The application of PLC technology in electrical automation control

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Abstract: With the continuous development and progress of industrial automation technology, programmable logic controllers (PLCs), as a specialized digital control device, have been widely used in various industrial automation control systems. This article provides a comprehensive overview of the application status, advantages, specific applications, and development trends of PLC technology in the field of electrical automation control. It focuses on the application of PLC in drainage management. PLC can execute control strategies such as liquid level control and flow control based on operating signals such as liquid level and flow rate, and automatically control execution equipment such as pump stations, gates, and valves. The PLC control system consists of a host, I/O modules, human-machine interface, instruments, etc. It integrates with various devices through analog, switch interface, and bus. Write control programs to achieve functions such as data collection, control algorithms, execution control, and communication interaction. Research has shown that the application of PLC technology can significantly improve the automation level of drainage management.

1. Introduction

Introduction: Electrical automation control is an indispensable and important component in modern industrial production and manufacturing processes. With the continuous improvement of industrial automation level, higher requirements have been put forward for the flexibility, reliability, and accuracy of control systems. In this context, programmable logic controllers (PLCs) have been widely used in the field of electrical automation control due to their unique advantages as an advanced digital operation control device. PLC technology was originally developed to replace traditional relay control systems. Compared to relays, PLC has advantages such as higher programmability, stronger anti-interference ability, more flexible scalability, and more convenient maintenance. The emergence of PLC greatly improves the flexibility and reconfigurability of control systems, making control logic easy to modify and adjust through programming, thus meeting the needs of different application scenarios .

2. Overview of PLC technology

PLC (Programmable Logic Controller) is a specialized digital operation circuit widely used in industrial automation control systems. It is a digital operation circuit composed of a microprocessor system specifically designed for operating sequence control. The main characteristics of PLC include:

2.1 Hardware Features

PLC adopts a modular hardware structure design, usually composed of multiple modules such as CPU module, power module, input/output module, communication module, etc. This modular design makes the configuration of PLC system more flexible, allowing different modules to be freely combined according to actual needs, and facilitating system expansion and upgrading. The PLC hardware design adopts a series of industrial level protection measures such as dust prevention, moisture prevention, and vibration resistance, which can adapt to harsh industrial environments.

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Usually, a sturdy metal shell is used, and the internal circuit is specially treated for anti-interference, such as using shielded cables, filter circuits, etc., with strong anti-interference ability. In order to meet the real-time requirements of industrial control, The PLC hardware adopts a high-performance CPU and real-time operating system, which can quickly respond to input signals and execute control instructions, ensuring the real-time and deterministic control process.

2.2 Software Features

The control logic of PLC is implemented through programming. Users can write programs according to actual needs to achieve flexible control of production lines, equipment, and process flows. This programmability makes PLC suitable for a wide range of application scenarios, whether it is simple control tasks or complex process flows, which can be achieved by writing corresponding programs. PLC software has strong fault tolerance and fault protection mechanism, which can diagnose and monitor the system on its own. Once abnormal situations are found, corresponding protection measures will be taken, such as deceleration, stopping processing, switching backup equipment, etc., to prevent fault expansion and system collapse, ensuring high reliability and stability of the system. Modern PLC programming languages support structured programming and modular design, which can divide control programs into different functional modules, which is beneficial for program readability, maintainability, and reusability.

2.3 Control performance characteristics

PLC can achieve high-precision control over production lines, equipment, and process flow. By precisely controlling the motion trajectory and process parameters of each actuator, it ensures the stability of the production process and product quality. PLC has strong reliability. Adopting numerous hardware and software fault-tolerant protection measures, it can operate stably for a long time and is suitable for harsh conditions in industrial environments. Through programming, PLC can achieve various complex logic control, sequence control, motion control and other functions, with strong flexibility and adaptability. Whether it is simple control tasks or complex process flows, they can be achieved by writing corresponding programs, which can meet diverse control needs.

