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Communication Redundancy for Reliability Improvement in an Industrial Monitoring and Control System

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Abstract : In development of monitoring and control systems, one of the most important points is to consider a redundancy so that the system can be operated normally although hardware faults are partly occurred. The purpose of this paper is to introduce a monitoring and control system with a redundancy function for I/O servers and communication networks. I/O servers composed with an active server and a standby server. Each server also has 3 communication ports. 2 ports of them were connected to field units and the other 1 port was connected to the other server. Field units have to be constructed to 2 communication ports connected I/O servers through communication lines. Also, server communication module was implemented for analyzing and handling fault elements, and was submodularized for linking easily with a monitoring and control module. An experiment with 2 servers and 2 field units was constructed to demonstrate its effectiveness.

Key words : Monitoring and Control System, I/O Server, Redundancy, Ethernet-based Communication Network, Fault Detection and Treatment.

1. Introduction

With the development of communication technologies, monitoring and control systems have been used in many fields. The systems monitor and control field-side devices at remote place by using a computer technology, and also support to a diagnosis and a trouble shooting when faults are occurred. In an early stage, a monitoring function was operated on computers in remote side and the control function was operated on the devices in field side. But nowadays, these functions are coupled together and operated on computers according to the development of a computer technology. Integration of functions requests reliability of computers and communication lines. In the system, one of the most important things consider a redundancy so that the system can be operated safely although

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hardware faults are partly occurred[1]-[3].

Recently, SCADA systems are used to develop a monitoring and control systems in industrial fields. Typical examples of the systems are In-touch, CITECT, KDT, UMS, HIPDS, and so on[4]-[6]. These systems are only supported by a single network or a lower level redundant network redundancy for field side. It is difficult to build a redundant network because the field devices consisting of the systems are using different protocols and interfaces. The systems, therefore, have a tendency to improve user interface only rather than to make better reliability.

This paper focuses to introduce a monitoring and control system with redundancy for I/O servers and communication networks. The system has an active server and a standby server. Each server also has 3 communication ports, 2 ports of them are connected to field units and the other 1 port is connected to another server. Field units have to be constructed to 2 communication ports connected to I/O servers through communication lines. Also, the server communication module is implemented for analyzing and handling the fault elements, and is submodularized for linking easily with a monitoring and control module. An experiment with 2 servers and 2 field units is carried out to demonstrate its effectiveness.

2. A general monitoring and control system

2.1 The present status

In industrial fields, systems are generally divided into an upper level network and a lower level network, and are constructed with Ethernet-based network for the upper level network and to filed bus network for the lower level network, as Profibus, Devicenet, and so on.

Therefore, it is a good solution to adopt the communication interface to connect to the upper level networks and the lower level network as follows[6]-[8]:

(1) Ethernet and Fieldbus (Profibus-DP, DeviceNet, LonWorks, and so on)
(2) Ethernet and serial communication
(3) Ethernet and Ethernet

The appearance of networks to connect all devices in one standard protocol might be impossible because of the concern among many companies. Therefore, many networks are connected together. An integrated networks are not just to connect all devices in one network and are only to connect devices to Ethernet. In an industrial system, a communication protocol can be different between upper level network and lower level network.

2.2 General structure of communication network

A monitoring and control system has generally several functions, such as alarm, trend, report, file, mimic, control, and so on. In early stage, the system was constructed and a computer had all functions. Nowadays, a computer has organized to operate only one function, since functions are getting to be complicated. It means that the system needs to be operated reliantly. For that, the system has to be organized with redundancy. There are 4 types of network, such as a single network, an I/O server redundancy, an upper level network, and a whole network redundancy.

In a single network system, one computer has one function. Servers are also connected to LAN, and I/O servers, and field control units are connected to fieldbus Ethernet and serial communication.

In an I/O server redundancy network system, the I/O servers are organized server in order to improve the communication reliability of field data. If a active I/O server is down, a standby I/O server acts automatically.

In an upper level network, the redundancy system has 2 I/O servers, 2 LAN cable control servers, and so on. In this system, the other servers except I/O servers can communicate each I/O server. Therefore, the system can deal with the trouble of I/O servers as well as the trouble of LAN cables.

