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Digital Signal Processor-Based Online Diagnostics for Electric Actuators

Maya Zhang, Oliver Reid, Ethan Brooks
Electrical Department of Taishan Nuclear Power Joint Venture Co.,Ltd.,Taishan City, Guangdong Province, 529200, China

Abstract

An electric actuator, which integrates power electronics technology, computer technology, sensor technology, and motor technology, is a new on-site terminal control device. Especially with the application of intelligent frequency conversion technology, the same device can have different operating speeds and breaking torques within a certain range. This feature is particularly suitable for different working conditions such as valve opening, closing, and operation. In this way, the product specifications and models are significantly reduced, which is conducive to production and user selection. At present, the prototype's test has been completed, and all performance indicators have met the requirements of industry standards. Some technical indicators have even been improved compared with the same type of products of internationally renowned brands. Therefore,its small batch production is being prepared.

Keywords: Electric actuator, Intelligentization, Frequency conversion technology, Digital signal processor

As power electronics technology, computer technology, sensor technology, modern control theory and new permanent magnet materials develop, there have been breakthroughs in the application of intelligent technology and frequency conversion technology in instrumentation. Especially the wide application of digital signal processors and programmable logic devices has greatly promoted the development of intelligent control technology, making it possible to apply digitalization, intelligence and frequency conversion technology to electric actuators.Meanwhile, the intelligent frequency conversion electric actuator also has a series of advantages, such as high positioning accuracy, good dynamic response, high-frequency operation, electronic torque protection, liquid crystal display, and self-diagnosis function for faults. Therefore, the successful development of the intelligent frequency conversion electric actuator will not only improve the technical level of the electric actuator and break the monopoly of foreign products in the Chinese market but also contribute to the rapid development of industrial automation instruments.

1. Overall Structure and Functional Characteristics of Intelligent Frequency Conversion Electric Actuator

1.1 Overall Structure of Intelligent Frequency Conversion Electric Actuator

The intelligent DC brushless frequency conversion electric actuator is mainly divided into the control part and the execution drive part in terms of structure. The control part mainly consists of a single-chip microcomputer PWM wave generator, an IPM inverter, A/D and D/A conversion modules, a rectifier module, input and output channels, fault detection and alarm circuits, etc. The execution drive part mainly includes a permanent magnet DC brushless motor, a position sensor, and a mechanical transmission device. The structural function block diagram is shown in Fig. 1.

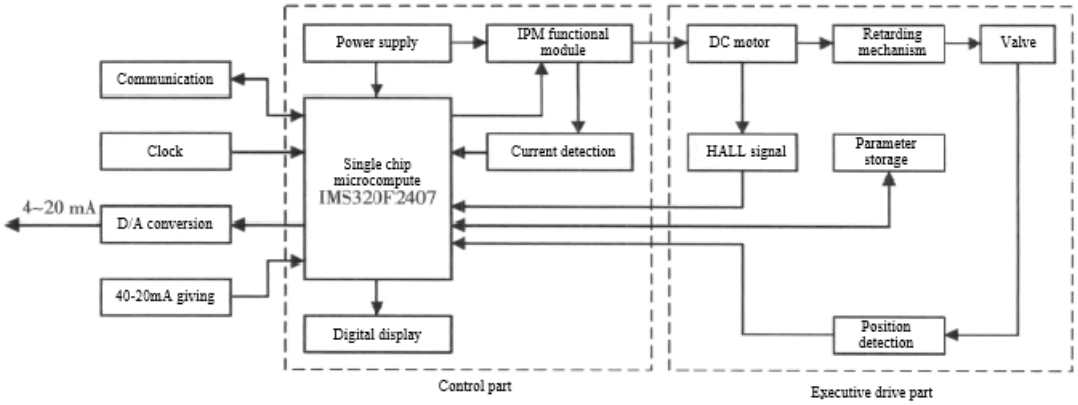

Fig. 1 Overall Structure of Intelligent Frequency Conversion Electric Actuator

1.2 Main Functional Characteristics

The intelligent frequency conversion electric actuator utilizes intelligent, digital frequency conversion technology and single-chip microcomputer technology to endow the electric actuator with characteristics such as intelligence, variable speed operation, good dynamic response, high adjustment and positioning accuracy, good stability, low failure rate, long service life, and a wider range of application scenarios.

(1) High control accuracy

The adoption of high-performance variable frequency speed control technology enables the valve opening and closing speeds in each stroke range of the electric actuator to be set by itself and realizes “flexible start” and “flexible shutoff”, which provides a new and high-precision control mode for the positioning of the actuator, making the positioning accuracy of the actuator reach 1%.

(2) Improve the working characteristics of the valve

For complex control processes, it is always hoped that the opening degree inside the valve is proportional to the flow rate of the medium. According to the characteristics inside the valve, the built-in intelligent control module automatically adjusts the operating speed during the whole process and divides the whole operating time into 10 grades. Each grade operates at a different speed. The setting is completed through parameter setting. This function is called the “process-speed characteristic” and is mainly used to improve the linear characteristic inside the valve. Besides,it also can improve the flow characteristic of the valve.

