

Typical Fieldbus and Its Fault Diagnosis

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Abstract: Fieldbus is a bus that transmits information between electrical equipment, which is simple and safe, and is applied in various fields such as automobiles, aerospace, power plants, etc. This article mainly introduces three types of fieldbuses: Profibus, FF, and WorldFIP, and provides hardware and software fault diagnosis for these three types of fieldbuses.

Keywords: Fieldbus, Fault diagnosis, WorldFIP.

1. Introduction

1.1. Purpose and significance of the project

Since the 1980s, fieldbus technology has gradually emerged and developed. Fieldbus technology has always been a popular technology in the field of industrial control. In order to meet the needs of process control safety and reliability, and to adapt to the trend of intelligence and networking brought about by the development of information technology, fieldbus technology continues to develop. The fieldbus has enabled automatic control equipment and systems to enter the ranks of information networks, opening up broader fields for their applications. Multiple control devices can be connected to a pair of twisted pairs on the fieldbus, which is convenient for saving installation costs. Due to the reduction of installed devices due to fieldbus, maintenance costs can be saved. The control equipment basically has self-diagnosis function, and the fieldbus adopts one-to-many bidirectional transmission signals, which use digital signals with high accuracy and strong reliability. These can improve the reliability of the system and provide users with more flexible system integration initiative. The field bus, as the road for transmitting data and information, is an industrial data bus that connects intelligent instruments, controllers, actuators, and other field devices. It is equivalent to the blood of field devices and plays a crucial role. If the field bus fails, causing information to not be transmitted, the entire field equipment will be affected.

With the continuous development of science and technology in China, it has greatly promoted the development of various industries. More and more engineering equipment and precision instruments are needed, and the reliability research and fault diagnosis of such engineering equipment or instruments are becoming increasingly important. Although China started relatively late, probably in the late 1970s, it has been striving to learn from foreign countries and continuously absorbing advanced technologies from Europe and America. In today's world, China is striving to catch up. Although the starting point is not high, its advantage lies in its ability to learn from the world's advanced technology, stand on the shoulders of giants, and rely on the research results of predecessors to help China develop and progress rapidly. In recent years, China's research results in fault diagnosis technology have been increasing, and the depth has gradually deepened. It can be said that China has made significant achievements in fault diagnosis technology. This phenomenon is commendable, but there is still a gap between

China and other countries that have studied for many years. Therefore, continuous efforts and progress must be made to become a world leader in fault diagnosis technology and stand among the world's strong forests.

1.2. Development Status at Home and Abroad

With the continuous development, more and more types of fieldbuses[1] have emerged. According to statistics, there are no less than 20 types of fieldbuses. There is an international standard for fieldbus protocols, IEC61158, which specifies 8 protocol types. There are certain differences in the structure and characteristics of the bus, so the application fields are also different. A company in the United States once conducted a survey, which showed that the proportion of various fieldbuses varies in different fields. The following are some of the survey results: In the field of process automation, fieldbuses FF, PROFIBUS-PA, and WorldFIP account for 15% of the total; In the pharmaceutical field, FF, PROFIBUS-PA, and WorldFIP fieldbuses account for 18%; Profibus-DP and DeviceNet fieldbuses account for 15% of the manufacturing industry; PROFIBUS-DP and DeviceNet account for 15% in the transportation field. Through the above investigation results, it can be found that in the future development of fieldbus, the application fields of fieldbus will gradually be determined, such as FF and PROFIBUS-PA are suitable for process control in metallurgical, petroleum, chemical, pharmaceutical and other process industries, while PROFIBUS-DP and DeviceNet are suitable for processing and manufacturing industries. But this is just the author's inference, and the development of the bus is still ongoing, and the field bus used in various industries is also uncertain.

The United States was the first country to propose fault diagnosis technology[2], which was first used in mechanical equipment. It is a technology for diagnosing faults in mechanical equipment, and the full name of fault diagnosis is State Detection and Fault Diagnosis (CMFD). Fault diagnosis is a comprehensive emerging discipline that identifies the source of faults based on the operational information and status of the system, and makes corresponding decisions. Since the birth of fault diagnosis technology, researchers have found its significance to be significant and has a significant impact on the development of equipment fault diagnosis worldwide, requiring special research. Since the early 1970s, software led fault diagnosis detection and diagnosis technology has been widely studied in the United States. Based on this, with the in-depth research and promotion of microelectronics, sensing technology, computer technology, etc., fault diagnosis technology has become more perfect.

