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Application of Distributed Intelligent Power Supply Technology in Expressway Tunnels

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Abstract: With the coordinated development of today's social economy with science and technology, various advanced technologies are being used in highway engineering, especially the distributed intelligent power supply technology in expressway tunnels, which has a very significant advantage. In order to realize the effective application of this technology and promote the power supply effect in expressway tunnel, this study analyzes the advantages of this technology and its application in expressway tunnel, hoping to provide scientific reference for the application of distributed intelligent power supply technology and the engineering development of expressway tunnels.

Keywords: Distributed intelligent power supply; Power supply technology; Expressway tunnel

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1. Introduction

In the traditional expressway tunnel power supply, a large number of high voltage and low voltage cables are required; there are also many bus cables, in which the cost is very high. The overall construction is very complicated because the traditional power supply system uses a three-phase power supply, in which the three-phase load balance needs to be maintained, and the lamps need to be connected separately. In addition, if there is a need for power monitoring and voltage regulation, the additional power monitoring system and voltage regulator settings will further increase the construction cost. In order to solve the aforementioned problems and fully meet the power supply demand in expressway tunnels, relevant units and technicians need to explore the distributed intelligent power supply technology and make it fairly applicable to the power supply in expressway tunnels.

2. Main power consumption facilities in expressway tunnels

In expressway tunnels, the main power facilities are equipment ventilation facilities, monitoring facilities, and lighting fittings. In expressway tunnels, the main ventilation equipment is the tunnel ventilator. At present, the main monitoring equipment applied to expressway tunnels are lane indication signs, smart boards, cameras, evacuation indication signs, and various detectors. The lighting section in the tunnel is usually divided into five parts: the first is the reinforced lighting section at the entrance; the second is the reinforced lighting section at transition 1; the third is the reinforced lighting section at transition 2; the fourth is the basic lighting section; and the fifth is the lighting section at the outlet. When dividing based on the function of lamps, the expressway tunnel can be divided into three: the first includes strengthening the lighting lamps; the second includes basic lighting lamps; and the third includes emergency lighting lamps.

3. Analysis of the power supply scheme in traditional expressway tunnels

The traditional expressway tunnel power supply scheme is mainly used for power facilities, including ventilation equipment, monitoring equipment, and lighting fixtures.

3.1. Power supply scheme for ventilation equipment in traditional expressway tunnels

When supplying ventilation facilities in expressway tunnels through the traditional power supply scheme, it is necessary to set up the loop of each fan separately and choose the cable specifications based on the actual length of the loop. Setting the fan control cabinet at the lower end of the fan allows for a more regulated soft start and positive and negative rotation.

3.2. Power supply scheme for monitoring equipment in traditional expressway tunnels

In regard to the power supply for expressway monitoring equipment through the traditional power supply mode, various detectors, indicators, smart boards, and cameras need to be jointly connected to the same power supply cable, and the power supply circuit needs to be set separately from the lighting lamp circuit. At the same time, the circuits need to be configured separately based on the different types of monitoring equipment. In such cases, a large amount of cable laying is required.

3.3. Power supply scheme for lighting fixtures in traditional expressway tunnels

In the traditional expressway tunnel power supply scheme, it is necessary to draw out 380V from the low-voltage cabinet in the substation, and then equipped the distribution box of lighting fixtures in the expressway tunnel through the switch at the low-voltage cabinet, in order to realize the power supply for lighting fixtures. Several bus power supply circuits should be allocated according to the different types of lamps. In this case, there will be a number of trunk cables in the expressway tunnel. Since the power supply of 380V is considerably high, there are requirements for a thicker cable; hence, thick four-core cables are usually used. In this way, the step-down requirements can be effectively met.

3.4. Main problems existing in the power supply scheme of traditional expressway tunnels

From the analysis of the traditional expressway tunnel power supply scheme, there are three main problems. First, high-voltage and low-voltage cables are required, and there are many bus cables. This situation not only increases the construction cost and the difficulty of operation and maintenance, but also brings about certain risks. Second, the power supply system in traditional expressway tunnels utilizes the three-phase power supply. Only by ensuring the three-phase load balance can we achieve good power supply effect. Therefore, it is necessary to connect the lamps to the three-phase, respectively, whose construction is difficult and complex. Third, in order to achieve good power monitoring and voltage regulation, it is necessary to include an additional power monitoring system and voltage regulator configuration, which will increase the engineering cost.

