Research on the Ventilation System Valve Control and Power Distribution of a Nuclear Power Plant Conventional Island

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Abstract: The conventional island ventilation system of a nuclear power plant has complicated types, numerous valves, and various control methods. These valves include electric valves and manual valves, and are connected to different control systems. Therefore, the control method and power distribution method of these valves are also different in each project. This article summarizes 8 control methods through classification and comparative analysis of these valves, and proposes 8 interface diagrams accordingly, standardizes the control and power distribution methods, and provides a basis for future engineering design and procurement.

1. Introduction

The conventional island plant of a nuclear power plant is an important part of the nuclear power plant, and its ventilation system is also one of the important systems in the conventional island plant. The system has the characteristics of complexity and hugeness [1]. Therefore, the design of the system and related fire protection are related to the healthy and stable operation of the entire nuclear power plant and the safety of personnel and property.

The conventional island plant ventilation system uses mechanical air intake and exhaust[2], and relevant fire dampers are set up in some important areas, and under corresponding conditions, automatic control and linkage protection functions can be realized [3]. The valve control and linkage functions in the system are usually implemented by the BOP centralized control system (BCS) and the fire detection and alarm system (FDS). The valve control and linkage functions in the system are usually implemented by the auxiliary workshop centralized monitoring system (BCS) and the fire detection and alarm system (FDS). The system includes different types of valves such as electric fire dampers, electric fire shutters, electric panel exhaust valves, electric air dampers, manual fire dampers, manual smoke exhaust valves, etc., and the control methods of some valves are also more complicated, including a variety of systems Joint control, such as both BCS and FDS control, and also includes the control of a single system, such as only BCS control or only FDS control. In addition, the electric valve power distribution in this system is also one of the urgent problems to be solved. According to the relevant specifications GB50016[4], GB50116[5], etc., the design unit put forward the control function requirements, but did not carry out in-depth detailed design. Therefore, this article puts forward the relevant interface design through the research on the control and power distribution of these types of complex, numerous, and distributed valves. On one hand, it provides an effective reference for the engineering construction and the procurement process. On the other hand, it also provides a basis for the subsequent design of related valve control and power distribution of the conventional island ventilation system in nuclear power plants.
2. Valve control

2.1. Range
Only applicable to conventional island non-class 1E valves, including: electric closed multi-leaf control valves, electric shutters, electric fire dampers, electric dampers, electric plate type smoke exhaust valves, manual smoke exhaust fire dampers, Manual fire damper, manual fire louver damper.

2.2. Control function
The control of these valves is more complicated. Some valves are controlled by a single control system, but the opening and closing commands of some valves belong to different control systems, and the state feedback is not fed back to the same system. First, research and study their functional signals. Sort them out and classify them into categories I to VIII, as shown in Table 1 to Table 8.

| Table 1. Class I functional signal | Table 2. Class II functional signal |
|----------------------------------|-----------------------------------|
| **Signal name** | **Type** | **Signal name** | **Type** |
| BCS output Open command | DO | BCS output Open command | DO |
| BCS input Opened | DI | BCS input Closed | DI |
| FDS output Close command | DO | FDS input Closed | DI |

| Table 3. Class III functional signal |
|-------------------------------------|
| **Signal name** | **Type** |
| FDS output Close command | DO |
| FDS input Closed | DI |

| Table 4. Class IV functional signal |
|------------------------------------|
| **Signal name** | **Type** |
| FDS output Open command | DO |
| FDS input Closed | DI |

| Table 5. Class V functional signal |
|-----------------------------------|
| **Signal name** | **Type** |
| Local output Open command | DO |
| Local input Opened | DI |

| Table 6. Class VI functional signal |
|------------------------------------|
| **Signal name** | **Type** |
| Local output Close command | DO |
| Local input Closed | DI |

| Table 7. Class VII functional signal |
|-------------------------------------|
| **Signal name** | **Type** |
| FDS input Closed | DI |

| Table 8. Class VIII functional signal |
|--------------------------------------|
| **Signal name** | **Type** |
| BCS input Closed | DI |

3. Comparative analysis

3.1. Control function analysis
For class I valves, the control functions belong to BCS and FDS respectively. It is remotely controlled by BCS to open and close, and FDS is remotely controlled to close, and the closing function of FDS should be prioritized with BCS. The open and closed states of the valve are only fed back to the BCS for the linkage of related ventilation equipment and the corresponding linkage function. It is also implemented in BCS. These valves mainly include electric fire dampers in various electrical equipment rooms in conventional island factories.

