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Application Status and Challenge of PROFIBUS Technology in Industrial Automation Field

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ABSTRACT

This article first introduces the basic concepts and principles of PROFIBUS technology, and then elaborates on its application status in the field of industrial automation from three aspects: manufacturing, process control, and drive technology, including its wide range of applications and advantages. Subsequently, the main challenges currently faced by PROFIBUS technology were analyzed, such as integration with emerging industrial Ethernet technologies, data security issues, and the complexity of system upgrades and maintenance. Finally, the article looks forward to the future development trends of PROFIBUS technology, including further integration with industrial Ethernet technology and the introduction of encryption algorithms to enhance data security. Overall, PROFIBUS is a mature fieldbus technology. Still crucial in the field of industrial automation. However, with the development of new technologies and changes in application requirements, its future development still faces many challenges and opportunities.

KEYWORDS

PROFIBUS; Application Status; Field Bus.

1. INTRODUCTION

With the rapid development of technology, industrial automation has become an indispensable part of today's manufacturing industry. Efficient communication technologies play a crucial role in this process. PROFIBUS, as a communication protocol widely used in industrial automation, plays an important role in the field of industrial fieldbus because of its high reliability, flexibility and real-time.

PROFIBUS has been widely used in the field of industrial automation with its unique advantages since its birth. From simple sensor and actuator connections to complex distributed control systems, PROFIBUS demonstrates exceptional performance[1]. However, with the advent of the era of Industry 4.0, intelligent manufacturing is also constantly advancing. Industrial automation is also increasingly demanding communication technologies. PROFIBUS as a mature technology, in the face of new challenges, how to maintain its leading position and continuous innovation, has become the focus of attention in the industry.

This paper aims to discuss the application status of PROFIBUS in industrial automation, analyze the main challenges it faces, and predict its future development trend. Through deep research and analysis, we hope to provide readers with the latest trends and advanced ideas about PROFIBUS technology, and make contributions to the further development of intelligent technology in manufacturing industry.

2. OVERVIEW OF PROFIBUS

The development of PROFIBUS Process Field Bus dates back to the 1980s. There was a growing need in the industry for a common communication protocol that could connect field devices. In 1987, Siemens AG developed the PROFIBUS protocol in cooperation with 12 other companies and five research institutes. This protocol was originally intended to achieve interoperability between automation equipment produced by different manufacturers. PROFIBUS has been approved as German standard DIN 19245 since 1987. Subsequently, in December 1989, a group of companies that volunteered to use the standard specification in their products came together to form the PROFIBUS User Organization (PNO). By June 30, 1996,PROFIBUS was approved as part of the European Fieldbus Standard. Since then, EN50170V.2 has replaced DIN 19245[2].

PROFIBUS technology modules are designed with reference to the model for information communication oriented to ISO-OSI standards, which defines all elements, structures and tasks required for communication. PROFIBUS technology simplifies the model, using only one of the layers 1), 2) and 7), and adds a user-oriented user layer, as shown in Figure 1:

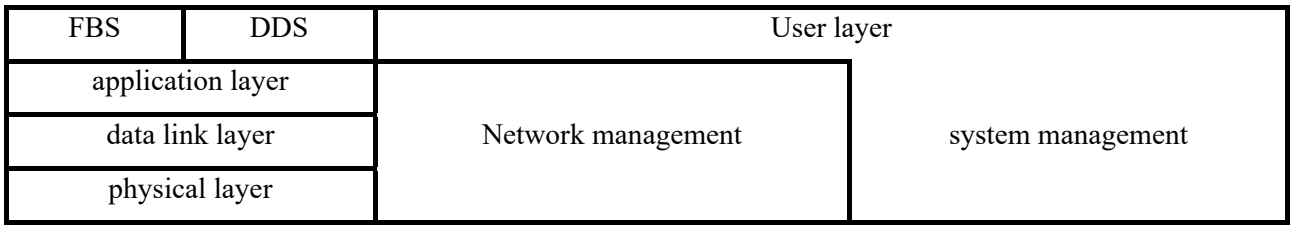

Figure 1. Simplification of the OSI model by ROFIBUS

PROFIBUS is a fieldbus technology for factory automation workshop level monitoring and field equipment level data communication and control, which can realize the distributed digital control and field communication network from the field equipment level to the workshop level monitoring, so as to provide a feasible solution for the realization of comprehensive factory automation and field equipment intelligence[3]. PROFIBUS transmission distance, high speed, high data security, simple installation, easy to use and easy to debug. It is widely used in manufacturing automation, process industry automation and other areas of automation such as building, transportation and power.