In a whole network, the redundancy system has 2 I/O servers, 2 LAN cables, 2 fieldbus cables, and so on. Therefore, the system can deal with trouble of I/O servers and I/O communication modules in field units.

3. The proposed system

We developed an industrial monitoring system for ship's engine room as shown in Fig. 1. The upper level network of the system was constructed to Ethernet and the lower level network can use Ethernet, LON, or RS-485.

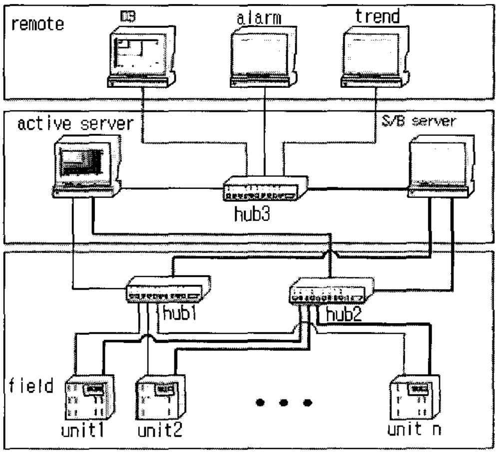

Fig. 1 The proposed monitoring and control system

The system has specially the redundancy for I/O servers and I/O cables. The I/O servers are called an active server and a standby server. Fig. 2 shows communication modules of I/O servers and the lower level networks. The modules are divided into a device connection module, a data management module, a server status management module, and a data save module. Modules are also acted through a management shared by memory or a device shared by memory.

Management shared by memory is organized as follows;

device line status : 2 × number of field units [byte]

device information : 1 × numbers of field units [Byte]

value information : 1 × numbers of field units [Byte]

value[i] = numbers of data from field units × data size [Byte]

Data size is 3 bytes in an analog value, but 1 byte in a digital value. Device line status means the status of a field unit and a communication line. Device information means an error of a field unit. Value information means whether data are digital values or analog values.

Device shared by memory is organized as follows;

device line status : 2 × number of field units [byte]

device information : 1 × numbers of field units [Byte]

value information : 1 × numbers of field units [Byte]

value[i] = numbers of data from field units × data size [Byte]

Data information means whether data are digital values or analog values, and this value is increased if number of field units are increased.

Data management module has the function as follows;

(1) To create the management shared by memory and device shared by memory

(2) To execute the device connection module

(3) To renew the management shared by memory

(4) To call the monitoring and control module

Device connection module is composed to a connection management thread and a data collection thread. Connection management thread is executed as follows;

(1) If a field unit is connected, the thread creates the data collection thread

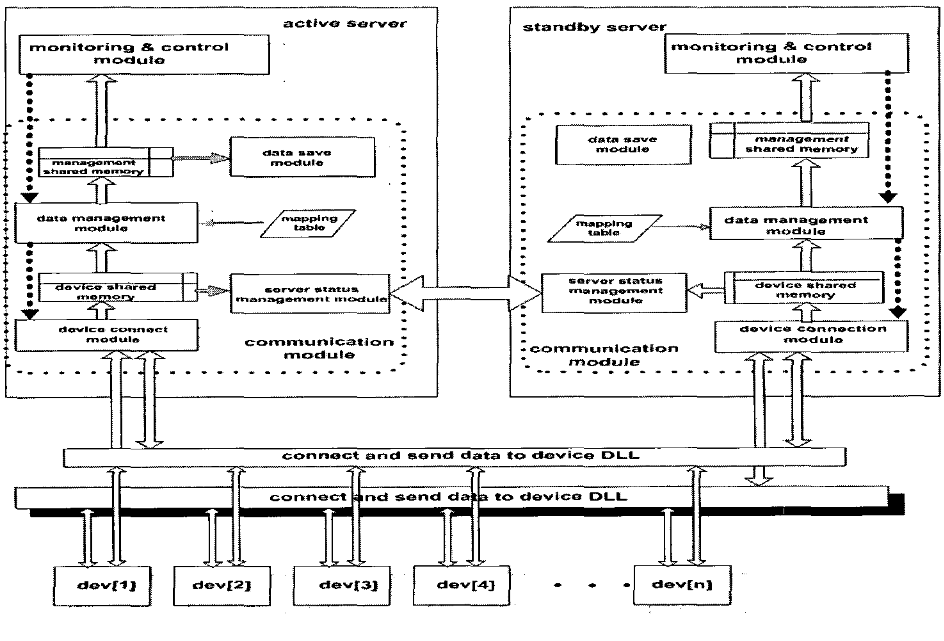

Fig. 2 Software structure of the proposed system

for the unit and appends it in field unit's connection list.

