Test and Research on Load Capacity of a 210MW Unit in Heating State

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Abstract. As large-scale photovoltaic and wind power are integrated into the power grid, new energy power generation has strong randomicity, volatility and anti-peak shaving characteristics. Both the power supply side and the load side of the power grid will have random fluctuations, which brings huge challenges to the safe and stable operation of the power grid. The power grid will need more capacity and more flexible peak shaving resources as the basis for ensuring the smooth and orderly power supply. During the heating period, the thermoelectric units are faced with double pressures of power consumption peak and heating peak, and are forced to further increase and reduce output to meet the requirements of heating. Therefore, carrying out load capacity test on heating units is conducive to finding out the real output range of units and providing data support for power grid departments.

key word: Deep peak shaving; Heating period; Electric load adjustment section

1. Introduction

The turbine model of a power plant is K-210-130-1 super high pressure, one intermediate reheat, three cylinder double exhaust condensing type. The unit was put into operation in December 1989. In 2001, Alstom technology and equipment were used to retrofit the flow path of the low pressure part. After the retrofit, the original Bowman stage was cancelled, the last stage blade was lengthened from 765mm to 916mm, and the stages of the low pressure rotor remained unchanged at 2×Level 4, the nameplate of the unit is increased from 210MW to 225MW. The rated main steam pressure of this type of turbine is 12.75MPa, the rated main steam temperature is 540℃, and the rated reheat steam temperature is 540℃. The unit is equipped with 7-stage regenerative heater, including 3 high-pressure heaters, 1 deaerator and 3 low-pressure heaters. The design cooling water temperature is 20℃, and the rated back pressure is 5.0 KPa. Table 1 is the main technical specifications of steam turbine.

Table 1. Main design technical specifications of steam turbine

Project	Design parameters	Unit
Rated power	225	MW
Rated steam flow	646	t/h
Main steam pressure	12.75	MPa
Main steam temperature	540	℃
Reheat steam pressure	2.44	MPa
Reheat steam temperature	540	℃
Rated back pressure	5.0	kPa
Stages of regenerative steam extraction	3JG+1CY+3JD	
Cooling water temperature	20	℃
Feed water temperature	248.8	℃
Unit heat consumption	8700	kJ/kWh

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In November 2018, the heat supply transformation of the low pressure cylinder optical shaft back press of Unit # 3 was implemented, and the heat supply capacity was increased by 334MW, which can give full play to the heat supply capacity of Unit 3, minimize the impact of heat supply on the power generation capacity of Phase III units, improve the comprehensive energy utilization efficiency, energy conservation and consumption reduction, and have good social and economic benefits.

The smooth shaft transformation of the low pressure cylinder of the steam turbine adopts the double rotor scheme. The low pressure rotor of Unit 4 is processed into a smooth shaft, which is used for heating in winter. The original low pressure rotor of Unit 3 is used for pure condensation operation in summer. At the same time, the diaphragm in the low pressure cylinder is disassembled and assembled accordingly. The installation elevation of the front and rear bearings of the low pressure cylinder is adjusted. The half couplings at both ends of the rotor can be interchanged, The accuracy of the bolt holes of the coupling shall be completely consistent in terms of centering or two halves. The optical axis rotor of the double rotor scheme can meet the safe operation of the unit under back pressure during the heating period, and the pure condensing rotor can ensure the load carrying capacity and operating economy of the pure condensing operation in summer.

The steam exhaust from the intermediate pressure cylinder of the steam turbine is no longer discharged into the low pressure cylinder through the connecting pipe of the intermediate and low pressure cylinder, but is discharged to the newly built initial heating station of unit 3. The original connecting pipe of the intermediate and low pressure cylinder is replaced with a newly designed exhaust short pipe, and a connecting flange is added. The newly added heat supply pipeline is connected from the connecting flange, and then led to the two new heat supply network heaters through the regulating valve, safety valve, etc. After the smooth shaft transformation of the low pressure cylinder of the turbine, the amount of steam entering the low pressure cylinder is zero. In order to ensure the impulse starting of the unit, a new ventilation pipe system from the intermediate pressure cylinder to the condenser is added, which is connected to the DN500 pipe behind the original large bypass pressure reducer, and then connected to the condenser.

