Application Research on Zero Output of Double Low Pressure Cylinder of 600MW Unit

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Abstract: Under the dual carbon target, the rapid development of new energy promotes the increasing peak shaving capacity of thermal power units as basic power sources. Taking 600MW unit as an example, this paper studies the feasibility of zero output of low pressure cylinder for heat supply transformation of 600MW unit, and analyzes the peak shaving capacity of the unit by cutting off double low pressure cylinder and single low pressure cylinder.

1. Introduction

The National Development and Reform Commission and the National Energy Administration issued the Fourteenth Five Year Modern Energy System Plan (the Plan). Compared with the Fourteenth Five Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Vision Goals for 2035 previously released, there are many changes in the expression of coal power. At the same time, the Plan also puts forward specific goals for the thermal power flexibility transformation and "three transformation linkage" of coal power: strive to achieve a cumulative flexibility transformation scale of more than 200 million kilowatts of coal motor units by 2025, focus on the flexibility transformation of 300000 kilowatts and below coal power units, and research and promote the flexibility transformation of 600000 kilowatts subcritical coal motor units in areas with difficult peak shaving. By 2025, the proportion of flexibly regulated power supply will reach about 24%, and the power demand side response capacity will reach 3%~5% of the maximum power load. We will vigorously promote the "three transformation linkage" of coal power energy conservation and carbon reduction transformation, flexibility transformation and heat supply transformation, and the scale of energy conservation transformation during the "Fourteenth Five Year Plan" period will not be less than 350 million kilowatts.

2. Analysis of heat supply transformation

The Notice on Improving the Flexibility of Directly Dispatched Utility Coal fired Power Generation Units in the Province issued by the Provincial Energy Administration clearly pointed out that during the "Fourteenth Five Year Plan" period, the flexibility of coal fired power generation units should be implemented according to 20% of the capacity every year, in which the minimum technical output of pure condensing units and condensing units should reach 30% and 40% of the rated capacity respectively under the condition of stable combustion, and the new pure condensing units and condensing units should reach 30% and 40% respectively, The condensing unit with the heat electricity ratio less than 50% shall be modified according to the standard of the condensing unit.

The steam turbine of a factory is a supercritical pressure extraction condensing steam turbine, with the model of C660/543-24.2/0.45/566/566 supercritical, one intermediate reheat, single shaft, four cylinders and four exhaust, and extraction condensing. The maximum continuous output is 710MW, the rated output is 660MW, the rated heating steam extraction is 560t/h, and the maximum steam extraction is 810t/h. The unit adopts compound variable pressure operation mode, and the turbine has seven stages of non adjustable regenerative steam extraction and one stage of regulated heating steam extraction. With the continuous expansion of urban areas and the continuous development of industry, the heating steam consumption for residents and industrial steam consumption are increasing; Considering the number of users, the nature of steam consumption, the law of steam consumption, and the pipeline loss in the central heating area, the design heat load of steam in the industrial area will be 355t/h at the maximum, 296t/h at the average, and 190t/h at the minimum in 2021; In 2022, the maximum is 515t/h, the average is 446t/h, and the minimum is 350t/h; In 2023, the maximum is 655t/h, the average is 576t/h, and the minimum is 510t/h. The extraction temperature of industrial steam extraction is 260 ℃ - 290 ℃, and the extraction pressure is 2.30MPa-2.55MPa。

According to the current heating and heating load and industrial steam extraction load, under the most unfavorable conditions in the heating season, the maximum heating capacity of the plant needs to reach 2844t/h. With the annual development of the heating and

heating load and industrial steam extraction load in the city, the long-term heating and heating area and industrial steam extraction demand show an increasing trend year by year。According to the current operation of 5 units, the maximum total steam extraction capacity can only reach 2056t/h; If there is no relevant transformation to improve the heating capacity, it is necessary to reduce the steam supply in the industrial zone to ensure the heating demand of people's livelihood during the winter heating period.

For this reason, the characteristics of typical technical schemes for flexibility transformation of heat supply units are analyzed, and the comparison of various transformation schemes is shown in Table 1.

