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Application of Smart Streetlights in Urban Road Lighting

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Abstract: The construction and installation of street lighting is an important element in the modernization of China's cities. Besides, it also plays an important role in raising the living standards of the people. In recent years, with the technological and economic development, smart street lighting has gradually emerged. Key functions of smart street lighting include road illumination, cultural promotion, meteorological monitoring, public broadcasting, and 5G micro-base stations. The overall quality of smart street lighting construction directly impacts the effectiveness of urban development and the city's comprehensive growth. This paper analyzes the concept of smart street lighting, its advantages and disadvantages, the functionalities of smart street light systems, and the application of smart street lighting in urban road illumination.

Keywords: Smart streetlights; Urban street lighting; LED streetlights

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1. Introduction

China is currently undergoing rapid development of information technology and urbanization, leading to the increasing emphasis on smart city construction. Smart street lighting is an important aspect of smart city construction [1]. The Chinese government places significant emphasis on the construction of smart streetlights, providing both technical and economic support. Unlike conventional streetlights, which only serve basic lighting purposes, smart streetlights can effectively collect road information. This capability not only advances the construction of smart cities but also enhances urban service functions and overall service levels. Consequently, the living environment for residents is significantly optimized [2].

2. Overview of intelligent street lighting

Streetlights are mainly composed of lamps and poles. Intelligent street lighting extends beyond basic lighting functions, incorporating advanced technology and additional features. Smart streetlights have more advanced technology and richer functions, but they also come with greater complexity. Smart streetlights overcome various limitations and obstacles associated with traditional streetlights. They expand functional applications

effectively without requiring significant investment in maintenance and repairs, thus reducing labor and economic costs. Additionally, smart streetlights enhance application security and stability [3].

Smart streetlights offer a comprehensive application process, effectively integrating and maximizing various functions. As a crucial component in the development and construction of smart cities, smart streetlights incorporate wireless communication technology and power line carrier technology. This integration allows for the serial connection of streetlights across different city areas, enabling centralized control of all streetlights. During the design and construction process, each smart street light is embedded with a wireless communication module. This creates a more complete network system, allowing the intelligent streetlights to transmit information about their operational status to the control center. They can also receive and execute instructions from the control center promptly. The use of general packet radio service (GPRS) technology in smart streetlights facilitates effective communication between the control center and the streetlights, enabling timely responses to commands regarding lighting brightness and schedules [4].

3. Advantages and disadvantages of smart streetlights

3.1. Advantages

(1) Low-carbon emission

Intelligent streetlights exhibit relatively low energy consumption in practical applications, making them advantageous in low-carbon environmental initiatives. Additionally, they incorporate a greater number of integrated functions and human-centric designs, which extend the service life of the street lights. In comparison to traditional streetlights, intelligent streetlights can maintain lighting intensity while reducing energy loss, aligning with current sustainable development strategies [5]. Traditional street lamps primarily use high-pressure sodium lamps, which have shorter service lives. In contrast, intelligent street lamps typically utilize LED lights, which offer longer service lives, greater energy efficiency, and environmental friendliness. This transition can effectively reduce operating costs while contributing to sustainability efforts.

(2) Efficient management

In the current social and economic landscape, the widespread adoption of intelligent street lamps in lighting projects enables effective management and regulation of street lamp illumination and switching. Furthermore, it facilitates the seamless integration of remote communication technology, GPRS technology, and electric power carrier technology. Through the deployment of intelligent street lamps, not only is network infrastructure efficiently established, but also the security and stability of data collection and transmission are ensured. This ensures that intelligent street lamps not only enable network functionality but also guarantee the safety and stability of data operations. As a result, the efficiency and quality of smart street light applications are enhanced.

(3) Functional diversity

Traditional streetlights typically serve a single function, necessitating additional installations of traffic signs for effective traffic management. In contrast, intelligent streetlights integrate functionalities such as traffic lights and signs, streamlining management processes. This integration not only saves space but also optimizes resource allocation, promoting the development of smart cities. Information collection technology deployed in smart streetlights facilitates efficient data collection, storage, and transmission [6]. Moreover, smart streetlights can integrate AC charging piles, enhancing the convenience of charging for new energy vehicles and optimizing urban management efforts. Additionally, the inclusion of a one-key alarm function enables quick assistance for individuals in emergencies, reducing response times

and enhancing urban security measures [7].

