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Application of Wireless Communication Technology in Chemical Production Process

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Industrial automation control has been widely used in the chemical production process. The rapid development of wireless communication technology can realize the wireless transmission of data signals between instruments. In this paper, the wireless transmission module was applied to the distributed control system (DCS) of chemical production to realize the design of chemical wireless distributed control system and also applied to the glycine production process control system. Besides, some switch control in the process flow of the distillation tower control equipment was simulated and tested to achieve the expected results. The result shows that the real-time database includes graphic display, data report, historical report, and historical database data, which are interconnected with the communication management module; through the wireless DCS, the management protocol is used to realize the freedom of communication between all connected devices, and the operation and production process control of the chemical wireless DCS is not affected by the system device failure.

1. Introduction

Chemical production is an important manifestation of the advancement of scientific and technological progress, human civilization, social development, and the current era of industrial information, as well as an important area of modern production (Jarrot et al., 2018, Guo et al., 2016). Wireless communication technology can realize the automatic control of chemical production process, including wireless LAN technology, Bluetooth technology, ZigBee technology and micro-power short-range wireless communication technology (Gorcin and Arslan, 2014). With the development of large-scale integrated circuits, the degree of integration has been increasing, more electronic components can be integrated with more powerful functions (Tan et al., 2017, Georgiadis and Bozzi, 2011). In the chemical production process, the application of wireless communication technology not only realizes uploading and downloading of control devices, real-time data monitoring, but also creates a real-time database generation information management system so as to form a complete monitoring and control network system of chemical system (Li and Murch, 2014).

The joint developments in microelectronics and radio communications have promoted the wireless communication technologies in the industrial production process. In the chemical production process, the DCS can realize the modern intelligent computer automatic control system, which can realize simultaneous control of multiple computers, improve the processing capability of information, and facilitate regulatory control. Current chemical production processes have more demands for DCS, and chemical production sites also need DCS that can adapt to a variety of unconventional environments. The traditional distributed control system completes data collection through wired transmission, which is not only difficult to lay, but also costly, and post-maintenance causes a great deal of human and financial waste. Therefore, this paper applies the wireless transmission module to the DCS of chemical production, realizes the design and application of the chemical wireless distributed control system, and increases the flexibility of the system implementation.

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2. Chemical wireless distributed control communication protocols and interfaces

2.1 Communication protocol

The communication protocol is an agreement reached by both parties of the communication on the data transmission format, the transmission speed, and the steps. Currently, the most widely used control layer protocol is the MODBUS RTU communication protocol, which has a low application threshold with high hardware cost performance. Fig.1 shows the Modbus communication stack. Modbus is more commonly used as the communication standard protocol between industrial devices on instrumentation. In the ISO/OSI model, the application layer represents the Modbus protocol, the data link layer represents the Modbus serial link protocol, and the presentation layer, the session layer, transport layer, and network layers are all empty. The Modbus serial link protocol follows the principle of host query and slave response. Modbus's function codes include public function code, user-defined function code, and reserved function code. The management layer protocol creates a link between the application and the actual control process, so that all connected devices can realize freedom of communication and form an integral whole.

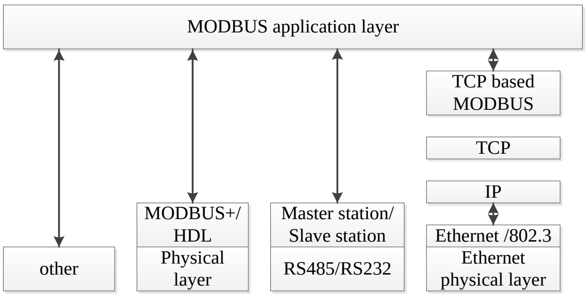

Figure 1: Modbus communication stack

2.2 Physical interface of communication protocol

The physical interfaces of the communication protocol include serial communication, Ethernet communication, and wireless communication. Serial communication is the widely used bit-based data transmission; data bits, stop bits and parity are the most important parameters to measure serial communication. Ethernet is a commonly used communication protocol standard in LAN applications. It is connected to the physical layer of ISO/OSI. The high-level protocol can be TCP/IP. The Ethernet protocol adopts the carrier sense multiple access technology with collision detection to monitor the data transmission on the network for signal transmission. During the transmission process, it will continuously monitor the network. If a conflict occurs, the network will be released. Wireless communication is to use the radio wave as the medium of data transmission. Fig.2 depicts the wireless data communication system. The wireless communication technology overcomes the shortcomings of traditional communication technologies and can greatly increase the production efficiency of the chemical industry.

