Networked Intelligent Motor-Control Systems Using LonWorks Fieldbus

Won –Pyo Hong
Hanbat National University, Dukmyung-dong, Yuseung-gu, Deajeon, Korea
Phone: 82-42-821-1179 Fax: 82-42-1175 E-mail: wphong@hanbat.ac.kr, Website: http://www.hanbat.ac.kr

Abstract-**The integration of intelligent devices, devices-level networks, and software into motor control systems can deliver improved diagnostics, fast warnings for increased system reliability, design flexibility, and simplified wiring. Remote access to motor-control information also affords an opportunity for reduced exposure to hazardous voltage and improved personnel safety during startup and trouble-shooting. This paper presents LonWorks fieldbus networked intelligent induction control system architecture. Experimental bed system with two inverter motor driving system for controlling 1.5kW induction motor is configured for LonWorks networked intelligent motor control. In recent years, MCCs have evolved to include component technologies, such as variable-speed drives, solid-state starters, and electronic overload relays. Integration was accomplished through hardwiring to a programmable logic controller (PLC) or distributed control system (DCS). Device-level communication networks brought new possibilities for advanced monitoring, control and diagnostics. This LonWorks network offered the opportunity for greatly simplified wiring, eliminating the bundles of control interwiring and corresponding complex interwiring diagrams. An intelligent MCC connected in device level control network proves users with significant new information for preventing or minimizing downtime. This information includes warnings of abnormal operation, identification of trip causes, automated logging of events, and electronic documentation. In order to show the application of the multi-motors control system, the prototype control system is implemented. This paper is the first step to drive multi-motors with serial communication which can satisfy the real time operation using LonWorks network.**

I. INTRODUCTION

In recent years, the complicated control systems, such as manufacturing plants, vehicles, power plant field, aircraft, and spacecraft, serial communication networks are employed to exchange information and control signals between spatially distributed system components, like supervisory computers, and input-output(I/O) devices. Each of the system components connected directly to the network is donated as a node. When a control loop is closed via a serial communication channel, we label it a networked control system (NCS). NCSs are being adopted in many application areas for a number of reasons [1,2] including their low cost, reduced weight, and power requirements, simple installation and maintenance, and higher reliability. Induction motors are the workhorse of any industrial plant. They are used for many applications, ranging from driving compressors and pumps, to blowers, and machine tools. It is not uncommon to have over 10,000 motors in one facility. In an industrial nation, they can typically consume between 40 to 50% of all the generated capacity of that country [3, 4]. This article explores the fieldbus network architecture, intelligent devices and motor control center (MCC), and software required to integrate this new technology into motor control system. We focus on the fundamental application technology of fieldbus network to the induction motor control systems in the thermal power plants. Fielsbus provides a digital, two-way, multi-drop link among intelligent field device and automation systems. Emergence fieldbus accelerates digitalization in field devices and brings higher functionality to the field. This change of instrumentation systems then invites openness in process control systems. A new capacity for measurement, control implementation and process diagnostics is now available. The goal for any industrial process is straightforward: minimize overall cost, enhance productivity, and improve personnel safety. Communication and advanced sensing technologies now exist at the device level and recent advancement makes a completely integrated solution both practical and affordable. Today, motor-control systems occupy a prominent role in industrial processes. These systems are often housed in a motor control center (MCC) and contain a comprehensive array of control and monitoring devices. In recent years, MCCs have evolved to include component technologies, such as variable-speed drives, solid state starters, and electronic overload relays. These advanced technologies provide a great deal of data and have digital communication capability, primarily used for programming the device or equipment monitoring, but transforming these islands of data into useful information presents a major challenge. The distributed control system (DCS) is the current standard for large process control applications. Application and results of DCS systems have satisfied many customers. In the thermal power plant, DCS also plays an important role in control and monitoring the low and high voltage induction motor control system. MCCs in the thermal power plants have used hardwire interwiring for control and monitoring of ON/OFF status, and the MCCs sometimes included transducers for process monitoring feedback. Nowadays, only ON/OFF operating status of low voltage motor is monitored and the monitoring function of the bearing and stator temperature is added in the high voltage motors. DCSs have a single process control computer to which all of the sensors and actuators are connected. They control all parameters. Therefore, Device-level integration through digital communication so called fieldbus is the key to unlocking the full potential in the electronic controls being installed in industrial plants today[5,6]. The most feasible subject to be considered seems to be how to harmonize fieldbus with conventional DCS to work at a full potential. In this paper, we introduce LonWorks and Controller Area Network (CAN) network related to induction motor control. The most suitable LonWorks and CAN control modules are developed to control and monitor the multi-motor system. This experimental motor control system with 2 induction motors and inverter systems is also fabricated to evaluate the performance of each control module. In case of the speed synchronization for multi-motors, the complex sensing and signal systems usually used to detect each motor speed and command the desired speed. We plan to propose the real time control schemes for feedback control of the multi-motor system and finally also are verified experimentally. This is the medium results of my research about multi-motor control using fieldbus network such as LonWorks and CAN. Continual study results expect to be presented in the near future.