Double-rotor scheme is adopted for the reconstruction of the light axis of the low pressure cylinder of the steam turbine. The low pressure rotor of Unit 4 is processed into a light axis, which is used for heating in winter. The low pressure rotor of the original Unit 3 is used for condensing operation in summer. At the same time, the diaphragms in the low pressure cylinder are disassembled and disassembled accordingly. The installation elevation of the front and rear bearings of the low pressure cylinder is adjusted. The half couplings at both ends of the rotor can be interchanged, The accuracy of the bolt holes of the center or the two halves of the coupling shall be completely consistent. The optical-shaft rotor of the double-rotor scheme can meet the back-pressure safe operation of the unit during the heating period, and the pure condensing rotor can ensure the load capacity and operation economy of the pure condensing operation in summer.

The exhaust steam from the intermediate and low pressure cylinder of the steam turbine will no longer be discharged into the low pressure cylinder through the connecting pipe of the intermediate and low pressure cylinder, but will be discharged to the new initial heat supply station of Unit 3. The original connecting pipe of the intermediate and low pressure cylinder will be replaced with the newly designed exhaust short pipe, and the connecting flange will be added. The newly added heat supply pipeline is connected from the connecting flange, and then led to two new heating network heaters through the regulating valve, safety valve, etc. After the modification of the light axis of the low pressure cylinder of the steam turbine, the amount of steam entering the low pressure cylinder is zero. In order to ensure the need of impulse starting when the unit is started, a new ventilation pipe system from the intermediate pressure cylinder to the condenser is added, which is connected to the DN500 pipe behind the original large bypass pressure reducer, and then connected to the condenser.

2. On load capacity test process under heating condition

2.1 Test conditions

Before the test, due to the high temperature in this winter and the limitation of the current heating area, the high load capacity of the unit is limited. According to the actual situation of the unit and in combination with the typical working conditions of the unit's designed heating working condition diagram, the tester determined the following three working conditions. The operating modes of each working condition are rated parameters, and the power is determined by heat. After the subsequent conditions are met, the maximum electrical load working condition of the unit can be verified again:

Under working condition 1: Under 110MW working condition, adjust the heating butterfly valve to make the steam extraction pressure (intermediate exhaust pressure) close to the rated value 0.16MPa, and measure the main steam flow and external steam extraction flow of the unit.

Working condition 2: Under 90MW working condition, adjust the heating butterfly valve to make the steam extraction pressure (intermediate exhaust pressure) close to the rated value of 0.16MPa, and measure the main steam flow and external steam extraction flow of the unit.

Working condition 3: Under 77MW working condition, adjust the heating butterfly valve to make the steam extraction pressure (intermediate exhaust pressure) close to the rated value of 0.16MPa, and measure the main steam flow and external steam extraction flow of the unit.

DCS historical data are used for generator active power, auxiliary power rate, main steam flow, main steam pressure, main steam temperature, reheat pressure, reheat temperature, environmental protection parameters, condenser vacuum, heating extraction flow, heating extraction pressure, heating extraction temperature and other parameters. The collection period is 30s, and the test duration is 2 hours. Steam and water analysis and coal quality analysis shall adopt the statements of the power plant.

2.2 Test process

Working condition 1

Slowly bring the load to 110MW, adjust the main steam pressure and temperature as close as possible to the design value, adjust the opening of the heating butterfly valve to make the intermediate exhaust pressure close to the rated exhaust pressure of 0.16MPa, and keep the unit load, main steam pressure, main steam temperature and other parameters stable for 30 minutes. The effective time of the test under this working condition is 14:30-15:30 on January 9, 2019. During the test, the average active power of the generator of Unit # 3 is 113.35MW, the average main steam flow is 485.786t/h, and the external steam extraction flow (calculated by using the drainage flow of the heating network heater) is 345.554t/h. Under this working condition, the unit operation parameters are normal; No overheating of heating surface is found in the boiler; The auxiliary machine works normally; The environmental protection device works normally, the environmental protection indicators are qualified, the water supply temperature of the heating network is limited, and the main steam flow has reached the maximum value that can be reached at present, so it is determined that this working condition is the current maximum electrical load working condition of the unit.