PROFIBUS can be divided into PROFIBUS-DP, PROFIBUS-PA and PROFIBUS-FMS3s three series versions according to the application. PROFIBUS-DP bus is designed for decentralized control of high-speed equipment. Especially suitable for programmable controllers and field-level decentralized I/O device communication. PROFIBUS-PA is designed specifically for process automation. PROFIBUS-FMS protocol layer specifications are more complex, can not adapt to the current requirements of high-speed field bus transmission, has gradually withdrawn from the practical application, now the most widely used are DP and PA series.

PROFIBUS has the following characteristics: PROFIBUS interface mode is based on RS-485 interface, using master-slave communication mode, allowing multiple slave devices to connect to a single master device, its communication rate is 9.6KB/s~ 12MB/s. It supports a variety of topology structures, including linear bus, tree network and star network. PROFIBUS uses asynchronous token communication mechanism to complete communication between master stations. PROFIBUS is an open fieldbus standard independent of manufacturers, which unifies the use of generic station description files (GSD) and electronic device data files (EDDL or FDT/DTM) to realize the interchange and interoperability of equipment from different manufacturers.

3. PROFIBUS IN INDUSTRIAL AUTOMATION APPLICATION STATUS

3.1. Manufacturing

In the field of manufacturing, PROFIBUS is widely used in production line automation to achieve efficient communication and data exchange between equipment. It is produced by connecting sensors, actuators, robots, conveyor belts, etc. Support the integration of manufacturing execution systems (MES) and underlying control equipment, thereby improving production efficiency and increasing production flexibility.

Modular automatic production line system is a typical automation system, which can be conveniently combined according to the needs of users to meet the needs of customers for different production processes[4]. This research takes the modular automation system composed of several stations, such as feeding, handling, processing, installation, handling and installation, classification, etc. as the research object.

The schematic diagram of modular automatic production process is as follows: after the sequential discharge of workpieces is completed at the feeding station, the workpieces are delivered to the handling station; the handling station completes the flow function and transports the bow to the processing station; the processing station sends out the work station after the workpiece processing is completed; the installation handling station moves the workpieces from the installation station to the installation station. The installation station then installs the corresponding small workpiece into the large workpiece. Then, the installation and handling station sends the installed workpieces to the classification station, and the classification station sends the workpieces to the corresponding bins. The workflow diagram of the modular automation production line system is as follows:

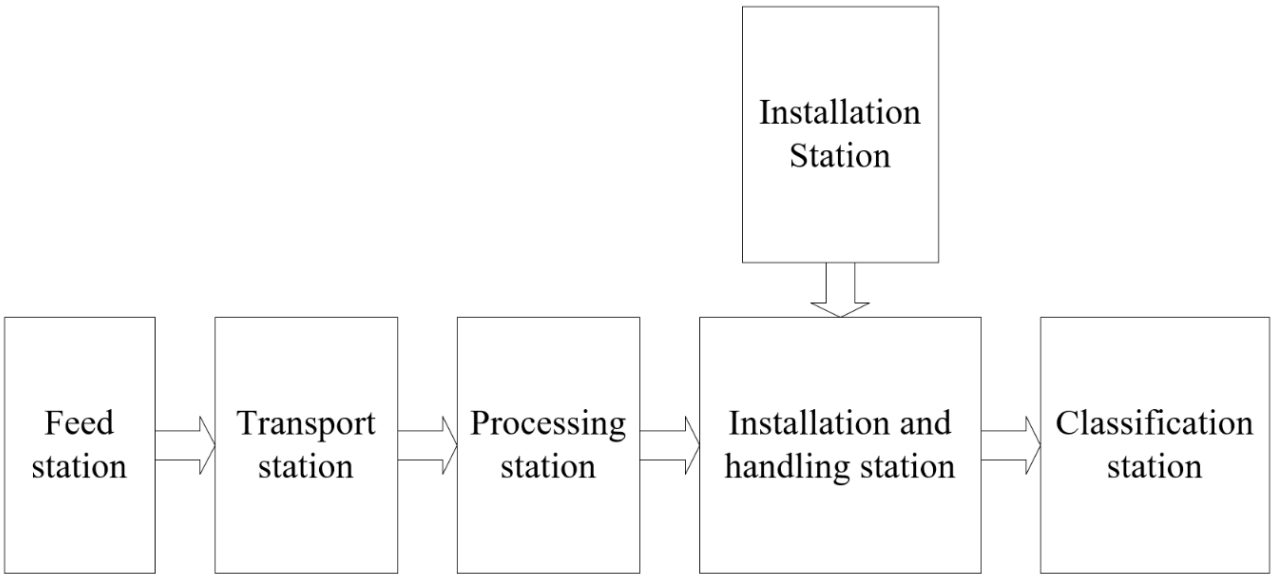

Figure 2. Schematic diagram of modular automation production line system

3.2. Process Control

In the field of process control, PROFIBUS-PA Process Automation version is particularly popular. It is suitable for continuous production processes such as chemical, petroleum and food processing industries. By integrating sensors and actuators directly on the fieldbus, PROFIBUSPA enables monitoring and control of complex processes while ensuring reliable communication in harsh environments.

A foreign copper and cobalt tailings reclamation project aims to recycle the tailings produced in the copper and cobalt ore processing plant for decades. The project adopts the wet smelting process of "stirring leaching → extraction → electrodeposition" to produce cathode copper with a production capacity of 105kt/a.Cobalt hydroxide products are produced by the process of "precipitation → press filtration → drying" with a production capacity of 21kt/a cobalt metal[5].

PCS7V8.2 of Ximen subsidiary company is adopted for the whole plant control system of this project, mainly composed of 2 engineering stations. Engineering System (ES), 2 redundant Operator System (OS) servers, 1 history data server, 1 OS Web server, 9 OS clients, 12 Automation Systems (AS) servers "AS") numbers AS1 to AS13, where AS9 is unused). PROFIBUS-PA field bus is adopted for plant control system to realize plant field instrument access. See Table 1 and Table 2 for main equipment model, PA network equipment and instrument equipment included in each AS.

Table 1. Main equipment models of PROFIBUS-PA system

Titile	Brand	Type	Description
DP Master	Siemens	6ES7410-5HX08-0AB0	CPU
	Siemens	6GK7443-5DX05-0XE0	Expand DP master station module
DP/PA Link	Siemens	6ES7153-2BA70-0XB0	
DP/PA	Siemens	6ES7157-0AC85-0XA0	Regular type
Coupler	Siemens	6ES7157-0AD82-0XA0	Explosion proof type
Active site distributor	Weidmuller	FBConPACG4wayLimiter	
		FBConPACG8wayLimiter	
		FBConPACG4wayEx	Explosion proof type
		FBConTerm.dExFM	Explosion proof terminal resistor

Table 2. Statistics of PA network equipment and instrument equipment included in each AS

Project	AS number												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Number of process instruments/piece	78	33	116	107	81	190	203	44	21	15	58	73	1029
Number of Couplers/piece	4	3	10	8	14	14	16	4	5	1	4	4	84

Since the control system was put into use in May 2018, it has continued to operate stably without any systematic failure. At the same time, the maintenance of the system instrument is relatively simple, instrument engineers only need to use PDM software on the engineer station to carry out fault diagnosis, parameter setting and other daily maintenance of the field instrument, which greatly reduces the work intensity and improves the work efficiency.

3.3. Distributed Control

In terms of DCS (Distributed Control System), PROFIBUS-DP (Decentralized Peripherals) is an optimized high-speed communication transmission protocol designed specifically for communication between distributed I/O and automatic control equipment, and supports flexible network structures and the characteristics of connecting slave stations with different communication rates and addresses.

In the intelligent construction project of copper refining facilities, all automation equipment must be connected to DCS for remote management. For devices equipped with programmable logic

controllers (PLC), they are usually incorporated into the system as intelligent slave devices and interconnected with DCS through Profibus-DP networks. Because the control structure of one of the high-end imported fans is relatively complex, the Siemens S7-1500 PLC it adopts does not support the slave device mode, so it cannot be directly connected with DCS by using the standard Profibus-DP communication interface[6].

Due to DP/DP coupler can connect PROFIBUS-DP network with different communication rate and different slave address. DP/DP coupler is introduced, DP network environment with multi-master station is established, and special monitoring and control signal channel is configured to realize remote monitoring of DCS system to fan. Siemens 1500PLC is adopted as the main controller of fan system, which is connected with local operation HMI and remote IO module through PROFINET bus. Figure 3 is the network structure diagram of fan control system.