4. Advantages of applying distributed intelligent power supply technology in expressway tunnels

4.1. Improve the overall economic benefit

Compared with the traditional expressway tunnel power supply technology, the application of distributed intelligent power supply technology can significantly improve the overall economic benefit. First of all, the application of the technology can realize the overall system construction investment savings. It only needs to set the upper power supply equipment in the substation to directly supply power to the reinforcement lamps at the entrance of the tunnel, and a single hole only requires one basic lighting and reinforcement lighting loop, as well as one monitoring equipment and emergency lighting loop. Compared with the traditional expressway power supply technology, the application of this technology can achieve a

significant reduction in the number of lines, and the cable diameter will also be greatly reduced, so as to achieve further savings in its construction cost [1]. Secondly, the system mainly uses the single-phase distributed long-distance power supply technology. In that case, the three-phase imbalance can be effectively avoided, so as to further extend the application lifecycle of the equipment in the tunnel, thus reducing the costs for operation, maintenance, and replacement [2]. Finally, this technology can realize the reasonable adjustment of ventilation and lighting in the tunnel, so as to further reduce the electricity cost. It can be seen that the reasonable application of this technology to the power supply in expressway tunnels allows a significant improvement in terms of the overall economic benefit [3-6].

4.2. Improve the energy-saving effect

Compared with the traditional power supply technology applied in expressway tunnels, the application of distributed intelligent power supply technology can achieve better energy-saving effect. First of all, through the reasonable application of line loss reduction technology, the power supply radius and load can be taken on the basis of ensuring the actual power supply demand to realize an apposite increase of power supply voltage, so as to reduce the cable current and realize the reasonable reduction of line loss. Secondly, through the application of reactive power compensation technology, the overall power factor of the system can be improved significantly, so that the reactive power loss can be prevented, and the overall power consumption can be effectively reduced [7-9]. Finally, through the application of lighting voltage regulation technology, dimming of lights can be carried out based on the actual situation in the tunnel, so as to minimize the power loss caused by the lighting while meeting the actual brightness demand of the expressway tunnel. Therefore, it can be said that the application of this technology has a very good energy-saving effect.

4.3. Improve social benefits

In addition to good economic benefits and energy saving effect, the application of distributed intelligent power supply technology also brings about social benefits. First of all, through the application of this technology, the overall expressway tunnel distribution system can realize remote monitoring, which has a positive role in promoting the improvement of the operation and maintenance levels of the system. Secondly, through the application of this technology, the lighting in the expressway tunnel can be more uniform, and the light sensing effect can be effectively reduced, so as to ensure the safety of vehicles. In this way, the social benefits of this technology are apparent.

5. Analyzing the distributed intelligent power supply technology in expressway tunnels

In order to achieve good intelligent power supply effect, relevant units and technical personnel need to integrate the main power facilities in expressway tunnel projects, in order to formulate a reasonable intelligent power supply scheme. As mentioned above, lighting fixtures, monitoring equipment, and ventilation equipment are the main consumption facilities in expressway tunnels. Hence, in the process of designing, formulating, and implementing the intelligent power supply scheme, relevant units and technical personnel need to deeply explore the intelligent power supply technology of these power supply facilities, including the intelligent lighting power supply technology, the intelligent monitoring power supply technology, and the intelligent ventilation power supply technology. These are reasonable intelligent designs, and a variety of electrical equipment power supply automation and intelligent control have been realized through the corresponding intelligent control system and control technology.

5.1. Intelligent lighting power supply technology

In tunnel lighting, the application of distributed intelligent power supply technology is mainly to set the upper computer in the substation to replace the traditional low-voltage distribution cabinet and the

traditional lighting distribution box by setting the lower computer in the position of the original lighting distribution box. The bus power supply loop of the single hole output (two in total) is connected to the lower machine. With the help of the lower machine, the volume output loop can be separately switched and controlled by the voltage control, so that the lighting lamps can be grouped according to different requirements [10-13]. **Figure 1** is a schematic diagram of the connection of the intelligent lighting power supply system.

