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Implementation of Network Control Systems for Improvement of Traditional Dyeing Processes

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Abstract—**In China, many traditional industrial processes need to be maintained and upgraded to incorporate new technology development. The paper reports our work in improvement of the traditional dyeing process using advanced network control technology. Based on a dyeing industry, we designed the network system of dyeing equipment using industrial Ethernet & Multi-bus technology. The system takes three-level structure: factory management level, workshop control level and field equipment level. Field equipments comprise some PLC and frequency conversion control systems; workshop level adopts two Siemens PLC to centrally control field equipments; HMI, monitoring room PC and remote office PC monitors and manages workshop control level. The network system has multi-stage monitoring, access control and remote alarm functions, realized management - control integration.**

Keywords-dyeing equipment; industrial Ethernet; Multi-bus technology; network system

I. INTRODUCTION

With IT network technology flying, "one network to the end" industrial system constructed by field bus and Ethernet makes factory senior management personnel can obtain the process information of production directly, realizing highly integration of factory management and production[1]. Dyeing industry is one of traditional industries in China; though the automation level of dyeing equipment has greatly increased, but only be single automation equipment, not be network system. In actual production, dyeing equipments of different types and brands are used; it's difficult to realize centralized management and control, adding cost burden to factory unquestionably. Based on the dyeing equipment's present situation of a factory in Qingdao, the paper designed a network system to realize the centralized management and control of production equipments.

II. NETWORK SYSTEM STRUCTURE

The network system structure comprises field equipment level, workshop control level and factory management level. 1) Field equipment level consists of all original dyeing automation equipments in the factory, including a set of batching equipment for dye ingredients, a set of wax printing machine, three sets of rotary screen printing machine and a set of variable frequency ventilation equipment. Siemens S7-200 CPU226 is the controller of batching equipment; rotary screen printing machines' controllers all are Siemens S7-200 CPU224; the wax printing machine uses Delta PLC of DVP - ES series as controller; and ventilation equipment's controller is Siemens MicroMaster420 inverter. 2) Workshop control level consists of two Siemens PLC, realizing the configuration control of field devices. 3) Factory management level uses monitoring room PC, office remote PC and on-site HMI to achieve data acquisition, management and monitoring of control units in the workshop level. The hardware structure of network is shown in Fig. 1.

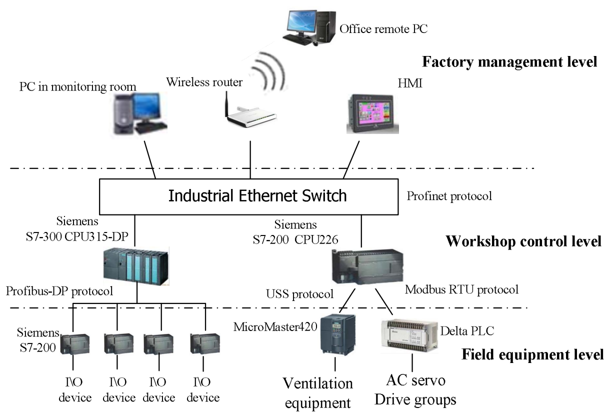

Figure 1. Structure of network system

This network system uses industrial Ethernet and Multi-field bus technology, as shown in Fig. 1. Industrial Ethernet is used for communication of factory management level and workshop control level, and fieldbus is used for communication of workshop control level and field equipment level. For the different control units adopted by dyeing equipments, meanwhile considering equipments' placement, the two sets of S7 PLC are used to realize centralized configuration control of all dyeing equipments in field level. One controller is Siemens S7-300 CPU315-2 DP, which communicates with the batching equipment and rotary screen printing machines using Profibus-dp protocol, form master-slave communication mode. Another controller is Siemens S7-200 CPU226, which communicates with the controller of wax printing machine using the USS protocol, communicates with the controller of variable frequency ventilation equipment using the Modbus RTU protocol.

III. THE INDUSTRIAL ETHERNET AND FIELDBUS

In the system, factory management level communicates with workshop control level via the PROFINET protocol, which has 100Mbit/s high ethernet transmission speed of IEEE802.3u standard, real-time response time of 10ms, meanwhile can communicate with computer using TCP/IP protocol, the transmission distance reaching 1.5 km [3].