II. MOTOR CONTROL SYSTEM

A. Integrated Process and Motor Control System

During the engineering and design phase for any new industrial facility, it is desirable t o u tilize t he most c urrent t echnology. The MCC and the DCS are areas within an industrial facility that typically require a substantial amount of wiring to provide electrical equipment status and control. These systems include microprocessor based device with digital communication capability and therefore are candidates for integration. Typically, the hardware u tilized for the purpose of providing electrical equipment status are electrical contacts which are mechanically actuated by motor starters, contactors, breakers, or other on-off devices. These contacts provide discrete inputs to the DCS, either directly or through an interposing relay. Additionally the DCS controls the equipment within the MCC with contacts that are actuated by output relays within the DCS or through interposing relays. These actuated contacts may control motor starters, contactors, o r energize trip relays within the MCC. Depending on the specific requirement for operator display, analog quantities may be necessary to provide operating status such as voltage, current and power. These analog devices require additional hardware within the MCC and DCS. This hardware, including the interconnecting wiring, can be replaced, in part, by networking the microprocessor devices and allowing the equipment status and control information to be digitally communicated. In order to determine whether such an integrating system is desirable, the scope of the system need to be established. Some of major issues that require evaluation include: (1) the quantity and type of the signals required for the control and status of equipment within the facility, (2) identify the users of the system, (3) what are the operational requirements, (4) where is the physical location of the system, and (5) what are the budgetary limits. After an evaluation of these major issues it was determined that an integrated system was desired and a typical monitoring system was proposed. This system includes the microprocessor relay within the MCC functioning as intelligent remote terminal units that digitally communicate to the D CS on a multiple address system with shared communication channels. The system proposed include supervisory control and data acquisition only. The protective functions and shutdowns for equipment within the facility would be implemented using the conventional hardware to the facility's DCS. It was judged that the implementation of the proposed supervisory system would save significant time during the detailed design and on the overall installed cost of the electrical interface between the DCS and MCC. The additional advantages of utilizing microprocessor devices to provide motor protection and remote manual control were added benefits. A specification was developed for the low-voltage MCC that included the functional requirements for the proposed the monitoring system with provisions for integration into the facility DCS. The specification emphasized the use of the common hardware, open architecture, and object-oriented programming.

B. Intelligent Motor Control Components

In an intelligent MCC, every motor-control unit related to the process must have communication capability. Ideally, all the MCC units should also have input points to monitor devices, like the disconnect switch, contactor, overload relay, or hand-off-auto elector switch. The two basic types of devices that form the core of a networked MCC are intelligent overload relays and miniature distributed input-output (I/O) block.

Intelligent Overload Relay

The most common device in an intelligent MCC is a motor starter incorporating a solid-state overload relay. Features available in this intelligent overload relay include:

- Built-in network communication
- Input points for monitoring disconnect or selector switch
- Output points for controlling the contractor
- LED for status indication
- Protective functions: thermal overload, underload, jam, current imbalance, stall, phase loss, and zero sequence ground fault.
- Programmable parameters for the protective functions: trip level, warning level, time delay, and inhibit window.
- Current monitoring: Phase, average, percent full load, ground fault, imbalance, and thermal capacity.
- Diagnostics: time to overload trip/reset and history of trips.