Table 1 Comparison of various transformation schemes

technology name	Lowpressure cylinderZero output technology	Heat storage and heating	Electric boiler heating	Optical shaft and high back pressure transformation
Principle	Cut off the steam inlet of low pressure cylinder for heat supply to realize zero output heat supply of low pressure cylinder.	The storage tank system is set at the heat supply network side to weaken the time coupling degree of thermal electrical load.	An electric boiler is arranged at the heat source side, and electricity is used as the heat source to realize thermoelectric decoupling.	Through equipment (double rotors) transformation, steam turbine exhaust steam is used for heat supply.
Characteristic	Cut off the steam inlet of low pressure cylinder during operation, and the operation mode is flexible	The single tank heat storage technology of atmospheric temperature gradient layer is adopted.	Direct electric heating boiler and regenerative electric heating boiler are mostly used.	The double rotor scheme is adopted for high heating economy.
Advantage	Small investment; Good heating economy; Flexible operation mode;	Small transformation of the original system; The heating is economical.	Small transformation of the original system; Strong thermoelectric decoupling capability.	Strong heating capacity; Good heating economy.
Shortcoming	Not fully implemented Thermoelectric decoupling.	High investment; Large floorarea;Theadaptabilityto long-term low load peak shaving of power grid is poor.	High investment; The heating economy is poor.	High investment; High maintenance cost; High requirements for heat load.

Comprehensively compare the technical advantages and disadvantages of each scheme, and in combination with the unit operation status and transformation requirements of the plant, it is recommended to implement the transformation scheme with zero output technology of low pressure cylinder as the route.

3. Analysis of steam extraction capacity of unit under zero output condition

3.1 Analysis of heating and steam extraction capacity of single cut off B low-pressure cylinder

When the low pressure cylinder is put into zero output operation, the cooling steam flow of the single low pressure cylinder is considered as 30t/h, and the heat supply and steam extraction capacity of the unit is calculated under the zero output condition when the low pressure cylinder B is cut off alone and the low pressure cylinders A and B are cut off simultaneously. See Table 2

for the check results of heat supply and steam extraction capacity under zero output working condition of the unit with single removal of low pressure cylinder B.

Table 2 Heat supply and steam extraction capacity of unit under zero output condition with single removal of low pressure cylinder B

project	Company	QG100MS	QG75MS	QG50MS	QG40MS	QG30MS
Power generation	MW	468.45	357.17	251.49	206.33	157.13
Main steam flow	t/h	1905.60	1429.20	952.80	762.24	571.68
Heating extraction flow	t/h	953.23	728.50	474.79	363.91	243.40
Industrial extraction steam flow	t/h	0.00	0.00	0.00	0.00	0.00
Total heat supply	MW	686.57	535.75	350.60	269.39	177.85
Heating ratio	--	0.49	0.49	0.46	0.43	0.37
Thermoelectric ratio	--	1.47	1.50	1.39	1.31	1.13
Power generation heat rate	kJ/kWh	5400.55	5606.50	5990.01	6312.06	6915.45
Coal consumption rate for power generation	g/kWh	202.32	210.04	224.41	236.47	259.08
Heating benchmark	W/m2	45.00	45.00	45.00	45.00	45.00
heating area	W/m2	1525.72	1190.56	779.11	598.65	395.21
Peak shaving capacity	%	70.98	54.12	38.10	31.26	23.81

Remarks: QG100MS in the table refers to the zero output operation of separate low pressure cylinder B when the main steam flow is 100% rated.

Under the zero output condition of single removal of low pressure cylinder B, when the rated main steam flow is 100% (QG100MS - single cylinder removal condition), the heat and steam extraction capacity of the unit under the zero output condition of single cylinder low pressure cylinder is 953.23t/h, equivalent to 686.57MW of heat load, 468.45MW of power generation, corresponding to 0.49 of heat supply ratio, 1.47 of heat and power ratio, and 202.32g/kWh of coal consumption; Compared with the theoretical maximum heat supply capacity of 859.70t/h before the unit transformation, it has increased by 93.54t/h, and the coal consumption for power generation has decreased by 12.81g/kWh.

Under the zero output condition of single removal of low pressure cylinder B, when 75% of the rated main steam flow (QG75MS - single cylinder removal condition), the heat and steam extraction capacity of the unit under the zero output condition of single cylinder low pressure cylinder is 728.50 t/h, equivalent to 535.75 MW of heat load, about 357.17 MW of power generation, corresponding to 0.49 of heat supply ratio, 1.50 of heat and power ratio, and 210.04 g/kWh of coal consumption.

