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Design and Application of Communication Gateway of EPA and MODBUS on Electric Power System

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Abstract

Through the research of EPA Industrial Ethernet technology, MODBUS fieldbus technology, ARM embedded system and μC/OS-II real-time operating system, this paper discusses how to design and develop communication gateway of EPA and MODBUS. The communication gateway can realize bidirectional data transceiving on EPA protocol and MODBUS protocol. The communication gateway can provide a stable, secure, real-time and flexible solution for process control of the power plant.

Keywords: EPA, MODBUS, Industrial Ethernet, Electric Power System, Embedded System

1.Introduction

Power industry is the first national sustainable development industry. With the rapid development of power industry, more and more large-scale units have been put into operation. 300MW, 600MW units has become the main units, and gradually to 1000MW ultra-supercritical generating units. It is predicted that by 2015, China's power installed capacity will exceed 1.1 billion KW. Thermal power units in the power system will continue to dominate more than 70% of the installed capacity and reach about 800 million KW[1]. Although China's power industry has made considerable progress, but the current national electricity demand growth is still very fast. Power supply shortages appear from time to time. At present, the efficiency, reliability and environmental performance of China's new units is equivalent with the developed countries'. However, because of large areas' serious power shortage problems, it makes many long-term power plant equipments work on overload. The security of the equipments also decreases. It requires monitoring production process parameters of the power plant equipments to ensure the boilers, turbines, generators and other host and auxiliary equipments normal operation. In addition, the increasing capacity of the units leads to increasingly complex structures and systems. How to ensure these units safe, reliable and cost-effective operation is very important to the development of the national economy

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Modern industrial control systems are increasingly focusing on decentralization of control, networking and intelligent. The new control system, represented by fieldbus and industrial Ethernet, overcomes the disadvantages of DCS, such as trouble laying, poor reliability and high cost. It has some good properties, mainly on digital communication, equipment intelligence, convenient maintenance and low cost.With fieldbus technology and industrial Ethernet technology continuously mature and power system informationization requirements continuous improving, fieldbus and industrial Ethernet control system will be the convenient, safe and effective solution for power system automation industry.

EPA, abbreviation of Ethernet for Plant Automation, is a standard based on our country proposed real-time industrial Ethernet communication control system solution. It is also the first fieldbus national standard that China owned its proprietary intellectual property right[3]. The standard was officially included as TYPE14 IEC61158-300/400/500/600 in October 2007, as CPF14 listed in real-time Ethernet international standard IEC61784-2.

EPA protocol is based on Ethernet, TCP / IP and other commercial computer communication technology. It combines the features of industrial control systems and network communication, and refers to ISO/OSI reference model. EPA protocol mainly provides as follows:

Firstly, EPA develops a specific application layer protocol. Secondly, EPA increases a communication scheduling management layer between data link layer and network layer without changing the network structure, and makes deterministic communication mechanism[4].

This paper designs and develops a communication gateway between EPA and MODBUS, including researching on EPA industrial Ethernet technology, MODBUS fieldbus technology, ARM embedded system and μC/OS-II real time operating system. The communication gateway implements bidirectional data transceiving on EPA protocol and MODBUS protocol. This paper's work will provide a stable, secure, real-time and flexible solution for process control of the power plant.

2.Outline of EPA Industrial Ethernet

As a fieldbus standard of real-time Ethernet, EPA has the following main features:

(1) Communication certainty: As CSMA/CD technology of data link layer used in commercial Ethernet, the inevitable uncertainty encounters communication problems. The current Ethernet communication uses various means to improve this problem, for example, using switching technology, full-duplex technology and prescriptive priority by IEEE802.1P&Q. These methods avoid data collisions to some extent, but defects are still evident. EPA takes two kinds of means to ensure communication certainty. Firstly, the control field is divided into several control areas. Communication associated facilities are placed in a same control area. Different control areas are isolated by EPA bridge. Secondly, in all control areas, each EPA facility sends messages time-sharing to network in accordance with pre-configured sending time and sending sequence. Time-sharing mechanism avoids sending packets collision and ensures certain and real-time communication.