2.4 Communication and integration features

PLC supports multiple industrial communication protocols and interfaces, such as Profibus Ethernet, Fieldbus can seamlessly communicate and exchange data with other control devices, upper computer systems, etc., achieving system integration and data sharing. With the development trend of open system architecture and standardization, PLC is developing towards a more open and interoperable direction, supporting more standardized communication protocols and open architectures, which is conducive to system integration and data sharing. PLC can be connected with enterprise network and Internet through industrial Ethernet to realize remote monitoring, data acquisition and other functions, support the development needs of Industry 4.0 and intelligent manufacturing, and further improve the manageability and scalability of PLC system.

3. The advantages of PLC technology in electrical automation control

3.1 Strong programmability

The programmability of PLC makes it highly flexible and adaptable, and both simple control logic and complex process flow can be achieved through programming. Simply edit and modify the program according to actual needs and download it to the PLC to quickly adjust the control logic without the need for tedious hardware rewiring. This greatly reduces the cost and workload of system transformation and upgrading, and improves the reconfigurability and maintainability of the control system. Li Jin (2024) found that compared to traditional hardwired control systems, The programmability of PLC brings enormous advantages, enabling it to adapt to constantly changing control needs and meet the special requirements of various industries and production processes. In addition, modern PLCs also support online and remote programming, allowing for real-time modification and downloading of programs during system operation, dynamic adjustment of control logic, and better adaptation to changes and abnormal situations in the production process.

3.2 Strong anti-interference ability

PLC has been specially designed and processed, with excellent anti-interference ability, and can work stably and reliably in harsh industrial environments, ensuring the continuity and safety of the production process. PLC usually adopts a sturdy metal shell, and the internal circuit adopts various anti-interference measures, such as shielded cables, filter circuits, etc., which can effectively shield external electromagnetic interference signals. At the same time, it also has characteristics such as vibration resistance, moisture resistance, and dust prevention, adapting to harsh industrial environments. In addition to hardware level protection, PLC software also has strong fault tolerance and fault protection mechanism, which can diagnose and monitor the system on its own. Once abnormalities are detected, protective measures such as deceleration, stopping processing, and switching backup equipment will be taken immediately to prevent fault expansion and system collapse, ensuring high reliability and stable operation of the system. This excellent anti-interference ability and fault-tolerant protection mechanism make PLC an indispensable core equipment in the field of industrial automation control.

3.3 Good Scalability

The PLC system adopts a modular hardware design, consisting of multiple modules such as CPU module, power module, input/output module, communication module, etc., and has good scalability. When the control requirements change, simply add or replace the corresponding modules to quickly expand and upgrade the system functions, without the need to rebuild the entire control system. For example, when it is necessary to increase the number of control points, I/O modules can be directly added; When supporting new communication protocols, corresponding communication modules can be added; When new control functions need to be implemented, special function modules can be added. This modular design makes the configuration of PLC systems more flexible, allowing for the free combination of different modules according to actual needs, meeting the needs of various application scenarios. Some high-end PLCs also support remote I/O and distributed I/O technology, which can distribute I/O modules to further improve system flexibility and scalability.