Since then, the United States, Japan, and the United Kingdom have put fault diagnosis systems into production and transportation on a large scale, making fault diagnosis technology increasingly mature.

2. Introduction to Typical Fieldbus

2.1. Profibus fieldbus

The structure of Profibus DP includes the physical layer and the Data link layer, which are the first layer and the second layer respectively. The structure also includes the user

interface. The structure of the Profibus bus makes information transmission faster and more efficient. The user interface introduces Profibus. Detailed description of the user interface for the first, second, and seventh layers. The user interface sets the functions that various devices can use. Profibus PA uses an extension protocol based on DP. Adopting PA regulations that can describe the specific behavior of the device. According to the IEC1158-2 standard, this protocol has high security and the bus can also transmit power to devices. Profibus PA equipment can be installed on Profibus DP by using segmented couplers.

EN50170 Volume 2 and DIN19245 Parts 1 to 4		
processing automation Profibus-DP good efficiency and moderate price	processing automation Profibus-FMS multi host communication	process automation Profibus-PA bus feeding intrinsically safe

Figure 1. Components of Profibus

Profibus consists of three parts: Profibus FMS can be used to provide communication tasks at the workshop level. The scope of communication is wide and can adapt to complex communication. The bus cycle is generally less than 100ms. Profibus-DP is a relatively inexpensive bus, but communication is relatively fast. Mainly used for communication between automatic control systems and decentralized I/O device levels. The bus cycle is generally less than 10ms. Profibus-PA is mainly used in the field of

process automation. This bus can install sensors and actuators on one bus. It can also be connected in the field of Intrinsic safety. According to the IEC1158-2 standard, Profibus-PA uses dual wires for bus power supply and data communication. The structural composition of PROFIBUS is shown in Figure 1. The application of Profibus is shown in Figure 2. Profibus [3] supports multi master communication (token based) and master-slave communication.

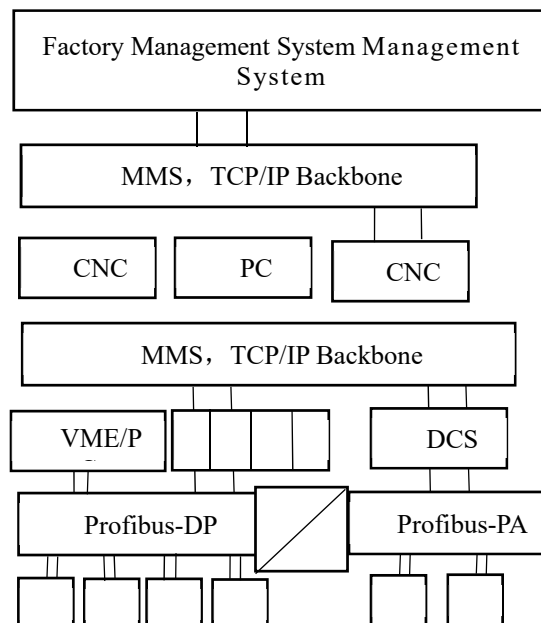


Figure 2. Profibus Application Range 2.2FF Fieldbus

FF is a global organization with over a hundred companies participating, which can be said to encompass most of the

manufacturing process control equipment in the world. The transmitters, DCS systems, actuators, and flow instruments produced by FF members account for 90% of the global market. ISP is the abbreviation for Interoperable System Protocol. Profibus can be said to be a cornerstone that ISPs can establish. ISP was established in 1992. When ISP was established, most of the participating companies were instrument companies, with over a hundred companies led by

Fisher Rosemount. WorldFIP is the abbreviation for the Factory Instrumentation World Protocol. The establishment of WorldFIP is based on FIP. When WorldFIP was established, hundreds of companies participated, and many of them were PLC manufacturing companies led by Honeywell. The Fieldbus Fund was established in 1994. It was formed by the merger of ISP and WorldFIP (North America). The bus model structure of FF is shown in Figure 3.

