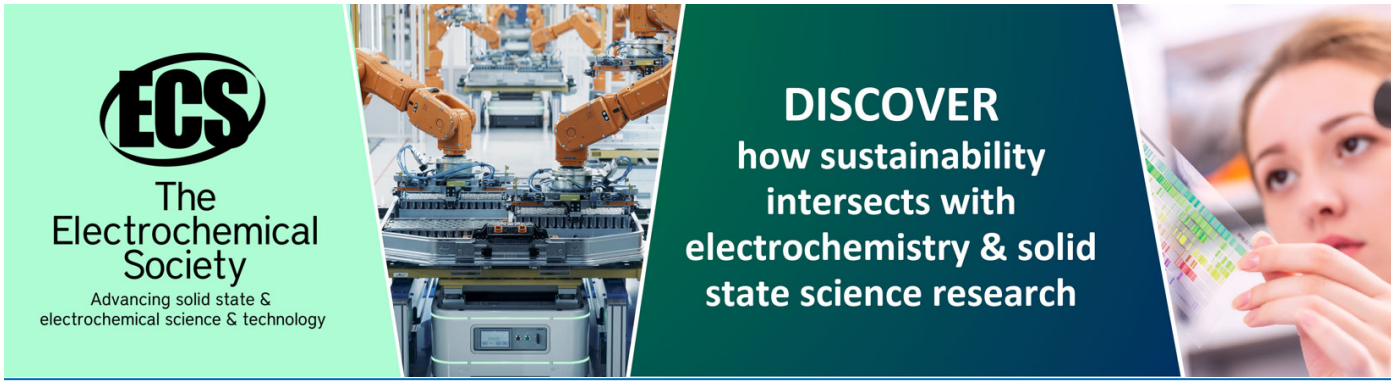
Intelligent lighting control system based on Internet of things technology



Intelligent lighting control system based on Internet of things technology

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Abstract—With the rapid development of the economy[1], the number of cars in our country continues to increase, underground parking garages have become commercial centers, supporting facilities in large residential areas, the number of underground garages is increasing, and the energy consumption of underground garage lighting systems is also rising. This question proposes an intelligent lighting control system based on the Internet of Things technology, studies the wifi protocol, wireless mesh networking technology, the Internet of Things cloud platform and other technologies. Based on the ESP32 chip, the terminal lighting control node is designed and developed, which cooperates with the sensor to realize the detection of personnel movement and light intensity information. The terminal lighting node controls the brightness and switch of the lamps according to this information, and realizes the effect of turning on the lights when the car arrives and turning off the lights when the car leaves, so as to achieve energy-saving control purpose.

1. Introduction

With the development of the times, people's requirements for lighting systems are constantly increasing[2]. The shortcomings of traditional lighting systems such as low light controllability and inflexible control methods have prompted people to start researching new light sources, new dimming technology and new lighting control. In terms of control technology, there are mainly DALI (Digital Adressable Lighting Lnterface) control technology, power carrier communication control technology and wireless communication control technology[3-6].In summary, this paper will design a new type of dimming control system based on the Internet of Things technology through the analysis of the above various light sources, dimming technology and control technology.

2. Several common intelligent lighting system control technologies

2.1 Pulse Width Modulation Dimming Technology

PWM technology is a technology that controls the output current by changing the period and duty cycle of digital pulses, PWM dimming, in simple terms, is to transmit the PWM signal to the gate of the MOS tube by connecting a MOS switch in series, so that the LED is in a fast switching state, and by changing the off and on time in one cycle, different LEDs can be achieved. When the stroboscopic frequency exceeds 200hz, due to the characteristics of residual vision of the human eye, the flicker generated by it will be ignored, and the effect of changing the brightness of the lamp will be observed. The waveform diagram of the PWM signal is shown in Figure 1.

