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Design of Multi-channel Temperature Control Inspection System Based on PLC

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Abstract—The temperature control system is widely used in the field of industrial control, such as the boiler's temperature control system in Steel, chemical plants and thermal power plants. For the requirements of remote centralized management and security monitor in temperature control system, a temperature control inspection system consisted by down-computer clew and up-computer , is designed in this paper. In this system, a programmable logic controller (PLC) is use as up-computer, multiple AI smart meters are use as down-computer clew. The structure of the system hardware and the interconnection of the various parts are introduced simply, the design and implementation of communication system of down-computer is elaborated in detail, and the part of the communication system program is given. The actual operation shows that the remote monitoring function can be realized and design requirements be satisfied by the application of intelligent instruments of real-time collection, processing and feedback on the site temperature, and high efficiency, high universality and reliable stability are the advantages of the system.

Keywords-Programmable logic controller; Intelligent instrument; Temperature control system; Communication system; Inspection

I. INTRODUCTION

Programmable controller (PLC) is general automation device using computer technology as the core, and has been widely used in industrial production due to its high reliability, variable control program, and strong adaptability for all kinds of vicious environments [1]. But the PLC controller itself does not have the human-computer interaction devices such as display, and can't realize the online adjustment of the control parameters and the display of the system motion state. So an operation display system, which reading temperature by the intelligent meter, using PLC as the core, industrial computer as the control and operation center, is designed. The real-time display of the data and the on-line modification of the instrument set data can be realized in this design. Because in practical applications, the industrial site temperature need be reflected and controlled timely, the good communication between up-computer in the control room and down-machine in the industrial site is very important. In this design, the up-computer is industrial control computer, and the down-computer consists of a Siemens S7-200 PLC and 20 artificial intelligence temperature controllers which type is YuDian AI –708. The key to implement the above functions is the serial communication between PLC and the AI-708 instrument. Therefore, S7-200PLC and AI-708 instrument communication is the focus of this design.

II. SYSTEM STRUCTURE

The system network is divided into two layers, Ethernet and field-bus, shown as figure 1. The master station of data acquisition in the field is the Siemens S7-200 PLC, connected with industrial PC through the Ethernet. AIBUS network topology structure is used in the field-bus, the RS485 communication mode based on AIBUS communication protocol is used in the connection between PLC and intelligent instruments. Because RS485 is half – duplex communication[2-3], SMB87.7 should be reset when the data sending and set when the data receiving in order to avoid the conflict between data sending and receiving. AIBUS uses a 16-bit summation correction, supports a variety of baud rate such as 4800,9600, 19200, under the 19200 baud rate, the master station visits every AI – 708 needs 20ms on average. The interface of AI instrument is asynchronous-serial communication, and the interface level complies with the rules of RS232C and RS485 standards, the data format is a start bit, 8 data bits, no parity,1 or 2 stop bits. AI instrument have 20 connection ports, the third port (A) and fourth port (B) of AI instrument are connected with the port 3(+) and

8(−) of PLC 485 communication port respectively. The first port and second port are connected with the positive and negative port of the 220V power supply, and the 17th port and 18th port are connected with 0-5V or 1-5V voltage signal[4-6]. The communication port must be ensured connected correctly before the communication with PLC.

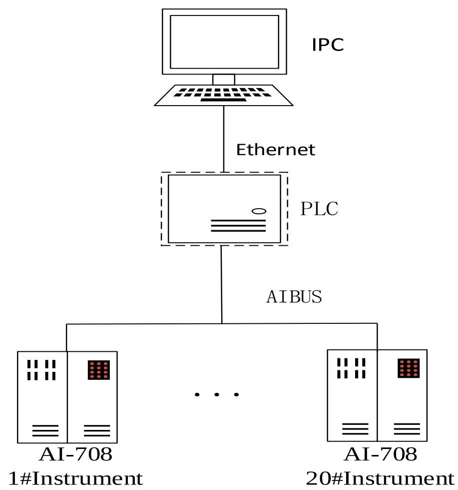

Figure 1. Detection system network structure

III. SOFTWARE PROGRAMMING OF COMMUNICATION BETWEEN PLC AND INTELLIGENT INSTRUMENT

Before compiling the serial polling communication program between PLC and the AI-708, the parameters of the communication must be defined. The serial communication port rate, information frame format, and PLC communication port communication mode should be set up, and communication message test control should be planned.