(3) Realize the functions of “soft start” and “soft close”

It gradually adjusts the valve opening at a low speed with the maximum torque and starts softly and flexibly, which significantly reduces the starting current. Even in the flow and pressure systems with a large number of frequent starts, the motor will not be burned out. This is the feature of variable-frequency flexible soft start and soft close. This function, which is difficult for traditional actuatorsto achieve, has been realized due to the adoption of the built-in integrated frequency converter.When approaching the set or limit position, the frequency converter automatically adjusts the frequency and voltage of the motor supplying the power, reduces the motor speed, and slowly reaches the position at the lowest speed. The electrical braking function is added to avoid overshoot and impact on the valve due to inertia so that the output torque of the actuator will never exceed the preset shutoff torque.

(4) High degree of intelligence

The torque, stroke, and speed of the intelligent frequency conversion electric actuator can be programmed and adjusted, which significantly simplifies the model types, saves the investment in spare parts storage, and facilitates management. The software system is developed for the requirements of various application scenarios of actuators and control valves. The input signal is standardized as 4-20mA and 1-5V; the position feedback signal is standardized; there is wire break protection; the action mode can be set arbitrarily on site; there is interlock control;

there are multiple protections such as phase loss, overheating, over-torque, and valve stuck; there are multiple functions such as watchdog and power-off protection[2-4].

2. Hardware and SoftwareImplementation Schemes of the System

2.1 Hardware Implementation Scheme of the System

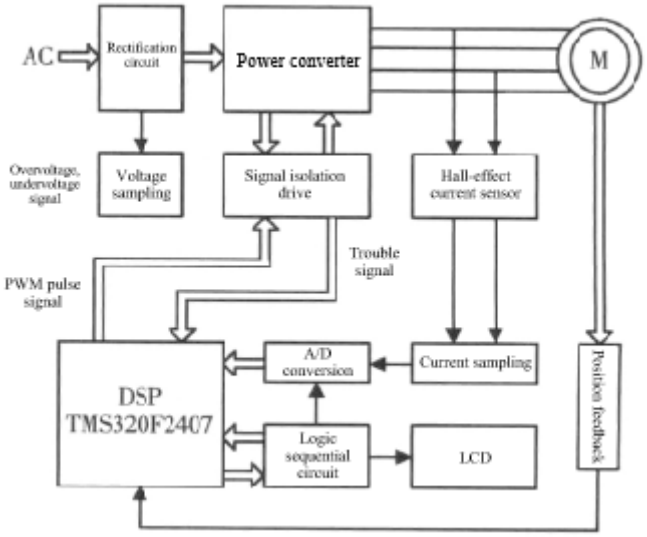

Fig.2 Functionalblockdiagramofthecontrolsystem

Fig. 2 shows the hardware implementation scheme of this system. The control circuit comprehensively processes the position command signal from the upper computer and the output signals of each sensor, and changes the rotation direction, speed, start, braking, torque, etc. of the motor according to the corresponding control strategy, thereby achieving the control of the position inside the valve. The power conversion circuit is the executor of the circuit, which realizes the function of controlling strong electricity by weak electricity in the power conversion. The control circuit uses an integrated chip DSP as the core processor. DSP series chip, TMS320F2407, produced by TI Company, is a special chip for motor control. As it is positioned in the control field, it integrates multiple peripherals suitable for control. The main peripherals include general-purpose I/O ports, SCI, SPI, and A/D. Besides, it is specially equipped with an event manager capable of generating PWM to generate PWM waves and complete the function of adjusting the dead zone[3].

The power conversion circuit uses the SPW frequency conversion control intelligent power module to receive the PWM signal and provide the energy required for the operation of the position control actuator motor according to the given PWM signal. The intelligent power module has a built-in freewheeling diode, which has a fast reverse recovery characteristic and can better suppress electromagnetic interference noise. Meanwhile, it contains internal pole drive control, fault detection and multiple protection circuits. The internal sensor is used to detect the status of the power device IGBT. The internal fault protection circuit is used to achieve fault protection such as overcurrent, short circuit, overheating and undervoltage, and can send the detection signal to the CPU[1,5].

2.2 Software Implementation Scheme of the System

The software of the intelligent frequency conversion electric actuator consists of three parts: control program software, motor drive software, and human-computer dialogue software. Fig.3 shows the software implementation flowchart.

2.2.1 Control Program Software

The control software determines the control strategy and actions of the actuator based on the set parameters and some real-time information. It is equivalent to the brain of the actuator and is the key to determining the quality of the entire control.

Firstly, after powering on, the control program initializes to ensure that all functions and parameters are normal. Secondly, it enters the working mode selection. Here, the working process after the system enters the automatic mode is mainly introduced: After entering the automatic mode, the system continuously detects the given signal, position detection signal and each functional I/O port, etc. Once there is a deviation between the given and the feedback, the software system automatically gives the control signal according to the three set mathematical models until the system reaches a new equilibrium point.

