

# Design and Implementation of Syrup Mixing Control System Based on S7-1200 PLC

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## Abstract

For the syrup mixing process commonly used in industry, the new Siemens s7-1200plc is used as the controller, the PROFINET communication configuration is carried out through Portal V15 software, and the general G120 frequency converter is connected to realize the multi-stage high-speed operation of the mixer; Thermocouple and temperature transmitter are used to improve the temperature measurement accuracy of the reactor to  $\pm 1\%$  FS; Through PLC modular programming, the high-precision mixing and stirring control of glucose and spices in the reactor is realized. At the same time, the simplified tp700hmi is used to realize the visual and monitoring operation of the whole system.

## Keywords

S7-1200PLC; G120 frequency converter; Syrup mixing control system; ROFINET communication.

## 1. Introduction

In the fields of food processing, pharmaceutical manufacturing and paper production, material mixing is a common process, and syrup mixing is an essential and important link in the process of food production [1]. The syrup mixing control system with strong scalability, high precision and stable operation can effectively shorten the production cycle, reduce the investment cost and improve the product quality. It is more and more widely used in enterprise production. With the development of automatic control technology and the new requirements of industry 4.0, the application of PLC fieldbus technology to production line has become an important engineering topic [2]. Therefore, the use of HMI and PROFINET technology to design a syrup mixing control system with stable operation, good scalability, high control precision and visualization can meet the urgent needs of food processing enterprises. On the other hand, many syrup mixing control systems still use the discontinued Siemens S7-300 / 400 PLC as the controller, which cannot meet the increasingly complex control and expansion requirements. Therefore, it is of great practical value to use the widely used Siemens s7-1200plc to realize the high-precision control of syrup mixing.

## 2. Demand Analysis of Syrup Mixing Control System

### 2.1. System Structure

The syrup mixing control system of a factory is shown in Figure 1. The main function of the syrup mixing system is to complete the automatic heating and stirring production of glucose and flavors in the reactor. The system is composed of glucose tank, glucose feed pipe, glucose valve, mixing motor, reactor, spice tank, spice feed pipe, spice valve, discharge valve and discharge pipe. When the glucose valve is opened, the glucose in the glucose tank enters the

reactor through the glucose feed pipe; When the glucose valve is closed, the glucose stops flowing into the reactor. Similarly, when the spice valve is opened, the spice in the spice tank enters the reactor through the spice feed pipe; When the spice valve is closed, the spice stops flowing into the reactor. A mixer and a thermocouple sensor are installed inside the reactor. The thermocouple is used to obtain the internal temperature of the reactor. The mixer rotates according to the temperature and process requirements to complete the mixing of syrup. When the discharge valve is opened, discharge the mixed syrup through the discharge pipe; Stop discharging when the discharging valve is closed.

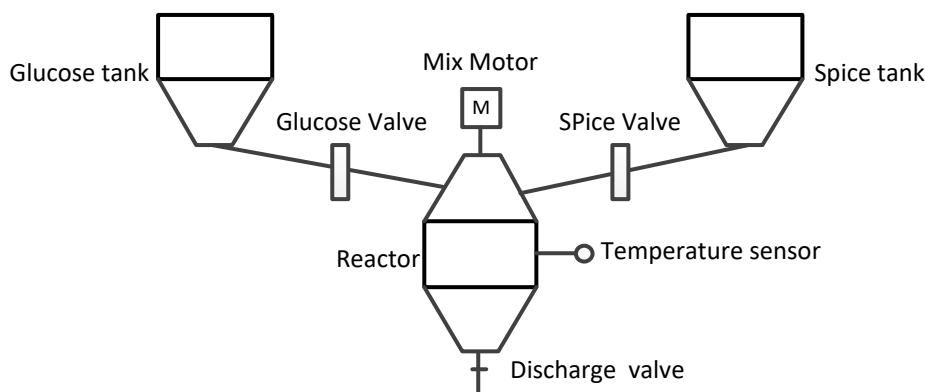


**Figure 1.** Structure diagram of syrup mixing control system

**Table 1.** Multi-element analysis of ore

|         |                                |      |      |      |                  |
|---------|--------------------------------|------|------|------|------------------|
| element | Pb                             | As   | Cu   | S    | Fe               |
| content | 0.022                          | 1.36 | 2.21 | 0.38 | 7.54             |
| element | Al <sub>2</sub> O <sub>3</sub> | MgO  | CaO  | Au   | SiO <sub>2</sub> |
| content | 10.50                          | 0.87 | 1.23 | 0.93 | 35.78            |

