Academic Journal of Engineering and Technology Science
ISSN 2616-5767 Vol.3, Issue 5: 13-20, DOI: 10.25236/AJETS.2020.030503

Research on Programming Failure of PLC Direct Translation Method

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Abstract. *Motor jog failure appears in the process of transforming relay control circuit into PLC ladder diagram with PLC direct translation. Taking the motor jog control system as an example, firstly analyze the root cause of failure according to PLC serial operation that is PLC contact soft component changes state after one scan cycle of its coil soft component. Then design solutions and improve program according to the functions of retention and memory of PLC auxiliary relay. Finally, the feasibility of the solution is verified through the experiment, and good results are achieved. The results supply some guidance for PLC programming in engineering.*

Keywords: *Auxiliary relay, PLC direct translation, Serial operation, Motor jog*

1. Introduction

PLC control technology is an indispensable key technology in industrial control. PLC technicians master the principle, programming and application of PLC control technology by doing, and improve the actual operation ability and hands-on innovation ability. PLC direct translation programming is an easy and necessary programming method for beginners of PLC control technology. It can connect the electrical control technology to PLC control technology effectively. However, the PLC direct translation programming fails in the classical motor jogging control, so, how to guide the students to analyze and solve the problem has become the key to the teaching of PLC control technology.

2. Failure of PLC direct translation programming

PLC control technology is a control technology developed on the basis of relay control technology. There are many connections between PLC program design and relay control circuit design. The switch, contact and coil in the relay control circuit are transformed into the soft element contact and coil in the PLC ladder diagram to realize the control function with the same effect. This method is called "transplant design method"[2] or "direct translation method"[3] of PLC program. However, in

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some cases, the function of direct translation method will fail, that is, the function that can be realized in the relay control circuit. After the corresponding PLC program is designed by direct translation method, the same function cannot be realized. The most typical is the motor jogging control.

As shown in Figure 1 below, when the inching control is required, press the inching button SB3, the normally open contact is closed, the normally closed contact is open, the output coil powers on, and the motor starts. Release the jogging button SB3, the normally open contact is open, and the normally closed contact is closed. However, due to the KM output coil and its normally open contact is open, then the motor stops, thus realizing jogging control.

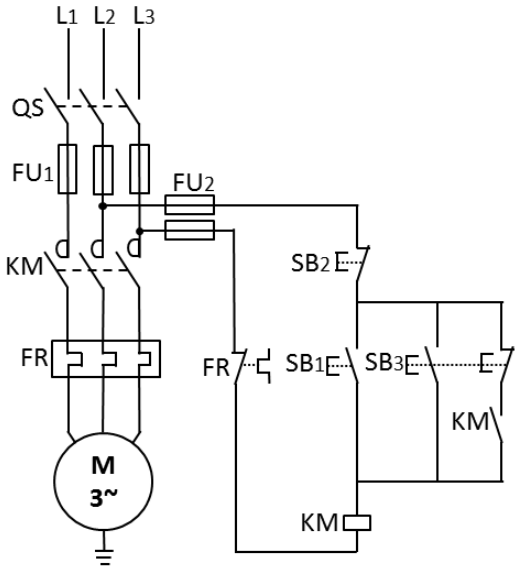

Figure. 1 Circuit diagram of motor jogging control system with relay

Siemens s7-1500 series PLC is selected, CPU is 1511-1pn, input module is DI 16x24vdc HF, output module is DQ 8x230VAC / 2A ST. The relay control motor jogging control circuit in Figure 1 is modified, and the ladder diagram is compiled by PLC direct translation method. The configuration, compilation and debugging are completed in Portal V14 software. The hardware wiring diagram and ladder diagram are shown in Figure 2 below. The debugging results show that when the jogging button is pressed, the motor starts; when the jogging button is released, the motor cannot stop, that is, the jogging function fails.

