Research on servo motor motion control system based on Beckhoff PLC

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Abstract. In order to meet the requirements of high precision, reliability and real-time control of biaxial motion. Taking Beckhoff PLC CX9020 and Yaskawa ∑-7S series AC servo controller as the control core, using Yaskawa SGM7J series motor and servo driver matching, the X-Y double axis servo motion control system is designed, and the overall hardware design of the control system is carried out. This paper focuses on the parameter setting, analog and digital acquisition, programming and HMI interface setting of servo motor control system. The debugging operation shows that the system runs stably and meets the control requirements of accurate positioning.

Keyword: PLC, servo control, Parameter setting

1. Introduction
With the rapid development of modern industry, PLC as a new technology is widely used in many aspects, especially in the servo motor motion control system. Now the test equipment has higher and higher requirements on the response time, stability and other performance indicators of the control system. Wei Lingzhi [1] in 2006, using Mitsubishi PLC parameter setting, programming and debugging, designed the electrical control schematic diagram to control two servo motors, through the sensor to detect the position of the workpiece, to achieve the control of shaft speed. Xu Xiaoguang [2] uses Siemens PLC to control the speed and position of four axes. The system has high servo precision and can be used in different applications. Shen Ting [3] introduced the characteristics and application scenarios of servo motor technology, and pointed out that the future development of motor will be intelligent and information-based. Xu Miaoling [4] applied PLC technology in industrial automation, through which analog quantity was collected and data processing was realized; Zhang Jingya [5] designed PLC AC servo motion control device, which greatly improved the fault tolerance of the system; Li Jun [6] studied the effective control of single and double motors in order to improve the motion control level of PLC servo motor. Jin Yongzhou [7] studied the servo motor motion control system, used the servo motor of SGDV-2R8A01A drive module, and realized the control of dual motor operation by using ladder diagram programming. Fan Qiming [8] designed a three-axis motion control system based on Mitsubishi intelligent positioning module QD75MH4. Liu Xiongping and Wang
Gaoli [9-10] introduced the application and development trend of servo motor. According to the functional requirements of the equipment, Beckhoff PLC CX9020 and Yaskawa Σ-7S series AC servo unit are selected as the control core. The advantages of PLC technology and servo control are combined to achieve higher precision of motion. With the development of industry 4.0, multi axis servo is very important, so the system has good application.

2. Hardware composition and working principle of servo system

2.1. Hardware composition of servo control system
Beckhoff PLC CX9020 can select the appropriate module according to the demand. The test equipment needs to collect bending moment signal, so the torque sensor of Kistler is selected. The maximum range of the sensor is 20NM. Since the torque sensor collects voltage signal, EL3002 module is selected, which can collect dual channel voltage signal. The device also needs to collect the angle value, so Omron photoelectric encoder is selected. The resolution of the encoder is 2000P/R. Because the encoder collects digital quantity, EL5101 module is selected. Through EL2521, the high-speed pulse module sends pulses to Yaskawa servo. The module can change the frequency of binary signal and send it in the form of E-bus electrical isolation. The maximum frequency of EL2521 is 500KHz, and the default is 50KHz. Table 1 is the definition of each channel: port 1 and port 5 are connected with positive and negative of phase a, port 2 and port 6 are connected with positive and negative phase B, so that they can work after wiring; if shielded wire is used, the shielding layer can be connected to port 8; ports 3 and 7 are two additional inputs, and port 4 is the GND of these two additional inputs. There are also EL1008 eight channel input module, which inputs digital signal through limit switch; EL2008 has two outputs corresponding to X-axis and Y-axis. Therefore, to consider the damage of PLC caused by over current, we add two intermediate relays at the output of EL2008 to control the large current through small current. As shown in Figure 1.

| Terminal point | NO. | Comment          |
|----------------|-----|------------------|
| Output +A      | 1   | Output +A        |
| Output +B      | 2   | Output +B        |
| INPUT T        | 3   | INPUT T          |
| T.Z.GND/T.Z. Ref.GND | 4 | Signal ground for outputs |
| Output -A      | 5   | Output -A        |
| Output -B      | 6   | Output -B        |
| INPUT Z        | 7   | INPUT Z          |
| SHIELD         | 8   | SHIELD           |

Table 1. EL2521 channel definition

The main function of motor is to convert electrical energy into mechanical energy, which is widely used. With the improvement of the level of electronic power, the intelligent characteristics of the motor are demonstrated. Through the coordinated development of the processor and digital servo system, the calculation performance of the numerical control system is improved correspondingly, and the time is greatly reduced. We chose Yaskawa SGM7J-04FC6S The servo motor controls the control accuracy of the motor through a rotary encoder. The encoder in the digital AC servo motor system is a 24 bit incremental encoder. At this time, the motor rotates for one cycle, receiving 16777216 pulses, and the pulse impulse is 0.00001246°. When the motor rotates, the encoder outputs pulse feedback to the servo driver to form a closed-loop control. The motor power is 750W, the main circuit power supply voltage is AC200 ~ 240V, 50 / 60Hz, the rated speed is 3000rpm, the maximum speed is 6000rpm, and the rated torque is 1.27NM.
Yaskawa SGD7S-5R5A servo driver is selected. L1 / L2 / L3 is connected to the main circuit power supply UVW. If it is single-phase, only L1 / L2 can be connected. L1C / L2C is connected to control circuit power supply. CN1 to upper computer, CN2 to motor encoder, and CN3 to digital operator. The main circuit of the system is single-phase electric connection air switch, and then through the main contact of AC contactor, it is finally connected to the L1 / L2 of servo system. The UVW of servo controller is connected with U1, V1 and W1 of motor, as shown in wiring diagram 2, and the wiring diagram of the whole system is shown in Fig. 3.
2.2 working mode and parameter setting of servo system