According to different communication functions of control units of dyeing equipments, in the communication of workshop level and field level, the network system adopts Profibus-DP protocol, USS protocol and Modbus RTU protocol. 1) Profibus-DP protocol is based on open Profibus industrial field-bus and an international standard bus used for workshop level and field level. Its transmission speed is 12Mbit/s; its response time is about 1ms. And the interface uses RS-485 mode and shielding twisted-pair cable. 2) USS protocol, which based on serial bus, uses master-slave communication mode, has low hardware cost and reliable message format, and meanwhile includes flexible data transmission. The protocol is suitable for communication of Siemens S7-200 PLC and MicroMaster420 inverter. 3) Modbus RTU protocol, which has become a general standard in the field of industrial control [4], also uses RS485 twisted-pair cable as communication medium. Siemens and Delta PLC both support Modbus RTU protocol, so it is chosen as the data transmission protocol between the S7-200 CPU226 and the DVP-ES series PLC.

IV. NETWORK SYSTEM COMMUNICATION

A. *Industrial Ethernet Communication Network*

The system has five industrial Ethernet stations, which use the Ethernet switch's RJ45 interface to communicate with each other. Every station of the system has its own IP address according to local LAN segments. Hardware configuration and IP address of every station are shown as in table I.

TABLE I. HARDWARE CONFIGURATION OF ETHERNET NETWORKS

Ethernet station	Connecting hardware	IP address
Office remote PC	Wireless router	192.168.68.10
Monitoring PC	Ethernet card	192.168.68.11
HMI	Ethernet interface	192.168.68.12
Siemens S7-300	CP341 IT module	192.168.68.13
Siemens S7-200	CP243-1 module	192.168.68.14

The Ethernet switch adopts Siemens SCALANCE X208, which has eight RJ45 interfaces. According to the IP address in the data frame from the sending station, the switch determines which station should accept data. Data transmissions of each group are mutual shielding. In online communication, the switch firstly sorts data, then gives the mapping of orders, and finally data exchanges through the internal mechanism.

In factory management level, remote PC and monitoring PC use Wincc6.2 configuration software as platform, which set different access to operate the two PLC in workshop control level. The HMI adopts MT8070iH touch screen, and using touch screen to communicate with PLC in workshop level, the operators can get the dyeing equipment production information easily and achieve three levels management of equipments.

B. *Profibus-DP Communication Network*

S7-300 PLC communicates with the four sets of S7-200 PLC, forming the structure of a master and four slaves. In the system S7-200 CPUs are all mounted EM277 intelligent communication module, communication rate adapting by itself. As slave station, EM277 accepts data from I/O configuration of master station S7-300. Master station can directly read or write data from S7-200 storage area.

The design process of profibus-DP network configuration is shown in Fig. 2.

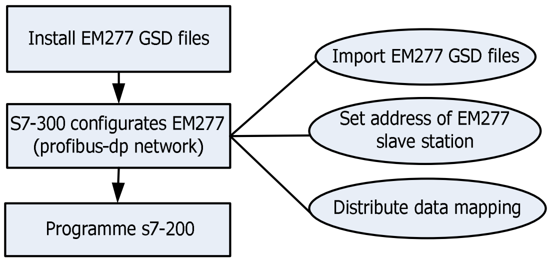

Figure 2. Flow chart of profibus-DP network configuration

After hardware are configured as shown in Fig. 3, the configuration information should be downloaded into S7-300 CPU module. When the four sets of S7-200 slave stations communicate with S7-300, both sides read or write data from the memory of master-slave data mapping (as shown in table II), and realize two-way communication.

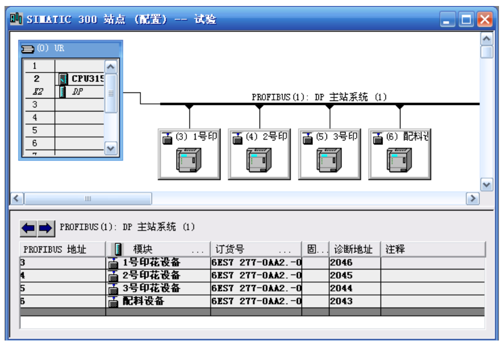

Figure 3. Hardware configuration of profibus-DP network

TABLE II. DATA MAPPING OF MAIN-SLAVE STATIONS

Slave station name	Add	Slave station memory	Master station memory
Printing machine 1	3	VB500～VB515	IB0～IB7 QB0～QB7
Printing machine 2	4	VB520～VB535	IB8～IB15 QB8～QB15
Printing machine 3	5	VB540～VB555	IB16～IB23 QB16～QB23
Batching equipment	6	VB560～VB575	IB24～IB41 QB24～QB41

C. *Communication program of Modbus RTU protocol*

Modbus protocol is located in the second floor of the OSI model and a main-slave protocol, which has only one master station in serial bus, adopts the way of request-response communication. The main station sends a string data involving slave station's address. Only the main station can start the Modbus communication. Slave stations don't send data before receiving the main station's request, also slave stations won't communication between each others.

