DESIGN AND MANUFACTURE OF PUBLIC LIGHTING CONTROL SYSTEMS BASED ON LIGHT INTENSITY MEASUREMENT

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Abstract:

The issue of efficient and energy-saving public lighting has received special attention from the Government, Ministries, and local authorities nationwide. Research and application of technological solutions for public lighting control are essential to reducing costs. This paper summarizes the design and development of a public lighting control system based on light intensity measurement aimed at saving energy and operational costs - an effective solution that has been practically implemented in Bac Ninh province.

Keywords: Lighting system, light intensity, PIC microcontroller, BH1750 sensor.

Tóm tắt:

Vấn để sử dụng năng lượng tiết kiệm và hiệu quả cho chiếu sáng công cộng nhận được sự quan tâm đặc biệt của Chính phủ, các bộ, ngành và địa phương trong cả nước. Việc nghiên cứu và ứng dụng các giải pháp công nghệ để điều khiển đèn chiếu sáng công cộng nhằm tiết kiệm chi phí là rất cần thiết. Bài báo trình bày tóm tắt kết quả thiết kế, chế tạo hệ thống điều khiển đèn chiếu sáng công cộng dựa vào đo cường độ ánh sáng nhằm tiết kiệm điện năng, tiết kiệm chi phí trong quá trình vận hành hệ thống chiếu sáng công cộng - một trong những giải pháp hiệu quả đã được ứng dụng trong thực tiễn tại tỉnh Bắc Ninh.

Từ khóa: Hệ thống chiếu sáng, cường độ ánh sáng, vi điều khiển PIC, cảm biến BH1750.

1. INTRODUCTION

Public lighting systems are a crucial part of urban infrastructure, consuming a significant amount of electricity while offering great potential for energy savings.

Street lighting is a core infrastructure component in urban and semi-urban areas, providing numerous benefits such as enhancing safety for drivers and pedestrians. Currently, street lighting accounts for approximately 13-14% of the world's annual electricity consumption, and the market continues to grow [1-4]. By 2027, the number of streetlights worldwide is expected to reach 363 million, leading to substantial energy consumption [5]. This makes it essential to develop solutions that reduce electricity usage in public lighting systems.

As a result, research on energy-efficient solutions for public lighting has gained increasing attention from scientists. Around the world, many countries have implemented measures to reduce electricity consumption

in public lighting systems, such as alternating light shutdowns, dimming streetlights, using energy-efficient lighting technologies, installing lower-power lamps, and adopting remote monitoring and control solutions. While these approaches have contributed to energy savings, they have certain limitations - most notably, the fact that existing control solutions often do not take natural light intensity into account.

This paper presents the design and development of a public lighting control system that dynamically regulates streetlights based on real-time light intensity measurements. By integrating a BH1750 light sensor [10] and a PIC microcontroller [7], the system automatically adjusts the lighting according to ambient light levels, ensuring optimal energy efficiency.

The proposed solution has been tested in real-world conditions in Bac Ninh City, proving its effectiveness in reducing energy consumption while maintaining stable lighting performance. The results indicate that intelligent public lighting control significantly enhances operational efficiency and supports sustainable urban development, making it a promising approach for smart city applications [11].

The remainder of this paper is structured as follows: Section 2 describes the design and development of the public lighting control system, including the system model, controller design, and software implementation. Section 3 presents the experimental results, and Section 4 provides the conclusion of the study.

2. DESIGN AND MANUFACTURE OF PUBLIC LIGHTING CONTROL SYSTEMS

2.1. Public lighting control system model

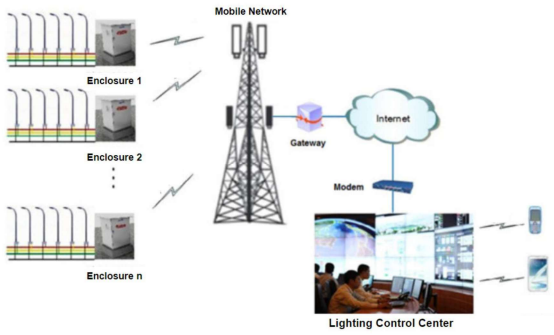


Figure 1. Public lighting control system

The public lighting control system consists of a streetlight control device and centralized management software.

