Redundant System based PLC Network for High Priority Process

T. Suesut, Prayut Inban. A. Numsomran, V. Tipsuwanporn
Faculty of Engineering,
King Mongkuts Institute of Technology Ladkrabang, Bangkok, Thailand.
Tel : (66-2)326-7347: ext.102, E-mail kstaweep@kmitl.ac.th

Abstract: This paper presents the development of Programmable Logic Controller (PLC) and network to design the redundant control system in order to control the high priority process. The industrial process that cannot be shutdown or the effect of the shutting down takes abundantly damage. In this article, we say that the high priority process. The redundant systems are designed for controlling the high priority process that the control system must have many controllers to instead the main controller when it has some error. This paper we designed the redundancy control system by the advantage of the high-speed communication on the PLC's network. The temperature control system and the traffic light control system used as the case study. Each example processes consist of two sets of controller. Our scheme we can increase the reliability prevents process down time and reduces the cost of opportunity to loss also.

1.Introduction

The PLC is widely used to control many kind processes such as discrete process or continuous process. It has been developed the special function for example PID control, Fuzzy control, positioning control as well as the communication and network system. By the advantage of high-speed communication therefore appropriate to design the redundant control system for the high priority process. The high priority process means the important process that cannot stop or controller cannot control if this process stops it will take many problems in production line and has affect to other process. This even must be lost a lot of cost and time to maintenance. Redundant system is the way to solve this problem because it has more than one controller to control process.

2. Redundant System

Redundant system has design for high reliability control to prevent failure in the system but it makes high cost too. Redundant has several types such as cold standby, hot standby, CPU-redundancy, full dual redundancy and fault tolerant system for more than two modules of controller. Each type has different its advantage and disadvantage which appropriate with different level of high priority process and mean time to shutdown of each process.

2.1Parallel system reliability
The system consists two independent system connected in parallel as shown in figure 1.

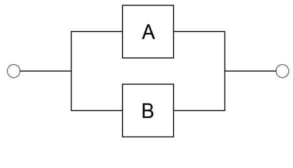

Fig 1. Parallel system

For the parallel system, if system A or system B can be worked that means the system can be succeeded control. The system reliability can be obtain by

$$R_p = 1 - Q_A \bullet Q_B \quad (1)$$

$$R_p = R_A + R_B - R_A \bullet R_B \quad (2)$$

From equation number (1) and (2), if the numbers of parallel system increases that means reliability is increased but when the number of parallel system increased, it will be increasing cost and more maintenance required also.

2.2 Cold standby system

Cold standby system has one backup system that can switch from active system to standby system quickly when active system have some problem which make active system cannot control the process. This method can reduce time to change a spare part in order to maintenance the system. Because it has a spare part that installed and waits to operation when active system has problems. The cost of this method is double and plus the cost of switching device. It is appropriate for longer permission downtime process.

2.3 Hot standby system

Hot standby system is use widely in industry. It looks like cold standby system but the spare system is operation synchronize with active system and detect failure of active system. If active system failure, spare system will take over control process from active system automatically but the outputs of controllers need time to recover state. If recover time is more than permission downtime then process must be shut down. The CPU redundancy method is linking CPUs with high-speed bus and copy active CPU status to standby CPU over the bus when active CPU fails the standby CPU will use this information to resume operation. Full dual redundancy has two systems of the CPU and I/O modules which operating at the same time but one output will send to control process by output switching. Fail tolerant system use for some processes that cannot have interrupt control because all components are active all time and the output is selected from output voter. The advantage of fail tolerant system is make uninterrupted control because all of controller are voting result of control data before send signal to control process therefore if one unit of controller fail, it has not affect to output signal.

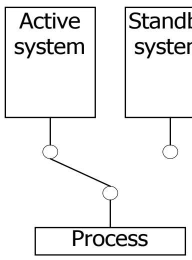

Fig. 2. Cold redundancy

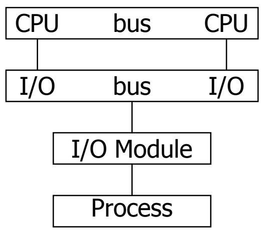

Fig. 3. CPU redundancy

3. PLC and Network system

The PLC communication network systems have many communication physical protocols for the flexible manufacturing system such as RS232C, RS485, CAN Bus, Fieldsbus etc, through the twisted pair, coaxial or fiber-optic cable as the communication media. We choose two PLC for controlling a high priority process. Each PLC has many special functions to control process such as PID control. Typically PLC has designed for discrete system but present PLC has more efficient, it can control continuous system by their special instruction and special I/O units. For continuous process, the PLC must have the special I/O unit to convert analog signal to digital signal for input unit and convert digital signal to analog signal for output unit. Input unit takes analog signal form process to PLC called Analog-to-Digital unit and output unit takes digital signal from PLC to process called Digital-to-Analog unit. When PLC receive data from process via input unit, special instructions are used to process data following the program and generate output data to output unit for send output signal from output unit to control the process. In this paper we used the OMRON factory automations network that is the Local Area Network for industrial applications. The specifications of this network system are shows on table 1.

