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Research and Design of Nuclear Fuel Manipulate Crane Control System

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Abstract

In order to solve the disadvantages of the Nuclear Fuel Manipulate Crane (ab. MC), the control system of MC is researched and designed, which is based on the operation experiences about Nuclear Fuel Transtion and Storage System (ab.PMC) in Daya Bay and Ling'ao Nuclear Power Plant.The new control system adopts single failure principle and makes use of the Device-net technology that is diffusely applied and extraordinary tried in practice. There are two Device-nets and one Ethernet, the two kinds of nets are combined.Applying the new technologies and new equipments, the new control system solves the defects which Ethernet and a single set of PLC don't satisfy single failure principle, improves the safety and whole performance of MC loading and unloading of nuclear fuel assembly, and makes control system simply to wire. According to the design of the new control system, the product of MC has been successfully applied to Educate Center in Daya Bay Nuclear Power Site and Fangchenggang Nuclear Power Plant, and the result is obvious.

Keywords: *PMC, manipulate crane, ethernet, device-net, control system*

1. Introduction

The Nuclear Fuel Manipulator Crane (ab. MC) is one of the essential equipments in a nuclear power station. 5.19 Event that is the most serious accident in China is aroused by the control system of MC. The major suppliers of PMC are Westhouse in America and REEL in France. Westhouse's control system is advanced but with poor security, because their products heavily depended on Ethernet, and some designs of control system aren't consistent with single failure principle, the equipment was from Westhouse in 5.19 Event. REEL's products have better security, but are conservative, the new technologies and equipments aren't applied into control systems. With the rapid development of control technologies, it is necessary to have an in-depth study of MC to apply the new technologies and equipments and make the control system to more advance and safer [1-7].

Making a particular analysis on the function requirements of CPR1000 and CNP1000, combined operation experiences in Daya Bay and Ling'ao Nuclear Power Plants, this paper designs a whole structure of control system, which is designed around one Ethernet and two Device-net bus networks, and based on single failure principle.

2. Overall Control Model

MC, above the RX Pool, mainly consists of bridge, trolley, hoist, auxiliary crane, and so on. It can move on the X-Y-Z coordinates, revolve 0~360° in reactor core, control the gripper to grasp and loosen nuclear fuel assembly.

The new design of MC control system is still adopted master/slave mode which with mature technology and widely used. The core equipments consist of Upper Computer (touch screen computer), Programmable Logic Controller (PLC), Drive and Servo Motor. The difference is to add a Safety PLC to protect security [8-16]. The overall control model is shown in Figure 1.

In Figure 1, Fuel Operator inputs the control signals into PLC by Upper Computer and Operating Equipment, and process the feedback data from PLC. Upper Computer displays the necessary information. Work PLC controls the DRIVE after receiving the command inputting by

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Fuel Operator, then processes the feedback data from DRIVE and sends related information to Upper Computer. When getting PLC commands, the DRIVE executes relevant actions to control Servo Motor running and can detect servo motor in real time, it passes the relevant message to PLC. Servo motor is running under the control of DRIVE and feedback the running state to DRVIE though internal sensor. The new added Safety PLC is redundant design for the security of Work PLC, aims to give security protection to the running of MC and resolve the defects of Work PLC with single failure principle.