## 2.2. System Control Requirements

According to the production process requirements, "start", "stop", "emergency stop" and "reset" buttons are set on the system control cabinet. At the same time, it is divided into manual control mode and automatic control mode. The switching of working mode is realized through the change-over switch, and the mode switching is allowed only when the system must be in the stop state.

### 2.2.1 Start Stop Control

Press the "start" button on the control cabinet to power on and start the system; Press the "stop" button and the system will pause. Press the "start" button and the system will continue to operate; Press the "emergency stop" button and the system will stop immediately. It is necessary to restore the "emergency stop" button and press the "start" button before the system continues to operate; Press the "reset" button to restore all devices of the system to the initial state.

### 2.2.2 Manual Control Mode

In the manual control mode, the opening and closing of glucose solenoid valve, spice solenoid valve, start and stop of reactor mixer (operating frequency is 30Hz) and opening and closing of discharge solenoid valve can be controlled respectively. All manual operations are realized on the touch screen.

### 2.2.3 Automatic Control Mode

Under automatic control mode, the system mainly meets the following requirements:

- (1) Press the "Run button" on the touch screen, open the glucose solenoid valve, put the glucose into the reactor for 20s, and then close the glucose solenoid valve.
- (2) The thermocouple detects the temperature of the reactor. When the reactor temperature is less than 20 °C or the reactor temperature is greater than 200 °C, the mixer stops and the system gives an alarm; When  $20\text{ °C} \leq \text{reactor temperature} < 80\text{ °C}$ , the operating frequency of the mixer is 30Hz; When  $80\text{ °C} \leq \text{reactor temperature} < 150\text{ °C}$ , the operating frequency of the mixer is 40Hz; When  $150\text{ °C} \leq \text{reactor temperature} \leq 200\text{ °C}$ , the operating frequency of the mixer is 50Hz;
- (3) After stirring the glucose for 60s, the spice solenoid valve is opened and the spice is added into the reactor. After 10s, the spice solenoid valve is closed.
- (4) mixer continue to run, continue mixing 60s, mixing sugar, glucose and essence mixture, stop stirring, delay 2S, open the reactor valve, release syrup, after 30s for a long time, close the discharge solenoid valve and stop discharging.
- (5) After the finished product is discharged from the reactor, wait for 5S to start a new production process.
- (6) After pressing the "stop" button on the touch screen, the "run" indicator on the touch screen goes out, and the "stop" indicator flashes for 5 seconds, and it is always on.

### 3. Hardware Design of Control System

#### 3.1. Selection of PLC

The selection of PLC mainly includes the selection of CPU module and I / O module. The selection principle is to pursue the scalability and high cost performance of the system on the premise of meeting the performance. After comparison, the small high-performance s7-1200 series PLC launched by Siemens in recent years is selected, and its CPU is 1214C DC/DC/DC type. The order number is 6ES7 214-1AE30-0XB0, including 14 digital inputs and 10 digital outputs. Compared with S7-300 or 400 series PLC widely used in the previous market, the advantages are reflected in faster information processing, higher rate PROFINET data communication, more efficient configuration and programming and lower maintenance cost [3], in which the execution time of word operation instructions is increased from 200 ns to 72 ns, It will effectively improve the real-time and accuracy of temperature control in the process of syrup mixing. Since the standard CPU module of S7-1200 series has no integrated analog I/O point, it is necessary to use the extended analog I/O module [4]. The temperature data of the reactor in the system is analog. Considering the real-time performance of the data and the scalability of the system, the analog input module SM1234 is selected with the order number of 6ES7 234-4HE30-0XB0, including 4 analog inputs and 2 analog outputs.

