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Design of Safety Drive Module for DC Switch Machine without Relay

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Abstract. Aiming at the shortcomings of centralized control in the railway signalling system interiorly. This paper introduces a safety driving module of the DC switch machine, which utilizes the advanced power electronics technology based on the “Failure-Safety” principle and could reach SIL4 level. The module is directly installed in the trackside control cabinet. After receiving the control command of the control centre, the module could ensure safe and reliable operation trackside DC switch machine without relay. At the same time, the module solves the problem of current surge when the DC Switch Machine is starting operation. The module is running stable, strong practicability by experiment. It will play an important role in the distributed trackside control system.

1. Introduction

In China, most railway signal control systems adopt centralized control mode [1-2]. That is the control system is centralized installed in the indoor. And the signal cable is used as transmission medium to connect the control system in the signalling equipment room with the outdoor controlled equipment. The drive in signal building adopts relay control mode to drive outdoor controlled equipment. The existing centralized control mode has some defects, such as limited laying length of signal cable, easy mixing, unsuitable for inspection and high cost [3]. This way is bound to gradually withdraw from the stage of history. At the same time, with the improvement of railway transport capacity requirements in China, the reliability and safety requirements of trackside equipment are becoming increasingly stringent [4]. Nowadays, many foreign signal manufacturers have begun to design their own trackside controllers, while our country's trackside control unit only exists in the theoretical stage.

Because the DC switch machine adopts relay drive mode, that is, relay node driver mode [5]. However, relay nodes in outdoor control systems are vulnerable to environmental factors [6-7]. And there is the problem of impulse current when the DC switch machine is started. It affects the operation life of the machine [8]. Therefore, it is necessary to change the traditional control mode and driving mode of the DC switch machine. In this paper, the driver module of the DC switch machine is placed beside the trackside. It could ensure the safe and reliable operation of the DC switch machine without relay node. It also could solve the problem of impulse current.

2. The driving module structure of the DC switching machine without relay

The driver module of the DC switch machine without relay node is a basic module of the trackside control unit. The structure of the mould is shown in figure 1.