Minimum Distributed I/O Blocks

Disconnects, circuit breakers, and nonintelligent starters have no means to communicate directly with networks. A distributed I/O block within the unit can link these devices to the network. The i/O block must have an adequate number of input and outputs but be small enough so that the MCC unit size is not altered. Four inputs and two outputs satisfy most motor-starter applications, since this allows monitoring of the contactor, disconnect, overload-relay auxiliary contact, and, if present, hand-off-auto selector switch.

Preconfigured Monitoring Software

To integrate the intelligent MCC h ardware e lements a nd deliver useful r eal-time i nformation with m inimal expense and efforts, a preconfigured monitoring software package offers an effective solution. This M CC so ftware eliminates c ostly customized M CC screens within operator interface software, yielding a plug-and-play solution.

Integrated Electronic Documentation

Good documentation is necessary for efficient startup and troubleshooting, but the documentation is either incomplete or misplaced altogether. I n the c ase of the i ntelligent M CC, e lectronic documentation can be accessed on the same PC running the monitoring software. This allows the users not only to view the real status of the MCC but also to view computer aided design drawings, user manuals, and spare parts information applicable to specific MCC units.

III. DEVELOPMENT AND DESIGN OF INTELLIGENT NODE WITH HIGHER PERFORMANCE

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.

A. Intelligent LonWorks node

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 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 presentation of 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. Most of intelligent functions are implemented by embedded neuron networks stored in EEPROM. 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].

B. LonWorks Hardware Configuration of Motor Drive Control Module

This module with high performance and compactness was developed to control and monitor the multi-motor systems. The basic contracts and scheduler are included. This controller has 29 I/O channels RTC (real time clock) scheduler, induction motor controller, digital scheduler and RTC function block, and PID Function block. Table 1 represents the detailed specification of a LonWorks control module for the precision control of induction motor. This LonWorks module was developed for controlling and monitoring AHU and this performance was already proved from the current utilization of this module in the fields. We developed another LonWorks control module that these can use in the low voltage motor control, such as AO, AI, DI, and DO control modules. The specification and characteristics of these modules are represented in Table 2.

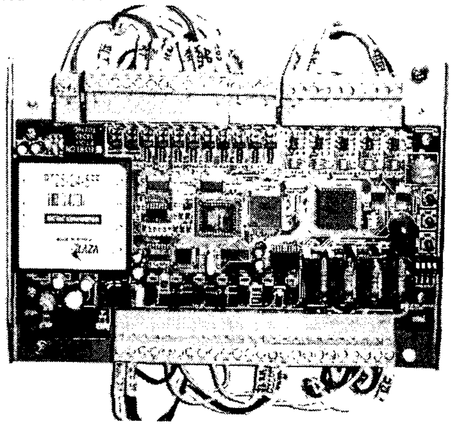

Fig. 1 Controller modules for AHU

Table 1 Hardware specification of AHU controller module

Items	Specification
Hardware	Processor type : FT3150 Processor Clock : 10MHz Memory:32K SRAM,32K ROM Communication Protocol: LonTalk Transceiver Type : FT-X1(Smart) Operating Voltage :AC/DC 18-36V I/O Channels : . Analog Input : 11 . Analog Output : 5 . Digital Input : 7 . Digital Output : 4
Scheduler	Real Time Clock
F.B.	PID Functional Block. AHU FB. Digital Scheduler RTC Controller

Table 2 Specification of the LonWorks I/O modules

ITEMS	Spec.	characteristics
DI modules	8 channels voltage (5 ~ 30 DCV) dry Contact (Max 15 kOhm Load) frequency Input 1 ~ 5 Ch Max 300Hz 6 ~ 8 Ch Max 30KHz pulse Count : 100Pulse/Sec	Input power : 16 ~ 30 VAC or VDC Neuron 3150 chip, 10MHz, 32K byte Flash ROM, 24K byte SRAM
DO modules	8 channels 3A 277V AC 3A 30V DC	Input power : 16 ~ 30 VAC or VDC Neuron 3150 chip, 10MHz
AI module	voltage 0 ~ 10 V current 0 ~ 20 mA resistance (0 ~ 50 kohm)	16bit analog input Input power : 16 ~ 30 VAC or VDC Neuron 3150 chip, 10MHz
AO module	Voltage 0~10V (Min 1K Ohm Load) Current 4~20mA (Max 550 Ohm)	12-bit Analog Outputs Two PID Controllers Input power : 16 ~ 30 VAC or VDC

