Research on Conceptual Design of Nuclear Non-security Distributed control system

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Abstract. The nuclear non-security distributed control system is very important to the security of the nuclear power system. So some special design is used to ensure the system’s reliability and security. But the redundant design makes the traditional non-security system large in size, more in cabinets and complex in wiring. To solve these problems, we would like to choose new technologies to optimize the system more simple. The new conceptual design can make the non-security distribute control system have less wiring and less cabinets, and the system can be high security.

1. Introduction
The nuclear non-security distributed control system is responsible for important non-safety functions such as reactor power control, secondary loop evaporator control system, and secondary loop main condensate feedwater control, so the system’s reliability highly relies on the non-security distributed control system. As a result, redundant design of the cabinet is needed. Though this deems to make the system wiring is complex and system scale huge.

With the development of new electronic technologies such as Wi-Fi technology, FPGA technology, fieldbus technology can make the non-security distributed control system minimized, simplified.

2. Analysis of common system structure
At present, in Civil nuclear power station, diversity and redundancy design is needed to the nuclear non-security distributed control system. Generally, people use two different channels to ensure the redundancy of non-security control system[1]. If there is one channel failure, there is still another one to achieve the goal.

Figure 1 is a typical nuclear non-security distributed control system’s structure.
Fig. 1 Two redundancy channels structure of non-security distributed control system

The system uses two channels to gather fieldbus sensors’ signal and two column output processing units to issue the driving signals to driving actuator.

It uses two redundant processing channels. Two different sequences of non-security characteristics, which make it large-scale and complex wiring, which means that there is a lot of room for optimization of non-security systems using new technologies.

3. New technology using in this system

The application of new technology in nuclear non-security distributed control system

Recently, the new technology can simplify the design and implementation of the non-security distributed control system. For security reasons, People choose technologies that have been proven to be mature for optimum design. We optimize the system from three aspects. (1) Industrial fieldbus technology; (2) Wireless technology; (3) Processor scheme (FPGA technology).

3.1. Industrial fieldbus technology

3.1.1. Advantages Industrial Fieldbus (such as profi-bus, modbus) can be used in the signal input or output of the executive agencies and other means of communication of the intelligent instruments, sensors, actuators. This technology can cut down the number of hard wires and simplify the input and output cabinet board card number. This design can improve the system integration. Because the signal processed by the system mainly comes from the process system, we use fieldbus technology instead of hard wiring, which can reduce the number of field cables, reduce the area of cable piercing through the containment, improve the anti-interference ability of the system, and facilitate later maintenance.

3.1.2. Disadvantages The reliability of intelligent instrument is lower than that of conventional instrument system. In order to improve the reliability of intelligent instrument, it is wise to develop redundant intelligent instrument based on fieldbus. Redundant fieldbus technology is the key to the application of this technology in non-security distributed control system.
3.2. Wi-Fi technology

3.2.1. Merits Wi-Fi technology can simplify the communication connection between cabinets, especially when a large number of redundant distributed control systems are used. Wi-Fi technology can reduce some communication paths. The traditional cable redundant communication system uses double cable redundant communication. If Wi-Fi technology is adopted, the redundant communication design with higher reliability will become more convenient. If two redundant communication channels are to be transformed into triple redundant channels, only Wi-Fi technology board in cabinet can be added under Wi-Fi technology, instead of connecting cable system\(^5\). The implementation of Wi-Fi technology can stimulate a communication mode and provide flexible and variable solutions. The "combination of wireless and wired communication mode" will be prevalent. This method can greatly enhance the reliability and diversity of communication.

3.2.2. Inferiorities Raise the reliability, availability of Wi-Fi technology is key to use this technology to non-security control system.

3.3. FPGA TECHNOLOGY

3.3.1. Strong points. Programmable logic device is another technique way to build nuclear plant digital control system. It has a lot of advantages compared with the microprocessor system. For example, the system built by programmable logic can be very simple, and maintain the independence of each function. The most important is that it can be used as a substitute based on microprocessor technology. FPGA can not use operating system. This merit can make system more safe, can avoid the common software failure.

The main processor module application based on FPGA architecture in the non-security system has the following advantages:

(1) Compared to the FPGA scheme and MPU scheme, FPGA is more suitable for a large number of input and output signals. If it is logical operated, FPGA can be divided into a plurality of modules\(^2\), as shown in Figure 2. Each module is unique for processing path of the input signal, and can be unified, so it has the superiority of processing a large amount of signal synchronization, as well as simplify system structure.

While the microprocessors need to be scanned respectively in processing large amount of input signals, so if the input signals increase, more time for processing is needed. But the FPGA’s parallel processing ability can handle mass input signals easily\(^3\).
4. Simplified design of non-security distributed control system

According to the above application of three new technologies, can obtain the non-security control system simplified scheme can be concluded as follows:

**Fig 2** CPU architecture and FPGA architecture

(2) The main processing module based on FPGA is quite different from the main processing module based on microprocessor in design concept. After compiling the software, the processor module based on FPGA will be written into the hardware circuit to "solidify" the chip. Otherwise in MPU, the program is written into ROM [4], read one by one, and then execute computer instructions. The two operation schemes are quite different. The processor architecture based on FPGA can maximize the diversity of hardware design.

3.3.2. Weak points The main processing module based on FPGA is not so mature as MPU processor in many aspects. For example, the security, reliability verification process, verification method etc. Although the working principal seems just to expect hardware logic array to achieve security, theory should be adopted on hardware verification process. But their developments, design processes and software design processes are similar. Whether use hardware reliability verification, or software based on FPGA system is still needed to be discussed.
The above chart shows internal communication from the input mode to processor for the transformation, can make the following effects:

1. Fieldbus technology
   Industrial fieldbus technology greatly saves the number of cables of field sensors and simplifies the cable layout.

2. The FPGA based on processing module
   The technology of FPGA can improve the parallel computing ability of the system and reduce the response time of the system. The degree of diversification and reliability of the system can be improved by using the in conjunction with the MPU processing module.

3. Wi-Fi technology
   By using reliable and safe Wi-Fi technology, a large number of data cable rooms can be saved and the system simplified. Wi-Fi technology can achieve a higher level of communication redundancy configuration without additional field cable laying.

5. Conclusion
   With the rapid development of electronic technology, control system will be more compact, reliable, stronger. Reliability and security of the traditional nuclear non-security control system makes it large in scale, and have complex wiring. As new technologies continue to be used in the nuclear power non-security distributed control system design will be simplified and the reliability of the system will be improved.

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