2018 IEEE Intelligent Vehicles Symposium (IV)
Changshu, Suzhou, China, June 26-30, 2018

Application Technology Investigation of Traffic Signal Controllers Which Output DC Signal

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Abstract— **Firstly, the paper gives a brief introduction to worldwide applications of specified traffic signal controllers which output direct-current signal. Secondly, related technologies to develop such traffic signal controllers as well as the problems that need attention are addressed in detail. Thirdly, several real benefits of using DC traffic signal controllers are given. Finally, the prospects of direct-current traffic signal controllers are analyzed and concluded.**

I. Introduction

Traffic signal control is an important component of urban traffic management and plays an important role in ensuring traffic safety and alleviating traffic congestion. The initial control of traffic signals began in London in the late 1960s, when police used semaphores to direct traffic. Later, the United States introduced a traffic signal control technology and replaced the semaphore with a signal light. The electromechanical device was used to control the signal light. With the development of computer and communication technology, microprocessor-based signal control equipment has become the mainstream of traffic signal control, forming a traffic signal controller (hereinafter referred to as a signal controller).

The light sources of early traffic lights were mainly tungsten halogen lamps, high-pressure sodium lamps, and incandescent lamps. The power supply methods used AC power. Most signal controllers therefore used AC power as the power supply for traffic lights. However, with the advent of light emitting diode (LED) lighting technology, traffic lights have begun to use DC powered LEDs as light sources. Compared with traffic lights of traditional light sources, LED lights have many advantages such as low energy consumption, long life, good visibility, and low heat generation [3]. Early LED light source traffic lights (hereinafter referred to as LED signal lights) were equipped with AC-converted DC circuits. Under the circumstances where LED lights were widely used, a direct-output DC signal-driven LED signal light came into being. The signal controller output DC signal directly can eliminate the AC conversion DC circuit of the traffic signal side, reduce energy consumption and save costs. In addition, malfunctions such as electric leakage and short circuit that endanger people's safety due to lightning strike, line aging, and construction damage can also be reduced, and operation safety can be improved. Therefore, a signal generator that directly outputs a DC signal and drives an LED signal (hereinafter referred to as a DC signal controller) has a good application prospect and may become a future development trend.

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II. Application of Traffic Signal Controllers Which Output DC Signal

At present, the signal controllers used in the market are still mainly output AC signals, but some manufacturers have also introduced DC signal controllers that output DC signals. The following briefly introduces these DC signal controllers.

A. Siemens ST950 ELV DC Signal Controller

In 2007, Siemens introduced the ELV (Extra Low Voltage) DC signal controller (Fig. 1) and conducted on-site installation and operation tests in Poole, Winchester and Newcastle. Siemens' latest model ST950 signal controller provides versions with two output drive voltages, 230V AC and 48V DC. The 48V DC version uses a fully rectified 48V ELV power supply to provide reliable control of LED signal lights.

Figure 1. ST950 ELV DC Signal Controller

B. AVT STOYE PTC9000 DC Signal Controller

More than 2,700 signal controllers are maintained in Germany by AVT STOYE. PTC9000 is the latest signal controller of AVT STOYE (Fig. 2). It can not only be compatible with the previous signal machine by directly transplanting the control program, but also has many new functions. It supports 10V, 40V, 230V signal output and can simultaneously meet AC and DC output requirements.

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Figure 2. AVT STOYE PTC9000 DC Signal Controller

C. SWARCO ACTROS DC Signal Controller

The Actros signal controller produced by SWARCO of the Austrian Swarovski Group employs a flexible modular architecture that can rapidly build the required signals and systems based on actual needs. The signal controller supports four signal lamp output voltages of 10V, 40V, 42V and 230V.

The above are several typical signal controllers that can provide DC output, among which the Siemens ST950 ELV signal controller has the widest range of applications and mature technology. Domestic manufacturers of DC signal controllers are few. Some manufacturers have introduced solar signal controllers that can be temporarily used at road intersections that do not have AC power supply and can be regarded as a simple DC signal controller.

I. Application Technologies of DC Traffic Signal Controllers

The main difference between the DC signal controller and the existing AC signal controller is that the DC signal is used to drive the LED signal lights. The technologies involved mainly include LED driver, low voltage transmission, DC detection, communication and power supply. They are separately described in the following.