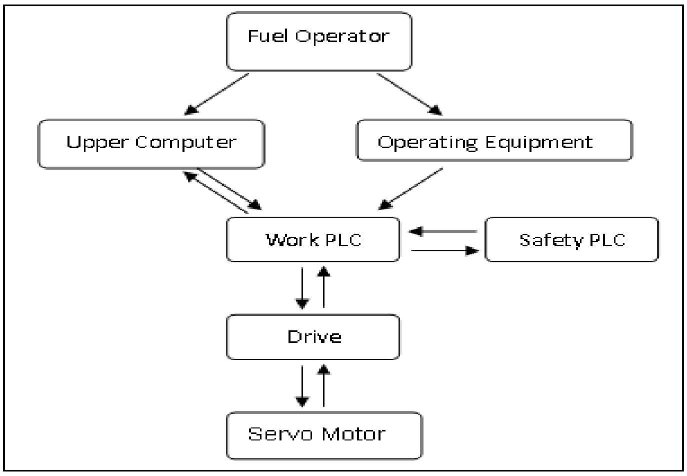

Figure 1. Overall Model Chart of MC Control System

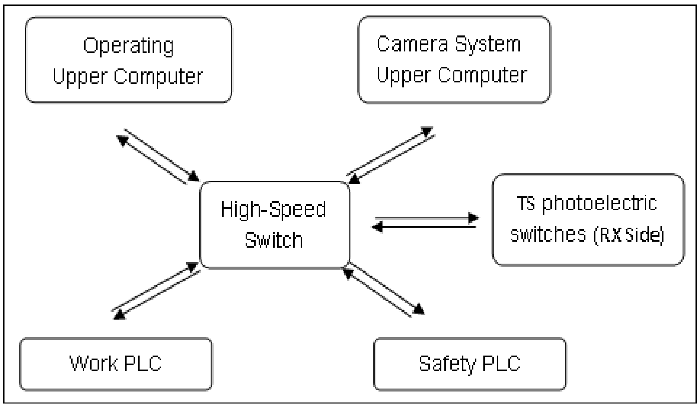

Figure 2. Connection Chart of Ethernet

In design, in order to avoid collision and falling of nuclear fuel assembly and accord with single failure principle, the redundant design is necessary for many equipments and protection functions to meet the requirements of security and accuracy.

3. Design of Ethernet

The control system of MC demands its data transmissionrapid and safe. When the Ethernet is error, the system needs to ensure the safe stop of MC, not collision and falling nuclearfuel assembly, the mechanical frame running in the allowed operating area. Based upon above requirements, the Ethernet of new control system adopts the 100M high-speed industrial switches with superior performance and high transmission rate. The equipments are linked together via the star network. See Figure 2.

In Figure 2, High-Speed Switch is the core of Ethernet's information exchange. Operating Upper Computer, using by the operator to control MC and read important information, is touch-screen computer with human–machine interface (HMI) software and inputs control command through touch. In addition, it has PLC program to monitor and modify the PLC programs at test and failure. Camera System Upper Computer is display equipment of monitor cameras during MC running, the difference from Westhouse and REEL is: the new design is not only display, but also is a touch-screen computer with dual-network card; one card connects with Ethernet of camera system it self, the other card connects with high-speed switch, making it as a redundancy Upper Computer. When Upper Computer fault happens, it can exit video monitor interface to start the same program as Upper Computer, and instead of Upper Computer. Work PLC acts as the logic control center of MC's work to control MC's operation. Safety PLC is redundancy design for the safe function of work PLC, it monitors signals which include position (front, back, left, right, and up), absolutely overload, absolutely underload, over speed, hooks sliding, axis breaking, and so on.

4. Design of Device-net Bus Network

In order to solve the defects of Westhouse and REEL's productions, the new control system adopts the Device-net bus network. Device-net, which has developed near 20 years, is widely used in Site Bus technique with advantages of simple wiring, having self-diagnosis function, low-cost and stable communication [17-25].

The New control system makes the best of Work PLC and Safety PLC, and using them as the master station to design 2 Device-net bus networks, as shown in Figure 3 and Figure 4.

