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Original Research Article

# Design of material sorting conveyor control system based on PLC

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***Abstract:*** To address the low efficiency, high error rate, excessive labor cost and poor safety of traditional manual material sorting, this paper develops a PLC-based automatic control system for material sorting conveyors catering to industrial production demands. Taking Siemens S7-200 SMART PLC as the core controller, the system integrates sensor detection, conveyor driving, sorting execution and human-computer interaction modules to realize automatic identification, transmission and classified sorting of materials with different textures and sizes. This paper systematically presents the system overall scheme, hardware selection, circuit design, software logic and debugging process. Experimental results show that the system features high stability, fast response and high sorting precision. It can replace manual sorting effectively, reduce production and maintenance costs, and improve industrial automation level, possessing favorable application and promotion value.
***Keywords:*** PLC; material sorting; conveyor belt; automatic control; industrial automation

## 1. Introduction

Material sorting is a key procedure in food, chemical, machinery manufacturing and logistics industries. Traditional manual sorting suffers from low efficiency, high error rate caused by human fatigue, potential safety hazards and rising labor costs, failing to meet the high-speed, high-precision and continuous operation requirements of modern production lines. Meanwhile, conventional relay-controlled sorting equipment has complicated circuits, high failure rate, difficult maintenance and poor scalability, which cannot adapt to flexible production upgrading.

Programmable Logic Controller (PLC) is widely adopted in industrial automation due to its high reliability, strong anti-interference capability, simple programming and convenient maintenance. It is extensively applied in pipeline operation, automatic sorting and equipment regulation. Targeting the defects of traditional sorting modes, this paper designs a PLC-based automatic sorting conveyor system. The system acquires real-time material signals via sensors, executes logical operation through PLC, and drives actuators to complete intelligent sorting, which significantly improves production efficiency and standardization of sorting processes.

## 2. Overall system design scheme

### 2.1. Control demand analysis

The designed sorting conveyor system realizes integrated functions including equipment start-stop control, stable material transmission, intelligent material identification, precise classified sorting, mode switching and safety protection. It can categorize materials by texture and size, with overload protection, fault alarm and emergency stop functions to guarantee stable and safe industrial operation. The core control requirements are summarized as follows: Dual manual/automatic modes for debugging and formal production; high-precision and delay-free material detection; stable and uniform conveyor operation to avoid material deviation; accurate sorting cylinder action with low error; and comprehensive safety protection for equipment and operators.

### 2.2. Overall system architecture

The system adopts a modular hierarchical structure consisting of PLC main control unit, signal detection module, execution drive module and human-computer interaction module, with simple structure,

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high stability and easy maintenance. The S7-200 SMART PLC serves as the core to receive sensor signals, execute logical operation and output control commands. The detection module adopts photoelectric, metal and size sensors to collect material information and convert analog signals into digital signals for PLC processing. The execution module includes conveyor motor, pneumatic sorting cylinders, solenoid valves and alarm devices to implement sorting and status indication. The human-computer interaction module realizes equipment control, parameter setting and real-time operation monitoring. It is shown in **Figure 1**.

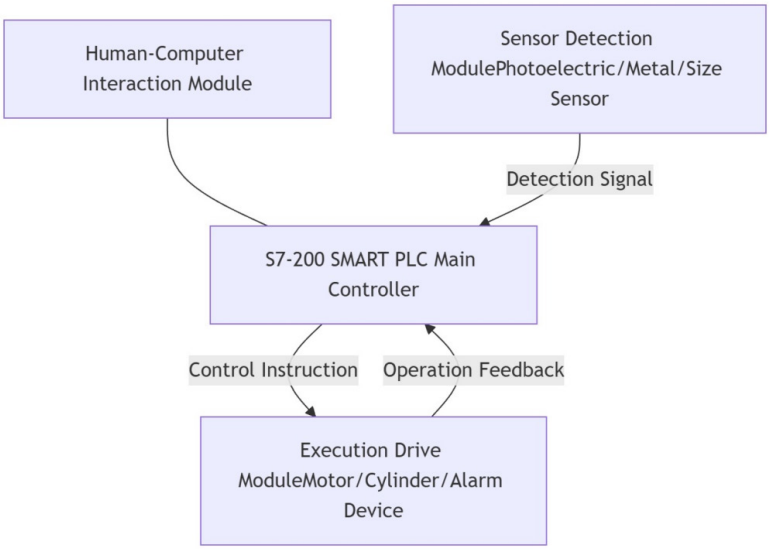


**Figure 1.** Overall architecture of the system.

# 3. System hardware design

## 3.1. Core hardware selection

Hardware selection follows industrial applicability, economy and stability principles. The core equipment selection is detailed as follows:

(1) PLC: Siemens S7-200 SMART SR40 PLC is selected, with 24 input and 16 output channels. It features strong anti-interference ability, simple programming and high cost performance, fully meeting the signal acquisition and drive control demands of the system.

(2) Sensors: Diffuse reflection photoelectric sensors detect material presence; metal sensors distinguish metal and non-metal materials; infrared size sensors identify material specifications, ensuring multi-type material sorting accuracy.