Fig.1 PWM waveform with 50 percent duty cycle

2.2 SCR dimming technology

Thyristor dimming technology is mainly used in the dimming of pure resistive lamps, such as fluorescent lamps and incandescent lamps,By chopping the input 220V voltage sine wave, the average value of the overall voltage is reduced,Figure 2 is the schematic diagram of the thyristor chopper. Since the voltage waveform of the fluorescent lamp and the incandescent lamp does not need to be a standard sine wave, the voltage can be controlled by controlling the conduction angle of the thyristor, thereby adjusting the brightness,The advantages of bidirectional thyristor dimming are high efficiency and strong stability, but when adapting to the dimming of LED light sources, it is still relatively complicated. , When the LED light source is connected, problems such as stroboscopic and noise will occur, so in the dimming of the LED light source, an LED driver IC compatible with thyristor dimming is generally required.

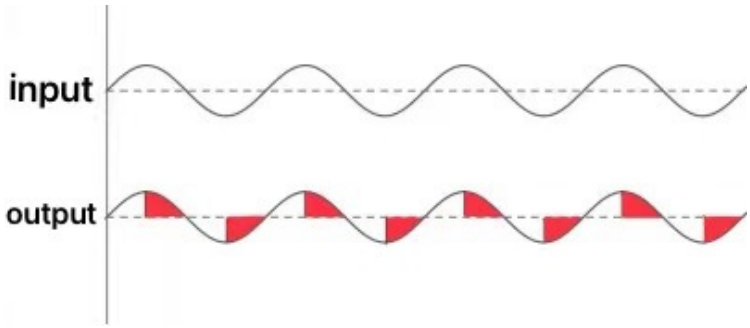

Fig.2 Schematic diagram of thyristor chopper

3. New dimming control system based on IoT technology

The system structure diagram of the intelligent dimming control system is shown in Figure 3.First set an esp32 chip as the root node,the lamp is used as a child node and integrates esp32 chip and triac dimming module on it,realize the dimming of AC lamps such as fluorescent lamps and incandescent lamps and upload the lamp status information, and send the running status and dimming parameters of the lamps to the Alibaba Cloud platform through the WIFI module that comes with the esp32 main control chip, and the Alibaba Cloud platform sends the information. To the computer client and mobile app, so that the administrator can perform remote manual dimming and switching on the computer client and mobile phone client. In addition, the infrared sensor is integrated on the main control chip, and the administrator can set the automatic mode through the client. Automatically turn on the light and adjust the brightness when someone passes by. Each light has a unique address as a child node, so that the brightness and switch control of the light can be finely controlled to a specific light.