The working mode of servo system is divided into position control mode, speed control mode and torque control mode. In this paper, the position control is adopted. The upper computer PLC generates pulses to servo control the motor rotation. The number of pulses determines the rotation angle of the servo motor, and the frequency of the pulse determines the speed of the motor. CN1 has 50 pins, each pin has its own definition. This paper uses 7, 8, 11, 12, 31, 32, 40, 47, in which 7 and 8 pins are defined as pulse input command, 11 and 12 pins are symbol command input, 31 and 32 are servo alarm output, and 40 and 47 are servo enable on. Among them, 7, 8, 11, 12 are connected with el2521 and 31, 32 and el1008 are connected. As shown in Figure 4. For servo drives, up to 500KHz pulses (differential input) can be received. The output torque of the motor is determined by the load. The greater the load, the greater the output torque of the motor. Of course, the rated load of the motor cannot be exceeded. Rapid acceleration or loading may cause the main circuit to be too large to affect the power device.

We use sigma Win + software of Yaskawa to set parameters. The main servo parameter settings of system design are shown in Table 2.

(1) The servo motor of this project is mainly used for precise positioning control.
(2) According to the connection mode of the interactive I / O signal between CPU and servo, the setting value of input and output parameters is determined.
(3) The pulse number and electronic gear ratio are determined according to the position control accuracy.

| Parameter No. | Parameter name                          | Setting value | describe                                      |
|---------------|-----------------------------------------|---------------|-----------------------------------------------|
| Pn000.0       | Rotation direction selection            | 0             | Take CCW as the forward turning direction      |
| Pn000.1       | Control mode selection                  | 1             | position control                              |
| Pn00B.2       | Power input selection of servo unit     | 1             | Single phase power input                      |
|               | with three phase input specifications   |               |                                               |
| Pn200A        | Pitch number of external encoder        | 0             | Symbolic + pulse                              |
| Pn200A        | Pitch number of external encoder        | 2500          |                                               |
| Pn20E         | Electronic gear ratio molecule          | 16777216      |                                               |
| Pn210         | Denominator of electronic gear ratio    | 10000         |                                               |
After setting the servo parameters, set the corresponding parameters on EL2521, as shown in Table 3.

Table 3. corresponding parameters on EL2521

| 8001:01 | Users switch-on-value | RW | 8 |
|--------|-----------------------|----|---|
| 8001:02 | Base frequency 1 | RW | 32767 |
| 8001:03 | Base frequency 2 | RW | 100000 |
| 8001:04 | Rising | RW | 1000 |
| 8001:05 | Falling | RW | 1000 |
| 8001:06 | Frequency factor | RW | 100 |
| 8001:07 | Slowing down frequency | RW | 50 |
| 8001:08 | Emerency | RW | 1000 |
| 8000:0E | Operating mode | RW | Pulse-dir |

After setting the parameters, start the off axis test run, set a frequency value to observe the speed of the shaft.

2.3 Programming of PLC part

Since the encoder is 2000p / R, the driver has 4-fold frequency technology, so a circle of 8000 pulses corresponds to 360 degrees. The range of torque sensor is 20NM, which is subdivided into 32767, so the corresponding formula is as follows:

\[
\text{angle} = \left(\frac{x}{8000} \times 360\right) / 180 \times 3.14
\]

\[
\text{NM} = \left(\frac{\text{niuju}3/32767}{20}\right)
\]

Where x is the uint unsigned variable and Niuju is also the unsigned variable. Angle and NM are real variables.

Declare some variables as follows:

X AT %I*: INT;
OUTPUT1 AT %Q*: BOOL;
OUTPUT2 AT %Q*: BOOL;
POWER: BOOL;
angle : REAL;
X1: REAL;
yspeed1: LREAL;
yspeed AT %Q*:INT;
wx AT %Q*: INT;
qulv: LREAL;
niuju1 AT %I*: INT;
niuju2 AT %I*: INT;
niuju3: INT;
NM: REAL;
niuju3: REAL;
St language is used for programming, some of which are as follows:
OUTPUT1:=POWER;
OUTPUT2:=POWER;
X1:=INT_TO_REAL(X);
angle:=(x1/8000*360)/180*3.14;

2.4 Design of HMI interface
Beckhoff software designs HMI interface by adding visualization in Twincat3 main program. As shown in Figure 5, two rectangular design button controls are designed to enable, forward rotation, reverse rotation, origin and emergency stop. Then it is connected with the corresponding variable. Through forward rotation, the shaft rotates in the forward direction, and reverses in the reverse direction. If the emergency stop is pressed, the shaft stops rotating; if the origin is pressed, the axis returns to the original position.

![HMI interface](image)

**Figure 5.** HMI interface

3. Conclusion
To sum up: in this paper, the data acquisition and the speed and position control of the two axes are successfully realized through Beckhoff PLC and its various modules. The servo driver is controlled by Beckhoff PLC HMI for forward rotation, reversal, origin and function to realize multi axis movement, which can easily realize the quasi synchronous operation of multiple axes.
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