Analysis and treatment of shutdown due to high condenser pressure towards ultra-supercritical 660MW turbine

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Abstract. During the normal operation of an ultra-supercritical 660MW steam turbine in a power plant, the pressure of condenser gradually increases, then reduced electrical load, condenser pressure continued to rise to the protection action, the unit shutdown. Through on-site inspection and inspection of the operation curve, it was found that after the water level of the collecting water tank of the boiler's starting hydrophobic system was zero, the B hydrophobic pump was still closed and the outlet electric door was not closed. The fault of the B hydrophobic pump's trip relay was diagnosed and investigated, and the cause of the fault was accurately analyzed. After replacing the tripping relay and adding the tripping logic of the drain pump, the unit can be restarted and run normally.

Keywords. Trap pump trip relay; Fault diagnosis; Fault treatment.

1. Overview of equipment
The unit of a power plant is an ultra-supercritical 660MW steam turbine generator set which joint designed and manufactured by Shanghai steam turbine CO., LTD. and Germany SIEMENS , model is N660-25/600/600. The steam turbine is a single intermediate reheat, single shaft, four cylinders, four exhaust steam, double back pressure, pure condensing steam turbine. The maximum continuous output is 718MW and rated output is 660 MW. The rated speed is 3000r/min.

2. Fault description
On May 31, 2017, the unit was started after temporary repair and connected to the grid at 05:00. At 07:34, the load was 238MW, the condenser pressure was 6.5KPa, the pressure of condenser gradually increased. At 07:36, the load was 224MW, the condenser pressure was 12.6KPa(seen in figure 1) , condenser pressure continued to rise to the protection action, the unit shutdown. ETS first issued as "condenser high pressure signal tripping".
3. Fault analysis

Refer to trip protection of the unit, it was found the condenser pressure high tripping value was a dynamic setting, and changed with pressure of medium and low pressure cylinder connecting pipe. The condenser pressure was 12.6 KPa when the trip, and there was no alarm value, the condenser pressure high dynamic tripping value as shown in figure 2, the condenser pressure was high tripping fixed value changing with pipe pressure curve as shown in figure 3.

The reason of shutdown was that condenser pressure rised to the protection action.

![Figure 2. Setting the high dynamic trip value of condenser pressure.](image2)

![Figure 3. The high trip value of condenser pressure varies with the pressure curve of the connecting pipe.](image3)
3.1. Analysis of high condenser pressure

Checked the systems and equipments connected to condenser, there may be the following reasons, one by one for investigation.

1) Effect of condenser circulating water system and equipment on vacuum

Checked the circulating water pipe of the condenser and no obvious leakage was found. Checked the related valves of the circulating water system and the valves were all in normal condition. Checked circulating water pump, motor current, water temperature and pressure at inlet and outlet of circulating water pump were normal. There was no obvious change before and after the shutdown of the unit, and the circulating water pump ran normally. So the influence of condenser circulating water system and equipment on vacuum could be eliminated[1].

2) Influence of steam turbine shaft seal system on vacuum

After checking the steam pressure trend of steam turbine shaft seal mother tube and low pressure shaft seal, no obvious abnormality was found. The steam pressure values of shaft seal mother tube and low pressure shaft seal were within the design requirements. Checked the draught fan of the shaft seal heater, the fan operated normally. Checked the water level of the shaft seal heater, all within the design requirements, the influence of the steam turbine shaft seal system on the vacuum could be eliminated[2-3].

3) Effect of condenser water level on vacuum

Checked the water level of the condenser, the water level was within the range required by the design, and excluded the influence of the high water level of the condenser to flood the cooling pipe or the extraction port, which will lead to the decrease of the heat exchange effect in the condenser and the decrease of the vacuum

4) Effect of condenser suction air system on vacuum

Checked the piping of the vacuum system and no obvious abnormality was found. Checked the pneumatic control valve and manual stop valve, the valve working state was normal. Checked the water ring vacuum pump, motor current and water ring vacuum pump water level were normal, the effect of condenser suction air system on the vacuum could be eliminated[4 - 6].

