Evaluation of operation regulation ability of a power plant unit in heating season

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Abstract. In order to further improve the operation level of thermal power units directly regulated by the power grid, the regulation capacity of a power plant unit is comprehensively analyzed and evaluated from the aspects of heating capacity, minimum startup mode of the whole plant, heating state and load capacity, etc., to provide support for the accurate dispatching of the unit.

Keywords: Unit heating, Peak shaving,Minimum output.

1. Equipment introduction

1.1 Turbine Equipment Overview

No. 1 and No. 2 steam turbines are N135-13.24/535/535 ultra-high pressure, single intermediate reheat, single shaft, double cylinder, double exhaust and condensing steam turbines. Unit 1 and unit 2 will complete the high back pressure heating[1] transformation in 2019 and 2021 respectively, with the designed circulating water volume of 6600 t/h and the exhaust pressure of 54kPa.

No. 5 and No. 6 steam turbines are C330-16.7/0.8/538/538 reactive, single shaft, primary intermediate reheat, high and medium pressure cylinder combined, double cylinder double exhaust, extraction and condensing steam turbines. The heating extraction position of unit 5 and unit 6 is the middle exhaust, the design extraction pressure is 0.8MPa, the rated extraction flow of single unit is 280 t/h, and the maximum extraction flow is 300 t/h; The industrial extraction position is the cold reheat and auxiliary steam header, and the designed extraction flow of the cold reheat is 50 t/h. Unit 5 will complete zero output [2-3] heating transformation of low-pressure cylinder in 2020. After the transformation, the maximum heating extraction flow of the middle exhaust is 640 t/h.

1.2 Heat supply

The heating and steam extraction pipes of units 5 and 6 are combined into one pipe in the steam turbine plant and then sent to the initial heating stations of phase I and phase II respectively.

There are two circuits of circulating water return in the heat supply network, which are first combined in the plant area and then divided into two circuits and sent to the condensers of units 1 and 2 for the first heating, absorbing the exhaust heat of the low-pressure cylinder and heating the circulating water temperature to about 75 ℃. The heated circulating water in the heat supply network is first combined and then divided into two circuits and sent to the initial heating station for the second heating.

There are 2 initial heating stations, and the steam source is from the exhaust and supply of No. 5 and No. 6 units. Three steam water heaters, three water-water heat exchangers and one exhaust steam heater are installed in the initial station of phase I; There are 3 circulating pumps in the heat supply network, including 1 electric pump and 2 steam pumps. The steam source of the small steam turbine is from the heating extraction header of unit 5 and unit 6. The phase II initial station is equipped with 3 steam water heaters, 3 water heat exchangers, 1 exhaust steam heater, 3 heat network circulating pumps, 2 electric pumps and 1 steam pump. The steam source of the small steam turbine is from the heating extraction header of unit 5 and unit 6.

1.3 Heating capacity

According to the statistics of the initial stage, the middle stage and the final stage of heating, the initial stage is from November 15 to December 14 every year, the middle stage is from December 15 to February 14, and the final stage is from February 15 to March 15. According to the statistics of heating extraction capacity, heating capacity, thermal power ratio, power generation capacity, power supply capacity, converted heating area and other indicators of a single unit and the whole plant, the converted extraction flow is calculated according to the heating heat index 40 W/㎡ converted heating area and the high back pressure unit. The above thermal power

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parameters are calculated according to the operating hours of the unit. In the heating season from 2019 to 2020, the heating capacity of residents is 148.27×10^5GJ, and the heating area of residents is 351.65×10^5 ㎡; In the heating season from 2020 to 2021, the heating capacity of residents is 442.37×10^5GJ, and the heating area of residents is 1057.86×10^5 ㎡; In the heating season from 2021 to 2022, the heating capacity of residents is 502.73×10^5GJ, and the heating area of residents is 1202.18×10^5 ㎡.

