Hidden danger and Optimization for the DEH Logic of STC-Siemens Ultra Supercritical Unit

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Abstract: With the wide application of STC-Siemens ultra supercritical unit technology, the structure design and control logic of the turbine electro-hydraulic control system (DEH) are also popularized. However, due to the defects of Siemens DEH logic design and the unavoidable mistakes of STC auto control center in the process of translating Siemens DEH logic, some hidden dangers of this type of unit are gradually exposed, which affects the reliability and safety of the unit. It is mentioned in this paper that due to the hidden trouble of ATT test logic, during the process of ATT test, 12% command signal of regulating valve setting is sent out, and the unit abnormal shutdown; When the unit is put into the AGC mode to track the AGC command, the logic hidden danger causes triggering of the quick closing condition C20 of the regulating valve (the deviation between the flow instruction converted by the valve feedback and the actual flow instruction is greater than 40%), and the unit abnormal shutdown. In order to solve these problems, the optimization suggestions of DEH logic are put forward, in order to improve the reliability of unit operation. It provides a reference for this type of unit.

1. Introduction
DEH system is an important part of steam turbine in power plant, it is the basis to ensure the normal operation of the whole steam turbine unit. If the most important electro-hydraulic control system fails, it will seriously affect the normal operation of the whole unit. This paper introduces two abnormal shutdown events caused by the hidden danger of DEH logic, analyzes the causes of the abnormal shutdown, and puts forward suggestions for the optimization of DEH logic.

2. Abnormal shutdown of unit caused by hidden trouble of ATT test logic

2.1. The course of the accident
During the sliding shutdown of a 1000MW Ultra Supercritical Unit, Conduct ATT test according to regular work schedule. The unit load is 498.1MW, three pulverizers A, B and C are in operation, the opening of the left ultra-high pressure control valve is 21.7%, and the opening of the right ultra-high pressure control valve is 22.8%, the left high pressure control valve, the right high pressure control valve, the left medium pressure control valve and the right medium pressure control valve are all opened. ATT test was started for the left ultra-high pressure control valve, during the recovery of full opening, the opening of the control valve gradually opened to 20%, and the opening of the high-pressure control valve and the medium pressure control valve did not change. One minute later,
the opening of all governing valves of the steam turbine suddenly closed to 12%, the unit load dropped to 216MW, the pressure behind the feed water operation console was 20.6Mpa, the main steam pressure rose to 20.0Mpa, the low feed water flow signal was sent out, and the boiler MFT protection action. During the test and shutdown, the opening of the control valve changes sharply, the rotor and shafting of steam turbine are unstable when the air flow impacts, the setting value of self starting speed of jacking oil pump is too low, failed to start the jacking oil pump as soon as possible to form a stable oil film, the lower bearing bush of No.1 bearing was worn.

2.2. Logic hidden danger of ATT test
Check that all turbine control valves trigger 12% opening logic, and all turbine control valves share a set 12% high limit logic. Check the logic of valve position high limit switching condition, Each switching condition of the control valve refers to an att sequence control 56 step sequence (after the completion of the control valve test, the high limit is restored to the state before the test), when this step does not reset for 2 seconds, the high limit positions of all control valves will be set to 12%. Check the condition that the 56 step sequence of ATT sequence control is issued for 2 seconds. The reset condition of 56 step sequence is that the high limit of each control valve is greater than 101.5%, and the normal setting is 105%, before this test, due to the vacuum leakage of the left ultra-high pressure control valve and the right ultra-high pressure control valve, after communication with the steam turbine manufacturer, the valve position was limited to less than 92%, so the valve limit of the ultra-high pressure control valve was set to 92%.

The reason of boiler MFT action is that low feed water flow triggers low flow protection MFT action; The main reason for the low feed water flow is that the steam pressure increases close to the pressure behind the feed water operation console, so it is difficult to feed water; The main steam pressure rises to the plateau because the opening of the super high pressure, high pressure and medium pressure control valves of the steam turbine decreases, and the pressure in front of the turbine increases; The reason for the decrease of valve opening was that the 56 step sequence of ATT test was not reset, and after 2 seconds, all 12% commands were sent out; The reason 56 step sequence was not reset in ATT test was that the upper limit of left ultra-high pressure control valve and right ultra-high pressure control valve was manually set to 92% before the test, which did not meet the 56 step sequence reset condition; The reason high limit of the left ultra-high pressure control valve and the right ultra-high pressure control valve was manually set to 92% is that the vacuum leakage occurs when the left ultra-high pressure control valve and the right ultra-high pressure control valve of the unit are fully open, and the valve position is limited to less than 92%.

2.3. Logic optimization
Optimize the ATT test circuit, implement 56 step sequence reset logic, and release the valve position limit of each control valve. When the time delay is less than 101.5%, the command signal of setting 12% of the regulating valve will be sent out in 2 seconds. Avoid abnormal shutdown of the unit due to ATT test under special conditions.