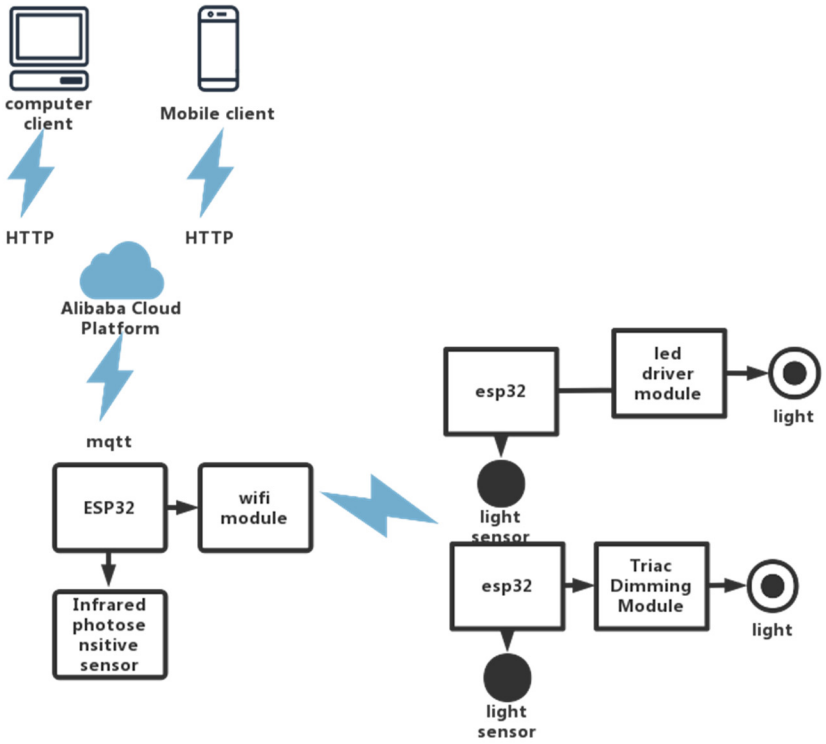

Fig.3 System structure diagram of intelligent dimming control system

4. System hardware design and development

4.1 Main board main control unit

The main control unit is the core of the hardware part of the entire intelligent dimming control system. The program of the main control unit controls the communication of the entire system and the scheduling of tasks such as light switching and illuminance adjustment, mainly including the minimum system, power conversion circuit, and lighting control circuit. .

4.1.1 Minimum System

The main controller selected ESP32 launched by Espressif. The main controller chip of ESP32 is a dual-core 32-bit MCU chip. The main frequency of the CPU is 240MHZ. The chip is powered by 3.3V. V4.2 and Bluetooth LE standards, with high performance and low energy consumption, the WIFI module supports three wireless protocols of 802.11b/g/n, of which 802.11n can reach a rate of 150Mbps, and the center frequency range of the working channel is 2412 to 2484 MHz. The hardware interface supports UART, SPI, IIC, IIS, LEDPWM, motor PWM, GPIO, pulse counter, ADC, DAC and other peripherals, and the price is also very low. It is widely used in smart buildings, smart agriculture, industrial automation and other fields. We will After comparing the STM32 chip with the same price as the ESP32, as shown in Table 1, we can see that the ESP32 is better than the STM32 in terms of main frequency, flash memory size and RAM size, and the STM32 has a lot more pins than the ESP32. , Since the number of peripherals in this system is not large, the demand on pins is not high. Since stm32 needs to be connected to the Internet through a wired network port, and ESP32 comes with a WIFI module and the price is lower, so after comprehensive consideration, This system uses ESP32 as the main control chip, which is convenient for function realization and cost saving. The minimum system schematic diagram of ESP32 is shown in Figure 4.

Table 1 Comparison of parameters between STM32 and ESP32

chip	flash	main frequency	pin	ROM	RAM	Supply voltage	WiFi module	price
STM32F407 VET6	512KB	168MHZ	100	512 KB	192K B	1.8V-3.6 V	no	38 yuan
ESP32	4MB	240MHZ	38	448 KB	520K B	3.0V-3.6 V	YES	25yuan

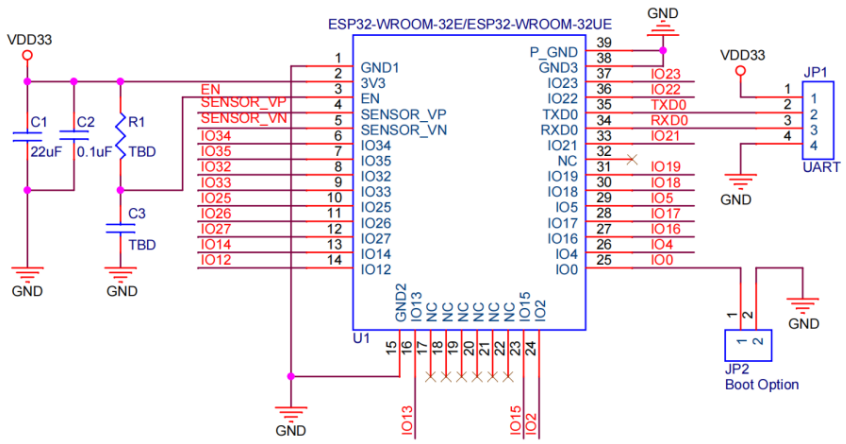

Fig.4 ESP32 minimum system circuit diagram

4.1.2 power conversion circuit

The mainboard supports AC220V AC power input, which can directly supply power to AC lamps such as fluorescent lamps. It can be stepped down to DC12V through the HLK-10M12 DC-DC power module to supply power for the pwm dimming module. After the DC12V is stepped down to DC3.3V through the PW2162 chip, the The main control chip is powered. The power conversion circuit based on the PW2162 chip is shown in Figure 5. The PW2162 chip supports input voltage DC4.5V-DC16V, output voltage is DC1V--15V, the maximum current can reach 2A, and the frequency is 600KHZ.

