Fault Diagnosis and Prediction of Traction Inverter for Metro Vehicles Based on Feature Fusion

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Abstract: However, due to the large number of subway lines, the short distance between stations, and the frequent start-stop, acceleration and deceleration of trains, the electrical parameters of the traction inverter are constantly changing. The emergence of logic control unit provides an important means to solve this problem. Its application can effectively alleviate problems such as traffic congestion in large and medium-sized cities. At present, traction inverters are the core components of urban rail transit traction equipment. With the rapid development of urban rail transit, the work related to accelerating the localization and autonomy of key core systems of urban rail transit equipment is also advancing simultaneously. The disadvantage is that it cannot directly measure the temperature of parts such as chips and solders encapsulated in insulating materials. By optimizing the current traction inverter overhaul process, the overhaul efficiency can be improved to a certain extent. Therefore, there will be some problems in the train, such as repeated equipment setting, low replacement relay ratio, large occupied space and insufficient simplicity of system control framework. The diagnosis method based on vibration signal is the most widely used bearing fault diagnosis method at present. The diagnosis method is mainly based on document source diagnosis. Misdiagnosis is easy to occur, and the running wind speed is fast or slow, so that the heat dissipation capacity of the heat pipe radiator changes accordingly. The research, development and production of Metro Traction AC drive system with independent technology has great economic and social significance, and better serves the independent promotion of key core equipment of urban rail vehicles in China. Through feature fusion, this paper shows that the design of metro vehicle traction inverter can fully meet the fault diagnosis and prediction of Metro AC traction drive system.

1. Introduction

With the development of China's economy and the acceleration of urbanization, the problem of urban traffic congestion has become increasingly prominent. However, due to the large number of subway lines, the short distance between stations, and the frequent start-stop, acceleration and deceleration of trains, the electrical parameters of the traction inverter are constantly changing. The emergence of logic control unit provides an important means to solve this problem [1]. Urban rail transit has gradually become an indispensable part of the modern transportation system due to its punctuality, speed, and large capacity [2]. Its application can effectively alleviate problems such as traffic congestion in large and medium-sized cities. At present, traction inverters are the core components of urban rail transit traction equipment. Due to product differences, there are many disadvantages such as inconsistent hoisting methods, difficult unification of mature technologies, difficult product quality control, large investment, and difficulty in reducing R&D and production costs [3]. With the rapid development of urban rail transit, the related work of accelerating the localization and autonomy of key core systems of urban rail transit equipment is also advancing simultaneously. The test analysis method can be carried out in the laboratory or in the actual running vehicle, with the advantage of high reliability of the temperature rise data [4]. The

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disadvantage is that it is impossible to directly measure the temperature of chips and solders packaged in insulating materials. By optimizing the current overhaul process of traction inverter, the overhaul efficiency can be improved to some extent.

With the rapid development of urban rail transit in China, the demand for traction equipment of urban rail transit is increasing. Traction inverter is the key component of metro vehicles, and insulated gate bipolar transistor module is the most core device in traction inverter [5]. Therefore, there will be some problems in the train, such as repeated setting of equipment, low ratio of replacement relay, large occupied space, and lack of concise system control framework. The diagnosis method based on vibration signal is the most widely used bearing fault diagnosis method at present, and the diagnosis method is mainly based on single evidence source diagnosis [6]. The theoretical absorption method is improved, which is also a weighted processing of the classical fusion results. However, due to the neutralization of high probability evidence, the result has the disadvantage of high probability of fault identification. The phenomenon of misdiagnosis is easy to occur, and the wind speed is fast or slow, so that the heat dissipation capacity of the heat pipe radiator also changes accordingly [7]. Therefore, it is impossible to accurately evaluate the performance of the heat pipe radiator and the fatigue life of the module only by calculating the steady-state temperature rise of the heat pipe radiator and a certain working condition of the module. The R&D and production of subway traction AC drive systems with independent technology has great economic and social significance, and can better serve the autonomous promotion of key core equipment of China's urban rail vehicles [8].

2. Application scheme analysis

2.1. System scheme

The above scheme is applied to a four-marshalling train with TMC-MP-MP-TMC. Two LCUs are applied in TMC car and one lcu is applied in MP car [9]. Overhaul requires comprehensive inspection, commissioning and testing of the train, so as to restore the train to the original factory standard, or improve it locally within the original technical level, and finally meet the requirements of regulations and quality acceptance standards. Using these two algorithms for reference, an improved fusion algorithm with more accurate fusion results is proposed, which is named as mean weighted fusion method. The disadvantage is that it is not conducive to the adhesive utilization of vehicles. When one of the converter units fails, it cannot be isolated separately [10]. Only the whole converter can be removed, and the power of the car will be completely lost. The left side of the traction converter box is the DC input line, the AC output line and the braking resistor connection line, and the right side is the control cable plug and auxiliary power plug. Taking the windshield as a reference, set the fluid outer boundary of the variable flow module wrapped by the windshield as the wall boundary condition. Comprehensively consider the correlation between the modules, as well as the overhaul characteristics and overhaul conditions of the modules themselves. On the premise of ensuring the overhaul needs, reorganize the process flow and shorten the overhaul time, so as to ensure the safe and reliable operation of the vehicle main line. At the same time, the I/O shared by the two is collected by one of them, and passed to the other through the intranet between the vehicle MVB or LCU, without repeated collection.

