Research on New Rail Transit Power Supply System Scheme

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Abstract. The tourism rail transit project has broad development prospects in China. The new type of rail transit represented by trams and monorails is suitable for the demand of the project of the rail transit, and the traction power supply system is great significance for the normal operation of the new type rail transit. This paper introduces the external power supply, medium-voltage loop network and traction power supply of new type of rail transit project. Through the comparison of technical schemes, the selection for several important engineering schemes in the new rail transit power supply system engineering design are obtained.

Keywords: New rail transit; External power supply; Medium-voltage loop network; Traction power supply

1. Introduction
With the rapid development of tourism in our country, in order to complete the flow of tourists between the tourist destination and the tourist source, the tourist rail transit has effectively improved the efficiency and quality of tourists' travel with its directness and convenience. Compared to traditional railway and urban rail transit, the tourism rail transit represented by the new rail project has the characteristics of large slope, bad external power supply conditions and low travel speed. There are many types of modes. According to technical standard characteristics, it can be roughly divided into steel wheel rail system, monorail system, magnetic levitation system, rack rail system, etc. [1]. When the train uses electric traction, different types of rail transit have different effects on the design scheme of their power supply system. Therefore, this article will focus on the characteristics of the new rail transit, analysis and research of its power supply system engineering design related issues.

2. External Power Supply
There are generally three kinds of external power supply modes for new rail transit projects, they are the decentralized power supply mode, the centralized power supply mode, and the power supply mode that combines decentralized and centralized power supply [2]. Decentralized power supply means that the local power grid along the rail transit line directly supplies power to the traction substations and step-down substations along the line. Centralized power supply means that the local power grid supplies power to the main substation or switching substation of the rail transit line, and then supplies power to the traction substations and step-down substations along the line through the medium-voltage network.
loop network. The combination of decentralized and centralized power supply is a combination of the two kinds of power supply methods above.

The new rail transit projects have the characteristics of shorter lines and lighter loads. The power supply distance of the main substation with centralized power supply mode can reach 25~30km. With the centralized power supply, the short power supply distance wastes the power supply capacity of the main substation, and there is no other line to share the main substation. The main substation covers a large area, has a long construction cycle and a high investment. In order to reduce the floor space, shorten the construction period, and save investment, the tourism rail transit generally adopts decentralized power supply.

Secondly, the classification of the traction load of the new rail transit will affect the design of the entire power supply system. The load levels are specified as follows in GB 50052-2009 Code for Design of Power Supply and Distribution Systems:

3.0.1 The electrical load shall be classified according to the requirements for power supply reliability and the degree of impact of interruption of power supply on personal economic loss, and shall comply with the following provisions:
   2.1. If one of the following conditions is in conformity with, it shall be regarded as a first-class load
       1) When the interruption of the power supply will cause personal injury to the customers.
       2) When power interruption will cause major economic losses.
       3) The interruption of power supply will affect the normal work of important power consumption units.

3. If one of the following conditions is in conformity with, it shall be regarded as secondary load
   When the interruption of power supply will cause big economic losses
   1) The interruption of power supply will affect the normal work of more important power consumption units.

   For different load levels, the power supply mode is also specified in GB 50052-2009 《Code for Design of Power Supply and Distribution System》:

3.0.2 The primary load should be powered by dual power sources. When one power source fails, the other power source should not be damaged at the same time.

3.0.7 The power supply system of the secondary load should be powered by two circuits. When the load is small or the regional power supply conditions are difficult, the secondary load can be supplied by a dedicated overhead line of 6kV and above.

According to the specification, if a new type of rail transit is judged to be a first-class load, its external power supply should be two independent power sources; if it is judged to be a second-class load, its external power supply should be two power supplies, and it can be one power supply when it is difficult.

4. Medium-voltage Loop Network
In the decentralized power supply mode, the medium-voltage loop network structure is mainly divided into double loop network connection form and single loop network connection form.

