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# Research on Smart City Lighting System based on Conduction Angle Communication

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***Abstract*—Street lamp is the natural node of smart city, and smart lighting system becomes the key of smart city. The stability of transmission and communication have become the key technologies of smart lighting system According to the classification of street lamp signals, for one-way control signals, the communication between the centralized controller and the single-lamp controller can be realized by coding the conduction angle of the thyristor in power supply. The communication principle by the conduction angle is analyzed, which is highly reliable and requires no additional communication lines and no high-frequency carrier. It is suitable for one-way and small data communication, which is the key guarantee for street lamp control. Then, based on the conduction angle communication, the design scheme of smart city lighting system is given, mainly including intelligent cloud platform, centralized controller, driving power and single lamp controller.**

***Keywords-smart city; lighting system; conduction angle; thyristor***

## I. INTRODUCTION

As the important part of urban infrastructure construction, street lamps are a natural node to realize a smart city because of their "ubiquitous" natural geographical advantage and the convenience of power supply with municipal electricity. It makes use of the Internet of Things, cloud computing, big data, spatial geographic information integration and other new generation of information technology, so that street lamps all over the city can perceive and analyze a number of key information of the urban operation system, and realize the intelligent management of urban services, public security, environmental protection and so on.

At present, many problems still exist in the smart cities built all over the country [1-2]. The information construction is inadequate. Each information platform is relatively independent and lacks unified management and coordination. There are many kinds of systems and the data are not unified. The accumulated data of information system does not provide strong support for management and public service. It does not make full use of the characteristics of broad street lighting layout, strong physical bearing capacity of light poles and mature street lighting network.

It can be seen that the current research focus is to realize the integration of smart city through unified physical platform, electrical platform, communication platform and cloud platform, thus reducing implementation cost and improving management efficiency.

## II. THE KEY TECHNOLOGIES OF SMART LIGHTING SYSTEM

Combined with the relevant architecture of China's smart cities [3-4], the overall architecture of smart city is the standardized architecture with six floors and two wings, as shown in Fig. 1. It includes perception layer, communication layer, data layer, support layer, application layer and presentation layer, with bilateral auxiliary system. Smart city lighting system belongs to the application layer.

The openness of the management platform and the stability of transmission and communication have become the key technologies that determine the success or failure of the intelligent lighting system [5].

Communication layer is the information channel of intelligent lighting system. At present, wireless communication, wired communication and power line communication are commonly used between centralized controller and single lamp controller. By wireless communication such as ZigBee and LoRa, single light access quantity is unlimited, but the stability is general, electromagnetic compatibility is poor, lightning protection level is low, easy to be affected by external environment, such as tree shielding [6-7]. By wired communication like RS485, separate wiring is needed, easy to be damaged in construction, easy to be disturbed by parallel strong wires. Power line communication needs existing power lines to couple analog or digital signals to power lines for transmission [8]. It has a high false alarm rate, limited single light access and transmission distance, and is greatly affected by line conditions.

## III. COMMUNICATION PRINCIPLE BY THE CONDUCTION ANGLE

According to the actual use of street lamps, intelligent street lamps mainly have two-way communication signals and one-way control signals. Two-way communication signals, such as lighting fault feedback, power metering, video monitoring, screen display, weather station, charging pile and so on, have large data volume and high real-time requirements. One-way control signals, such as on and off light signals, pulse-width modulation signals, belong to one-way downlink transmission, with high reliability requirements, but small data volume and low real-time requirements.

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For one-way control signals, the power conduction angle can be coded for communication, and its reliability is equivalent to that of the power supply, and there is no need to lay additional communication lines. Silicon controlled rectifier, also known as thyristor, is widely used in rectifier circuit, is the main component of the centralized controller and driving power.

The working characteristics of thyristor are as follows. When the external reverse voltage is connected, the thyristor does not conduct no matter whether the gate pole has triggered current. When the external positive voltage is connected, the conduction is only carried out when the gate pole has trigger current. Once the conduction is carried out, the conduction is maintained regardless of the gate pole trigger current. To turn off the conducting thyristor, the electricity current must be reduced to near zero.

Take the single-phase half wave rectifier circuit waveform for example, as shown in Fig. 2. The primary voltage $u1$ changes to the secondary voltage $u2$ by the transformer. At ωt1 of the positive half cycle of $u2$, trigger pulse voltage $ug$ is given to the thyristor to conduct. Until $u2$ drops to 0 at π, the electricity current is 0, which means the thyristor is off.

