Electrical and Computer Engineering Studies
Volume 1, Issue 1, No. 3
Published online November 3, 2022

Sanderman Publishing House

Improvement of important load power supply mode of Qinshan Phase 2 extension project and its impact on operation

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Abstract. In this paper, the improvement measures of important load power supply mode of Qinshan Phase 2 Extension Project are summarized, involving important loads of power supply to the control cabinets of the reactor protection regime (RPR), the process instrument control system (KRG) and the digital electric hydraulic (DEH) control system. The improvement is performed by automatic or manual switching for dual power supply and adding diesel generator backup start logic. Through the research on these improvement measures, the impact of these improvement measures on operation was analyzed. In addition, the problems after implementation of the improvement measures were analyzed and discussed, and suggestions for subsequent improvements were proposed.

Keywords. Improvement of power supply mode, power supply reliability.

1. Introduction

Qinshan Phase 2 Extension Unit is the unit improved based on Unit 1 according to the feedback of experience and requirements of the national nuclear safety authorities. As a result, the reliability of the unit has been significantly increased. As for a nuclear power plant, the reliability of power supply has always been an important issue, which is also true for the supply of important load devices in the plant. The extended unit sorted out the loads in the plant, and implemented a series of improvements regarding the power supply modes for some important load devices. The improvements regarding the power supply modes for these important load devices include transformation of automatic switch of dual power supply for critical control system cabinets, the addition of another diesel engine for standby power supply, and the setting of a dual power system for load devices requiring high continuity of power supply. The implementation of these improvement measures can further improve the operation reliability of the unit, increase the operational flexibility, and simplify the incident handling procedures. In this paper, the measures for improvement of the power supply mode for important load devices of the extended unit were summarized, and some suggestions were proposed to improve the shortcomings.

2. Specific improvement measures

2.1. Improvement measure 1: Improvement of automatic switching for dual power supply to important instruments

1) Improvement of dual power supply for KRG control cabinet. KRG control cabinet is the instrumentation control system cabinet of the nuclear power plant. It can control and protect all systems in the primary circuit and some important control systems in the secondary circuit. It is responsible for processing the measurement signals from the control and protection instruments of the process system, and outputting specific control and alarm signals. Without the KRG control cabinet, the regulation system of the nuclear power plant would be invalid, and could result in a major transient state. The original power supply scheme for the KRG control cabinet was to introduce 220V AC power from the uninterrupted power system of the nuclear island, and realize power supply in a ring connection mode. Therefore, the extended unit implemented the transformation of automatic dual power supply for the KRG control cabinet. The power supply from uninterrupted power system of the nuclear island was reserved, and UPS power supply from the conventional island was added. The two sources of power supply were transmitted to power boxes of the KRG cabinet, which could be automatically switched with ST1-B component. ST1-B, a power receiving/switching device, can receive 220V power from the two sources, and select one circuit for output. ST1-B can automatically select the mode of operation: when both sources of power supply are normal, ST1 may select the main power source - UPS of the nuclear island - for power supply; when the voltage of the main power supply drops to 90% (about 198VAC), ST1-B would switch to the standby power supply, namely UPS of the conventional island; and when the voltage of the main power supply rises to 95% (about 210VAC), ST1-B would switch back to the main power supply. The improvement greatly improved the reliability of the power supply to the process instrumentation control system of the nuclear power plant, and simplified incident handling.

2) Automatic dual power supply to the reactor trip system cabinet and special system cabinet for the reactor.

The two cabinets were respectively powered by UPS of the nuclear island prior to the improvement, but there was only one circuit of UPS power supply. Due to the negative logic of the reactor trip system cabinet and special system cabinet, the loss of power supply to the logic cabinet would protection false triggering. Because of the negative logic (power loss action) of the trip system output cabinet, the order of tripping would be sent in error. As for special system cabinet, due to the positive logic (power-on triggering) of the output cabinet, the loss of uninterrupted power in the nuclear island under normal conditions would lead to action rejection of the special system. In order to ensure safety of the reactor, avoid malfunctioning of the reactor trip system and rejection of the special system, the extended unit implemented dual power supply modification for the reactor trip system cabinet and special system cabinet. While

reserving the original power supply, UPS power supply of automatic switching was set for columns A/B. After the improvement, the loss of power of a single uninterrupted bus would not lead to error reactor tripping and rejection of action of the special safety system due to the problem of power supply; therefore, it can improve economy on the basis of ensuring safety.

3) Automatic dual power supply to DEH cabinet, DCS cabinet and GME cabinet. Phase 2 Extension Project implemented digitized transformation for the DCS system of the conventional island. In order to increase the reliability of power supply to the DCS system, reduce the impact of DCS failure on the normal operation of the unit, the extended unit realized automatic dual power supply to the DCS cabinet and DEH cabinet. At the same time, in order to increase the independence of the two power sources, the extended unit added one circuit of UPS power supply, to further increase the reliability of the power supply. The above improvement could effectively avoid the impact of the loss of power of DCS cabinet on the unit. Unit 1 was once disturbed by the failure of DCS cabinet.