(2) Interoperability: Communication control system solves not only signals' interoperation and interconnection, but also information recognition. Only to achieve information understanding and recognition, devices' interoperability will be realized. EPA standard defines the application layer service specification, as well as TCP / IP layer interface, and solve the identification and interoperation problem of device information to achieve interoperability between devices. In addition, in order to facilitate the EPA equipment from different vendors to achieve interoperability, EPA standard also uses eXtensible Markup Language (XML) as the basic language of device description. Device description XML file describes users the EPA device resources, including device capabilities, interfaces and some specific characteristics.

(3) E network in the end: The basis of EPA protocol includes Ethernet (IEEE802.3), Wireless LAN (IEEE 802.11) and Bluetooth (IEEE 802.15). Networking mode is flexible, which can be any combination of one or several networks. It can be easily integrated in the automation of industrial enterprises and realize "E network in the end" of smart factory to achieve information seamless integration. The management layer can use EPA agents to connect the remote Internet. Users who have access priority can use the browser or other connection software access to any device of the intelligent plant.

(4) Layered security control: Through the control system divided into information management layer, system monitoring layer and field device layer, EPA uses the layered network security control strategy. Control layer in accordance with the control requirements and the actual physical location of equipment is divided into some segments. Each segment is connected by EPA network. Any unrelated illegal data will be isolated by EPA bridge.

3.Outline of MODBUS Fieldbus

MODBUS protocol was proposed by Modicon company (later purchased by Schneider) in 1979. It is the first worldwide bus protocol used for industrial field. According to incomplete statistics, as of 2004, MODBUS installation nodes are over 800 million, and 75% of products are non-Schneider products. The installation of the regions is around the world. It makes MODBUS become the de facto fieldbus protocol standard.

Compared with other fieldbus protocols, MODBUS protocol has the following 3 distinct advantages:

(1) Open standard: users are free and safe to use MODBUS protocol without paying license fees and infringing intellectual property rights. Currently, MODBUS supported manufacturers are more than 400 and products are more than 600. There are a lot of MODBUS supported products in domestic.

(2) Message oriented: MODBUS can support a variety of electrical interfaces, such as RS232, RS422, RS485, Ethernet, etc. It can also be transmitted in a variety of media, such as twisted pair, fiber optic and RFID. It should be noted this is different from many fieldbuses. It does not need a dedicated chip and hardware and only uses commercially available standard parts, which ensures the lowest cost of products.

(3) Simple and efficient: MODBUS frame format is the simplest and most compact protocol. Users and vendors can download various sample programs, controls and software tools from MODBUS-IDA website and other third-party websites. Years of field experience proves MODBUS has secure communication capability.

4.System Design

System structure diagram of communication gateway of EPA and MODBUS is shown in Figure 1. The system uses 32-bit embedded ARM7 for the processor and μC/OS-II as the real-time operating system.

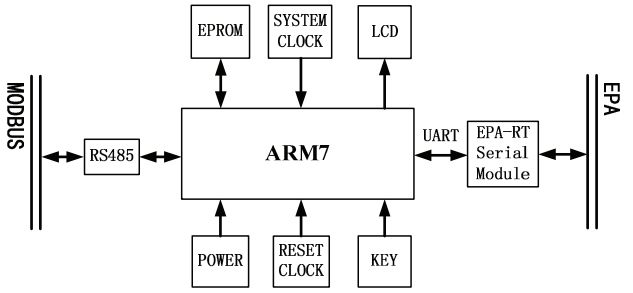

Figure 1. Structure Diagram of Communication Gateway of EPA and MODBUS

Communication gateway of EPA and MODBUS mainly realizes bidirectional protocols conversion. The communication gateway connects with other EPA equipments via an Ethernet switch to form an EPA communication micro network segment. It connects with other MODBUS equipments via RS485 bus connection. EPA-RT serial module is responsible for the formation and delivery of EPA messages. ARM7 chip completes the formation and delivery of MODBUS messages directly.

4.1. Hardware Design

Hardware design of communication gateway mainly includes 2 parts: EPA network communication and MODBUS network communication. LPC2132, an ARM7 chip produced by NXP, is chosen as the control chip.

The function of EPA network communication is realized by EPA-RT serial module. EPA-RT serial module is a field device communication module, through UART connects with other field devices, and uses EPA protocol to realize information exchange between different modules and module to controller. This module contains the processor, EPROM, network adapter, watchdog, JTAG interface and power supply unit. The structure of module is shown in Figure 2.