(2) The thread executes to the data collection thread in field unit's connection list in a row.

(3) The thread checks error of communication lines.

(4) If the thread detects error of communication lines, the standby server is acted.

Data collection thread is executed as follows:

(1) To initialize the variables and wait a self turn.

(2) To analyze received device whether a function is command or data.

(3) If a command or a data reply, write data in the device shared memory.

(4) To check a response time, if it exceeds a limited time, confirm error of communication lines. If it exceeds a limited time, confirm error of loop.

Server status management module has functions as follows:

(1) To use TCP/IP protocol between the active server and the standby server.

(2) In the active server, the module sends the data of the device shared memory to the module of the standby server.

(3) The modules in the active server and the standby server confirm the communication state of the other one together.

(4) The modules send or receive a server switch-over message by user request or communication error.

4. Fault Detection and Treatment

The system can be simplified as shown in Fig. 3. In this system, two kinds of fault can exist in communication faults. One is the fault of the active server and the other is the fault of the communication lines or the field units. For confirming the faults of the active server, the standby server checks periodically the status of the active server using 3 methods as follows:

(1) standby server → ⓑ → hub3 → ⓐ → active server

(2) standby server → ⓕ → hub1 → ⓓ → active server

(3) standby server → ⓖ → hub2 → ⓒ → active server

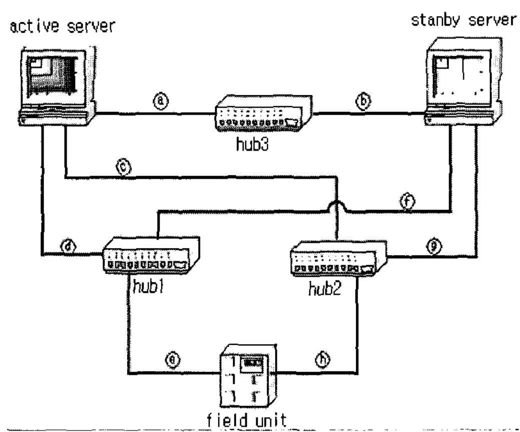

Fig. 3 The simplified structure of the system

There are 4 cases of communication faults. First, if the active server is active and fault in ⓔ (or ⓗ) location is occured, communication way of the active server will be changed to ⓒ → hub2 → ⓗ (or ⓓ

Table 1 Communication faults related to the active server

fault location	treatment
ⓔ / ⓗ	■ To Change a communication interface to ⓗ/ⓔ line. ■ The field unit occurring communication error will communicate to the other hub.
ⓒ / ⓓ	■ To Change a communication interface to ⓓ/ⓒ line. ■ The other hub will be activated.

Table 2 Communication faults related to the standby server

fault location	treatment
ⓔ / ⓗ	■ To Change a communication interface to ⓗ/ⓔ line. ■ The field unit occurring communication error will communicate to the other hub.
ⓕ / ⓖ	■ To Change a communication interface to ⓖ/ⓕ line. ■ The other hub will be activated.

→ hub1 → ⓔ), as shown in Figure 3 and table 1, 2. Second, if the standby server is active and fault in ⓔ (or ⓗ) location is occured, communication way of the active server will be changed to ⓖ → hub2 → ⓗ (or ⓕ → hub1 → ⓔ). Third, if the active server is active and fault in ⓒ (or ⓓ) location is occured, communication way of active server will be changed to ⓓ→ hub1 → ⓔ (or ⓒ → hub2 → ⓗ). Fourth, if the standby server is active and fault in ⓕ (or ⓖ) is occured, communication way of the active server will be changed to ⓖ → hub2 → ⓗ (or ⓕ → hub1 → ⓔ).

