Design of Experimental Device for Electrical Performance of Mine DC Stabilized Power Supply

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Abstract. In order to improve the testing method of the electrical performance of the mine-used DC stabilized power supply, this paper designed a test device for the electrical performance of the mine-used DC stabilized power supply based on STM32F407VET6 single chip microcomputer. The device is mainly composed of AC power output, DC power input, analog load, operation control and other units. It can achieve AC0\textasciitilde1254V AC voltage output underground and the output voltage deviation value, source effect, load effect, and overload of the mine DC stabilized power supply. The current protection value and short-circuit current value are tested and displayed on the display of the industrial computer.

1. Introduction

Mine DC regulated power supply can supply power for all kinds of mine safety instruments and meters, which is a necessary condition for the use of all kinds of mine instruments and meters. The manufacturers of mining DC regulated power supply are increasing day by day [1]. The main performance of the power supply directly restricts the stability and effectiveness of various safety instruments used in the mine. The output voltage deviation value, the stability of output with the fluctuation of AC input voltage, the influence of load size on the power output, etc. can cause instability of power supply in the process of practical application, thus affecting the practicability of various safety instruments and meters [2]. In serious cases, all kinds of instruments and meters can not work normally, which will lead to various monitoring, monitoring and normal equipment operation failure in the mine. In serious cases, it can lead to mine accidents and a series of safety problems [3]. Therefore, it is very important to test the main performance of mine DC regulated power supply. At present, the national coal mine explosion-proof safety product quality supervision and inspection centers in China have to provide AC power input separately when testing DC regulated power supply, and equipped with resistance box meeting the measured power capacity requirements [4]. At the same time, it also needs a separate voltage and current detection equipment to test its main performance, and the test results also need to be calculated manually. This process is very cumbersome, both in time and in actual operation are relatively backward. Therefore, it is necessary to study the electrical performance test equipment of automatic mine DC stabilized power supply.
2. Overall design

2.1. Design scheme of test device
The device is composed of AC power output, DC power input, analog load, operation control and other units, which can automatically select AC output and DC power input modes through industrial computer. By selecting analog load, the output voltage deviation value, source effect, load effect, overcurrent protection and short circuit protection can be tested and displayed through the display of industrial computer. The block diagram of the system is shown in Figure 1. The voltage level of AC output power can be selected by industrial computer, and the industrial computer is electrically connected to the central processor (STM32F407VET6 single chip microcomputer), which transmits instructions to the AC power control circuit, and selects AC AC0 ~ 1254 V voltage through the AC power output circuit. At the same time, the mode of "no load", "load" and "short circuit" of DC power supply can be selected by industrial computer, and the central processing unit (STM32F407VET6 single chip microcomputer) transmits instructions to the analog load control circuit and DC power supply control circuit, which is electrically connected with the analog load connection circuit, and the analog load is put into use according to different modes. The load box indicator light indicates differently according to the mode selection, and the DC power control circuit is electrically connected with the DC power input circuit. The DC power input circuit collects the voltage and current data of the DC input power from the signal collector by switching the no-load and load modes. The signal collector transmits the data to the industrial computer through RJ45 Ethernet port, so as to test the output voltage deviation value, source effect, load effect, overcurrent protection value and short circuit protection value of the DC input power supply, and display the test results through the industrial computer display.

![Figure 1. Test and analysis device composition](image)

2.2. Design of central processing unit
The embedded STM32F407VET6 microcontroller, 32-bit microcontroller based on high-performance ARM and RISC kernel are used in the central processing unit, and the working frequency is as high as 168 MHz. It has floating point unit (FPU) single precision and supports all ARM single precision data processing instructions and data types. It also implements a complete set of DSP instructions and memory protection unit (MPU), which can enhance the security of application programs. It adopts high-speed embedded memory (flash memory up to 1 Mbyte, SRAM up to 192KB), backup SRAM up to 4 KB, and various enhanced I/O and peripheral APB buses connected to the two. Two AHB buses and a 32-bit multi-AHB bus matrix, as well as standard and advanced functional communication interfaces [5].
3. Design of AC power output unit
The test device includes two functions: AC power output and DC power input, and the output voltage level of AC power output can be selected as required.

![Figure 2. AC power control circuit](image)

The AC power output unit is mainly realized by AC power control circuit (Figure 2) and AC power output circuit (Figure 3). When the industrial computer selects the AC output voltage, it transmits the instruction to the central processing unit. The central processing unit sends the relevant instructions to the AC control circuit after processing, and the signals are isolated by the optical coupler and then transmitted to the AC power output circuit. The AC power output circuit outputs a selection signal to the intermediate weak current relay, and the intermediate relay controls the high-voltage AC controller after being pulled in, so that the corresponding AC output branch is turned on and the AC voltage of the corresponding range is output, thus realizing the AC power output.

