LonWorks/Ethernet 서버를 이용한 HVAC의 Web 기반제어에 관한 연구

Web-Based Control and Monitoring System Using LonWorks / Ethernet Sever for HVAC Application

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요 약

본 연구에서는 프랜트 및 빌딩자동제어 분야에서 적용이 확대 되고 있는 LonWorks 필드버스를 이용하여 기존의 공기조화 시스템를 제어하고 있는 DDC제어기를 대체할 수 있도록 필드버스에서 사용이 가능한 고성능 저가의 지능형 제어모듈을 개발하였다. 이는 필드버스 기반의 AHU 전용 지능형제어기를 새로운 설계기술로 개발하고 상품화를 실현하였다. 특히 S/W부분에서도 8 bit Neuron chip에 매우 콤팩트하게 내재된 고성능 응용프로그램도 개발하였다. 또한 Echelon 사의 iLON 100 server의 Soap/XML을 사용하여 Web 브라우저에서 쉽게 프로그램을 작성 제어모니터링 기법을 개발하엿다. 공조기의 실험 시스템을 구축하여 개발된 전용 제어기 및 Web 기반제어를 실험한 결과 밸브, 댐퍼제어 및 감시기능이 기존 DDC 제어기보다 우수함을 확인하였으며 원격제어 기반을 구축하였다..

1. Introduction

Recently, it is of great interest to adopt the Internet/Intranet to develop and to operatemanagement system (BMS) of intelligent building. Significant advances in Internet and computer technology have made it possible to develop Internet-based control, monitoring, and operation system for controlling environments around us - in buildings, factories, homes, trains, or where control is needed[1,2]. The proliferation of distributed control networking has permitted control devices to reap the same benefits from networking that PCs enjoyed in the past decade. The seamless integration of data networks with control networks allows access to any control point from anywhere. The extension of the Internet into devices allows people to reach devices using a familiar medium- the web browser. To allow this integration to happen now, control network for the lowest levels of the systems hierarchy provides all the components necessary to implement fully openness and interoperability[3]. Now, distributed architectures based on smart component and fieldbus technologies are becoming more common in modern control system. They replace the controller-to-sensor current(4 to 20 mA) or voltage loop connections by digital, bidirectional, multi-drop serial bus communications, Field compatible field devices become so-called "smart" devices, capable of executing simple control, diagnostic and maintenance functions and providing bidirectional serial communication to higher level controllers[4].Field devices, as sensors or transducers, usually make use of fieldbuses, while control devices, as industrial PC, PLC or SCADA, are often interconnected using Ethernet IEEE802.3 [5,6]. The most important HVAC of BAS has received nationwide attention because of higher portion of more than 40% in building sector energy use and limited resources. This paper presents the Internet-based monitoring and control architecture andof LonWorks modules for AHU (Air Handling Units) of HVAC in viewpoint of configuring BAS network.

