Performance Diagnosis and Analysis of a Thermal Power Turbine Unit in a Power Plant

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Abstract. In order to further improve the operation level of the provincial grid direct thermal power units, optimize the data quality of the provincial thermal power unit system, diagnose and analyze the operation data of the thermal power unit system, and comprehensively analyze and evaluate the unit regulation ability from the aspects of heating capacity, the minimum startup mode of the whole plant, and the load capacity of the heating state, so as to provide support for the accurate scheduling of the unit.

keyword: Heat supply unit, diagnostic analysis, Precise scheduling.

1. Introduction

The planned capacity of the thermal power plant is 1800 MW, which is one of the main power plants in a province. The design service life is 30 years. Two 300MW subcritical coal-fired units were installed in the first phase of the project. After the full four-dimensional flow transformation design, the capacity of Nanjing Steam Turbine Factory was expanded to 330MW, and the connecting pipes of the middle and low pressure cylinders were perforated for steam extraction and changed to heat supply units. Two 670MW supercritical coal-fired units are installed in the second phase of the project, and the two units have also been transformed into heat supply units through drilling and steam extraction. The thermal power plant has carried out the reconstruction of the new condensate pumping back of Unit 1 in November 2019, and it runs well after commissioning. The reconstruction of the new condensate pumping back of Unit 2 is planned in November 2020; In 2020, the first station of Phase I will be expanded and reconstructed. After the reconstruction, the heating capacity of the whole plant will be further improved[1].

Thermal Power Plant Phase I 2 × 330MW steam turbine is subcritical, reheated in the middle, two cylinders and two exhaust steam, extraction condensing type heating turbine, model: N330/C275-16.67/0.4/537/537, maximum continuous output: 345.7MW, rated output: 330MW. Heat is supplied by steam extraction from IP casing, with rated steam extraction capacity of 330t/h, pressure of 0.40Mpa (a) and maximum live load of 270.6MW; The maximum live load of the unit is 248.2MW at the maximum heating extraction capacity (450 t/h). Phase I 2 × 330MW boiler is a subcritical natural circulation drum boiler DG1025/18.2 - Ⅱ 4, burning high volatile bituminous coal, and # 0 diesel oil is used for ignition and combustion support. 330MW generator set is a QFSN-330-2-20 three-phase synchronous steam turbine generator. The rated capacity of the generator is 388MVA, the rated power is 330MW, the rated power factor is 0.85, and the maximum continuous output power is 340MW.

Thermal Power Plant Phase II Project 2 × 670MW steam turbine is a supercritical, single shaft, three cylinder, four exhaust, intermediate reheat, condensing steam turbine, with the model of N670-24.2/566/566, the maximum continuous output of 711MW and the rated output of 670MW. The unit adopts compound variable pressure operation mode[2]. The turbine has eight stages of non adjustable regenerative steam extraction, and the rated speed of the turbine is 3000 r/min. Phase II boiler is a supercritical parameter variable pressure once through boiler, with single furnace, primary reheating, tangential firing, balanced ventilation, outdoor arrangement, solid slag removal, full steel frame, and full suspension structure Π SG-2102/25.4-M954 boiler. Thermal Power Plant Phase II 2 × 670MW generator set is a QFSN-670-2 three-phase synchronous steam turbine generator produced by Shanghai Steam Turbine Generator Co., Ltd. The rated capacity of the generator is 744.4MVA, the rated power is 670MW, the rated power factor is 0.9, and the maximum continuous output power is 708MW [3].

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2. Heat supply system of thermal power plant

2.1 Steam extraction system of intermediate and low pressure connecting pipe

The four steam turbine units in the thermal power plant provide heat and steam extraction by adjusting the pressure through butterfly valves from the connecting pipes of the middle and low pressure cylinders. The steam extraction pipes are arranged in the main pipe# 1. The output of one main pipe of unit # 2 is sent to the first phase heating station and the first phase expansion station respectively# 3. The steam extraction pipeline of unit # 4 is led out from the DN1400 pipeline of each unit, and then sent to the Phase II initial heating station through the DN1600 header pipe in the machine room. It serves as the steam source for the basic steam water heater, 5 small steam driven circulating water pumps and 10 asynchronous generators of the Phase II initial station. The steam source for the exhaust steam heater of the Phase II heat supply network is from the exhaust steam of 5 small steam driven circulating water pumps.

2.2 Cold re extraction

The industrial steam supply of the unit adopts the steam from the reheating cold section of the turbine to inject the steam extracted from the fourth section of the turbine (using the pressure matching device), and then the external steam supply. The capacity of the pressure matcher is 50t/h of the reheat cold section steam, and the flow of the pressure matcher is adjustable from 5% to 100%; The optimal economic regulation operation condition is 50t/h of reheat cold section steam. When the pressure matching device cannot absorb the steam extracted from the fourth section of the turbine, the pressure matching device has the function equivalent to the pressure relief device, and can ensure the outlet parameters to meet the external heat supply.

