

## Application of SIMATIC PCS7 in co-rotating twin-screw large extrusion granulation unit

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**Abstract:** This article elaborates on the composition and production process of each unit in a large co-rotating twin-screw extrusion granulation unit. It discusses in detail the usage of the Siemens SIMATIC PCS7 system in domestic large co-rotating twin-screw extrusion granulation units from both hardware and software perspectives. It also analyzes the various functions and features of the system's HMI.

**Key words:** co-rotating twin-screw large-scale extrusion granulation unit; Siemens; SIMATIC PCS7

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As the backbone of the plastics industry, co-rotating twin-screw large extrusion granulation units play a crucial role in the chemical industry. For decades, Japan and Germany have dominated the market. To break this market monopoly and overcome technological blockades, domestically produced units have emerged. Their control system utilizes PCS7 industrial control software, and the configuration object is a 410-5H controller.

The Siemens SIMATIC PCS7 system is a typical modern Distributed Control System (DCS). The entire system consists of numerous Siemens hardware components, including automation instruments, actuators, analog and digital signal modules, controllers, communication processors, engineer stations, and operator stations. All these hardware components can be supported and configured by various powerful PCS7 software tools.

### 1 Unit process flow

The large-scale mixing and extrusion granulation unit primarily consists of the following components: drive system, feeding and compounding system, mixing and extrusion system, start-up valve, damping control valve, melt gear pump, screen changer, die head and pelletizing system, and pellet processing system.

The drive system consists of a turning gear motor, a

beyond clutch, a main motor, a main reduction gearbox, and a lubrication station; the blending and mixing system consists of a core shaft and spiral components; the pelletizing system consists of a water chamber, a knife shaft, a knife disc, and cutting knives; the granular material processing system consists of a centrifugal dryer, a large lump material collector, a particle separation valve, a dehumidification fan, a cyclone separator, and a vibrating screen. Such a large unit also features a wide variety of instrument components and electrical components, including sensors, transmitters, isolation barriers, controllers, frequency converters, transformers, and so on. These small components, ranging from screws and sensors to large power units and joints, constitute the large-scale mixing, extrusion, and pelletizing unit.

Polypropylene powder enters the extruder hopper through the rotary valve and spiral feeding system from the feeding system. At this point, the barrel temperature has reached over 200°C. After the powder enters the barrel, the helical elements on the screw push the material forward towards the drive valve. In the barrel, the material passes through the conveying section and mixing section. As the barrel temperature reaches the melting point of polypropylene powder, the powder gradually

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becomes molten and continues to flow towards the gear pump, screen changer, and die plate. Pushed by the gear pump and screw, the melt forms a pressure of up to tens of megapascals in the barrel cavity and is finally extruded through the small die holes of the die plate. The rotating cutter cuts the extruded strand into small particles. Under the impact of granular water, the particles are transported to the centrifugal dryer. In this process, the particles are cooled and solidified under the impact of granular water. The dryer uses centrifugal force to separate the moisture from the particles, which enter the vibrating screen through the separation valve. The oversized particles, undersized particles, and normal particles are screened, and finally, the qualified particles are blown to the finished product silo by the pneumatic conveying system.

## 2 Composition of control system

The control system of the entire extrusion press consists of a controller master station, distributed slave stations, IO cards, communication cards, network cabinets, engineer stations, operator stations, on-site touch screens, and other components. A detailed introduction is provided below.

The engineer station serves as the highest-privileged supervisory computer, capable of performing software development tasks such as programming, compiling, and downloading for the controller. It can also run WINCC screens for process parameter operations and is located in the field control room (FAR). The engineer station computer is equipped with a redundant Siemens-specific network card, which connects to the control station via Ethernet. Since the controller also features redundant configuration, two network loops are formed within the entire control local area network, namely Control Network A and Control Network B. This configuration serves as a "double insurance" for the operation of the entire production line, ensuring normal production of the equipment in case of a single equipment failure in the control system.

Compared to the engineer station, the operator station lacks programming and other software development functions. It is a computer specifically designed for technicians to monitor and operate processes. One unit is placed in the field control room (FAR), while the other two units will be placed in the control center lobby (CCR). The operator station computers are also equipped with redundant Siemens-specific network cards,

connected to the controller via Ethernet, and are linked to the A and B control networks.

The on-site touch screen serves as the core operation panel for the on-site startup of the extrusion press. It is connected to the operation station via Ethernet for VNC or RDP communication, enabling remote desktop-style command control and status monitoring of the extrusion press on-site.

The redundant controller is installed in the control cabinet, serving as the central control brain that receives signals, performs calculations, and issues commands. Multiple distributed slave stations are installed in other cabinets, equipped with digital input, digital output, analog input, analog output, and various communication cards. The slave stations communicate with the IO cards through a backplane, and communicate with the master station either through Profinet Ethernet or Profibus DP bus. The switch in the network cabinet aggregates remote fiber optic signals and various collected Ethernet signals to form a crisscross control network.

