Study on the electrothermal coupling characteristics of different types of thermoelectric units

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Abstract. The electric heating characteristics of thermoelectric units refer to the coupling relationship between the generating power P and the steam extraction volume G of the unit for external heating. The heat supply forms of directly regulated public thermoelectric units mainly include steam extraction condensing heat supply and back pressure circulating water heat supply. Through the research on the electrothermal coupling characteristics of different types of thermoelectric units, we can master the electric load output range of thermoelectric units in the heating season, provide data support for the power grid dispatching department, effectively promote the consumption of new energy, and ensure the smooth and orderly supply of electric energy.

key word: Thermoelectric unit; Electrothermal coupling characteristic; Deep peaking.

1. Introduction

With the development of urbanization, the demand for clean and efficient central heating is becoming increasingly urgent[1]. Thermal power units can give consideration to both power generation and heat supply, with high energy utilization efficiency and significant economic benefits of energy conservation and emission reduction. Therefore, the proportion of thermal power units in coal power units is increasing year by year.During the "13th Five Year Plan" period, in order to comprehensively promote the implementation of the "three reform linkage" of coal power units, Shandong Province will complete the heat supply transformation of 30 sets of 19.9 million kilowatt units. In recent years, heat supply units have begun to develop towards large capacity and high parameters, and the capacity and heating area of thermoelectric units are increasing. In the future, with the reduction of coal consumption and the shutdown of small boilers and small thermoelectric units, the heating area and pressure of thermoelectric units will continue to increase[2].

Thermal power unit refers to a generator unit that not only produces electric energy, but also uses steam to heat users[3]. The thermoelectric unit is used to extract part of the steam that has been worked in the steam turbine and directly or indirectly supply it to the heat users, so as to reduce the cold source loss of the steam cycle (that is, the heat taken away by the circulating water in the condenser), so it has a good economy.

Thermal power units can be divided into back pressure units and condensate extraction units according to different heating modes. The heating modes and thermal characteristics of the two types of units are analyzed in detail below.

2. Thermodynamic characteristics analysis of different types of thermoelectric units

2.1 Back pressure unit

To increase the exhaust steam pressure of the steam turbine, the exhaust steam is used to provide heat directly to the heat users or the heat exchanger is used to provide heat indirectly to the heat users. The steam turbine that uses the exhaust steam to provide heat is called back pressure steam turbine. For back pressure steam turbine, the total heat of steam turbine exhaust is used for regenerative water supply and external heating. In actual operation, the electromechanical load of back pressure steam turbine is determined by the external thermal load, and its insufficient power is borne by the condensing steam turbine units operating in parallel in the power plant[4]. The back pressure turbine is also divided into a pure back pressure type B unit (with only one type of steam exhaust) and an extraction back pressure type CB unit (with two-stage regulating extraction of steam extraction with higher pressure and lower pressure). The exhaust steam of the back pressure turbine is used for heating, and the heat released from the exhaust steam is no longer an energy loss. The heat rate of the unit is independent of the cycle efficiency of the thermal system

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and the relative internal efficiency of the unit, but only depends on the boiler efficiency, pipe efficiency, mechanical efficiency and generator efficiency. The heat supply mode of the back pressure machine is shown in Figure 1:

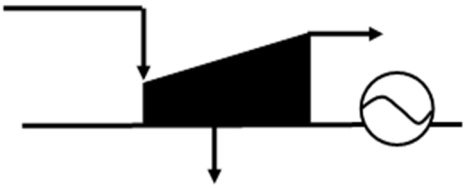

Fig. 1 Heat supply schematic diagram of back pressure machine

(1) Heating mode

In Shandong Province, pure back pressure units and extraction back units are generally small units below 50MW. Generally, this type of unit is used more in small local thermal power plants, and this type of unit has been basically eliminated in large direct dispatching power plants. Therefore, this project will not study the heating mode and thermal characteristics of this type of unit too much.

In recent years, with the increase of heat supply demand, some large capacity pure condensing or extraction condensing units in Shandong Province have also started to carry out heat supply transformation, including high back pressure transformation, optical shaft transformation and removal of low pressure cylinder operation. The heat supply mode of the transformed units is basically the same as that of the back pressure units.

