# The Formulation of BOP Auxiliary System Centralized Control Network in Nuclear Power Plant

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**Abstract.** With the rapid development of modern computer technology, control technology and communication technology, it has become a practical problem to optimize the monitoring mode of BOP sub-items, to seek more reasonable and effective, more economical and convenient, more stable and reliable engineering application solutions that reflect the mature automation technology today and to uniformly monitor and design these sub-items. In particular, it has been mature in thermal power plant applying auxiliary control network technology in auxiliary workshops, and the technology has been widely used in chemical industry, metallurgy and other industries. BOP sub-items are networked on the basis of the current monitoring mode, and without affecting the project progress. Realizing of moderate centralized control will improve the level of automatic operation and management of nuclear power plant, and meet the requirements of informatization management of the plant.

**Keywords:** Auxiliary system · Auxiliary control network · BOP

## 1 Introduction

### 1.1 A Subsection Sample

Different from the unit digital control system (hereinafter referred to as DCS), BOP auxiliary system centralized control network (hereinafter referred to as BOP auxiliary control network) is a centralized monitor, control and management network of process systems or sub-items which are distributed dispersedly and play an auxiliary role in unit operation through network technology, so as to promote informatization management of the whole plant.

BOP auxiliary control network has not been applied materially in China in nuclear power projects whether under construction or in service. The operation and management mode of on-site PLC control system plus computer monitoring are still used in controlling BOP auxiliary system and sub-items of nuclear power plant, which lead to the phenomenon of "information islands". This kind of operation and management mode not


Y. Xu et al. (Eds.): SICPNPP 2020, LNEE 779, pp. 114–122, 2021.
https://doi.org/10.1007/978-981-16-3456-7_13

only has a relatively low level of informatization, but also brings a lot of inconvenience to the spare parts, operation and maintenance of the instrument control equipment. With the development of network technology, the BOP auxiliary system is adopted to monitor the network, which is conducive to improving the informatization level of the unit, realizing the unattended operation of sub-items and the reduction of operating personnel and increasing efficiency. It is an inevitable trend for the development of nuclear power plant auxiliary system and sub-items design in the future.

## 2 BOP Auxiliary System Control Network Analysis

The BOP auxiliary system is not closely related to nuclear power plant units, considering its operation. The majority of the systems operate intermittently. And most of the auxiliary systems serve multiple units simultaneously. Normally, nuclear safety functions are not involved. Even system failure or short-term outage will not immediately lead to the withdrawal of the unit state [1].

With the rapid development of modern computer technology, control technology and communication technology, it has become a practical problem to optimize the monitoring mode of BOP sub-items, to seek more reasonable and effective, more economical and convenient, more stable and reliable engineering application solutions that reflect the mature automation technology today and to uniformly monitor and design these sub-items. In particular, it has been mature in thermal power plant applying auxiliary control network technology in auxiliary workshops, and the technology has been widely used in chemical industry, metallurgy and other industries. BOP sub-items are networked on the basis of the current monitoring mode, and without affecting the project progress. Realizing of moderate centralized control will improve the level of automatic operation and management of nuclear power plant, and meet the requirements of informatization management of the plant.

### 2.1 Status of Auxiliary System Control

At present, the BOP auxiliary system of nuclear power plant is generally equipped with local duty room and independent control device. Most of them use local PLC control system and local operation station to realize the detection and control of auxiliary process system. Only a small amount of relatively important information of the system is sent to the main control for indication or alarm through hard wiring. Some systems need operators to operate on the local control device when performing specific operations. The schematic diagram of the control system is shown in Fig. 1 below.

In practice, the BOP auxiliary system is not limited to the several BOP auxiliary systems shown in Fig. 1. The locations of sub-items are scattered, and the information exchange is very little between the main control room and each sub-item, which is not convenient for monitoring and maintenance management of site operation.