User
Fieldbus FMS FAS
Data Link Layer
Physical layer

Figure 3. FF fieldbus model structure

Major instrument companies worldwide have joined FF. The adaptability of FF fieldbus is very good. It is precisely because many of the enterprises joining FF are manufacturing process control equipment, so FF bus can well adapt to process control equipment, which makes FF unique in process control and extremely convenient to use. Devices from the same company can communicate with each other. FF can

perform functions between devices from different companies. Different companies can use similar devices to replace each other without any functional issues.

2.2. WorldFIP fieldbus

The architecture of the WorldFIP fieldbus is shown in Figure 4

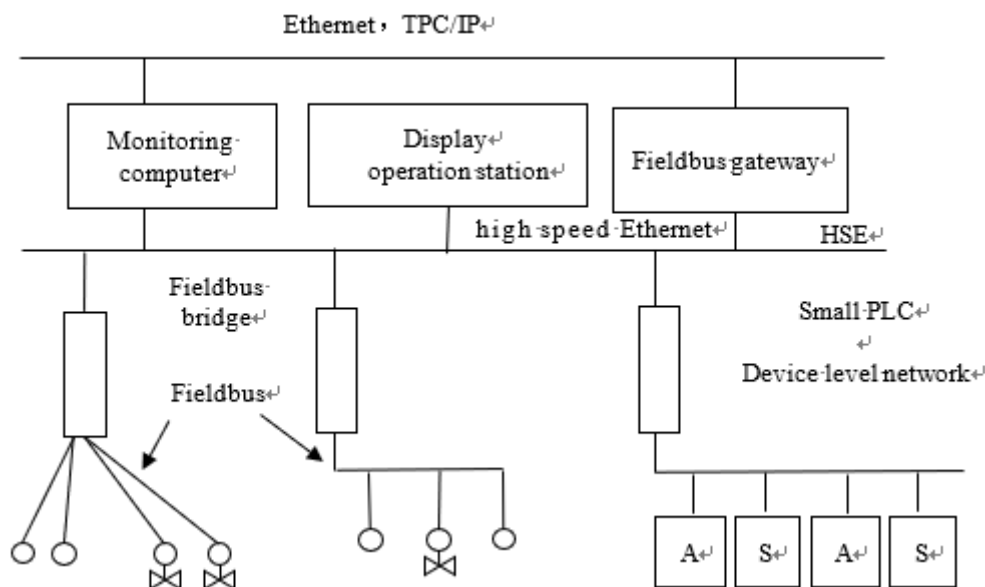


Figure 4. WorldFIP Fieldbus Architecture

From Figure 4, it can be seen that the composition of the WorldFIP [4] fieldbus can be divided into three parts, namely the process level, control level, and monitoring level. When composing process control, factory manufacturing processing systems, and various drive systems, only WorldFIP fieldbus is needed, rather than using combinations like other buses to meet the system's needs.

The structure of WorldFIP bus includes physical layer, Data link layer and application layer. They are the first, second, and seventh layers in ISO/OSI. The WorldFIP physical layer is basically consistent with the IEC158-2 physical layer standard. The application layer includes MPS and SubMMS. MPS specifies periodic/non periodic services for data communication, while SubMMS specifies a subset of data communication packets. The Data link layer mainly includes functions such as variable and message database, variable data refresh and message transmission. The application layer

can provide MPS periodic /aperiodic variable service and SUB-MMS thermal insulation transmission service. The database in the Data link layer accepts the MPS periodic /aperiodic variable service, then proposes a database refresh request, receives the requested message transmission, and then transmits the message

High communication efficiency. WorldFIP fieldbus can support 128 byte variable message or 256 byte message message at most, which is more efficient than CAN short message fieldbus. It can transfer a large amount of information on a bus without interfering with time limit variables, which benefits from the scheduling mode of producer /user mode and Bus mastering, and control information and non control information can be transferred on the same bus without interference. WorldFIP has strong anti-interference ability and real-time performance. WorldFIP fieldbus can not only fully meet the EMC standard of IEC on

Electromagnetic compatibility, but also adapt to various environments. Its communication mode supports background transmission of messages, cycles, and event variables, enabling real-time control while transmitting diagnostic information. Although the WorldFIP protocol is single, its adaptability is relatively good. In low-speed networks, WorldFIP [5] only uses one set of protocols. In high-speed networks, it is also a single protocol. If WorldFIP wants to achieve a connection between low-speed and high-speed networks, it can only be done using software. WorldFIP can adapt well to various control systems and does not require any additional functions, unlike adding bridges or gateways to other buses to adapt to control systems.