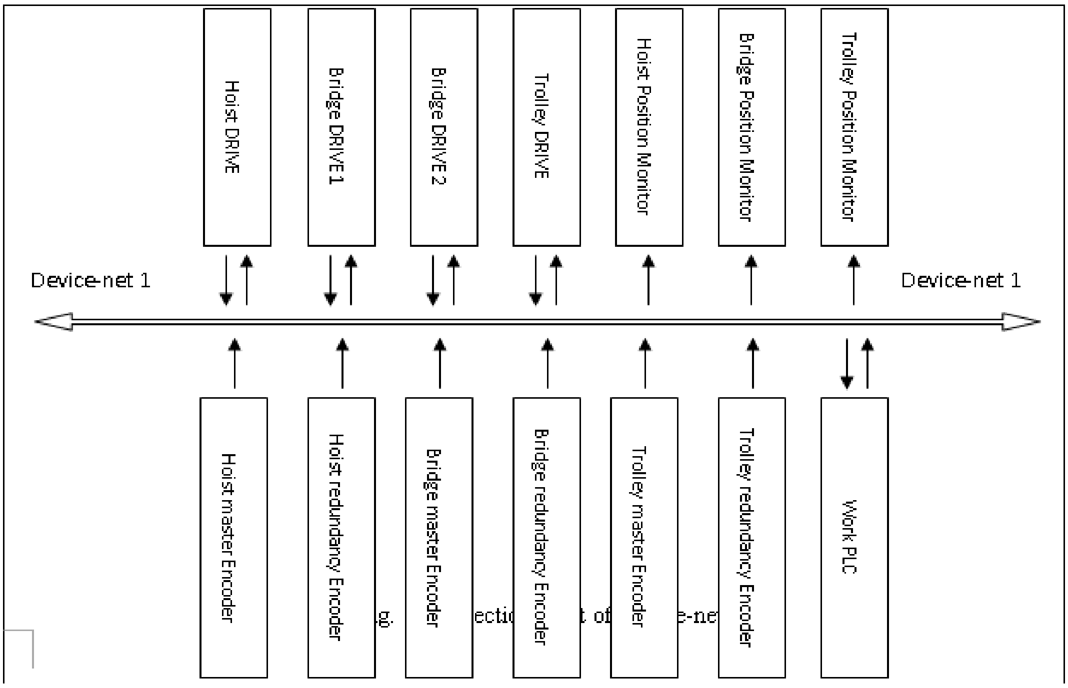

Figure 3. Connection Chart of Device-net 1

In Figure 3, Device-net bus network 1 connects Work PLC, four Drives, six Encoders and three Position Monitors, which simplifies hardware wiring and ensures the prompt and accurate of communication. But for safe operation of MC, bus network 1 haven't connected the signals of limit positions and important security into network though I/O module of bus network, and connected these signals directly to Work PLC or control loop to guarantee the diversity of redundant design. Bus network 1 used Work PLC as master station, others as terminal station to achieve the monitoring and controlling of Work PLC to other devices. Work PLC controls

Drives through bus network, and ultimately controls motors. Instead of traditional mechanical switches, six absolute Encoders using for position detect directly connects to bus network. In order to prevent encoders' failure, all encoders have redundant design to compare each other. After calculating the position signals of absolute coders, Work PLC outputs the position messages of main coders through bus network and displays them on Position Monitors. The display process is with less links, shorter delay and clearer display, and provides more precise real time location of MC, especially its dynamic location.

In Figure 4, Device-net bus network 2 connects Safety PLC and three Encoders, and Safety PLC as master station, three absolute Encoders used for detecting positions of hoist, bridge and trolley as terminal station. The major function of bus network 2 is to collect position information of Encoders.

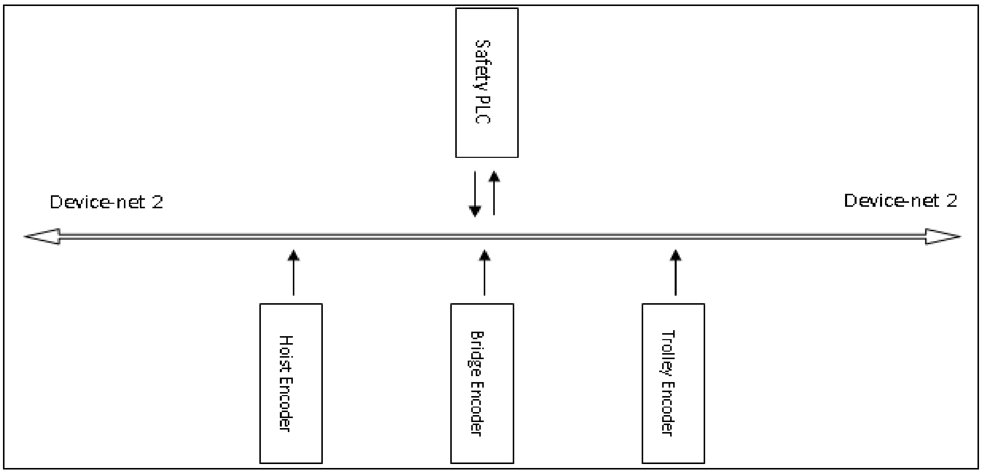

Figure 4. Connection Chart of Device-net 2

The main function of Bus Network 1 is control and position MC, while that of Bus Network 2 is position MC. These two bus networks relate directly to the stability, high speed and precious position of MC. Considering the importance of position signal in the whole control process, the new control system not only designs the redundant Encoder in bus network 1, but also adds the bus network 2 to compare with Bus Network 1 to reduce the error data caused by Bus Network 1.

5. Overall Network Structure

The design of the new control system converges the Ethernet and Device-net bus network, andconnects through PLC. The two kinds of nets can communicate and make full use of their advantages. The overall connection of the two kinds of nets as Figure 5 showed.

In Figure 5, PLCs are the core equipments, information exchange intermediary of the two kinds of nets, and the master station of the two Device-net bus networks. Work PLC is to control the running of MC with most complicated configuration and process most data; Safety PLC is to give security protection for the running of MC; it is the redundant design of Work PLC for security function. These two PLCs can communicate through high speed switch of Ethernet, and then realize the communication of two Device-net bus networks, ultimately the data validation among two bus networks and one Ethernet.

In addition to the above network connection, Figure 5 designs three cameras to monitor the handling nuclear fuel assembly process of MC, it can help the operator in the trolley to have a clearer observation of the handling situation. The three incremental encoders are to detect running speeds of bridge, trolley and hoist, using Safety PLC to provide over-speed protection; they are the redundant design of Work PLC for over-speed protection.