#### 3.2. Selection of Temperature Measurement Module

The temperature measurement module is mainly composed of thermocouple and temperature transmitter. The model of thermocouple is WRC-330, that is, the material is copper-copper-nickel alloy. It is installed and fixed with movable flange and has waterproof function. The measurement temperature is 0 °C ~ 350 °C. The temperature transmitter adopts Siemens TH200 model, the input power supply is DC24V and the output current is 4-20mA.

#### 3.3. Selection of Frequency Converter

In the system, the frequency converter is mainly used to control the high-speed and low-speed operation of the agitator motor, fast acceleration and deceleration. In the process of operation, it is required to achieve high safety, realize remote control from the field control requirements, and technically have strong communication function. Combined with the above situation, Siemens G120 series frequency converter with built-in dynamic braking unit, flexible use,

stable communication, convenient configuration, easy maintenance and mainly used for material transportation is selected. Its model is G120 CU250S-2PN VECTOR, order number is 6SL3246-0BA22-1FA0, and the corresponding power module model is PM240-2 IP20, order number is 6SL3210-1PE12-3UL1, The power range is 0.37 ~ 250 kW, which can meet the system requirements.

### 3.4. Selection of HMI

HMI, also known as industrial man-machine interface or touch screen monitor, mainly realizes intelligent operation control and display function. The system needs to realize manual, automatic, reset, stop, start and other button operations, system operation status or indicator light of solenoid valve, real-time display of reactor temperature and other functions. Based on comprehensive consideration, Siemens TP700 COMFORT touch screen with order No. 6AV2 124-0QC02-0AX1 is selected. The touch screen can display the most complex operations under appropriate size and color performance, especially on PROFINET network, seamless integration with SIMATIC S7-1200 PLC controller system and convenient configuration with portal software.

### 3.5. Motor and Drive Selection

Ordinary Siemens squirrel cage three-phase asynchronous motor with order No. 1LE0001-0DB22-1AA4/0.55 is selected as the mixing motor, which can meet the requirements.

### 3.6. System Hardware Wiring Diagram

The hardware wiring circuit diagram is shown in Figure 2. The three-phase asynchronous motor of the mixer is directly connected to the G120 frequency converter, in which R, s and T are connected to the three-phase power supply, PE is grounded, u, V and W are connected to the three-phase input of the motor, the frequency converter is connected to the CPU of PLC through PROFINET, and the CPU controls the speed of conveyor motor M1 by sending the control word of the frequency converter, Read the speed of the motor by accepting the status word.

The wiring of HMI is relatively simple. It only needs to connect the positive and negative and ground wires of 12 V power supply at the corresponding terminals.

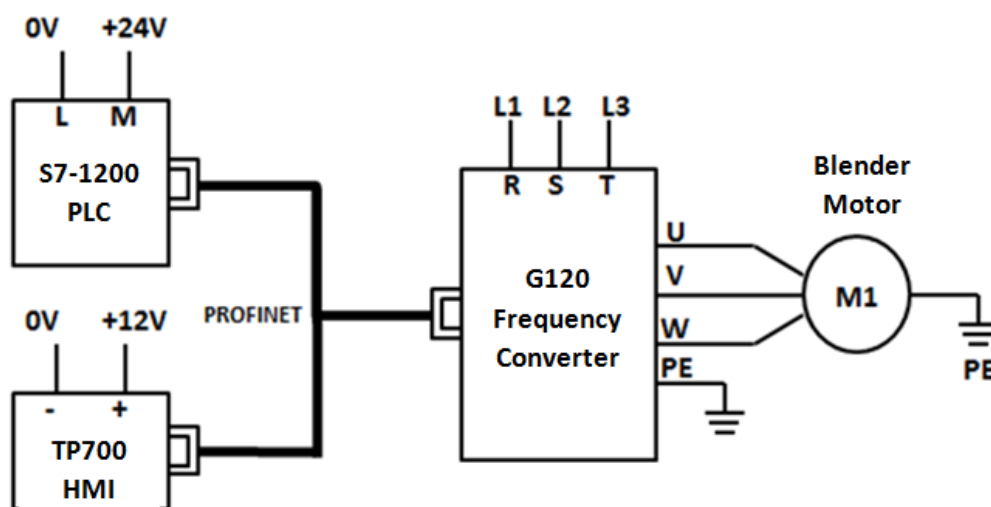


**Figure 2.** Hardware wiring diagram of syrup mixing control system

### 3.7. I / O Distribution and Wiring of PLC

The I/O of PLC CPU is mainly used to connect the control buttons, sensors, indicators, etc. of the system. The I/O distribution is shown in Table 1, from which the I/O wiring of the system can be defined.

