Study on power load adjustment capacity of a 300MW cogeneration unit in heating season

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Abstract. After the formulation of the "3060" double carbon target, the installed capacity of new energy has increased rapidly and the proportion of power generation has become higher and higher. In the heating season, under the operation mode of "determining electricity by heat" of cogeneration units, in order to meet the consumption of renewable energy and the heating guarantee of people's livelihood, the contradiction with power grid peak shaving is increasing. This paper mainly introduces the load capacity of a 300MW cogeneration unit in the heating season. Through the test method, find out the load capacity of the unit under different heating capacity, which can be used as a reference for power generation enterprises and power grid dispatching.

1 Background

The cogeneration unit uses high-grade energy for power generation, and the low-grade steam after power generation is used for industrial production or heating. It can not only meet the needs of production and life, but also improve the comprehensive utilization efficiency of energy, and realize the policy of "proper distribution, different needs, corresponding temperature and cascade utilization" for energy. The advantage of cogeneration is to turn the hierarchical utilization of energy into reality. The cogeneration [1] unit itself has high energy efficiency, but limited by the operation mode of "determining electricity by heat", it reduces the peak shaving capacity of the power system. In order to meet the consumption of renewable energy and the heating guarantee of people's livelihood, the contradiction with power grid peak shaving [2-4] is increasing. Therefore, it is necessary to find out the actual load capacity of cogeneration units in the heating season and break the restrictions of the original heating working diagram. Taking a 300MW cogeneration unit as an example, its load capacity is obtained through test [5].

2 Equipment introduction

2.1 Overview of steam turbine equipment

The steam turbine is C300/256-16.7/0.39/537/537subcritical, one intermediate reheat, single shaft, two cylinders and two exhaust, condensing steam turbine, with eight stages of non regulated regenerative steam extraction. Rated power 300MW, rated main steam flow 900.9t/h; The maximum continuous output is 321mw and the maximum steam

flow is 979t / h. Table 1 shows the main design parameters of steam turbine.

Table 1 Main parameters of steam turbine under rated extraction conditions

Name	Company	THA	Rated heating	Maximum heating
Main steam flow	t/h	900.9	950.5	950.5
Main steam pressure	MPa	16.67	16.67	16.67
Main steam temperature	℃	537	537	537
Reheat pressure	MPa	3.179	3.319	3.319
Reheat temperature	℃	537	537	537
Feed water temperature	℃	272.4	275.6	275.6
Heating extraction capacity	t/h	/	350	550
Heating extraction pressure	MPa	/	0.39	0.39
Heating extraction temperature	℃	/	246.3	246.3

2.2 Overview of boiler equipment

The boiler is SG-1025/17.4-M851subcritical, intermediate primary reheat, natural circulation and coal-fired drum boiler. The positive pressure direct blowing four corner tangential combustion is adopted, the main steam temperature is regulated by two-stage water spray desuperheating, and the reheat steam temperature is regulated by flue gas baffle and water spray

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desuperheating. Table 2 shows the main design parameters of the boiler.

Table 2 Main design parameters of boiler

Name	Company	numerical value
Rated evaporation	t/h	1025
Superheated steam outlet pressure	MPa	17.5
Superheated steam outlet temperature	℃	540
Reheat steam flow	t/h	842.05
Reheat steam inlet pressure	MPa	3.86
Reheat steam inlet temperature	℃	326.7
Reheat steam outlet temperature	℃	540
Exhaust gas temperature -- before correction	℃	135.6
Exhaust gas temperature - corrected	℃	128.3

2.3 Introduction to heating system

The heating steam extraction of the four units in the plant is the exhaust steam extraction of intermediate pressure cylinder, and there is no industrial steam. The steam extraction of the steam turbine is realized by adjusting the pressure through the butterfly valve of the connecting pipe of the medium and low pressure cylinder. The heating steam extraction pipeline is arranged in a unit system. The steam extraction of the unit is sent to the corresponding heat network heater through the steam extraction pipeline to heat the circulating water of the heat network, and the circulating water pump of the heat network is used for external heating. There are 2 initial heating stations in total, including 4 heating network heaters and 0 heat network circulating pumps in the initial heating network station of phase I; The initial station of phase II heat supply network has 5 heat supply network heaters, 9 heat supply network circulating pumps, all of which are electric pumps. The return water of the heat supply network first enters the initial station of the phase II heat supply network. After the pressure head is raised by the circulating water pump of the heat supply network, it enters the phase I and phase II heat supply network heaters respectively. The temperature is heated from 60 ℃ to about 120 ℃ and sent out.

