Control System for Digital High-Voltage DC Power Supply

Huasong Yang[1, 2, 3], Hongkui Zhang[1, 2, 3, *]

[1] CCTEG Shenyang Research Institute, Fushun, CO 110178, China

[2] State Key Laboratory of Coal Mine Safety Technology, Fushun, CO 110178, China

[3] Fushun CCTEG Inspection Center Co. Ltd, , Fushun, CO 110178, China

*Correspondence: 18940021505@126.com

Abstract. High-voltage DC power supplies are important equipment in the power industry, and automation and digitization are the development trends for high-voltage DC power supplies. A control system for high-voltage DC power supplies has been designed with a digital signal processor (DSP) as the core, along with the design of a full-bridge inverter circuit, current detection circuit, and voltage feedback circuit. This system achieves stable control of high-voltage DC power supplies and provides a reference for the continuous and healthy development of the DC power supply industry.

Keywords: Coal mine; load center; selectivity; leakage protection.

1. Introduction

With the rapid development of the power industry and manufacturing technology, the use of DC equipment is increasing in various fields such as industry, aviation, and civilian applications. The application areas of high-voltage DC power supplies are very broad. Traditionally, high-voltage power supplies have been realized either by directly using transformers to step up and rectify or by employing voltage doubling rectification methods. Due to the inherent voltage characteristics of high-voltage power supplies and limitations in control, traditional high-voltage DC power supplies have many shortcomings, including larger size and weight, significant output voltage ripple in the power supply system, and relatively low operational efficiency. These factors lead to certain limitations in their applications. However, with the continuous improvement and development of modern power electronics technology, digitization, high-frequency operation, miniaturization, and modularization have become inevitable trends in the development of high-voltage DC power supplies.

2. Control System

As shown in Figure 1, the digital high-voltage DC power supply control system mainly includes a control unit, a DSP, a drive protection circuit, a full-bridge inverter circuit, temperature sensors, a temperature control circuit, current sensors, a current detection circuit, voltage transformers, a voltage feedback circuit, communication circuits, an upper computer, a display unit, and the power grid. The output terminal of the control unit is connected to the input terminal of the DSP; the input terminal of the drive protection circuit is connected to the PWM signal output terminal of the DSP; the control signal input terminal of the full-bridge inverter circuit is connected to the output terminal of the drive protection circuit. The power input terminal of the full-bridge inverter circuit is connected to the output terminal of the power grid; the temperature sensor is fixed on the surface of the power devices in the full-bridge inverter circuit. The input terminal of the temperature control circuit is connected to the output terminal of the temperature sensor, and the output terminal of the temperature control circuit is connected to the signal input terminal of the DSP. The wires passing through the current sensor connect to both input and output terminals of the full-bridge inverter circuit. The output terminal of the current transformer is connected to the input terminal of the current detection circuit, and the output terminal of this detection circuit is connected to the signal input terminal of the DSP. The input side (primary side) of the voltage transformer is paralleled with both input and output terminals of the full-bridge inverter circuit. The output side (secondary side) of the voltage transformer is connected to the input terminal of the voltage feedback circuit, which in turn connects its output terminal to the signal input terminal of the DSP. The input terminal of the communication circuit connects to the communication interface of the DSP, while its output terminal connects to the communication interface of the upper computer. Finally, the input terminal of the display unit connects to the signal output terminal of the DSP.