2.2. Application function design

In order to fully guarantee the running ability of the vehicle in emergency traction mode without affecting the safety of the train, it is necessary to make some circuits still controlled by hard-wired relays. A voltage sensor is connected in parallel between the positive and negative ends of the bus to detect the voltage of the network. The positive and negative ends of the bus are connected with a current sensor respectively, and one is used for DC overcurrent protection of the converter. The other one is used for grounding detection protection of traction circuit. A voltage sensor is connected in parallel between the positive and negative ends of the bus to detect the voltage of the network. The overhaul operations undertaken by each station are interrelated and have technical

differences. Therefore, when carrying out the modular design, whether the maintenance content of each process can be carried out simultaneously or not. The parameters obtained after signal processing are mainly divided into time domain parameters and frequency domain parameters, and the time domain parameters of the signal usually contain more noise interference. It is not good for fault diagnosis, so frequency domain parameters are selected for extraction. From a design point of view, it is desirable to have a unified platform on which all rail transit traction inverters are developed. Simplify the design of different applications, such as different voltage levels, different application areas, etc. At the same time, 2 chassis redundant parallel outputs are used for individual key signals.

3. Experimental comparative analysiss

3.1. Implementation of feature parameter extraction and fusion algorithm

In order to check and compare the accuracy and reliability of the mean weighted fusion algorithm, a program is written to verify the whole algorithm on the experimental platform. At the same time, it has complete fault protection function, fault diagnosis function and self-reset function for minor faults. It consists of two parts: hardware and software. The hardware is the support of the software, which is mainly responsible for the conversion and setting of input/output signals and provides an environment for the software to run and play. Each cavity is provided with a door cover, and modules and other components can be easily extracted from the front of the converter, ensuring that the traction converter can be easily maintained in the extremely limited space under the vehicle. Design and build a bearing fault diagnosis test platform. The experimental platform is composed of frequency converter, motor, coupling, sleeve shaft, bearing seat, acceleration sensor and diagnosis host. As shown in Figure 1.

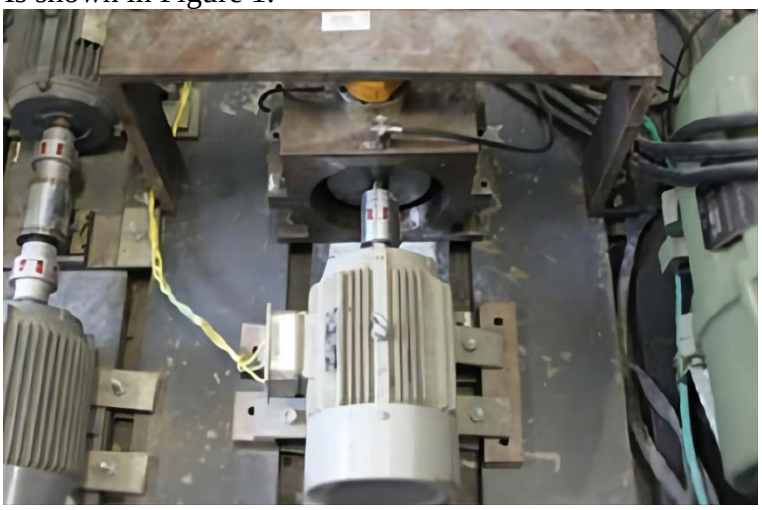

Figure 1 Physical diagram of experimental platform

Therefore, in the finite element model, only the heat transfer between the solid and the fluid-solid coupling surface needs to be considered, and the convective heat transfer coefficient distribution is a very critical boundary condition in the finite element model. Through the train line, the contacts of each "single-car parking braking state" relay are connected in series, and then the "train parking braking state" relay of the head car is driven to monitor the parking braking state of the train. At present, many intelligent optimization algorithms such as genetic algorithm, ant colony algorithm and simulated degradation algorithm are used. Based on the current limited experimental platform conditions, it is more convenient and accurate to obtain relevant parameters through artificial summary.

3.2. Implementation of feature parameter extraction and fusion algorithm

The accuracy data can not distinguish the advantages and disadvantages between the mean weighted fusion method and the absorption method, because the absorption method neutralizes the

classical results with the larger part of the probability value. The heat transfer principle of heat pipe is based on the energy absorbed and released by the vaporization of liquid and the liquefaction of gas. It has high thermal conductivity and excellent thermal response. The standard value of the element "uncertain" is the middle value of the standard values of "faulty" and "no fault". As shown in Table 1.