2.3 Heat supply network system

The first station of heat supply network is divided into Phase I, Phase II and Phase I expansion. The first station of Phase I was built in 2012, mainly receiving steam extraction from Unit 1, and will be expanded and reconstructed in 2020, mainly receiving steam extraction from Unit 2; The first station of Phase II was completed in 2017 and expanded in 2018, mainly receiving steam extraction from Units 3 and 4. The first stations of the two phases are introduced below. 3.4.4 Basic information of Phase II initial station

In 2017, in order to cooperate with the steam extraction transformation of Unit 4, the first station of Phase II was started. The first station of the heat supply network was transformed according to the heating and steam extraction transformation of Unit 4, equipped with corresponding heat supply facilities, and reserved space for the heat supply network heater, heat supply network circulating water pump and other equipment added for the heating and steam extraction transformation of Unit 3. In 2018, in order to cooperate with the heating and steam extraction transformation of Unit 3, the initial station of Phase II will be expanded and transformed, and the heat exchange capacity of the initial station of Phase II will reach 885MW.

The total designed steam consumption of the heat supply network is 1200t/h, the total steam consumption of the circulating water pump turbine is 135t/h, and the water make-up and deaeration is 7t/h. The design supply and return water temperature of the heat supply network is 105°C and 55°C respectively, the water supply pressure is about 148mH_2O, and the return water pressure is about 33mH_2O.

3. Diagnosis and analysis of heat supply unit in thermal power plant

The heat supply diagnosis and analysis of the thermal power plant shall be based on the analysis and summary of each unit. This paper only conducts diagnosis and analysis for one unit, and other units are similar.

According to the test data, the maximum output of the test is lower than the upper limit of the design output, mainly because the main steam flow of the test is about 1977t/h, which does not reach 2102t/h under the design condition; The minimum test output is lower than the lower limit of design output when the heating extraction flow is 401t/h and 574t/h, and higher than the lower limit of design output when the heating extraction flow is 634t/h. When the heating extraction flow is 634t/h, the lower limit of load is higher than the design output. The main reason is that the butterfly valve opening of the connecting pipe of the middle and low pressure cylinder is about 15%, which does not reach the minimum steam intake of the low pressure cylinder.

According to the test data, the upper and lower limit fitting formulas of the calculated force are shown in the following table.

Tab. 1 Fitting Formula for Upper and Lower Limits of Design Output of a Unit

Extraction volume range	Upper output limit fitting formula	Fitting formula of lower output limit
0≤y<610	y = -0.2705x +722.74	y = -0.2761x+520.53
610≤y≤700		y = 0.4444x+81.889

Tab. 2 Fitting formula for upper and lower limit of actual output of a unit

Extraction volume range	Upper output limit fitting formula	Fitting formula of lower output limit
0≤x<401	y = -0.3513x + 724.15	y = -0.5642x + 521.5
401≤x≤634		y = 0.3959x + 130.16

According to the test data, the fitting formula for calculating the upper limit of steam extraction capacity is shown in the following table.

Tab. 3 Upper limit fitting formula of steam extraction capacity of a unit

Design extraction capacity		Actual extraction capacity	
Load range	**Upper limit fitting formula**	**Load range**	**Upper limit fitting formula**
353≤y<393	x=2.2502y-184.2687	295≤y<398	x=2.5259y-328.77
393≤y<534	700	398≤y<498	634
534≤y<723	x=-3.6969y+2671.867	498≤y<723	x=-2.8466y+2061.34

4. Conclusion

According to the fitting formula of the thermal power plant, the upper and lower limits of the output of a unit in the thermal power plant are calculated to provide a basis for the accurate dispatching of the provincial dispatching; The limiting factor of unit output is analyzed and summarized. The calculation results of the upper and lower output limits of a unit are shown in the following table.

Tab. 4 Calculation Results of Upper and Lower Output Limits of a Unit

Heating steam extraction volume(t/h)	Upper limit of output (MW)		Lower limit of output (MW)	
	Design value	**Test value**	**Design value**	**Test value**
401	600	586	395	295
574	568	525	360	335
634	551	498	375	398

There are four main factors limiting unit output. Under the same heating extraction flow, the high load limit conditions are: the maximum evaporation capacity of the boiler; The low load limiting conditions are: the butterfly valve opening of the connecting pipe of the intermediate and low pressure cylinder is 15%, the alarm is given when the exhaust temperature of the intermediate pressure cylinder exceeds 388℃, and the alarm is given when the pipe temperature of some high-temperature reheaters exceeds 595℃.

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