The high back pressure heat supply unit is to improve the exhaust steam pressure of the low pressure cylinder rotor of the unit by retrofitting it, and directly heat the circulating water for external heat supply by using the exhaust steam. In this way, all the exhaust steam waste heat of the unit is taken away by the circulating water for heat supply, and the cold source loss is zero, which greatly improves the economy of the unit.

This type of unit is a retrofitted unit that has emerged in recent years to adapt to the heating and heating in the north. Most of them are retrofitted from pure condensing or pumped condensing units. It was used in Northeast China in the 1980s. In the 1990s, Shandong Huangtai Power Plant # 1 Unit (50MW) took the lead in reforming and applying high back pressure heat supply. In 2009, Yantai Power Plant carried out the transformation of high back pressure circulating water heating on the 150MW unit for the first time. The successful transformation of Yantai Power Plant lies in the elimination of the cold source loss of the unit during the heating period in winter, and the coal consumption for power generation is reduced to 150 g/kW H below, the overall operation is relatively normal. The main problem is that the efficiency of low pressure cylinder in non heating period is too low, about 16.8 percentage points lower than the design value, and the heat rate is far higher than the design value about 770kJ/kW h。 After further transformation, the problem of low efficiency under summer working conditions was basically solved by disassembling and assembling blades[5].

In order to meet the heat exchange requirements of the primary heating network and the secondary heating network as much as possible, the high back pressure circulating water heating adopts a tandem two-stage or three-stage heating system. The circulating water of the heating network first heats up through the condenser to absorb the waste heat from the exhaust steam of the low pressure cylinder, and then completes the second heating through the local extraction steam heater in the initial heating station[6]. In case of heat supply spikes, the temporary extraction steam heater is used for the third heating to generate high temperature hot water, The hot water is sent to the hot water pipe network to exchange heat with the circulating water of the secondary heat network through the secondary heat exchange station. The high-temperature hot water is cooled and then returned to the unit condenser to form a complete circulating water circuit.

(2) thermodynamic property

Without considering heat supply, high back pressure heat supply units are actually pure condensing units with high exhaust pressure. Therefore, from the perspective of power grid peak shaving, high back pressure heat supply units can participate in peak shaving. Their maximum electrical load is limited by the maximum evaporation capacity of the boiler, and the minimum electrical load is limited by the minimum stable combustion load of the boiler.

However, in the current dispatching mode of Shandong power grid, considering that the high back pressure heating units have no cold source loss and are more economical, the high back pressure heating units do not participate in the peak shaving of the power grid. The power plant reports the output curve of the units for the next day to middle note every day, and middle note dispatches according to the output curve reported by the power plant. However, as the number of units with high back pressure below 300MW in the province gradually increases, new energy grid connection and external power into Shandong increase, The peak shaving pressure of the power grid is increasing day by day, so the possibility of high back pressure heating units participating in peak shaving will not be ruled out in the future.

Under the current situation, for thermal power plants, the high back pressure heat supply units do not participate in peak shaving. Therefore, in actual operation, the high back pressure heat supply units are brought to full load to bear the main heat load. Other condensing units can bear less heat load, and the peak shaving capacity is enhanced, thus improving the overall peak shaving capacity of the whole plant.

2.2 Condensate extraction unit

(1) Heating mode

Condensate extraction unit refers to the steam extracted from an intermediate stage of the steam turbine to supply heat to external heat users, thereby reducing the amount of steam discharged into the condenser. According to the

nature of heat users, it can be divided into single extraction (industrial steam), single extraction (heating steam) C-type units (steam pressure can be different), and CC type units that also provide two types of steam or two extraction parameters for industrial or heating steam. The condensing unit can meet the needs of both thermal and electrical loads changing at any time. Extraction steam is extracted from an intermediate stage of the turbine and sent to the heat user. After the heat user releases heat, the condensate is partially or completely recycled to the drain collector of the power plant, and then sent to the boiler by the water pump for recycling. If the heat load increases during operation, the steam turbine will increase the steam inlet according to the demand of heat load to meet the demand of external heat load increase. When the external heat load changes, the extraction capacity for heat supply and the total steam inlet capacity of the turbine can be adjusted at the same time to keep the power generation unchanged.