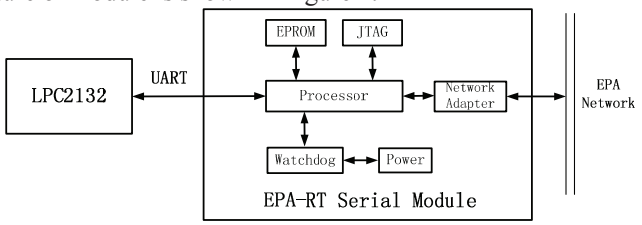

Figure 2. EPA-RT Serial Module Structure

The function of MODBUS network communication is realized via RS485 interface. The system provides a RS-485 bus interface, using SP3485 as the bus transceiver. SP3485 is a 3.3V low-power half-duplex transceiver. It fully meets the RS-485 serial protocol requirements and the electrical specifications of RS-485. Its data transfer rate is up to 10Mbps. The circuit diagram is shown in Figure 3. The communication direction is controlled by P2.16. When P2.16 is low, system can receive data from bus. When P2.16 is high, system can send data to bus. Although RS-485 uses differential signal transmission, however, from the reliability point of view, system uses 3-wire transmission: RS485A, RS485B and GND.

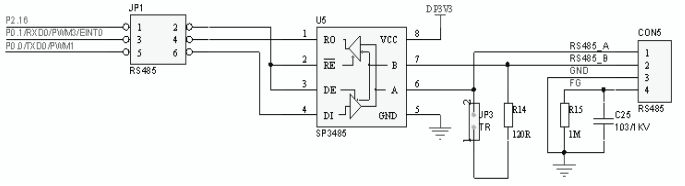

Figure 3. RS-485 Interface Circuit Diagram

4.2. Software Design

EPA-RT serial module integrates the EPA communication protocol stack, custom communication interaction protocol and user function block application process modular function. EPA-RT serial module uses UART to connect data acquisition module, and uses custom protocol to interact with the development. EPA-RT module also includes network modules to meet the EPA protocol for standard communication.

EPA-RT serial module uses the following format of interaction protocols:

TABLE I. EPA INTERACTION PROTOCOL FRAME FORMAT

Bytes	1	2	3	4	5	…N-1	N	N+1
Content	Head	Version/ Command	ObjectID		Length	Data	Checksum	

Frame formats:

Head of Frame: 1 byte, the value is 0x5A (fixed for detecting the beginning of the frame).

Version/Command: 1 byte, the top 3 bits mean communication protocol version and last 5 bits mean specific command functions.

Variable Object Index: 2 bytes, from 1 to 65535 (Corresponding to the platform of the function block identifier AppID as 2000. The object identifier index ObjectID is user-defined).

Data Area Length: 1 to 200 bytes.

Checksum: 16 bits checksum, the entire frame data from the head to data area

Data interaction between EPA-RT serial module and user platform is shown in Figure 4. When initializing, user application maps user variable objects to the EPA-RT serial module. When EPA network accesses user objects or publishes user variable objects, EPA-RT serial module responds or publishes user's mapping variable objects.

On the one hand, when user's mapping variable objects in EPA-RT serial module are updated through EPA network, the generated interrupt signal (about 5μs low level) informs the user platform so as to send a command to read the updated value. On the other hand, when user data are modified, according to communication protocol specification, data will be updated to EPA-RT serial module, and dealt with according attributes.

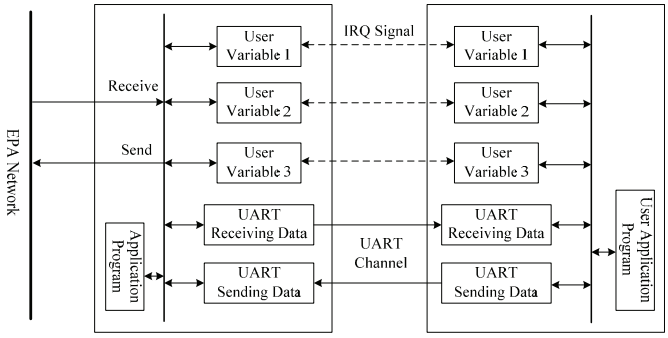

Figure 4. EPA-RT Serial Module Data Interaction Diagram

System software flow chart is shown in Figure 5.