(3) Actuators: A three-phase asynchronous motor matched with a frequency converter realizes uniform conveyor speed regulation. Small pneumatic cylinders cooperate with solenoid valves to complete stable and accurate sorting actions. Indicator lights and buzzers are configured to display equipment operation and fault status in real time.

## 3.2. I/O port allocation

According to the system control logic, the PLC input and output ports are standardized to clarify the corresponding functions of each port, simplifying program writing and later maintenance. The core I/O port allocation is shown in **Table 1**.

**Table 1.** PLC core I/O port allocation table.

| Port Type | Port Address | Function Description | Port Type | Port Address | Function Description |
|---|---|---|---|---|---|
| Input | I0.0 | System Start Button | Output | Q0.0 | Conveyor Motor Operation |
| Input | I0.1 | System Stop Button | Output | Q0.1 | No.1 Sorting Cylinder Action |
| Input | I0.2 | Emergency Stop Button | Output | Q0.2 | No.2 Sorting Cylinder Action |
| Input | I0.3 | Photoelectric Sensor Signal | Output | Q0.3 | Operation Indicator Light |
| Input | I0.4 | Metal Detection Sensor Signal | Output | Q0.4 | Fault Alarm Buzzer |
| Input | I0.5 | Size Detection Sensor Signal | Output | Q0.5 | Fault Indicator Light |

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### 3.3. Hardware circuit design

The system hardware circuit comprises PLC main control circuit, sensor signal acquisition circuit, motor drive circuit, cylinder control circuit and alarm circuit. A 24V DC power supply supplies power for PLC, sensors and indicator lights, while 380V AC power drives the conveyor motor. Air switches are equipped for overload and short-circuit protection. Sensor digital signals are transmitted to PLC input ports and filtered to ensure signal stability. PLC output ports are connected with actuators via relays for electrical isolation, preventing core module damage from current impact. The normally closed emergency stop circuit ensures rapid shutdown in emergencies to guarantee operational safety.

## 4. System software design

### 4.1. Software development environment

The system software is developed on STEP 7-Micro/WIN SMART software, supporting ladder diagram, statement list and function block diagram programming. Ladder diagram is adopted for its intuitive logic and convenient on-site debugging. Modular programming is applied to divide the program into main program, manual control subprogram, automatic sorting subprogram and fault alarm subprogram. Independent operation of each module facilitates subsequent modification and function expansion.

### 4.2. Main program flow design

After power-on, the system initializes and conducts self-inspection of all hardware modules. It enters standby mode if no fault is detected, otherwise triggers an alarm. Operators can switch between manual and automatic modes. The manual mode is used for equipment debugging and maintenance with independent control of conveyor and cylinders. The automatic mode performs full-process intelligent sorting. The system monitors emergency stop and fault signals in real time during operation, and will shut down and alarm immediately once abnormalities occur, resuming operation after fault elimination.

### 4.3. Core control program design

The automatic sorting program is the core of the system. In automatic mode, the conveyor runs continuously at a constant speed. The photoelectric sensor monitors material delivery in real time. Once a material is detected, metal and size sensors are activated for material identification. Metal materials are pushed into the corresponding bin by No.1 cylinder, large-size non-metal materials are sorted by No.2 cylinder, and small-size non-metal materials are conveyed to the terminal bin. All cylinders reset automatically after sorting, and the system circulates to wait for the next material signal.

The fault alarm program monitors system operating status in real time. Abnormal sensor signals, motor overload or cylinder operation failure will trigger immediate system shutdown, with fault indicator light and buzzer activated to remind staff of troubleshooting, ensuring system operational safety and stability.

## 5. System debugging and result analysis

### 5.1. Debugging environment and steps

System debugging is divided into three stages: Hardware inspection, software simulation and prototype test. The hardware stage checks circuit connection and equipment integrity to eliminate wiring faults. The software stage verifies the accuracy of program logic via simulation. The prototype test adopts different types of materials to inspect system sorting accuracy, response speed and safety protection performance.

### 5.2. Debugging result analysis

Debugging results show that the system operates stably with sensitive start-stop and uniform conveyor operation. Sensors achieve error-free material identification, and the sorting accuracy reaches over 99%. Mode switching is smooth, and safety protection functions respond timely and reliably. After 24-hour continuous operation, no malfunction or shutdown occurs. Compared with traditional schemes, the system improves sorting efficiency by more than 60%, effectively reducing labor and maintenance costs.

## 6. Conclusion

This paper designs a PLC-based material sorting conveyor system combining sensor detection and

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pneumatic control technology. Adopting modular design, the system has simple structure, strong anti-interference ability and high operational stability, adapting to complex industrial working conditions. Test results verify its high sorting precision and efficiency, which can replace manual sorting and reduce production costs.

The system features high flexibility and scalability, which can adapt to different sorting demands by program modification, suitable for various industrial sorting scenarios. Future research can integrate Internet of Things technology to realize remote monitoring and fault tracing, further improving system intelligence.

## About the author

Gong Li, works in Xi'an Mingde Institute of Technology, majors in electrical control and PLC.

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