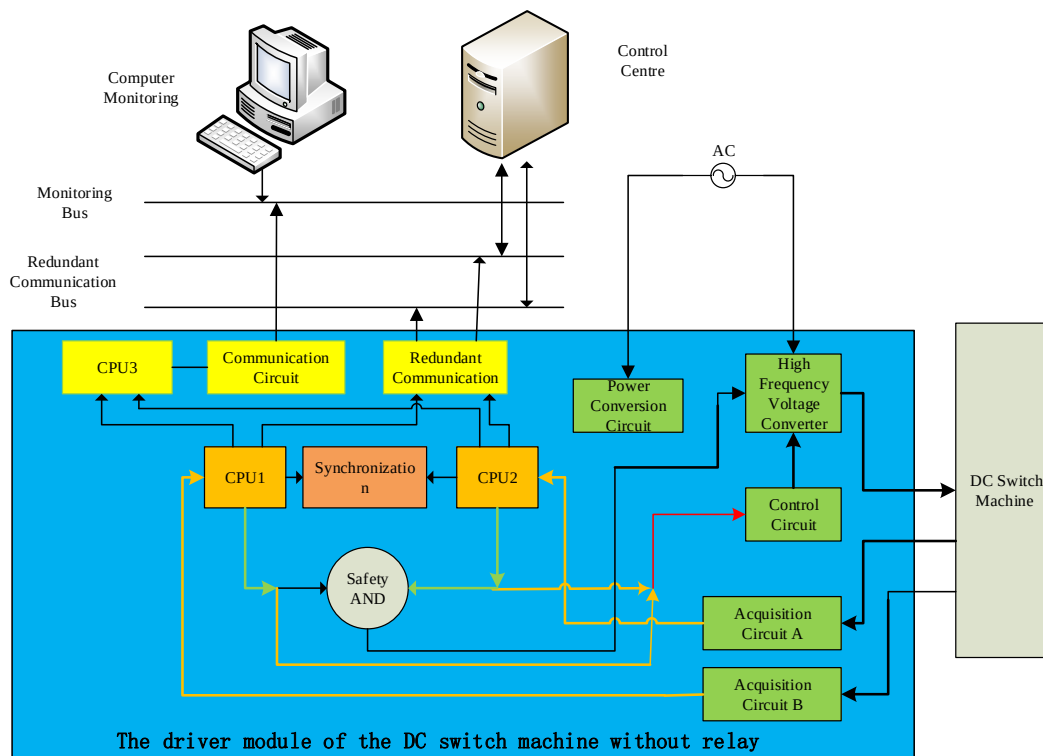


Figure.1 Structural diagram of DC switching machine driving module

The whole module adopts “2 to 2” structure. It is connected with the control centre through communication cable. After checking the communication data received synchronously by the dual CPUs, the mould begins to execute commands. Two CPU generate the “Safety AND gate” and control signals. These two signals could control the power supply of the driving circuit to ensure that when any CPU fails, the high-power circuit has no output. Because of the primary and secondary sides of high-frequency transformer isolated, no matter whether the high frequency voltage conversion circuit fails or not, the secondary side of transformer will not have output. Therefore the mould could drive the DC switch machine safety and reliable. Because of having output voltage and current detection, it could monitor the change of output in real time and stop the output when there is any exception. After the driver is completed, the dynamic acquisition circuit is used to judge whether the switch is in place. Then the position of the DC switch machine is reported to the control centre.

This module has the functions of monitoring, controlling, driving and communication. It could achieve the real-time monitoring of the control centre to the DC switch machine. The characteristic of relay-less nodes reduces the risk of the whole system. And it also has the characteristics of simple wiring, easy maintenance and low cost.

3. The module function

For the DC switch machines in trackside execution units, such as ZD6/ZD9, the module adopts double closed-loop control of voltage and current and “double-cut” safe driving technology has been used to output circuit, which is like traffic signal control mode. Two CPUs receive commands, operation independently and output control signal for the safety drive module together. Accordingly, the “fail-safe” function of the module is realized. This module could achieve the following functions:

- Receiving the control signal of the centre, carrying out double CPU verification, and executing the control command after the verification passed;
- Real-time collecting the position and status of the DC switch machine;
- Driving the DC switch machine to the fixed or inverted position, and automatically stopping the output when it is in place;

- Real-time detecting and monitoring of output voltage and current;
- Self-checking of Driving Circuit and representation Circuit.

The safety drive module for DC switch machine without relay mainly consists of dual CPU logic control circuit, “Safety And” circuit, high-frequency voltage conversion circuit, dynamic acquisition circuit and power conversion circuit.

4. Hardware part

4.1. Power supply

The whole module is powered by trackside AC 220V, which is divided into two routes. The one as the power supply converts AC 220V to DC 24V through switching power supply. And then the DC-DC isolation power supply module is used to supply power for weak current circuits such as control chips. The other as the input voltage of the drive module achieves the rated output voltage by power conversion. Security signals generated by two CPUs control the power supply of driver chips. Therefore, the driver mould could ensure that no matter which CPU fails, there is no output.

4.2. CPU

Adopted the standard “2 to 2” structures, each CPU acquires control information from the communication line independently and constitutes a closed-loop control structure. Two CPU judge the commands from centre, the position of the DC switch machine and detection the output by “2 to 2” logic. High frequency isolation is used between CPU and acquisition, driver circuit.

4.3. Acquisition circuit

The acquisition circuit is divided into two parts: driving acquisition and position acquisition. The driving acquisition circuit gets the information of output voltage and current when the driver module is working and self-checking. It uses isolated operational amplifier to isolate the high voltage electric circuit from the acquisition circuit. The acquisition circuit uses a heterogeneous way, and each result is respectively given to the corresponding CPU. Comparing the acquisition results, two CPUs judge whether the output is normal and the DC switch machine is in place. The schematic diagram is shown in figure. 2.