The streetlight control device can automatically regulate public lighting based on preset schedules or be remotely controlled from the central system, utilizing real-time light intensity measurements.

The centralized management software enables remote control of public lighting, data storage, reporting, and statistical analysis of the lighting system's performance.

2.2. Design and manufacture of public lighting controller

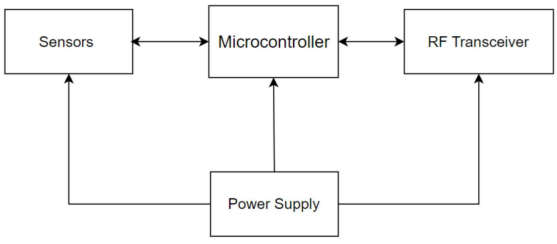


Figure 2. Block Diagram [6]

a) Microcontroller

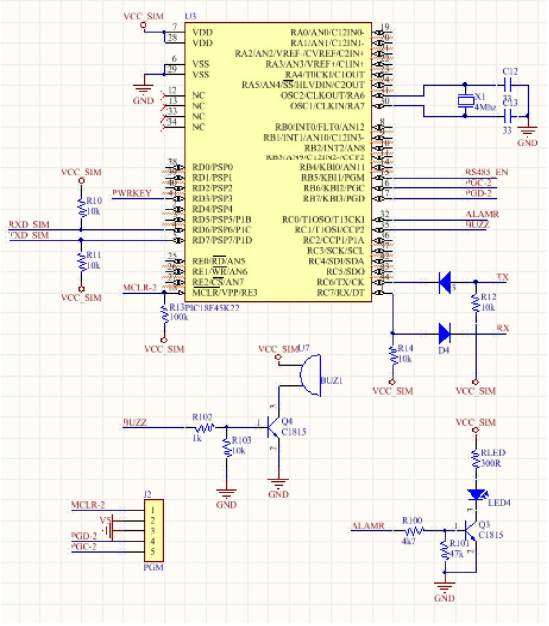


Figure 3. Schematic diagram of microcontroller

To ensure the functionality of the device, the central processing unit utilizes the PIC18F45K22 microcontroller, operating at a maximum clock speed of 64MHz. This allows it to process approximately 16 million instructions per second. The core configuration of the MCU is as follows: 64 kB of program memory, 3,896 bytes of RAM, 1,024 bytes of EEPROM, a 10-bit ADC module, and support for SPI, I2C, and UART communication protocols [7]. The schematic diagram of the central processing unit is illustrated in Figure 3.

b) Power Supply

This power module ensures a stable voltage supply for various functional blocks. The LM317 linear regulator delivers up to 2A, providing a stable 5.4V output, filtered to reduce noise [8]. For the communication module, the LM2576 switching regulator supplies up to 3A, efficiently powering the circuit [9].

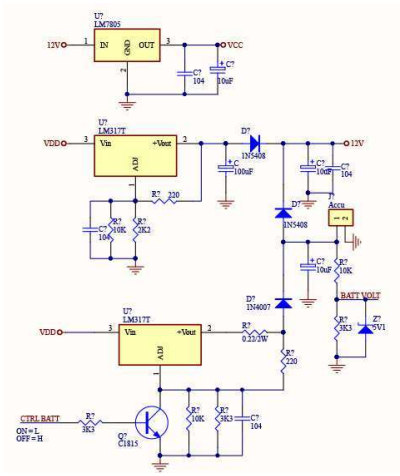


Figure 4. Schematic diagram of power supply

Additionally, a real-time clock (RTC) ensures accurate timekeeping, while an expansion interface enables connectivity with multiple devices, enhancing scalability.

