Analysis and treatment of abnormal shutdown of ultra-supercritical 660MW unit due to low feed water flow

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Abstract. During the normal operation of an ultra-supercritical 660MW steam turbine generator set in a power plant, the output of the coal mill was insufficient, and the boiler feed water flow gradually decreased. After reducing the power load, the boiler feed water flow continued to decrease to the protection action, and the unit tripped. Through on-site inspection and inspection of the operation curve, it was found that the main steam pressure was high, and the re-circulation valves of the steam-driven feed pump A and B were opened. Cause of the fault was accurate analysis. After optimizing the flow rate of the steam feed pump, the unit was restarted and ran normally.

Keywords: Boiler feed flow; Steam feed pump recirculation valve; Fault diagnosis; Fault treatment

1. Overview of equipment

The unit of a power plant is an ultra-supercritical 660MW steam turbine generator set, the model is C660/612-28/0.5/600/620, the steam turbine is a highly efficient ultra-supercritical, primary and intermediate reheat, impulse type, single shaft, four cylinders, four exhaust steam, nine stage reheat, single extraction condensate type. It has a single - flow high - pressure cylinder, a single - flow medium - pressure cylinder and two double - flow low - pressure cylinder. High pressure has 12 pressure levels; Medium pressure has 10 pressure stages; Low pressure double shunt has 2 × 2 × 5 pressure levels, total structure series is 42. High pressure blades are all equipped with crown blades. Rated heating extraction flow is 450t/h, extraction steam pressure is 0.5MPa, extraction temperature is 266.2 ℃; Maximum heating extraction capacity is 700 t/h, extraction steam pressure is 0.5 MPa, extraction temperature is 266.3 ℃.The water supply system is equipped with two steam driven feed pumps with a capacity of 50%BMCR, which are A steam pump and B steam pump respectively. The supporting steam turbine models are all NK63/71 produced by hangzhou steam turbine co., LTD. The feed pump steam turbine is of single cylinder, axial flow and reaction type, and the exhaust steam is directly discharged to the main engine condenser. The rated speed is 5500r/min, the working speed is from 3000 to 5990r/min, and the first-order critical speed is above 7000r/min. A and B steam pumps are of the horizontal multi-stage barrel core enveloping structure, the shaft end sealing type is labyrinth sealing, and the rated speed of the feed pump is 5500r/min.
2. Overview of fault phenomena
On November 4, 2017, the unit load was 317MW, coordinated control mode, the main steam pressure was 24.76 MPa, A, B, E, F coal mill output were around 12 t/h, D coal mill output was 30 t/h, F layer micro oil, oil gun, E layers A and B (E2 - E5) oil gun, A and B small machine remote control, automatic feed water running, A feed water pump outlet flow was 452 t/h, B feed water pump outlet flow was 499 t/h. At 14:37, boiler feed water flow dropped to 252 t/h and the unit tripped.

3. Cause analysis of fault

3.1. Reasons analysis on the shundown of unit
Through consult the relevant parameters of the unit operation curve, it was found that the boiler feed water flow was reduced gradually, A and B feed pump minimum flow valves were opened entirely when feed water flow rate dropped to 252 t/h, but the boiler feed water flow continued to fall, boiler feed water flow dropped to protection value, eventually triggered boiler MFT, then caused the protection operation of the unit, the unit tripped.

3.2. Cause analysis of low feed water flow rate of boiler
Checked the historical trend of the equipment operation, it was found that unit load was 340MW at 13:28, A, B, E, F coal mill output were low, coal-feed was 12t/h, differential pressure of coal mill was high, then caused full grinding and pumping powder frequent (seen in figure 1). All of these led to coal mill outlet temperature automatically adjust the deflection, remove hot air automatically, automatic fuel master resection, the unit coordinated control excision, superheating temperature was reduced. C layer oil gun was put into operation, the unit lead dropped to 300MW and main steam pressure increased from 13.95 MPa.

Figure 1. Grinding and pumping powder of coal mill.
At 13:50, the output of coal mill tended to be stable, and the C-layer oil gun was shut down. At 13:53, the main steam pressure slowly rised to 25.1MPa, the automatic state of the small machine A and B was lowered, the door was fully opened, and the feed water flow was 950t/h. At 14:18, the unit coordinated control and begin to increase the load, feed water flow control instructions slowly decreased. At 14:35, small machine adjustment valves of A and B pump were turned down, feed water flow reduced from 945 t/h to 279 t/h. At 14:36, A and B feed water pump minimum flow valve interlocks opened. At 14:37, MFT was triggered due to low boiler feed water flow (shown in figure 2), the unit tripped.

The main reason for the low feed water flow rate of the boiler was that the set value of feed water flow rate of the boiler was 741t/h, and the actual operating value was 958t/h when the load was 317MW. When the feed water flow rate dropped to 760t/h (the open flow rate of the recycle gate of each steam pump was set at 380t/h), the steam pump recirculation door was adjusted and opened according to the flow rate curve of the steam feed pump inlet, which further reduced the boiler feed water flow rate, and the high pressure of the main steam exacerbated the decrease of the flow rate of the steam feed pump outlet.

3.3. **Reason for opening the recycle valve of the steam feed pump**

The inlet flow of each steam feed pump was lower than 380t/h, and the recycle valve of the steam feed pump was adjusted and opened according to the inlet flow curve. When the unit was under low load and the feed water flow required by the boiler was close to the set value of the steam pump recycle door, it was easy to cause the recycle door to open frequently, resulting in the decrease and aggravation of feed water flow.

3.4. **Cause analysis on high main steam pressure**

The grindability of coal was poor and the output of coal mill was low and unstable, the output of coal mill A, B, C, E and F changed frequently between 0-12t/h. In order to stabilize the combustion of the boiler, too many oil guns were put into, while the load was not increased in time, the superheat rised and failed frequently, and the operator's adjustment was not timely, resulting in the high steam pressure.

4. **Exposed major problems**

The operators do not know enough about the set value of the main steam pressure when the unit was under low load, which led to the high main steam pressure when the unit was under low load.

The constant value of the combined opening flow of the steam pump recirculation door was too close to the value of the feed water flow required by the boiler at low load, which may easily lead to the frequent opening of the recirculation door at low load.

The minimum flow setting value of feed water control was too low, which was 600t/h.
5. Troubleshooting measures and results achieved

The operators should strengthen the training on the starting curve of the unit to ensure that the main steam pressure of the unit matches the actual load.

Optimized the flow setting value of the steam pump recirculation gate opening, and contacted the manufacturer to reset the setting value.

Adjusted the minimum flow setting value of feed water control to match the opening value of the minimum flow valve to ensure sufficient margin between the fixed opening flow value of the steam pump recirculation valve and the feed water flow value required by the boiler's low-load operation at low load.

Operation personnel shall strengthen the monitoring of operation parameters of related equipment, especially the water supply flow, and set a first-level alarm to prevent the occurrence of similar events.

According to the treatment plan, the unit was started again and connected to the network, and the operation was normal.

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