Theory and Practice of Science and Technology
2024, VOL. 5, NO. 6, 123-131
DOI: 10.47297/taposatWSP2633-456918.20240506

Design and implementation of automatic control System For Chemical Production Line Based On PLC

Shumin Li

University of Science and Technology Liaoning

ABSTRACT

This paper aims to discuss the design and implementation of automatic control system for chemical production line based on PLC. With the rapid development of chemical industry and the intensification of market competition, it has become an important demand for chemical enterprises to improve production efficiency, ensure product quality and realize automation and intelligence of production process. Firstly, this paper analyzes the characteristics and requirements of chemical production line, as well as the requirements and objectives of automatic control system. Then, the overall architecture design, hardware design, software design, system implementation and testing process of the automatic control system of chemical production line based on PLC are described in detail. The feasibility and effectiveness of the system are verified by the analysis of practical application cases. The research results show that the automatic control system of chemical production line based on PLC can significantly improve production efficiency, reduce production costs, ensure product quality and enhance the market competitiveness of chemical enterprises. The research in this paper provides new ideas and methods for the design and implementation of automatic control system in chemical industry.

KEYWORDS

PLC; Chemical production line; Automatic control system; Design and implementation; production efficiency

1 Introduction

With the rapid development of the global economy and the increasingly fierce market competition, the chemical industry is facing great challenges and opportunities. Improving production efficiency, reducing cost, ensuring product quality and realizing automation and intelligence of production process have become important demands of chemical enterprises. However, there are many shortcomings in the traditional control mode of chemical production line, such as low control accuracy, slow response speed and high failure rate, which seriously restricts the production efficiency and product quality of chemical enterprises. Therefore, it is very important for chemical enterprises to research and develop an efficient, stable and reliable automatic control system.

As an advanced industrial control equipment, programmable logic controller (PLC) has the advantages of programmability, expansibility and high reliability, and is widely used in various industrial control systems. In chemical industry, the application of PLC can not only improve the automation of production line, but also realize intelligent management and optimal control of production process. Therefore, the design and implementation of automatic control system of chemical production line based on PLC has important research value and practical significance.

This paper aims to discuss the design and implementation method of automatic control system of chemical production line based on PLC. By analyzing the characteristics and requirements of chemical production line and the requirements and objectives of automatic control system, a design scheme of automatic control system based on PLC is put forward, and its hardware design, software design, system implementation and testing are carried out in detail. Through the analysis of practical application cases, the feasibility and effectiveness of the system are verified, which provides new ideas and methods for the design and implementation of automatic control system in chemical industry.

2 Overview of PLC system

Programmable Logic Controller (PLC) is a kind of digital operation electronic system designed for industrial environment. It uses a kind of programmable memory, which is used to store instructions for performing logical operations, sequence control, timing, counting and arithmetic operations, and controls various types of mechanical equipment or production processes through digital or analog input/output.

2.1 the basic composition and function of PLC

The PLC system usually consists of central processing unit (CPU), input/output unit (I/O unit), memory, programmer and power supply. Among them, CPU is the core of PLC, which is responsible for executing user programs and completing various logical operations and data processing; I/O unit is responsible for connecting field devices to realize data input and output; The memory is used to store user programs and data needed for PLC operation; Programmers are used to write, modify and debug PLC programs; Power supply provides stable power supply for PLC system.

The main functions of PLC include logic control, timing control, counting control, sequence control, data processing and communication. Through programming, PLC can realize accurate control of various mechanical equipment and production processes, and improve production efficiency and product quality.

2.2 the working principle and operation process of PLC

The working principle of PLC is based on the computer control principle of "stored program". When PLC is put into operation, its working process is generally divided into three stages: input sampling, user program execution and output refresh. In the input sampling stage, PLC reads the status information of field devices through the input circuit and stores the information in the input image register. Then, PLC enters the user program execution stage, and performs logic operation and data processing according to the instruction sequence in the user program. Finally, in the output refresh stage, PLC outputs the results of user program execution to the corresponding output image register, and controls the actions of field devices through the output circuit. The running process of PLC is cyclic, that is, the process of input sampling, user program execution and output refresh is repeated continuously. This circulating scanning mode enables PLC to respond to the changes of field equipment in real time and realize continuous control of production process.