The phase angle from the start of the positive voltage to the end of the trigger pulse is called the trigger delay angle, expressed by $\alpha$. The phase angle when the thyristor is conducted during one period is called the conduction angle, represented by $\theta$ and $\alpha=\pi-\theta$. The average DC voltage output to the load is:

$$U_d = \frac{1}{2\pi}\int_{\alpha}^{\pi} \sqrt{2}U_2 \sin\omega t \, \mathrm{d}(\omega t) = 0.45U_2 \frac{1+\cos(\pi-\theta)}{2} \qquad (1)$$

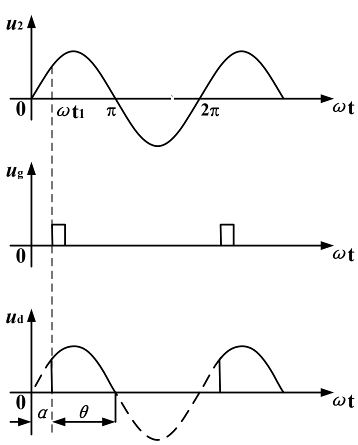


Figure 2. Conduction Angle modulation waveform

It can be seen that the value of dc output voltage can be controlled by adjusting the conduction angle $\theta$. Each voltage value corresponds to a set of digital signals. Through a certain coding method, the conduction angle is corresponding to the digital signal.

As shown in Fig. 3, the centralized controller modulates the one-way control signals by adjusting the conduction angle of the power supply output, and transmits it to the driving power through the power line. The driving power contains demodulation circuit, which decodes the signal containing the conduction angle into the corresponding control signal, thus realizing the communication of the one-way control signals by the conduction angle.

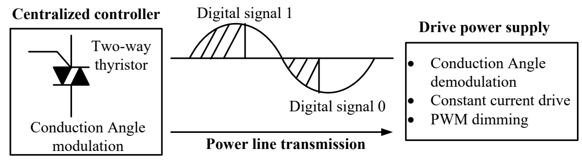


Figure 3. Schematic diagram of conduction Angle modulation process

This communication method has obvious advantages. It is suitable for long-distance transmission because of its wide detection interval and small attenuation effect. It has high fault tolerance. For example, the digital signal 0 corresponds to the sending conduction angle of 45° and the receiving conduction angle of 20 ~ 70°. The digital signal 1 corresponds to the sending conduction angle of 135° and the receiving conduction angle of 110 ~ 160°. In addition, this communication method does not affect the normal power supply.

For one-way street lamp control signals, each signal generally does not exceed 24bit, including 5 starting bit, 1 checking bit, 10bit address signal and 8bit control signal. The power supply signal is 50Hz, so the communication time of each signal is:

$$t = 24 \times \frac{1}{50} = 480\text{ms} \qquad (2)$$

The modulation of the conduction angle of the power supply will generate harmonics to reduce the Q value of the power grid and cause the distortion of the power supply. But in practice, one-way control signals of street lamps will not exceed 5 in 24 hours. According to Equation (2), the communication time of each signal is only 480ms. Obviously, in a 24-hour cycle, the impact of such a short power supply distortion on the power grid can be almost ignored. In addition, every street area is controlled by multiple centralized controllers, each of which controls a limited load power (generally no more than 20KW) and transmits signals alternately, so the power source distortion at any time is very limited and the interference to the grid can be ignored.

## IV. Design Scheme of Smart Lighting System

Smart city lighting system is mainly composed of intelligent cloud platform, centralized controller, driving power and single lamp controller. Additional functions such as video monitoring, information release, charging management and weather station are optional, as shown in Fig. 4.

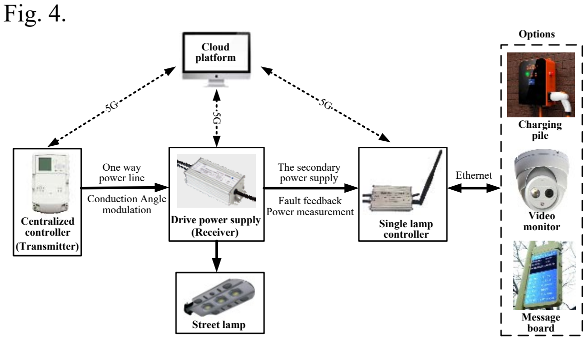


Figure 4. Design scheme of smart lighting system

Cloud platform is a system level monitoring platform. The monitoring system management software is Browser-Server architecture. Users can directly open and access it through the browser. No monitoring system software needs to be installed. Any computer in the network can directly monitor the city street lights through the browser and master the running situation of street lights. As the core, database and management interface of the system, cloud platform realizes application layer functions and data management and storage. Its functions are not limited to intelligent control of street lamps, but also have strong scalability and upgradability.

