Replacement Scheme of Drive Boards For Traction Inverter Module of Beijing DKZ31 Metro Vehicle

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Abstract. Nowadays, the status of metro in urban traffic is particularly prominent in Beijing. How to ensure the normal operation of metro train is particularly important. At present, the problems of high failure rate, high maintenance cost and long maintenance cycle exist in the drive boards of imported traction system. In view of the above problems, this paper put forward the alternative scheme of drive boards on DKZ31 metro, and carried out the test work. On the basis of ensuring the safety and reliability, the maintenance cost is greatly reduced and the maintenance efficiency is improved. At present, the samples of drive boards have been completed and the relevant functional tests have been carried out. The test results show that the performance of the drive boards is good, which meets the requirements and achieves the predetermined goal.

1. Introduction

Drive circuit board, as a key component of auxiliary and traction system, undertakes the tasks of transmission, isolation, conditioning and protection feedback of driving signals. In practical use, it is inevitable to repair and replace. As the drive board is imported from abroad, there are some problems such as high maintenance cost and long maintenance cycle, which will affect the maintenance process and online speed of the faulty vehicle. According to the operation principle of traction and auxiliary inverter system for DKZ31 vehicle of Beijing metro line 15, the drive board of traction and auxiliary system is researched and developed. By analyzing the circuit board of the original manufacturer and replacing the components, the function of the driving board is realized and the task of self-development is completed which will simplify the maintenance process of module failure caused by the fault of driving circuit board, greatly reduce the maintenance cost and shorten the maintenance period.
2. Analysis of original drive board

2.1. Traction inverter module introduction
There are 4 same drive boards working in the traction inverter VVVF power module. Three boards are used to drive 6 IGBTs of three-phase leg. One board completes chopping function. The input of the module is 750V DC voltage, and the module converts the DC voltage to 572V AC voltage to power the traction motor of the metro.

![Figure 1. Traction inverter VVVF power module of DKZ31.](image)

The type of the IGBTs in the module is CM1200DC-34N. According to the datasheet, the Gate-emitter threshold voltage is 6-8V. But in real condition, the voltage maybe higher to ensure the complete conduction of IGBT. Therefore, it is necessary to measure the output drive voltage of the original drive board to ensure the normal operation of IGBT.

2.2. Mechanical parameters of drive board
In order to ensure the adaptability of the self-developed drive board, the mechanical parameters of the self-developed drive board should be consistent with original imported drive board, including the thickness overall dimension of the drive board. The hole spacing and hole diameter of the fixed hole should also be the same to the original board. According to the surveying and mapping, the shape and dimension of the original drive board are shown in the figure below. There are 6 fixed holes. The positions are marked by yellow numbers of 1-6, and the hole radius is 98.838mil. The hole spacing of 1-2 and 4-5 is 5323mil, 2-3 and 5-6 is 2157mil, and that of 1-4, 2-5 and 3-6 is 5714mil.

![Figure 2. Overall dimension diagram of original drive board.](image)
2.3. Electrical parameters of drive board

The interface configuration of the self-developed drive board is consistent with that of the original drive board. Therefore, the input and output electrical characteristics of the self-developed drive board should be the same with the original drive board to ensure the functional realization of the self-developed drive board. As shown in the following icon note, red box 1 is the input port labeled X1, and red box 2 and 3 are two-way output ports labeled X11 and X10.

The figure below shows the schematic diagram of X1, X10 and X11. The input and output electrical parameters of the original drive board are measured, and the results are shown in the table below.

| Port | Signal name       | Parameter                  |
|------|-------------------|-----------------------------|
| X1-10| PWM1 signal input | 0-15V square wave           |
| X1-11| PMM2 signal input | 0-15V square wave           |
| X1-16| Power GND         | 0V                          |
| X1-17| Power input       | 15V                         |
| X10-1| PWM1 signal output| 0-15V square wave           |
| X10-2| PWM1 signal output| 0-15V square wave           |
| X10-4| GND output        | 0V                          |
| X10-6| VCC output        | 15V                         |
| X11-1| PWM2 signal output| 0-15V square wave           |
| X11-2| PWM2 signal output| 0-15V square wave           |
| X11-4| GND output        | 0V                          |
| X11-6| VCC output        | 15V                         |
3. Part circuit design of self-developed drive board
This chapter mainly introduces the design of some key circuits. The self-developed drive board is designed according to the following principles:

1. The mechanical structure of the self-developed drive board should be completely consistent with the original drive board, including the shape of the drive board, interface design, location and size of the fixed hole, as to match the requirements of the module for the installation of the drive board and signal connection.

