Research on Application of Remote IO Technology in Nuclear Power Plant

Hui Wang, Tian-Sheng Ji, Ai-Guo Lv and Hao Zhong

Abstract The technology of remote I/O system has the characteristics of good physical dispersion, high reliability, high accuracy of measurement and control, openness, strong function, high degree of intelligence and strong communication ability. Remote I/O technology, as a mature bus technology, has been widely used in thermal power, chemical industry, metallurgy, petroleum and other fields. All systems and sub items in nuclear power plant are still using the traditional distributed control system (DCS), some signals by hardwire have a long distance transmission, which against economic and signal stability. In this paper, from the plant and system environment restriction condition, functional requirements (Operational protection requirements), system performance requirements, installation requirements, equipment identification, cost and other system interface and other factors, to analyze the feasibility of remote I/O technology used in nuclear power plant. Determine the scope of the implementation of remote IO technology for nuclear power plant. Finally, pumping station as an example, the implementation plan of using the remote I/O technology under the various technical route of nuclear power plant was studied in detail.

Keywords Remote I/O technology · Distributed control system (DCS) · Local control system · Pumping station

1 Introduction

The remote I/O technology transfers the data processing and control function of the traditional DCS to the field equipment nearby, and the multiple monitoring points are connected with the PLC or DCS through the bus. The remote I/O technology have been widely used in thermal power, chemical industry, metallurgy, petroleum

H. Wang (✉) · T.-S. Ji · A.-G. Lv · H. Zhong
State Key Laboratory of Nuclear Power Safety Monitoring Technology and Equipment,
China Nuclear Power Engineering Co., Ltd., Shenzhen, China
e-mail: hui.wang@cgnpc.com.cn

and other fields, the technology has been very mature. But all nuclear power plant system and sub items still use the traditional DCS. Some signals were long-distance transmission, detrimental to the economy and the stability of the signal, it is necessary to research and analyze the feasibility of using remote IO in nuclear power plant, and timely improved.

The technology of remote I/O system has the characteristics of good physical dispersion, high reliability, high accuracy of measurement and control, openness, strong function, high degree of intelligence and strong communication ability. At the same time, the economic benefits are obvious.

2   The Application of Remote IO in Conventional Thermal Power Plant

Remote I/O system has been widely used in thermal power plant, the application of the main two aspects of thermal power plant.

2.1   To Replace the IO Acquisition Module

The typical application of thermal power plant is the application of metal temperature group. Metal temperature of the main steam turbine and boiler and the main auxiliary groups including boiler tube wall temperature, wall temperature of steam turbine, a generator coil and iron core temperature and main auxiliary equipment (such as pumps and fans) temperature. These measured parameters usually changes slowly, does not participate in the system regulation, the remote IO of on-site temperature acquisition and digital processing, then transmitted signals to DCS through the communication bus (also have a way of transmitted signals through control cable to DCS).

In this application, remote I/O is only as a data acquisition system, not through the DCS system on the remote intelligent I/O online configuration. Data are transmitted to the DCS system simply from the remote I/O system [1].

2.2   Using the Remote IO Station to Form Medium and Small Scale Production Monitoring and Management Information System

In thermal power plant, some auxiliary equipments part away from the unit, such as water supply and drainage treatment pump station, the exception of ash slag station, heat metering station and booster stations, due to their distance from the main

control room far away, so the control is difficult to incorporate into conventional DCS, before we used the independent monitoring system. When the remote I/O is used, the monitoring information of the equipment can be transmitted to the main control room, centralized and unified management.

In this application, remote I/O is not only used as a data acquisition system, but also need to realize the control function. In this case, the communication between the DCS and the remote I/O is a two-way street. The normal operation of a large number of data in remote intelligent I/O and DCS system exchange, at the same time, through the DCS system engineer station can also be configured for remote intelligent I/O [2].

3 Feasibility Analysis of Remote I/O Using in Nuclear Power Plant

The application of remote I/O in nuclear power plant can be considered from the environmental constraints of plant and system, function requirements (operational protection requirements), system performance requirements, installation requirements, equipment identification, cost, other system interface and other point of view, do feasibility analysis of the remote I/O technology application in the nuclear power plant.