3 Test process

3.1 Maximum output test when heating extraction steam is 150 t/h

Gradually increase the main steam flow to 950t/h, close to the maximum steam inlet of 979t/h, and then bring the unit heating extraction flow to 150t/h. at the same time, the outlet water temperature of the heating network meets the requirements of the current thermal power company. During the test, the heating extraction flow was 148.50t/h, and the average active power of the generator was 289.48MW.

3.2 Minimum output test when heating extraction steam is 150 t/h

First, gradually reduce the unit load to about 171MW. At this time, the intermediate exhaust pressure is 0.09MPa, close to the alarm value of 0.08MPa, but the heating extraction steam flow is higher than the required 150t/h. adjust the heating extraction steam flow to 150t/h by turning down the heating quick closing valve. Because there is a logical relationship between the heating butterfly valve of the connecting pipe of the medium and low pressure cylinder when the heating quick closing valve is fully open, The electrical load of the unit cannot be reduced again by adjusting the opening of the heating butterfly valve of the connecting pipe of the medium and low pressure cylinder, but can only be maintained in the current state. During the test, the heating extraction steam flow of the unit was 142.33t/h, and the average active power of the generator was 171.03MW.

3.3 Maximum output test when heating extraction steam is 250 t/h

Gradually increase the main steam flow to 950t/h, close to the maximum steam inlet of 979t/h, and then bring the heating extraction flow of the unit to 250t/h. During the test, the heating extraction flow is 250.06t/h, and the average active power of the generator is 276.92MW.

3.4 Minimum output test when heating extraction steam is 250 t/h

Gradually reduce the unit load to about 150MW. At this time, the heating extraction flow of the unit is about 250t/h, and the load reaches 50% of the rated capacity required by the dispatching agreement. During the test, the heating extraction steam flow of the unit is 250.93t/h, and the average active power of the generator is 150.02MW.

3.5 Maximum output test when heating extraction steam is 350 t/h

Gradually increase the main steam flow to 950t/h, close to the maximum steam inlet of 979t/h, and then bring the heating extraction flow of the unit to 350t/h. During the test, the heating extraction flow was 346.87t/h, and the average active power of the generator was 262.41MW.

3.6 Minimum output test when heating extraction steam is 350 t/h

Firstly, bring the heating extraction flow of the unit to 350t/h, gradually close the steam inlet butterfly valve of the low-pressure cylinder, reduce the steam inlet of the unit and maintain the heating extraction flow unchanged. When the unit load is reduced to about 203MW, the opening of the steam inlet butterfly valve of the low-pressure cylinder is 16.04%. Due to the jamming of the butterfly valve, the butterfly valve cannot be closed continuously, and the test is started under the current state. During the test, the heating extraction steam flow of the unit is 348.60t/h, and the average active power of the generator is 203.02MW.

3.7 Output test at heating extraction 440 t/h

Firstly, bring the heating extraction flow of the unit to 440t/h. at this time, the steam inlet butterfly valve of low-pressure cylinder has been closed to the minimum opening (it can only be reduced to 16% due to valve jamming), meeting the requirements of minimum electrical load test; Meanwhile, the main steam flow is 950t/h, close to the maximum main steam flow of 979t/h, meeting the requirements of the maximum electric load test. During the test, the heating extraction flow was 439.11t/h, and the average active power of the generator was 233.10MW.

4 Test result

4.1 Difference between actual output and design output

Table 3 Comparison between actual output and design value of unit

Heating extraction capacity （t/h）	Upper limit of output （MW）		Lower limit of output （MW）	
	Design value	Test value	Design value	Test value
145.42	298.85	289.48	197.20	171.03
250.49	281.39	276.92	177.47	150.02
347.74	265.23	262.41	159.26	203.02
439.11	250.04	233.10	188.29	233.10
145.42	298.85	289.48	197.20	171.03
250.49	281.39	276.92	177.47	150.02
347.74	265.23	262.41	159.26	203.02
439.11	250.04	233.10	188.29	233.10
145.42	298.85	289.48	197.20	171.03

4.2 Limiting factors of unit output

The maximum electric load test of the unit is limited by the maximum steam inlet of the unit. During the test, the main steam flow is about 950t/h, which is close to the maximum steam inlet of the unit of 979t/h.