2. A Review of Technologies for integrating control network and internet

In the building automation world there is a strong tendency toward integrating the building automation and control network with more enterprise-wise networks. For this reason we linked the fieldbuses each other with an enterprise intranet, based on the Ethernet. The Intranet is a worldwide-interconnected computer network. An intranet is an interconnected computer network within an organization. Internet becomes popular due to its low cost data transfer between any location worldwide and aggregated data on single-page displays. The choice of this type of net was born from the consideration that currently the Ethernet is the more widely used in the world and is characterized by the constant decrease of costs and by increasing availability of software tools, that are essential in building application. The use of the same backbone for BMS and computer network in an organization open up opportunities for improving management efficiency and reducing costs. Large amount, high quality and accurate information of various types can be accessed simultaneously with high-speed connection via Internet/intranet. As Ethernet data networks are available in most commercialbuildings, it is of great interest to utilize these networks for BMS integration. Local control network use LonWorks, BACnet and EIB. Internetemploys Transmission Control Protocol/Internet Protocol (TCP/IP) and HyperText Transfer Protocol (HTTP). To integrate a local control network and the Internet, an interface between these two types of protocols needs to be developed. Advanced information technologies, such as Component Object Model/ Distributed Component Object Mode (COM/DCOM), Extensible Makeup Language (XML), Simple Object Access Protocol (SOAP) and OLE for process control (OPC), have been recently developed along with the rapid advance of Internet technology. With those technologies, it is possible to translate codes and data in real-time between BMS local network and the Internet. Two or more BMS control networks can be integrated by using Internet/intranet as the communication backbone. The integrated networks can be accessed by various managers and clients using standard Internet protocol, i.e. TCP/IP and HTTP. TCP/IP protocol is the commonly adopted standard for communications between computers and other intelligent devices in building environments, i.e. intranet HTTP is the standard World Wide Web (WWW) protocol. In fact WWW is a distributed information system built on top of TCP/IP. It can be used conveniently as the result of the widespread Web browser applications. The basic Web page is programmed and supported by HyperText Makeup Language (HTML) and its extensions. A Web sever is the source of the information. Ethernet frame length runs from 8+64 octets to a maximum of 8+1518 octets because it is mostly used to transfer large amount of data. However, the most shortcoming of this solution is its intrinsic non-determinism. In other words, Ethernet does not provide a fixed time for nodes to access the network. This behavior is due to the medium access strategy, called Carrier Sense Multiple Access with Collision Detection (CSMA/CD). Despite this consideration, many Ethernet-based implementations are on the rise in real-time industrial environments. How is this possible? First of all, the least evolution of the IEEE802.3 standard is an higher data rate capability. In expensive controllers running at 100Mbps, according to 100BaseT or FastEthernet standard, or even at 1 Gbps, according to GigaEthernet standard, are now available. In this way, the probability of a collision is greatly reduced.

2.1 UseoftheembeddedWebserver

For BMS of small scale, the embedded Web server and IP router devices are used. There are various types of IP routers providing embedded Web severs, In this case, the IP router play two roles:

(1) Router- provides connection between LonWorks control network and IP data network;

(2) Web server- provides access to the variables on control devices and makes them available through standard Web browsers.

The applications of embedded Web sever are main issue to be concerned in this approach, while the function of router is used to integrate the control networks and Internet/intranet. The embedded Web, accessible by a standard Web browser, serves the Web pages that refer to the AHU variables. The embedded Web sever has been extended with HTML tag definitions, providing the functions which meet needs for data exchange between the control networks and sever, incorporating the HVAC variables to HTML Tags. In extended Web sever, to return a Web page to a browser, the Web sever explains the Web pages, find out the special extended HTML tags and indicates a network variable reference. The Web server substitutes the current value of a HVAC variable for the tags when returning the information to the browser.

By extending the HTMLtags only, the Web pages are compatible with standard Web pages and can be written using common editing tools. When embedded Web server is used, it is easy to access the control devices in the control networks. To display the network variable by a browser, one need to write the correct HTML tags in the display places only. Using the embedded Web server, the program to access control network is easy to develop. However, the function and capability of the embedded Web sever provided are limited due to the price and market needs. In particular, the graphic user interfaces for Web browser need large memory space to store graphic files. It is not practical to use the embedded Web server.

2.2Internetserver

To connect LonWorks based everyday devices to the Internet, a LAN or a WAN, the iLON 100 Internet server is used. This allows a service center to configure, monitor, and control everyday devices from across the room, or across the globe. The iLON 100's software applications provide a rich set of functions that enable it to work as a self-contained controller without the need for a PC or host processor. Standard application includes scheduling, data logging, alarm detection & dispatch, and meter reading. The iLON 100 applications are accessible from web pages, SOAP/XML, or via standard LNS plug-ins. The free topology twisted pair interface uses in expensive twisted pair wiring to interconnect devices without regard to wiring topology: the installer id free to route the wire in the most expeditious manner. The 10/100 Base T interface provides connection to a local Ethernet network and also supports a built-in web server and SOAP server. The iLON 100 e-mail client is used to send e-mail dispatches of alarm conditions and data log content. The combination of web and SOAP servers enables the creation of web browser-based interfaces as well as connectivity to enterprise system such as manufacturing, accounting, and SCADA application. All information id provided in ether HTML or XML formats. This server is design for use in both local and wide area networks, and is compatible with the most popular IP networking protocol TCP, STMP, SNTP, ICMP, FTP, DNS and so on. . Regardless of whether one is connecting to a LAN, WAN, or ANSI 709.1 protocol based system, the iLON 100 offers interoperable networking based on open standards [7].

