Analysis of large deviation between reheat steam temperature of 200MW unit and main steam temperature of steam turbine side

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Abstract. With the increasing task of energy conservation and emission reduction, the accuracy of important parameters of the unit is particularly important. In this paper, the main steam temperature on the side of a steam turbine in a thermal power plant is lower than that on the side of a boiler. Through analyzing the possible problems of measuring medium, measuring element, measuring channel and parameter display one by one, the reasons for the deviation of measured parameters are obtained, so as to improve the safe, economic and stable operation of the unit. This article has certain reference value to the similar question.

1. The introduction
A power plant has four 200MW coal-fired generating units. The boiler is a UG-670/13.7-M type boiler manufactured by WuXi boiler factory. The boiler is ultra-high pressure primary intermediate reheat, natural circulation solid slag discharge pulverized coal furnace. Type boiler adopts Π layout. The boiler is designed to be fueled by bituminous coal.
It has been 10 years since the unit was put into operation. With the continuous aggravation of energy saving and emission reduction tasks, it has been exposed that the main steam temperature deviation on the side of the engine and furnace caused by various factors is large, leading to large temperature reduction water volume and economic decline. The steam parameters entering the turbine regulating gate are one of the decisive factors affecting the overall cycle efficiency of thermal power units. Whether the boiler can run stably, safely and reliably is directly related to the social and economic benefits of the power plant.

2. Existing problems
Since the overhaul of the unit, the screen display value of the main steam temperature on the side of the turbine is 13℃ lower than that of the reheat steam temperature of the boiler, which seriously affects the safe, economic and stable operation of the unit. In order to facilitate the analysis of problems, we divided the temperature measurement system into several links: measuring medium, measuring element, measuring channel and parameter display. The thermocouple transmits the signal to the I/O module through compensating wires. The signal arriving at the I/O module is transmitted to the controller through the I/O bus. The controller sends the signal to the operator station through cold end compensation and finally displays in front of the operator on duty. In the measuring medium section, steam temperature, casing temperature, surface temperature of insulation layer and other measuring points are marked[1], as shown in the figure 1 below:
The temperature measuring element is thermocouple, thermocouple as one of the most simple, the most common temperature sensor, with its wide temperature measuring range, from -200 ~ +1600℃, even up to 2800℃, can convert the temperature signal into voltage signal, achieve long-distance transmission. However, in the actual work, due to the bad working environment of thermocouple for a long time, if the thermocouple is not paid attention to in the use, or the installation is not correct, it is likely to bring great errors or faults to the measurement, leading to the system working disorder, resulting in product quality and equipment safety accidents.

3. Possible cause of error
Since this phenomenon is of low temperature and the thermoelectric potential output by thermocouple is lower than the actual value, the possible reasons are as follows:

3.1. Local short circuit in thermocouple

3.2. Damp inside thermocouple. There is leakage of air and water inside the protective casing

3.3. The thermocouple electrodes have corroded or deteriorated

3.4. Local short circuit in the internal terminal of the thermocouple junction box

3.5. Local short circuit of compensation conductor, mismatch between compensation conductor and thermocouple, polarity inversion of compensation conductor and thermocouple [2]. The thermocouple temperature measurement principle and the connecting conductor rule decide that the compensating conductor must be used in its connecting line to extend the cold end temperature to the constant instrument room. In the meantime, thermocouple has the cent of positive and negative pole, the compensation wire that matches with it also has positive and negative pole, compensation wire and thermocouple must have same thermoelectric property, namely the compensation wire model that chooses must match with thermocouple, can produce measurement error likewise otherwise.

3.6. Thermocouple installation location or insert depth is not enough [2]. Regarding the installation environment and location of thermocouple, the representative measuring position of the pipeline should be selected to avoid the high magnetic field area. When the nominal diameter of high-temperature and high-pressure (main) steam pipeline is equal to or less than 250mm, the insertion depth should be 70mm, and when it is larger than 250mm, the insertion depth should be 100mm.
3.7. Thermocouple reference temperature is too high or two contact temperature is different.