3.2. Disadvantages

(1) Insufficient heat dissipation

Smart streetlights face challenges related to heat dissipation, particularly when exposed to ultraviolet rays and fluctuating temperatures. This can lead to a rise in the temperature of the smart streetilights, significantly impacting their performance. In the application of intelligent street lamps, not all electrical energy is converted into light energy; a portion is inevitably converted into heat energy. Prolonged operation of intelligent street lamps in high-temperature conditions may lead to damage or reduced effectiveness.

(2) Poor management

Currently, smart streetlights have been implemented in numerous cities across China. However, their application and supervision modes are relatively simplistic. Therefore, there is ample room for continuous optimization and upgrades during the application and construction phases of smart street lighting projects. These efforts aim to enhance the effectiveness of smart streetlight applications and improve management practices in each city [8].

4. Smart streetlight system function

4.1. Information acquisition module

The information collection module embedded within smart streetlights facilitates the effective collection of various data during practical applications, including data storage, transmission, and utilization. The LED light pole full-color screen serves as a platform for disseminating a variety of network information, including advertising and important content. This screen is versatile and capable of displaying commercial advertisements, public service announcements, and emergency information. By leveraging the information module in intelligent streetlights, urban management effectiveness is enhanced, while also improving the overall quality of life [9].

4.2. LED street light module

The application of LED streetlight modules in smart streetlights yields significant energy-saving benefits. Compared to traditional sodium lamps, LED lamps effectively reduce electricity consumption. In the construction of smart cities, smart streetlights allow for precise control at the terminal station and remote management of LED streetlights, including their switching status and brightness levels. This ensures quick and accurate transmission of collected data and information to the data terminal. Furthermore, in the application of LED street light modules, external electrostatic spraying is employed, and materials with higher thermal conductivity are selected based on actual conditions. This maximizes the effectiveness and advantages of intelligent streetlights. Moreover, it's crucial to analyze the application of smart street lamps in different cities in detail. Reasonable installation of regulators and relevant adjustment mechanisms at the corner positions of street lamps facilitates easy lamp replacement, thereby fully utilizing the functions and roles of smart street lamps [10].

4.3. Smart alarm module

Smart streetlights offer numerous advantages, with one of the most crucial being the intelligent alarm module. This module, when applied to intelligent streetlights, enables effective monitoring of outdoor areas by the monitoring center, facilitating the timely broadcasting of information. Broadcasting plays a key role in releasing emergency information and other relevant content, such as news and government announcements, to the public.

Outdoor extensions, on the other hand, are primarily utilized for emergency calls. In the event of an emergency on the road, individuals can activate the emergency alarm button to request assistance promptly. Through the network platform, the specific location of the alarm can be accurately pinpointed, providing people with essential social services and fostering the healthy development of the city.

4.4. Charging module

The charging module is an extremely important content component in smart streetlights. It provides charging locations for electric vehicles, thereby enhancing the overall effectiveness of smart streetlights. Moreover, when integrated with electric vehicles, this module can clearly display charging modes, power levels, and associated charging costs. Such features significantly contribute to the convenience of people's daily lives and travel experiences. Furthermore, this advancement aligns with China's trajectory toward smart city development, ensuring convenient and sustainable living environments for residents.

4.5. Monitoring module

The monitoring module is also a crucial component of smart streetlights. Within the smart monitoring system, the camera serves as the front-end intelligence unit. It effectively carries out tasks such as vehicle identification, video tracking, and video detection, providing crucial support for the emergence and development of video surveillance technology. Through the application of this advanced technology, smart streetlights can fully leverage its effects and roles. The inclusion of video cameras enables comprehensive monitoring of road conditions and records the entire road operation. Furthermore, integrating the camera with emergency visual alarm equipment allows for comprehensive monitoring of relevant areas. The data and information collected by these cameras are then transmitted to relevant management departments, providing robust support for urban development efforts.

5. Application of intelligent street light in urban road lighting

5.1. Power supply system

Smart streetlights place high demands on the reliability and safety of the power supply system to ensure a stable power supply, thus enabling the normal operation and auxiliary functions of smart streetlights for effective streetlight system management. Therefore, it is crucial to design the power supply system tailored to the specific requirements of smart streetlights, maximizing the advantages of both the power supply system and the smart streetlights while guaranteeing their normal operation.

(1) Specialized transformer and ring network power supply

The design of the power supply system should consist of a specialized box-type transformer and the application of a ring network power supply processing mechanism for the high-voltage part. This ensures the continuity and stability of the power supply system, minimizing disruptions. Additionally, when positioning the low-voltage component, ensuring a power supply radius of approximately 500 meters highlights the advantages of the low-voltage system, ensuring the safe and stable operation of smart streetlights.

