Journal of Zhejiang University SCIENCE A
ISSN 1009-3095 (Print); ISSN 1862-1775 (Online)
www.zju.edu.cn/jzus; www.springerlink.com
E-mail: jzus@zju.edu.cn

Research of network technology for Intelligent Circuit Breaker Controller*

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Received Dec. 19, 2006; revision accepted Jan. 5, 2007

Abstract: With the current development trend of Ethernet gradually towards the control network of plant-floor layer and devices layer, much management information on Intelligent Circuit Breaker Controller (ICBC) is becoming distributed and networked. This paper describes a mixing structure of complex industrial field control network based on Ethernet frame, then mainly discusses three network management methods of ICBC, such as the interconnection method based on PCI, embedded gateway and embedded Web server. At the same time, it also gives the basic hardware framework of implementing interconnection, the type of main components, and the real-time operation system supporting the embedded TCP/IP protocols and Web server.

Key words: CAN bus, Control network, Ethernet, TCP/IP, Embedded Web
doi:10.1631/jzus.2007.A0464 **Document code:** A **CLC number:** TM564.8

INTRODUCTION

Low Voltage Circuit Breaker (LVCB) is one of the main appliance switches in the distributing system. It can switch on/off the normal-loaded current, the current used by motor as well as overload current; on the other hand, it can connect and break short-circuit current. Besides, when faults such as serious over-current, overload, short circuit, loss of phase and so on appear, LVCB can cut-off the circuitry automatically and cause the breakdown to be isolated to great extent. As a result, it plays important role in protecting network circuitry, appliance and electric motor, and thereby has been widely applied.

Based on LVCB, Intelligent Circuit Breaker Controller (ICBC) adds intelligent breaking control function and simple communicative access, which can pass data to computer for control (Ni, 2003). With the development of application of communicative and network technology to appliance control systems, and the increasing trend that the industry controls network as well, new demands are put forward for information management of ICBC, which are mainly manifested in two aspects:

(1) Realization of computer network communications and the interconnection based on heterogeneous networks;

(2) Sharing of various information including diverse control information and working information (e.g. operating mode—on/off, ready to work, warning, breakdown, and so on; the electric parameters on operating branching channels such as current parameter, fault parameter, etc.; control network working parameter), was managed through network.

COMPREHENSIVE CONTROL NETWORK BASED ON ETHERNET FRAMEWORK

The latticing on intelligent devices need to meet the following conditions: realizing the function of Internet/Intranet/Ethernet at the level of field bus; transferring from the traditional control method such

* Project (No. F2005000077) supported by the Natural Science Foundation of Hebei Province, China

as field switch signals, analog signals to Internet control method formed by field bus; adopting Internet technology to industrial network and realizing industrial control network based on TCP/IP protocol (Yin *et al*., 2003). The core technology is to cause the control network to realize interconnection, in other words, the realization of intercommunication between different media, rate and communicative treaties, and finally reach the goal that information can be exchanged between the facilities in different subnet (Shen *et al*., 2003). At present, the way to control the interconnection of the network mainly depends on the comprehensive network made up of various field bus, shown in Fig.1.

WAY TO CONNECT INTELLIGENT BREAKER TO ETHERNET

Following the principle of full-opening, full-deconcentration and interoperation manifested in the comprehensive control network, the facilities on the spot connecting to Ethernet are realized in three ways:

(1) Plug the communication card into the industrial PC and PCI, in which the information exchange is completed (Liao *et al*., 2001). The data are transferred to the computer in Ethernet layer through the computer.

(2) Adopting specialized gateway to realize the shift between different communication protocols, to connect facilities to Ethernet.

(3) Plugging directly the Web server into PLC or control facilities (Wu *et al*., 2003). The data are interacted dynamically by means of Web server and common browser.

Interconnection based on PCI model

As the technology based on PCI model is relatively advanced, it has been widely used. This kind of model consists of intelligent breaker, computer, card and relevant software. Fig.2 takes CAN (Controller Area Network) for example to show the framework of the hardware in the interconnection (Yang, 1999).

Intelligent facilities mainly including the basic system of MPU may adopt (Intel 87C196KC), the collection of control logic, analog quantity shift and collection, switching value input/output handlers, output control, CAN communicative interface and CAN transceiver (the selected pattern is shown in Table 1).