The main application areas of the WorldFIP bus are in the fields of automobiles, nuclear power, and subways. There are many projects using WorldFIP bus in China, such as Ling'ao Nuclear Power Plant, Shanghai Metro and Junliangcheng Power Plant. The European Nuclear Research Center spent billions of dollars to build the world's most powerful Large Hadron Collider. WorldFIP bus is one of the standard buses used by the Collider

3. Introduction to Fault Diagnosis

Around the 1960s, the United States began researching fault diagnosis technology and was the earliest country to study it. It was initially applied in the fields of aviation and military industry. With the continuous development of technology, the level of automation has become higher and higher, and fault diagnosis technology has gradually been

applied to the field of automation. The research on fault diagnosis technology in China began around the 1980s. Although it started relatively late, in recent years, it has gradually narrowed the gap by drawing on the research achievements of other countries. Fault diagnosis technology has contributed to the improvement of modern industry and automation level, providing assistance in personal safety, equipment safety, and production work, and reducing many economic losses for enterprises. Fault diagnosis technology includes two aspects: one is the monitoring of equipment and facilities, monitoring the real-time status of equipment; Secondly, when a fault occurs, a clear analysis can be conducted to determine the location of the fault, locate the fault, and facilitate subsequent fault repair to ensure equipment safety. The main methods of fault diagnosis can be summarized into the following three types: analytical model based methods, signal processing based methods, and empirical knowledge based methods. The model-based method is the first used fault diagnosis method. By establishing the mathematical model of the diagnosis object, a series of methods are used, such as establishing a State observer, calculating the residual between the calculated output and the actual output, etc. Although this method is relatively accurate, it is too complex. Firstly, it involves mathematical modeling of a diagnostic object. For a very complex object, establishing a mathematical model may be a huge engineering task, so this method has significant drawbacks. It is often used in systems with simple diagnostic objects and easy to obtain mathematical models. The basic steps of this method are shown in Figure 5.

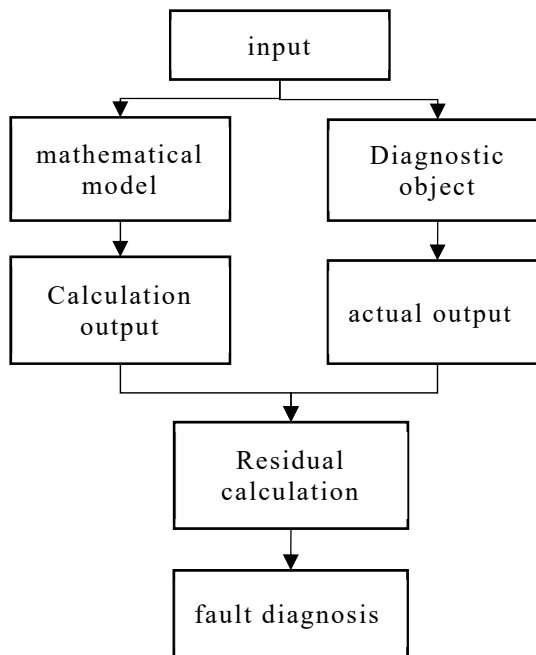


Figure 5. Model based fault diagnosis

The method based on signal processing only needs to monitor the signals and states of the diagnostic object, and does not require the establishment of complex mathematical models, so it is suitable for fault diagnosis of some complex systems. By using signal analysis theory to obtain multiple feature vectors in the time and frequency domains of the system, and then by their relationship with a certain part, it can be determined that the fault occurs at the location of the equipment when a fault occurs. The fault diagnosis method based on empirical knowledge is more suitable for nonlinear

systems. This method does not require the establishment of a mathematical model and is a manifestation of using knowledge in artificial intelligence for fault diagnosis. Establish an intelligent diagnostic system using empirical knowledge, such as neural networks, fuzzy neural networks, logical reasoning, or expert systems. At present, this method is mostly used for diagnosing a specific operating state, and it needs to be refined in terms of comprehensive state diagnosis and universality. The process of fault diagnosis is shown in Figure 6.