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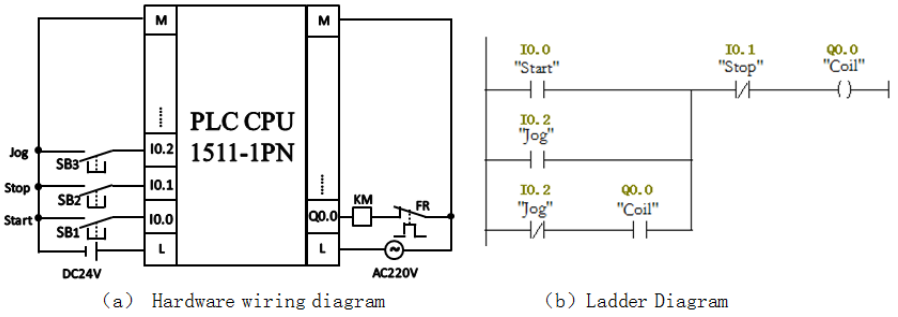

Figure. 2 Hardware wiring diagram and ladder diagram in case of jogging failure of PLC control system

3. Cause analysis of jogging failure

The problem of motor jogging failure needs to be analyzed from the scanning cycle, memory structure and serial operation mode of PLC, and through the single-step operation mode of the program, observe the change of PLC soft element state when jogging failure, and find out the root cause of failure.

3.1 Scan cycle of PLC

The motor jogging system controlled by PLC is mainly composed of external input, external output, CPU module, working memory and system memory. The external input mainly includes start button SB_1, stop button SB_2 and jog button SB_3. The external output is contactor coil KM. During the operation of the system, the CPU periodically scans the user program in the working memory according to the sequence number of instruction steps, and completes the operation of the program through three stages: centralized input sampling, program execution and centralized output refresh [6]. The task of the input sampling phase is for the CPU to read the information of the input image register. The task of the program execution stage is CPU operation, processing the program written by the user, and outputting the result to the auxiliary contactor m and the output image register. The task of the output refresh phase is for the CPU to write the information in the output image register to the output latch. The three stages are carried out in sequence, but the time taken is quite different. Because the structure of memory and the process of PLC scanning cycle are fixed, the time length of PLC scanning cycle is mainly determined by the speed of CPU execution and the number of user programs.

CPU execution time is usually microseconds or nanoseconds. Taking the Siemens PLC series with the highest market share as an example, the bit operation time of the fastest cpu1511-1pn / DP ODK is $1.0x10^{-6}$ seconds (i.e. 0.001 microseconds). This jogging control program has 10 bit operations in total, and the time required to execute the program phase is $1.0x10^{-5}$ seconds (i.e.0.01

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microseconds). Even with the time of centralized input sampling and centralized output refresh phase, the time of a scanning cycle is microsecond level. The response time of input and output actuators (such as buttons and contactor coils) is about 0.5 seconds, which is 50000 times or more than that of a scanning cycle. Therefore, on the one hand, the PLC control system ensures that whenever the button is pressed, the CPU can read the changed input signal in the input image register and write the result to the output latch to change the output state. On the other hand, for each operation (such as pressing the jog button once), the PLC will perform multiple scan cycles and maintain the results of the last scan cycle.

3.2 Serial operation mode of PLC

In the relay controlled motor jogging control system, the control elements are in parallel operation mode [5]. That is, in one operation, the state changes of input button, contactor or relay coil and contact (normally open or normally closed) are completed at the same time. Although there is the possibility of response lag of contactor coil during operation, it will not cause contact competition without time relay [7]. As shown in Figure 1, during jogging operation, the normally open contact of jogging button SB_3, the normally closed contact of jogging button SB_3, and the normally open contact of contactor change simultaneously.

Because the scanning cycle of PLC is in the order of "input sampling → program execution → output refresh". The state change of the coil and its corresponding normally open contact and normally closed contact in PLC soft element is carried out in the way of coil first, then contact. Therefore, when the program is executed, the state of a coil is changed. After the output is refreshed, the state of the contact will change in the next scanning cycle. This kind of operation mode, which changes the coil first and then the contact, is called serial operation mode. Therefore, in a complete operation process, the input contact soft element and the output coil soft element change the state first, and the contact soft element corresponding to the output coil soft element will change the state in the next scanning cycle. As shown in Figure 2, when the jog button SB_3 is pressed, the normally open contact and normally closed contact of the input jog button SB_3, and the output coil Q0.0 change the state in a scanning cycle first, while the normally open contact Q0.0 of the output coil changes the state in a scanning cycle later.