Table 1 Standard values of peak ratio of characteristic frequency spectrum

Fault type	Standard value
Out of order	1.6
Uncertain	1.4
No trouble	1.3

And no power consumption, no noise, easy to use and maintain. The problem of peak overvoltage suppression generated in the process of component switching is solved, and the excessive turn-off overvoltage and current change rate of components are effectively reduced. The switching loss of the device is reduced and the conversion efficiency is improved. According to Newton's cooling law, through the introduction of convective heat transfer coefficient, all convective heat transfer processes such as air cooling and water cooling can be described with simple laws. It mainly tests the emergency traction function of trains. By disconnecting the two-system control power supply of any LCU, simulate the LCU fault condition of the chassis, and test whether the emergency traction motor car can be carried out. As shown in Table 2.

Table 2 Simulation of chassis failure test

Serial number	Fault condition	Emergency traction motor car
1	TMC vehicle lcu1 chassis fault	Yes
2	TMC vehicle lcu2 chassis fault	Yes
3	MP car LCU chassis fault	Yes

For the above measures to improve reliability, corresponding fault simulation shall be carried out in the vehicle commissioning stage to verify the maintenance of system function under corresponding fault conditions. The selected project practice data samples are not enough, and the factors of artificially improving maintenance efficiency in the short term have not been ruled out. It can ensure the detection accuracy of the faulty bearing, so consider comparing the misdiagnosis rate of the two algorithms for the non-faulty bearing.

4. Conclusions

Accurately judging the occurrence of bogie bearing faults and determining the fault location are the key conditions to ensure the safe operation of subway vehicles. The fault model of the subway vehicle bogie bearing is analyzed, the classical evidence fusion theory is improved, and the mean weighted fusion algorithm is proposed. Not only can it meet the special working environment of urban rail transit vehicles, but also has the characteristics of convenient installation and maintenance, high structural strength, compact internal structure, and beautiful and delicate appearance. Especially from the three aspects of product construction, communication and system application, it is elaborated and demonstrated in detail, and finally the reliability of the scheme is verified by the method of simulation test. It can provide reference for the implementation of more subsequent projects. According to the relevant data of Y company, the outsourcing supplier of rail transit traction inverter, the feasibility of the model is verified. The bearing experimental platform is designed and built, and the mean weighted fusion method proposed in this paper, the existing mean k-coefficient method and absorption method are applied on the platform under the same probability distribution function. The fault detection and comparison of bearing outer ring, inner ring and rolling element are carried out respectively. The test data and different simulation methods verify that the developed fast calculation method can meet the requirements of calculation efficiency and calculation accuracy at the same time, and provides a new way to solve the problem.

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References

[1] Ding Jie, Yin Liang, Liu Qiyuan. Noise test and simulation analysis of traction converter for metro vehicles. Journal of shijiazhuang tiedao university: Natural Science Edition, vol. 34, no.3, pp. 7, 2021

[2] Wang Yang, Zhang Jingmeng, Hao Xie, et al. Performance analysis of heat pipe radiator of traction inverter for metro vehicles under low wind speed. China Machinery, no.13, pp. 2, 2020.

[3] Merry ma, Liu Yang. Application of traction inverter in Urumqi Metro Line 1. Internal Combustion Engine and Accessories, no.6, pp. 3, 2020.

[4] Zhang Ximao, Sun Congjun. Research on regenerative braking energy storage converter of three-level subway. Electrified Railway, vol. 32, no.1, pp. 8, 2021.

[5] Gong Yongchen, Wu Chongxi, liu junhua, et al. Design of traction inverter for DC750V rack-controlled metro car. Railway Locomotive and Motor Train, no.6, pp. 5, 2020.

[6] Lei Shutian, Li Kai, Wissing, et al. Development of integrated traction auxiliary converter for metro vehicles. Automation Application, no.7, pp. 3, 2020

[7] Li Xiaobo, Wu Hao, Weng Xiaotao, et al. Research on comprehensive test technology of thyristor traction converter for metro trains. no.9, pp., 2022.

[8] Chu yanting, Yu yuting, Kun Li. modeling and simulation of metro traction inverter based on MATLAB/SIMULINK. new industrialization, vol. 11, no.7, pp. 2, 2021.

[9] Wang Yongxiang. Design of Metro Traction Converter Controller Based on Redundant Processor Structure. Electronic Design Engineering, vol. 29, no.22, pp. 7, 2021.

[10] Chu Yanting, Yu Yuting, Kun Li. Optimization analysis of output current sensor test strategy of metro traction inverter. New Industrialization, vol. 11, no.8, pp. 3, 2021.