VI. EXPERIMENTAL RESULTS

The developed LonWorks control modules was applied to test their performance and availability in the single duct with variable volume systems. Fig. shows single duct, variable air volume (VAV) systems combine the simplicity of the single duct s ystem with energy saving due to variable air volume control. The AHU has two fan systems, such as the supply fan and return fan. To keep the constant pressure of the supply duct system generated by the load variation of the conditioned room. The fan speed should be controlled by the variable voltage variable frequency (VVVF) system, so called inverter driving system. Especially, our research groups focus on the application of LonWorks modules to these inverter driving systems. Table 3 represents the specification of the inverter and the induction motors. The two inverters installed in the motor control center (MCC) are shown in Fig. 3. The Inverter systems were used, which were fabricated by LG Industrial company. They are capable of operating the closed loop and vector control Two LonWorks control modules for controlling the speed of induction motors are represented in Fig. 5. These modules are LonMark devices that provide 12 bit analog output that can control 0-20mA or 0-10V actuators. Using LonMark tool, the user links together the functional blocks of the AO, other LonWorks devices. To created open distributed control system. Networks design and configuration id simplified by the VISIO interface of the LonMark tool.

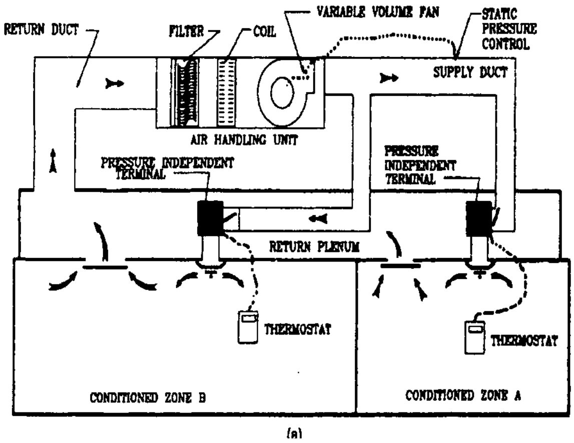

Fig. 2 Schematic view of Air Handling Unit of HVAC

Table 3 Specification of inverters and induction

items		Supply Fan	Return Fan	
Inverter iS4-5		037	022	LG Co.
Rating for I.M		3.7kW	2.2kW	LG Co.
Output rating of inverter	kVA	6.1	4.5	
	Current(A)	8	6	
	frequency	0- 40Hz(sensorless vector control: 0-300Hz), vector control: 0-120Hz		
	Votage	380-460V		
Input rating	Voltage	3 phase 380-460		
	frequency	50-60Hz		