c) Sensors

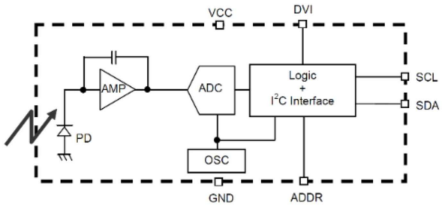


Figure 5. Schematic diagram of sensors

The sensors block utilize BH1750 sensor, which is optimized for efficient measurement signal reading and power consumption. The sensor can be read using the I2C protocol. The BH1750 is a 16-bit digital light sensor IC designed to measure ambient light intensity via the I2C communication protocol. It is ideally suited for capturing ambient light data to adjust the backlight brightness of LCD screens and mobile phone keyboards. This sensor offers a wide measurement range with high resolution, detecting light intensity from1 lux to 65,535 lux [10].

d) RF Transceiver

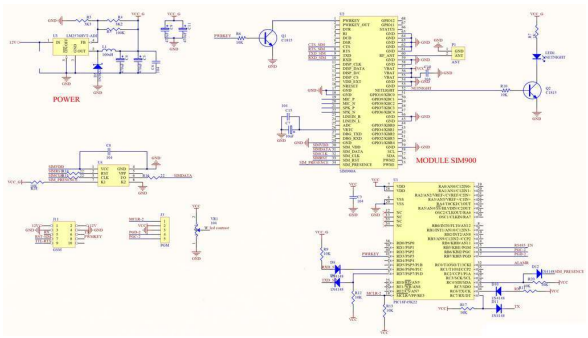


Figure 6. Schematic diagram of RF Transceiver

Figure 7. Hardware observation

This block handles sending and receiving control commands, information exchange and feedback between the public lighting control device and the communication module to send to the Microcontroller. It has five smaller parts: SIM Module, Power Supply, SIM Card Socket, Signal and LED module and antenna, which are demonstrated in Figure 6 below.

In addition to manually sending street light switch commands, rules can also be set on the center. Complete the command to automatically switch street lights according to the ambient light intensity. When the light intensity is greater than the threshold, the platform issues a light-off command, and when the light intensity is less than the threshold, the platform issues a light-on command [6].

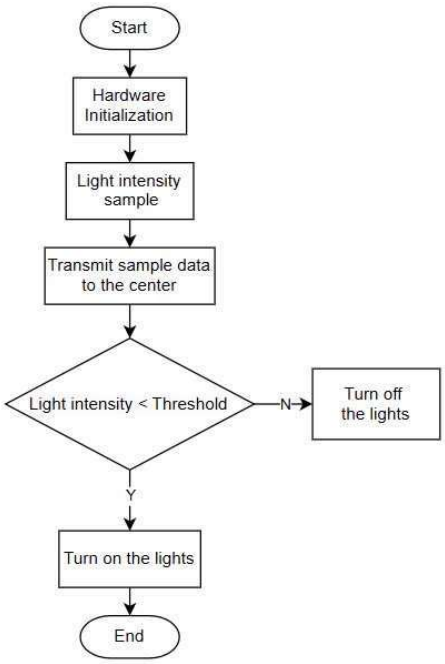


Figure 8. Flowchart

2.3. Software at controlling center

The public lighting control software is developed to meet the following requirements:

- The system is deployed on a web-based platform that supports multiple users and is backed by a stable network infrastructure and powerful servers.

- The web interface is designed to be user-friendly, ensuring ease of use and convenience.

- The system guarantees security and data protection, safeguarding user information and data collected from connected devices.

- Database Management: A relational database management system (DBMS) is selected to handle data efficiently.

- System Development: Built on a web-based platform, allowing deployment in one location while enabling access from multiple places.

- Real-time Data Display: Utilizes JavaScript and asynchronous XML (AJAX) to display measurement results dynamically.