4) Improvement of dual power supply to solenoid valve of the pneumatic valve. In the nuclear island, there is dual power supply to solenoid valve of the outlet flow control valve of the evaporator auxiliary feed pump. While in the conventional island, there is dual power supply to solenoid valves of all voltage levels. The gas supply line of outlet flow control valve of the auxiliary feed pump is installed with two solenoid valves in a series mode. In the case of the loss of power of either solenoid valve, the outlet flow control valve of the auxiliary feed pump would return to the fully open safety location due to the loss of pressurized air. At this time, the control room would not be able to adjust the flow rate at the outlet of the auxiliary feed pump, and cause water injection into the evaporator at the full flow rate, thus causing excessive cooling of the primary circuit of the reactor. In order to control the feedwater flow of the steam generator, it can only be manually adjusted on site, which would waste valuable manpower in accident handling and cannot accurately control the water level of the evaporator. In this regard, the extended unit implemented dual power supply to the solenoid valve of the outlet flow control valve of the auxiliary feed pump, added DC power supply and made use of the intermediate relay for automatic switching of power supply to the solenoid valve. The extended unit also implemented automatic dual power supply to the solenoid valves of important pneumatic valves in the conventional island. These solenoid valves include AST solenoid valve, OPC solenoid valve, solenoid valve of the bypass system discharge valve, and solenoid valve of normal emergency trap.

2.2. Improvement measure 2: Addition of two sources of power supply to important load devices, improvement of power supply switching by manual switching mode

1) Addition of LRT system. LRT system is an overhaul resupply system, which can ensure power supply to some important load devices in the case of failure of the corresponding distribution panel. This system can simplify the resupply process in the case of busbar failure, and can also prevent the destruction of fire barriers caused by the temporary laying of resupply cables. For resupply, the switching can be realized by plugging and unplugging the socket, which is relatively simple. With the LRT system, in the case of 380V/220V AC busbar failure during normal operation, the important downstream load devices can be restored through the LRT system, so as to limit the impact of busbar failure on state of the unit.

2) Improvement of dual DC power supply for AC busbar control. Dual power supply was set for 110V DC control busbar for 6kV busbar of the conventional island, and 6kV common busbar of the nuclear island. 110V DC power is the DC operating power supply of 6kV power distribution cabinet, and the loss of 110V power would lead to trip of the downstream contactor and maintain the breaker load at the initial state, but could not be operated. At this time, due to the power supply load of the breaker, the protection signals of the process system and the electrical protection signals of the switch cabinet would not work. In the event of an emergency, the equipment may only be shut down by pressing the in-situ shutdown button, or cutting off the entire busbar and even the substation of the conventional island. In order to limit the consequences of the loss of busbar control power supply, and increase the flexibility of the operation mode, the extended unit provided two sources of 110V DC power supply for 6kV busbar of the conventional island, and 6kV common busbar of the nuclear island, which could be manually switched. The improvement increased the flexibility of the overhaul plan. During fault handling, the dual power supply can be switched, to restore the DC control power supply of 6KV busbar, and limit the consequences.

2.3. Improvement measure 3: Improvement of auxiliary diesel engine for important 220V AC instrumentation and control power supply of the nuclear island

Important 220V AC instrumentation and control power supply (LLS) of the nuclear island is the final instrumentation and control power supply for the nuclear power plant, which can provide power supply for important instrumentation and control under design-base accidents. Each unit of the extension project was set with a small diesel generator for power supply to important instrumentation and control devices of the nuclear island. In order to improve the reliability of the power supply, the extended unit can automatically switch to the diesel engine of another unit for power supply in case of failure in startup of its LLS diesel generator. When the LLS diesel generator of the unit receives an emergency start signal but fails to start (such as three failed starts, low battery voltage for starting), the LLS diesel generator of another unit would be started. The logic of starting a backup diesel engine can make full use of the diesel generators of the adjacent units, to further increase the reliability of the power supply for important 220V instrumentation and control devices of the nuclear island, and ensure the control of unit conditions of the nuclear power

plant in case of an event.

3. Analysis on shortcomings after the improvement

1) Verification of the availability of dual power supply automatic switching devices. As for important load devices, the dual power supply automatic switching can ensure that important load devices can still run normally in the case of the loss of one circuit of power supply, thus ensuring the normal operation of the unit. However, this function should depend on the performance of the automatic switching-over device, and the intended function may fail in the case of decrease of the performance and even failure of the automatic switching device. Without the performance monitoring device, the improved automatic switching device could not timely find the failure. The failure could only be found by testing, but due to the importance of the load, online testing could not be conducted during normal operation. Therefore, preventative maintenance of automatic switching-over devices and regular testing during shutdown overhaul should be considered.

2) As for the automatic switching-over device, since it could switch automatically without disturbance in the case of failure of one circuit of power supply, the operating personnel cannot detect the switching action based on the normality of load. Under normal conditions, the reliability of the backup power supply is not as high as that of main power supply, and the long-term use of backup power supply would result in degradation of equipment reliability. Therefore, it is suggested adding the alarm function for switching of the power supply, so as to facilitate the operating personnel to find the fault. As for the switching device that cannot set with the alarm function, it is suggested performing regular check of the operation situation of the automatic switching device.

4. Conclusion

Through analyzing the measures for improvement of power supply mode for important load devices in the extended unit, it could be find that these improvement measures could significantly improve the safety and economy of the unit, and would also significantly reduce operation transient events due to power supply failure upon normal operation. Since the setting of dual power supply should be tested by actual operation, some suggestions on improvement of dual power supply were proposed in this paper, for reference in subsequent improvement.

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