![Figure 3. AC power output circuit](image)
There are 10 intermediate relays and 10 high-voltage relays in the AC power output unit of the device. The intermediate relay is directly controlled by the AC power output circuit, and the high voltage relay is controlled by the intermediate relay, which can realize the output of AC voltage from AC0 to 1254 V.

4. Design of DC power output unit

4.1. Design scheme
The test of mine DC stabilized power supply can be realized by inputting DC power supply. After selecting this function, the simulated load is put into use, and the current can be adjusted by adjusting the load value, thus realizing the test of output voltage deviation value, source effect, load effect, overcurrent protection value and short circuit protection value of DC stabilized power supply.

As shown in the DC power input circuit in Figure 4, the measured DC regulated power is input through the DC power acquisition input interface, and the input end of the control board is connected with the DC power control circuit, as shown in Figure 5. After selecting the no-load and load modes of the DC regulated power supply, the industrial computer transmits the instruction to the central processing unit. After processing, the central processing unit sends the instruction to the DC power control circuit, and the DC power control circuit feeds back the information to the DC power input circuit. A data collector in the DC power input circuit collects the voltage and current of the input power through the received information, and transmits the collected voltage and current values back to the industrial computer through the transmission interface.

Figure 4. DC power input circuit

Figure 5. DC power supply control circuit
At the same time, the central processing unit also processes the instructions transmitted by the industrial computer and sends them to the analog load control circuit (Figure 6), which is connected with the circuit, as shown in Figure 7. The relay is selected to be turned on by the control command, and the simulated load is put into use. Testers can test the voltage and current of DC regulated power supply under different load conditions by adjusting the simulated load.

![Analog load control circuit](image)

**Figure 6. Analog load control circuit**

At the same time, the load box controls different indicator lights according to the sent instructions, which can provide more intuitive instructions for testers.

![Analog load connection circuit of the present invention](image)

**Figure 7. Analog load connection circuit of the present invention**

4.2. Test result analysis

By detecting the voltage and current values of the DC regulated power supply under different simulated loads, the device can test the output voltage deviation value, load effect, source effect, overcurrent protection value and short-circuit current value in its electrical performance.

After receiving the test data transmitted by the data collector, the industrial computer calculates the voltage deviation value, source effect and load effect by formula (1), (2) and (3).

\[
A = \left| \frac{\Delta U_0}{U_x} \right|
\]  

(1)
In the formula, $\Delta U_0$ is when the load current is zero and rated, the source voltage is adjusted to the specified minimum, nominal and maximum values, and the maximum value of the difference between the corresponding stable output voltage $U_{01}$ and the nominal value $U_X$ is measured.

$$B = \frac{\Delta U_0}{U_0}$$  \hspace{1cm} (2)

In the formula, $\Delta U_0$ is the load current step from the rated value to zero. With the step change of the load current, the stable output voltage measured in the time interval from $5t_e$ to $5t_e + 10s$, the source voltage is adjusted to the specified minimum, nominal and maximum values, and the corresponding stable output voltage $U_{01}$ and The maximum value of the difference between the nominal value $U_X$.

$$C = \frac{\Delta U_0}{U_0}$$  \hspace{1cm} (3)

In the formula, $\Delta U_0$ is a step change of the source voltage from the specified minimum value to the nominal value to the maximum value. On the contrary, with the step change of the source voltage, the stable output voltage measured in the time interval of $5t_e$ to $5t_e + 10s$ respectively. The load current is adjusted to the zero value and the rated value respectively, and the maximum value of the difference between the corresponding stable output voltage $U_{01}$ and the nominal value $U_X$ is measured [6].

To sum up, the industrial computer will directly display the calculated output voltage deviation value, load effect, source effect, measured overcurrent protection value and short-circuit current value on the display. The test device realizes automatic test, saves a lot of time for calculating test results and selecting simulated loads, and greatly improves the test efficiency.

5. Conclusions
Aiming at the problems existing in the electrical performance test of mine DC stabilized power supply, a test device which can provide AC output voltage and realize automatic test of the electrical performance of DC stabilized power supply is designed. The functions are as follows:

1. AC0~1254V voltage can be supplied to external equipment.
2. The output voltage deviation value, load effect, source effect, overcurrent protection value and short-circuit current of DC input power supply can be automatically tested.
3. The measurement results can be visually displayed by the display, which improves the test efficiency.

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