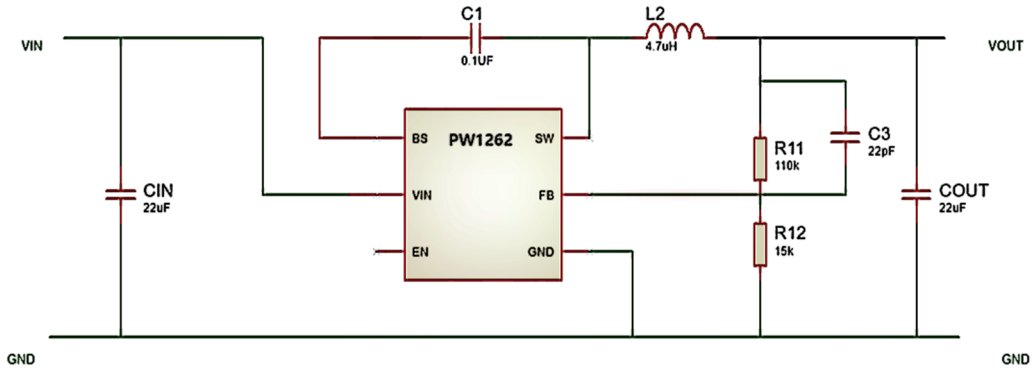

Fig.5 Power conversion circuit

4.1.3 Lamp control circuit

The lamp control circuit is the execution part of the system. The main board is designed with a PWM dimming circuit that controls the output current by changing the period and duty cycle of the digital pulse, and a fluorescent lamp dimming circuit based on triacs, which can realize LED lamps at the same time. And the 0%-100% stepless dimming of fluorescent lamps, and a zero-crossing detection circuit is designed to detect the zero point of AC voltage. MOC3061 is a photocoupler, which is used to drive thyristor and electrical isolation. LED constant current source The driving circuit chooses to

use the PT4115 constant current source driver chip, which can convert the DC voltage into a constant current and drive the LEDs. The io14 and io12 of the main control chip are used to collect the zero-crossing detection information and control the conduction angle of the thyristor for the fluorescent lamp. For dimming, io22 is connected to the DIM port of the PT4115 constant current source driver chip, which is used for PWM dimming of led lamps. The schematic diagram of the lamp control circuit is shown in Figure 6