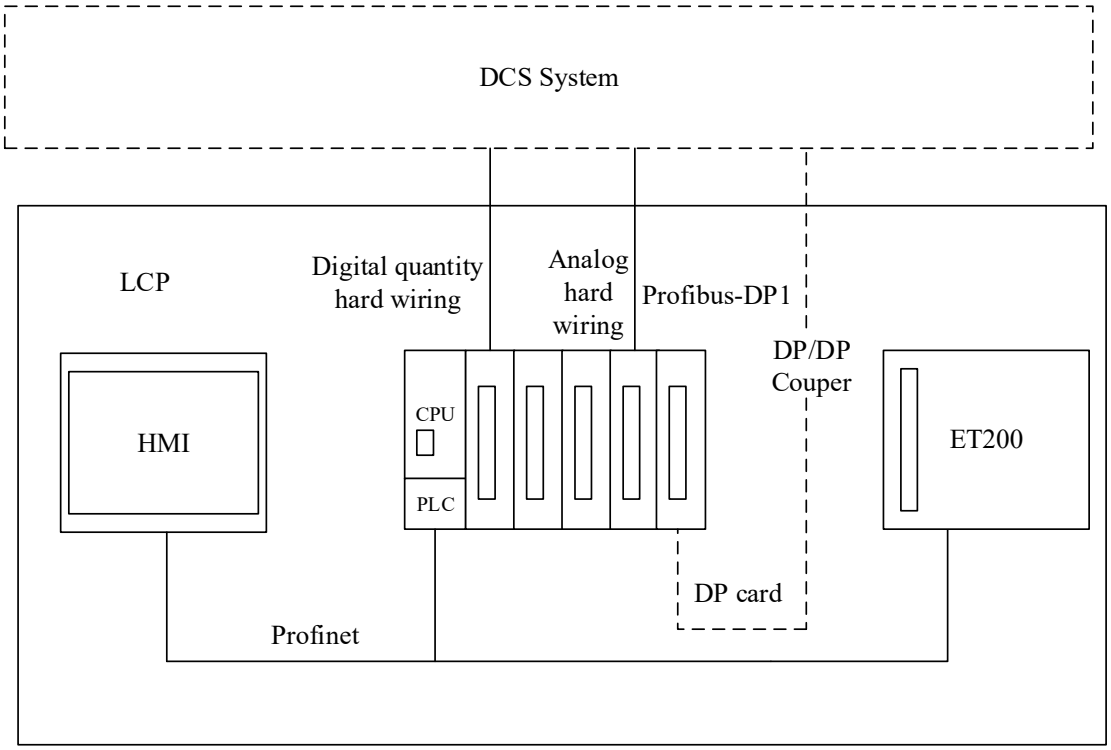

Figure 3. Fan control system network structure diagram

Driven by Industry 4.0, driven by intelligent manufacturing. Although PROFIBUS faces competition from new industrial Ethernet technologies such as PROFINET and ETHERCAT, it maintains an important position in the field of industrial automation due to its mature technology, extensive market access and deep accumulation in existing systems. However, with the development of Industry 4.0 and IoT, the requirements for industrial communication networks are higher. For example, higher data rates, stronger network security, and better integration capabilities. Therefore, PROFIBUS technology also faces some challenges, such as the need to compete and converge with emerging industrial Ethernet technologies such as PROFINET, ETHERCAT, etc. to adapt to the needs of modern industry for high-speed data exchange and complex network structures.

PROFIBUS technology is still an important and widely used communication standard in the field of industrial automation, but it needs to be continuously updated and improved to adapt to the evolving needs of industrial automation.

4. CHALLENGES

Although PROFIBUS technology occupies an important position in the field of industrial automation, it inevitably encounters a series of new challenges. These challenges come from the market demand for higher efficiency and higher security, but also from the continuous emergence of new technologies, which together push PROFIBUS technology towards more advanced and perfect direction.

4.1. Competition with Emerging Industrial Communication Protocols

With the development of Industry 4.0, and intelligent manufacturing. Emerging industrial communication protocols such as PROFINET, ETHERCAT, Modbus TCP and other Ethernet technologies are rapidly emerging. These emerging protocols offer higher data rates, better network topologies, and greater data processing capabilities. In contrast, PROFIBUS, while stable in existing industrial environments, may not be fast and flexible enough to meet the latest industrial automation needs. PROFIBUS therefore needs to constantly upgrade its technology to maintain its market share.