Double loop network connection form: The substations of the stations on the whole line are divided into several power supply districts, the medium-voltage network adopts double loop network connection mode, the two adjacent power supply zones are connected by two loop network cables, as Figure 1 shows. The connection mode is flexible and highly reliable, one power supply section is powered by two external power sources, the two external sources may come from the city substations in different areas, or from different buses in the same substation, the substation introduced by the external power supply can also be used as a power switching station to supply power to the power supply divisions on both sides. The double loop network connection form is suitable for the medium-voltage loop network of the first-level load of new rail transit. In order to increase the reliability of power supply, the external power supply of one power supply zone is supplied by the external power supply of one road, but the external power supply of different power supply zones is
required to come from different city substations, the substation introduced by the external power supply can also be used as a power switching station to supply power to the power supply divisions on both sides.

![Figure 1](image1.png)

**Figure 1.** Schematic Diagram of Double Loop Network Connection Form

Single loop network connection form: The substations of the stations on the whole line are divided into several power supply districts, the medium-voltage network adopts a single loop network connection mode, and two adjacent power supply areas are connected by a single loop network cable, as shown in Figure 2. The connection mode is simple, one power supply zone is powered by an external power supply, but the external power supply for different power supply zones is required to come from different urban substations to increase power supply reliability [3]. The substation introduced by the external power supply can also be used as a power supply. The opening and closing stations provide power to the power supply zones on both sides. The single loop network connection form is suitable for the medium-voltage ring network of the second-level load class new rail transit.

![Figure 2](image2.png)

**Figure 2.** Schematic diagram of single loop network wiring form

Compare single-loop and double-loop connections: Double loop network wiring has high reliability of power supply. The connection reliability of single-loop network is relatively low. Each substation of single loop network connection (except for the switching substation) has only one incoming line and one outgoing line, simple wiring, less equipment, less project investment; Each substation of double loop network connection (except for the switching substation) has two incoming lines and two outgoing lines, and set with bus tie switch, wiring is complicated. There is more equipment than a single loop network, and the number of cables is also more than that of a single loop network. It is difficult to lay the cables between sections, and the equipment occupies a larger area than a single loop network.

5. Traction power supply

Traction power supply system is one of the important systems of new rail transit, combining the landscape requirements of tourist attractions, choosing a traction power supply method that suits the characteristics of the route and the driving plan is a necessary work in the research of new rail transit projects. At present, there are three main power supply solutions for new rail transit: The first is
overhead catenary power supply for trains. The second uses segmented power supply along the ground power supply facilities. The last is to use on-board energy storage devices to power trains. The solution of laying power supply facilities along the ground solves the impact of overhead catenary on the environmental landscape, but buried equipment is greatly affected by the environment, and drainage facilities along the line need to be improved. The high cost is not conducive to promotion [4]. Overhead catenary power supply is basically the same as that used by traditional railways and most subways. The train obtains electric energy from the overhead catenary through the roof pantograph, and the power supply voltage is usually 750 V DC [5].

The power supply mode of the on-board energy storage device is divided into two types: battery energy storage and super capacitor energy storage. Battery is usually only used for short distance power supply because of its small storage capacity and long charging time; the super capacitor [6] has a large capacity, and the super capacitor can be charged with a fast-charging device, which can maintain its long power supply time, and is suitable for long-distance power supply. This paper will introduce in detail the design of a charging station that uses a supercapacitor energy storage device to supply power to the train.

Supercapacitor uses DC charging, each charging station is equipped with a set of complete charging devices, through the changeover switch of the charging device, the upstream and downstream charging can be switched respectively. When only one train stops in the station, the train will be charged separately by a complete set of charging devices. When two trains stop at the same time in the station, after the first train is fully charged, the transfer switch of the charging device will be switched to complete the charging of the other train.

