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A Study on Evaluation index for Current Collecting Quality of Shoe Rail Power Supply System.

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Abstract: The evaluation of current collecting quality of the third rail power supply system is a comprehensive and complex problem, which shall take overall factors into consideration such as technology development, economical efficiency, correlativeness among each index and accessibility of these indexes. This paper not only introduces the types and advantages of the third rail current collecting system, but also its procedure for establishing the evaluation index and evaluation standard. Then this paper puts forward some constructive suggestions on how to evaluate the current collector and the third rail current collecting quality in view of the evaluation index of Pantograph-OCS system and the experience of domestic urban rail vehicle operations.

Key words: current collector, the third rail, current collection standard, contact pressure, deviation

Introduction

The subway vehicle, as a way of transportation characterized by high density and huge passenger flow, plays an important role in urban rail transportation, which extremely calls for the stability and security of the current collecting system. Any current collecting breakdowns or accidents in the power supply system will lead to a deadly harmful impact on our society. Slight current collecting breakdown may lower the operation efficiency of the subway, thus leading to a terrible effect on people's daily traveling and some certain economic losses. However, heavy current collecting breakdown may interrupt the operation of the subway, thus putting tremendous pressure on ground traffics and causing serious economic losses and even threatening our social order and stability. [1] Therefore, ensuring good current collecting quality of the vehicles will benefit a lot for the normal operation of subway, which will not only improve riding comfortableness, decrease breakdown rate and maintenance cost, but also bring plenty of social benefits.

1.Question Rising:

At present, power supply approaches to urban rail traffic vehicles both at home and abroad mainly includes rigid and flexible suspension contacting network as well as the third rail power supply.

The third rail power supply, also called contacting rail power supply, is to construct a third power supply rail along with the rail where the vehicles ride as well as a current collector on the truck frame of the vehicles. Then the current collecting sliding shoes will contact with the third rail under pressure, thus forming a closed loop circuit to transmit the electricity[2].

The third rail current collecting can be divided into three types, namely above-contacting, below-contacting and side contacting according to different installations. Compared with contacting network power supply, the third rail power supply has numerous advantages involving reliable operations, convenient maintenance and management and

long cycle use, economized space as well as beautified urban landscape and so on [3].

Therefore, it is widely applied in the urban rail transportation both at home and abroad.

As is depicted in chapter six of GB/T14894-2005 Regulations for Detecting and Testing of Assembled Urban Rail Traffic Vehicles about the quality standard for the third rail power supply, “the quality of tested operation power supply shall be negotiated in the beginning of the contract by the users and manufacturers.

It is known that the current collecting quality evaluation of the third rail power supply is still vacant in China . Thus, it is necessary to carry out an evaluation standard index for the current collectors and the third rail current collecting system, which shall not only be applied in evaluating the dynamic current collecting quality of the collectors, but also optimizing the parameters in all parts of the current collecting system and improving the national standard system.

2. Procedures for establishing the index

Since the current collecting quality evaluation of the third rail system is a comprehensive and complex problem, each country shall insist on their own approaches and perspectives on it in light of its national conditions and scientific and technological development levels. This paper advises to study the evaluation of the third rail current collecting quality in China by the following procedures:

(1) It shall fully consider China’s basic national conditions and each city’s subway operations, maintenances and costs as well as technological level in analyzing technology related to the different current collector types and the third rail system at home and abroad in order to establish the shoes rail physical model and mathematical model in accordance with China’s basic national conditions

(2) It shall establish the contact model of current collector and the third rail system to carry out computer dynamic simulation, analyze dynamic contacting of shoes rail and find out the essential factors influencing dynamic current collecting quality. It shall establish a current collecting quality evaluation standard suitable for China’s basic national conditions. By analyzing the computer dynamic simulation results, combining the laboratory small-scale model and field experiments, and referring to the research on the evaluation standard of the current collection quality of the Pantograph-OCS system [5].