For class II and VIII valves, the control functions of these valves only belong to BCS, among which:

1. In class II, the BCS remotely controls the opening and closing, and the valve status signal is
only fed back to the BCS. These valves have nothing to do with FDS. Therefore, the linkage relationship between the valve and the controlled equipment in the system is also in the BCS achieve. Mainly the electric damper on the air duct below the zero meter level of the conventional island factory.

(2) In class VIII, these valves are mainly manual fire dampers arranged in the lubricating oil room. When the valve reaches 70℃, it will automatically fuse and send a signal to the BCS, so that the operator can remotely control it. Surveillace.

For class III, IV, VI, VII valves, the control functions of these valves only belong to FDS, among which:

(1) In class III, only the FDS remote close function is available, and the closed state signal is also fed back to the FDS, and there is no remote open function. These valves are mainly arranged in the electronic equipment room and the air duct of the control room in the conventional island plant. When a fire is encountered, the FDS will issue a remote closing command to close the above valves.

(2) In class IV, the FDS remotely controls the opening and closing, and the valve status signal is only fed back to the FDS. These valves are mainly electric plate type smoke exhaust valves at the entrance of the high-temperature exhaust fan. The main function is that after a fire, the operator can Open the exhaust valve remotely to exhaust the smoke, and then manually close and reset after exhausting.

(3) In class VI, only FDS remote opening function is available. It is worth noting that the difference from category III is mainly in command function and status feedback. For this type of valve, both the open and closed status signals need to be fed back to FDS. This type of valve There is only one type, which is the electric plate-type smoke exhaust valve of the lubricating oil chamber. The operator manually opens the valve to open the corresponding smoke exhaust fan in a chain.

(4) In class VII, these valves have no remote control function, and only feedback the closed state signal to the FDS. These valves are mainly manual fire dampers related to ventilation and air conditioning. When the temperature inside the valve reaches 70℃, it will fuse and send signal feedback. To FDS.

For class V valves, these valves are not remotely controlled and belong to local control. In the engineering design of this type of valve, if the electric valve is arranged at a higher position, it is inconvenient for operators to operate on-site. Therefore, in the functional design On the other hand, local control and power distribution need to be considered.

3.2. Power distribution analysis

The above-mentioned electric valves, because their voltage levels are all 24V DC, their driving power is often overlooked in the design process. Therefore, the drive power supply can be configured with a local control cabinet and powered by the control cabinet. The local control cabinet power supply can be provided by an external power supply system arranged in the same plant. The control cabinet can be equipped with a power conversion module to match these valves. Voltage level. For electric valves without control cabinet power supply, their driving power can be provided by the corresponding control system.

4. Design and results

Based on the analysis of the control function and power distribution of these valves, first of all these valves should be connected to their control system, the input and output terminals of the local control cabinet partly or completely. Secondly, the BCS, FDS, and local control cabinets should be connected to the relay contacts through the relay contacts. The motor winding of the switch type electric air valve is energized or the solenoid coil is energized, and then the motor or electromagnet and its reset mechanism drive the valve to the fully open or fully closed position. This article designed 8 kinds of interface diagrams, covering all the valves of the ventilation system in the nuclear power plant's conventional island plant, so that the interfaces of the control and power distribution of these different types of electric valves are consistent and the corresponding requirements are put forward. These
diagrams are for these The design and purchase of the valve put forward the guidance basis and corresponding requirements, as shown in Figure 1~Figure 8.

Figure 1. Interface diagram of on-off electric valve with FDS override control(Class I)

Figure 2. Interface diagram of fail-safe electric valve controlled by BCS(Class II)

Figure 3. Interface diagram of on-off electric valve controlled by FDS(Class III)

Figure 4. Interface diagram of fail-safe electric valve controlled by FDS(Class IV)
5. Conclusions

This article categorizes and compares the valves of various control modes in the ventilation system of the nuclear power plant’s conventional island, and gives the corresponding control and power distribution interface schemes. By adopting the configuration of the local control cabinet, the effective connection is achieved. In addition, the on-site controlled equipment and remote control systems are implemented, and the power supply configuration can be realized by setting the on-site control cabinet. The proposal of this plan effectively divides the valves in the ventilation system of the nuclear power plant conventional island plant into several types, and proposes a unified interface based on these
types, which is a reference basis for the corresponding engineering design in the future, and it is also a reference for the supply. The supplier provides the supply requirements for the corresponding hardware configuration. In the future engineering design, the eight interface diagrams proposed in this article can be used to correspond to different types of valves one by one. Only a comparison table of control cabinets and valves needs to be compiled, which will greatly shorten the design process. It is also convenient to check related information during the construction process.

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