3. Development and design of intelligent node withhigherperformance

The section of microprocessors is governed by various factors, being mainly dependent on the nature of the applications to be addressed. Among field-bus systems and control networks on the market. LonWorks offers perhaps the most powerful features in term of architecture, communication flexibility and network management. LonWorks is chosen for the research study largely to take advantage of its architectural features, flexibility and its comprehensive range of development tools. The case study is based on the use of Neuron chips which are sophisticated VLSI devices that make it possible to implement low-cost local operating networks applications.

3.1IntelligentLonWorksnode

LonWorks from Echelon is a complete system that incorporates a communication standard with ANSI/EIA 709.1. It also includes management and control. The neuron chip contains three eight-bit processors. The block diagram of the master controller developed for a water treatment process control is shown in Fig.3. The application processor is executing user code written in a variant of Neuron C language with powerful input/output functions. A network processor handles addressing, routing, authentication of packets and the presentationof data to the application processor. The MAC processor is responsible for encoding I/O, importing measurement, calculating, calibration and transmission of packets of data to the network. Embedded neuron networks stored in EEPROM implement most of intelligent functions. These two processors comply with six layers of the ISO reference model. This allows the transparent use of the network to pass information between the different programs in the application processors.

• Simplified interface module design

There are 34 different I/O objects available within a Neuron chip. Various I/O objects may be used simultaneously if desired. With this provision, the interface circuit between the controller and the physical devices can be greatly simplified, reducing the size and the costs of the devices and offering enhanced reliability.

• Three dedicated CPUs and built-in firmware

Three CPUs are employed on a Neuron chip, with two of them handling the layers one to six which conform to the seven-layer network protocol stack, i.e. driving the communications subsystem hardware, executing the collision avoidance algorithm, network variable processing, addressing, transaction processing, authentication, background diagnostics, software timer, network management, and routing functions, This enables the development effort to focus on application programming, instead of spreading a considerable amount of time in dealing with the communications protocol and communication interface circuit. The firmware embedded in the Neuron chip contains communication protocol, an operating system and data I/O applications library. This simplifies applications programming as the data I/O communication and I/O devices are automatically handled through a library call. Multi communication medium and communication data rates Neuron chip based on LonWorks supports multi-communication medium, such as; twist pair cable, coaxial cable, power line, radio frequency, infrared and optical fiber. It also supports a wide range communications data rates from 4.9-1250Kbit/s. The versatility in communication medium and data rates in fact a unique feature among fieldbus systems and control networks currently available on the market.

• High level programming language

Neuron C is a programming language designed for Neuron chips and is based on the ANSI C language. It includes extension to ANSI C that directly supports the Neuron chip firmware, which make it a power tool for the development of LonWorks application. The use of high level programming languages is a desirable feature now offered by controller developer and suppliers. This can be seen as a move towards code portability and self-documentation. The dependency of software code on a particular processor or platform is seen as a stumbling block for developers from quickly adapting to the use of the latest and most appropriate processing platforms.

• Exploitation of network variables

Using the Neuron chip as the controller of the intelligent devices you can use Standard Network Variable Types (SNVTs). SNVTs provide a data-oriented application protocol. Application data items such as speed, length, states, text strings, and other data items are exchanged between devices in standard engineering and other defined units. Commands are encapsulated within the application programs of the receiver devices rather than being sent over the network. In this way, the same engineering value can be sent to multiple devices even though each device has a different application program for the data item. SNVTs facilitates interoperability by providing a well-defined interface for communication between nodes made by different manufactures, A node may be installed in a network and logically connected to other nodes via network variables as long as the data types match. Comparing network variables with commands and using network variables rather than commands will result in smaller application programs, implicit buffer allocation/freeing and optimizing communication services at installation rather than during application development. A developer does not then have to concern himself with how and where the devices will be connected and the communication with other devices is established.