2.3 the characteristics and advantages of PLC system

PLC system has many remarkable characteristics and advantages, which make it widely used in the field of industrial control. First of all, PLC has high reliability and stability, and can run stably for a

long time in harsh industrial environment. Secondly, PLC has rich I/O interfaces and powerful data processing capabilities, which can meet the needs of various complex control tasks. In addition, PLC has good expansibility and flexibility, which can be expanded and modified according to actual needs. Finally, the PLC system is easy to maintain and debug, which reduces the maintenance cost and downtime.

To sum up, as an advanced industrial control equipment, PLC system has a wide application prospect and important research value in the chemical industry. Through reasonable design and application of PLC system, precise control and optimal management of chemical production line can be realized, production efficiency and product quality can be improved, and production cost and environmental pollution can be reduced.

3 Demand analysis of automatic control system of chemical production line

3.1 Characteristics and Requirements of Chemical Production Line

(1) Process flow and parameter control of chemical production line

The production line of Angang Chemical Plant has typical chemical production characteristics, and its technological process is complex and fine, involving many chemical reactions and physical processes. These processes need to accurately control key parameters such as temperature, pressure, flow and liquid level to ensure product quality and production efficiency. For example, in Angang's 3800 production line, the on-line length of strip is over 3000m, and there are 118 steering rollers, so it is difficult to control the installation accuracy. The allowable deviation orthogonality is 0.05/1000, levelness is 0.05/1000, centerline is 0.3mm, and roller elevation is 2mm. This requirement of high precision makes the parameter control of chemical production line particularly important.

(2) Safety and environmental requirements of chemical production line

The safety of chemical production line is the primary consideration. Because a large number of flammable, explosive, toxic and harmful substances are involved in the chemical production process, it is necessary to ensure the safe and stable operation of the production line. In addition, with the improvement of environmental awareness, the environmental requirements of chemical production lines are increasingly strict. Angang Chemical Plant needs to take a series of measures to reduce the discharge of pollutants such as waste water, waste gas and waste residue in order to realize green production.

3.2 Requirements and objectives of automatic control system

(1) improve production efficiency and product quality

The introduction of automatic control system can significantly improve the production efficiency of chemical production line. By accurately controlling various parameters in the production process, errors and losses in the production process can be reduced, thus improving product quality. For example, in Angang Chemical Plant, the automatic production line can realize robot operation, full automatic control, digital management, etc. Compared with manual operation, its production efficiency can be greatly improved and the production cycle can be greatly shortened.

(2) Realize the automation and intelligence of the production process

Automatic control system can realize the automation and intelligence of production process. By integrating advanced technologies such as sensors, actuators and controllers, real-time monitoring and precise control of the production process can be realized. In addition, by introducing technologies such as artificial intelligence and machine learning, the production process can be further optimized, and the production efficiency and product quality can be improved. In Angang

Chemical Plant, the application of automatic production line can also reduce the fatigue and injury of workers in the production process and greatly improve the working environment.

(3) Ensure the safe and stable operation of the production line

The automatic control system can monitor the running state of the production line in real time, and find and deal with potential safety hazards in time. By introducing technologies such as fault early warning and fault diagnosis, preventive maintenance of the production line can be realized, and the failure rate and downtime can be reduced. In addition, the automatic control system can also realize remote monitoring and remote control of the production line, which is convenient for managers to grasp the running state of the production line at any time and ensure the safe and stable operation of the production line. In Angang Chemical Plant, the application of automatic control system has significantly improved the safety and stability of the production line.

4 Design of automatic control system for chemical production line based on PLC.

4.1 System overall architecture design

(1) Selection and implementation of distributed control structure

In view of the complex production technology and huge production line scale of Angang Chemical Plant, the overall architecture design of the system adopts distributed control structure. This structure disperses the control task to multiple controllers, each controller is responsible for controlling a part of the production process, and information sharing and cooperative work among the controllers are realized through the communication network. This design not only improves the reliability and stability of the system, but also facilitates the expansion and maintenance of the system.

In Angang Chemical Plant, the distributed control structure is realized through the integration and configuration of PLC, HMI, actuators and other components. As the core controller, PLC is responsible for executing control logic and data processing; HMI provides a friendly man-machine interface, which is convenient for operators to monitor and control the production process. Actuators perform corresponding actions according to the instructions of PLC, such as opening and closing valves and adjusting flow.