### 2.2 Solution of BOP Auxiliary Control Network

A BOP auxiliary control network solution is proposed to solve the above problems. With reference to the relevant regulations in the Technical Rule for Thermal Power

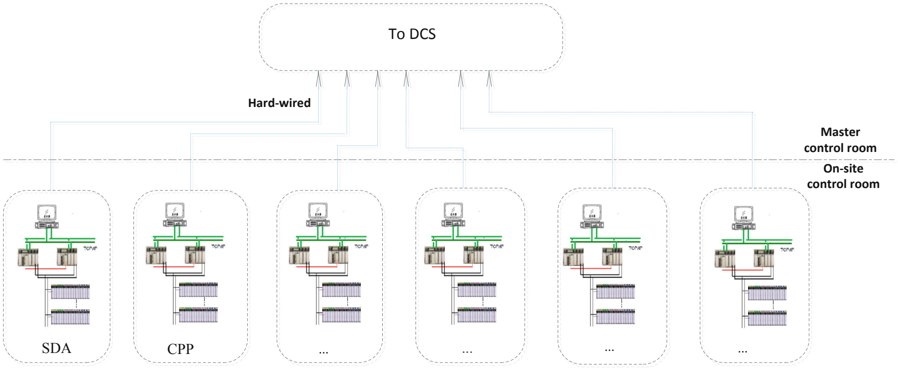


**Fig. 1.** Schematic diagram of the current BOP auxiliary control system

Automation Design for Auxiliary System (shop) of Fossil Fuel Power Plant (DT/L5227–2005), auxiliary systems of similar nature can be appropriately merged with control points according to geographical distribution [2].

The "water" system accounts for a large proportion of the auxiliary system of nuclear power plant. The "water" related systems and sub-items are centralized through the Ethernet. And the monitoring room is located in the chemical water plant to realize centralized control and unified management, hereinafter abbreviated as the "water" solution. The solution is preferred as it is in line with the current operational requirements of nuclear power plants, as shown in Fig. 2 below.

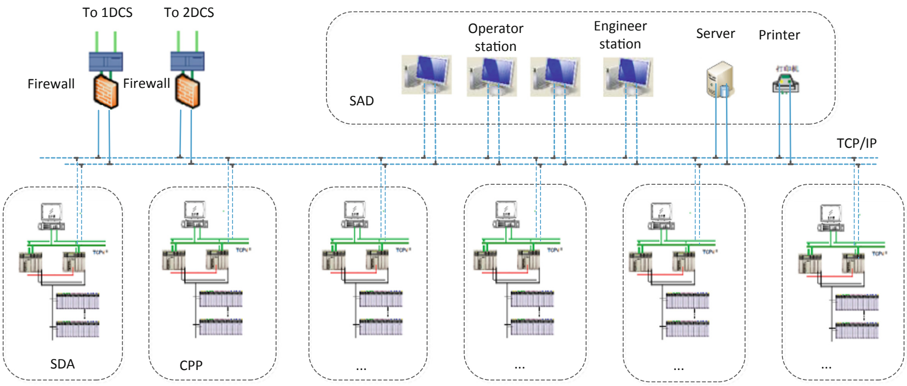


**Fig. 2.** Schematic illustration of BOP auxiliary control network structure for nuclear power plants

Another solution is to make an auxiliary control network of full range, which can cover in all the auxiliary control systems of a nuclear power plant, realizing the overall centralized control of the BOP system, hereinafter referred to as the "whole" solution.

There is no essential difference between the two solutions, except the scope. Considering that it is applied to nuclear power projects for the first time, it could be more reasonable to give priority to including water-related sub-items into the scope of the auxiliary system centralized monitoring network. At the same time, plan to reserve all kinds of interfaces at one time, and lay a good foundation for subsequent expansion on the basis of the future.

# 3 Network Architecture and System Composition

The auxiliary control network can be constructed by various networks, typically single-loop network, double-loop network and star network [3], And maybe hybrid network architecture according to the equipment function and arrangement. The single-loop network is shown in Fig. 3 below.

