Analysis and Prevention of Boiler fire-extinguishing Caused by the Thermal DCS Fault

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Abstract: The number 4 boiler of a certain power plant happened the boiler fire extinction events. Because of main and auxiliary DPU switched failure, more piece of card took off the network and malfunctioned, both of PAF(Primary Air Fan) stop, which triggered MFT, that lead to the boiler fire-extinguishing. Aimed at the course of the boiler fire-extinguishing and the measure that had been adopted, this paper expounds in detail, analyzes the cause of the incident and other aspects of the problem that the incident exposed to, finally, in view of the existing problems and potential safety hazard, this paper gives specific recommendations.

1. Introduction
With the adjustment of the national energy structure and the increase of the proportion of new energy, higher requirements are put forward for the peak shaving flexibility of the power grid. The State Grid puts forward higher requirements for the reliability and stability of the operation of thermal power generating units, and the non-stop assessment of thermal power generating units is increasing day by day. Due to the poor reliability and stability of large thermal power generating units, unit tripping has seriously threatened the safe operation of power grid and main equipment of the system, increased the maintenance cost within the service life of the equipment, and seriously affected the profitability of thermal power generating units. However, unit tripping often occurs for some units due to defects in the system and equipment.

Aiming at a boiler fire extinguishing event in an ultra-high pressure unit, this paper analyzes the causes of the event and other problems exposed in this event, and gives specific preventive measures for the existing problems and potential safety hazards.

2. System Overview
The boiler of the unit is an ultra-high pressure primary intermediate reheat, natural circulation solid-state slag discharge pulverized coal boiler. The pulverizing system is of the hot primary air positive pressure direct blowing type of the medium speed coal mill, the pulverized coal burner is of the swirling type, the front and rear walls are arranged, the opposed combustion mode is adopted, the balanced ventilation is adopted, the whole steel frame single drum suspension structure, and the design fuel is bituminous coal.

DCS system is a tcs3000 instrument electric integrated distributed control system of a company. Its
main functions include: data acquisition system (DAS), analog control system (MCS), sequence control system (SCS) and furnace safety monitoring system (FSSS) [1]. The controller adopts redundant configuration, that is, one controller chassis is equipped with two sets of main and auxiliary controllers. The whole controller consists of controller power supply, DPU controller and gateway. The hardware of DPU controller is provided by MOX company, and the software and controller are imported OEM products.

At 01:48 on a certain day, No. 2 main DPU failed, and the DPU automatically switched between main and auxiliary DPUs. During the switching process, the main and auxiliary DPUs operated alternately. In this process, 01:51:33 forced draft fan a tripped, 01:52:22 induced draft fan B tripped, 01:52:32 primary air fan B tripped, 01:52:42 primary air fan a tripped, MFT occurred in the boiler and the boiler was extinguished. Then, the load of unit 4 decreased from 201MW to the target value of 1.5MW, the steam turbine operated and the generator was not disconnected. 02:03 the thermal maintenance personnel manually cut off the power supply of the main DPU, the auxiliary DPU operated normally, then turned on the power supply of the main DPU, and the main DPU was in standby state. The main and auxiliary DPUs are switched. At 02:16, the operator started the primary air fan a, started the plasma ignition at 02:18, started the No. 1 coal mill at 02:20, gradually increased the load, increased the load to 100MW at 02:57, and the unit returned to normal operation. During the whole recovery process, the minimum parameters of the unit are: load 1.187 MW, main steam pressure 8.781mpa, main steam temperature 449.9 ℃ and reheat steam temperature 424.3 ℃.

Table 1 parameter status during fire extinguishing

| Back wall of flue | 54 | 41 | 71 | 38 |
|-------------------|----|----|----|----|
| 45                | 25 | 34 | 21 |
| 23                | 37 | 48 | 16 |
| 42                | 17 | 41 | 27 |
| 51                | 27 | 38 | 57 |
| 37                | 11 | 26 | 12 |
| 28                | 9  | 16 | 35 |
| 21                | 30 | 26 | 19 |
| 24                | 11 | 30 | 26 |
| 26                | 41 | 18 | 31 |

3. cause analysis

According to the time sequence of SOE records, it is found that at 01:48:08, the main and auxiliary DPUs begin to switch, and after this time, the cards begin to fail one after another. Through the analysis of the event process and SOE records and the test of cards, it is found that the load rate of No. 2 DPU exceeds 40% (standard value 40%) and the maximum exceeds 60%, which affects the system safety.

By referring to the function introduction in 2.1 DCS operation monitoring function and 2.3.3 DPU status [2] of tcs3000 operation and maintenance manual, the analysis shows that the reason why DPU cannot complete automatic switching for a long time is that the data flow increases and the network is blocked, resulting in excessive load of main DPU and sharp decline in processing speed, thus triggering the redundant switching function of main and auxiliary DPU. At the same time, the "redundancy" between DPUs fails, the "redundancy" is lost, and the controller cannot be switched normally.