Table 1. PLC network specification

No	Description	Specification
1	Network Topology	Token-ring
2	Communication media	Fiber optic
3	Distance	3km with repeater
4	Data transmission	2 Mbps
5	Maximum node per loop	126 nodes per loop
6	Maximum message size	2 kbyte
7	Protocol	TCP/IP

The Fiber-optic local area network has automatic loop back function to prevent a failure on optical transmission paths. The loop back function automatically makes new communications paths at the time of any optical fiber cable are disconnected. Normal loops of network as shown in figure 4. All nodes can communication normally. Thus the automatic loop back can be increased the reliability on communication network as well.

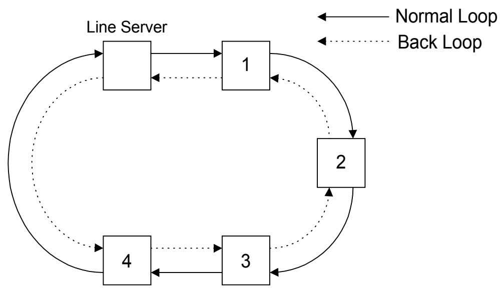

Fig. 4. Normal loop

When fiber optic path between node 3 and node 4 are disconnected. Node 3 is an upstream back-loop node and node 4 is downstream back-loop node. The condition of the other nodes is operating normal. If have two broken wire are disconnected then the node between two broken wire are disconnected from network but the other nodes still normal. Loop back function of fiber optic network gives more reliability than normal network cause if communication paths are disconnected the other paths in network without any affect.

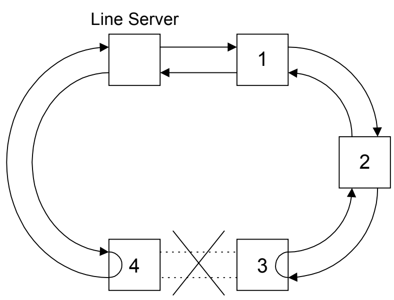

Fig.5. Back loop

Each PLC has link area for transfer data together. It can write data on specific area. Other PLC can read that data automatically therefore if we use this link area, we can copy current state to other PLC in network for transfer information of active PLC and if active PLC failure standby PLC has take over control process from active PLC.

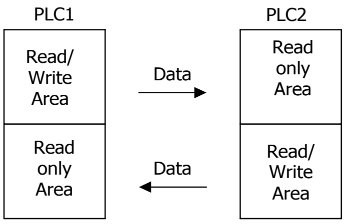

Fig. 6. Link area

4.System Design

The system design is divided into two parts, there are hardware and software. This paper we choose two PLCs for experimental system. Figure 7 has shown the system diagram

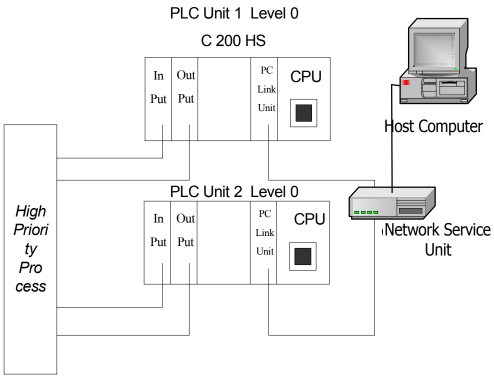

Fig. 7. System diagram

The host computer is the supervisory control system. All software such as PLC programming, data acquisition and monitoring are operated on this computer. The host computer has network service unit to communicate with the PLC for exchanging data. The system diagram has two CPU modules of fiber-optic PLC network. All CPU can exchange data together and communicate to host computer with high-speed rate. If one CPU unit has fail then other CPU still operates and sends output data to output signal to control process continuously.

The operation of the redundancy system flow chart is shown on fig. 8. The PLC unit number 1 worked as the active system and the PLC unit number 2 worked as the standby system. When the active system has failure condition by any reasons such as ladder program error, power supply failed and communication error. Consequently, the standby system will be operating instead the active system and then alarming on the host computer in order to maintain system.