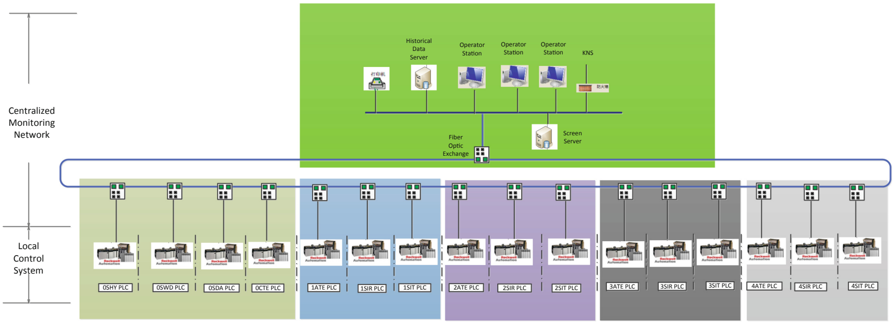


**Fig. 3.** Schematic diagram of a single-loop network.

The single-loop network adopts the hand-in-hand structure, and the data can be transmitted in two directions that are connected with the Ethernet communication module [7]. One communication module failure in the loop affects only the monitoring of the system in which the communication module located, the other systems are unaffected. The main advantage of the network is simple structure, easy to build and maintain [5]. In the case of on-site monitoring, the single-loop network can still meet the needs of centralized control of auxiliary systems.

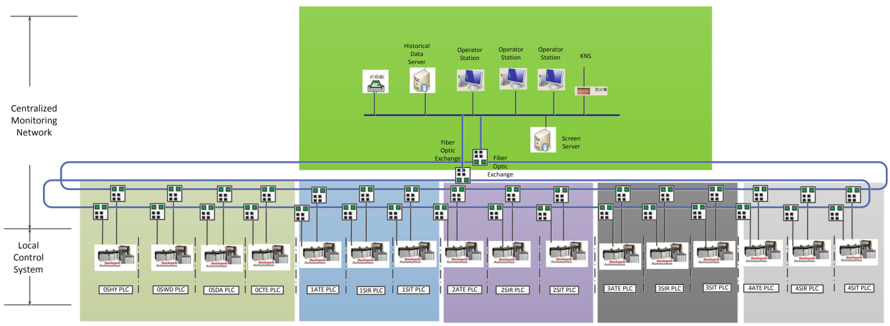


**Fig. 4.** Schematic diagram of a double-loop network

See Fig. 4 for double-loop network. The communication equipment of this network mainly includes switch, photoelectric converter, optical fiber, and network server, etc. The communication system consists of two completely independent paths (data bus), including redundant bus interface module. Two data buses will always work at the same time, one data bus failure does not affect operator to monitor and operate normally. In order to provide reliable and effective communication among systems, the data communication system will be connected with the control system input/output processing system, data acquisition system and system peripherals. If one communication data bus system fails, the other should be put into operation immediately to ensure smooth and undisturbed communication.