- Report Generation: Implements RDLC reporting tools integrated within Visual Studio .NET and ASP.NET for simple and effective report creation.

- Data Exchange: Communicates with the server using Web API interfaces for seamless data transmission.

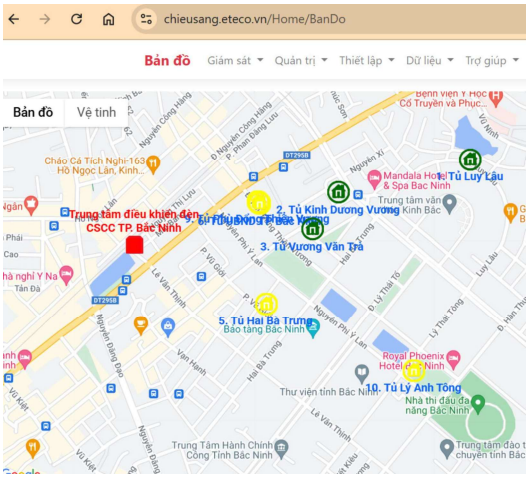


Figure 9. Web interface at controlling center

In addition to ensuring reliability during operation, security and system integrity are paramount. Therefore, a user management system is incorporated into the design. The system is structured in a modular format, allowing different modules to interact seamlessly during operation.

3. EXPRIMENTIAL RESULTS

3.1. Testing contents

The system has been tested at the research institution and in practical applications (12 lighting cabinets in Bac Ninh City) to evaluate its features and stability [11]. The testing focused on the following key aspects:

- The function of measuring light intensity.

- The function of communication between the device and the control center.

- The function of controlling public lighting, storing, and exporting data for management purposes.

3.2. Testing results

The installation of devices in 12 lighting cabinets of Bac Ninh City along with 02 light intensity measurement devices and public lighting control software (installed at the headquarters of An Hung Group Urban Environment and Public Works Joint Stock Company) [11].

Figure 10. The device installed at Le Thai To 1 cabinet

In addition to controlling the public lighting system, the system also has the capability

to store and export data for management purposes.

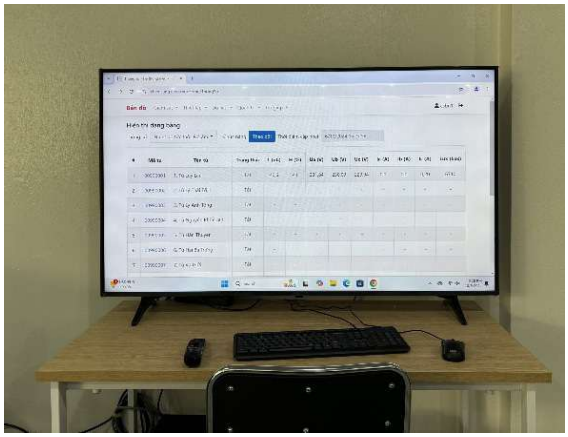
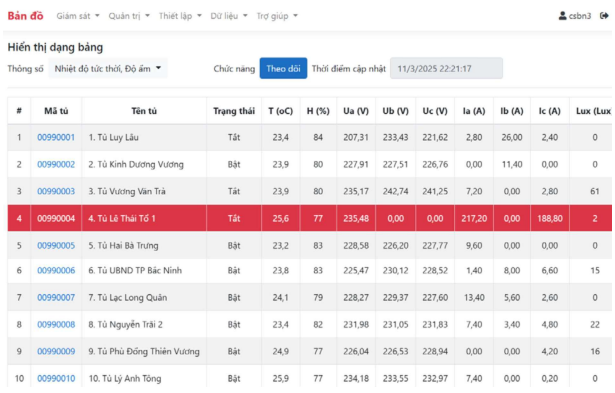