CAN includes: intelligent PCI-CAN with high-speed double RAM, direct mapping into the memory space, realizing the data exchange between CAN and PC. The embedded MPU (87C592) can lighten the burden to the host computer and fulfill the complex communicative work.

The host computer can be connected to Ethernet through built-in network card or modem, in order to exchange the data by other subnet.

Interconnection based on gateway

The special gateway is used for interconnection between certain field bus equipment and industrial Ethernet is a kind of compromising strategy employed by many bus developers to enlarge their market share without neglecting the products. The frame with dotted line in Fig.1 demonstrates the detail

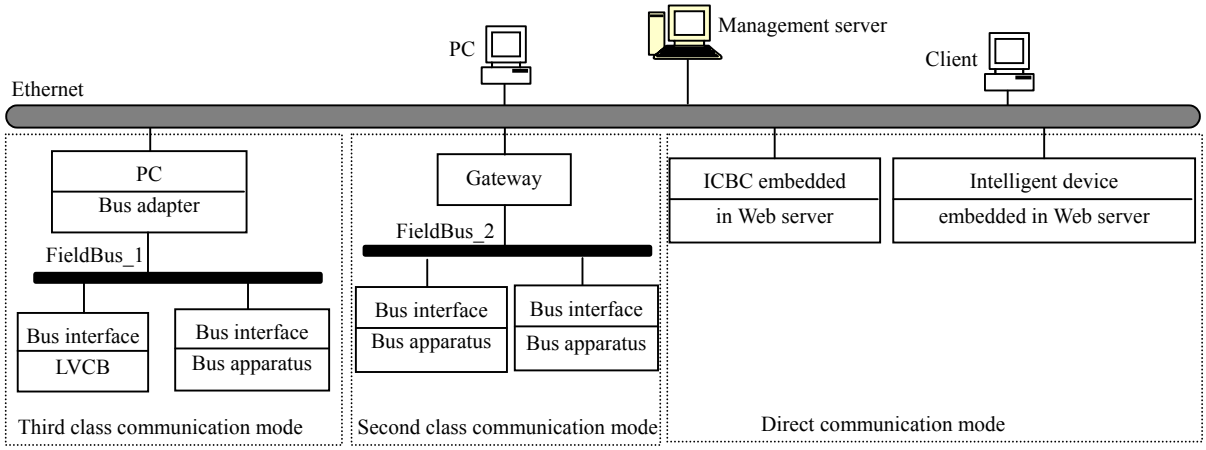

Fig.1 Comprehensive network based on Ethernet

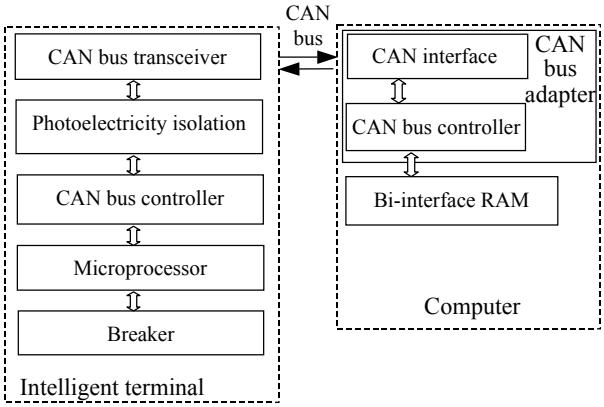

Fig.2 Interconnection based on PCI

Table 1 Main CAN bus apparatus

Producer	Product type	Functions and features of apparatus
Intel	82526	CAN communication controller, according with CAN2.0A
	82527	CAN communication controller, according with CAN2.0B
	8XC196CA /CB	Extended 8XC196+CAN communication controller, according with CAN2.0B
Philips	82C200	CAN communication controller, according with CAN2.0A
	SJA1000	82C200 substituted product, strengthen CAN mode, supporting CAN2.0B
	8XC592	8XC522+CAN Communication Controller, deleting I^2C, according with CAN2.0A, adding secondary RAM 256 bytes
	8XCE598	Advancing electromagnetism compatibility
	82C150	I/O interface of data and analog signal according with CAN2.0A
	82C250	High performance CAN bus transceiver
	P51XA-C3	CAN communication controller, according with CAN2.0B
Motorola	68HC05X16 Series	68HC05 microprocessor+CAN communication controller, according with CAN2.0A
Simens	81C90/91	CAN communication controller, according with CAN2.0A
	C167C	Microprocessor+CAN communication controller, according with CAN2.0A/B
NEC	72005	CAN communication controller, according with CAN2.0A
Silioni	SI9200	CAN bus transceiver
TI	TMS320F2 43DSP	MPU+CAN communication controller, according with CAN2.0A/B