4. The specific application of PLC technology in the electrical automation control of drainage management

4.1 Control Policy

PLC needs to execute multiple control strategies in drainage management systems to cope with different work scenarios and environmental conditions. In response to large-scale rainfall, PLC needs to start the facilities of the pumping station and regulating pool in an orderly manner based on the rainfall monitoring data of each region. When a certain area experiences heavy rainfall, The PLC will prioritize starting the local pumping station based on the amount of rainfall in the area to pump rainwater into the pipeline network. At the same time, nearby regulating tanks will be activated to temporarily store some of the rainwater to divert the pressure of the pipeline network. As the rainfall gradually decreases, The PLC will control the pump station to discharge the accumulated water in the regulating pool into the downstream pipeline network in batches to prevent overflow and leakage due to excessive pressure in the downstream pipeline network. Throughout the entire control process, PLC needs to continuously dynamically adjust the pumping station's water output and regulating pool water level based on real-time rainfall data in various regions, ensuring efficient and orderly operation of the drainage system. Meanwhile, He Tian's (2024) study found that, PLC also needs to consider the influence of other factors such as river water level, and if necessary, priority can be given to discharging some rainwater into the river to prevent urban waterlogging. In addition to dealing with heavy rain weather, Under normal circumstances, PLC also needs to implement conventional drainage control strategies, reasonably schedule the operation of each pump station based on the pressure of the pipeline network, and maintain the smoothness of the pipeline network. In addition, for different peak water usage periods, PLC also needs to adjust the drainage mode to ensure that the sewage treatment capacity matches the domestic discharge volume. All these complex control strategies and response to operating conditions need to be impleme.

4.2 Hardware Components

As the "brain" of the system, the CPU module of the PLC is responsible for executing control programs, performing logical operations and data processing, and is the core of the entire system. The power module supplies power to each module to ensure stable system operation. The input module is a sensor between the PLC system and on-site equipment, which can collect data signals from various sensors, including flow meters, water level gauges, pressure sensors, rainfall monitoring equipment, etc., helping the PLC to obtain real-time information on the operation status and environmental changes of the pipeline network. The output module is the "only outlet" of the PLC controlled on-site execution device, which controls the switch status of the pump station equipment, valves, butterfly valves, and other execution mechanisms, PLC can adjust the flow direction and drainage volume to maintain stable operation of the pipeline network. The communication module enables seamless connection between the PLC system and the upper computer system, ensuring real-time data transmission and remote monitoring. Through communication methods such as industrial Ethernet and fieldbus, PLC can upload various operational data of the drainage system to the monitoring center for management personnel to remotely monitor the system status and issue control commands based on actual situations. At the same time, the upper computer system can also transmit rainfall warnings and other related information issued by the meteorological department to the PLC through communication modules, enabling the PLC to prepare in advance. Geng Kelei (2024) pointed out that in addition to being connected to the upper system, the communication module can also integrate with other related systems, such as flood control command systems, video monitoring systems, etc., to achieve information sharing and collaborative operation among various systems. In addition, for large-scale drainage management systems, PLC hardware can also adopt remote I/O or distributed I/O str.

4.3 Software Programming

Programmers need to carefully write control programs using programming languages such as ladder diagrams and instruction lists based on the control requirements and process flow of the system, transforming various complex control logic into PLC executable instructions. In the control program of the drainage system, response control logic for changes in rainfall must be included. The program needs to obtain real-time rainfall monitoring data for each region, and trigger different control strategies based on preset threshold conditions, such as starting pumping station drainage, opening regulating pool water storage, sending warning information to the upper system, etc. At the same time, the program also needs to include the start stop control logic of the equipment, reasonably schedule the start stop timing of each pump station based on the operation status of the pipeline network, and control the opening of valves, butterfly valves and other executing mechanisms to maintain the pressure of the pipeline network within a safe range. In addition to basic control logic, The PLC program also needs to have comprehensive fault alarm processing functions. By collecting various sensor data and making logical judgments, the program can promptly detect abnormal situations during system operation, such as abnormal pipeline pressure, excessive water level, equipment failures, etc., and send alarm signals to the on duty personnel in a timely manner according to preset alarm conditions. At the same time, corresponding protective measures can be implemented, such as switching backup equipment, closing some valves, etc., to minimize the expansion of faults and system paralysis. To improve the maintainability and readability of programs, modular programming is usually adopted. Splitting different functional logic into different program modules, each module is only responsible for completing a specific task, and interaction between modules is achieved through parameter passing and function calls. For example, rain response control,equipment control, alarm processing and other functions can be written as independent modules, and different modules can be called in the main program as needed. This modular design is not only beneficial for development and debugging, but also greatly improves the reusability and scalability of the program. When new features need to be added, simply write new program modules and integrate them with existing modules, without the need to rewrite the entire control program. Ma Hongde (2024) pointed out that in addition to structured programming, PLC program development can also draw on other advanced concepts and methods in software engineering, such as object-oriented programming, model driven development, etc., to further improve the quality and development efficiency of the program. Meanwhile, the application of software engineering practices such as version control and unit testing in PLC program development can also improve the maintainability and reliability of the program. In short, excellent PLC programs are the foundation for achieving automated control and intelligent operation and maintenance in drainage management systems. They must be carefully designed and coded according to actual needs, and advanced concepts must be continuously absorbed to improve the quality and efficiency of the programs.