**Table 1.** The PLC I/O distribution

| Address | Symbol | Function       | Address | Symbol | Function        |
|---------|--------|----------------|---------|--------|-----------------|
| I0.0    | SA1    | Manual/Auto    | Q0.0    | H1     | Run indicator   |
| I0.1    | SB1    | Start          | Q0.1    | H2     | Stop indicator  |
| I0.2    | SB2    | Stop           | Q0.2    | YV1    | Glucose valve   |
| I0.3    | SB3    | Reset          | Q0.3    | YV2    | Spice valve     |
| I0.5    | SB5    | Emergency stop | Q0.4    | YV3    | Discharge valve |

## 4. Software Design of Control System

### 4.1. System Configuration and Configuration

Connect the CPU module, G120 frequency converter module and HMI module of PLC with PROFINET on Portal V15 software to complete the system configuration, as shown in Figure 3.

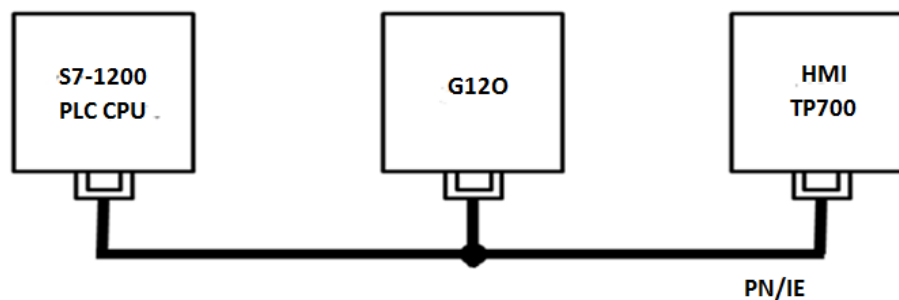


**Figure 3.** System configuration

Then, make settings in the analog expansion module SM1234, that is, select channel CH0, select current for measurement type, select 4-20mA for current range, and note that the channel address is the default IW96. Then, Siemens standard message 111-PZD [5] is added to G120 inverter drive module, so that the software configuration is completed.

### 4.2. HMI Screen Production

According to the system control requirements, the HMI screen shown in the figure below is made, including manual control mode and automatic control mode. In the manual control mode, set "ON" and "OFF" buttons for glucose solenoid valve, spice solenoid valve, discharge solenoid valve and mixing motor respectively. In the automatic control mode, set four operation buttons: start, stop, reset and emergency stop, and set five indicator lights: start, stop, glucose solenoid valve, spice solenoid valve and discharge solenoid valve.