of this kind interconnection. The whole network adopts 2-layer structure: the lower part is the low-speed field bus, while the higher part is the field bus network with the high-speed Ethernet as the core, integrating different protocol standards. The seamless connection of heterogeneous networks between two layers can be realized by the embedded gateway. The following part will take the CAN bus as an example to introduce the interconnection method of intelligent breaker controller by adopting the embedded gateway.

Embedded gateway is responsible for constructing and analyzing the complete CAN protocol data package at the application layer level. Then it transfers the data package as the data for TCP/IP application layer. During the process, no explanation about the actual significance of the communicating data will be presented by it, therefore, the interconnection between high speed Ethernet and the relatively low speed field bus can be achieved and the transfer of protocols between TCP/IP and various field buses can occur.

The embedded gateway is made up of three parts: communications processor, CAN bus controller and Ethernet controller. The basic hardware structure is presented in the frame with dotted line of Fig.3. The mode of operation is as follows: At the scheduling of microcontroller, using the Ethernet controller to exchange the data with operating station; embedded CAN controller can exchange data with every node of intelligent breaker in CAN bus or with other field equipment.

The choice of microcontroller can be the em-

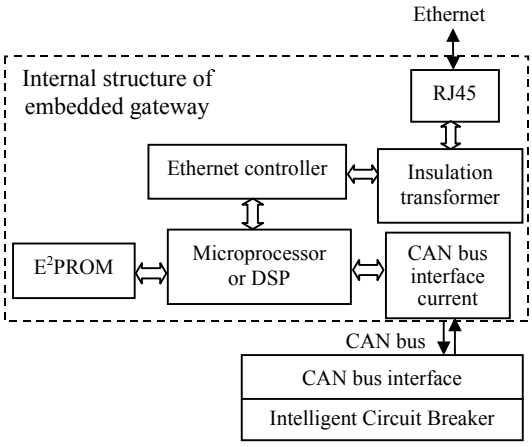

Fig.3 Interconnection based on embedded gateway

bedded CAN communication module MC68HC05X16 or DPS series, such as TMS320F206DSP, or the TMS320F243DSP chip with embedded CAN communication module. The choice and design of CAN interface and the communication interface of the intelligent breaker in CAN bus may be referred to Section 2.1.

Usually the choice of Ethernet controller is RTL8019AS produced by Realtek. RTL8019AS is the highgrade cryptosystem which supports the chips with IEEE802.3 standard and the PnP standard of Microsoft. It also supports the 8-bit, 16-bit and 32-bit microprocessor and its software is compatible with NE2000. It can be applied to Ethernet II, IEEE802.3, 10Base5, 10Base2, 10Base-T.

The sending and receiving speed can reach 10 Mbps. SRAM (built-in 16 kB) is responsible for receiving and sending buffer memory; it reduces the demand of the major processor's speed. Besides, Ethernet controller can use AM7790 or AM7794 produced by AMD, CS8900 produced by Crystal, or 82596 produced by Intel.

Interconnection based on embedded Web server

The development of embedded technology enables embedded network technology to be the major resolution of heterogeneous networks (Zhang *et al*., 2001; Li, 2002). The exploration of intelligent field device with Web server software becomes the best way for controlling industrial of network interconnection. Embedded network technology is the technology using intelligent equipment based on the original embedded system adopting RTOS—the real-time operation system which supports embedded network protocol groups (such as TCP/IP, etc.) and makes it to have the function of network, thus RTOS can work as network server that connects to Ethernet using plug and play method and form the embedded network system.

Adopting this interconnection method, the implementation of hardware relies mainly on the model in the intelligent breaker which is in charge of information processing and network communications. Due to the complexity of TCP/IP protocol, the communication models involved in the realization of the protocol are MCU, Ethernet controller and Ethernet transceiver. The methods of interconnection fall in two ways:

(1) Transferring the Ethernet card configuration embedded in the PC which is shown in Fig.3 to the device level, while the MCU is required to have higher performance.