In the minimum electric load test, when the heating extraction steam flow is 347.74t/h and 439.11t/h, the steam inlet butterfly valve of low-pressure cylinder has been closed to the minimum opening (it can only be reduced to 16% due to valve jamming). In order to maintain the heating extraction steam flow, it is impossible to continue to reduce the unit load; When the heating extraction flow is 250.49t/h, it reaches 50% of the rated capacity required by the dispatching agreement. In order to ensure the safety of the unit, the load of the power plant will not be reduced; When the heating extraction steam flow is 145.42t/h, in order to ensure that the heating extraction steam flow reaches the test value and maintain the middle exhaust pressure greater than 0.08MPa, the measures of reducing the heating quick closing valve shall be taken during load reduction. Due to the logical relationship that the heating butterfly valve of the connecting pipe of the medium and low pressure cylinder can be adjusted only when the heating quick closing valve is fully open, the unit load cannot be further reduced by

adjusting the opening of the heating butterfly valve, Can only maintain the current state.
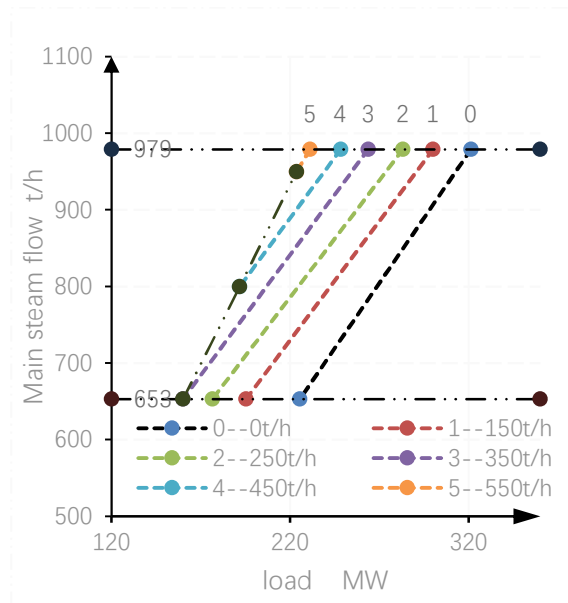
4.3 Heating working condition diagram

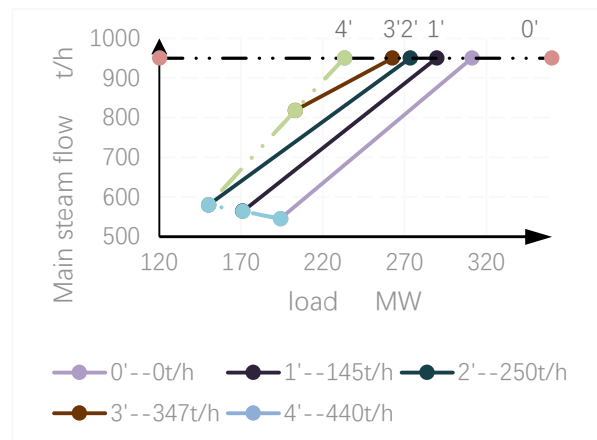

Fig. 1 Design heating condition of unit

Fig. 2 Actual heating condition of the unit obtained from the test
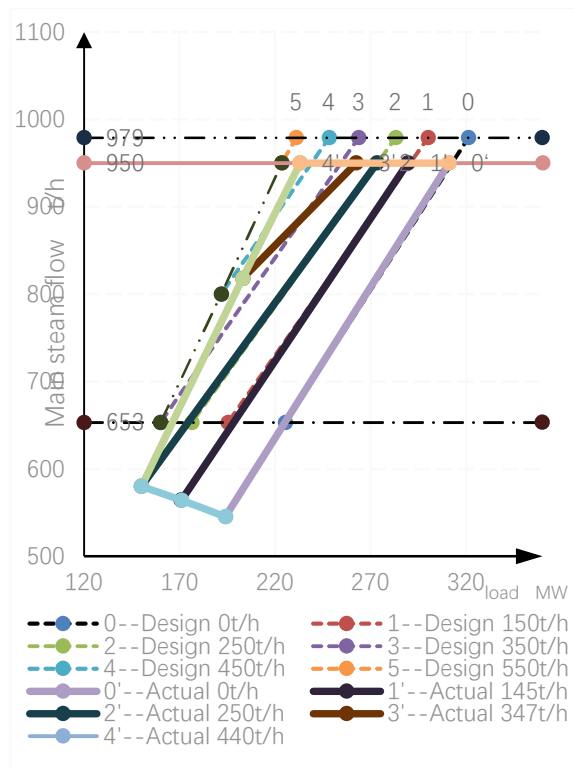
Fig. 3 Comparison between actual and designed heating conditions of the unit