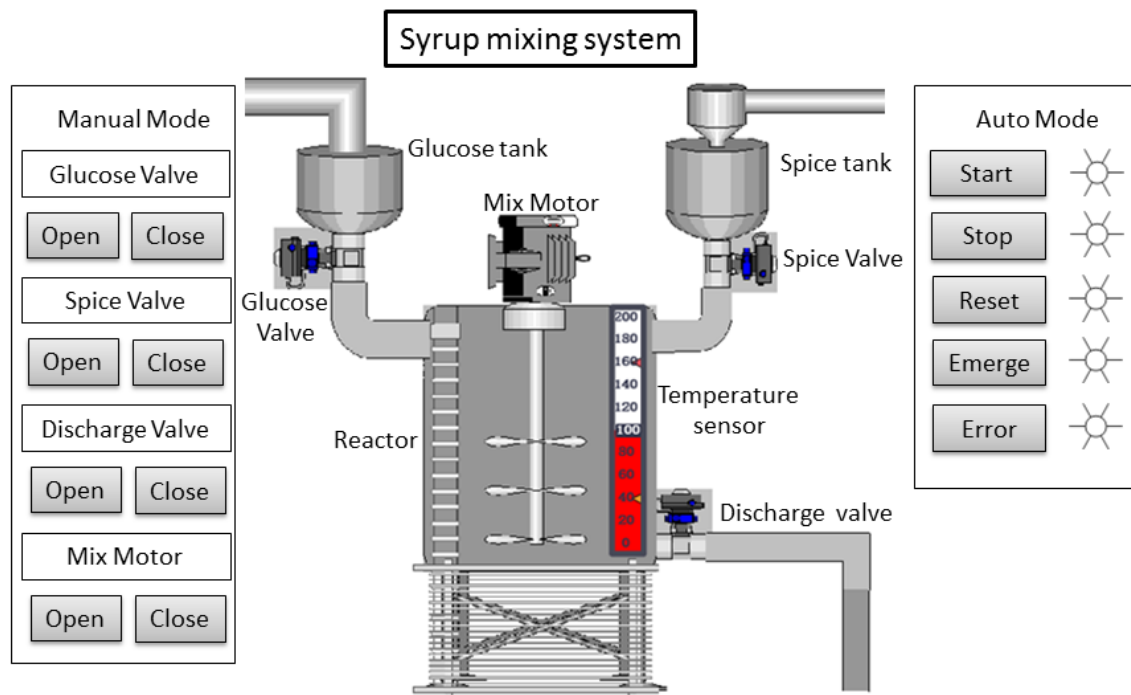


Figure 4. HMI screen

### 4.3. Key Procedures

According to the idea of modular programming, the programming is completed in portal software.

#### 4.3.1 Initialization Procedure

The initialization program realizes the reset of various components, frequency converters and automatic programs through FirstScan electric shock.

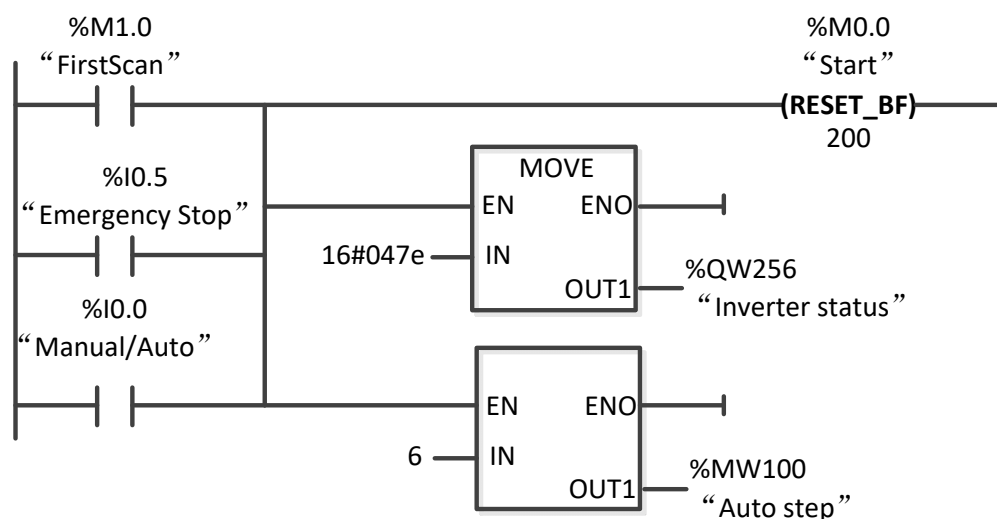


Figure 5. Initialization program

#### 4.3.2 Manual and Automatic Switching Procedure

As shown below, set MD300 register to 2 in manual mode and 1 in automatic mode, and make manual and automatic FC blocks respectively to realize interlocking.