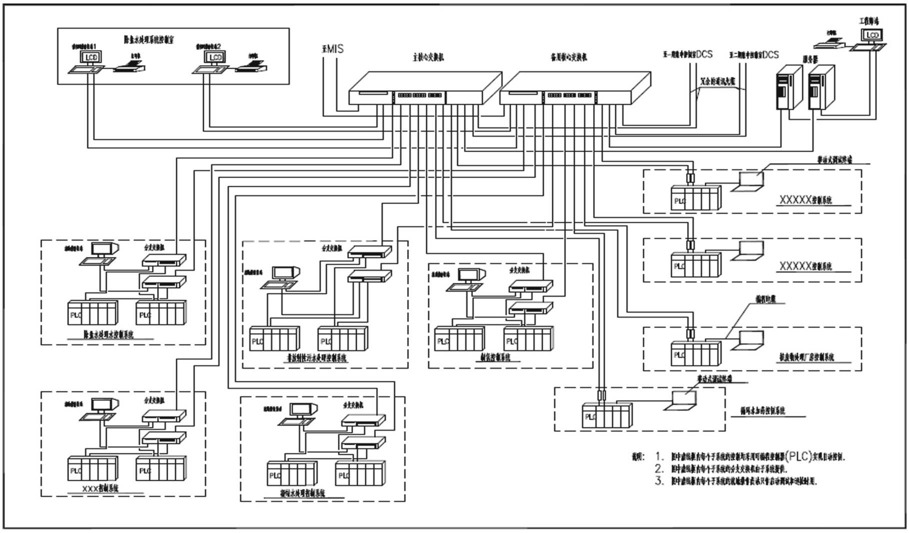

**Fig. 5.** Schematic illustration of the star network structure

The star network is shown in Fig. 5. The communication equipment mainly includes core switch, access switch, network server, data server, etc. It can be connected by optical fiber or twisted-pair cable. If optical fiber is used, the network equipment also includes photoelectric converter and optical fiber. The main switch receives the data from each system at the same time. When the main switch fails, the standby switch immediately takes over the operation of the network main loop network without affecting the monitoring of the system. In order to provide reliable and effective communication between systems, the data communication system will connect the control system input/output processing system, data acquisition system and system peripherals. If one communication data bus system fails, the other should be put into operation immediately to ensure smooth and undisturbed communication.

The operator station and the engineer station in the above three solutions are communal to each auxiliary system. The BOP auxiliary control room of nuclear power plant can be set up in the desalination plant and shared with the desalination system control room. At the same time the on-site control room can be canceled, the on-site electronic equipment room retained. Considering the actual needs in operation, some important systems such as condensate system, hydrogen production station can retain the on-site host computer on the spot, and for the other systems touch screen can be set on the spot as a temporary and supplementary means for debugging starting and network failure.

To lay the foundation for further improving the information level of the whole unit, and solve the problem of "information island" thoroughly, the BOP auxiliary system control network has communication interface DCS with each unit, which can send the relevant data information to the main control room for display, storage and analysis according to the need [6]. After the BOP auxiliary control network is adopted, the operator can realize centralized control and control of the system or sub-items in the control room, reduce the frequency of operation inspection, which in turn lead to a decrease in the number of field operators. The efficiency and economy of system operation are improved.

## 4 Analysis on the Implementation of BOP Auxiliary Control Network

BOP auxiliary control system control network of nuclear power plant is realized in two situations: new construction and in-service transformation. Whether a new project or an in-service renovation, it is necessary to analyze and demonstrate the progress, interface, purchase, installation, commissioning, operation and maintenance of the auxiliary control network.

### 4.1 Impact Analysis of New Construction Progress

In order to meet the requirements of the unit DCS manufacturing schedule, in the nuclear power design of the new project, the general special schedule plan will be drawn up for management and tracking to ensure that the system design will be basically solidified in the preliminary design stage, and to minimize the impact of later system design changes on the DCS schedule [4]. When the BOP auxiliary control network solution is adopted, the BOP system design schedule and DCS are basically no longer related, which can minimize the impact on the DCS, thus reducing the progress pressure on the BOP auxiliary system design caused by the advanced manufacturing schedule. It is beneficial to the construction schedule control.

### 4.2 Impact Analysis of New Works Design

The control room should be set up separately after the BOP auxiliary control network solution is adopted. Most of the signal exchange DCS with the unit will be transferred to the centralized control network of the BOP auxiliary system, which brings the following effects (Table 1):