3.1 Environmental Restrictions

According to the layout nuclear power plant can be divided into nuclear reactor plant, nuclear auxiliary building, nuclear fuel plant, steam turbine plant, electrical plant and BOP building. Different areas of the application conditions of requirements, Application of remote I/O system should meet the RCC-E (2005) d 2100 provisions of regional environmental restrictions, such as temperature, humidity, pressure, radiation, including:

- Environmental conditions when the device is not running.
- External safety shell normal environmental conditions and accident condition.
- Normal environment conditions and accident conditions inside the safety shell

Some areas have certain radiation, so it is necessary to carry on the radiation supplementary test to the equipment used in this area [3].

Consider from environmental constraints, for the reactor building, nuclear auxiliary plant, nuclear fuel plant, because of radiation and other environmental problems, the remote I/O should not be used. For the turbine plant, electrical plant and BOP building, environmental conditions can meet the basic requirements of remote I/O, you can consider the use of remote I/O system.

3.2 Operation and Protection Requirements

Based on the importance of the executive function, distributed signal transmission requirements and smart device application status, the principle of following system or equipment should adopt the conventional DCS (hard wired connection), should not be application of field bus remote I/O:

- The system has a significant impact on the safety of the reactor and turbine engine (such as RPR, GSE etc.).
- Important control circuit, such as NSSS, GRE, etc.

Consider the system operation and protection requirements, Nuclear reactor plant, nuclear auxiliary plant, nuclear fuel plant and electrical plant ventilation system are not suitable to use the remote I/O system, because the bus signal may be disturbed. Conventional island auxiliary system and BOP plant can be considered using remote I/O system.

3.3 System Performance

The precision and response time of the system (such as SOE) should not be based on remote IO system.

Field bus to meet the main performance indicators of the protection system (response time: 150 ms, sampling accuracy of 0.25%), So in addition to the reactor building, nuclear auxiliary building, nuclear fuel plant, steam turbine plant, electrical plant and BOP building on the accuracy and response time without the special requirements of the system basically meet the system performance requirements by remote I/O Technology.

3.4 Installation Requirements

Should follow the DL/T 1212 on the field bus equipment, communication cable/optical fiber and grounding installation technical requirements, such as plant restrictions or site construction conditions do not meet the requirements of DL/T 1212, remote I/O should not be used [4].

3.5 Equipment Identification

Select field bus system and equipment should be according to the importance of the safety function of the equipment, and carry out corresponding equipment identification tests, identification steps and procedures see volume requirements RCC-E B.

For safety level systems, the control system is required to carry out relevant identification, According to the research of the remote I/O system on the markets, the current remote I/O device can't meet the requirements.

Therefore, only the non safety level of the plant or system using remote I/O.

3.6 Cost

Some system and equipment which are not far away from DCS electronic equipment room, can be not consider using a remote I/O, due to the adoption of the remote I/O do not lower investment cost. Some sub item far away from the DCS electronic devices room, using the intelligent remote I/O technology can reflect the advantages of remote I/O.

From the cost considerations, only some BOP building distance from DCS electronic equipment room, can reflect the cost advantage of remote I/O.

4 Feasibility Analysis of Nuclear Power Plants Using Remote I/O

According to the second section, for the reactor building, nuclear auxiliary building, nuclear fuel building, consider to environmental conditions (such as radiation), operational protection system requirements, and the distance between the DCS electronic equipment room, without consider using the remote I/O system.

For the steam turbine building, due to the short distance between the DCS electronic equipment room, operation and protection requirements, system performance and other factors, in principle, it is not considered the use of remote I/O.

Only some BOP sub term which distributed in the main plant around, there is a need to use remote I/O.

There is no radiation in most BOP building of the nuclear plant, the environmental conditions between the nuclear power plant and the thermal power plant is no obvious difference, except the individual execution level of nuclear safety and nuclear safety related functions of BOP building, plant environment meet the basic conditions of remote I/O equipment.

4.1 BOP Buildings Controlled by Local PLC

The hydrogen station, air compressor room, condensed water fine treatment plant and other BOP buildings and systems are relatively independent. In design of nuclear power plant, by the local PLC achieve local control, the control cabinet is arranged in the BOP buildings. For this type of equipment and systems are relatively independent sub items, the use of remote I/O is not significant [5].