5) Influence of boiler starting hydrophobic system on vacuum

After the unit trip, the water level of the water collecting tank was checked, and it was found that the water level meter with magnetic flip plate was zero. Checked the drain pump and outlet electric valve, read the operation curves of the drain pump, the outlet electric door and the remote liquid level meter of the water collecting tank, it was found that furnace side collection tank B drain pump frequency conversion operation after the unit was connected to the network (At 5:00, May 31). At 6:32, frequency converter instruction of B drain water pump reduced to zero (motor speed to zero). The water level of the water collecting tank was 1.2m, but DCS showed B drain pump for the electrical switching state, the outlet electric valve was not closed, the level of water tank continued to decline. At 7:14, the level of water tank declined to zero (seen in figure 4), then the condenser pressure gradually increased.

![Figure 4. The boiler starts the drainage system.](image-url)
The outlet valve of the drain pump in the collector tank B was not connected, the condenser was connected to the collector tank through the high-pressure hydrophobic expansion vessel and the hydrophobic pipe at the side of the machine. Under the action of the negative pressure of the condenser, the storage water in the collector tank was sucked slowly and the water level continued to drop. When the water level of the water collecting tank dropped to zero, the condenser was connected with the atmospheric expansion vessel through the water collecting tank, resulting in the rapid rise of condenser pressure.

3.2. Analysis of outlet valve of the drain pump of the collecting water tank was not closed

The collecting water tank had two analog water level measuring points, which were measured by differential pressure transmitter. The main purpose was to control the speed of the steam pump to adjust the water level of the collecting water tank, and to set a low water level alarm (the alarm signal had been sent out when the water level of the unit before tripping was 1m). Another water level switch was installed, which was directly connected into the electrical control loop through hard wiring, to stop the drain pump when the water level was as low as 0.6m. After the unit tripping, the water level switch had been activated and the node had been closed.

It was found that the logic was set to interlock and close the electric valve of the drain pump outlet after the pump shut down. After the unit tripping, the DCS screen showed that the drain pump B was in the closing state, so the electric valve of the drain pump outlet of B was not closed. The thermal control logic diagram of the electric door of the drain pump outlet was shown in figure 5.

Figure 5. Electric thermal control logic diagram of steam trap valve.

It can be known from the above analysis, the main reason why the outlet valve of the drain pump in the collector tank B was not closed was that the opening signal of the drain pump in the collector tank B was not sent out, which lead to the fact that the drain pump in the collector tank B was still closed, making the electric door at the outlet not closed.

3.3. Analysis of the drain pump of collecting tank B did not open the valve

Checked tripped relay of the B steam pump tripping signal circuit, it was found that B drain pump tripping signal circuit relay KA4 coil had pseudo soldering and relay was damaged, these lead to the signal of water tank water level B drain pump tripping commands cannot KA4 jumped by tripping relay contactor, lead to drain the water pump for switching state, still drive set water tank water level low associated stop dredging pump principle diagram as shown in figure 6.
Figure 6. Schematic diagram of drain pump with connection of low water level opening in water collecting tank.

After on-site investigation and analysis, the main reasons for the failure of tripping of the drain pump B were as follows: the virtual welding of the coil contact of the tripping signal circuit of the drain pump B relay KA4 caused the relay to be damaged, making it impossible for the drain pump B to tripping the contactor after receiving the tripping instruction and perform tripping.

4. Treatment measures and effects
1) Replace KA4 trip relay and check the same type of relay. And the frequency conversion cabinet to check the protection, to prevent moisture intrusion.
2) Add the electric vavle logic of the jellyfish tube in the collector tank when the water level is 0.6m low.
3) Add the protection logic of the catchwater drain pump with the simulated water level as low as 0.6m.
4) The operation personnel shall strengthen the monitoring of the operation status of related equipment to prevent similar events from happening.

In accordance with the formulated treatment plan, the unit was started again and connected to the network, and the unit returned to normal operation.

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