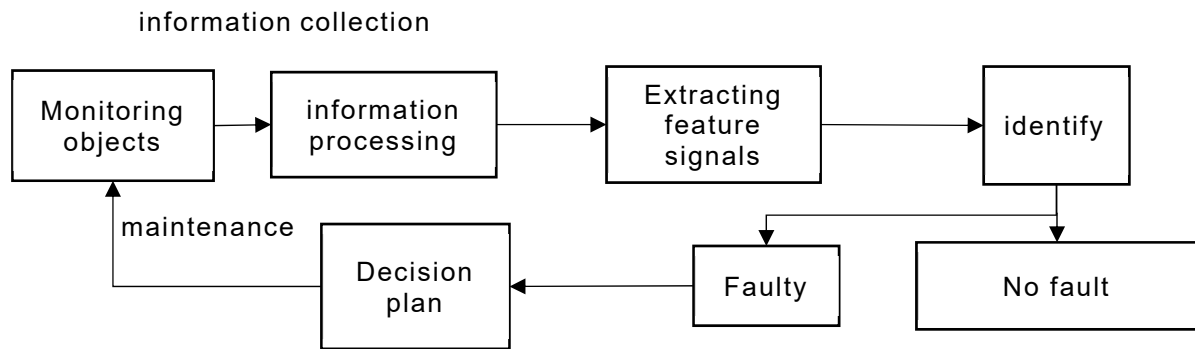


Figure 6. Fault Diagnosis Process

4. Field Bus Fault Diagnosis

The fault of the fieldbus [7] may not only occur on hardware, but also on software. Therefore, when diagnosing the fault of the fieldbus, both hardware and software fault diagnosis are usually performed to ensure that the fault of the fieldbus can be fully located, facilitating the subsequent elimination of the fault.

4.1. Profibus

Hardware failures of Profibus fieldbus typically occur in network cables, connectors, or electromagnetic interference, such as poor contact caused by oxidation or damage of DP connectors, faults caused by broken DP network cables, and faults caused by poor network connection due to electromagnetic interference.

1. Hardware diagnosis

1) DP interface

Interface failure phenomenon: When the DP interface fails, the network will malfunction. At the same time, the PLC network fault indicator light will be constantly red, and most network connections will be interrupted, resulting in communication failure and even production interruption. Fault cause: 1. Rust or oxidation occurred at the terminal resistor switch, resulting in poor contact. 2. Rust or oxidation occurred at the connection between the shielded twisted pair and the connector, resulting in poor contact. Detection method: Use a multimeter to check the resistance between pins 3 and 8. If there is no fault, when the switch is in the "NO" position, the resistance between the two pins is 220 ohms. When the switch is in the "OFF" position, the resistance is infinite.

2) DP network cable

The phenomenon of DP network cable failure is consistent with DP interface failure. Fault reason: 1. The network cable was damaged while moving the device. 2. The staff stepped on it or crushed it due to other reasons. 3. Small animals bite or scratch the insulation layer, causing a short circuit between the data cable and the shielding layer. Detection method: Check if the network cable is damaged or broken, and check if the insulation layer is broken.

3) Electromagnetic interference

Fault phenomenon: The network is constantly disconnected and unstable. Fault cause: 1. Electromagnetic interference occurs when using electrical equipment. 2. Due to the fact that the DP network cable and power cable are in the same trunking, it is possible that the power cable may have electromagnetic interference with the DP network cable. 3. The shielding layer of the DP network cable is damaged,

resulting in improper grounding. Detection method: Stop using electrical equipment, check if there is any electromagnetic interference, check if the power cable has caused electromagnetic interference to the DP network cable, and check if the shielding layer of the network cable is damaged.

2. Software diagnosis

Use the STEP7 tool software [8] to perform fault diagnosis analysis and monitor the status of network configuration. If the DP icon is displayed in red with a diagonal line, then the DP slave station is faulty. If the icon is dashed with a diagonal line, then SFC12 has disabled the station. Read the fault alarm information through the CPU diagnostic buffer. If there is a fault in the system, the diagnostic system status will display "ERROR", and then view the fault alarm information. You can see the alarm type, address, troubleshooting, and methods and measures to eliminate the fault displayed in the alarm record.

4.2. FF fieldbus

FF fieldbus equipment works stably and performs well. Faults mainly occur in cable damage, poor terminal contact, or interference signals, which can cause network segment communication interruption and generate alarm signals.