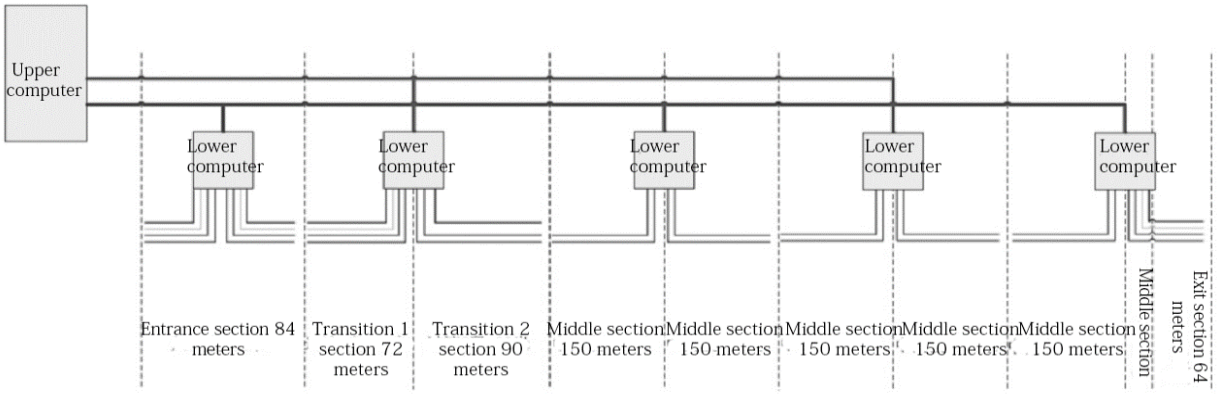

Figure 1. Schematic diagram of the connection of the intelligent lighting power supply system

The upper machine at the entrance of the expressway tunnel can be divided in two forms: the first is the basic lighting and enhanced lighting form, and the other is the upper computer in the emergency form. The emergency form requires the configuration of uninterrupted power supply cabinet. After a series of operations, such as voltage stabilization, compensation, and filtering, there will be an output of 3.3KV single AC power to the lower machine, and the system will reduce it to 220V through the lower machine, so as to meet the actual power supply demand of the lamp. The lower machine is configured in the original distribution box. There are four main forms of lighting: the first is to strengthen lighting, the second is the transition lighting, the third is the basic lighting, and the fourth is the emergency lighting. Among them, the lower machine of the enhanced lighting form needs to be configured at the entrance of the expressway tunnel. Its main purpose is to supply power to the lamps at the entrance and exit of the tunnel. The lower machine of the over-lighting form needs to be configured in the first lighting distribution room after the expressway tunnel enters the hole. Its main purpose is to supply power to the enhanced lighting lamps in the first ITD and the second ITD. The basic lighting and emergency lighting subunits need to be interleaved at other lighting distribution rooms in the expressway tunnel. Their main function is to supply power to other lamps in the tunnel [14]. For practical application requirements, EPS emergency power should be set in the emergency monitoring engine and connected to the power supply engine of the emergency lighting system. For other forms of lower computer, they can be combined in the design and then connected to the enhanced lighting and basic lighting forms.

5.2. Intelligent monitoring power supply technology

For expressway tunnel engineering, monitoring is a crucial electrical equipment. Hence, in the application of distributed intelligent power supply technology in expressway tunnel power supply design and construction, relevant units must pay full attention to the reasonable application of this intelligent monitoring power supply technology. In expressway tunnels, all the monitoring equipment needs to be connected with EPS power supply. Its connection mode and emergency lighting power supply have similar properties; hence, it does not need to lay other cables separately in the design and application process, only the monitoring loop through the emergency and monitoring machine output, so that the actual power

demand of all monitoring equipment in the tunnel can be well met [15-18]. The power supply circuit needs to be consistent with the original monitoring circuit, but the power supply section should be divided based on the emergency power supply section.

5.3. Intelligent ventilation power supply technology

In the design and construction of the power supply system of expressway tunnels through the distributed intelligent power supply technology, the power supply of the ventilation system is also a very important aspect. Hence, relevant units must reasonably apply this intelligent ventilation power supply technology. In its application, the upper engine of the fan should be set in the distribution room of the intelligent power supply system, and a voltage of 3.3KV should be transmitted to the lower engine of each fan via a three-core cable. At most times, the same bus cable can be used for the three sets of fans, but the cable needs to be laid on a cable trench bracket in the expressway tunnel. With the help of the fan engine, the voltage output of three circuits can be realized, in which the output voltage of each loop is 380V. The fan engine and the fan should be connected by a four-core cable [19,20]. Each fan's lower engine can supply power to three fans, and each fan should be set with a forward turn function, a reverse function, and a soft start function. In this way, the power supply effect of the fan is ensured, guaranteeing its operation to effectively provide sufficient ventilation in expressway tunnels and further improve the comfort and safety of drivers.

6. Conclusion

In conclusion, the lighting, monitoring, and ventilation conditions will have a direct impact on the quality and safety of traffic. In order to realize a good guarantee of these functions, relevant units and technical personnel need to innovate their power supply technology. The distributed intelligent power supply technology has significant advantages from its application. The application of this technology will not only realize the expressway tunnel power supply construction and operation as well as maintenance cost savings, but also achieve better energy-saving effect, reduce the operation intensity of staff, and improve the traffic safety. Therefore, relevant units and technical personnel must strengthen the research on this technology, so as to give full play to its advantages and promote the construction, application, and development of highway engineering.

Disclosure statement

The author declares no conflict of interest.

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