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Analysis and Treatment of Shutdown Due to Bearing Vibration 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 temperature of low-pressure shaft seal steam inlet gradually increases, and the vibration of steam turbine bearing suddenly increases, leading to the steam turbine shutdown. The diagnosis and troubleshooting of major vibration faults of steam turbine bearing are carried out, and the causes of faults are accurately analysed through collecting field data, checking maintenance records and disassembling inspection of relevant equipment. Taking corresponding effective measures to eliminate the potential equipment safety hazard.

Keywords. Ultra-supercritical 660MW steam turbine; Bearing vibration; Fault diagnosis; Fault treatment.

1. Overview of equipment

The unit of a power plant is an ultra-supercritical 660MW steam turbine generator set, model is C660/612-28/0.5/600/620. The steam turbine is of high efficiency ultra-supercritical, primary and intermediate reheat, impulse type, single shaft, four cylinders, four exhaust steam, nine stage reheat, single extraction condensation type. The unit has a single - flow high - pressure cylinder, a single - flow medium - pressure cylinder and two double - flow low - pressure cylinder. High pressure 12 pressure levels; Medium pressure 10 pressure stages; Low pressure double shunt 2×2×5 pressure levels, total structure series 42. The high and middle pressure blades are all equipped with crown blades. Rated heating extraction flow is 450 t/h, extraction steam pressure is 0.5 MPa, extraction temperature is 266.2 °C; Maximum heating extraction flow is 700 t/h, extraction steam pressure is 0.5 MPa, extraction temperature is 266.2°C.

Steam turbine shaft seal system adopts self-sealing type, as shown in figure 1. When the unit is in normal operation, there is no need to supply steam from outside the system, but the leakage steam from both ends of the high and middle pressure cylinder is fed into the low-pressure shaft seal after cooling by the condensate water spray, and the excess leakage steam will overflow to the condenser or #8 low-pressure heater [1,2].



2. Fault description

On December 7, 2018, the unit load is 327MW, the main steam temperature is 600 °C, reheat temperature is 596 °C, reheat steam pressure is 2.68Mpa, reheat steam temperature is 249 °C, the vibration value of #7 and #8 bearings suddenly rose to 250 μ m and 243 μ m respectively in Y direction. The ETS protection action and the steam turbine shutdown. The first reason is "bearing vibration is large" (Protection logic is that this bearing vibration exceeds the trip value 250 μ m, and any other bearing vibration exceeds the alarm value 150 μ m). There is no abnormality in bearing temperature, differential expansion of low-pressure cylinder, axial displacement and other parameters in the process of machine shutdown.

3. Fault analysis

3.1. Reasons analysis of vibration of steam turbine bearing

After the unit shutdown, we review the historical trend immediately for analysis, it can be found : On December 6 01:47, low last warm tone opening reduction is 60.41%, shaft seal steam temperature is 156 °C; 01:50, Low closing seal inlet steam temperature rises to 215 °C (shown in figure 1), low pressure shaft seal desuperheating valve open to 99.3% automatically, due to the temperature and the set value deviation (165°C) is greater than 50 °C, remove automatically[3]. At the time of 01:55, the operator throws the automatic switch again, and the switch remains fully open. Until 2:17 on the seventh of December, low closing seal steam temperature fluctuates between 240-270°C (higher than that of the steam turbine equipment manufacturer design value standard 121-177°C). Personnel did not adjust the shaft seal temperature during the operation

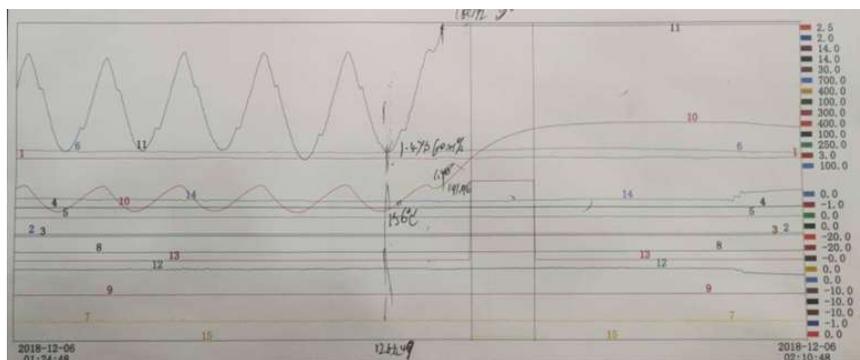


Figure 1. Trend chart of low pressure shaft seal steam inlet temperature.