5. Experimental results

Development environment of the system was as follows:

- ■ OS : Windows 2000
- ■ Compiler : Borland C++ Builder 5.0 and MS Visual C++ 6.0
- ■ I/O server : 2 PCs with Intel Pentium 2.0GHz
- ■ Network : TCP/IP protocol and 3 HUBs
- ■ Field units : IIM7100A test boards

The experiment for detection of communication error was done according to 5 circumstances as follows:

(1) To power off hub1.
(2) To power off active server.
(3) To power off field unit.

Fig. 4 shows the communication error in case of (1). The system decides that hub1 is fault because ⓓ, ⓕ, and ⓔ are inactivated, and displays "hub1 error!!".

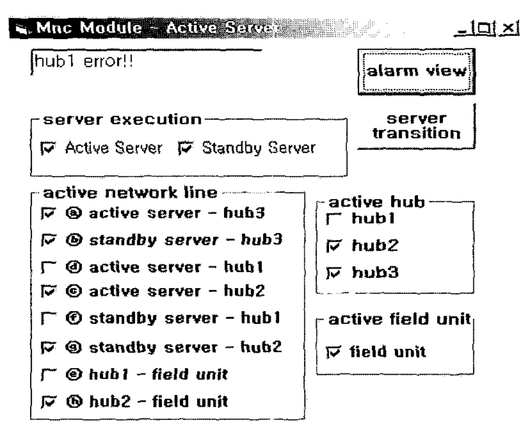

Fig. 4 Detecting fault of hub1 in active server side

Fig. 5 shows the communication error in case of (3). The system decides that active server is fault because ⓐ, ⓓ, and ⓒ are inactivated, and displays "active server down!!". Fig. 6 shows the communication error in case of (4). The system decides that field unit is fault because ⓔ and ⓗ are inactivated, and displays "field unit error!!".

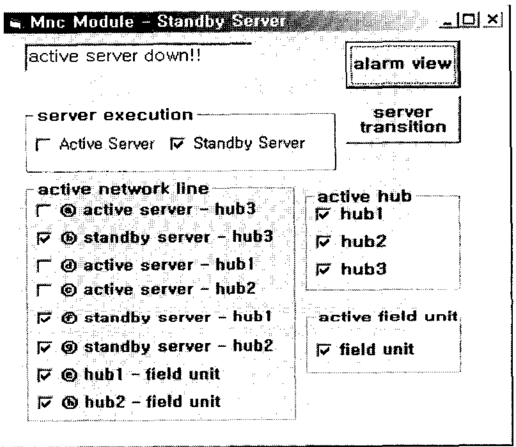

Fig. 5 Detecting fault of active server in standby server side

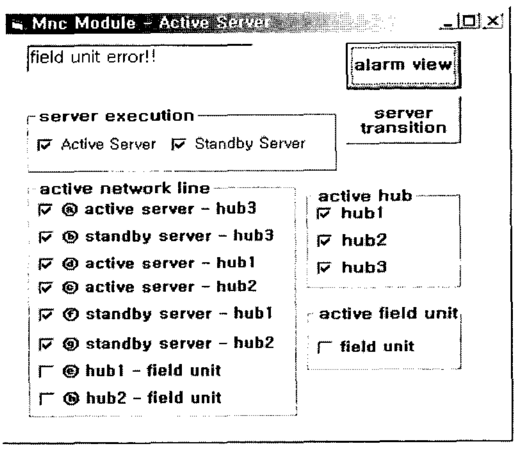

Fig. 6 Detecting fault of field unit

6. Conclusion

The system with I/O servers and multi communication networks has successfully developed. If a communication error occurs, the system will change I/O server or communication way. By organization method of the system, the several specifications are summarized as follows:

(1) Reliability of the system with I/O servers and multi communication networks will improve higher than other system with multi communication networks only.

(2) Sub-modularization of communication modules will be updated and deployed easily.

(3) The system detects the error for one device only, and needs to improve decision algorithm to find communication error for multi devices and an intelligent transition of I/O servers.

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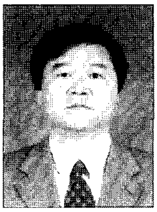

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