**Table 1.** Design impact assessment tables.

| S/N | Impact item | Description | Assessment and response measures |
|---|---|---|---|
| 1 | Unit operating procedures and system operating procedures; | Description and requirements of unit operating procedures and system operating procedures; | The operating procedures of the BOP system only need to be adjusted according to the changes in the management method, which can be resolved |
| 2 | Affect the physical interface with the unit DCS | Change of physical interface and functional interface with DCS | Solved through negotiation with DCS. It will not affect the overall progress of the unit's DCS |
| 3 | Cable path channel | Changes in the type and quantity of cables between each sub-item and DCS | The communication cables are all optical fibers, and the total number of cables is reduced, which is conducive to the overall planning of the cable channel, and has no effect on the cable channel planning in the corridor |
| 4 | Auxiliary control room layout design | New layout design of auxiliary control room | Consider sharing with a sub-item (demineralized water) control room. The price of land and construction is not affected. It can be implemented when conditions are met |
| 5 | Auxiliary Control System Technical Specification | Changes in procurement requirements and scope of supply | The scope of supply and technical requirements of each sub-item procurement technical specification shall be formulated uniformly |
| 6 | Power supply design of auxiliary control system | Request to increase dual power switch + uninterruptible power supply | The power capacity requirement is less than 5 KW. The new load will not have a significant impact on the electrical professional design |
| 7 | Control response time requirements | After the auxiliary control network is adopted, the processing of the signal intermediate link is increased. The overall response time of the system lags behind | BOP has no special requirements for response time.. The response time is within the allowable range (the time for one-way data upload and command to reach the entire channel is less than 1 s) |

### 4.3 Impact Analysis of New Construction Procurement

One of the basic requirements of BOP auxiliary control network is to realize the unified brand, communication interface, data interface and man-machine interface of the PLC control device [8]. In order to achieve the above purpose, it is necessary to adjust the purchasing strategy of each auxiliary system (sub-items) of the original nuclear power reference project. There are two ways for selection:

Mode 1: one of the auxiliary suppliers is responsible for BOP centralized control of the supply of network equipment, as well as the integration of interfaces with other auxiliary systems, and to ensure the overall performance of the centralized control network. The biggest advantage of the solution is that it will not have a significant impact on the existing procurement model.

Mode 2: Separate the control device (PLC) from the original supply scope of different Party B complete systems. Party A will conduct unified bidding and procurement. Separately entrust a third party to carry out the integrated design. The biggest advantage of this scheme is that it can ensure the unity of design requirements. However, the shortcomings are also prominent. For the sake of intellectual property, the logic diagram is only a functional expression, which will set up a great obstacle for the third party control system integrator in the process of specific logic configuration design.

No matter which solution is adopted, the overall design institute of nuclear power project is required to make detailed regulations on the software and hardware's brand, performance index, communication interface, picture line type, color, graphic symbol, etc. in each procurement technical specification.

## 4.4 Impact of Transformation on In-Service Power Plant Operation

Based on the mode of in-service transformation, the original control equipment and on-site monitoring means of the BOP system are retained. On this basis, the auxiliary control network is added to extract the information from the control system to the monitoring layer, display and operate centrally, and have the function of switching operation right at any time.

When the unit has been in operation, independent design and procurement of BOP auxiliary control network will not affect the unit operation. The schedule may have a certain impact on the overhaul progress of the unit. For example, the design and layout and software filling can be carried out during normal operation, and some access work can be carried out in a short interval period of a single BOP system. The overall system connection and step-by-step commissioning using the overhaul window will not affect the overhaul progress.

The focus is on the impact of operation mode and management which is brought about by the addition of auxiliary control network ports. The BOP system has its own independent control. There are rules to be followed in the inspection and examination procedures. However, with the addition of the auxiliary control network, the changes brought about by breaking the original rules may bring a certain impact on the stable operation of the BOP system. In order to avoid such an impact, it is necessary to carry out adaptive planning and training on the operation mode of the auxiliary control network in advance, make adjustments to personnel deployment, inspections, and examination procedures, manage the auxiliary control network spare pieces and spare parts well.

## 5 Conclusion

Nuclear power plants can learn from the mature application experience of the above-mentioned industries, especially thermal power, without technical problems and application risks. After the BOP auxiliary system is adopted to centrally monitor the network, it can significantly improve the informatization level of the unit, reduce staff and increase efficiency, and has many other advantages such as convenient spare parts management and system maintenance. This paper presents a centralized monitoring network plan for the BOP auxiliary system of nuclear power plants, analyzes the impact of the adoption of the BOP auxiliary system centralized monitoring network on the current mature nuclear power plant design, procurement, construction, and commissioning modes, and lays the foundation for the transformation implementation of the BOP auxiliary centralized monitoring network in new and in-service constructions.

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