As the master station, S7-200 CPU226 communicates with Delta PLC of the wax printing machine through own Port0 on Modbus RTU protocol. Useing Modbus RTU master instruction in STEP 7-Micro/WIN V4.0 SP5, the digital quantity, analog I/O and holding registers from Delta PLC can be read and written. Before programming, order library should be added and the instruction for calling "Modbus Master Port0" should be chosen. Because the Port0 is taken up by the master station of Modbus, it is set as free port communication mode.

The basic structure of Modbus RTU communication frame is shown in Fig. 4. The slave station address is from 0 to 247 in the frame. The slave address and function code both stand one byte, the starting address and CRC both stand one word in command frame. Data uses word as the unit, high byte in the front, low byte at last.

Station Address	Function Code	Data 1	...	Data n	CRC Low Byte	CRC Hight Byte

Figure 4. The basic structure of Modbus RTU communication frame

Part of the Modbus RTU communication program code is shown as in Fig. 5:

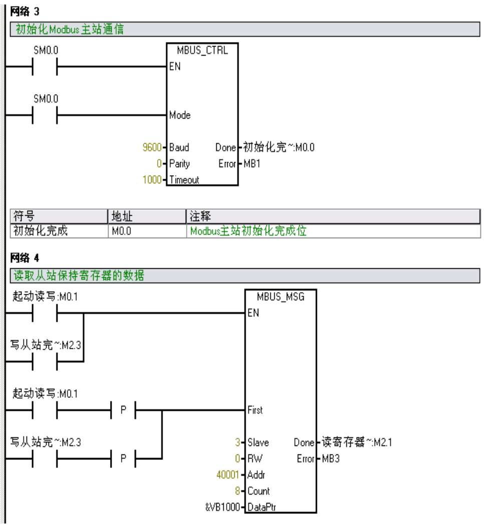

Figure 5. Part of communication program of main station of Modbus RTU

In the Modbus RTU communication, the most important design is the calculation of CRC yards. The CRC data in message are regarded as a continuous binary number, and the most significant bit is sent first. The message data move left by 16 bits, and then are divided by generated polynomial $x^{16}+x^{15}+x^{2}+1$ (the corresponding binary digits is 2 # 1000 0000 0000 0101), the remainder which has 16 bits is the CRC code. It will be attached to the back of message and be sent together. If the process of transmission has no mistakes, the receiving message should be able to be divided with no remainder by the generated polynomial. If happens CRC mistake in the process of transmission, PLC will give up the message data and transmit again. The CRC calculation flow is shown as in Fig. 6.