(3) It shall apply subjective and objective weight allocation methods to endow corresponding weigh with the evaluation index based on established shoes rail current collecting quality evaluation and carry out comprehensive evaluation approaches by using mathematical theory like fuzzy evaluation.

This paper mainly discusses how to establish the evaluation standard of the shoes rail current collecting quality . The established evaluation standards was suggested to meet the following conditions:

① Parameterization: The evaluation system and index parameter is the final reflection of the evaluation standard of the current collector and the third rail current collecting quality. The index parameter and index weigh shall be quantized as much as possible in order to evaluation the current collecting quality directly and exactly.

② Availability: The evaluation index in the standard system can obtain its parameter by present detection technology and the standard shall be universal so as to adapt all kinds of current collectors.

③ Economy: A relatively high evaluation standard may decrease the operation maintenance while increasing the construction difficulty and one-off investment; and vice versa. Therefore, the establishment of the third rail current collecting system shall try it’s best to reduce the Life Cycle Cost(LCC)

④ Comprehensiveness: The established evaluation standard for current collecting quality are as following: GB50157−2003 Subway Designing Regulations[6], GB50490-2009, Regulations for Urban Rail Transportation Technology [7], GB/T14894-2005 Regulations for Detecting and Testing of Assembled Urban Rail Traffic Vehicles[4]and so on. These regulations shall be interconnected and interacted as well as complemented each other to keep integrity with the established standards in macro level.

⑤ Partial speed level: It shall determine the parameter of the current collecting quality evaluation index according

to different speed. The current collectors and the third rail contacting specialty differs along with different speeds. Increasing or decreasing the standard will lead to a change in shoes rail dynamic contact pressure and the parameter current collection structure, where appears a problem on whether the investment cost can be realized.

3. Constructive index

Based on the existing theory and testing research, this paper tries to put forward three constructive indexes for evaluating third rail current collecting quality by the experience in establishing pantographs evaluation standard, China's subway operation, and contacting specialty between sliding shoes and the third rail as well as detecting levels.

3.1 Static index

The static index of the third rail current collecting system is commonly about the extreme value, mean value, amplitude, standard deviation of the contacting pressure as well as the contacting area of the sliding shoes with the third rail. Since the extreme value and amplitude as well as the standard deviation of the contacting pressure varies slightly under static state or extremely low speed, it can be negligible. Thus the static index of the third rail current collecting system mainly involves mean contacting pressure and contacting area.

3.2 Dynamic index

(1) Dynamic mean contacting pressure

In order to ensure the normal current collecting when the vehicles operating, the swing arms of current collector shall make a contact between the sliding shoes and the third rail under the influence of structure springs, and the pressure to keep contacting is known as contacting pressure.

Contacting pressure depicts the contacting degree and state between the sliding shoes and the third rail. The stronger the contacting pressure becomes, the closer the two will contact[8.9]. However, when the contacting pressure is too strong, the abrasion of the sliding shoes will heavily increase, causing higher maintenance cost. When the contacting pressure is too weak, the collector will be liable to deviate under the influence of hard point impact. Therefore, the dynamic mean contacting pressure is a critical index for current collecting quality. It can be acquired as following:

$$F_m = \frac{1}{n}\sum_{i=1}^{n} F_i$$

In the above equation, i severs as sample point, n as total samples,Fi as the sample value of the dynamic contacting pressure of the i th sample point.

(2) Dynamic contacting pressure standard deviation

Contacting pressure standard deviation reflects the fluctuation range and deviation degree of the dynamic contacting pressure of the third rail current collecting system within rated operation pressure. The smaller the standard deviation degree is, the smaller the contacting pressure will range and the more stable the contacting pressure will be and the better the contacting specialty will be. And vice versa. It can be acquired as following:

In this equation,Fi severs as the dynamic contacting pressure of the i^{th} sample point, F_m as the mean contacting pressure in a certain zone.