(2) Adherence to relevant specifications

In designing the power supply system, strict adherence to relevant specifications and requirements of the streetlight system is necessary. This ensures that the cable line voltage consistently complies with regulations, aiming to keep it below 10%. Maintaining voltage parameters within acceptable limits is crucial for end equipment to function effectively, supporting efficient and high-quality information transmission for smart streetlights, while also ensuring data safety and accuracy.

5.2. Light pole line system

In the design and application of smart street lamps, optimizing and improving the lamp post line design is essential to ensure effective use while enhancing aesthetics and reducing safety hazards. (1) Upon completing the design of communication and power cables, it is crucial to lay them underground in a manner that aligns with the actual conditions. Adhering to relevant standards for power engineering cable design optimization ensures the security and scientific integrity of communication engineering and pipeline design. This approach highlights the characteristics of cable application while minimizing the impact on the surrounding environment. (2) Design work should adhere to relevant standards and regulations to ensure the construction of cable branch wiring. Typically, corresponding wells are set near command light poles. Additionally, based on the piggyback processing mode of intelligent streetlights, ensuring smooth implementation of relevant work is essential. This provides crucial support for the stable operation of intelligent streetlights.

5.3. Lighting control system

To ensure that the smart streetlight system meets the requirements of environmental protection during actual applications, it is crucial to conduct a comprehensive analysis of the lighting system. This includes an accurate assessment of relevant factors to enhance the security and rationality of streetlight management and design efforts. In the preliminary design phase of intelligent streetlights, the use of LED lights and transformers is necessary. This helps optimize the lighting control system, enabling a better understanding of traffic levels and weather conditions through the application of relevant intelligent systems. By integrating LED lights and transformers, the lighting system can be more energy-efficient, contributing to environmental protection efforts. Additionally, leveraging intelligent systems to monitor traffic and weather conditions facilitates resource management, ensuring optimal use of resources while minimizing environmental impact.

5.4. Intelligent management

As China's intelligent technology continues to advance, intelligent streetlights are evolving towards greater sophistication. Therefore, it is imperative to underscore the importance of intelligent streetlights and develop a more refined technical control mode that aligns with current practical application requirements and technical capabilities. This approach will fully leverage technological advantages, enhancing the quality and efficiency of intelligent management and facilitating the implementation of intelligent streetlight development. (1) Smart streetlights incorporating video surveillance technology can efficiently capture and record relevant data. This data can provide valuable assistance and support to traffic departments for accident investigations, thereby enhancing the effectiveness and accuracy of accident assessments. (2) Pedestrian sensing technology is another crucial aspect of smart streetlights. When no pedestrians are detected, the streetlights can remain energy-saving. However, upon detecting pedestrians, the lights can immediately illuminate, ensuring safe passage for pedestrians. This technology enhances pedestrian safety while optimizing energy usage.

5.5. Development prospect of intelligent streetlights

In the future development and construction of cities, there's immense potential for deep integration of various elements and the application of more equipment and technology to establish a comprehensive intelligent perception network. This network facilitates resource sharing, leading to reduced management and construction costs, as well as improved operational and maintenance efficiency. In the era of 5G development, smart streetlights emerge as crucial infrastructure. From the perspective of regulatory agencies and market institutions, it's essential to continuously streamline the approval process and related structures. This will ensure that smart streetlights evolve towards standardization, specialization, and diversification. By simplifying approval

procedures and fostering standardization, the deployment and management of smart streetlights can be more efficient and effective, ultimately contributing to the advancement of smart city initiatives.

6. Conclusion

In the future development and construction of cities, there is immense potential for deep integration of various elements and the application of more equipment and technology to establish a comprehensive intelligent perception network. This network facilitates resource sharing, leading to reduced management and construction costs, as well as improved operational and maintenance efficiency. In the era of 5G development, smart streetlights emerge as crucial infrastructure. From the perspective of regulatory agencies and market institutions, it is essential to continuously streamline the approval process and related structures. This will ensure that smart streetlights evolve towards standardization, specialization, and diversification. By simplifying approval procedures and fostering standardization, the deployment and management of smart streetlights can be more efficient and effective, ultimately contributing to the advancement of smart city initiatives.

Disclosure statement

The author declares no conflict of interest.

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