The unit load reduced from 423MW to 330MW, low closing seal steam temperature risen from 267 °C to 286 °C (shown in figure 2). The low pressure shaft seal produces large radial expansion in the long over temperature environment, at the same time, the rotor with low pressure seal also produces great radial deformation due to high temperature steam. Because the heated area of the rotor is large, the radial expansion produced by the low-pressure rotor is obviously greater than that of the low-pressure shaft seal. The result is that the low pressure shaft seal and rotor collide radially. The leaf spring on the back of the low-pressure shaft seal is heated after low pressure shaft seal steam inlet temperature increasing, the stiffness is obviously reduced and even loses its elasticity. When the radial dynamic and static friction between the low-pressure shaft seal and the rotor occurs, the radial movement of the low-pressure shaft seal body cannot reduce the friction between the dynamic and static, resulting in a sudden and sharp increase in vibration (seen from figure 3), until the shaft vibration is greatly protected, and the machine shutdown.

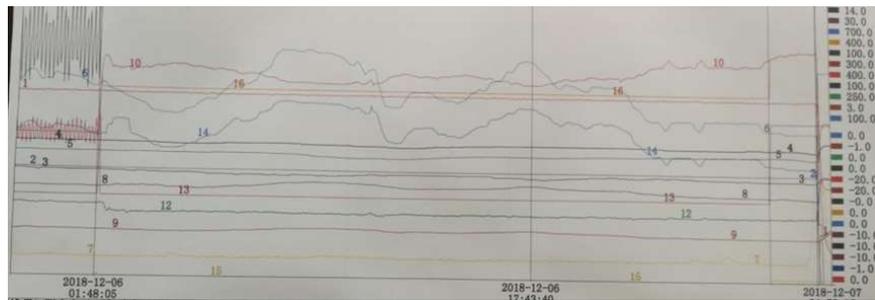


Figure 2. Trend chart of turbine bearing vibration.

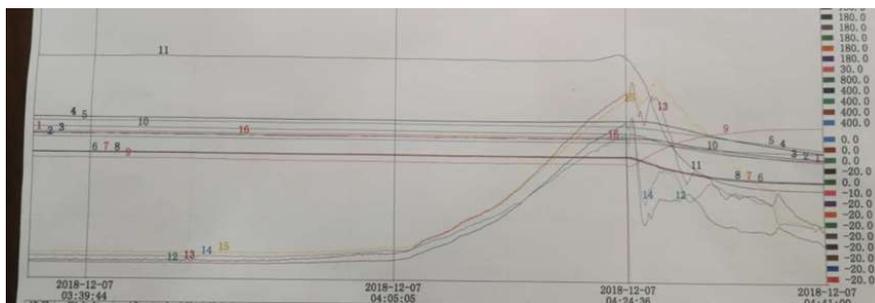


Figure 3. Trend chart of turbine bearing vibration and temperature.

3.2. Reasons analysis of high inlet temperature of steam turbine low pressure shaft seal

Focus on the analysis of the reasons for the rise of low-pressure steam inlet temperature, combined with the actual operation of operators and field equipment of the shaft seal system, there may be the following reasons, one by one for investigation.

1) Low pressure shaft seal desuperheating water regulating valve blockage

After the unit is switched off, the bearing system cannot realize self-sealing by leakage of steam in the high and medium pressure shaft seal, and can only be supplemented by external auxiliary steam to meet the steam supply flow required by the low-pressure shaft seal and ensure the vacuum of the condenser. Shaft seal steam source instead of auxiliary system, low closing seal steam temperature is 157 °C (equipment manufacturer design value standard is 121-177 °C), adjust the low finale with warm water regulating valve opening reduction, found that low closing seal steam temperature changes with the opening of the regulating valve.

It is impossible to accurately judge whether the low-pressure shaft seal desuperheating water regulating valve is blocked through the test, and then the method of disintegrating the low-pressure shaft seal desuperheating water regulating valve is adopted to check whether there is foreign body blockage. The disintegration inspection is shown in figure 4.



Figure 4. Low pressure shaft seal desuperheated water regulating valve disassembly inspection.