(2) Integration and configuration of 2)PLC, man-machine interface, actuator and other components

In the overall architecture design of the system, the integration and configuration of components such as PLC, HMI and actuator is the key link. PLC is connected with field equipment through input and output modules to realize data acquisition and control instruction transmission. HMI is connected with PLC through communication network, which displays the running status and parameter information of the production process in real time and provides an operation interface for operators. The actuator performs corresponding actions according to the instructions of PLC, and realizes accurate control of the production process.

4.2 Hardware design of PLC control system

(1)PLC selection and configuration

According to the production demand and process characteristics of Angang Chemical Plant, the selection of PLC takes into account its processing capacity, input and output points, communication function and other factors. The PLC model with stable performance, strong expansibility and easy programming and maintenance is selected. In configuration, according to the scale and complexity of the production line, the input and output points of PLC are reasonably allocated, and sufficient

expansion space is reserved.

(2) Design and implementation of input and output module.

I/O module is the interface between PLC and field equipment. In the design, according to the type and quantity of field devices, the appropriate input and output modules are selected, and the corresponding signal conditioning circuits and protection measures are configured. The input module is used to collect the status information of field equipment, such as temperature, pressure, flow and other parameters; The output module is used to send control instructions to actuators, such as opening and closing valves and adjusting motor speed.

(3) Selection and configuration of sensors and actuators

Sensors and actuators are important parts of PLC control system. In the selection, its accuracy, reliability, durability and other factors are considered. Sensors are used to monitor key parameters in the production process in real time, such as temperature, pressure, flow rate, etc. Actuators perform corresponding actions according to the instructions of PLC, such as opening and closing valves and adjusting flow. During the configuration, according to the layout and process requirements of the production line, the position and quantity of sensors and actuators are reasonably arranged.

4.3 Software design of PLC control system

(1) Design and development of 1)PLC program

PLC program is the core of PLC control system. In the design, according to the production process and control requirements, the corresponding control logic and data processing program are written. The program adopts the modular design idea, which decomposes the complex control task into multiple subtasks, and each subtask is realized by an independent program module. This design not only improves the readability and maintainability of the program, but also facilitates the debugging and modification of the program.

(2) Design and implementation of man-machine interface program

Man-machine interface program is the interactive interface between operator and PLC control system. In the design, the operating habits and needs of operators are considered, and a friendly operating interface and rich functional menus are designed. The interface displays the running status and parameter information of the production process in real time, and provides interactive elements such as operation buttons and indicator lights for operators to use. At the same time, it also realizes the functions of alarm and fault prompt, which is convenient for operators to find and deal with abnormal situations in time.

(3) Functional module division and integration of system software

The functional module division and integration of system software is an important link in the software design of PLC control system. According to the production process and control requirements, the system software is divided into several functional modules, such as data acquisition module, control logic module, data processing module, human-computer interaction module and so on. Each module realizes a specific function, and exchanges information and cooperates with other modules through communication interfaces. During the integration, the dependence and interface specification between modules are considered to ensure the stability and reliability of the system.

4.4 control program design based on Mitsubishi PLC

If you want to use PLC to realize this line, you must first allocate the required input and output ports. According to the actual requirements, there are three input signals and two output signals in this example. After connecting the hardware wiring diagram according to the distribution table, it is

converted into the corresponding PLC ladder diagram according to the design diagram of the traditional control circuit, as shown in Figure 1.

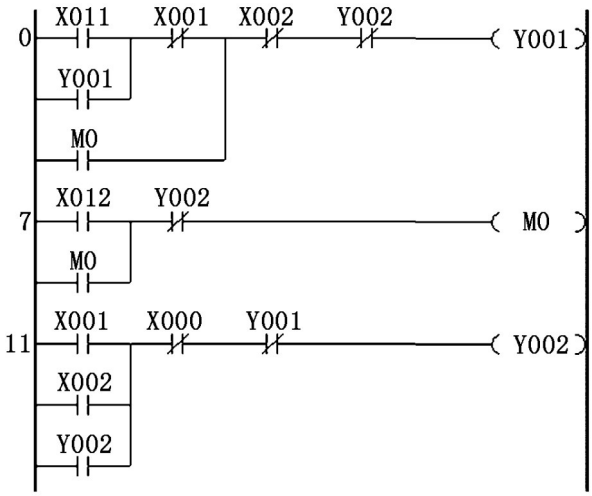

Figure 1 program ladder diagram

If there is no design basis of traditional control circuit, other control programs can be formed directly based on PLC control circuit, as shown in Figure 2. In Figure 2, two auxiliary relays, M0 and M1, are introduced, representing the 1# station and the 2# station respectively. No matter which call button is pressed, the robot can start Y1 and forward. The returned control signals X1 and X2 correspond to M0 and M1 respectively, so that the original M0 and M1 lines will respectively make Y1 lose power.