Table1: Comparison for the main features of the short-range wireless communication technology

Technical parameters	IEEE802.11	Bluetooth technology	ZigBee technology	Micro-power short-range wireless communication
System power	< 500mA	< 120mA	< 35mA	< 60mA
Communication distance	< 350m	< 15m	< 90m	< 800m
Communication rate	> 2Mb/s	< 1Mb/s	< 350Kb/s	< 1Mb/s
Communication frequency	2.5GHz	2.5GHz	2.5GHz	455MHz
Frequency application	NO	NO	NO	NO
Development difficulty degree	Difficulty	Difficulty	Easier	Easy
Module cost	High	High	Lower	Low

Table 1 shows the comparison for the main features of the short-range wireless communication technology. It can be clearly seen that the system power required for wireless communication is small, the communication distance is the largest, the communication frequency is the minimum, and the module cost is the lowest.

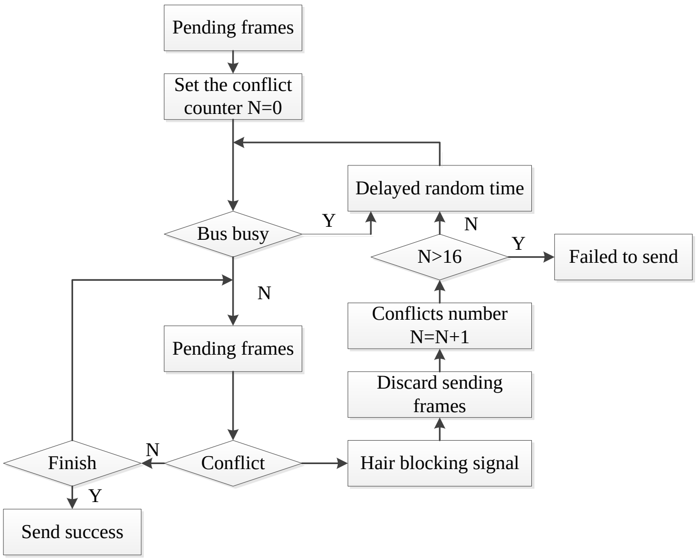

Figure 2: Wireless data communication system

3. Design of chemical wireless distributed control system

3.1 Software and hardware design of chemical wireless distributed control system

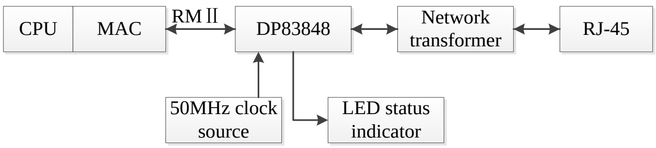

Figure 3: DP83848 typical application

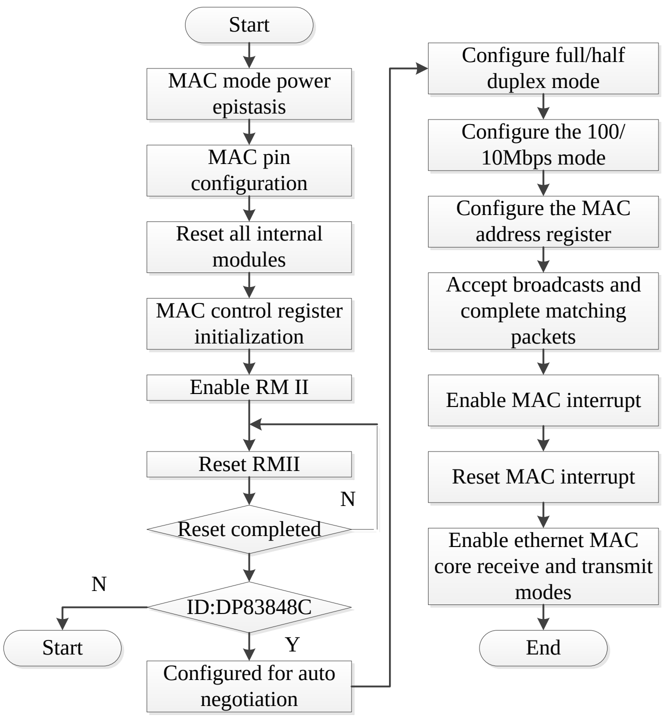

Figure 4: Ethernet software initialization program

The wireless main-control module is the main module of the wireless distributed control system, usually using the DP83848 physical layer chip (Fig.3); the physical layer interface has a carrier sense multiple access function with conflict detection, so as to better adapt to industrial control and factory automation. The hardware design of the system must ensure the normal operation of the main control card. The design of the software enables data exchange on the main control card. Fig.4 shows the software initialization flow of Ethernet. The upper bits and pin configuration of the media access control module reset all internal modules and initialize the control registers of the media access control module. If the reset is completed, full/half duplex mode, 100/10Mbps mode and media access control address register are configured. During the entire network configuration process, more attention should be paid to the channel configuration, interface mode, and selection of verification mode.