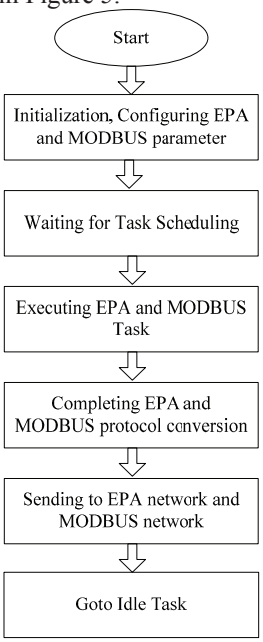

Figure 5. System Software Flow Chart

MODBUS protocol is implemented in μC/OS-II real-time operating system. MODBUS protocol uses a master-slave response mode communication protocol. A master station can correspond to one or more slave stations. MODBUS protocol provides 2 kinds of transmission protocol: ASCII mode or RTU (Remote Terminal Unit) mode. RTU mode defines each byte in the message contains 2 hexadecimal characters and uses CRC (cyclic redundancy check) to verify the data. Due to the maximum use of each data bit, improving communication efficiency and transmitting more data than ASCII mode under the same baud rate, system uses MODBUS RTU communication protocol.

5.Experiment Result

The communication gateway experiment structure diagram is shown in Figure 6. Communication gateway connects 2 EPA remote I/O equipments. Each EPA remote I/O is responsible for two-channel analog data acquisition. Meanwhile, the communication gateway connects PC host system through MODBUS. In the PC host system, monitoring the analog data from EPA remote I/O equipments uses ModScan32 software.

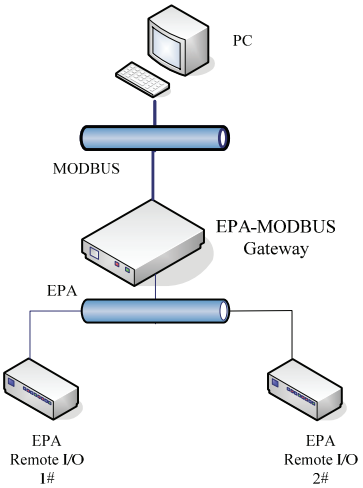

Figure 6. Experiment Structure

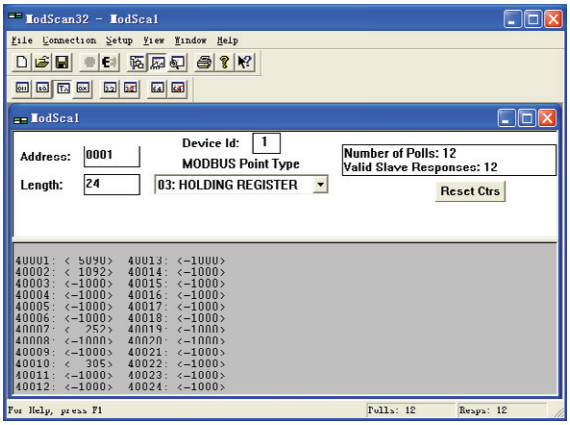

Figure 7. Experiment Result

In the EPA remote I/O 1#, 1st and 2nd channel are connected with ordinary resistors. In the EPA remote I/O 2#, 7th and 10th channel are connected with thermal resistors. MODBUS serial communication network parameter is set to 9600 baud rate, 8 data bits, 1 stop bit and even parity. The experiment result is shown in Figure 7.

6.Conclusion

With the rapid development of information network technology, industrial Ethernet has become a hot spot in automatic control area. EPA standard provides a real-time Ethernet solution, and fills the blanks in the field of industrial automation of China in international standards.

Domestic power plant automatic control systems generally use DCS systems. Some systems use combination systems with DCS system and fieldbus system, and fieldbus system mostly uses MODBUS fieldbus. Compared with DCS system, industrial Ethernet system has the advantages of whole digital communication, less signal interference and online diagnosis. It has broad development prospect in power plant. This paper designs and develops communication gateway of EPA and MODBUS based on ARM7 and μC/OS-II. Experiment results show that using EPA-RT serial module can quickly and reliably develop EPA field device, without changing original DCS structure. The paper's work has great significance for power system device digitalization and informatization.

Acknowledgment

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