Figure 11. Controlling Center in Bac Ninh City



#	Mã tủ	Tên tủ	Trạng thái	T (oC)	H (%)	Ua (V)	Ub (V)	Uc (V)	Ia (A)	Ib (A)	Ic (A)	Lux (Lux
1	00990001	1. Tủ Luy Lâu	Tắt	23,4	84	207,31	233,43	221,62	2,80	26,00	2,40	0
2	00990002	2. Tủ Kinh Dương Vương	Bật	23,9	80	227,91	227,51	226,76	0,00	11,40	0,00	0
3	00990003	3. Tủ Vương Văn Trà	Tắt	23,9	80	235,17	242,74	241,25	7,20	0,00	2,80	61
4	00990004	4. Tủ Lê Thái Tổ 1	Tắt	25,6	77	235,48	0,00	0,00	217,20	0,00	188,80	2
5	00990005	5. Tủ Hai Bà Trưng	Bật	23,2	83	228,58	226,20	227,77	9,60	0,00	0,00	0
6	00990006	6. Tủ UBND TP Bắc Ninh	Bật	23,8	83	225,47	230,12	228,52	1,40	8,00	6,60	15
7	00990007	7. Tủ Lạc Long Quân	Bật	24,1	79	228,27	229,37	227,60	13,40	5,60	2,60	0
8	00990008	8. Tủ Nguyễn Trãi 2	Bật	23,4	82	231,98	231,05	231,83	7,40	3,40	4,80	22
9	00990009	9. Tủ Phù Đổng Thiên Vương	Bật	24,9	77	226,04	226,53	228,94	0,00	0,00	4,20	16
10	00990010	10. Tủ Lý Anh Tông	Bật	25,9	77	234,18	233,55	232,97	7,40	0,00	0,20	0

Figure 12. Monitor cabinets from center

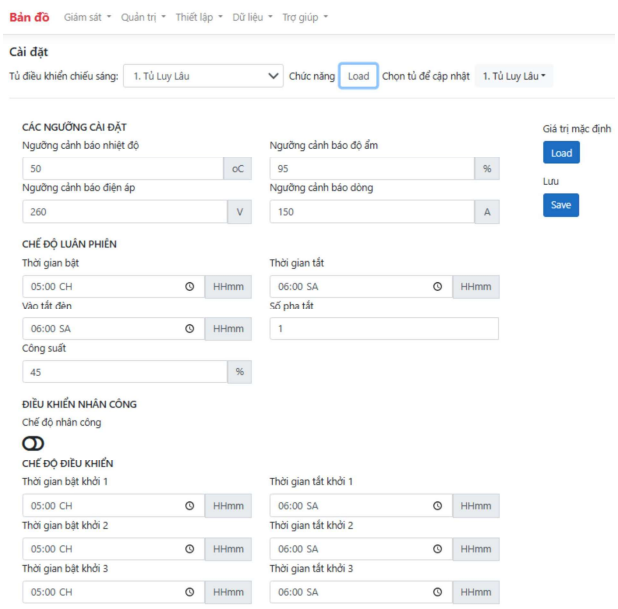


Figure 13. The function of setting the lighting control mode from the central system

4. CONCLUSIONS

The paper presents the key results of the research, design, and development process of the public lighting control system. The system consists of public lighting control devices and a central control center. It has been tested in practice in Bac Ninh City, yielding positive results and demonstrating potential for real-world application in public lighting control.

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Biography

Duy Phong Pham received the B.E. degree in telecommunications engineering from the University of Communications and Transport, Hanoi, Vietnam, in 2000, the master's degree in electronics and telecommunications from the Hanoi University of Technology, Hanoi, in 2007, and the Ph.D. degree in telecommunications engineering from the Vietnam Research Institute of Electronics, Informatics and Automation, Hanoi, in 2013. He was a Researcher with the Posts and Telecommunications Institute of Technology, from 2000 to 2005. He is currently the Dean of the Faculty of Electronics and Telecommunications, Electric Power University, Hanoi.

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