A. The structure of communication program between PLC and multiple smart meters

The serial polling communication between PLC and intelligent instruments is master - slave communication, PLC is the master, the intelligent instruments are slaves. The master initiates a communication request, the slave responds after receiving a communication request, the slave does not exchange data with the other slave or actively send data to the master. Free port mode communication of PLC involves sending instructions XMT and receiving instructions RCV[9]. Interruption will be generated at the end of these two instructions execution, so the whole process of communication can be controlled by sending and receiving complete interrupt. The interrupt events are shown in Table 1[7-8].

Initialization process is to set port 0 communication modes, serial communication information frame format and baud rate, message control etc. Specifically, it is completed by setting corresponding value for the four special registers listed in Table 2.

TABLE I. THE FREE PORT COMMUNICATION INTERRUPT EVENT

Event Number	Port	Interrupt Declaration	Priority Level
9	0	Transfer is completed	0
23	0	Receive information is completed	0
24	1	Receive information is completed	1
26	1	Transfer is completed	1

After initialization is completed, PLC sends a communication request to the 1# temperature controller, 1# AI-708 temperature controller receives the master request and sends the return data back to the master. At the same time, the main station generates a send-finished interruption of interrupt-9 after the XMT instruction sending the request. This PLC's interruption is connected to an interrupt 0 application, which executes receiving instruction RCV. When the return data from the instrument 1# AI is received completely, a complete interruption event of 23 can be produced. Connect this event with another break 1 program which processing and checking data, if the processing and checking pass, moves the data from data receive buffer to the specified area and clears the receive buffer; otherwise, clears the receive buffer directly. Then, PLC sends a communication request to the 2# AI instrument and processes the received data from the 2# AI, cleans the receive buffer, and then sends a communication request to the 3# AI instrument ,and so on. Until the PLC completes the processing accepted from 20# AI instrument, and cleans the receive buffer, send communication request to 1# AI instrument communication, and repeat.

TABLE II. REGISTERS COMMAND VALUES

register	set value	implication
SMB30	16#09	The baud rate is 9600, 8 data bits, 1 bit start, no check bit, 1 stop, port 0 is free port
SMB87	16#10	The timer is the message timer, using the interrupt condition to start the message detection
SMB90	0	Message wait time is 0
SMB94	16#10	The maximum number of characters to receive is 10

B. Serial communication baud rate, information frame format, port 0 communication mode and message detection control

Usually the temperature change in the field is slow, the polling frequency is too high to be practical, which only increases the burden of the PLC program. The values of registers in Table 2 are the best values by debugging repeatedly. The polling frequency of PLC can be reduced effectively by setting reasonable value for timeout testing timer T38, and the frequency of communication with online instrument can be reduced, so the load of PLC program is reduced, and the whole communication paralyzed causing by a device fault or communication line fault can be prevented.

The request instructions format of the master and return data format from station multiple slaves are shown as formula (1) and formula (2), where in the formula the baud rate is 9600 bits/s, one character frame is 10 bits (one start bit + 8 bits of data a + 1 stop bit), ignoring a few free bits between characters frames, The time passing one character can be calculated by the formula (1). It's about 1.42 ms. In this formula，B is the baud rate and N is the data number. The length of read and write instruction is 16 characters, and the time that the host sends a data is 22.72 ms[10]. The slave sends data instruction back after receiving the host instruction and time-delaying. The delay time is usually tens of milliseconds. This data is given by some instrument manufacturer, and can set within a certain range by user, and is fixed and not given by some instrument manufacturer. The delay time in this design is fixed. The time of return data can be calculated by the formula (2), where in the formula t is the delay time. If data formats returns from slaves are 20 characters, assuming that t is 20 ms, the T is 28.4 ms.

$$T = \frac{1}{B} \times N \quad (1)$$

$$T = \frac{1}{B} \times N \times \mathrm{t} \quad (2)$$

C. Communication format between PLC and intelligent instrument

PLC in Figure 1 collects the data of 20 pieces of smart meters with master-slave scanning communication protocol mode, each communication process is initiated by the master station, responded by the slave station to transmit information back, then a communication is completed. All kinds of instruction code and data in AI instrument are indicated by hexadecimal data formats. There are two standard communication instructions only, one is read instruction, the other is write instruction, through optimization design to AI instrument software communication instruction. It makes the PLC software writing easy, and can complete instrument operation 100%. The read instruction format for the AI instrumentation is shown in Table 3, and the write instruction format is shown in Table 4.