• ID of the devices

A unique 48-bit ID is assigned with each Neuron chip when manufactured. The 48 bit ID may be read and used by application programs as a unique product serial number. It can also be used as a network address during installation and configuration [8].

3.2 Hardware configuration of AHU controller module

Direct digital controller (DDC) became popular for HVAC controls in the 1980s. Distributed processing and digital control capabilities of DDC systems with their inherent excellent stand alone capabilities made them popular among the building owner and HVAC engineer. As increasingly powerful algorithms were developed, tighter control over processes could be achieved. However, the issues associated with adds, moves, and changes remained and grew increasingly complex as systems grew in size. The software required to handle large systems was very complex, each controller represented a single point of failure, and each controller was still tethered to all of the sensors and actuators by cable bundles that were not easily modified. Moreover, the manufacturers of DDCs developed them using proprietary internal architecture: if you wanted to expand a DDC system then you had to use components from the original manufacturer. Fig.1 show a LonWorks controller module for AHU which provide interoperability among the components of that system, as well as other related systems that must exchange information. This module with equal performance and compactness was developed to replace the conventional DDCs. The basic contracts and scheduler are concluded. This controller has 29 I/O channels RTC (real time clock) scheduler, AHU control, digital scheduler and RTC function block. Table 1 represents the detailed specification of a LonWorks control module for AHU.

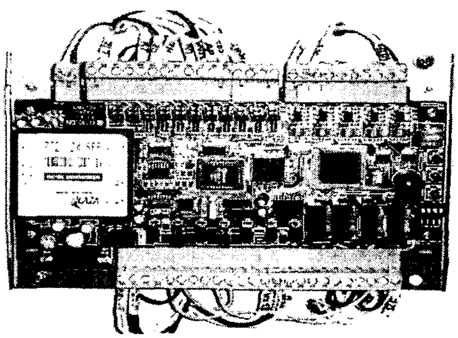

Fig. 1 Controller modules for AHU

Table 1. Hardware specification of AHU controller module

Items	Specification
Hardware	Processortype:FT3150 ProcessorClock:10MHz Memory:32KSRAM,32KROM CommunicationProtocol:LonTalk TransceiverType:FT-X1(Smart) OperatingVoltage:AC/DC18-36V I/OChannels: ?AnalogInput:11 ?AnalogOutput:5 ?DigitalInput:7 ?DigitalOutput:4
Scheduler	RealTimeClock
F.B.	AHUFB,DigitalScheduler RTCController

3.3DevelopmentofsoftwareforAHU

RTC Function Block is implemented to control and monitor AHU. This can also control the setting value and adjust sensor parameters easily. Computer programs that perform "useful work"are called application programs in the realm of direct digital control, these are the data acquisition, metering, monitoring, control, energy management and operator-machine interface programs. This LonWorks control module is developed to include all of the control and monitoring logic of the system level DDC. Fig.2 represents an example for the control logic of cooling and heating system of AHU. The 7-layer interoperability is based on the concept of network variables (NVs). NVs are a comfortable way to share data within a distributed application. The neuron C programs that use NVs do not deal with the mechanisms of the communication or the network. NVs are distributed via the network together with address information and other attributes (priority, ete.) and are received by the corresponding node.

NV's are sent and updated automatically and appear as an ordinary variable inside the application program. NV's can trigger events and launch functions in application program which react on the updated value of the NV. Fig.3 shows the network variables for AHU LonWork control module. 18 input network variables and 23 out network variables are implemented by LonMaker for Windows for AHU control and monitoring.

Plug-in guide of AHU controller provide the type of AHU, set properties, digital I/O, Analog input, and analog output is selected and is utilized to operate the functions of AHU, such as reconfiguring controller, sensors and actuator. Fig. 4 shows the plug-in guide of AHU LonWorks control module. The example of set properties menu clicked in the plug-in menu of AHU controller is represented. We can set the operating function by function block of AHU, such as set temperature point, set humidity point, out temperature compensation, schedule control, enthalpy control, night setback, CO2 set and fire emergency set value and so on.

