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Study on Wireless Communication Distributed Control System in Chemical Production Process Control

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To understand the control of wireless communication distributed control system in chemical production. With industrial chemical production as the research subject, this article designs the functional modules of wireless communication distributed control system and analyzes the application effect of the system through experiment. Research results show that the system designed in this article can achieve the goal of low power consumption and facilitate the chemical enterprises in cutting down their production cost. STM32 chip may be used as main CPU of wireless communication computing control system and control the chemical production process through the network.

1. Introduction

As an intelligent control system, wireless communication distributed control system may play a certain role in chemical production control. In the application of wireless communication distributed control system, multiple computers are needed to conduct centralized control to improve the information processing effect of the system and facilitate the control of the chemical production process. However, due to certain difference in various computers for system control, distributed phenomenon may be found in the application of wireless communication computing control system, thus affecting the control efficiency of chemical production process. Since 2000, much quicker development of large-scale integrated circuit and more powerful functions of electronic devices have played certain active role for automated control of chemical enterprises. Compared with international developed countries, China remains low in terms of the development of domestic wireless communication distributed control system with most control systems obtained through import. Though China has made certain achievements with respect to the application and research of wireless communication distributed control system, it needs a great deal of production cost which is not beneficial to the operation and development of an enterprise.

2. Literature review

The DCS system in China is often referred to as a distributed control system. Compared with traditional industrial instrumentation control, it is a modern intelligent computer automatic control system. It is a new generation of automation control system after the base regulator, pneumatic/electric unit combination meter, direct digital control system (DDC) and supervisory computer control system (SCC). González-Potes et al. pointed out that DCS can improve the processing capabilities of information by centrally controlling multiple computers and facilitate monitoring and management. The separate control of different regions by the computers facilitates the decentralization of risk (González-Potes et al., 2016). With the advantages of powerful decentralized control, simple centralized management, solid reliability, convenient configuration software, rich control algorithms, and open networking capabilities, DCS is playing an increasingly prominent role in the field of industrial automation and control. It has gradually become the mainstream of applications. The main application of DCS system and most of the markets are concentrated in some complex industrial processes such as petrochemicals. In the petrochemical industry and other industries, the collection and monitoring of on-site signals such as pressure, flow, and temperature account for the absolute proportion. DCS's predecessor direct digital control system has mature monitoring technology. DCS can meet the analog

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data acquisition and control functions in the chemical field. In addition to analog quantities, the sequential control of digital quantities or switching quantities is also very important. Because large-scale processing equipments such as tower, trough, kettle and tank are required to operate during the chemical production process, Knowles et al. pointed out that these equipments work naturally and indispensably monitor the switching of various electromechanical devices (such as pumps, fans, and compressors) and valves. In terms of digital control, DCS has the advantage of meeting chemical production functional requirements (Knowles et al., 2015). The simple analog digital quantity acquisition control is not enough to complete the entire process flow, such as reactors and other equipment. Their job characteristics are intermittent. The equipment does not work continuously. After the first raw material is put into the reaction output, it must be after a certain period of time before the second raw material is put in again. In view of the working characteristics of this kind of production device, the petrochemical industry uses mass control methods to effectively solve it. The batch control form requires the combination of analog and digital phases for acquisition and control, so that the petrochemical industrial control system is now called the hybrid control system, which is actually the DCS control system. In addition, the DCS control system also has features such as easy installation, safe and reliable performance, friendly man-machine interface, easy to use and maintain, and easy extension and upgrading to better serve and meet industrial control requirements.

In the latter part of the 20th century, with the development of large-scale integrated circuits, its integration became higher and higher, more electronic components could be integrated and functions were more powerful. Coupled with the universal application of 8-bit microprocessors, the industrial automation instrumentation industry has undergone qualitative changes. The combined microprocessor technology of the centralized computer control system has developed the overall decentralized control system of the microprocessor, namely the microcomputer distributed system (Srbinovska et al., 2015). On this basis, Carlsson et al. first published the TDC2000 overall decentralized control system. The system can complete eight loop controls separately, and the basic controllers of each loop can be set independently (Carlsson et al., 2018). The communication system is served by the data highway's bus as a network medium. Several basic controllers and CRT (Cathode Ray Tube) operation stations are connected to ensure that each node has computer decentralized control and centralized display management at the operation station. At the same time, the United States, Japan, Britain, France, and Germany have also started to develop corresponding products. At that time, it was mainly used in analog control loop-based systems, including chemical engineering, electricity, petroleum, metallurgy and other public projects, and such products are collectively referred to as DCS.