To sum up, the design of automatic control system of chemical production line based on PLC has

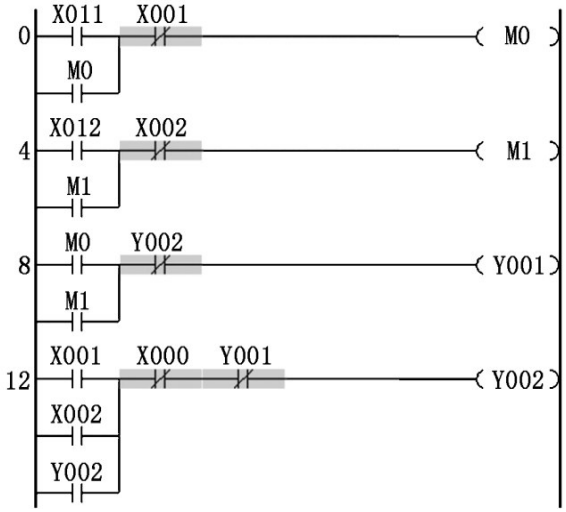

Figure 2 Program ladder diagram

been successfully applied in Angang Chemical Plant. Through reasonable overall system architecture design, hardware design and software design, the precise control and optimal management of the production process are realized, the production efficiency and product quality are improved, and the production cost and environmental pollution are reduced.

5 System implementation and testing

5.1 System Implementation Process

(1) Programming and debugging of 1)PLC control system

In the process of system realization, the programming and debugging of PLC control system is the key step. Firstly, according to the production process and control requirements, the control logic and data processing program are written by using PLC programming software (such as Siemens Step 7 and Mitsubishi GX Developer). After the program is written, it is simulated and debugged, and the correctness and reliability of the program are verified by simulating the running state and parameter information of the field equipment. After the simulation debugging passes, download the program to PLC for actual debugging. In the actual debugging process, according to the actual situation and feedback of field equipment, the program is modified and optimized to ensure that the PLC control system can control the production process stably and accurately.

(2) Development and integration of man-machine interface

The development and integration of man-machine interface is another important link in the process of system realization. According to the operator's operating habits and needs, we use human-machine interface development software (such as WinCC and Kingview) to design a friendly operating interface and a rich functional menu. After the interface design is completed, the interface and PLC control system are integrated and debugged to ensure that the interface can display the running status and parameter information of the production process in real time, and provide interactive elements such as operation buttons and indicator lights for the operators to use. At the same time, it is necessary to test and verify the alarm and fault prompt functions of the interface to ensure that operators can find and deal with abnormal situations in time.

(3) overall debugging and optimization of the system

In the process of system realization, the whole system needs to be debugged and optimized. First of all, the PLC control system, man-machine interface and actuator are jointly debugged to ensure the normal communication and information exchange among the components. Then, according to the production process and control requirements, the system is optimized as a whole, including adjusting control parameters, optimizing control logic and improving system response speed. Through overall debugging and optimization, the system can run stably and efficiently to meet the production requirements.

5.2 System Testing and Verification

(1) Functional test and performance test

In the process of system testing and verification, functional testing and performance testing are carried out first. The function test mainly verifies whether the system meets the production process and control requirements, including the correctness of control logic, the accuracy of data processing and the friendliness of man-machine interface. Performance test mainly evaluates the response speed, stability and reliability of the system. Through the function test and performance test, the system can be ensured to complete the production task stably and accurately.

(2) Safety and stability test

Security and stability testing is an important part of system testing and verification. In the test process, simulate various possible faults and abnormal situations, such as power failure, communication failure, equipment failure, etc., to verify the security and stability of the system. At the same time, it is necessary to test and verify the alarm and fault prompt functions of the system to ensure that operators can find and deal with abnormal situations in time and ensure the safe and stable operation of the production line.