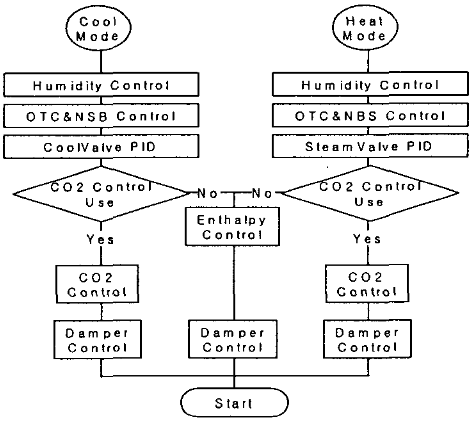

Fig. 2. Flow chart of control logic of AHU heating and cooling system

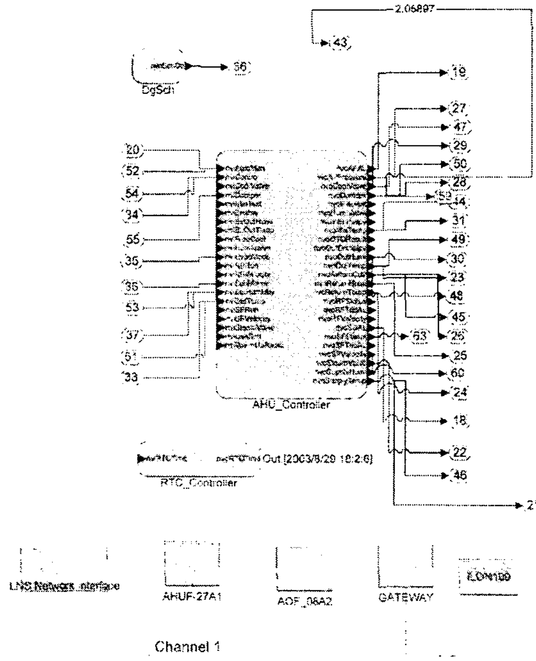

Fig. 3. Network variables for controlling AHU

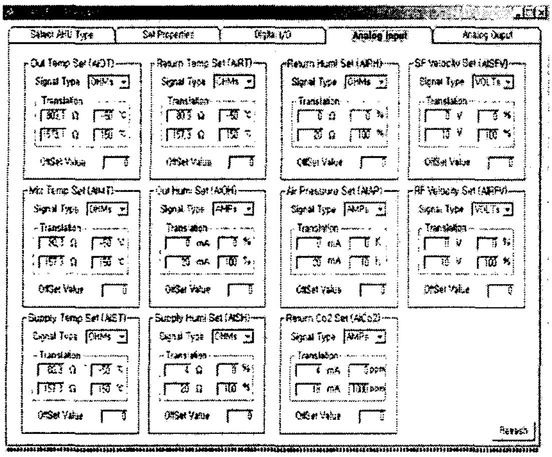

Fig. 4. Analog Plug-in

4. Implementation of Experimental system ofAHU

A small simulator for AHU experimental system is implemented to test the performance of LonWorks fieldbus control module which cancontrol and monitor *the constant air volume* (CAV) *or variable air volume* (VAV) system of AHU.

This experimental system consists in the data network (Ethernet) and LonWorks control network. iLON 100 Web server connects two networks. LonWorks control network is composed of three parts, such as AO Lon Module for digital gauge, AHU LonWorks control module and gateway for touch screen which is design to use in the field. This gateway can be converted LonWorks protocol to RS 232C.

Fig.6 represents the block diagram of experimental system. LonWorks/Ethernet server is represented at *the left side of Fig. 7. Fig. 8 shows the Web pages* implemented to control and monitor AHU. This page is composed of three parts, such as AHU image page, AHU control and real time operating values of AHU and finally the image page projected by Web camera. This image page concludes the simulator of AHU experimental system of Fig. 5. The manipulating page is designed to control the selection of manual or automatic control mode of AHU, stop or start control of AHU, setting desired values of heating and cooling mode, setting of inverter mode and setting of humidity system. We experimented all controlling and monitoring items for AHU used in official building. *The experiment involves creating a Web control page* for the Internet-based AHU system control. Authorized users can request this Web page from the HVAC Web server; then click on the "start"or "stop" button to submit the operation request to the Web server to dispatch the control requests to the appropriate I/O modules in LonWorks control module of AHU. JavaScript is used in this control page to show date and time information. Because of the condition limited paper page, it is unfortunate that the source code of this HTML page is not listed in paper. Experimental results confirm the high performance of AHU LonWorks control module.