4.2 BOP Buildings Controlled by DCS

BOP buildings controlled by DCS mostly is the combined pump station. In CPR1000 project, most system in combined pump station adopts the traditional DCS, The signals are sent to DCS electric equipment room directly from combined pump station.

Through some experience feedback from the projects under construction and in operation, combined pump station using traditional DCS control have some problems as follows:

- Combined pump station is far from DCS electric equipment room, signal transmission path is long, for some analog signals, appeared significant voltage drop.
- Combined pump station due to the extreme conditions of coast (such as fish signal period, Seaweed flood season etc.), circulating water pump mal operation problem, the corresponding design change more, after the cable tray sealing, appeared with increase measuring points and cables to DCS many times, resulting in site construction difficult, poor scalability, if using remote I/O, the situation can be improved.
- Signals are sent to DCS cabinet through hard wiring, the more cables, high costs. Due to the huge number of cables, the DCS electric equipment rooms always have cable over capacity problem.

Through above analysis, combined pump station has the necessity and feasibility of using remote I/O.

5 Remote I/O Program Implementation of Combined Pump Station

5.1 Remote I/O Program of Combined Pump Station Under the CPR1000 Technical Route

The main process system of combined pump station include: circulating water filtration system (CFI), circulating water system (CRF), circulating water pump

lubrication system (CGR), essential service water (SEC), fire water production system (JPP), nuclear plant pump station ventilation system (DWS), circulating water pumping Station ventilation system (DVP), sewage collection system (SEO), etc. CFI/CRF/CGR/SEC/JPP/DWS are taken into DCS control, and CFI/SEO are taken into local PLC control.

In CPR1000 project, circulating water pump station and essential service water pump station jointly build, essential service water system and circulating water system using common filtering. Essential service water system is safety function system, circulating water filtration system and SEC supporting ventilation system DWS are safety related function system. The specific I/O points are shown in Table 1.

In CPR1000 project combined pump station did not using remote I/O. The main reason is as follows.

1. There is no instrument control equipment room in CPR1000 project of combined pump station, instrument control equipment to be shared with the electrical equipment in electrical room. Electrical room congestion has poor environmental conditions. Electrical room layout is as shown in Fig. 1.

Table 1 Specific I/O measuring points of CPR1000 project pumping station

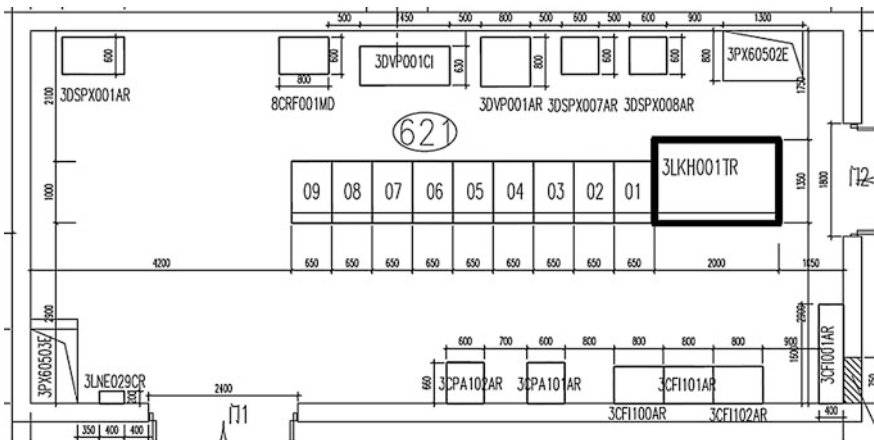| Sys.	Total	Single unit							
		1E				NC			
		DI	DO	AI	AO	DI	DO	AI	AO
CFI	337	86	24	–	–	62 99	12 50	4	–
CGR	46	–	–	–	–	29	16	1	–
CRF	134	–	–	–	–	64	30	40	–
SEC	196	20	12	6	–	82	–	54	22
DWS	62	16	8	–	–	26	12	–	–
JPP	45	6	4	–	–	14	4	17	–

Fig. 1 Combined pump station electrical room layout

2. SEC, CFI and other systems belong to safety and safety related function systems, need to be put in safety DCS to achieve control function, there's no safety remote I/O. This part is not recommended to achieve remote I/O product now.
3. Only more than 200 NC level I/O signals can using the remote I/O, if using remote I/O, different channel of equipment need distribution in different cabinets and remote I/O requires at least three cabinets, and each cabinet arranged 60 measuring points or so, then using the remote I/O not only reduce the cost, there may cause cost increase.