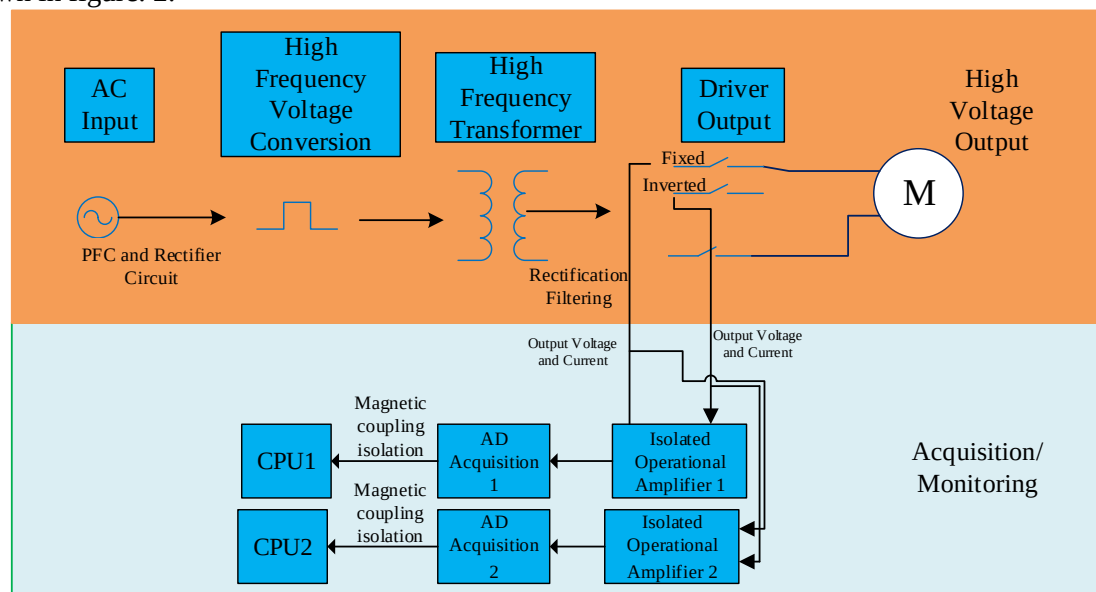


Figure.2 Principle diagram of drive acquisition circuit

The position acquisition circuit uses the principle of dynamic acquisition. It sends the collected results to two CPUs for judging whether the DC switch machine is in place or not.

4.4. Safety drive output

After AC 220 V voltage passing the PFC circuit and AC filter circuit, the voltage is converted to high frequency voltage. The circuit makes power frequency 220V AC signal to high frequency pulse signal. After the high frequency transformer converts this signal, the voltage is converted to the required voltage of the DC switch machine by rectifier filter circuit. The output changes the power electronic device with high voltage resistance and high current, which is controlled by “double-cut”. The schematic diagram is shown in figure. 3.

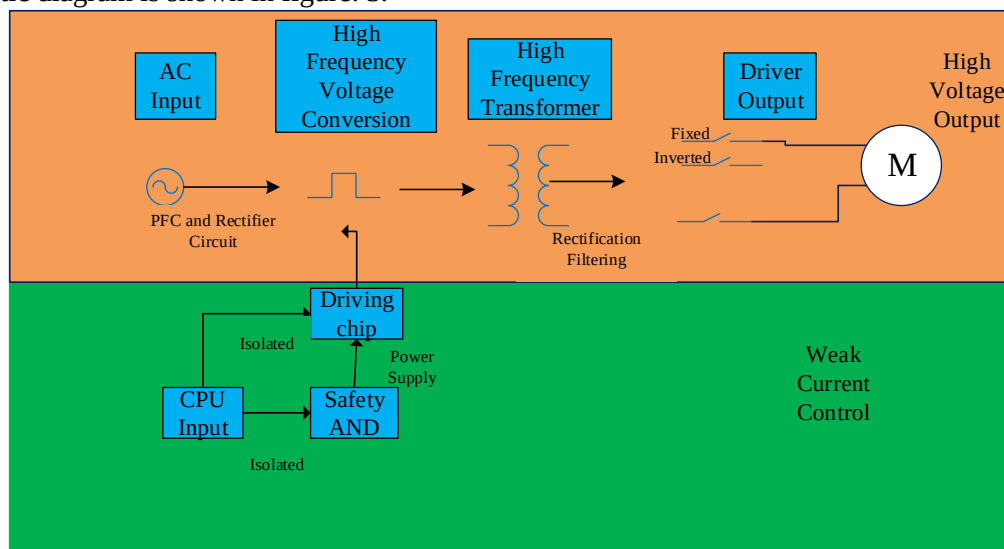


Figure.3 Principle diagram of safety drive circuit

The power electronic devices are controlled by driver chips to convert DC voltage into controllable high frequency AC voltage. The control signal of high frequency voltage conversion circuit is calculated by two CPU through voltage and current acquisition circuit. This signal is sent to the driver chip through the isolation device. In the meantime, CPU generates “Safety AND” signal, and “Safety AND” circuit output controls the power of the driver chip. Only when the dual CPU and the “Safety AND” circuit is working properly, the driver circuit could work normally. When the driver circuit is starting to output, it uses the soft start control mode. That is the mould is steady increase of output voltage to rated voltage within 1s. In this way, the starting current of the DC switch machine does not exceed the normal current when it is starting. This improves the reliability of the circuit and prolongs the life of the DC switch machine.