As the control core, the centralized controller is the bridge between the cloud platform and the single-light controller. It has independent off-line control ability and constitutes a completely independent system. Based on the principle of conduction angle communication, the centralized controller encodes the conduction angle of the thyristor while supplying power to the adjustable optical drive, so as to transmit one-way control signals. The core of the centralized controller is DSP high performance processor, which runs fast and has strong real-time performance. The conduction Angle coding adopts DSP to control the on-off mode of high-power SCR thyristor, which needs accurate control. The structure block diagram of the centralized controller is shown in Fig. 5.

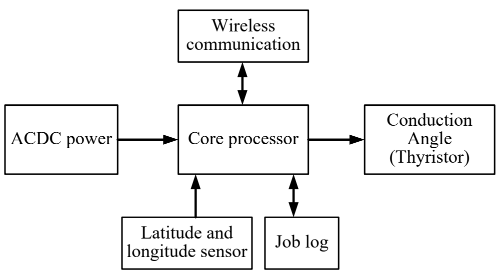


Figure 5. Schematic diagram of centralized controller operation

The drive power supply mainly includes EMC circuit, rectifier filter, constant-current driver, control circuit, ACDC converter. One-way control signal based on conduction angle coding is filtered through rectification. After linear voltage reduction, it is sent to the control circuit for detection and decoding, and the street lamp is turned on, off or dimmed by unidirectional control. The drive power supply structure block diagram is shown in Fig. 6.

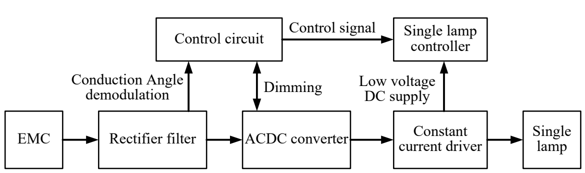


Figure 6. Structure diagram of drive power supply

The single lamp controller is the core of a single street lamp node, which realizes two-way communication between a single lamp node and the cloud platform. Ethernet communication is used between the single lamp controller and each subsystem within a single lamp pole. Besides the state of the driving power, the transmitted signals also include the signals of other subsystems such as video monitor, message board and charging pile. The structure block diagram of the single lamp controller is shown in Fig. 7.

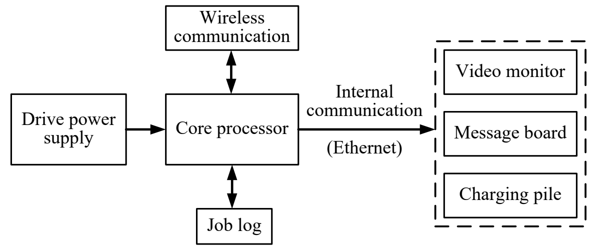


Figure 7. Structure diagram of single lamp controller

The smart lighting system can also be equipped with video monitor, message board, charging pile, weather station and so on. The existing mature hardware can be integrated into the main system and the nodes can be separated freely by hot plugging.

## V. CONCLUSIONS

Street lamp is the natural node of realizing smart city. Smart lighting system mainly includes intelligent cloud platform, centralized controller, drive power supply and single lamp controller. According to the classification of street lamp signals, one-way communication between the centralized controller and the single-light controller can be realized by using the conduction angle coding of the thyristor for one-way control signals. According to the working characteristics of thyristor, the basic principle of communication by conduction angle is analyzed. This communication method has obvious advantages and is suitable for short time and low frequency communication.

In the future, the research focus of smart city will be how to cooperate with smart traffic system, smart city management system, smart public security system and other urban subsystems.

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## REFERENCES


[1] L. Deren, Y. Yuan, S. Zhenfeng, "Big Data in Smart City," Geomatics and Information Science of Wuhan University, vol. 39, Jun. 2014, pp. 631-640, doi:10. 13203/j. whugis201401235.
李德仁, 姚远, 邵振峰. 智慧城市中的大数据[J]. 武汉大学学报(信息科学版), 2014, (06): 631-640.

[2] J. F. De Paz, J. Bajo, S. Rodriguez, G. Villarrubia, J. M. Corchado, "Intelligent System for Lighting Control in Smart Cities," Information Sciences, vol. 372, Dec. 2016, pp. 241-255, doi: 10.1016/j.ins.2016.08.045

[3] C. Cong, "The Design and Implementation of the Smart City Lighting System," Graduate Division, electronics and communication engineering, Jilin University, Jilin, 2019.
陈聪. 智慧城市照明系统的设计与实现[D].吉林大学,2019.

[4] C. Xi, L. Jicheng, Z. Yeming, H. Jing, C. Kai, "Study on Key Technologies in Design and Application of Smart Lighting System," Zhaoming Gongcheng Xuebao, vol. 28, Dec 2017, pp. 115-118, doi: 10. 3969/j. issn. 1004-440X. 2017. 06. 021.
陈希, 陆继诚, 张晔明, 韩靖, 陈铠.智慧照明系统设计应用中的关键技术探讨[J].照明工程学报,2017,28(06):115-118.