5.2 Remote I/O Program of Combined Pump Station Under the AP1000 Technical Route

Combined pump station provides cooling and production with seawater respectively to circulating water system (CWS), plant water system (SWS), open cooling water system (OWS), circulating water dosing system (WIS), seawater desalination system (SWD) and the drum washing water system.

In AP1000 project combined pump station includes the following process: circulating water system (CWS), circulating water filtration system (WFS), gear box lubricating oil system (GOS), plant water system (SWS), follow the pump room ventilation system (VPS), production wastewater system (WWS), life water distribution system (DPS), plant drainage system (DRS), etc. The number of DCS I/O points is shown in Table 2. Other systems are controlled by local control box.

In AP1000 project combined pump station can use remote I/O. The reasons are as follows:

1. AP1000 as a new designing, can be considered setting independent instrument and control electronic devices room in combined pump station.
2. In AP1000 project, combined pump station does not perform safety related functions, all systems for non-safety system.
3. Combined pump station is far away from DCS electric equipment room, more interlocking with other systems, need to be sent to DCS system.

Table 2 Specific I/O measuring points of AP1000 project combined pump station

System number	Total	Single unit					
		DI	DO	AI	RTD	AO	Communication
WFS	433	337	66	30	–	–	–
GOS	69	33	12	21	3	–	–
CWS	243	78	18	15	90	–	42
SWS	4	The main control equipment in the steam turbine plant, pumping station only 4 AI					

4. The pump station has more measuring points, after using the remote I/O, the advantages of remote IO technology can be fully reflected.

5.3 Remote I/O Program of Combined Pump Station Under the EPR Technical Route

Under EPR project, the pumping station, in addition to the number of flow channels differ from CPR1000, Other are the same as CPR1000 design. Therefore, under the EPR technology route the pumping station is not suitable for the use of remote I/O technology.

5.4 Remote I/O Program of Combined Pump Station Under the HPR1000 Technical Route

Under HPR1000 technical route, circulating water pump station and essential service water pump station have completely independent. SEC system increases the filter section on the original basis, CFI system no longer supply water to SEC system. Circulating water pump station no longer perform safety related functions, including only circulating water filtration system (CFI) and circulating water system (CRF) and circulating pump lubrication system (CGR), circulating water pump station ventilation system (DVP), sewage collection system (SEO) system.

Essential service water system (SEC) and its related supporting system are arranged in essential service water pump station. Essential service water pump station due to the implementation of safety and safety related functions, are still using the traditional DCS control. I/O points of systems in Circulating water pump station with a slight increase compared CPR1000.

HPR1000 project considering use of remote I/O program, the main reasons are as follows:

1. Projects under the HPR1000 technical route are all new projects, the setting and the size of the electronic equipment room, the environmental requirements and so on in the planning stage can be considered completely;
2. HPR1000 project has been confirmed that circulating water pump station and essential service water pump station are separated, circulating water pump station equipment are non safety equipment;
3. The pump station has more measuring points, after using the remote intelligent IO, the advantages of remote IO technology can be fully reflected.

6   Conclusions

As mentioned above, based on the characteristics of the remote intelligent I/O Technology, In this paper, from the nuclear power plant and system of environmental constraints, functional requirements (protection operation, system performance requirements, installation requirements, equipment identification, cost and other system interface and other factors to the feasibility of the nuclear power plant using remote I/O technology are analyzed in detail, determine the scope of the implementation of remote I/O technology for nuclear power plant. Namely in the CPR1000 project and EPR project, do not consider the use of remote IO Technology. In the AP1000 project and HPR1000 project, can be considered using remote intelligent I/O Technology in the pumping station (circulating pump room), to reduce number of cables, enhance the reliability of signals, improve the scalability of control systems in pumping station, and improve the cable capacitance in DCS electronic equipment room.

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