1. Hardware diagnosis

Fault phenomenon: The digital signal of the network segment is interfered with, and the communication of the network segment may malfunction. The FF bus field bus is lost on the network segment, even affecting the loss of other field devices. Fault cause: 1. The cable sheath at the junction box where the bus cable enters is crushed, resulting in two terminal grounding of the cable shielding wire. 2. FF on-site equipment is powered off, the wiring terminals are loose, or the equipment has water ingress. 3. The device where LAS is located is affected and has encountered a problem. 4. Individual FF transmitters have poor quality and may cause interference to the network segment. Detection method: Detect the resistance, capacitance, and insulation performance of the cable. Use FBT-3 to test the circuit of the network segment, and remove the second section of the bus cable from the DCS and transmitter. Due to the built-in power supply of FBT-5, which serves as an LAS and can emit bus signals instead of bus transmitters, FBT-3 can detect fault information on the network segment.

2. Software diagnosis

Check the network segment port and device fault statistical parameters on the DeltaV resource manager to identify the main three statistical parameters of network segment faults: a. NUMDIITokenPassTimeout - This indicates that the fieldbus

device has not received the token (PT) information sent to it, the H1 card has not received a response to the token, or that the device has held the token for more than the token holding time (TokenHoldTime). b. DIIRetries - The number of times a token has been resent, and the number of times a c.NumLiveListAppearance device has been lost and

reappeared. If the above three parameters gradually increase over time, it indicates a serious problem with the FF fieldbus network segment. If the number of "NumberofLiveListAppearance" gradually increases, it indicates poor cable connection contact.