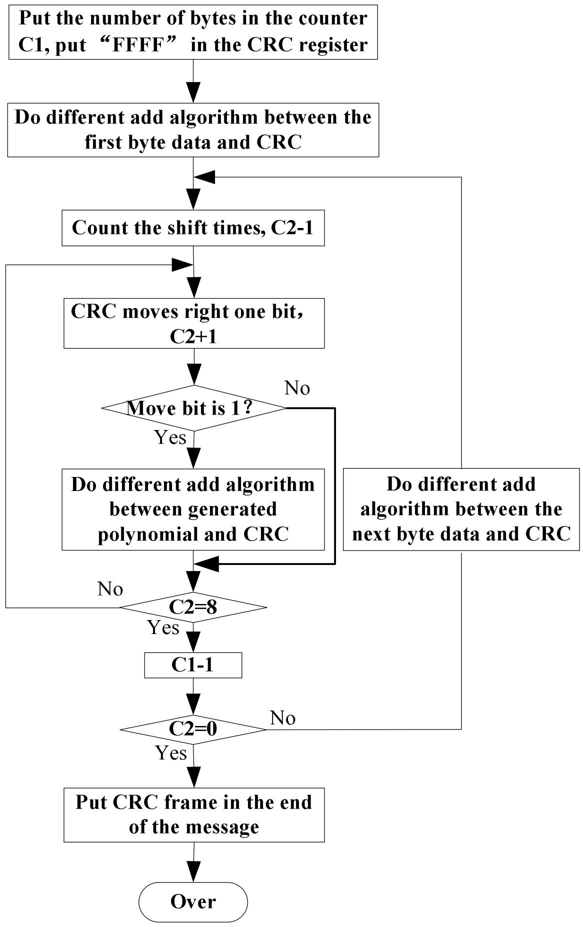

Figure 6. Calculation flow chart of the CRC

D. Communication program of USS protocol

The master station of S7-200 CPU226 uses the USS protocol to communicate with Siemens frequency converter of ventilation equipment through Port1

In the process of controlling frequency converter MicroMaster420, the main program calls communication procedure in S7-200 CPU226 to communicate with the MicroMaster420. Communication hardware consists of twisted pair and built-in RS485 communication interfaces of PLC and frequency inverter. The instructions of USS protocol are used ccording to the following steps: 1) Code user program. After installing Siemens order library, call control order in "USS Protocol Port 1"; 2) Distribute storage area for order library of USS protocol. In the frame of "storage area of library", set starting address for storage area; 3) Set communication parameter. Set communication parameter for the frequency inverter through the MicroMaster420 operation panel, to keep baud rate and address of slave station consistent with that in the user program. Part of the USS communication program code is shown as in Fig. 7.

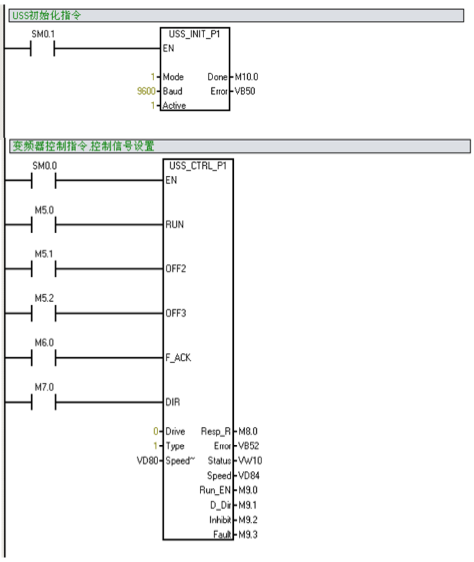

Figure 7. Part of USS protocol communication program

In the software program, most attraction should be put on the design of initial instruction USS-INIT and frequency inverter control instruction USS-CTRL. The initial instruction is used to allow, initialize or prohibit the communication of Micro-Master frequency inverter. The directive can set up communication protocol type and baud rate, activate the corresponding inverter. USS-INIT instruction must be first carried out successfully before other instructions, set “Done” after the instruction completion, and then can continue to carry out other instructions. Inverter control instruction USS-CTRL is used to control the Micro-Master frequency converter which is active. Each converter can only use one such instruction. This instruction puts user commands in a communication buffer. If one frequency converter appointed by "DRIVE" is just right selected by "ACTIVE" parameter in the USS-INIT instructions, the user commands in buffer will be sent to the inverter.

V. CONCLUDING REMARKS

This article mainly aims at present situation of automation dyeing equipment in factory, designs the network system of three layers communication structure with industrial Ethernet and multi-field bus technology, realizing the integration of equipment management and control. The experiment proves that this system provides a good platform of manufacturing management and monitoring for enterprise management personnel, promotes the management level and production efficiency, and reduces the cost of factory management. The paper provides a feasible technology route for network design of production equipment in industrial control field.

REFERENCES

[1] Li Zheng-jun, Design of field bus and industrial Ethernet application system [M], Beijing: People's Post and Telecommunication Press, 2006.

[2] Zheng Xiao-qian, Real-time monitoring system design based on industrial Ethernet communication [J]. Micro computer Information, 2010, 26 (3), pp.82-84.

[3] Liao Chang-chu, PLC program and application [M], Beijing: Mechanical Industry Press, 2008, 1.

[4] Siemens Automation Company, The manual of SIMATIC configuration hardware and communications connection, 2007, 2.

[5] Tan Ming, Wei Zhen etc. Analysis for Switched Ethernet Real-time Informations [J]. Microelectronics and Computer, 2011, pp. 51-54.