According to the rated external heating capacity of the power plant, the allowance of replaceable heating area of the unit is analyzed: Unit 1 and unit 2 are high back pressure heating units, which have reached the rated heating capacity and are irreplaceable; Unit 5 is divided into two operation modes: cylinder cutting and non cylinder cutting. Under the cylinder cutting operation mode of unit 5, the available heat supply area margin of the whole plant is 1355.85×10^5 ㎡, and under the non cylinder cutting operation mode, the available heat supply area margin of the whole plant is 778.97×10^5 ㎡.The alternative heating area is shown in Table 1.

Table 1 Alternative heating area of each unit and the whole plant

Generator Set	Rated heating extraction flow/ t/h	Rated heating area/ $\times10^5$ ㎡	Actual heating extraction flow/t/h	Actual heating quantity/ GJ	Actual heating area/ $\times10^5$ ㎡	Alternative heating area allowance/ $\times10^5$ ㎡
1	High back pressure heating unit has reached the rated heating capacity					0
2	High back pressure heating unit has reached the rated heating capacity					0
5	No cylinder cutting280/ Cylinder cutting576.68	No cylinder cutting544.44/Cylinder cutting1121.32	145.87	1157489.06	276.79	No cylinder cutting267.79/ Cylinder cutting844.53
6	280	544.44	21.65	138491.71	33.12	511.32
Whole plant (except unit 1 and 2)	No cylinder cutting560/ Cylinder cutting856.68	No cylinder cutting1088.88/ Cylinder cutting1665.76	132.81	1295980.77	309.91	No cylinder cutting778.97/ Cylinder cutting1355.85

2. Operation analysis

2.1 Analysis of operation during Spring Festival

During the Spring Festival, the actual average people's livelihood heating flow is 778.71t/h, and the actual average industrial steam supply flow is 0.30 t/h. The minimum startup [4] mode of people's livelihood heating and comprehensive heating should actually be one large and two small. The power plant reviewed and reported that it was two small and the cylinder of unit 5 was cut off for operation.

He analysis is as follows: in the middle period of heating, the power plant reported that the additional demand of 400 t/h people's heating flow for unit 1 and unit 2 under high back pressure operation exceeded the rated heating extraction flow (280 t/h) of unit 5 and unit 6. However, the maximum heating extraction flow of unit 5 under cylinder cutting mode was 640 t/h, which could meet the demand reported by the power plant, Therefore, before the heating season, the minimum start-up mode of the people's livelihood heating and comprehensive heating in the middle of the heating season is the two small units plus the cylinder cutting operation of unit 5; The actual average heating steam extraction volume of unit 5 during the Spring Festival is 227.02 t/h, while unit 6 basically has no heating steam extraction. The actual heating volume required by unit 1 and unit 2 under high back pressure operation is less than the rated heating steam extraction flow (280 t/h) of unit 5 and unit 6. Therefore, according to the actual heating volume, the minimum start-up mode during the Spring Festival shall be one large and two small, and it is not required to cut off the cylinder of unit 5 for operation.

2.2 Analysis of electric load adjustment capability

Unit 1 and Unit 2 are high back pressure heating units, which operate stably in the heating season and basically have no power load adjustment capacity. Unit 5 has passed the minimum technical output verification test [5]. During the test, the heating steam extraction flow is 218.83t/h, the industrial steam extraction flow is 18.16t/h, and the minimum technical output is 128.48MW (the verification requirement is 132MW); Unit 5 is a cylinder cutting unit, and there are two operation modes: non cylinder cutting and cylinder cutting. However, the average heating steam extraction flow of unit 5 at the beginning, middle and end of heating is lower than the required value of cylinder cutting (since the minimum technical output test after flexible transformation is verified according to 40% rated output, the required value of cylinder cutting is set as 278.49t/h under 40% boiler evaporation). To sum up, the electric load adjustment capacity of units 5 and 6 is as follows:

At the initial stage of heating, the adjustable output range of Unit 5 for people's livelihood heating is 132MW～314.18MW, and the adjustable output range of comprehensive heating is 132MW～ 308.32MW; The adjustable output range of livelihood heating of unit 6 is 170.59MW～306.20MW, and the adjustable output range of comprehensive heating is 173.13MW～299.79MW.