Through the disassembly inspection of the low-pressure shaft seal desensitization regulating valve, it is found that the valve core and the valve seat sealing surface are intact without any abnormality, the valve channel is free from blockage, and there is no foreign matter, so the reason for the blockage of the regulating valve is excluded

2) Low pressure shaft seal desuperheated water filter screen blockage

Check the maintenance record of the low-pressure shaft seal desuperheating water filter, and it is found that the filter was not cleaned during the overhaul, and the filter was prone to clogging due to the long running time. In order to further accurately judge the clogging situation of the filter, the filter was disassembled for inspection.

According to the disassembly inspection (seen from figure 5), there is no foreign body on the inner and outer surface of the filter mesh, and there is no abnormal site, so the blockage of the filter mesh is eliminated.

3) Low pressure shaft seal desuperheated water regulating valve before and after manual door opening

After the machine shutdown, the bearing of the low-pressure cylinder of the steam turbine shall be inspected on site for no difference in sound, and the adjusting door of the steam reducing warm water in the low-pressure shaft sealing system shall be fully opened. The manual door shall be opened about 50% before and 50% after the valve adjustment, and the manual bypass door shall be opened about 25% after the valve adjustment.

Due to the poor adjustment performance of the low-pressure shaft seal desuperheated water valve, the inlet temperature of the low-pressure shaft seal is difficult to control. In normal operation, the operator should close the manual door before and after the minor adjustment, and adjust the temperature by adjusting the bypass manual door opening. When the inlet temperature of the low-pressure shaft seal rises, the operator fails to timely adjust the opening degree of the desuperheating valve, resulting in insufficient desuperheating flow and high inlet temperature of the low-pressure shaft seal[4].



Figure 5. Disassembly diagram of the warm water filter in the low-pressure shaft seal.

4) Vacuum variation

The unit load is low, the heat extraction capacity is large, the exhaust capacity of the low-pressure cylinder is reduced, the condenser vacuum is high, the steam supply capacity of the low-pressure shaft seal is increased, and the flow of the desuperheated water is not changed, resulting in the temperature of the low-pressure shaft seal is further increased.

From the above analysis, it can be seen that the temperature increase of low-pressure shaft seal steam inlet is caused by the increase of vacuum. When the annular flow area of the low-pressure shaft seal and rotor remains unchanged, the required steam supply flow increases and the total heat carried increases. In order to control the inlet temperature of low-pressure shaft seal within the range of design value, it is necessary to increase the flow of low-pressure shaft seal desuperheated water, conduct sufficient heat exchange, and reduce the inlet temperature of low-pressure shaft seal. Due to the limited opening of the manual door before and after the adjustment of low-pressure shaft seal desiccant water, the flow requirements of low-pressure shaft seal desiccant water cannot be met, which eventually leads to the gradual increase of steam inlet temperature of low-pressure shaft seal.

4. Exposed problem

1) Poor operation management: The low-pressure shaft seal steam inlet temperature rose to the machine shutdown due to large vibration, the time was as long as 26 hours, the steam inlet temperature exceeded the allowable value. The operator shifted of duty for many times and no people reported this problem to the workshop, resulting in the problem for a long time, leaving the accident hidden danger.

2) Operating personnel skills are inadequate: Insufficient understanding of abnormal rise of shaft seal inlet steam temperature. Personnel on multiple shifts did not take effective measures to control and adjust shaft seal temperature to normal range.

5. Treatment measures and effects

1) Strengthen the standardized management of operation, sort out the out-of-standard parameters of operation comprehensively, and formulate operational adjustment measures to prevent the abnormal equipment caused by the over-limit parameters.

2) Strengthen the operation personnel training, improve the analysis and judgment of vibration abnormal situation and emergency handling capacity.

3) Optimize the shaft seal desuperheating water pipeline, add the screen isolation door, and realize the online isolation and cleaning of the screen.

4) Optimize the flow characteristic curve and PID control parameters of low pressure shaft seal inlet steam desuperheating valve, and realize the accurate adjustment of desuperheating water flow with the change of temperature of low pressure shaft seal inlet steam[5].

5) Increase low closing seal steam into high and low temperature alarm (low alarm point is 121 °C, high alarm value is 177 °C), add soft light plate in the DCS, remind operators after abnormal.

After the unit is shutdown, the maintenance personnel and operation personnel actively carry out fault diagnosis and analysis. After treatment, when the unit is switched on again, the vibration condition of the unit returns to normal.

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