3. Abnormal shutdown caused by C20 logic hidden trouble of regulating valve fast close

3.1. The course of the accident
Under AGC mode, AGC target load is 509mw, load instruction is 517mw, unit load is 547mw, main steam temperature is 567.8℃, total coal quantity is 189.9t/h, main feed water flow is 1534.5t/h, and total valve position instruction is 77%. In the process of tracking AGC command, the unit triggers the boiler "reheater protection loss" and boiler MFT protection action. Interlock trip turbine and generator, and large interlock protection action is normal. Figure 2 shows the historical data of valve sudden drop.
3.2. logic hidden trouble of regulating valve fast close

After the AGC mode is put into operation, since AGC target load is 509MW, load instruction is 517MW, unit load is 547MW, and the deviation between load instruction and actual power is greater than 30MW, the boiler main control is switched from automatic mode to manual mode, the unit is switched from pressure limiting mode to initial pressure mode (TF), the pressure circuit output is 76.27%, the load circuit output is 76.32%, the DEH control circuit is switched to the pressure control circuit, and the turbine high-pressure regulating valve is closed to 64.6% The set value of main steam pressure is 21.45MPa, and the actual main steam pressure is 20.3MPa. In order to ensure that the main steam pressure reaches the set value, continue to close the high-pressure regulating valve of the steam turbine. The total valve position command (OSB) suddenly drops from 76.27% to 36.39%, the high-pressure control valve of the steam turbine is reduced to 12.9%, and the intermediate pressure control valve is reduced from 99% to 23.7%. At this time, the set pressure value is 21.17MPa, the actual pressure value is 20.23MPa, and the actual load of the unit is 410MW. The reason for the sudden drop of the total valve position command is that the load tracking signal is not triggered after 0.96 seconds when the pulse of pressure limiting and initial pressure switching disappears for 1 second (after checking the "and" logic function module of the output load tracking signal, the output is 0 when the two inputs are 1, the state is not flipped, and the load tracking signal recovers after 2 seconds). Because the load circuit did not track in time and there was load negative deviation, the output of the load circuit continued to decrease. The output value of the load circuit was lower than the output value of the pressure circuit, which led to the disappearance of the activation signal fdprie of the pressure circuit, and the pressure output went through the tracking circuit. According to the pressure deviation condition of 0.9MPa at that time, the output of the pressure circuit decreased by about 6% in 50ms of a scanning cycle When the total valve position command OSB is selected as the output value of pressure circuit.In the next scanning cycle, due to the negative deviation of load, the upper PID limit pipyu of load circuit is the total valve position output minus the load loop feed-forward, which is limited by the output of pressure controller. If the calculation is continued on the basis of pipyu, the output value of load circuit will be lower than that of pressure circuit in this scanning cycle, and the small total valve position command OSB is selected as the output value of load circuit. After several scanning cycles, the total valve position instruction OSB value decreases rapidly. Due to the acquisition accuracy of historical stations, only a certain time value in the process of OSB descending can be captured. Therefore, the total valve position instruction OSB suddenly drops from 76.27% to 36.39%. The total valve position instruction OSB continues to turn from 36% to 20% in the process of switching back and forth between the DEH pressure and the load loop, triggering the quick closing condition C20 of the valve, closing the high key gate to 2.3%, adjusting the switch to 0%, and adjusting the gate feedback less than 5%. C20 trigger logic is shown in Figure 1. The total valve position command of the steam turbine is 20%, and the quick closing command of the control valve disappears. The high pressure control valve of the steam turbine is opened from 2.36% to 6.68%, and the intermediate pressure control valve is opened from 0% to 2.38%.
3.3. Logic optimization

Because of the loopholes in the "and" logic block which triggers the load tracking signal, the trigger condition can not be triggered in time. Update the system patch of DEH software in time, clean the controller regularly, clear the residual garbage files in the controller, delete the load tracking signal and logic block.

Because the make-up valve has a flow command of 80% ~ 100% empty stroke, the make-up valve has not been put into use at this stage, so it can not participate in the regulation. Now the make-up valve is cut off in logic and the flow of high-pressure regulating valve is redistributed, so there will be no empty stroke problem.

The delay time of load tracking is too long (0.96 s) in the process of limiting the initial pressure. When the load circuit has negative deviation (more than 14MW), the 0.08 bias of the load circuit can not work in time, resulting in the load circuit will continue to function in the initial pressure mode. When the pressure limit is switched to initial pressure, the set load tracking actual load delay time is changed to 0.48 seconds.

During normal pressure limiting operation of the unit, the load circuit and pressure circuit switch back and forth due to the large pressure deviation. Change the pressure circuit offset from -15 to -20.

The reheater protection loss is optimized by delay time. After KU triggering, the gate is fast closed, the delay time is 3 seconds to trigger MFT, and the delay time is relatively short, which is not conducive to the automatic recovery of the unit after the load rejection. Based on the investigation of contract type units, the loss of reheater protection delayed 10 seconds to trigger MFT. Reasonable delay time, after C20 quick closing command acts, the control valve will close. When C20 condition is not met, the control valve will open slowly again and maintain the operation of the unit twice the auxiliary power load.

After the boiler main control automatically switched to manual mode, the pressure setting value did not track the actual value. After the boiler master control automatically switched to manual mode, the pressure setting was changed to track the actual pressure instantaneously. The target pressure maintained the original target pressure and was sent to DEH after the speed limit (2.5MPa/min). In the process of load increase and decrease, the steam temperature changes greatly, which weakens the change range of water and coal. It is necessary to increase the time delay for the main control of the boiler to cut off the automatic control system after the signal mutation.

4. Conclusion

Through the analysis of two abnormal shutdown events, this paper points out some hidden dangers in DEH logic, and puts forward targeted logic optimization measures. At present, the DEH system of most newly-built units in China has realized the integration with DCS system, so engineers have to
convert the control logic of Siemens DEH to realize the corresponding functions. However, due to the differences in structure, algorithm module, operation mode and mechanism of different control systems, some functions cannot be consistent with the original Siemens control system, and even there are hidden dangers endangering the safety of the unit. Therefore, it is necessary to further investigate and optimize the logic of DEH.

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