At the same time, the DPU hardware of unit 4 was upgraded to a higher version DPU, and the card was not replaced with a matching new card. The incompatibility between the old card and the new DPU is also one of the reasons for the card failure. The following figure is the schematic diagram 3 of the cause of the event.

In addition, the arrangement of important auxiliary control signal cards in DCS system does not
consider the risk dispersion in case of failure. The control signals of forced draft fan, induced draft fan, air preheater and primary air fan are arranged in the same DPU (No. 2 DPU); The control signals of No. 1 and No. 2 feed pumps are arranged on the same control card (No. 1 card on the first floor of No. 9 DPU); The control signals of AC and DC lubricating oil pumps and high-pressure starting oil pumps are arranged on the same control card (No. 5 card on the third floor of No. 8 DPU); The control signals of No. 1 and No. 2 condensate pumps are on the same control card (No. 1 card on the first floor of No. 9 DPU); Once the control station or control card fails, it will cause the important auxiliary equipment of the unit to lose control.

It can be seen from the analysis process that the causal relationship leading to this event is: firstly, the data flow is large, the network is blocked, the DPU load rate increases, and the DP module fails, resulting in the failure of the main DPU. After the failure of the main DPU, the main and auxiliary DPUs operate alternately, and the old card is incompatible with the new DPU, resulting in the failure of multiple cards in this process. After the card fails, The wrong signal was input into the DPU, resulting in confusion in the internal program of the DPU, instantaneous misoperation of some commands, random full stop of two primary fans, triggering MFT, and the boiler fire extinguishing event occurred.

4. analysis conclusion

4.1 direct cause
The data flow increases, the network is blocked, the DPU load rate increases, the DPU fails, the DPU switching is unsuccessful, the DP module fails, and the card is offline.

4.2 indirect causes
Unreasonable arrangement of important auxiliary control signal cards of DCS system; The upgrading and transformation of DCS system in the whole plant is not complete; The DCS operation and maintenance is not in place.

5. preventive measures
Accident prevention should take measures from the aspects of technology, equipment and organization management to improve the ability of accident prevention on the whole, so as to effectively control events and ensure production safety.

5.1 according to DL / T 5175-2019 technical regulations for design of thermal control system of thermal power plant, important auxiliary equipment shall be redistributed on DCS [3]:

① The control signals of forced draft fan, induced draft fan, air preheater and primary air fan are arranged in different control stations respectively;
② The control signals of No. 1 and No. 2 feed pumps are arranged on different control cards respectively;
③ The control signals of AC and DC lubricating oil pumps and high-pressure starting oil pumps are arranged on different control cards respectively;
④ Arrange the control signals of No. 1 and No. 2 Condensate Pumps on different control cards respectively;
⑤ Test the changed important auxiliary control circuit to ensure that the auxiliary control function is normal.

5.2 due to the unstable operation of DCS system, high card failure rate, failure of automatic switching of DPU and long switching time, the following work shall be carried out:

① Contact the DCS system manufacturer to check and repair the controller and communication network;
② Strengthen the patrol inspection of DCS network operation and deal with problems in time;
③ The DCS system shall be completely transformed and upgraded at the right time. Strictly review and control the feasibility study, design, implementation scheme and other links of the project, eliminate hidden dangers, improve reliability and ensure safe operation;
④ After the upgrading, the DCS system shall be strictly accepted according to DL/T 659-2016 code for acceptance and test of distributed control system in thermal power plant, and the performance of DCS system shall be comprehensively tested [4].

5.3 network congestion and DPU failure. The following two aspects should be strengthened:
① Strengthen the monitoring of DPU load rate in DCS system, especially DPU with a large number of control equipment and large data flow. When it is found that DPU load rate is high, contact the operator, take safety measures and manually switch DPU. At the same time, it is necessary to strictly implement Article 9.3.1 of the 25 key requirements for the prevention of power production accidents (GNQ [2014] No. 161). For power plants equipped with distributed control system, an emergency treatment mechanism in case of distributed control system failure shall be established according to the specific conditions of units, and a practical and operable emergency treatment plan for distributed control system failure shall be formulated under various conditions, And conduct regular anti accident drills [5];
② Test the network load in DCS system. If it does not meet the performance requirements, it shall be reformed in time;
③ It is necessary to deeply study the tcs3000 instrument electric distributed control system - software manual and tcs3000 operation and maintenance manual.
④ Add bypass to the output command in the logic of important auxiliary equipment, and input the bypass into RS trigger for monitoring.

6. Conclusion
In view of the events occurred in the plant, the thermal control discipline should strengthen the management of DCS system, carry out thorough transformation, redistribute the distribution of equipment in the transformation process, and improve the reliability of DCS system.

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References
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[5] Twenty five key requirements for preventing power production accidents (GNQ [2014] No. 161)