The main manufacturers of DCS control systems are concentrated in the United States, Germany, Japan, and other countries, such as Honeywell’s TDC300O\MICRO, TDC3000X, Foxboro’s I/A Series, and Westinghouse’s WDPF, Yokogawa's CENTUM CS, Germany's Siemens's TELEPERM and SIPAOS 200 and ABB's MOD300. The Fieldbus Control System (FCS) can be said to be a fifth-generation process control system. It became practical in the 1990s and is rapidly developing with a rapid momentum. Foreign companies have been focusing on the promotion of FCS and FCS meters in recent years, and have invested less in wireless communications on the system. Even if a few manufacturers have wireless communication cards, they are very expensive (Cherchi et al., 2017).

Zhu et al. pointed out that the level of domestic DCS is relatively backward. It mainly relied on the introduction of foreign imported DCS systems (Zhu et al., 2018). In the 1970s, China's petrochemical and other process industries that used crude oil and natural gas as raw materials grew rapidly. There is an urgent need for investment in large-scale DCS systems in China. However, the level of development of domestic DCS is inconsistent with market demand. Several sets of devices with an annual output of 250,000 tons of sulfuric acid were imported from abroad. Others such as large-scale soda-alkali caustic soda, chemical fiber, ethylene rubber and other chemical production facilities are all imported. After nearly 30 years of efforts, there are many DCS manufacturers in China, who are capable of integrating production and research and development. Ho Li Shi, Zhejiang central control and Shanghai Xinhua are outstanding. In China's petrochemical industry, there are thousands of large and medium-sized DCS systems in use. The application level can reach 90% of the automatic operation rate. Domestic manufacturers have occupied a certain scale of the domestic market by virtue of their superior cost performance. These products are even exported to foreign countries. Qin pointed out that the role of the DCS control system in industrial control is irreplaceable. Although fieldbus technology has gradually emerged, the company has introduced its own bus technology because there is no unified standard so far. Openness and interoperability are difficult to unify. In addition, the cost is high and the technology is not mature enough to win a wide market (Qin, 2014). In the future and even a long period of time, the status of DCS in petrochemical and other special industrial controls is beyond doubt. However, tasks such as the improvement of functions after the replacement, the transparency of new technology compatibility, the improvement of application service level, and the reduction of the product market price are also urgent issues (Liu et al., 2017).

In summary, with the development of technology, the traditional DCS cable control has failed to meet the ever-increasing performance requirements of the control system in the industrial production process. It is difficult to lay communication cables. Control nodes are scattered. Industrial conditions are harsh. In response to these problems, wireless communication networks are used to compensate for the lack of wired communication. Therefore, the commonly used wireless communication protocols and chemical DCS system applications in modern control are studied. From the perspective of low power consumption and low cost, the overall design scheme based on the embedded wireless communication DCS system in the control of chemical production process was proposed. The basic architecture of a wireless network node is given.

3. Methods

3.1 Wireless main control module

For wireless main control module, STM32F107 chip researched and produced by ST with Cortex-M3 being the kernel is adopted as main processor. STM32F107 is a high-performance product in the new STM32 interconnection 32-bit micro-controllers launched by STMicroelectronics, including Thumb-2 command set with upgraded performance and increased code density, significantly improved velocity of response to interruption, and all functions with extremely low power consumption. More importantly, STM32F107 chip not only integrates various high-performance industrial standard interfaces, but also integrates high-performance Ethernet module internally and supports data receiving and sending via Ethernet, giving it a great advantage in Ethernet communication. The main control processor with Cortex-M3 kernel has an operating frequency of up to 72MHz and built-in high-speed storage, Ethernet MAC (medium access control) and dedicated DMA controller. STM32F107 is also provided with many I/O ports and peripheral devices. STM32F107 is provided with Ethernet MAC controller but no PHY device, therefore it needs external PHY chip to realize Ethernet communication. Interface controller DP83848 chip in the physical layer of Ethernet is provided with partial functions of carrier sense multiple access with collision detection (CSMA/CD), which may detect whether there is signal transmission in the network before data is sent. If there is signal transmission, it may wait. If the network is idle, the signal may be transmitted. If any collision is detected, all nodes waiting for information transmitting may follow the back-off principle, which may offer the support to reliable data transmission. In addition, the device is based on high-end peripheral device with network transmission distance of 120m, and suitable for bad industrial environments. (Typical application of DP83848 is shown in Figure 1)