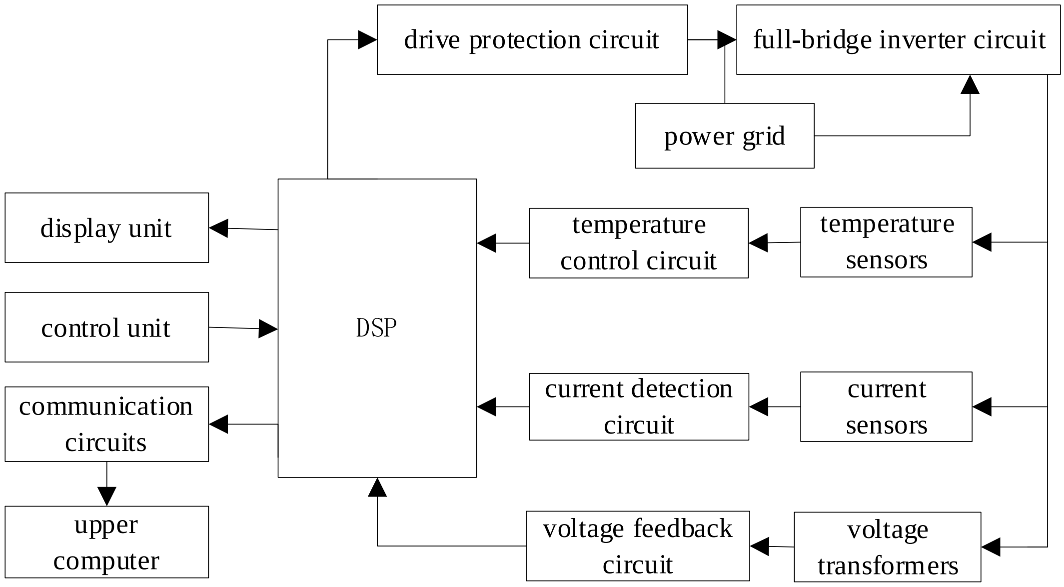

Figure 1. Structure sketch of digital high-voltage DC power supply control system

In this digital high-voltage DC power supply control system, the full-bridge inverter circuit shown in Figure 2 consists of IGBTs, capacitors, resistors, and diodes. The IGBTs are arranged in pairs in series and then paralleled to form a bridge circuit. Resistors and diodes are parallel-connected with capacitors in series to form a buffer circuit that parallels with both collector and emitter terminals of IGBTs. This buffer circuit prevents transient operational voltages from impacting IGBTs and reduces switching losses while ensuring safe and reliable operation of rectifier units. During IGBT turn-off processes, capacitor C charges through diodes, absorbing du/dt generated during turn-off. After IGBT activation, capacitor C discharges through resistor R across its terminals.

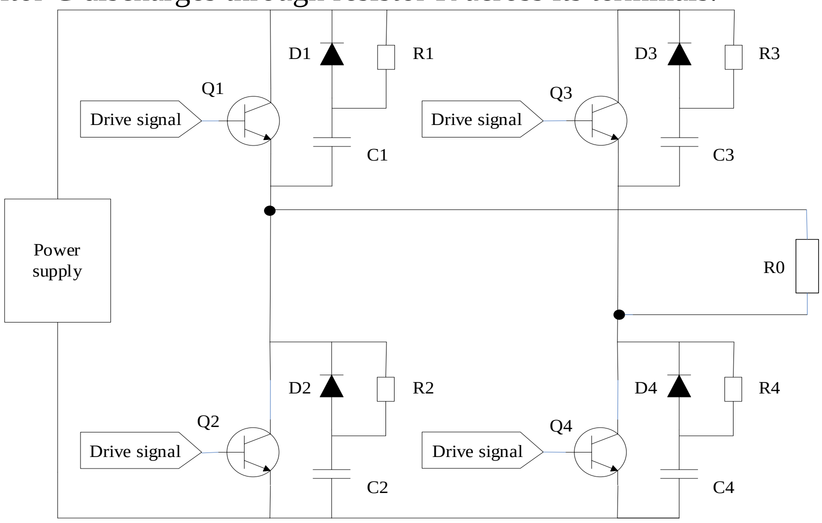

Figure 2. The full-bridge inverter circuit

Current is the primary parameter collected in the digital high-voltage DC power supply control system and serves as a key indicator for assessing the quality of the control system. Current detection utilizes Hall-effect current transformers, with a supply voltage of ±15V. The current detection circuit is shown in Figure 3. Voltage is another important parameter for the output of the digital high-voltage DC power supply, and the voltage feedback circuit is illustrated in Figure 4.

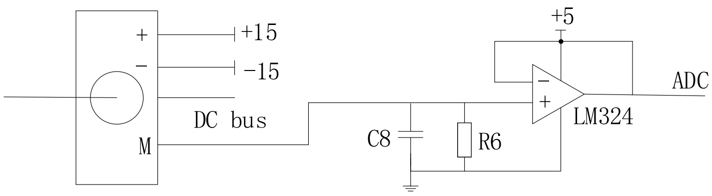

Figure 3. Current detection circuit

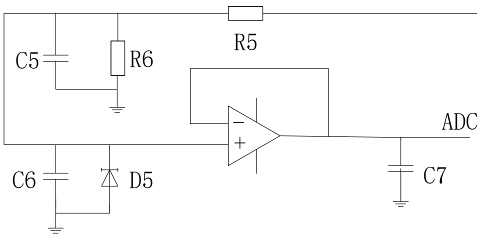

Figure 4. Voltage feedback circuit

The software component of the digital high-voltage DC power supply control system mainly includes the system's main program and interrupt subroutines. The main program in Figure 5 is responsible for initializing the entire system, including initializing pointers, variables, registers, communication modules, event managers, and AD acquisition modules. Additionally, it features functions such as interrupt settings, loop waiting, and implementation of PID control algorithms. System initialization includes configuring the system clock, setting up watchdog registers, and configuring general I/O ports. Event manager initialization refers to setting up and allocating various timers within the DSP. During loop waiting, tasks such as fault detection, input scanning for control units, and communication with the upper computer need to be completed. When a fault occurs in the high-voltage DC power supply—such as damage to an IGBT or excessive output current or power from the full-bridge inverter circuit—safety hazards may arise. Therefore, a dedicated interrupt subroutine for fault feedback shown in Figure 6 must be established to handle these issues by disabling PWM output and disconnecting external power sources to ensure system stability and prevent safety incidents.