3.8. Too much scaling on the surface of thermocouple protection tube.

4. Troubleshooting

4.1. Thermocouple check
Remove the measuring element and check it with tube furnace. All the test results are qualified. No moisture inside the thermocouple, no leakage of the protective pipe, water leakage and other phenomena. No corrosion or deterioration of hot electrode. There is no local short circuit in the terminal post of the thermocouple terminal box.

4.2. Measurement channel inspection
The display value of the middle pressure reheat steam temperature on the right side of the steam turbine of #1 unit is 15℃ lower than that on the side of the boiler, so the measurement channel is inspected on site. The results are as follows: the temperature measuring element is k-type thermocouple, the polarity connection of compensation cable is correct, and the compensation temperature of cold end in DCS control cabinet is 27℃, which is consistent with the reality. Disconnect the compensation wire of the reheat steam temperature measuring thermocouple on the right side of the #1 steam turbine, and add the voltage signal of 20.7mV there with the signal generator; Meanwhile, the ambient temperature was 31.4℃ measured by infrared thermometer, and the corresponding voltage of K thermocouple indexing meter was 1.28 mV. It's calculated that20.7mV + 1.28 mV= 21.98mV. Check the K thermocouple indexing table, and the corresponding temperature under this voltage is 531.57℃. The temperature curve of DCS screen shows the value of 531.57℃, and the error is within 1.6℃, which is basically normal. There are no obvious problems in the measurement channel circuit.

4.3. Check the thermocouple protection sleeve
Standard DL 5190.4-2012 《The Technical Specification for Electric Power Construction》 part 4: requirements for thermal instruments and control devices, "for high and medium pressure pipelines, if the socket is all in the insulation layer, it is appropriate to choose soft insulation material from the end of the socket for insulation, the height of the socket should not be lower than the thickness of the insulation layer.

4.4. Depth check of thermocouple insertion
If the insertion depth of the measuring point protection sleeve is not enough, the thermocouple will not be able to truly feel the actual temperature of the measured steam, affecting the measured value and producing measurement errors. The insertion depth of thermocouple protection sleeve of reheat steam pipe of unit #1 was checked, and the inspection results are shown in table 1:

| Reheater steam outlet pipe | Medium pressure cylinder inlet steam pipe |
|---------------------------|------------------------------------------|
| Left element insertion depth | Right element insertion depth | Right element insertion depth | Right element insertion depth |
| 122mm | 120mm | 105mm | 104mm |
| 125mm | 121mm | 103mm | 107mm |

Standard DL 5190.4-2012 《The Technical Specification for Electric Power Construction》 part 4: thermoelectric instruments and control devices
"When the nominal diameter of high-temperature and high-pressure (main) steam pipeline is no more than 250mm, the insertion depth should be 70mm; When nominal diameter is greater than 250mm, the insertion depth should be 100mm."
When the outer diameter of general fluid medium pipe is no more than 500mm, the insertion depth shall be 1/2 of the outer diameter of the pipe; When the outer diameter is greater than 500mm, the insertion depth should be 300mm. Therefore, from the perspective of the data of table 1, the steam pipe wall thickness of 20 mm, minus the insertion depth of pipe wall thickness, according to the standard, the side of the furnace components insertion depth basic standard, but the side component insertion depth of less than 100 mm, actually reheat steam pipe nominal diameter greater than 530 mm, and belongs to the medium pressure steam pipeline, therefore, the side temperature measuring element insertion depth did not meet the requirements of the industry standard. This is one of the main reasons for the low measured value of reheat steam on the engine side.

5. Check the measured steam temperature

Since the installation port of thermocouple is welded to the steam pipe at the entrance of the medium pressure cylinder on the side of the steam turbine and the reheater outlet on the side of the boiler respectively. The temperature at the installation port bulge can approximate the surface temperature of steam pipe wall on both sides of the steam turbine and boiler. The temperature difference at the bulge on both sides of the steam pipeline can approximately represent the temperature drop degree of the pipe wall of the pipeline. The temperature difference on the surface of the insulation layer on both sides of the steam turbine and boiler can represent the heat dissipation loss. T1 represents the temperature at the bulge of the thermocouple installation port on the boiler side; T1 'represents the surface temperature of the insulation layer of the steam pipe on the side of the boiler; T2 represents the temperature at the raised installation port of the thermocouple on the turbine side; T2 'represents the surface temperature of the insulation layer in the steam pipeline on the turbine side, as shown in figure 2.