3.3 Jogging failure process

In order to further observe the process of jogging failure, the ladder diagram shall be debugged in one step, and the process is as shown in Figure 3 below. The solid line in the ladder diagram indicates that the circuit is on, and the dotted line indicates that the circuit is off. During the jogging process, there are four scanning cycles in which the state of the soft element changes. The first scanning cycle is the initial state; In the second scanning cycle, just press the jog button Sb3, the soft element of the normally open contact I0.2 and the output coil Q0.0 changes from off to the power on; In the third scanning cycle, the button SB_3 is in the pressed state,

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and the normally open output coil Q0.0 changes from off state to on state; In the fourth scanning cycle, when the jogging button SB_3 is just released, the normally open contact of I0.2 changes from on to off, and the normally closed contact of I0.2 changes from off to on. However, at this time, the normally open contact of Q0.0 keeps on state of the third scanning cycle, which makes the output coil of Q0.0 keep on and the motor keep running, making the jogging stop fail.

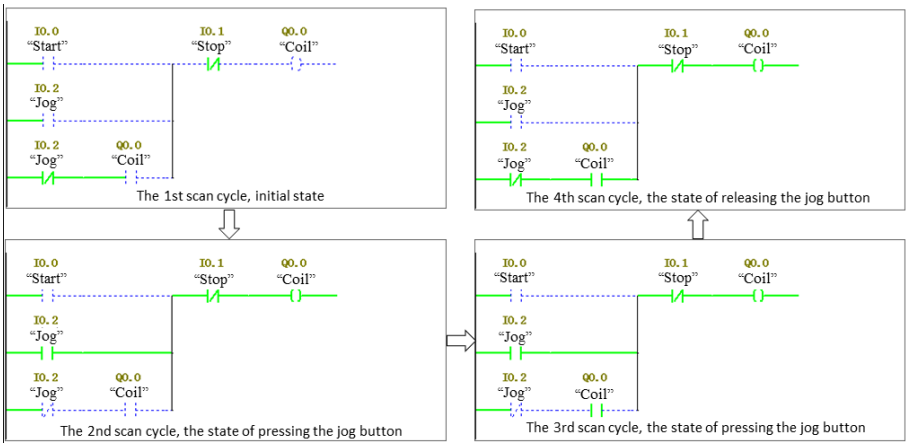

Figure. 3 Failure process of motor jogging

4. Solutions to failure

On the basis of the root cause, the idea of solving the problem of jogging failure and the improvement procedure are designed and verified.

4.1 Thinking analysis

It can be seen from the above analysis that the root cause of jogging failure is that when the fourth scanning cycle of SB_3 is released, the input normally closed contact of I0.2 is on, and the input normally open contact of I0.2 is off, however, due to the serial operation mode of PLC, the output normally open contact Q0.0 maintains the on state of the third scanning cycle, which results in the simultaneous on of the input normally closed contact of I0.2 and the output normally open contact of Q0.0, making the output coil of Q0.0 on. Therefore, the solution is to find a way to let the input normally closed contact of I0.2 and the normally open contact of Q0.0 output not be powered at the same time when the fourth scan cycle of the jog button SB3 is released. And because the state of the Q0.0 output normally open contact will always maintain the on state of the previous scan cycle, only the input normally closed contact of I0.2 can maintain the off state of the previous scan cycle. Because the auxiliary relay has the function of maintaining a certain state [8] and the

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phase memory state [9], the auxiliary relay is designed to solve the problem in the original program.

4.2 Program improvement

According to the process flow of the system, the PLC program ladder diagram of the system is designed as follows. A program is added at the last line of the original program. The normally open contact of I0.2 is connected in series with the output coil of auxiliary relay M0.0, and the normally closed contact of M0.0 is used to replace the normally closed contact of I0.2. Utilizing the phase memory state of M0.0, when the jog button SB_3 is released, the M0.0 normally-closed contact maintains an off state for one scan cycle, causing Q0.0 to lose power, thereby achieving the jog function.