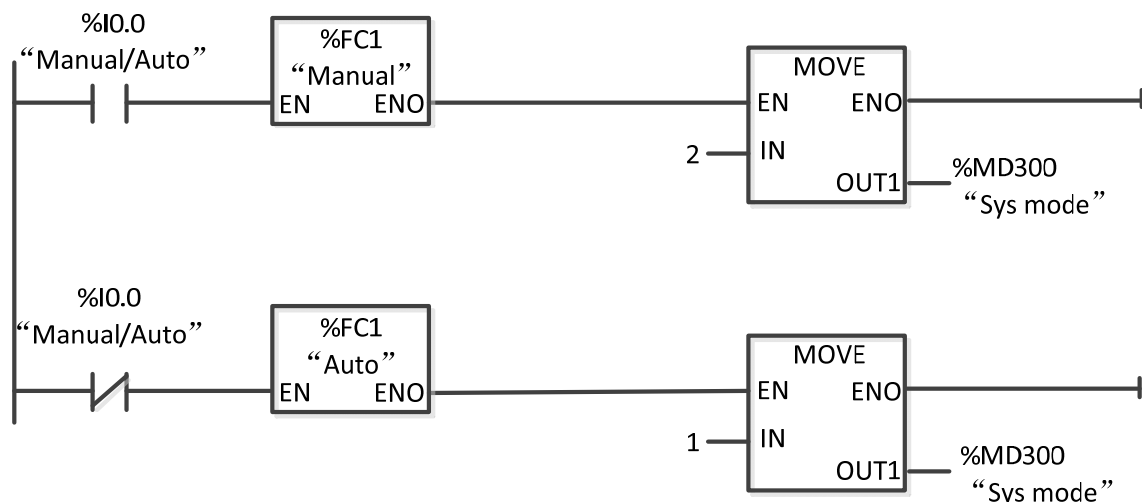


**Figure 6.** Manual / automatic switching procedure

#### 4.3.3 Temperature Conversion Procedure

Use the "SCALE" function to convert and read the temperature in the reactor. In is connected to the actual temperature IW96. The measurement range of temperature sensor corresponding to LO\_LIM and HI\_LIM is 0-350 °C. Out is connected to MD200 register, corresponding to the actual temperature value. The calculation formula [6] of this function is  $OUT = [((IN - 0) / (27648 - 0)) * (HI\_LIM - LO\_LIM)] + LO\_LIM$ , as in this procedure,  $OUT = (IN / 27648) * (350 - 0)$ .

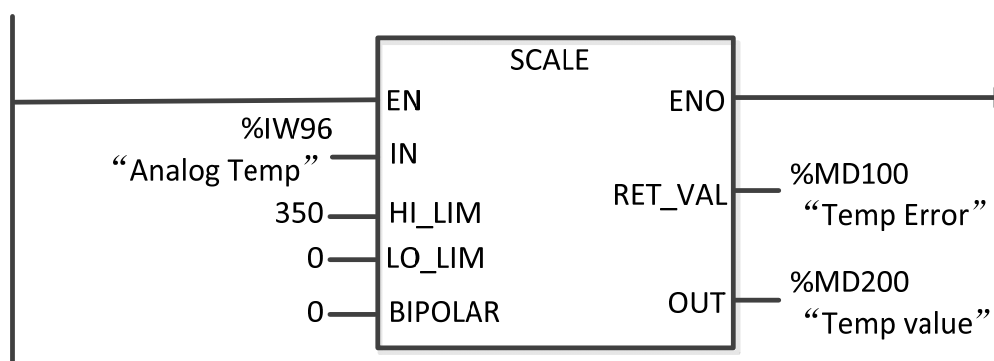


**Figure 7.** Temperature value conversion program

#### 4.3.4 Mixer Control Procedure

The speed and direction of the mixer are mainly controlled by G120 frequency converter. QW256 is a status word. Different values have different functions. Specifically, stop: W#16#047E; Start: W#16#047F; Reverse: W#16#0C7F; Reset: W#16#04FE. QW258 is a speed word, corresponding to  $16384 = 100\% = 50\text{Hz}$  at full value, so the relationship between in value and frequency F is  $IN = 16384 * F / 50$ . For example, when the mixer operates at 30Hz, the corresponding input value is  $IN = 16384 * 30 / 50 = 9830$ . When the mixer operates at 40Hz, the corresponding input value is  $IN = 16384 * 40 / 50 = 13107$ . When the mixer operates at 50Hz, the corresponding input value is  $IN = 16384 * 50 / 50 = 16384$ . The procedure for multi-stage speed operation of agitator is as follows.