The address is codenamed by two identical bytes (the meter address + 80H) according to the AI instrument communication protocol. For example, the meter parameter Addr = 10 (16 decimal number is 0AH, 0A + 80H = 8AH), and the name of the instrument is 8AH 8AH. [11]

TABLE III. AI METER READING INSTRUCTION FORMAT

0	1	2	3	4	5	6	7
address	address	52H(82)	The parameter code to read	0	0	Check code	Check code
0~80H	0~80H	52H(82)	00H-56H	0	0	XX	XX

TABLE IV. AI METER WRITING INSTRUCTION FORMAT

0	1	2	3	4	5	6	7
address	address	43H（67）	The parameter code to write	Write in low bytes	Write several high bytes	Check code	Check code
0~80H	0~80H	43H（67）	00H-56H	XX	XX	XX	XX

Parameter code: the parameters of the instrument is replaced by a parameters code with an 8 bit binary number (one byte, written as hexadecimal number), it indicates the parameters name to be read/written in the instructions.

Check code: the check code uses 16 bits summation check method, and the check code of reading instruction can be calculated as formula (3) .

$$R * 2^8 + 82 + ADDR \quad (3)$$

The check code for writing instruction is the remainder of 16 binary addition calculations for the following formula (4).

$$W * 2^8 + 67 + K + ADDR \quad (4)$$

The Numbers in these two formulas are decimal, The ADDR in the formula is the parameter value of the meter, the range is 0~80, R is the parameter code to read, W is the parameter code to write, K is the parameter values to write. The check code is the remainder of the binary 16 bit integer addition to the above formula, the remainder is 2 bytes, its low byte is in front, and the high byte is follow. The parameter values to be written are represented by a 16-bit binary integer.

Return data: whether read or write, the instrument returns the following 10 bytes of data.

Measure Value (PV) + Given Value(SV) + Output Value(MV) and alarm status + read/write parameter value+ check code

The PV, SV and read parameter value takes 2 bytes each, represents a 16-bit signed binary complement integer, low byte in the former and high byte follow. The decimal integer cannot be shown, so need be processed in the upper machine by the user [12].The MV takes up a byte, eight bits of symbol binary number format, the numerical range -110 ~ +110, the state bit occupies a byte, the check code is two bytes, and all of them is ten bytes.

Return check code: the remainder (the numbers in the formula is decimal) when added by integer addition.

$$PV + SV + (S * 2^8 + MV) + C + ADDR \tag{5}$$

In the formula, S is the alarm state, C is the parameter value. In the calculation of the check code, each of the eight bytes consists of a 16-bit binary integer for addition, and the overflow number is ignored and the remainder is used as a check code. [13]

IV. Program Operation and Analysis

Communication program between PLC and intelligent instrument is written by using trapezoidal diagram, the instruction such as rising edge, timer, timer interrupt, is used in the program to insure the accuracy and stability. In order to make it more intuitive, trapezoidal diagram is converted into an instruction table form, and the program is as follows.

LD S M0.0

ORB VB122, VB101 //The AI meter address plus 80H is in VB122.

MOVB VB101, VB102 // The current address of the instrument is in VB101.

MOVB 16#43, VB103 //Written instructions.

MOVB 16#0, VB104 //Write the set value.

LD SM0.0

BTI LW0 //The current meter address is given to LW0.

R SM87.7, 1 //Enable the receive message function.

RCV VB110, 0 //Receive the first address of the buffer, store the number of bytes received, and the next offset address is the first character received.

XMT VB100,0 //The first address of the sender area, where the number of bytes is sent, the next offset address is the first character to be sent.

V. Conclusion

In guarantee the absolutely agree in the baud rate, information frame data bits number, start bit number, number of stop bits, odd/even check or without the check digit between the two communication site, the communication can be created in the process of debugging. The data exchange between PLC and 20 AI-708 smart meters is very stable, accurate and reliable. By adopting AIBUS agreement, the communication between S7-200 programmable controller and many intelligent instruments is implemented efficiently in the form of hexadecimal number, and the parameter setting is convenient, the control and operation of the industrial field device is easy. The temperature control system introduced in this paper can meet the different process requirements, and it’s control method is convenient, practical and feasible. RS485 network can communicate serial polling with much more intelligent instruments. But the longer communication distance, the lower communication baud rate. The use of optical fiber and expensive consumables can be prevented by realizing the communication function only, and then the cost is reduced.

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