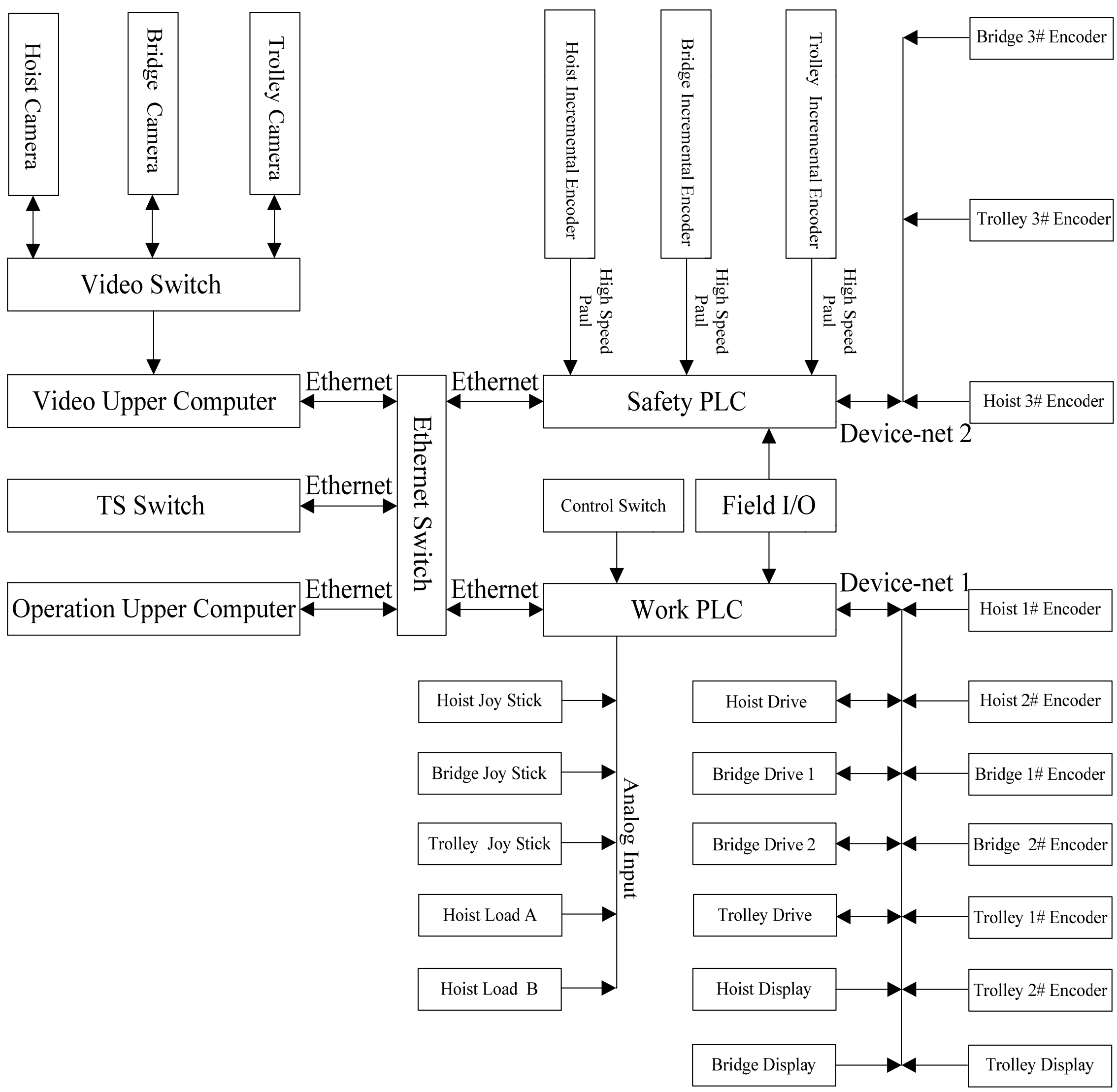

Figure 5. Structure Chart of MC for Control System

6. Conclusion

This paper adopts the widely used and advanced Device-net technology, abides single failure principle, and designs a whole structure of control system. The design of the new control system is based on one Ethernet and two Device-net bus networks, the two kinds of nets are communicated and made full use of the advantages themselves. The new control system solves the defects of Westhouse and REEL in design, and makes the control to more advanced and safer.

In this design, Safety PLC is new design, and give security protection for the running of MC. It's the redundant protection of Work PLC for security function,but Safety PLC isn't used enough, and needs to further enrich. Device-net bus network has the advantages of simple wiring and stable communication,whereas for the safe running, these equipments connected into Device-net bus network are few, bus network 2 particularly, is conservative, Device-net bus network's advantage of easy to connect is not given full play. After practice applying, equipments in Device-net bus network can be added further.

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