A. LED driver

Most of the existing LED signal lights are driven by the switching power supply. At present, the quality of the switching power supply in the domestic market is uneven. If the reliability is poor, the heat is high, and the anti-interference ability is weak, damage is easily caused and the output cannot be normal. At present, with the popularity of LED lighting, LED drivers are becoming more and more widely used, and many manufacturers have introduced integrated LED driver modules. For example, a kind of bipolar multi-string LLC topology architecture, compared to the traditional LED drive architecture, the architecture of a series of high-voltage bucks into multiple transformers in series LLC resonant circuit, the direct realization of constant current drive, greatly improved efficiency. The number of peripheral components is greatly reduced, improving reliability and providing excellent EMI performance. The power of the LED signal light is relatively small, and it is required to be below 20W. Therefore, there is a large selection range when selecting the LED driving circuit and module, and the use of integrated high-quality modules can greatly improve the product stability.

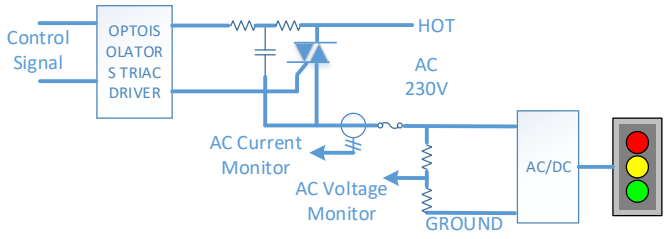
B. Low Voltage Transmission and Constant Current Control

DC signal controller adopts DC low-voltage transmission, which can reduce or avoid the safety hazards such as leakage and short circuit caused by the aging of the line. It also can prevent accidents such as electric pole damage caused by AC 220V leakage and signal cabinets being electrically damaged or even electrocuted. While improving safety, because the power of the LED signal light does not change, the output voltage of the signal controller decreases, the current of the transmission line increases, and the voltage drop on the transmission line increases. Therefore, the voltage loss on the transmission line must be effectively solved to ensure the low voltage transmission of the DC voltage. The luminous intensity of the LED signal lamp is not affected under the circumstances. The luminous intensity of the traditional incandescent light source lamp decreases with the decrease of the supply voltage, but the light output of the LED lamp can be maintained at a constant level within a certain supply voltage range. When the supply voltage is lower than a certain threshold Switch to a lower light output level instantaneously. If the supply voltage is significantly reduced due to the attenuation of the transmission line, the signal light will be dimmed or even extinguished. The United Kingdom has developed the CLC/TS 50509 specification for LED signals, which specifies that the LED signal lamp dimming voltage is 57% of the normal power supply voltage, while the traditional AC 230V signal lamp dimming voltage is 66% of the normal power supply voltage.

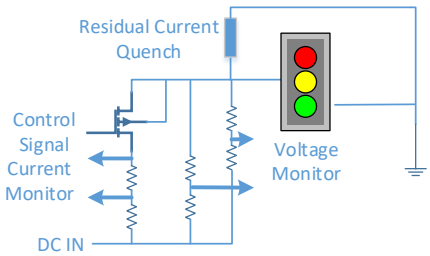
Because LED is a current-driven device, many parameters such as light efficiency, power efficiency, heat dissipation, and product brightness can be determined by precisely controlling the LED drive current in order to avoid voltage losses caused by low voltage transmission. A feasible way is to use a distributed constant current control method. It sets up an independent constant current source at the parallel branch points of each lamp group to manage, maintain, and control the stability of the branch and branch, the branch and the overall line. The distributed constant current circuit is a complete line structure for the signal controller, and the practical application is distributed in the lamp group nodes, which is a circuit structure that can be controlled by constant current and can communicate with each other. The distributed constant current branches can communicate with each other, implement an adaptive linkage mechanism, and are compatible with control and data read/write interface functions. In addition, the peripheral design is zero-device, and the output voltage of the power supply matches the load impedance, thereby realizing the integration of the constant current source and the LED light source.

C. DC detection

In order to accurately determine the output status of the LED signal lamp, the voltage and current of each signal lamp must be detected. Based on this, the actual signal lamp status is obtained and compared with the status set by the signal controller to perform green conflict, red light extinguishment, and full lamp group. Extinguish and detect faults such as lamps and lanterns, ensure the normal and safe operation of the signal. After changing the AC output to DC output, the signal detection circuit needs to be redesigned to detect the DC voltage and current. The AC signal controller measures the AC 220V voltage on the output cable and the current flowing through the output cable; the voltage drop of the DC signal generator circuit is relatively large, and the voltage at the output terminal of the measurement signal does not accurately reflect the actual voltage at the signal terminal (Fig. 3). The test can measure the current flowing through the transmission cable. For the detection of DC current, it needs to be comprehensively considered in terms of accuracy, power consumption, reaction speed, etc. The measurement method is usually divided into direct mode and indirect mode.