4.2. Technology Upgrading and Compatibility Issues

With the continuous advancement of technology, industrial equipment manufacturers have launched devices that support new communication protocols. This demands that existing PROFIBUS systems be compatible with the new devices or undergo necessary upgrades and transformations. However, this often involves significant costs and complex engineering implementation processes. At the same time, maintaining the normal operation of old systems while introducing new technologies also adds extra complexity to system integration and maintenance.

4.3. The Challenges of Network Security and Data Integrity

In industrial control systems, network security is essential. PROFIBUS systems may face external network attacks such as viruses, Trojan horses, and hacker intrusions, which could lead to production stoppages, data leaks, and even property loss. Therefore, PROFIBUS systems need to enhance security protection measures, such as encrypted communications, access control, and regular security audits.

4.4. Complexity of System Integration and Maintenance

With the expansion of industrial automation systems, their complexity also increases. Integrating and maintaining PROFIBUS systems becomes more difficult. The system may contain hundreds or thousands of devices and nodes, each of which requires proper configuration and debugging. Furthermore, as the system runs for an extended period, equipment aging and increased failure rates will also make maintenance more challenging. Therefore, professional technical support and regular maintenance plans are required to ensure the stable operation of the system.

5. DEVELOPMENT TRENDS

With the global manufacturing industry to intelligent and networked transformation. Industrial automation systems are also constantly upgrading their requirements for communication technology. PROFIBUS is the pioneer of fieldbus technology, and its future development trend is particularly critical. Driven by concepts such as Industry 4.0, the Industrial Internet and networking, PROFIBUS must adapt to new technological requirements and market changes in order to maintain its leading position within the industry[7]. In the future, PROFIBUS technology is expected to innovate and improve in several key areas:

5.1. Enhance Data Transmission Security

Introduce higher level encryption algorithms, such as AES (Advanced Encryption Standard), to protect the security of data transmission. Implement stricter identity authentication and access control mechanisms. For example, use digital certificates and multi-factor authentication to ensure that only authorized users can access and control the system. Regularly assess security vulnerabilities and update patches to prevent malware and hacker attacks.

5.2. Convergence with Industrial Ethernet Technology

A gateway device compatible with PROFIBUS and PROFINET is developed to realize seamless data exchange between the two. At the software level, it provides a unified engineering tool and configuration environment to simplify the system integration and maintenance process[8]. The use of high-speed transmission capabilities of Industrial Ethernet improves data throughput and real-time performance of PROFIBUS networks.

5.3. Wireless Communication Integration

wireless sensor network (WSN) technology is adopted. To realize the difficult area of wiring monitoring and control[9]. Develop wireless PROFIBUS protocol stack to ensure compatibility and data consistency between wireless communication and wired PROFIBUS network. Wired connections are maintained in critical applications for maximum stability and reliability. Wireless technology is used in non-critical areas to increase flexibility.

5.4. Energy Efficiency Management

Integrated energy management module, real-time monitoring and analysis of equipment energy consumption, automatic adjustment of operating parameters to reduce unnecessary energy consumption. Predictive maintenance strategy is adopted to predict equipment failure through data analysis, repair or replace in advance, and avoid energy waste. Optimize production process, reduce downtime, improve production efficiency. Thus, the overall energy efficiency is improved.

5.5. Integration of IoT Technologies

Utilize IoT technology to collect operational data of on-site devices, conduct big data analysis through cloud computing platforms, and provide support for decision-making. Develop IoT devices and interfaces compatible with PROFIBUS to achieve seamless access to device data and remote monitoring. Intelligent logistics and supply chain management are achieved through the Internet of Things. Improve the tracking ability of materials and products, reduce inventory and operating costs.

Overall, PROFIBUS technology will continue to evolve to meet the growing demand for industrial automation. Provide smarter communication solutions. And maintain its relevance and advantages in the competition of the new generation of communication standards.

6. SUMMARIZE

Although the development of fieldbus technology faces constraints from various protocols and international standardization challenges, as well as uneven support from different countries, it is difficult to form a unified situation in the short term. Users may also feel inconvenient when choosing, and competition between various protocols will become increasingly fierce. However, thanks to the significant advantages of PROFIBUS bus itself and the strong support of PLC manufacturers, coupled with the slow development of other bus standards, PROFIBUS bus technology is expected to usher in a more rapid development momentum, becoming the most popular and promising field bus

technology at home and abroad. Therefore, the industry and research institutions should continue to devote themselves to the updating, maintenance, talent cultivation, research and development innovation, standardization work, safety improvement, and energy efficiency management of PROFIBUS technology, jointly promoting the widespread application and continuous development of this technology in the global industrial automation field.

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