## 3 Programming

### 3.1 Hierarchical division

The PCS7 software is divided into a factory view and a component view, with program development work being completed in the factory view. First, a project file is created, followed by the division of the next level according to the various unit joints of the extruder, including the main drive, mixing, gear pump, pelletizing, and other units. After the first level of each unit is expanded, it includes the second level of AI, DI, AO, DO, valves, and motors. Within this level, there are process objects (PO) used in the project.

### 3.2 Process Object

PO: Process Object, which refers to a control object. Process objects typically encompass a valve, motor, analog monitoring, PID, etc., all of which belong to a single PO.

#### 3.2.1 Channel block

When programming with PCS 7, hardware IO data is accessed not by directly referencing the IO address, but by associating the IO address (which must be in the process mapping area) through channel driver blocks. The driver blocks provide an interface between the user program and the hardware input/output components. The following channel blocks can be connected to symbolic addresses.

The blocks Pcs7AnIn, Pcs7AnOu, Pcs7DiIn, Pcs7DiOu, and PcsDiIT are exclusively designed to process signals from the S7-300/400 signal modules. They are capable of converting raw values into physical values. Specifically, Pcs7DiIT is utilized for high-precision timestamping functionality.

### 3.2.2 Monitoring block

The AI\_CH channel block's PV\_IN pin is connected to an external hardware address, with a measurement range set to 0-1 and a unit code 1132 indicating MPa. It is connected to the AI monitoring block's PV pin through the PV\_Out pin. The monitoring block is set with an upper limit of 0.55 MPa, a lower limit of 0.05 MPa, and a lower lower limit of 0.03 MPa. This allows dynamic monitoring of the variable on the HMI after compiling the download program and the OS screen.

### 3.2.3 Motor block

In PCS 7, the MotL function block of the APL library is primarily used to control unidirectional start-stop motors. It allows for manual, automatic, and local control of the motor. The control command can be a single-point high/low level start-stop signal or a dual-point pulse control start-stop signal. During motor startup or operation, safe interlock protection control can be implemented.

Motor block input pins: FbkRun connects to the MCC feedback operation signal, Permit connects to the motor start-up permission condition, and Intlock connects to the motor interlock shutdown condition. Output terminals: P\_Start connects to the MCC start command, P\_Stop connects to the MCC stop command, and Run connects to the motor running status. If the motor does not have a local operation column and only has remote start-stop functionality, then LocalSetting = 0 to disable the local mode.

### 3.2.4 Valve block

The valve drive block is similar to the motor block. The VlvL function block is primarily used to control two-position (open/close) valves, enabling manual, automatic, and local control of the valves. The control command can be a single-point high/low level switch or a dual-point pulse control switch. During the opening or closing process of the valve, safe interlock protection control can be implemented.

Valve block input pins: openAut and closeAUT are input signals for opening and closing, AutModLi and ManModLi are for automatic and manual modes, OosLi is a fault input, and

LocalSetting=2 indicates that manual and automatic modes can be switched. Output terminal: Ctrl is connected to the valve output, with 1 indicating power-on and 0 indicating power-off.

### 3.2.5 Interlocking block

The interlock function block, Intlk, provides interlock information for motors and valves, and supports interlock reset and interlock first-out functions. This block is used to calculate standard interlocks that can be displayed on the OS. Up to 16 input signals can be provided to this block. They are linked using optional binary logic. The state of the output signal can also be determined. OUT=0: interlocked, OUT=1: healthy.

IN01-IN04 are the four input pins of the interlock block, each connected to a respective interlock condition. Their logical relationship follows an AND logic. When all four input signals are 1, the output OUT is 1, indicating a normal state; if any one of the signals is 0, the output OUT is 0, indicating an interlock state.

## 4 HMI host computer

Open the created project file in the component view, insert a new object SIMATIC PC station, and name it ES130. Right-click on PLC to proceed with configuration. The configuration includes: PC framework, WINCC application for WINCC multi-user project, and redundant CP1623 network card.

### 4.1 Alarm records

During the production process of the unit, the factory building is basically unattended, and only the operators in the control room can understand the operating status of the unit. Figure 1 shows the alarm records of the PCS7 system. It can be seen that the pop-up alarms are divided into different colors, which are distinguished according to different alarm levels. Red alarms have the highest level and priority, mostly for interlock values and interlock actions. Yellow alarms have a lower priority than red, mostly for prompt warning functions. Black is a system alarm, indicating a card channel fault alarm. Blue-green is an operation prompt, indicating action records. In the alarm records, the system's alarm time, date, area, and other information can be clearly seen. In addition, the alarm will also emit an alarm bell sound, which, together with the pop-up window, prompts the operator.