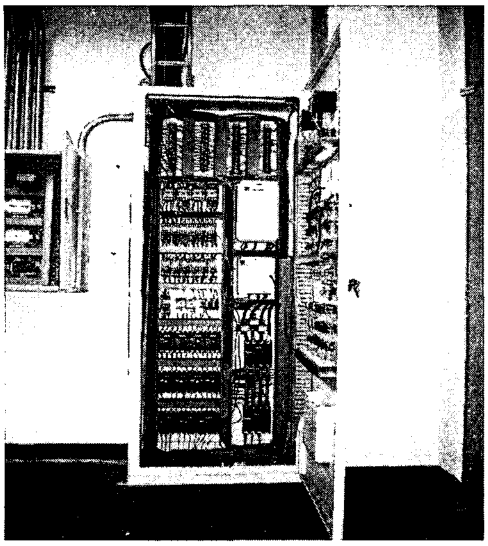

Fig. 3 View of Motor Control Panel

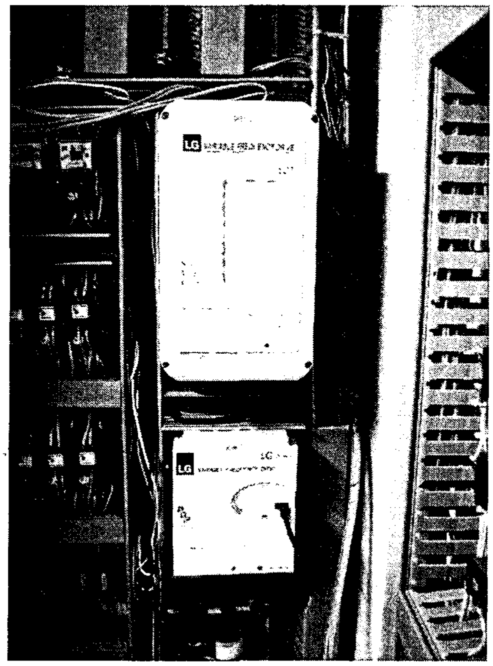

Fig.4 View of Motor Control Panel

The module operates from 18-36VAC or VDC, allowing it to powered from the same sources as the actuators. Resident within the module is a powerful, configurable application program. The program includes a variety of the software functional blocks that define how module will function. Analog Output functional blocks provide configurable input value to out signal translation, preset, override, and heartbeat control of the analog control. PID Controller functional blocks provide configurable closed-loop control of the analog output. Analog functional blocks perform configurable logic, math, or enthalpy calculations on two analog inputs to generate analog and digital outputs. These LonWorks control modules to be installed in MCC can play an important role for controlling the motors. The Intelligent MCC born again from the conventional one can satisfy the requirements of the advanced and intelligent control. An intelligent MCC solution would address these requirements through the use of a device-level communication network, intelligent motor control components, and integrated preconfigured software.

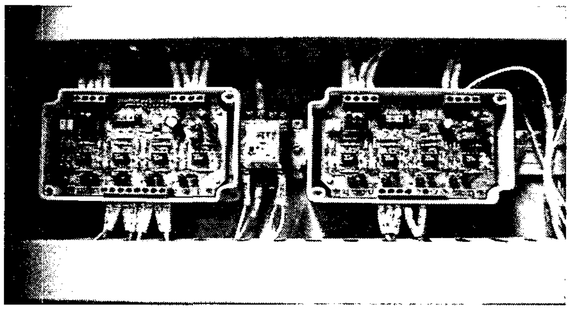

Fig. 5 LonWorks control modules for 2 inverters of supply and return fan

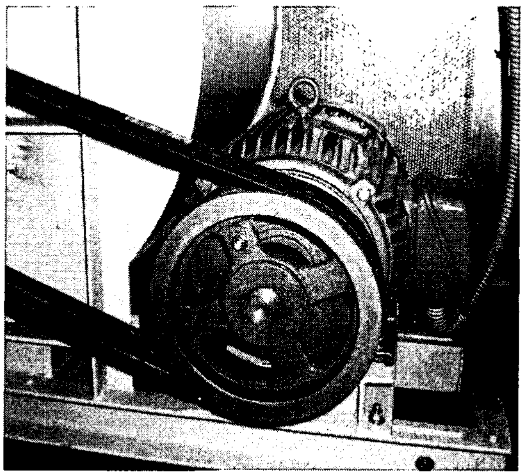

Fig. 4 Indu6ction motor for supply fan of AHU

V. Summary and Conclusion

Recently the networked control became a hot research area in process control practice and communication due to advances in computer technology, software engineering, in expensive sensory and control practice. Therefore, Technology has reached the point where it is both practical and affordable to utilize networked intelligent motor-control system using fieldbus network. An intelligent MCC installed with fieldbus control modules provides users with significant new information for preventing or minimizing downtime. This information includes warnings of abnormal operation, identification of trip causes, automated logging of events, and electronic documentation. We developed the intelligent control modules with IEEE/EIA 709.1 protocol for controlling and monitoring multi-motor system. To valify the performance and availability of these control modules, These modules are applied in the practical field of the air handling units that is operating in our university. It is confirmed that the inverter system control very well the speed of supply fan and return fan to keep the constant static pressure of supply duct. In next study, the multi-motor control system including the closed loop system that motor speed is sensed is implemented and then experimented. The intelligent MCC is also implemented in this system.

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