![Figure 2. Pipe name and schematic diagram of temperature measuring point](image)

The temperature values of these four points were measured by infrared thermometer, and the temperature values of t1 and t2, t1 ' and t2' were compared. Then, the heat dissipation loss of the steam pipeline was judged. Under normal circumstances, the temperature t2 of the thermocouple socket boss on the turbine side should be slightly lower than t1 of the thermocouple socket boss on the boiler side. The surface temperature of the steam pipe insulation layer on the steam engine side t2 'should also be slightly lower than that on the boiler side t1'. If the temperature t2 of the thermocouple socket boss on the side of the steam engine is much lower than the temperature t1 of the thermocouple socket boss on the side of the boiler, it indicates that the temperature loss of the steam pipe is large.

The measurement results of the insulation layer of the reheat steam pipe of unit #1 are shown in table 2.

As can be seen from table 2, the surface temperature of the insulation layer of the inlet pipeline of the medium pressure cylinder is 7 °C higher than that of the outlet pipeline of the reheater, which indicates that the insulation effect of the pipeline is not good, and the heat dissipation loss of the pipeline is large, making the surface temperature of the insulation layer of the pipeline increase.
Table 2. Reheat the surface temperature of the insulation layer of the steam line

| Surface temperature of insulation layer at the left exit tube of boiler reheater $t_1$ ($^\circ$C) | Surface temperature of insulation layer at the left inlet pipe of the steam engine medium pressure cylinder $t_2$ ($^\circ$C) | Steam turbine side contrast boiler side ($^\circ$C) |
|---|---|---|
| 62 | 69 | ↑ 7 |
| Surface temperature of insulation layer at the right exit tube of boiler reheater $t_1$ ($^\circ$C) | Surface temperature of the insulation layer at the inlet pipe on the right side of the steam engine medium pressure cylinder $t_2$ ($^\circ$C) | Steam turbine side contrast boiler side ($^\circ$C) |
| 53 | 60 | ↑ 7 |

The measurement results of the reheat steam pipe element socket boss for unit #1 are shown in table 3.

Table 3. Reheat steam pipe temperature measuring element boss temperature

| Temperature of thermocouple 1 boss on the right outlet pipe of boiler reheater $t_1$ ($^\circ$C) | Temperature of thermocouple 2 boss on inlet pipe at right side of steam engine medium pressure cylinder $t_2$ ($^\circ$C) | Steam turbine side contrast boiler side ($^\circ$C) |
|---|---|---|
| 310 | 250 | ↓ 60 |
| Temperature of thermocouple 1 boss on the left outlet pipe of boiler reheater $t_1$ ($^\circ$C) | Temperature of thermocouple 2 boss on inlet pipe at left side of steam engine medium pressure cylinder $t_2$ ($^\circ$C) | Steam turbine side contrast boiler side ($^\circ$C) |
| 300 | 250 | ↓ 50 |

As can be seen from table 3, the poor insulation effect of the reheat steam pipeline of unit #1 results in a large reduction in the surface temperature of the pipeline, indicating a large temperature drop of the pipeline. Therefore, this is a major reason for the low measured value of reheat steam on the turbine side.

6. Conclusion

According to the above investigation results, there are two main reasons for the low inlet temperature of the medium pressure cylinder.

6.1 Thermocouple insertion depth reasons
due to insufficient insertion depth of thermocouple protection sleeve at the inlet of the medium pressure cylinder of machine #1, the thermocouple cannot feel the real steam temperature.

6.2 The insulation layer of main steam pipe does not meet the insulation effect
due to the poor insulation effect of the reheat steam pipe of unit #1, the pipe heat dissipation causes the temperature of the thermocouple protection sleeve to drop, thus reducing the measured value of the thermocouple.
The thermocouple temperature measurement system is complicated and operates in a bad environment. As long as the thermocouple application rules are observed, the error can be effectively reduced by rational selection and correct wiring, and the error of thermocouple temperature measurement system can be controlled within its allowable error range.

7. References

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Acknowledgments

The author gratefully acknowledge the contributions of the Science and technology project of China Huadian Corporation Ltd. (CHDKJ18-01-73)