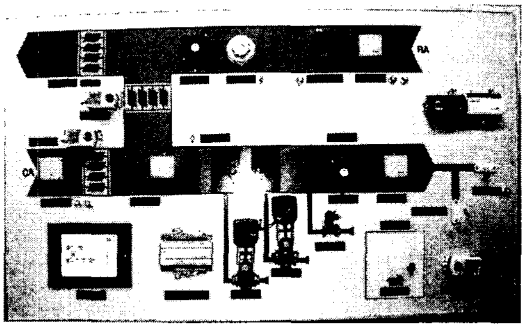

Fig. 5. View of a small simulator for AHU experimental system

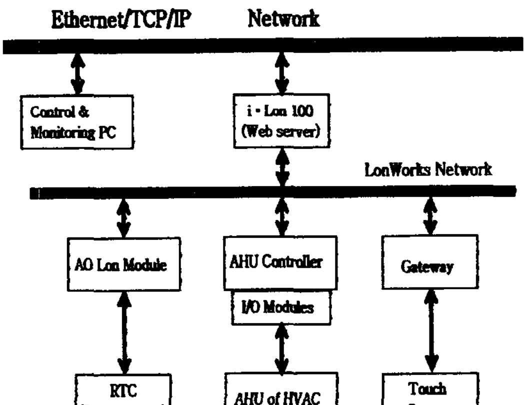

Fig. 6 Block diagram of experimental system

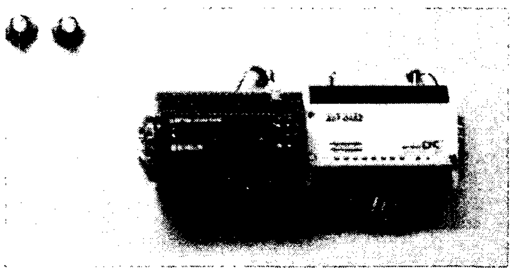

Fig. 7 LonWorks/Ethernet server

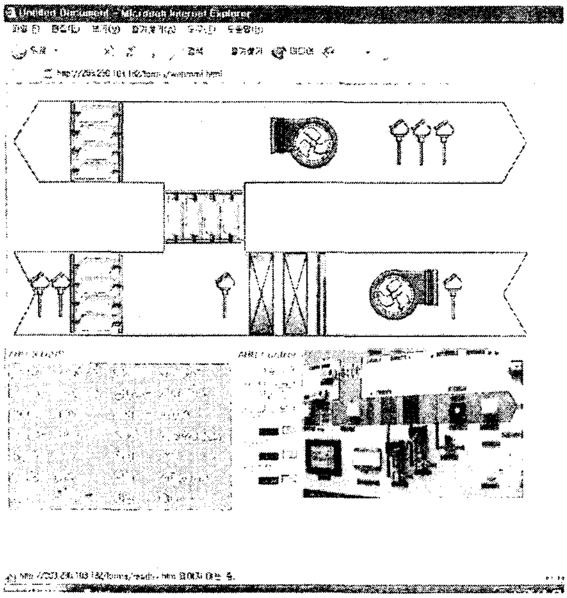

Fig.8 Web pages for controlling and monitoring AHU

5. Conclusions

This paper presents the architecture of Internet-based HVAC control and monitoring system using LonWorks fieldbus. An experimental system was configured for verification of the developed fieldbus control module and integration methods of control and data networks. The main results of the proposed Internet-based HVAC system, LonWorks protocols, and software systems suggest the following findings :

1) The architecture is flexible and scalable.

2) Compact and economical control module allows easier installation and connection of devices.

3) It can link easily with TCP/IP-based office network

The author expects to continue the study on issues related to integration this system with existing legacy control of BAS

Acknowledgments

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