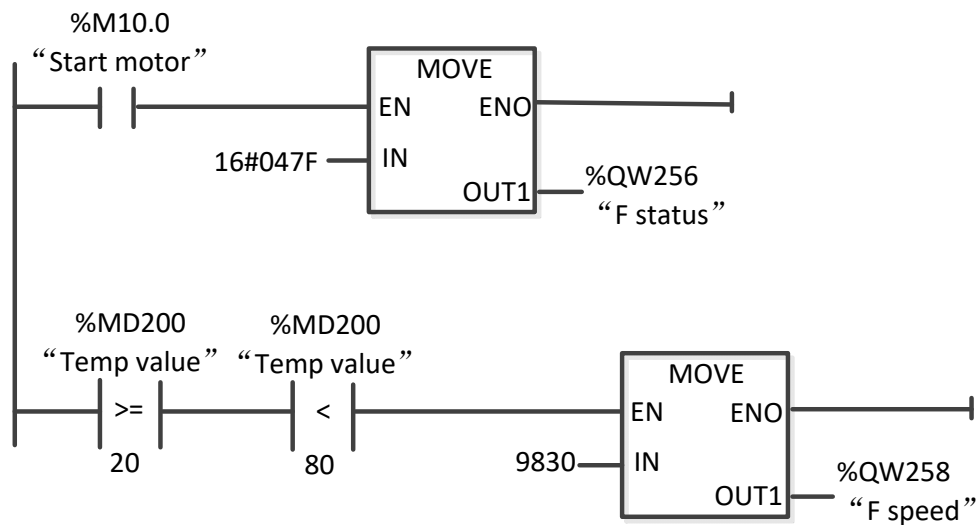


**Figure 8.** Example of mixing control procedure

#### 4.3.5 Manual Control Procedure

The manual control program mainly controls the opening and closing of each solenoid valve through the setting and reset of SR function. The following is the procedure for manually controlling the switch of glucose solenoid valve.

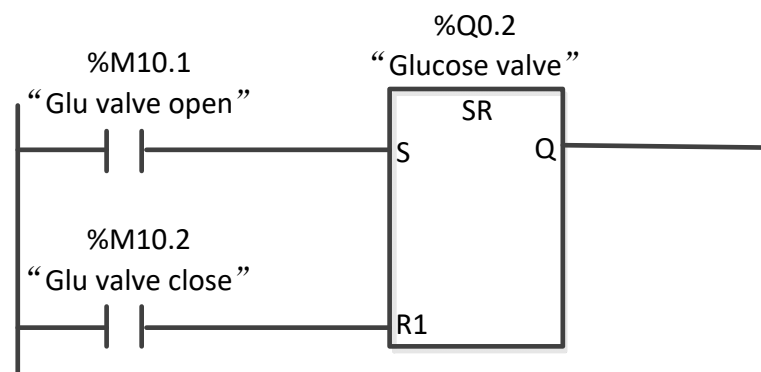


**Figure 9.** Example of manual control program

## 5. Implementation Effect of Control System

On the basis of system design, through system layout, hardware wiring, software programming, debugging and optimization, the control requirements of the system are met. The hardware layout of the system is divided into three parts: pneumatic area, electric area and control cabinet area. The pneumatic area includes sensor detection and solenoid valve control; The electric area includes the rotation of the mixer (driven by multi-stage speed operation of three-phase asynchronous motor); The control cabinet area includes system start, stop, reset, indicator display and HMI monitoring module. After repeated tests for many times, the temperature inspection error is within  $\pm 1\%$  FS, and the action of the agitator is stable, which can meet the production requirements of the enterprise.

## 6. Conclusions

With Siemens s7-1200plc as the core, G120 frequency converter is controlled to realize multi-stage high-speed operation of the mixer, and the mixing process of syrup is completed in combination with sensors and cylinders. At the same time, the visual monitoring operation of

the system is realized with simplified TP700 HMI. The final implementation results show that the system has complete functions, stable operation and high cost performance. The system can be debugged on the enterprise production line to realize production application and produce economic value. It can also carry out project training and promote teaching and scientific research.

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