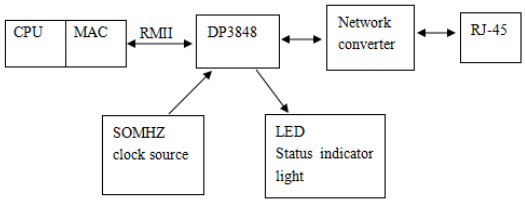

Figure 1: DP83848 typical application

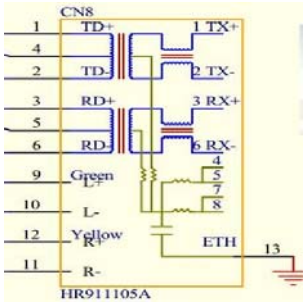

Figure 2: HR911105A schematic diagram

For main control unit of wireless main control module, STM32F107 chip is used because its excellent performance may ensure the implementation of the functions of main control card and Ethernet PHY chip DP83848 combined with RMII standard interface may offer a good Ethernet communication solution which not only reduces the number of pins necessary for MAC to PHY interfaces, but also allows designers to lower the

system design cost while maintaining all characteristics specified in IEEE802.3. Therefore, DP83848 can be better adapt to industrial control and factory automation and general embedded system and other applications. The receiving and transmitting lines of DP83848 are differential pair which is connected with the network cable through the Ethernet transformer with transformer ratio of 1:1. When the Ethernet device is connected with RJ45 through PHY, a network transformer may be installed in it. Ethernet network transformer is mainly used for impedance matching, signal shaping, network isolation, network filtering and high-voltage isolation. (HR911105A schematic diagram is shown in Figure 2)

3.2 Production principle of schematic diagram

Upon completion of the schematic diagram, PCB board may be plotted. PCB plotting need to follow many technical specifications, including layout principle, wiring requirements and specifications, etc. For instance, PCB dimensions may be planned according to the principle of “cost saving, rational and beautiful device placement, convenient production and generous wiring”. Amongst others, the layout of components and devices directly affects the performance of the entire circuit board, and the analog chip should be as far as possible from the digital chip to avoid mutual interference. Certain heat may be generated in the electronic device during the operation, and especially, heat generated by devices with higher power may interfere with those surrounding devices sensitive to temperature. If such heat cannot be inhibited properly, electric performance of the entire circuit may change. As for wiring principle, one requirement is for concentrated wiring, to keep a clearance of up to 8 ml, or 10ml and more for general circumstances. (Main control PCB board is shown in Figure 3)

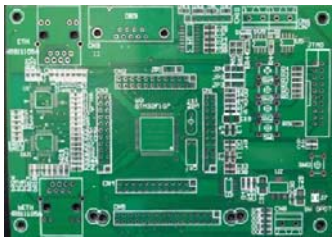

Figure 3: Main control PCB board

3.3 Wireless communication module

Table 1: DTD465B technical indicators

performance	DTD465B	performance	DTD465B
Central frequency MHz	433	Sleep current uA	<20
Working voltage DCV	3.3~5.5V	Way to work	GFSK
Transmitting power dBm	27	Communication interface	TTL/RS232/RS485
Sensitivity of DBM	-120	Communication distance m	>1000
Transmitting current mA	<300	External dimension mm	53*38*10
Receiving current mA	>50	Working temperature □	-35~70

DTD465B wireless data transmission module is researched and produced by Xi’an Dataie Electronic Co., Ltd. and applied in wireless data transmission area. Typical applications include data acquisition, detection, alarm and process control in remote control, remote sensing and telemetry systems. DTD465B wireless data transmission module offers high-stability, high-reliability and low-cost data transmission. In addition, its peripheral interface is provided with complete circuit functions and featured by flexible use, strong penetration, convenient networking and wide coverage. It can adapt to such application scenarios as multiple and disperse nodes and complex and changing geographic environment and may be widely used in such sectors as chemical, industry, electric power, transportation, meteorology, environmental protection, bank, alarm and GPS information transmission. Wireless module DTD465B has 2 serial ports which support 3 working modes. COM1 serial port adopts TTL level UART interface mode, and COM2 serial port which is customized may be RS232/RS485 interface mode, allowing it to adapt to serial connection at different levels and replace wire RS485 transmission network at any time. DTD465B standard configuration supports 8-channel transmission

and uses efficient forward error correction (FEC) channel coding technique with FSK modulation mode which greatly improves the immunity in signal transmission. It is widely used in industrial remote, telemetry system (DTD4658 technical indicators are shown in the following Table 1)

3.4 Conventional I/O module

Wireless I/O module is designed to integrate switch input, switch output and analog output function and simulate the implementation of remote control of I/O module in wireless DCS site. Wireless I/O module adopts STC89C52 single-chip microcomputer produced by STC Micro as main control chip. Based on the single-chip microcomputer testing board, the entire circuit board is added with the interfaces of wireless module DTD465B through serial port of the single-chip microcomputer, thus implementing functional design of wireless I/O module. STC89C52 is featured by kernel of enhanced 8051, working frequency ranging between 0~40MHz, working voltage of 3.3V~5.5V, 40 general I/O ports, each with driving capability of 20mA, output current not more than 55mA, high-speed and low power consumption. It is a new generation single-chip microcomputer with strong immunity, of which command codes are compatible with conventional 8051. Program download and debugging may be realized through serial port without needing a programmer or simulator. Therefore, it is convenient and fast, and has high price-performance ratio.