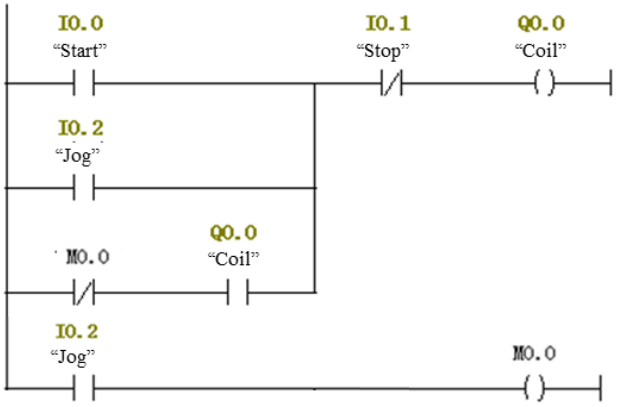

Figure. 4 Improved ladder diagram using auxiliary relay M0.0

4.3 Verification of results

Complete the hardware wiring according to the hardware wiring diagram, and perform software configuration, programming, compilation, download, and verification in Portal V14 software. The results show that when the jog button SB_3 is pressed, the motor runs normally. After the jog button SB_3 is released, the motor stops normally and the jog control is realized. At the same time, the running status of the program is monitored under step debugging, and the process is shown in the figure below. At this time, the PLC changed from the original 4 scan cycles to 5 scan cycles. The 1st scan cycle is the initial state, and the changes in the second to fifth scan cycles are analyzed as follows. During the 2nd scan cycle, just press the jog button SB_3, the normally open contacts of I0.2, the output coil of Q0.0 and the output coil of M0.0 are on, and the motor runs. During the 3rd scan cycle, the jog button SB_3 is in the pressed state, the normally open contact of Q0.0 is on, the normally closed contact of M0.0 is off, and the motor runs; during the 4th scan cycle,

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the jog button SB_3 is in the released state, the normally open contact of I0.2 is off. At this time, because the normally closed contact of M0.0 still maintains off state of the previous scan cycle, no branch is turned on, Q0.0 and M0. 0 output coil is off and the motor stops; During the 5th scanning cycle, the jog button SB_3 is in the released state, the normally open contact of Q0.0 is off, the normally closed contact of M0.0 is on, and the motor keeps stopping. Thereby, a jog function is realized.

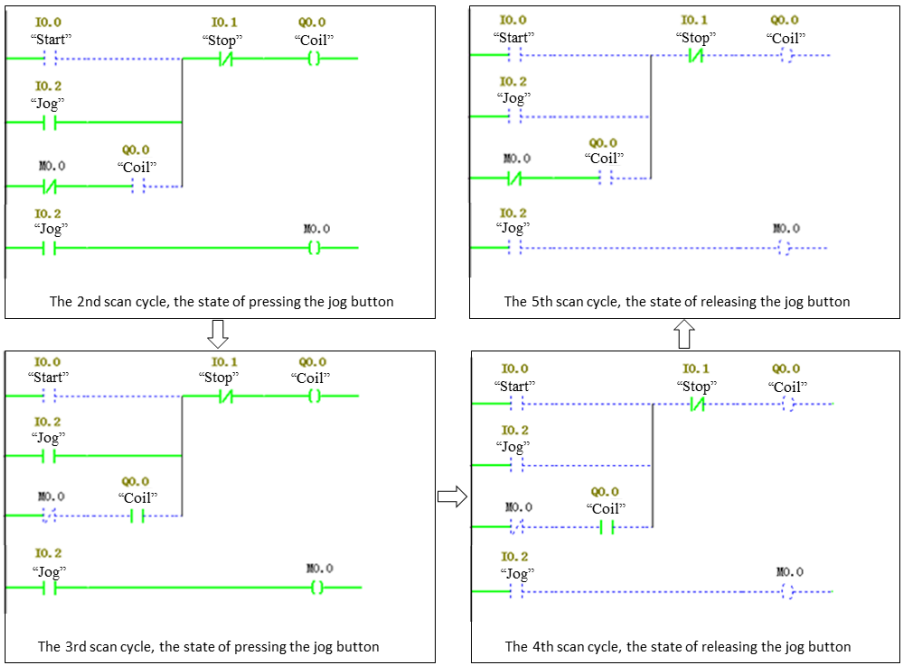

Figure. 5 The operation process of the improved ladder diagram

5. Concluding remarks

Taking the classic motor jog control as an example, to solve the problem of the failure of the jog function in the direct translation method of PLC, starting from the PLC scanning cycle and combining the characteristics of PLC serial operation, analyzing that the PLC coil changes state in first scanning cycle, and the corresponding contact changes the state after one scanning cycle, which is the root cause of the problem. According to the retention of the auxiliary relay and the effect of periodic memory, the improvement ideas are determined, the original program is improved, and the effectiveness of the improvement is verified through experiments. In the process of solving the problem, the method of step debugging is innovatively used to intuitively detect the changes of various states in the running of the program, and the idea of using the auxiliary relay to improve the program to solve the

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problem is proposed and verified. Apply the results to the actual project to effectively avoid PLC programming failure.

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