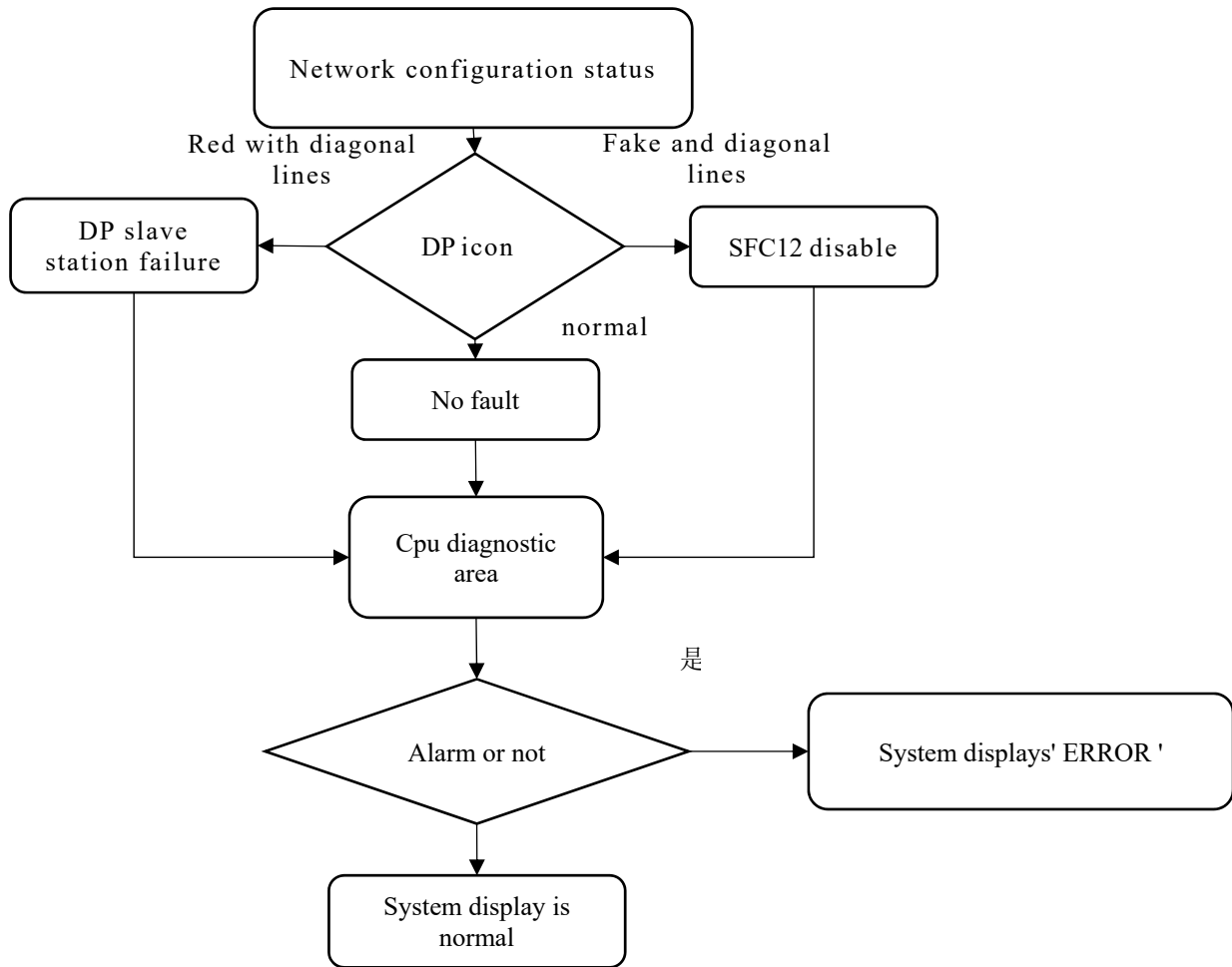


Figure 7. STEP7 Diagnostic Logic

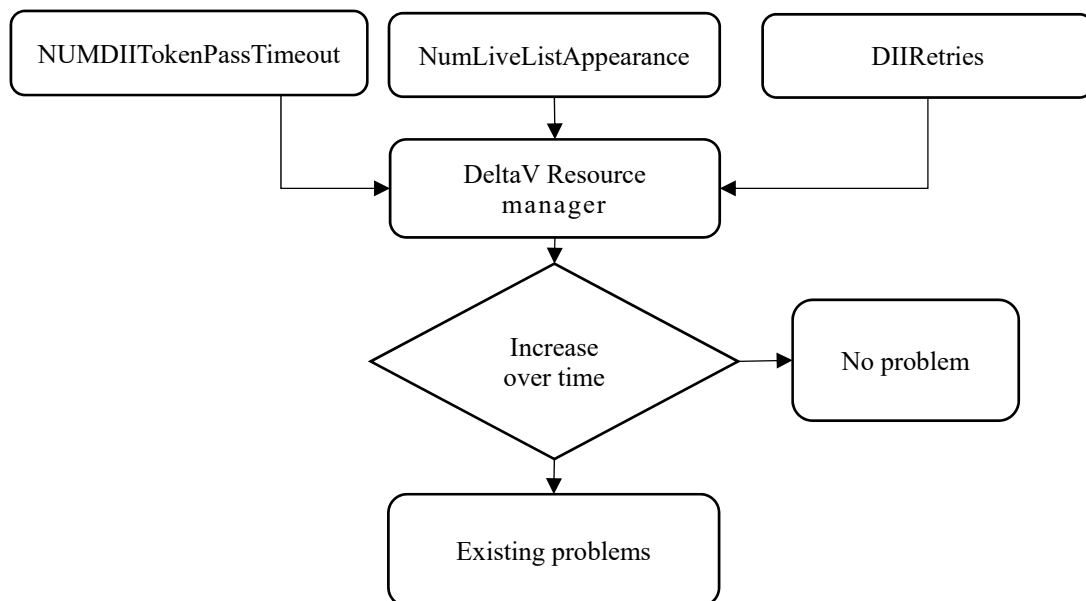


Figure 8. FF Bus Software Diagnostic Logic

4.3. WorldFIP fieldbus

The WorldFIP fieldbus implements a backup arbitration unit mechanism on the network. When the active arbitration unit fails, the backup arbitration unit is replaced, so that the network will not fail due to the CEO unit. However, there may be failures due to equipment hardware damage, parameter configuration errors, or network card working mode errors, resulting in device alarms and abnormal device functionality.

1. Hardware diagnosis

fault phenomenon: WorldFIP network malfunction, resulting in abnormal alarms, abnormal equipment functions and self operation, and even system abnormalities that mistakenly send shutdown signals. Fault reason: 1. WorldFIP is connected to the controller backplane through a board card, and the board card is damaged or the interface is damaged. 2. The shielding layer of the network cable is damaged, causing interference to the network cable. 3. Damaged fiber optic or

jumper cables or poor jumper connections can cause signal distortion. 4. The malfunction of the photoelectric conversion machine leads to network signal distortion and network malfunction. Test method: Check the network circuits one by one, check the hardware parameters, test whether the resistance and capacitance are damaged, check and measure the shielding layer, record the waveform under strong interference, check whether the waveform is normal, replace the network card, optical fiber jumper, and photoelectric converter, and repeat the fault to find out the fault.