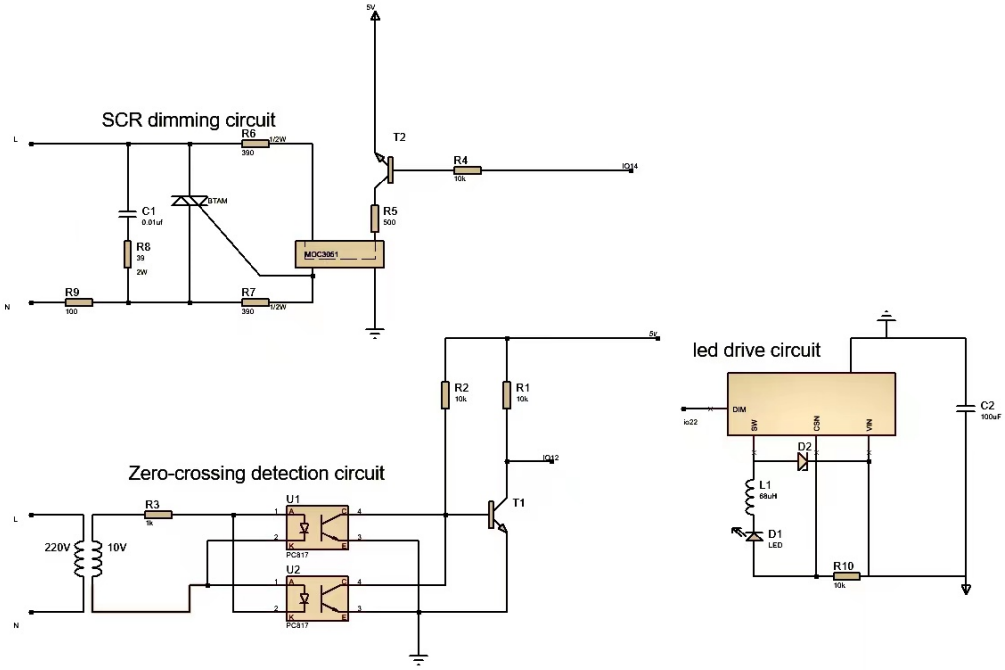

Fig.6 Schematic diagram of the lighting control circuit

4.2 Sensor selection

(1) Infrared sensor

In order to realize the detection of human body, a human body infrared sensor is used, as shown in Figure 7. The sensor has low power consumption, small size, high sensitivity, and long service life. It supports DC 3-12V input, and the static power consumption is less than 0,1mA. It is 2-5m, and the maximum sensing angle is 120 degrees. When there is human activity within the sensing range, the sensor will trigger the output to a high level, and after a delay for a period of time, it will drop to a low level. When the next human activity is sensed The delay will be recalculated. It is an important part of the intelligent lighting system to realize the lights off when people walk away and the intelligent sensing.

Fig.7 Human infrared sensor

(2) Light sensor

In order to obtain the operating status of the lamp and the light intensity of the external environment, a light intensity sensor is selected, as shown in Figure 8. This sensor has low power consumption and high measurement accuracy. It can be powered by 3.3V, and the measurement accuracy is 1lux. It uses an IIC communication interface. Small in shape, 26mm in outer diameter and 26mm in height, the measurement range is from 1-655251lux, and the light source dependence is weak. It can support the measurement of incandescent lamps, fluorescent lamps, halogen lamps, LEDs, fluorescent lamps and other light sources, and can also measure the illuminance of the external environment.

Fig.8 Light sensor

5.System software design and development

5.1 End node software design and development

The terminal nodes need to realize data acquisition, data transmission, and lighting control respectively. The terminal nodes use the form of wireless mesh networking. The networking process is as follows:

(1)First configure each node with the same mesh network id, router configuration and SoftAP configuration

(2) After the device is powered on, the ESP32 module starts the wifi mode, and enables the AP and STA modes

(3)According to the set root node, it forms a connection with the upstream, and starts to form the connection of the downstream node.

(4) Idle nodes other than the root node are connected to the root node to form a second-layer network

(5)Idle nodes other than the second layer are connected to the nodes of the second layer network

(6)Repeat (4) (5) until there are no more idle nodes or the set number of network layers is reached

After the terminal node is initialized, it first scans the channel, scans the network that can be joined, and sends a signal to establish a connection to the node with the strongest signal around it. After verifying the mesh network id and password, it connects to the network, and sends the sensor data to The root node. After the root node is initialized, it starts to scan the wifi network and joins. After the connection is successful, it starts to request to connect to the cloud server and sends a connect message. The key information of the connect message includes user name, password, will information QoS (quality of service level), The connection flags of the connect message are as follows:

Bit	7	6	5	4	3	2	1	0
	User Name Flag	Password Flag	Will Retain	Will QoS		Will Flag	Clean Session	Reserved
byte 8	X	X	X	X	X	X	X	0

Fig.9 Connect message connection flag

The server establishes a connection after verifying the connect message information, and performs message distribution and heartbeat detection. The data collection process is shown in Figure 10:

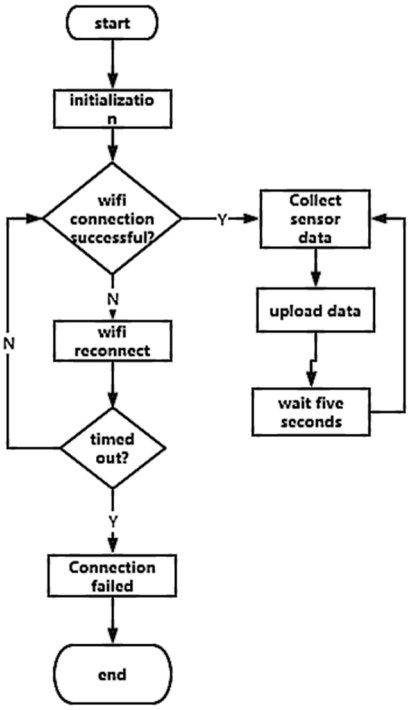

Fig.10 Data acquisition flow chart

When writing the host computer program, first determine the id of the terminal node, product id number, APIKEY, and authentication information. The difference between different types of equipment can be distinguished by the setting of the product id. In the mqtt cloud server, the same lighting The terminal node of the partition is placed under a topic. After the host computer publishes the message to the specified topic through the mqtt protocol, it parses the payload message body in the message to obtain the corresponding dimming parameters and realize the dimming control of the area. , can also be sent to a single lighting device to control the dimming of a single lighting device. Part of the key code of the parsing function of the payload message body is as follows:

```
StaticJsonDocument<400> doc1; //Create a Doc object of type StaticJsonDocument
DeserializationErrorerror1=deserializeJson(doc1,(char*)payload);//Parse doc1
const char* mmethod = doc1["method"];
long mid = doc1["id"];
String message = doc1["params"]; //extract the corresponding information
```

5.2 Deployment and Maintenance

Due to the decentralization of the mesh networking of the equipment, the MAC address of the lighting equipment and the installation address of the lighting equipment need to be in a one-to-one correspondence for precise control. The equipment deployment process is as follows:

(1) Install the equipment at the designated location according to the installation plan on site

(2) After the device is powered on, the device will be automatically discovered and networked

(3) Enter the serial number of the equipment installation location (area number + group number + address number) into the equipment on site

(4) The device sends the mac address and installation location serial number to the terminal

In order to remotely upgrade the functions of the device and repair system vulnerabilities, the mesh terminal node can achieve remote OTA upgrade through the mqtt protocol and file server. The

upgrade process is as follows:

(1) First create an OTA task on the mqtt cloud platform, including the mac address of the device to be upgraded

(2) The terminal device receives the upgrade instruction from the set OTA topic through the mqtt protocol

(3) The terminal device gets the job_id from the command

(4) The terminal device obtains firmware information (file server ip address, version information) from the cloud platform

(5) The terminal device downloads and upgrades the firmware through the file server

(6) Write the firmware into the flash memory and restart

(7) The upgrade is successful

6. System function realization

We implement the function of the system in an underground garage. The garage lighting consists of parking lights and lane lights. The remote lighting nodes of the underground garage are arranged as shown in Figure 11:

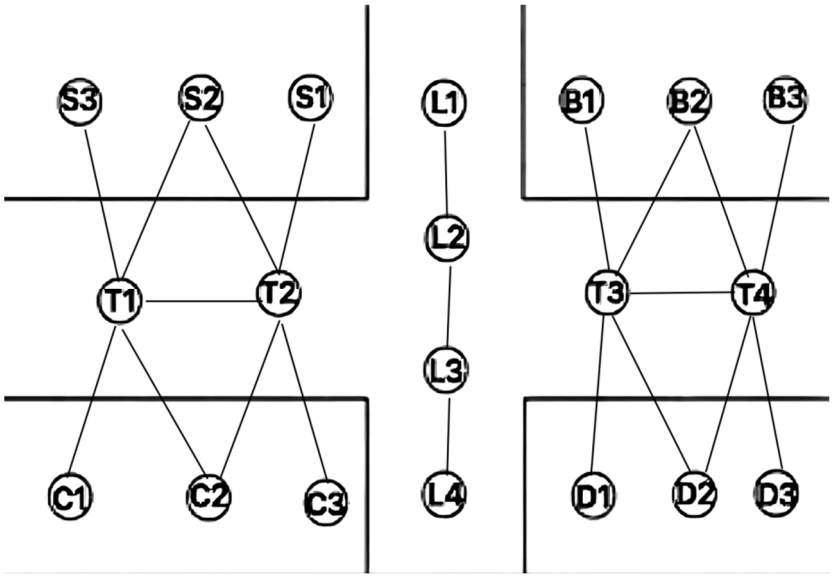

Fig.11 Layout of remote lighting nodes

The C-numbered lamps and T-numbered lamps are the lane lighting areas, and S, D, C, and B are the parking space lighting areas. When the vehicle enters from the entrance and exit, after the infrared sensor on L1 is triggered, the cloud server addresses and adds and subtracts the address number. The first lamp releases the dimming message, and lights the front and rear lamps together. At the same time, the L1 and L2 lamps use the linear dimming mode, which has the effect of gradually brightening, preventing the dazzling caused by the rapid change of brightness, and improving the driving safety. At L2, L1 and L3 will be brightened, other lane lights are in the lowest power running state, the brightness of the parking light will be increased after detecting that there is a car stopping, and it will be turned off after a delay of 5 minutes. When the vehicle leaves, it will be turned off after a delay of 3 minutes to achieve When the car comes, turn on the lights, when the car goes, the lights go out.

7. Conclusion

In this paper, an intelligent dimming control system based on wifi network is studied by using ESP32 chip, and each module of the terminal node of the intelligent dimming control system is designed and developed. And the stepless dimming of DC led lamps, and in-depth research on wireless mesh networking technology, mqtt protocol, the use of remote OTA technology, through the Internet of

Things cloud control technology and wireless forwarding technology, to achieve networking and remote switch dimming of lamps, the running status and fault information of lamps can be monitored in real time through sensors, and the control of the lighting system is more flexible and refined. The research of the control strategy and the versatility of the system in various scenarios of the intelligent dimming control system will take time and test. With the accumulation of experience, the intelligent dimming control system can reduce labor costs, improve lighting efficiency, and facilitate management and maintenance, which is the general trend of future lighting systems.

References

[1] Yang Bisheng.Analysis of energy-saving design of LED lighting in underground garage[J].Chinese Journal of Lighting Engineering,2020,31(04):105-109.
[2] Wu Haobo, Huang Ke, Wang Yongqiang. Energy-saving measures for underground garage lighting [J]. Lights and Lighting, 2018,42(01):44-46.
[3] Yang Chao, Wei Dong, Zhuang Junhua. Research and development of underground garage lighting energy-saving control system based on ZigBee wireless network technology [J]. Journal of Electrotechnical Technology, 2015, 30(S1): 490-495. DOI: 10.19595/j.cnki.1000- 6753.tces.2015.s1.084.
[4] Liao Jianjun.Analysis and Comparison of Lighting Schemes of Underground Garage[J].Intelligent Building Electrical Technology,2014,8(02):105-107.DOI:10.13857/j.cnki.cn11-5589/tu.2014.02.019.
[5] Song Ningliang, Wang Yajun, Luo Bingdong, Wang Ali, Liao Kun, Lv Haiyu. LED Lighting Design of Underground Garage Based on DILAUX[J]. Chinese Journal of Lighting Engineering, 2014, 25(01): 72-75.
[6] Bing Shukui, Wang Yunfeng, Gao Jie.Application of LED in Underground Garage Lighting Project[J].Chinese Journal of Lighting