(2) Adopting the CMOS chip which integrates Ethernet controller and microcontroller, as Fig.4 shows, based on this configuration, the data exchange between Ethernet controller and microcontroller can be directly implemented within the CMOS chip; as a result, communication efficiency is advanced, meanwhile, the capabilities of anti-interference and reliability are better than the separated configuration.

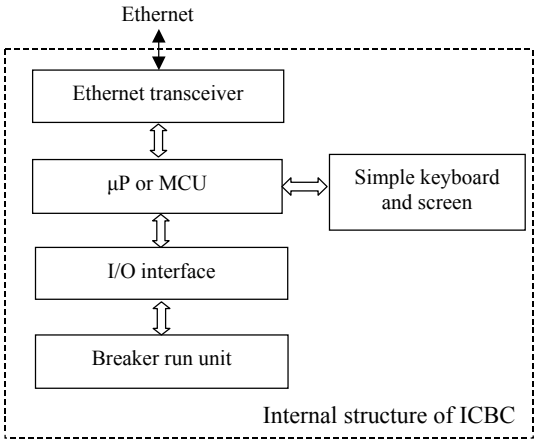

Fig.4 Interconnection based on embedded Ethernet CMOS chip

As shown in Fig.4, the microcontroller/microprocessor which form the Ethernet controller may adopt the 68K series produced by Motorola such as MC68020, MC68030, MC68360, PowerPC series such as MPC860, MPC8260, or Net ARMD produced by SAMSUNG. Ethernet sender can use AM7991 produced by AMD, LXT901 and LXT907 produced by Level one, or 68160 produced by Motorola.

The software part of the CMOS chip with multifunction consists mainly of the embedded real-time multitask operating system—RTOS and Web server software. Real-time operating system can adopt VxWorks produced by Windriver, Palm OS produced by 3Com, Windows CE produced by Microsoft; in addition, some foreign companies such as Windriver, Microsoft, QNX and Nuclear produce software development platform which is embedded to Web. DeltaSystem platform developed by CoreTeck Company is more mature at home.

Data exchange between the embedded Web intelligent breaker and PC in the Ethernet usually adopts the method of client/server, namely, one client exchanges data with several servers. PC, as a client, monitors the whole system state online. Every monitor node, formed by site intelligent cell and embedded network server, receives control command sent by the client and provides needed system parameter to the client. It reflects basically request/correspond, that is, the client sends information and data request to the server, and then the server processes it and returns the processing result to the client.

CONCLUSION

With the development of integrated circuit, industrial Ethernet technology and embedded Internet technology, industrial control network based on Ethernet mix mode will be replaced gradually by the Internet control network. On the basis of TCP/IP protocol group, embedded Web server and intelligent field device with plug and play function play an important role in the revolution of manufactory information integration and control network architecture. Study on network technology for Intelligent Circuit Breaker Controller is significant and practical.

References

Li, Z.J., 2002. Design of intelligent node of can bus based distributed measuring and control system. *Journal of Shandong University of Technology*, **32**(5):465-468.

Liao, L.Q., Ling, Y.H., Yang, X.R., 2001. An intelligent protecting and monitoring system based on CAN field-bus for high voltage switchboard. *Journal of Central South University of Technology*, **32**(5):532-535.

Ni, Y.P., 2003. The Modern Low Voltage Apparatus and Control Technique. Chongqing University Press, Chongqing, p.18-24 (in Chinese).

Shen, G., Wei, Z., Cai, Y.Z., 2003. Delivery delay analysis of a real-time Ethernet MAC protocol. *Acta Electronica Sinica*, (3):175-179.

Wu, Z.J., Hu, M.Q., Du, Y.S., 2003. Application of embedded Ethernet to communication networks in substations. *Power System Technology*, **27**(1):71-75.

Yang, X.H., 1999. Fieldbus Technology and Application. Qinghua University Press, Beijing p.309-347.

Yin, J.W., Zou, J.G., Zhu, S.Y., Yuan, Y.D., 2003. To observe the development trend of low voltage electrical apparatus in the world from Germany industry exhibition. *Low Voltage Apparatus*, (1):3-7; (2):3-6.

Zhang, J.D., Zhang, W.D., Xu, X.M., 2001. Research of fieldbus interconnection with Ethernet. *Computer Engineering*, **27**(5):19-21.