4.4 System Integration

The modern drainage management system is no longer an independent control system. It needs to be closely integrated with other related systems in the city to achieve data sharing and business collaboration, thereby improving the intelligence level and operational efficiency of the entire city. As the control core of the system, PLC not only needs to complete direct control of on-site equipment, but also shoulders the responsibility of integrating and interconnecting with various related systems. Firstly, PLC needs to be integrated with the urban flood control command system, share rainfall monitoring data, and receive flood control instructions. In case of extreme weather such as rainstorm, the flood control command center can issue an early warning according to the rain situation, and send the early warning information to the drainage system in time through the data interface with the PLC, so that the PLC can switch to the emergency drainage mode in advance to minimize the risk of urban waterlogging. Meanwhile, The PLC will also provide real-time operational data of the pipeline network to the flood control system, providing reference for command and decision-making. Secondly, The PLC system needs to be integrated with the environmental monitoring system to achieve online monitoring of sewage discharge. PLC can upload real-time water quality data from the drainage network to the environmental protection platform. The environmental protection department can monitor the discharge of pollutants based on this data and issue sewage treatment instructions to the PLC system as needed, start the corresponding treatment program, and achieve timely treatment of sewage. In addition, The PLC system also needs to be integrated with the video surveillance system Integrated with GIS systems, providing comprehensive visual support for drainage management. By integrating PLC data with video surveillance footage By combining GIS geographic information, managers can clearly and intuitively grasp the real-time operation status of the entire drainage system, including network pressure, water level changes, equipment operation status, etc. in various areas, thus enabling more efficient and accurate command and scheduling. Meanwhile, Sun Fang and Xia Shuyue (2024) pointed out that these integrated systems also provide strong support for emergency command, fault diagnosis, etc. [5]. The key to achieving the above system integration lies in the communication capability of the PLC. PLC usually needs to support various industrial communication protocols such as industrial Ethernet and fieldbus in order to interface with different systems. Through network communication, PLC can transmit on-site data in real-time to the upper computer and other systems, and receive control instructions from these systems. In the process of system integration, standardization and interoperability of data are also important issues. It is necessary to develop a unified data model and communication specifications to ensure smooth integration between various systems. In short, the construction of contemporary smart cities has put forward higher requirements for drainage management systems. Single automation control can no longer meet the needs. It is necessary to integrate the system to enable the drainage system to closely cooperate with other urban managementystems, achieve data sharing and business collaboration, and thereby improve the overall operational efficiency and intelligence level of the city. As the control core, PLC plays a pivotal role in system integration, connecting with various related systems through powerful communication capabilities to achieve efficient data transmission and precise execution of control instructions. It is an indispensable and important part of smart city construction.

5. Conclusion

In summary, PLC technology plays an irreplaceable and important role in the field of electrical automation control. With its outstanding advantages such as strong programmability, strong anti-interference ability, and good scalability, PLC has become an indispensable core control equipment in multiple fields of drainage management systems, laying a solid foundation for achieving automation and intelligent production. Although PLC technology still faces some challenges, such as the difficulty of programming complex systems, higher requirements for real-time and determinism, and increasing demands for networking and information integration, with the continuous progress and innovation of technology, PLC will undoubtedly usher in broader development prospects and continue to make important contributions to the field of industrial automation control.

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