(3) Evaluation and feedback of practical application effect

After the system test and verification is completed, the actual application effect is evaluated and fed back. By comparing the production efficiency, product quality and production cost before and after the application of the system, the actual application effect of the system is evaluated. At the same time, collect the feedback from operators, understand the advantages and disadvantages of the system in the actual use process, and provide a basis for further optimization and improvement of the system.

To sum up, the realization and testing of the system is the key link to ensure that the automatic control system of chemical production line based on PLC can run stably and efficiently. Reasonable system implementation process and comprehensive system testing and verification can ensure that the system meets the production process and control requirements, improve production efficiency and product quality, and reduce production costs and environmental pollution.

6 Conclusion

Through in-depth research and application practice of automation control system in Angang Chemical Plant, we have reached the following conclusions:

Automatic control system is the key to realize the digital transformation of chemical production. After the introduction of automatic control system based on PLC in Angang Chemical Plant, the production efficiency has been significantly improved, the product quality has been more stable, the energy consumption has been greatly reduced, and the production cost has been effectively controlled. This shows that automatic control system has important application value in chemical production and is the key technology to realize digital transformation and intelligent upgrading.

The design and implementation of the system should be closely combined with the production process and control requirements: when designing and implementing the automatic control system, the particularity and complexity of chemical production must be fully considered, and the production process and control requirements should be closely combined to ensure that the system can meet the actual production requirements. At the same time, it is necessary to pay attention to the expansibility and maintainability design of the system, so as to facilitate the subsequent function expansion and upgrade maintenance.

Friendly man-machine interface and system stability are very important: friendly man-machine interface can reduce the difficulty and labor intensity of operation and improve the work efficiency and satisfaction of operators. The stability of the system is the basis to ensure the safe and stable operation of the production line. Therefore, we must pay attention to the friendliness of man-machine interface and the stability of the system when designing and realizing the automatic control system.

Continuous improvement and optimization is the key to improve the performance of the system: although the automatic control system has achieved remarkable application results in Angang Chemical Plant, some problems and deficiencies have also been found in the actual application process. Therefore, it is necessary to continuously improve and optimize the system design and implementation process, and improve the performance of the system in terms of data processing ability, response speed, accuracy and reliability.

To sum up, the automatic control system based on PLC has important application value in chemical production and is the key technology to realize digital transformation and intelligent upgrade. In the future development, we will continue to study the application and optimization of automation control system, and provide more comprehensive and efficient technical support for the digital transformation and intelligent upgrading of chemical production enterprises. At the same

time, we also look forward to cooperating with more chemical production enterprises to jointly promote the intelligent development of the chemical industry.

Funding

Innovation and Entrepreneurship Project Approval for University Students of University of Science and Technology Liaoning, 2025.

About the Author

Shumin Li, Gender: Male Origin: Kunming City, Yunnan Province Ethnic Group: Yi Major: Electrical Engineering and Automation Class: Electrical 225.

References

[1] Research on integrated control of robots and PLC in industrial automation production line. Zhou Wei. Smart City, 2020(09)

[2] Application of PLC technology in automatic production line. Bai Yufeng. Electronic Technology, 2024(02)

[3] Design of training equipment for automatic production line based on PLC. Li Youbing; Lin Yong. Electromechanical Engineering Technology, 2022(12)

[4] Discuss the integrated control of robot and PLC in industrial automation production line. Ye Qingang. china plant engineering, 2021(02)

[5] Application of frequency converter based on PLC control in automatic production line. Sun Yongfang; Zhang Gang. Scientific and Technological Innovation and Application, 2019(35)

[6] Research on the application of PLC-controlled inverter in automatic production line. TongFu.kabu. Paper Equipment and Materials, 2022(12)

[7] Research on the Application of PLC Technology in Automatic Production Line. Wu Yanfeng. Enterprise Technology and Development, 2022(05)

[8] Design of industrial briquette automatic production line based on PLC. Fu Wei; Masile. Industrial Control Computer, 2011(08)

[9] Research on project-based teaching reform of PLC course based on automatic production line. Hu Renping; Zhang Qian; Deng Jianping; Lv Youping; Hu Ling. Southern Agricultural Machinery, 2021(22)

[10] robot PLC control technology in automatic production line. Chun Li. Electronic Technology, 2021(04)