In the medium term of heating, the adjustable output range of Unit 5 livelihood heating is 132MW～272.04MW, and the adjustable output range of comprehensive heating is 132MW～266.94MW; The adjustable output range of livelihood heating of unit 6 is 165MW～330MW, and the adjustable output range of comprehensive heating is 160.36MW～325.36MW.

At the end of the heating period, the adjustable output range of Unit 5 livelihood heating is 132MW～294.81MW, and the adjustable output range of

comprehensive heating is 132MW～ 293.92MW; The adjustable output range of livelihood heating of unit 6 is 165MW～330MW, and the adjustable output range of comprehensive heating is 165MW～330MW.

Table 2 Statistics of deep peak shaving and derating

period	Generator Set	Rated capacity of unit（MW）	Minimum output of unit（MW）	Minimum adjustable output of comprehensive heating（MW）	Maximum adjustable output of comprehensive heating（MW）	Whether it has deep adjustment capability	Deep regulation load（MW）	Reduced output load（MW）
Initial stage of heating	1	145	73	98.34	98.34	no	High back pressure heating	
	2	145	73	99.45	99.45	no		
	5	330	165	132	308.32	yes	33	21.68
	6	330	165	173.13	299.79	no	0	30.21
Mid heating period	1	145	73	98.45	98.45	no	High back pressure heating	
	2	145	73	103.66	103.66	no		
	5	330	165	132	266.94	yes	33	63.06
	6	330	165	160.36	325.36	yes	4.64	4.64
End of heating	1	145	73	99.59	99.59	no	High back pressure heating	
	2	145	73	98.40	98.40	no		
	5	330	165	132	293.92	yes	33	36.08
	6	330	165	165	330	no	0	0

2.3 Analysis of electric load adjustment ability after thermal load distribution of the whole plant

Distribution principle: according to the approved minimum operation mode, the heat supply is distributed manually, and the high back pressure units are distributed preferentially. The adjustable range of the remaining heat supply bearing units is calculated, and the sum is the adjustable output range of the whole plant.

According to the actual heat supply, the minimum start-up mode of the people's livelihood and comprehensive heating at the beginning, middle and end of heating is one large and two small, i.e. (1, 2, 5 or 6). Since unit 5 has passed the minimum technical output test after flexible transformation, there are two combinations of the minimum start-up mode (1, 2, 5) and (1, 2, 6). Unit 1 and unit 2 are high back pressure heating units, with average loads of 98.69MW and 101.71MW respectively. When the heat load of the whole plant is distributed [6], the maximum and minimum adjustable output shall be taken as the average value of the whole heating season, and the heating steam extraction shall be taken as the average value of the whole heating season. To sum up, the power load adjustment capacity of single unit and the whole plant after the thermal load of unit 1 and unit 2 is preferentially distributed is as follows:

At the initial stage of heating, the adjustable output range of Unit 5 for people's livelihood heating is 132MW～302.03MW, and the adjustable output range of comprehensive heating is 132MW～289.70MW; The adjustable output range of livelihood heating of unit 6 is 165.75MW～302.03MW, and the adjustable output range of comprehensive heating is 176.01MW～289.70MW. When the minimum startup mode is (1,2,5), the adjustable output range of the whole plant's livelihood heating is 332.40MW～502.43MW, and the adjustable output range of comprehensive heating is 332.40MW～ 490.10MW; When the minimum startup mode is (1,2,6), the adjustable output range of the people's livelihood heating of the whole plant is 366.15MW ～ 502.43MW, and the adjustable output range of comprehensive heating is 376.41MW～490.10MW.