(a) AC Drive And Monitor Schematic



(b) DC Drive And Monitor Schematic

Figure 3. Drive and Monitor Schematic

The direct method is generally connected in series with a resistor in the transmission line, and the current on the transmission line is calculated by measuring the voltage across the resistor. The indirect method calculates the magnitude of the current by monitoring the magnetic field generated by the current. The direct measurement method has a simple circuit and low cost but requires a high accuracy and good temperature drift characteristics. For a DC signal controller, the output voltage is not high and the current is relatively small, and it is relatively suitable to use the resistance detection. For the detection of DC voltage, it needs to be done at the input end of the signal lamp. If you only care about the on and off of the signal lamp, you don't need to get the specific voltage value, you can set the corresponding voltage threshold, and send the signal at the input end of the signal lamp to the signal function through the circuit. The processed signal is connected back to the signal controller; if it is necessary to accurately obtain the input voltage value of the signal lamp, a high-precision A/D detection circuit needs to be used at the front end, and the acquired value is transmitted to the signal controller with a digital signal.

D. Communication

The communication of the DC signal controller includes the communication between the signal controller and the traffic control center, and the communication between the signal controller and other road traffic control equipment. The former basically uses the Ethernet wired transmission method, and the latter includes Ethernet, serial communication, wireless, etc. Because the signal and traffic control center need to maintain effective and reliable communication, including the delivery of the program, the uploading of signal status, the uploading of fault information, and the uploading of detection data. At present, the fiber-optic cable transmission method is widely used, but it is necessary to suppress the network. Measures such as storms, network downgrade processing, and data encryption are implemented to ensure reliable communications under the premise of ensuring the stable operation of the signal.

Wireless methods have been used between vehicle detectors (mainly geomagnetic detectors) and terminals, and between on-board devices and receiving terminals. The signal setting of road intersections is directional. Generally, poles need to be erected in all directions, and the cables of the lamp group are gathered at the signal controller. This requires the laying of a large number of cables, which not only requires an increase in the number of working hours during construction, but also increase the cost, and it will also bring difficulties to the post-maintenance. If the signal and the signal groups in all directions can communicate by wireless, eliminating the cable connection between them, you can save a lot of costs. At present, some master-slave wireless communication-based traffic signals use wireless means to achieve communication between the traffic signals and signal groups of various directions. The key to restricting the widespread use of such master-slave wireless communication-type signaling devices is the stability and reliability of wireless communication.

Currently used wireless communication methods include Bluetooth, ZigBee, infrared, NFC, HomeRF, ultra-wideband, Z-wave, WiFi, etc., among which Bluetooth, infrared, NFC, ultra-wideband transmission distance is short, it is difficult to meet the road intersection signal and the communication requirements between the signal lamps and other communication methods can basically meet the communication distance. However, because of the different communication rates, networking methods and operating frequencies, there are differences in the feasibility of applying them to road intersection wireless communication. In a comprehensive view, ZigBee and WiFi are more suitable for use. ZigBee is a low-speed, low-power wireless control protocol. It features automatic network configuration. Each node in the network can relay data, but it needs a centralized node to manage the entire network. Complete conversion of ZigBee protocol and Internet protocol, commonly known as

ZigBee routing device. WiFi has high transmission speed but high-power consumption, can directly access the Internet, and seamlessly connect and communicate with mobile devices such as mobile phones without additional equipment. At present, ZigBee is mainly used in low-rate and low-power applications to build wireless sensor networks, such as industrial control, environmental monitoring, and smart home. WiFi is mainly used for the establishment of a certain range of wireless networks. Its coverage range is about 100 meters, and wireless networking of various devices within the coverage area is realized.

The road intersection has a special operating environment and the electromagnetic environment is complex. It will affect the strength of wireless transmission signals. Traffic signal control requires high stability and real-time performance. Packets that transmit traffic light control data are lost or delayed. At this time, the output errors and lags of the signal lamps in one direction will be affected, which will cause more serious consequences. From the current point of view, it is difficult to guarantee the reliability of traffic control data transmission using wireless communication between the host and the slave. It is not recommended to use wireless communication in traffic signal control. The use of wireless communications to achieve the connection between the external equipment and the signal, such as bus priority module, vehicle detection module, handheld terminal module, etc., to obtain data and achieve status query and parameter configuration, due to relatively low real-time requirements, compared to wired connection does not require wiring, is easy to use, has great advantages, and is being gradually promoted. Therefore, the application of wireless communication in traffic signal control also requires field testing and verification. It also depends on the maturity of wireless communication technology. It is believed that wireless communication will occupy a place in traffic signal control in the future.

E. Power Supply

Different from the AC signal controller, the DC signal controller directly outputs the DC control signal, so it must have DC power supply that meets the intersection signal light and signal controller power demand. Possible methods include AC to DC power supply or solar energy plus DC battery supply. AC to DC power is a more reliable method. It mainly uses a switching power supply, but it needs to provide sufficient power output and ensure the quality of the power supply is reliable. If there are more traffic light groups in the intersection, you can consider using multiple power supplies to power each direction lamp group.