Under zero output condition of single removal of low pressure cylinder B and 50% of rated main steam flow (QG50MS single cylinder removal condition), the heat and steam extraction capacity of the unit under zero output condition of single cylinder low pressure cylinder removal is 474.79t/h, equivalent to 350.60MW of heat load, about 251.49MW of power generation, corresponding to 0.46 of heat supply ratio, 1.39 of heat and power ratio, and 224.41g/kWh of coal consumption.

Under the zero output condition of single removal of low pressure cylinder B, when the rated main steam flow is 40% (QG40MS - single cylinder removal condition), the heat and steam extraction capacity of the unit under the zero output condition of single cylinder low pressure cylinder is 363.91t/h, equivalent to 269.39MW of heat load, about 206.33MW of power generation, corresponding to 0.43 of heat supply ratio, 1.31 of heat and power ratio, and 236.47/kWh of coal consumption.

Under the zero output condition of single removal of low pressure cylinder B, when the rated main steam flow is 30% (QG30MS - single cylinder removal condition), the heat and steam extraction capacity of the unit under the zero output condition of single cylinder low pressure cylinder is 243.40t/h, which is equivalent to 177.85MW of heat load, 157.13MW of power generation, 0.37 of heat supply ratio, 1.13 of heat and power ratio, and 259.08g/kWh of coal consumption; The peak shaving capacity under this working condition reaches 23.81%.

3.2 Analysis of heating and steam extraction capacity under zero output condition when cutting off low pressure cylinders A and B

See Table 3 for the check results of heat supply and steam extraction capacity under zero output condition when the unit cuts off low pressure cylinders A and B.

Table 3 Heat supply and steam extraction capacity of the unit under zero output condition when cutting off low pressure cylinders A and B

Project	Company	QG100MS	QG75MS	QG50MS	QG40MS	QG30MS
Power generation	MW	455.62	344.78	240.26	195.52	147.39
Heating extraction flow	t/h	1048.63	822.58	567.42	455.98	334.89
Industrial extraction	t/h	0.00	0.00	0.00	0.00	0.00

Project	Company	QG100MS	QG75MS	QG50MS	QG40MS	QG30MS
steam flow						
Total heat supply	MW	755.28	604.92	418.97	337.51	244.65
Heating ratio	--	0.54	0.55	0.54	0.53	0.51
Thermoelectric ratio	--	1.66	1.75	1.74	1.73	1.66
Power generation heat rate	kJ/kWh	5010.24	5086.22	5245.71	5406.67	5740.93
Coal consumption rate for power generation	g/kWh	187.70	190.55	196.52	202.55	215.07
Heating benchmark	W/m2	45.00	45.00	45.00	45.00	45.00
heating area	W/m2	1678.39	1344.26	931.05	750.02	543.66
Peak shaving capacity	%	69.03	52.24	36.40	29.62	22.33

Remarks: QG100MS in the table refers to zero output operation of low pressure cylinders A and B at the same time when 100% of the rated main steam flow is achieved.

Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when the rated main steam flow is 100% (QG100MS - double cylinder switching condition), the heat and steam extraction capacity of the unit under the zero output condition of double cylinder low pressure cylinder switching is 1048.63t/h, equivalent to 755.28MW of heat load, about 455.62MW of power generation, corresponding to 0.54 of heat supply ratio, 1.66 of heat and power ratio, and 187.70g/kWh of coal consumption for power generation; Compared with the theoretical maximum heat supply capacity of 859.70t/h before the unit transformation, it has increased by 188.94t/h, and the coal consumption for power generation has decreased by 27.44g/kWh.

Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when 75% of the rated main steam flow (QG75MS - double cylinder switching condition), the heat and steam extraction capacity of the unit under the zero output condition of double cylinder low pressure cylinder switching is 822.58t/h, equivalent to 604.92MW of heat load, 344.78MW of power generation, corresponding to 0.55 of heat supply ratio, 1.75 of heat and power ratio, and 190.55g/kWh of coal consumption.

Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when 50% of the rated main steam flow (QG50MS - double cylinder switching condition), the heat supply and steam extraction capacity of the unit under the zero output condition of double cylinder low pressure cylinders is 567.42t/h, equivalent to 418.97MW of heat supply load, about 240.26MW of power generation, corresponding to 0.54 of heat supply ratio, 1.74 of heat and power ratio, and 196.52g/kWh of coal consumption.

Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when the rated main steam flow is 40% (QG740MS - double cylinder switching condition), the heat and steam extraction capacity of the unit under the zero output condition of double cylinder low pressure cylinder switching is 455.98t/h, equivalent to 337.51MW of heating load, about 195.52MW of power generation, corresponding to 0.53 of heat supply ratio, 1.73 of heat and power ratio, and 202.55g/kWh of coal consumption.

Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when 30% of the rated main steam flow (QG30MS - double cylinder switching condition), the heat and steam extraction capacity of the unit under the zero output condition of double cylinder low pressure cylinder switching is 334.89t/h, equivalent to 244.65MW of heat load, 147.39MW of power generation, corresponding to 0.51 of heat supply ratio, 1.66 of heat and power ratio, and 215.07g/kWh of coal consumption; The peak shaving capacity under this working condition reaches 22.33%.

4. Comparison and analysis of two cylinder cutting methods

For two different cylinder cutting methods, three typical working conditions are selected for analysis and comparison, as shown in Table 4.

Table 4 Comparison of Typical Working Conditions of Two Cylinder Cutting Modes

Project	Company	QG100MS		QG50MS		QG30MS	
		Double cylinder cutting	Single cylinder cutting	Double cylinder cutting	Single cylinder cutting	Double cylinder cutting	Single cylinder cutting
Power generation	MW	455	468	240	251	147	157
Main steam flow	t/h	1905	1905	952	952	571	571
Heating extraction flow	t/h	1048	953	567	474	335	243
Industrial extraction steam flow	t/h	0.00	0.00	0.00	0.00	0.00	0.00
Total heat supply	MW	755	686	419	350	245	178
Heating ratio	0.00	0.54	0.49	0.54	0.46	0.51	0.37

Thermo electric ratio	0.00	1.66	1.47	1.74	1.39	1.66	1.13
Power generation heat rate	kJ/kWh	5010	5400	5245	5990	5741	6915
Coal consumption rate for power generation	g/kWh	187	202	196	224	215	259
Heating benchmark	W/m$_2$	45	45	45	45	45	45
heating area	万 m^2	1678	1525	931	779	543	395
Peak shaving capacity	%	69	71	36	38	22	24

Note: QG100MS in the table refers to 100% rated main steam flow.

It can be seen from the above table that under the same steam flow, the peak shaving capacity of the unit when switching double cylinders is about 1W higher than that when switching single cylinders; At the end of the load month, the higher the coal consumption is, the higher the heat rate of power generation is. The heat rate of power generation under the double cylinder switching mode and the horizontal bar switching mode are lower, and the lower the load is, the greater the difference in the heat rate of power generation is.

5. Conclusion

Under the zero output condition of single removal of low pressure cylinder B, when the rated main steam flow is 100% (QG100MS single cylinder removal condition), the heat supply and steam extraction capacity of the unit is 953.23t/h, and the coal consumption for power generation is 202.32g/kWh. Compared with the theoretical maximum heat supply capacity of 859.70t/h before the unit transformation, the heat supply capacity is increased by 93.54t/h, and the coal consumption for power generation is reduced by 12.81g/kWh; When the rated main steam flow is 30% (QG30MS single cylinder switching condition), the heat and steam extraction capacity of the unit is 243.40t/h, the generating power is about 157.13MW, and the electric peak shaving capacity reaches 23.81%. Under the zero output condition of simultaneously cutting off the low pressure cylinders A and B, when the rated main steam flow is 100% (QG100MS double cylinder cutting condition), the heat supply and steam extraction capacity of the unit is 1048.63t/h, and the coal consumption for power generation is 187.70g/kWh, which is 188.94t/h higher than the theoretical maximum heat supply capacity of 859.70t/h before the unit transformation, and the coal consumption for power generation is 27.44g/kWh lower; When the rated main steam flow is 30% (QG30MS double cylinder switching condition), the heat and steam extraction capacity of the unit is 334.89t/h, the generating power is about 147.39MW, and the electric peak shaving capacity reaches 22.33%.

The implementation of flexible heating transformation can greatly improve the peak shaving capacity and low load heating capacity of units, meet the needs of flexible transformation and heating capacity increase, and enhance the competitiveness and profitability of units in the peak shaving market of electric auxiliary services.

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