Combined with the requirements of the charging device, the main wiring of the traction substation considers the following two options:

First, comparison of centralized installation and decentralized installation of rectifiers. The scheme of centralized installation of rectifier devices is to set up rectifier stations in the middle of adjacent station sections, centrally configure rectifier devices, and set up charging stations at each station. The rectifier station adopts a single bus connection form, with two sets of rectifier devices running in parallel. Stabilizing charging devices are installed in the charging stations of two adjacent stations, and the rectifying devices are shared by the two stations. The wiring scheme of this way is shown in Figure 3:

![Figure 3. Schematic diagram of centralized setting of rectifier device](image-url)
The decentralized installation of rectifier devices is to set up charging stations at each station. The charging stations adopt a single bus connection form and set up a complete set of charging devices. The wiring scheme of this way is shown in Figure 4 and 5:

Centralized installation of rectifier transformers and rectifier devices can simplify the configuration of station charging devices and reduce the number of rectifier units and rectifier transformers. However, the centralized installation of the rectifier can reduce the scale of the charging device. It is necessary to set up a rectifier station within the interval, the land acquisition pressure is relatively high, and the realization is difficult.

Second, installing charging devices at stations
1) Install two sets of charging devices at the station separately, the substation adopts single bus wiring form, as Figure 4 shows:

Figure 4. Schematic diagram of dual charging devices

Two rectifier transformers and two charging devices are installed on the substation bus. During normal operation, the two sets of equipment operate independently, and charge different trains separately.

   During normal operation:
   When only one train stops at the station, it will be charged by the corresponding charging device.
   When two trains stop at the same time in the station, two sets of charging devices will be charged separately.

   During abnormal operation:
   When a set of equipment fails or overhauled, the electric isolation switch at the outlet of the charging device can be used to support power supply.

   Install a set of charging device in the station separately, and the substation adopts single bus connection form, as Figure 5 shows:
Figure 5. Schematic diagram of a single set of charging device

A rectifying transformer and a single set of charging device are arranged on the substation bus [7]. During normal operation, the charging device is equipped with an automatic switch to charge the upstream and downstream trains respectively.

During normal operation:
When only one train stops at the station, it will be charged by the charging device.
When two trains stop at the station, after the first train is fully charged, use the switch inside the device to complete the charging of the other train.

During abnormal operation:
When the charging device fails, consider the mobile emergency charging device to charge the train.

For the scheme of station charging device, two sets of charging device have high reliability, but high investment, large area of equipment, difficult land acquisition in urban areas, and difficult implementation [8]. For the solution with only one set of charging device, the scheme can save investment, but the reliability is relatively low. Combined with the actual situation of the current charging device, the reliability of the charging device is higher, and there are fewer failures and routine maintenance, setting up a set of charging devices can effectively reduce investment costs, and is also in line with the train's low-carbon, energy-saving and environmentally friendly design concept, and a certain number of mobile charging devices can be configured to make up for system reliability problems.

6. Conclusion
This paper introduces the different design schemes of external power supply, medium-voltage loop network and traction power supply of the new rail transit power supply system, and proposes detailed schemes for the design of charging stations under super capacitor power supply. Due to the special environmental location and small project investment for the construction of new rail transit projects for tourist rail transit, the power supply system should be designed according to the project’s geographic location, line length, horizontal and vertical section, etc., to determine the external power supply, design schemes of medium-voltage loop network and traction power supply, but don’t have to be constrained to a specific system mode.
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References
[1] Guan Wang. Analysis on the realistic demand of tourism rail transit development. Railway Investigation and Surveying, 06, pp.110-114, 2017.
[2] Huilin Ouyang. Study on scheme for urban track transportation system power supply. Guangdong Power Transmission Technology, 09 (10), pp.64-67, 2009.
[3] Yong Yuan. Characteristics of power supply system for monorail straddle traffic engineering. Electric Railway, 04 (20), pp.33-35, 2005.
[4] Zhixin He. Selection of train traction power supply modes. Journal of Technology, 07, pp. 105-113, 2013.
[5] Jiqiang Shen. Train type selection and power supply modes. China Municipal Engineering, 10, pp.66-75, 2012.
[6] Siemens. Avenio: A new generation of 100% low-floor trams developed by Siemens transportation technology group. Shanghai: Simens, 2010.
[7] Xiujie Zhao. Analysis of the construction of new rail transit in EPC mode. Transportation Enterprise Management, 36 (02), pp.81-83, 2021.
[8] Jun Tian, Chao Tang. Application of new mapping technology in intelligent construction of rail transit. Bulletin of Surveying and Mapping, 09, pp.23-26, 2020.