Currently, solar traffic lights and solar street lights have been used because they are more energy-efficient and environmentally-friendly than ordinary signal lights. It is not necessary to install power cables during installation, and it can effectively cope with unexpected situations such as power outages and will become more and more popular. For DC signal controllers, the use of solar power has a natural advantage, because the solar battery output is DC, can directly drive LED lights, eliminating the need for inverter and AC to DC links. Solar power supply generally includes solar panels, battery packs, and control systems. Among them, solar panels and battery packs are the core components. They must be selected and deployed according to the actual conditions on the ground.

The main problem of using solar energy is the length of time that the obtained electricity can work continuously, especially if it is continuous and rainy, whether solar energy can maintain normal operation. A simple calculation can be made here. If the effective light-receiving area of the solar panel is 8 square meters, the photoelectric conversion efficiency is 30%, the radiation power per square meter is 1 kilowatt, and the one-day illumination time is 6 hours. The electric energy is 14.4 kWh. According to the four signal lamp groups, each signal lamp group has 20 watts of power, and the normal working total power is 80 watts. Theoretically, the continuous working time can reach 180 hours, which can basically meet the needs of use. However, in practical applications, the solar panel size and the battery capacity need to be selected according to the local lighting conditions, the power of the lamp group, etc. If necessary, AC 220V and solar power may be used at the same time to ensure the normal operation of road intersection signal controllers.

II. Benefits of Using DC Traffic Signal Controllers

Compared to AC signal controller, DC signal controller output DC signals to drive LED lights, which have the following advantages:

A. Increased Electrical Safety

For AC signal controller, AC 220V signals are transmitted on the lines. These lines are connected to each signal group in every direction of the intersection through underground pipelines. Once the lines are damaged, leakage may occur, which may cause equipment damage and pose a threat to public safety. Even if the line is not damaged, in order to ensure that members of the public will not be the risk of electric shock, the terminal with the power potential is usually set up where people cannot easily reach. This will increase the difficulty of maintenance work and increase the risk of operation. The situation of DC signal controller is different. When the DC signal line is damaged, because the voltage is within the safe range, even if someone touches it, it will not cause harm, which will greatly improve the safety. Due to the use of low-voltage equipment, it can be placed in a position easily accessible by maintenance staff, reducing work difficulty and improving safety.

B. Reduced Energy Consumption

The power of the LED signal light is continuously declining. The new LED light consumes approximately 10W in the case of brightness. This is much lower than traditional incandescent lights. It can offer up to 80% power saving over traditional signal lights. For the AC signal controller using the same LED lamp, although the power consumption of the LED light is equal, but due to the use of AC power supply, AC/DC conversion is needed, which will bring losses. The loss of used switching power supplies includes conduction losses and switching losses. A good power supply efficiency can reach about 80%. Therefore, the DC signal controller can avoid this conversion loss, saving at least 20% of energy consumption.

C. Reduced Installation Costs

In addition to reducing energy costs, DC signal controllers can also save a lot of installation costs. The high and low voltage parts of the AC signal controller usually need to be separated to ensure safety. For example, connecting a light group and connecting a detector requires two separate cables, one for the high voltage lamp group and one for the low voltage detector line. Since the DC signal controller adopts low-voltage transmission, no line separation is required, thus reducing the number of cables. The monitoring of the DC signal can be carried out directly, without the need to install additional equipment and devices such as transformers, which reduces the cost of the signal controller. Taken together, using a DC signal controller can reduce the construction cost of the intersection by about 30%

III. CONCLUSION

Most of the existing signal controllers use AC power, and a large part of the reason is that they are limited to the early metal halogen lamps, high-pressure sodium lamps, and incandescent lamps as light sources. With the popularity of LED signals, the use of DC signals has become a better choice. DC signal controllers can not only convert AC power to DC power, but also can use other clean energy sources and have wide applicability. For example, existing solar energy signal controllers on the market can work by converting solar energy into DC power. It can be looked as a kind of simple DC signal controller. The installation of DC signal controllers can be carried out without replacing existing infrastructure facilities. Existing pipelines and signal lights can be used and have better implementation conditions. DC signal controllers also have advantages in terms of safety. Using low-voltage transmission can effectively prevent threats and injuries to surrounding personnel.

With the accelerating process of urbanization in our country, the investment in road construction will increase accordingly. It can be foreseen that there is a large market demand for signal controllers. At present, the technology involved in DC signal controllers has matured and can completely cover all the functions of traditional AC signal controllers, and it has the advantages of safety, energy saving, stability and low cost, and has a good application prospect.

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