2. Software testing:

Export FIP network configuration configuration and parameters through an engineer station for comparison, ensuring consistency with the configuration and parameters in good condition. Check whether the system is overloaded, check the load distribution of the Bus mastering scheduling table, and check whether the load exceeds the upper limit.

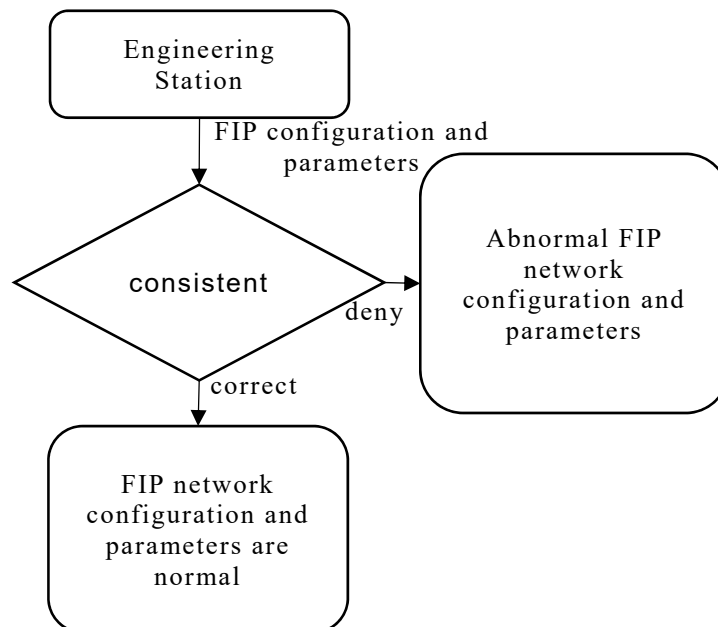


Figure 9. Diagnostic FIP Logic

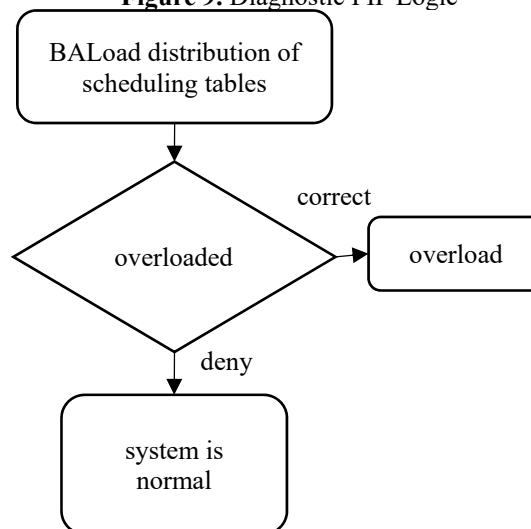


Figure 10. Diagnostic System Logic

5. Summarize

In recent years, with the development of science and

technology and automation technology, fieldbus technology has also received increasing attention. It emits light and heat in various fields, mainly used for information transmission

and digital communication between electrical equipment and controllers, execution equipment, and its economic, practical, simple, and reliable characteristics have attracted people's attention. Although the development of fault diagnosis technology in China started relatively late, on the basis of learning from the development experience of other countries, China is also continuously accelerating the development of fault diagnosis technology, and has made significant achievements. However, further progress is still needed, as there is still a gap between China and mature countries such as the United States. The fault diagnosis of fieldbus is particularly important in today's widespread use of fieldbus. If a fieldbus malfunctions during use, it can range from network failure and inability to communicate to electrical equipment malfunction and even endanger personal safety. Therefore, research on fieldbus fault diagnosis technology needs to be accelerated. This article introduces the Profibus, FF, and WorldFIP fieldbus protocols, structures, and applications. After gaining sufficient understanding of the bus, it conducts fault diagnosis and introduces hardware and software fault diagnosis for the fieldbus. Hardware fault diagnosis refers to the detection of electrical equipment and cables that are prone to faults. Software fault diagnosis testing uses corresponding software to detect faults on the fieldbus, And provide a logic diagram for software fault detection.

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