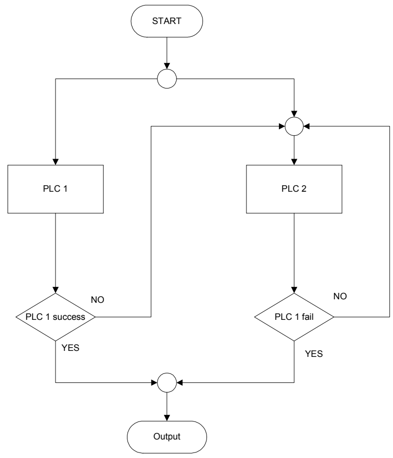

Fig. 8. System operation

5.Implementation

In this system, we implement for 2 applications. There is temperature process control and traffic light control system. Figure 7 shown temperature process is controlled by fiber optic PLCs network. There are two PLCs connect together with fiber-optic local area network and PLC1 have analog input connect to sensor element (RTD) to detect temperature in heat chamber and analog output connect to heater for control heater to give temperature with heat chamber. This temperature process has controlled by PID function in each PLC, which have same program for control temperature process. The PLCs are receive same input signal data from link area and take this data to processing in PID block function at the same time and generate output data of each PLC and send output data to voter. When voter receive two output data from each PLC, voter will send one appropriate data to analog output unit to convert output data be output signal and send to control heater.

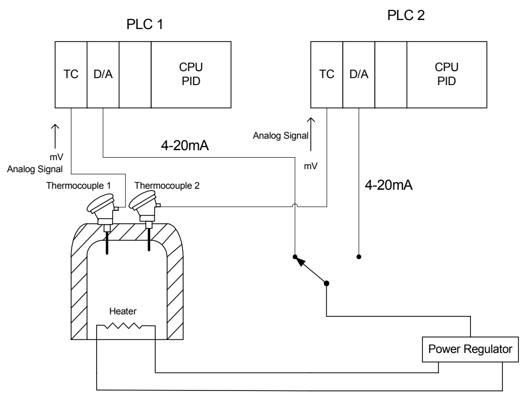

Fig. 9. Temperature process control.

When sensing element has detected temperature in heather chamber, it sends a little signal to amplifier for amplify signal to standard signal (4-20mA) and send signal to analog input unit. Analog input unit is 12bit-resolution converts 4-20mA signal to 0-4000 data input for PID function, in the other word, analog output unit is 12bit-resolution convert 0-4000 data from voter to 4-20mA signal and send to amplifier to expand signal for control heater. The experimental result has shown on fig 10 with the arrow that points the interval time when the active system has error and then the standby system is working instead.

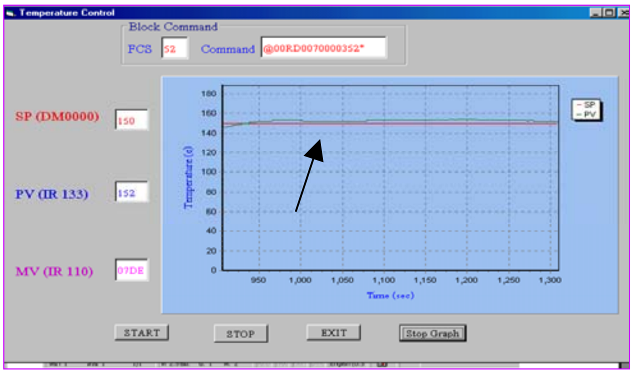

Fig.10. Experimental result.

In experimental method, assume CPU of PLC1 has fail by stop PID function in program of PLC1 and observe output signal.
The traffic light control system is the model of the crossroad with 4 points of traffic light. In the experimental method we assumed the active system was turned off power supply and then the standby system operated instead immediately.

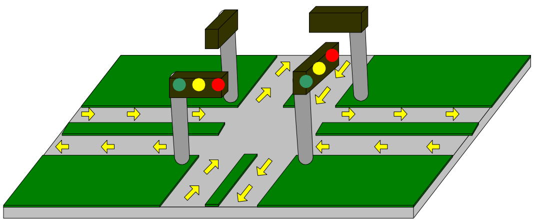

Fig. 11. The traffic light control system.

6.Conclusion

In this paper, the experimental of two PLCs control temperature process and the traffic light control system via fiber-optic local area network with redundancy system can control temperature process continuously although CPU of PLC1 has fail, other CPU in network still control process. This means temperature process has long permission down time therefore output signal can recover respond on range of permission down time of temperature process. If other process has shorter permission down time than temperature process, we may consider other method to improve redundant system for control that process. Thus we can consider failure tolerant system to control high priority process for more reliability prevent process down time and reduce maintenance time. PLC network has more efficient than one PLC; it has some ability such as data exchange, redundant properties, back-up data etc. for more reliability system.

Reference

[1] Roy Billinton and Ronald N. Allan, *"Reliability Evaluation of Engineering Systems"* PLENUM PRESS Newyork,1992
[2] Wayne Johnston, *"A Survey of Redundant Control Methods"* CONTROL MICROSYSTEM INC.
[3] Louis P. Bolduc, *"Redundancy Management System"* IEEE AESS Sstems Magazine, May 2001
[4] Michael A. Martin and Robert R. Buell, *"Pinelines, Programmable Logic Controllers, and Safety"* IEEE,1997
[5] FA NETWORK, Sysmac net, Operation manual, OMRON Electronics, Japan, 1990
[6] Sysmac C200HS, Operation manual, OMRON Electronics, Japan, 1990