4. Results and discussion

4.1 Implementation of wireless main control module

Similar to IEEE802.3 series standards, Ethernet is really a physical layer protocol. It must be combined with higher network transfer protocol to complete information transfer of the entire network. The software implements TCP/IP protocol with mature technology and convenience for transplantation. MAC in STM32F107 and external PHY forms the physical layer and data link layer, and LwIP forms the network layer and transfer layer. As a light IP protocol, LwIP may work normally whether the cooperation with the operating system is available. The key to implement LwIP is to reducing the occupation of RAM while maintaining main functions of TCP protocol, thereby allowing LwIP to be suitable for an embedded system with limited resources. An equipment abstraction layer is defined between LwIP and network interface driver. Each network interface is provided with a netif structure (which, in lwIP, is used to describe a hardware network interface) that corresponds to it. (Software initialization flow of Ethernet is shown in Figure 4)

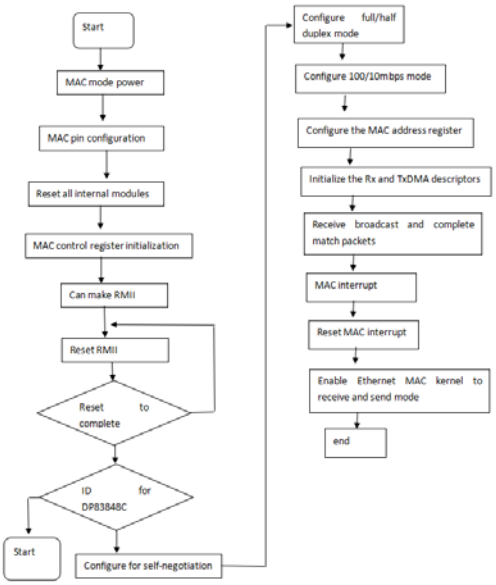

Figure 4. The software initialization process for Ethernet

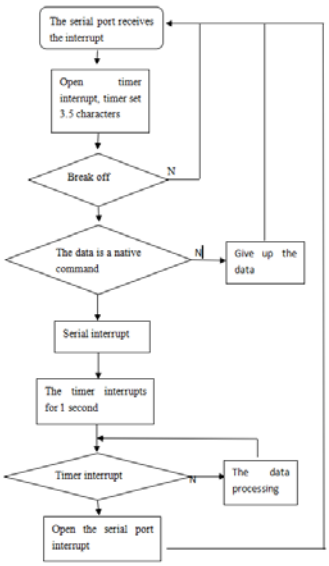

Figure 5 interrupts partial program flow chart

4.2 Implementation of conventional I/O module software

Conventional I/O analog acquisition module is mainly used to implement the acquisition of site analog signal. However, besides, compared with main control card, it is necessary to respond to the host (main control card) and transmit testing control information. That is to say it is in the position of ModBus slave. ModBus slave monitors serial ports at any time, receives host polling, judges and identifies the data as received, and

compares the CPU-consuming loads. However, the analog processing velocity advantage of AD7715 may reduce the CPU burden. The module may acquire 16-channel analog signal simultaneously. The single-chip microcomputer may select to switch to which channel signal by controlling the ON/OFF of JJJJMMMMNN and complete the acquisition of all signals within 1 second through polling. With data acquisition rate of over 50Hz, AD7715 may complete the acquisition of 16-channel analog within 1 second, while DCS system requires that the acquisition rate of the analog be kept at second level and may meet majority of site operations. In order to improve the conversion velocity, the program is not provided with the optimization algorithm. So the chip can only acquire the data once and use it as final conversion value without significant change found in excellent performance and accuracy of AD7715 chip. Following a great deal of optimization, it cannot meet the processing velocity at second level required for DCS system. (The flow chart upon interruption of partial program is shown in Figure 5)

5. Conclusion

This article studies the wireless communication distributed control system with chemical production as the research subject. The wireless main control card module is the core part of the control system and has important influence on normal operation of the system. When the application of Ethernet protocol is designed, tolerance processing is conducted through software program to support safe system operation. It can be seen from the system software function test that wireless communication distributed control system can meet the application needs for chemical production and result in the reduced chemical production time and improved working efficiency.

In view of limited length of this article, there are a lot of contents that remain to be further studied, but only simple experiment analysis is conducted on the functional modules of the system. Though wireless communication distributed control system designed in this article can meet the needs for chemical production, its stability and safety remain to be verified through time. Since wireless communication distributed control system involves a lot of contents, researchers need to make a good deal of initial preparation and improve system functions based on the application results of the system.

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