It can be seen from the above table and the heating working condition diagram that the maximum output of the test is slightly lower than the upper limit of the design output, mainly because the main steam flow of the test is about 950t/h , which does not reach 979t/h under the design working condition; The minimum output of the test is lower than the lower limit of the design output when the heating extraction flow is 145.42t/h and 250.49t/h, and higher than the lower limit of the design output when the heating extraction flow is 347.74t/h and 439.11t/h. When the heating extraction steam flow is 347.74t/h and 439.11t/h, the lower limit of load is higher than the design output, mainly because the opening of butterfly valve of connecting pipe of medium and low pressure cylinder is about 16%, which does not reach the minimum steam inlet of low pressure cylinder.

4.4 Upper and lower limit fitting formula of output

According to the heating working condition diagram, the upper and lower limit formulas of output are fitted, as shown in the table below.Where, x is the heating extraction capacity；y is Unit load.

Table 4 upper and lower limit fitting formula of unit design output

Steam extraction interval	Upper limit fitting formula of output	Lower limit fitting formula of output
0≤x<350	y = -0.1662x + 323.02	y = -0.1878x + 224.51
350≤x≤550		y = 0.3176x + 48.824

Table 5 upper and lower limit fitting formula of actual output of unit

Steam extraction interval	Upper limit fitting formula of output	Lower limit fitting formula of output
0≤x<250.49	y = -0.1876x + 320.98	y = -0.3055x + 222.47
250.49≤x≤439.11		y = 0.4416x + 42.69

5 Conclusion

After long-term operation and heating transformation[6] of cogeneration units and the needs of heat users, and the current difficult situation of peak regulation of thermal power units is not considered in the early design stage, the original design heating working condition diagram can not reflect the real electric load adjustment range of the unit; At the same time, in the heating season, the contradiction between power grid peak shaving and cogeneration units continues to deepen. Under the new situation of vigorously developing new energy, cogeneration units are bound to break through the operation range of the original heating working condition diagram. Through tests, find out the actual electrical load adjustment range of the unit, remove the margin left for safe operation, and reflect the real peak shaving level of the unit.

Acknowledgements

References

1. Dawei Huang, Zheng Huang, Weichun Ge, et al. Analysis on electric power flexible regulation capacity for combined heat and power units in heat-led mode[J]. Automation of Electric Power Systems, 2018,42(24):27-35+52+36-39.

2. Haiying Dong, Lei Fang, Kun Ding, et al. Peak regulation strategy of csp plants based on operation mode of cogeneration[J].Acta Energiae Solaris Sinica,2019,40(10):2763-2772.

3. Yongqi Liu, Hongpeng Zhang, Qun Li, et al. Design and practice of electricity peak-shaving assistant service market in northeast power grid[J]. Automation of Electric Power Systems, 2017, 41(10):148-154.

4. Guangcai Zhang, Ke Zhou, Fen Lu, et al. Discussions on deep peaking technology of coal-fired power

plants[J]. Thermal Power Generation, 2017, 46(09):17-23.

5. Xuhui Zhang, Zhonghua Zhao, Fuxing Cui, et al. Experimental Research on Deep Peak Regulation Characteristics of 1030 MW Ultra Supercritical Unit[J]. Shandong Electric Power, 2021,48(02):58-62.

6. Fuxing Cui, Daning You, Xuhui Zhang, et al. Research on Increasing Flexibility of Thermal Power Units by Flue Gas-water Heat Exchanger[J]. Shandong Electric Power, 2021,48(05):54-58+64.