2. The input and output parameters of the self-developed drive board should be completely consistent with the original drive board, as to meet the functional requirements of the self-developed drive board and be able to work normally in the module.

3. The selection of key components should be completely consistent with the original drive board to meet the temperature rise conditions, power conditions, voltage and current conditions of the drive board. On this basis, the key function circuit is constructed to realize the function of the drive board.

3.1. Power supply circuit design
The power supply circuit needs to complete the isolation, voltage transformation and voltage stabilization of the input power supply voltage. It is mainly composed of transformer, power diode, triode, transistor, pulse chip and voltage chip. The key circuit design schematic diagram are followed.

3.1.1. Pulse circuit design
This pulse circuit outputs 15V of 45% duty cycle driving pulse to drive transistor and MOSFET to complete voltage regulation.

![Figure 6. Schematic diagram of pulse circuit.](image)

3.1.2. Transformer circuit design
The transformer circuit completes the function of transforming and isolating the input voltage. It convert 15V to 12V for chip power supply.

![Figure 7. Schematic diagram of pulse circuit.](image)
3.2. Signal circuit design
The signal circuit completes the isolation and conditioning of the input driving signal. It is mainly composed of transistor, operational amplifier and voltage regulator. The key circuit design schematic diagram are followed.

3.2.1. Signal logic circuit
This circuit completes the logic judgment of the input signal to ensure that the two driving input signals are complementary, and prevent the IGBTs of the same bridge arm from conducting at the same time.

![Figure 8. Schematic diagram of pulse circuit.](image)

3.2.2. Signal amplifying circuit
The following figure is the schematic diagram of signal amplifying circuit. This circuit completes the isolation and power amplification of the input signal, and improves the driving ability of the signal to ensure the normal turn on and off of IGBT.

![Figure 9. Schematic diagram of signal circuit.](image)

4. Function test of self-developed drive board
In order to more intuitively compare the functionality of the self-developed drive board and the original drive board, and verify the substitutability of the self-developed drive board, the V-phase drive board in the module is replaced with the self-developed drive board to do module test.

We verify whether the V-phase waveform is normal and whether there is difference between the V-phase waveform and the U-phase waveform to verify whether the V-phase bridge arm works normally, thus proving that the function of the self-developed driving board is completed. Test conditions are as followed.

| Table 2. Module test conditions. |
|----------------------------------|
| Test time | 60mins |
| Input voltage | 150V DC |
| Control method | SVPWM |
| Replaced phase | V-phase |
| Contrasted phase | U-phase |
Measurement parameters

| Channel 1 | Channel 2 | Channel 3 | Channel 4 |
|-----------|-----------|-----------|-----------|
| U-phase current | V-phase voltage | U-phase voltage | V-phase voltage |

Measurement wave forms are as followed. Channel 1 and 2 measured U-phase current and V-phase current. Channel 3 and 4 measured U-phase voltage and V-phase voltage.

![Figure 10. Working picture of V-phase self-developed board.](image1)

![Figure 11. U-phase and V-phase measurement waveforms.](image2)

We can learn from the waveform that V-phase current and voltage waveform is normal and has no difference with U-phase. It can be concluded that the function of self-developed drive board has been realized.

5. Conclusion
The development and preliminary functional test of self-developed drive board for traction module of Beijing Metro DKZ31 train have been completed. The self-developed driver board is designed according to the process of input and output port confirmation, schematic diagram and PCB board mapping, component selection, prototype trial production, static test, power on test and function verification. The test results of module function test are good. In the follow-up, a 6-month on-metro test is required to verify whether the self-developed driving plate meets the requirements in actual subway operation. If there are no other problems in the follow-up test, a batch of boards will be carried out to shorten the maintenance cycle of the original imported drive board and speed up the maintenance process.

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