Figure 1 Alarm record diagram

## 4.2 Trend chart

The PCS7 OS system provides a rich trend curve display function. Users can call the trend screen belonging to the object through the APL control object's screen panel. They can also create trend groups online to display multiple measurement

variables in the same trend curve window for global display, as shown in Figure 2.

Since PCS 7 V9.0, users can easily create customized user trend groups through the AOTC (APL Operator Trend Control) control. AOTC, based on user's on-site applications, provides a more flexible and convenient way to configure trend curves. The display function of the AOTC control is also more abundant and closer to actual needs. In addition to the regular trend functions, it can also achieve:

- 1) Display the trend curve in conjunction with a scale.
- 2) Switch the trend time interval using "minutes", "hours", "days", and "weeks" as time units.
- 3) Real-time trend printing (including curves and scales).
- 4) Relevant alarm message entries associated with trend variables.

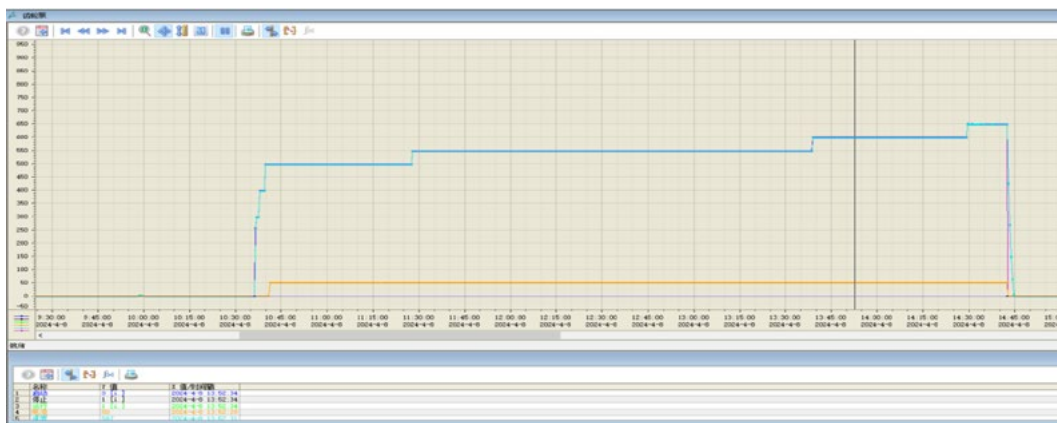


Figure 2 Trend chart

## 4.3 First alarm record

In the previous chapter, we introduced the use of interlock blocks. These blocks not only possess specific logic operation functions but also feature a first alarm latching function. Whenever there is a change in input conditions that leads to an output result interlock, the block will latch the first signal that caused the interlock, serving as a first alarm recording function. As shown in Figure 3, this is a screenshot of the first alarm displayed by the interlock block after the extruder interlocked and stopped. In this screenshot, the blue background with white letter B represents the bypass condition, the green box indicates the normal condition, and the purple dot signifies the first condition that caused the interlock output. This function provides a basis for fault analysis and judgment after

the extruder interlocks and stops, making it an indispensable feature in the system.

As a crucial asset of the country, the control system of the unit is crucial to ensuring the smooth operation of the entire production process, necessitating stability, reliability, and accuracy. From the above introduction, it can be seen that the various functions of PCS7 can meet various operational requirements, providing strong support for the stable operation of the extruder with its powerful capabilities.

## 5 Conclusion

This article discusses the use of hardware and software for the automatic control system of a PP extruder based on PCS7, focusing on the characteristics of a domestically



**Figure 3 First alarm record chart**

produced co-rotating twin-screw large-scale extrusion granulation unit. This system utilizes the concept of centralized control and decentralized management, integrating over 800 control points of the large-scale extrusion granulation unit into the control system. The program is developed using CFC language, making operation simple and logic more intuitive. After compiling channel blocks, monitoring blocks, motor blocks, valve blocks, and interlock blocks, they can be

directly displayed in the OS interface, facilitating interface development work. Alarm records and trend chart functions provide beneficial support for the unit's startup and operation. The alarm first-out latching function allows operators to quickly and accurately identify the cause of interlock shutdown. Multiple operator permission functions assist in hierarchical permission management. The powerful 410-5H redundant controller serves as the central brain to process incoming and outgoing data, with redundant buses and various cards coordinating and cooperating to ensure smooth and stable system operation. This reduces downtime, increases unit productivity, and brings higher profits to the enterprise.

The PCS7 system can be further developed based on its current usage, leveraging its excellent scalability and powerful communication capabilities to achieve system integration between the feeding system, pneumatic conveying system, and extruder. This will enable a highly integrated and optimized control of the entire granulation system.



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