(3) The maximum value and minimum value of the contacting pressure

When transient contacting pressure between the sliding shoes of the current collector and the contacting rail is too strong, it shall scratch the sliding shoes and the third rail surface, thus lower service cycle; when transient contacting pressure is too weak, it is liable to lead to the consequence such as 0 contacting pressure, bad power supply and even arc discharge. Contacting pressure can be distributed according to Gaussian distribution and can establish the limit variation range for contacting pressure by the standard deviation and mean value.

Contacting Pressure	Numerical Range
68.3%	on
95.5%	on
99.7%	on

Table I:Gaussian Distribution of contacting pressure

(4) Dynamic contacting pressure amplitude

Contacting pressure amplitude shows the variation ranges of contacting pressure in the process of vehicle operating and the stability of the dynamic contacting pressure. The equation is as following:

$$\Delta F = (F_{max} - F_{min})/2$$

In the above equation, F^{max}serves as the maximum value of dynamic contacting pressure, Fmin as the minimum value of dynamic contacting pressure.

(5) Non- uniformity coefficient of contacting pressure

Generally speaking, Non- uniformity coefficient of contacting pressure is used to measure the influence of different pressure value in different zones exerted on the current collecting quality. The equation is as following:

$$F_{CP} = \frac{1}{n}\sum_{i=1}^{n}\frac{F_{imax} - F_{imin}}{F_{imax+Fimin}}$$

In this equation, Fimax and Fimin respectively serve as the maximum value and minimum value of the sampled contacting pressure in certain testing zone.

(6) Sliding shoes vibration amplitude of current collector

Sliding shoes vibration amplitude refers to the vibration range of the sliding shoes in sampled zones, which is usually expressed as 2A, namely the deviation of the maximum value and minimum in the height of the surface distance of sliding shoes with riding rail in dynamic state. The equation is as following:

$$2A = H_{max} - H_{min}$$

In this equation, Hmax and Hmin respectively serve as the maximum height and minimum height of the sliding shoes in certain zone. Vibration amplitude of sliding shoes reflects the stability of the sliding shoes under the disturbance of the outside. The smaller the 2A is, the smoother the motion trace of sliding shoes will be and the better the quality will remain.

(7) Deviation

When the sliding shoes of current collector can't vibrate well along with the third rail, the deviation will happen. The sliding shoes of current collector will lose voltage when deviated, and the arc will occur between the sliding shoes and the third rail, which will likely burn the surface of sliding shoes and increase abrasion, thus leading to a breakdown in operation. In addition, deviation will cause instable operation of the vehicles and extra abrasion between sliding shoes and the third rail. Deviation is mainly measured by three indexes, namely deviation frequency, deviation rate and duration for one single deviation.

Deviation frequency: it refers to the total times the sliding shoes deviated in certain zone. It is expressed by M. The fewer the deviation frequency is, the better the current collecting quality will be.

Deviation rate: it refers to the ratio the deviation times to total operation time. The equation is as following:

$$K = \frac{1}{T}\sum_{i=1}^{m} t_i \times 100\%$$

In this equation, m serves as the times the sliding shoes deviate from the rail, t i as the deviation times in the i th

times, t as total testing time.

Duration for a single deviation time. Deviation theory claims:

Duration	Classification	Reason
<0.01S	Small deviation	Micro-vibration in sliding shoes and abrasion of contacting rail
0.01S~0.1S	Medium deviation	Varied height of contacting rail fails to make current collecting shoes have completely contact or hard point impact
>0.1S	Large deviation	

Chart II：Classification of Deviation

4. Conclusion

At present, the research on the current collecting quality for current collector and the third rail system remains rare and few in China, not to mention establishing a series of complete evaluation standard for current collecting quality. This lead to uncertainties in choosing parameters when designing current collector, constructing the third rail, and actually operating, failing to offer basic statistics supports for some relevant researches. With the rapid development of urban rail transportation and the increased utilization of third rail power supply, it's urgent for China to study on the evaluation standard of current collecting quality for the third rail system. China should quicken its pace in establishing evaluation standard for current collectors and the third rail current collecting system so as to instruct the formulation of some relevant regulations and the compilation of some designing files.

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