In the middle of heating, the minimum output under the average heating steam extraction of unit 5 calculated according to the design heating working diagram is lower than the minimum technical output test verification value (132MW), and the minimum adjustable output is taken as the calculated value of the heating working diagram. At this time, the adjustable output of the two combinations (1, 2, 5) (1, 2, 6) is the same value. The adjustable output range of Unit 5 or Unit 6 unit for civil heating is 114.67MW～270.78MW, and the adjustable output range of comprehensive heating is 123.67MW～259.96MW. The adjustable output range of people's livelihood heating of the whole plant is 315.07MW ～471.18MW, and the adjustable output range of comprehensive heating is 324.07MW ～ 460.36MW.

At the end of heating, the adjustable output range of Unit 5 livelihood heating is 132MW ～ 330MW, and the adjustable output range of comprehensive heating is 132MW-330MW; The adjustable output range of livelihood heating of unit 6 is 165MW～330MW, and the adjustable output range of comprehensive heating is 165MW～330MW. When the minimum startup mode is (1,2,5), the adjustable output range of the whole plant's livelihood heating is 332.40MW～530.40MW, and the adjustable output range of comprehensive heating is 332.40MW～530.40MW; When the minimum startup mode is (1, 2 and 6), the adjustable output range of the whole plant's livelihood heating is 365.40MW ～ 530.40MW, and the adjustable output range of comprehensive heating is 365.40MW～530.40MW.

3. Analysis of output reduction

3.1 Analysis of actual average heat supply decreasing output

No. 1 and No. 2 units are high back pressure heating units with stable operation. The average load in the heating season from 2021 to 2022 is 98.69 MW and 101.71 MW respectively, which deviates from the blocked capacity applied by the power plant by 1.31 MW and 1.71 MW. The output reduction application is reasonable. The upper limit of the theoretically calculated adjustable output under the actual average heating extraction steam flow and average industrial extraction steam flow of unit 5 during the heating season from 2021 to 2022 is 283.17MW, which is 43.17MW different from the applied

blocked capacity of the power plant, and the application for output reduction is unreasonable.

3.2 Analysis on verification test of reduced output

The unit shall be subject to the verification test of output reduction and analyzed according to the test results. Analysis basis: 1) during the test, whether the main steam flow reaches the main steam flow of the unit under TRL (high back pressure) condition; 2) Whether the heating extraction steam flow is reduced.

No. 1 and No. 2 units are high back pressure heat supply units, which operate in the mode of heat and constant power. During the test, the main steam flow did not reach the main steam flow under TRL condition. The unit still has the space for output increase of 11.03MW and 10.16MW. The application for output reduction is unreasonable. During the test of unit 5, the output was not increased by adjusting the heat supply; When the heating extraction steam flow is unchanged, the main steam flow of the unit does not reach the main steam flow under TRL condition, and the unit still has 24.59MW of output increase space, so the application for output reduction is unreasonable.The analysis results of output reduction verification test are shown in Table 3.

Table 3 Verification test results of output reduction in heating season from 2021 to 2022

Generator Set	Unit load during test（MW）	Main steam flow during test（t/h）	Main steam flow under TRL condition（t/h）	Test heating extraction steam flow（t/h）	Industrial extraction steam flow（t/h）	Power plant application adjustable upper limit（MW）	Theoretical maximum output under test steam extraction（MW）	Output up regulation space（MW）	Whether the output reduction application is reasonable
1	109.27	345.5	420	-	0	100	120.30	11.03	unreasonable
2	109.95	363.97	420	-	0	100	120.11	10.16	unreasonable
5	280.18	889.42	980.8	47.36	16.59	240	304.77	24.59	unreasonable

4. Conclusion

This paper analyzes the alternative heating area margin of a power plant from its heating capacity and actual heating situation, analyzes whether the minimum startup mode is reasonable according to the estimated heating capacity of the power plant, verifies its electric load adjustment capacity in this mode, and then verifies its electric load adjustment capacity after the thermal load distribution of the whole plant. According to the actual average heat supply of the unit in the heating season and the verification test of output reduction, analyze whether the application for output reduction of the unit is reasonable, and provide a basis for the reasonable dispatching of the power grid dispatching department.

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