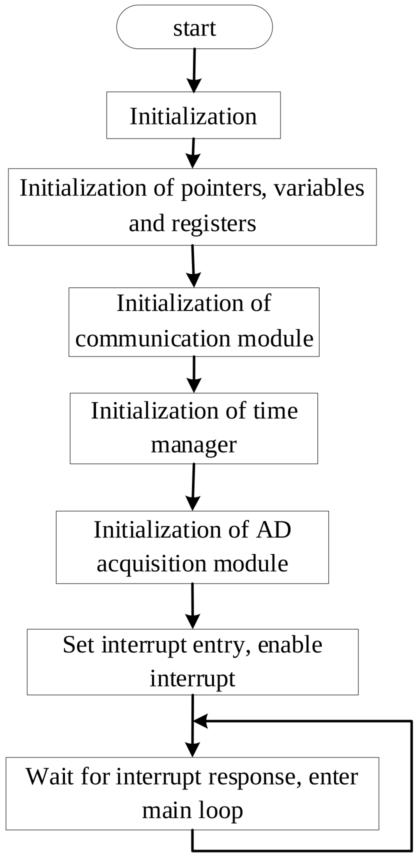

Figure 5. Flow chart of main program of the system

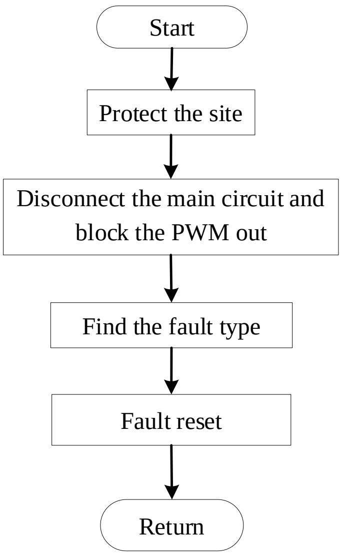

Figure 6. Fault detection subroutine flowchart

3. Conclusion

The digital high-voltage DC power supply control system can convert AC electricity from the power grid into stable DC electricity. It features a simple structure, good reliability, and strong controllability while also providing temperature control, overcurrent protection, and voltage linear regulation functions. This design aligns with the development trends of digitization and modularization in DC power supplies.

References

[1] C. Xin, M. Yan, Li Cheng-xiang, Y. Chen-guo, Du Lin and W. Shi-shou, "Programmable voltage regulating method for high voltage DC power supply based on digital potentiometer and linear photoelectric coupling," 2008 International Conference on High Voltage Engineering and Application, Chongqing, China, 2008, pp. 746-749

[2] H. Li, J. Tang and L. Lin, "Design of digital Control High-voltage DC Power Supply," 2019 12th International Symposium on Computational Intelligence and Design (ISCID), Hangzhou, China, 2019, pp. 19-22

[3] M. K. Badapanda, A. Tripathi, R. Upadhyay and M. Lad, "High Voltage DC Power Supply With Input Parallel and Output Series Connected DC-DC Converters," in IEEE Transactions on Power Electronics, vol. 38, no. 6, pp. 6764-6768

[4] M. G. Giesselmann, T. T. Vollmer and W. J. Carey, "100-kV High Voltage Power Supply With Bipolar Voltage Output and Adaptive Digital Control," in IEEE Transactions on Plasma Science, vol. 42, no. 10, pp. 2913-2918

[5] P. Zajec, D. Voncina, J. Nastran and M. Petkovsek, "Low Power Multiple Output DC Supply - Part II: Crossover Voltage Control in Multiple Output DC Supply," 2006 12th International Power Electronics and Motion Control Conference, Portoroz, Slovenia, 2006, pp. 672-676

[6] C. W. Huang, W. T. Hsu, G. J. Cai and Q. J. Xiao, "Design of Digital Controlled High-Voltage DC Power Supply Based on STM32 Microcontroller," 2020 7th International Forum on Electrical Engineering and Automation (IFEEA), Hefei, China, 2020, pp. 81-84

[7] Zhang YiJie, Zeng Xiangjun, Liu Weibo, Zhao Zhenfeng and Li Jian, "Power supply's design and research for high voltage circuit of active ECT," 2010 International Conference on Power System Technology, Zhejiang, China, 2010, pp. 1-6