[5] K. Fanyu, C. Jianbo, Z. Tongyuan, C. Pengfei, "Smart Lighting Information System Design Based on Above and Below Ground Data," Zhaoming Gongcheng Xuebao, vol. 26, Oct 2015, pp. 14-18, doi: 10. 3969/j. issn. 1004-440X. 2015. 05. 003.
孔繁宇, 崔健博, 邹同元, 褚鹏飞.基于地上地下数据的智慧照明信息系统总体设计[J].照明工程学报,2015,26(05):14-18.

[6] Z. Xiaobo, L. Wenpeng, Y. Yue, "Research on the Standard System Framework of Smart Pole," Zhaoming Gongcheng Xuebao, vol. 27, Aug 2016, pp. 12-20, doi: 10. 3969/j. issn. 1004-440X. 2016. 04. 003.
庄晓波, 李文鹏, 杨平越．智慧路灯标准体系框架研究[J]．照明工程学报, 2016, 27 (4): 12-20．

[7] W. Wei, W. Min, "The Design of ZigBee Routing Algorithm in Smart Lighting System," Ferroelectrics, vol. 549, Oct. 2018, pp. 254-265, doi:10.1080/00150193.2019.1592568

[8] Z. Yonglong, "Design and Implement of the Control of PLCC Smart Street Light," Graduate Division, Software Engineering, South China University of Technology, Guangzhou, 2015.
占永隆. 基于 PLCC 的智慧路灯控制的设计与实现[D]. 广州: 华南理工大学, 2015.

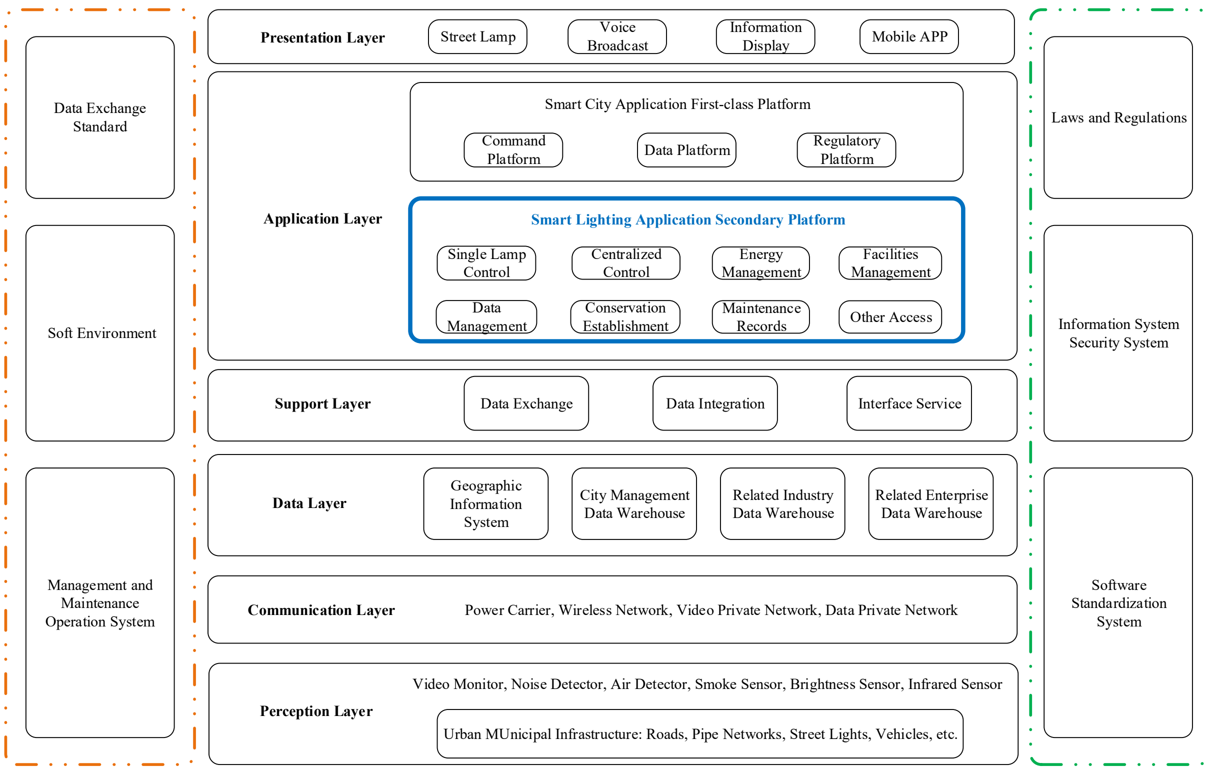


Figure 1. Structure diagram of smart city