3.2 Software application of chemical wireless distributed control system

uC/OS-II is a complete embedded operating system that enables task scheduling, control, and coordination of concurrency in software applications. Fig.5 shows the file structure of uC/OS-II, which is divided into two modules: software and hardware. It is roughly sub-divided into four parts: the core part, task processing, time processing, task synchronization, and communication. As a real-time operation system kernel provided in the form of source code, the scheduling mode includes two types: task-level and interrupt-level task scheduling. In the uC/OS-II, there are five kinds of wait state tasks: sleep state task, ready state task, running state task, and interrupted service state task.

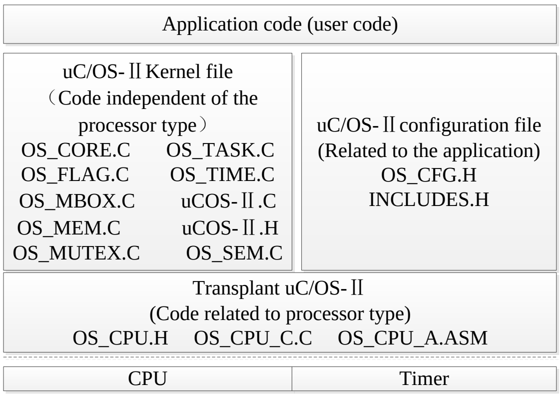

Figure 5: uC/OS-Ⅱ file structure

4. Application of chemical wireless distributed control system

4.1 Analysis of safety performance of chemical wireless distributed control system

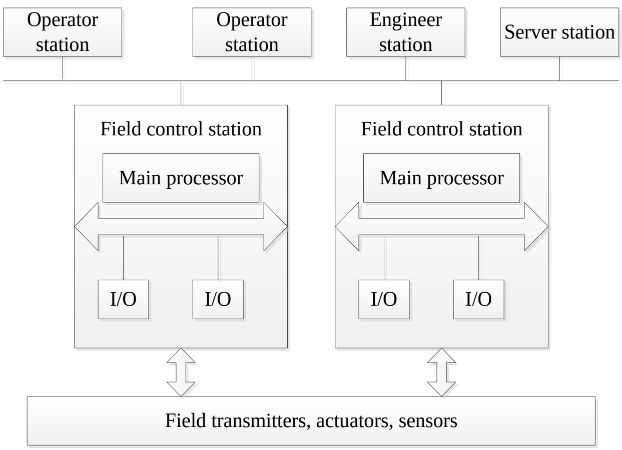

Figure 6: Typical distributed control system architecture

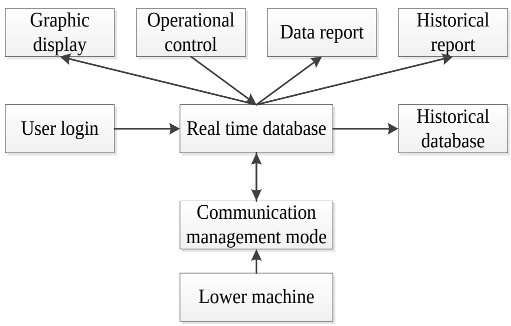

Figure 7: Real-time database transaction scheduling

In the chemical production process, the chemical wireless DCS has gradually replaced the independent control system and instrumentation, and the wireless DCS is mainly used in chemical equipment with high degree of complexity and automation. It must ensure that the system runs without trouble as long as possible, and the operation and production process control of the system is not affected by the failure of the system components. Fig.6 depicts a typical distributed control system architecture. The operator station, engineering station, server station, and field control station are connected to transmitters, actuators, and sensors at site to achieve faster data transfer. Fig.7 shows the real-time database transaction scheduling. The real-time database includes graphic display, data report, historical report and historical database data, and is interconnected with the communication management module. The safety and reliability of electronic components directly affect the overall safety of the distributed control system. Through the analysis for the failure rate of electronic components, the safety performance of the entire system can be evaluated. The calculation formula of failure rate is shown in formula 1: $\lambda=\frac{r}{T}$. Where, r is the number of system failures, and T is the product of the number of systems and the runtime. After a lot of theoretical and practical analysis, it can be found that the failure rate and time show a “bathtub”-like curve (Fig.8). The curve includes the initial failure period, the random failure period and the loss failure period.