2.2.2 Motor Drive Software

It mainly solves the problems such as the rotation direction and rotation speed of the motor. Meanwhile, it can also transfer events such as over-torque, overheating, stalling, phase loss, and wire break, as well as the instantaneous steering, rotational speed, and motor current to the control circuit according to the preset trigger conditions. For example, for overcurrent fault diagnosis: the operation process aims to detect the sampled current and set two current limit values. If the current exceeds the limit value and lasts for 1 second (this parameter can be set), then the program will set the overcurrent position as and block the pulse. Later, the electric actuator stops operation, stores the fault code, and displays the overcurrent fault.

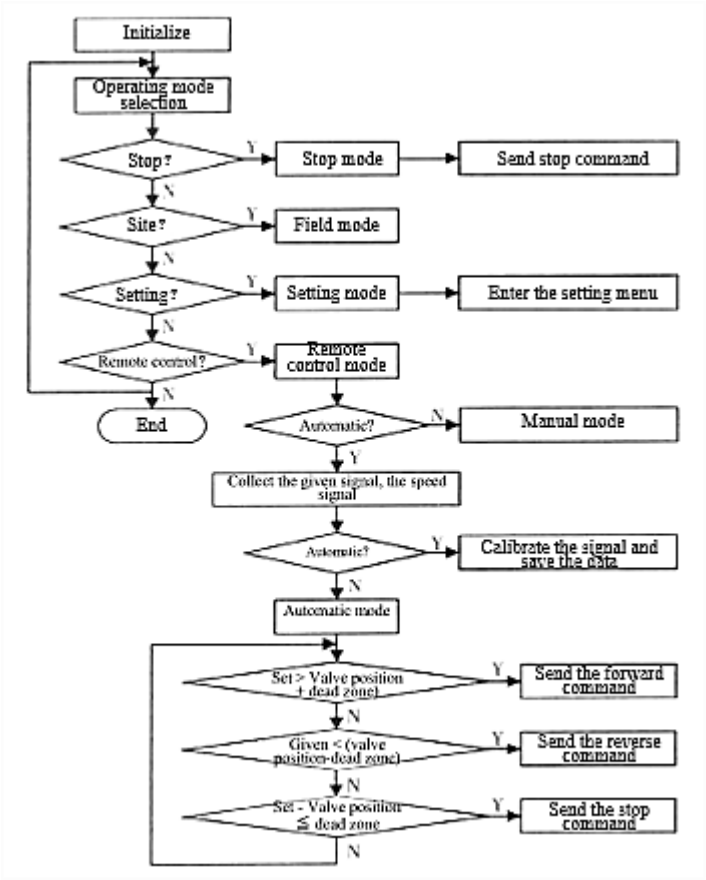

Fig.3 Flowchartofsoftwareimplementation

2.2.3 Human-Computer Dialogue Software

It is mainly used to set some common parameters of the intelligent frequency conversion electric actuator, such as the steering of the actuator, dead zone, fog point, full scale, fault query, restore settings, over-torque protection settings, rotational speed settings, acceleration and deceleration position settings, and minimum speed settings. A start/stop characteristic curve of the actuator can be set by adjusting the parameters such as “rotational speed”, “acceleration position”, “deceleration position”, and “minimum speed”, as shown in Fig. 4, to meet the requirements of different application scenarios for the electric actuator.

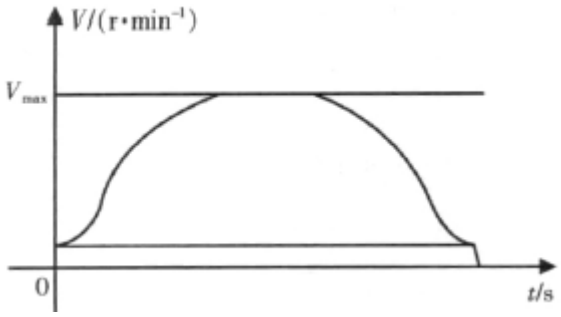

Fig.4 Start/stopcharacteristiccurvesoftheelectricactuator

3. Operating Performance of Intelligent Frequency Conversion Actuator

The main purpose of adopting intelligent frequency conversion technology is intelligentialization and speed variation. As traditional electric actuators have processes such as running, braking, stopping, reverse running, braking, and stopping during operation, frequency conversion actuators have processes such as acceleration, uniform speed, deceleration, stopping, reverse acceleration, uniform running, deceleration, and stopping during operation. After adopting the frequency conversion technology, the soft start and soft close of the actuator are well realized, and the problems such as braking and control accuracy of traditional actuators are solved, which significantly improves the operating performance of the electric actuator.

4. Conclusion

The control system of the intelligent frequency conversion electric actuator adopts a controller integrated with the BLDC motor drive, with all the functional requirements of the intelligent frequency conversion electric actuator. It has achieved a comprehensive breakthrough in frequency conversion technology and intelligent technology for electric actuators. As the core unit of industrial control, it can significantly improve the performance and reliability of the control system and is widely used in industrial control systems in various industries. In this paper, the design and implementation of the software and hardware of the entire intelligent frequency conversion control system is mainly introduced.

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