Working condition 2

Slowly bring the load to 90MW, adjust the main steam pressure and temperature as close as possible to the design value, adjust the opening of the heating butterfly valve to make the intermediate exhaust pressure close to the rated exhaust pressure of 0.16MPa, and keep the unit load, main steam pressure, main steam temperature and other parameters stable for 30 minutes. The effective time of the test under this working condition is 11:30-15:30 on January 8, 2019. During the test, the average value of the active power of the generator of Unit # 3 is 90.79MW, the average value of the main steam flow is 399.702t/h, and the external steam extraction flow (calculated by using the drainage flow of the heating network heater) is 282.569t/h. Under this working condition, the unit operation parameters are normal; No overheating of heating surface is found in the boiler; The auxiliary machine works normally; The environmental protection device works normally and the environmental protection indicators are qualified.

Working condition 3

Slowly bring the load to 77MW, adjust the main steam pressure and temperature as close as possible to the design value, adjust the opening of the heating butterfly valve to make the intermediate exhaust pressure close to the rated exhaust pressure of 0.16MPa, and keep the unit load, main steam pressure, main steam temperature and other parameters stable for 30 minutes. The effective time of the test under this working condition is 10:30-12:30 on January 9, 2019. During the test, the average value of the active power of the generator of Unit # 3 is 78.36MW, the average value of the main steam flow is 357.342t/h, and the external steam extraction flow (calculated by using the drainage flow of the heat network heater) is 259.227t/h. Under this working condition, the unit operation parameters are normal; No overheating of heating surface is found in the boiler; The auxiliary machine works normally; The environmental protection device works normally, the environmental protection indicators are qualified, and the main steam flow has been 374t/h lower than the minimum designed stable combustion flow of the boiler. Therefore, it is determined that this working condition is the lowest electrical load working condition of the unit.The test points are arranged according to the requirements of ASME PTC 6-2004 test procedure.

2.3 Main limiting conditions for the test of extraction condensing unit:

1) Different thermal users have different requirements for steam extraction parameters, and the steam extraction parameters of the unit shall not exceed their limits.
2) The minimum electrical load of the unit is limited by the minimum steam intake of the low-pressure cylinder, the minimum stable combustion capacity of the boiler, the inlet flue gas temperature of the denitration device, the wall temperature of the heating surface, and environmental protection parameters.
3) For the reheater unit with steam extraction from the HP cylinder steam exhaust pipe, when the electrical load is low and the heat supply steam extraction volume is large, it is easy to occur that the reheater wall temperature exceeds the temperature, thus limiting the minimum electrical load of the unit.
4) For units that extract steam from the connecting pipe of the intermediate and low pressure cylinders, the exhaust pressure and temperature of the intermediate pressure cylinder shall not exceed the limits of the manufacturer.
5) The maximum electrical load of the unit is limited by the maximum evaporation capacity of the boiler, the wall temperature limit of the boiler heating surface, the quality of steam and water, the design output of the boiler denitration, desulfurization, dust removal and slag removal devices, and the design output of the main auxiliary equipment, including the pulverizing system, the six major fans, environmental protection parameters and the maximum steam inlet flow of the steam turbine.
6) The monitoring parameters affecting the unit safety shall not exceed the alarm value.

3. Conclusion

During the test of the unit #3, the minimum external heating steam extraction flow is 259.227t/h, and the corresponding unit electrical load is 78.36MW MW; The maximum external heating extraction flow is 345.554t/h, and the corresponding unit electrical load is 113.35MW.The load capacity test of the heating unit is conducive to understanding the actual output range of the unit and providing data support for the power grid department.

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References

1. Shi Qingli， Wen SheJiao.Application of thermal test in thermal power plants [J].Qinghai Electric Power, 2004，23 (4): 4-10.
2. Weng Sicheng.Thermal performance test of SAIC 300MW steam turbine (Wangting Power Plant Unit 12) [J]. Shanghai Turbine，1983 (01)：5-20.
3. Ji Ansen.Results and Analysis of Thermal Performance Test of Unit #12 in Wuhu Power Plant before Overhaul [J].Anhui Electric Power Technical Information，2000，000 (002)：7-8.
4. Wang Xuedong，Wang Xuetong，Yang Jianzhu，etc.Energy saving transformation and thermal performance assessment test of flow passage of Unit 2 in Laiwu Power Plant [J].Shandong Electric Power Technology, 1998 (4)：4-12.
5. Wang Jizhou Study on thermal system mechanism model and off design operating characteristics of coal-fired power generation units [D].Huazhong University of Science and Technology，2015.
6. Wang Wei.Analyze the application of thermal test in thermal power plants [J].China Science and Technology Wealth，2012，000 (014): 214-214.