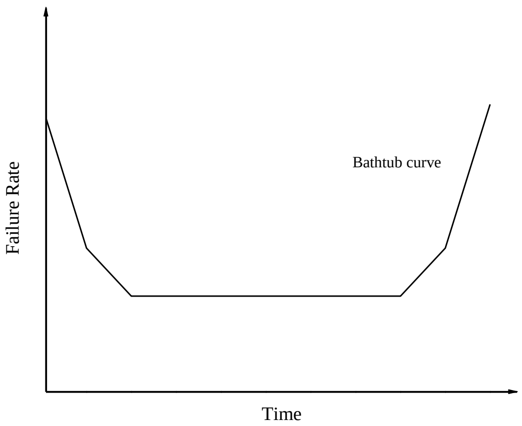

Figure 8: Bathtub curve

4.2 Application test of chemical wireless distributed control system

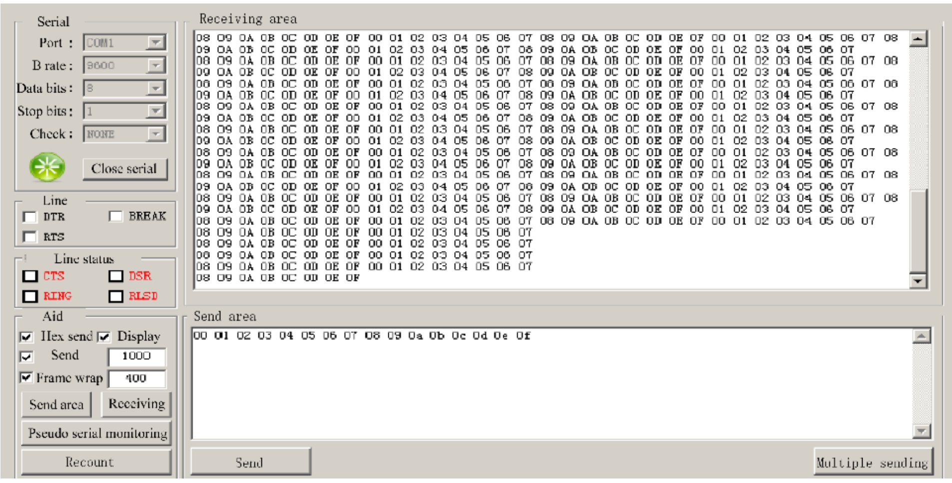

Figure 9: Wireless module communication test chart

The chemical wireless DCS is mainly used in the debugging of wireless communication modules. In order to better fit the actual chemical production, the debugging process was selected in a multi-electromagnetic interference and complex and changeable environmental conditions. Fig.9 is a wireless module communication test chart, where the main module is divided into serial configuration, line control, line status and auxiliary function window, including the two windows of receiving area and the sending area; the wireless main control card module is located in the host’s position, through the host computer to connect the main control card module, and send and receive data together with the serial port assistant.

Figure 10: Master module field electrical connection diagram

Fig.10 shows the on-site electrical connection diagram of the main control module. The experimental design realized the monitoring function of the entire system by connecting the serial port assistant of the chemical wireless distributed control system. After the laboratory debugging was completed, it’s installed in the glycine production process control system to conduct chemical field simulation test, and the simulation test was mainly performed for some of the switch quantity control in the process flow of the distillation tower control equipment, achieving the expected effect.

5. Conclusions

This paper applies the wireless transmission module to the distributed control system of chemical production, to realize the design and application of the chemical wireless distributed control system. The specific conclusions are as follows:
(1) Wireless communication technology overcomes the deficiencies of traditional communication technologies so as to greatly increase the production efficiency of the chemical industry. Wireless communication requires less system power, the largest communication distance, the lowest communication frequency, and the lowest module cost.
(2) The chemical wireless distributed control system must ensure that the system has a trouble-free running time as long as possible, and the operation and production process control of the system is not affected by the failure of the system components. The chemical wireless distributed control system is applied to the glycine production process control system, to realize full process control and achieve the desired target.

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