5. Software design

The software of the module mainly completes the secure communication with the control centre, implementing the tasks of the control centre and stopping the output when an exception is found and reporting it to the control centre. The software of the two CPUs is also designed with the “2 to 2” structure. The flow chart is shown in figure 4.

The software initializes, configures the registers, and self-checks the software at the beginning of work. The position of the DC switch machine is collected after the self-checking. The collected results are processed synchronously by two CPUs, and the collected information is uploaded to the control centre. After the control order is issued by the centre, two CPUs synchronized compare to obtain control information from their respective communication line. The module starts to control the position acquisition circuit and analyse the collected information. Compared with the control command, if the position information is inconsistent, the software calls the driver module for output. The position acquisition works again after the output completed. Compared again with the control command, the software sends command execution information to control centre after the information is consistency. When it is idle, the module carries out self-checking operation according to the prescribed time.

6. Conclusion

The DC switch machine is an important part of trackside actuator unit. The driving module is directly determined the travelling efficiency of the train and even affecting the safety of life. This module is designed according to the principle of “Failure-Safety”. High frequency transformer isolation is used for output. And the driver circuit is timing self-checking. The position acquisition circuit adopts dynamic acquisition mode to ensure the safety and reliability of the whole module. Using this module in modern trackside control unit would significantly reduce the laying of signal cables, reduce the number of equipment rooms, mitigate the workload of maintenance personnel and short the troubleshooting time. This module will play an important role in distributed trackside control system.

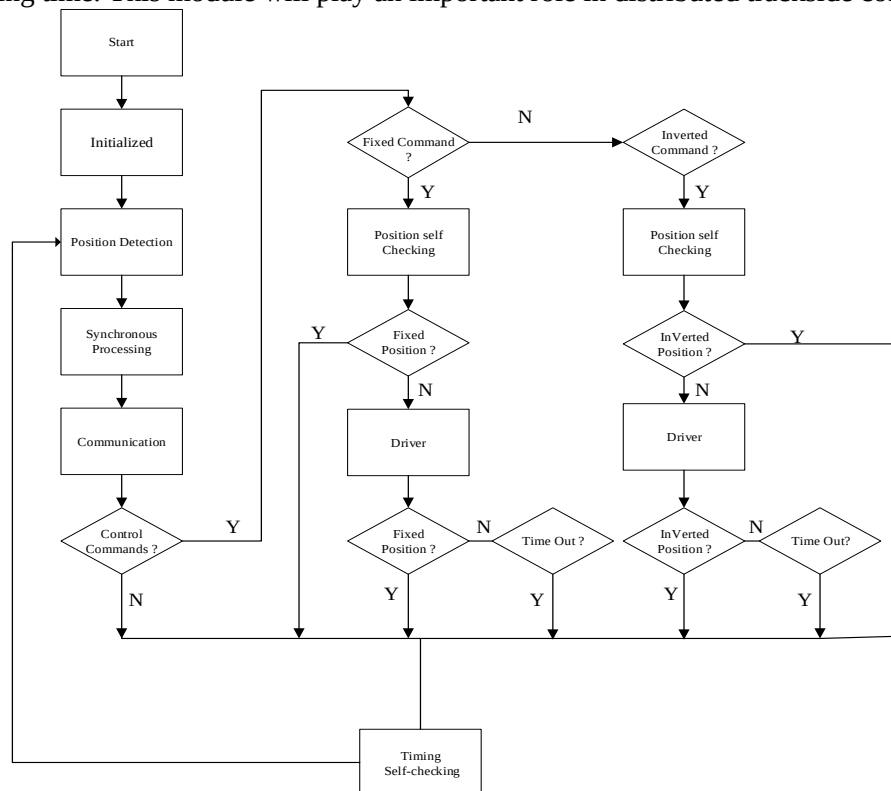


Figure.4 Flow chart of software structure

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