(2)Thermodynamic characteristics

For the condensing unit, the peak shaving capacity of the unit is directly related to the external steam extraction volume. When the steam extraction volume changes, the output range of the unit also changes. Generally speaking, the larger the steam extraction volume of the unit is, the smaller the adjustable range of the unit load is. The upper limit of the unit load is subject to the maximum steam inlet volume of the turbine, and the lower limit of the load is subject to the minimum steam inlet volume of the low pressure cylinder or the middle exhaust temperature limit. The relationship between the main steam flow, steam extraction volume and load under the steam extraction condition of the unit can be expressed by the heating working condition diagram. If two of the three parameters are known, the other one can be found according to the heating working condition diagram.

3. Limiting conditions for peak shaving capacity of thermal power units

The peak shaving capacity of thermal power units is the highest and lowest electrical load that the unit can reach under a certain external steam extraction capacity. The limiting conditions for different types of thermal power units to carry the highest and lowest electrical loads are also different.

3.1 Limiting conditions for peak shaving capacity of high back pressure heat supply units

1) 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, the design output of the main auxiliary machines including the pulverizing system, six fans, environmental protection parameters, the maximum steam inlet flow of the turbine and the maximum exhaust temperature of the low-pressure cylinder.

2) The minimum electrical load of high back pressure heat supply unit with steam extraction is limited by the minimum steam inlet of low pressure cylinder.

3) For high back pressure heating units without steam extraction, the minimum electrical load is limited by the minimum stable combustion load of the boiler, flue gas temperature at the inlet of the denitration device, wall temperature of the heating surface, and environmental protection parameters.

4) The monitoring parameters affecting the safety of the unit shall not exceed the alarm value.

3.2 Limiting conditions for peak shaving capacity of condensate extraction unit

1) Different heat users have different requirements for steam extraction parameters, and the steam extraction parameters of the unit cannot exceed their limits.

2) The minimum electrical load of the unit is limited by the minimum steam inlet of the low-pressure cylinder, the minimum stable combustion capacity of the boiler, the flue gas temperature at the inlet of the denitration device, the wall temperature of the heating surface, environmental protection parameters, etc.

3) For the reheater unit that extracts steam from the exhaust pipe of the high-pressure cylinder, when the electrical load is low and the amount of heat and steam extraction is large, the reheater wall temperature is easy to overheat, which limits the minimum electrical load of the unit.

4) For the unit that extracts steam from the connecting pipe of the intermediate and low pressure cylinder, the exhaust pressure and temperature of the intermediate pressure cylinder shall not exceed the limit value 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, the design output of the main auxiliary machines including the pulverizing system, six fans, environmental protection parameters and the maximum steam inlet flow of the turbine.

6) The monitoring parameters affecting the safety of the unit shall not exceed the alarm value.

By studying the limiting conditions of peak shaving capacity of high back pressure heating units and condensing units in actual operation, it can provide reference for daily operation of thermal power plants.

4. Conclusion

The peak output capacity of the condensing unit is negatively related to the heat load. With the increase of heating and heating capacity of the unit, the output range of the unit becomes narrow and the peak output capacity is limited. The peak capacity of condensate extraction unit is limited by the main steam flow under TRL working condition (high back pressure working condition), and the main steam flow under TRL working condition (high back pressure working condition) reaches or approaches the

main steam flow under TRL working condition (high back pressure working condition) when the unit has the maximum output.

The high back pressure heating unit operates in the mode of "determining power by heat" in the heating season. It does not undertake the peak shaving task in the heating season, and the load trend is almost a straight line. The greater the heating heat load of the unit, the higher the corresponding electrical load. The steam pressure after the high back pressure unit transformation increases. Therefore, the maximum output under the high back pressure operation state can only be brought to about 80% of the pure condensing state.

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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. Lv Kai, Wang Hongyu, Zhou Jia, etc.Study on characteristics of electrothermal coal for cogeneration units [J].Thermal Power Generation, 2018, 47 (5): 7-12
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): 7-10.
4. Zhang Guangcai, Zhou Ke, Lu Fen, etc. Discussion on deep peak shaving technology of coal-fired units [J].Thermal Power Generation, 2017, 46 (9): 7-15.
5. Wang Wei.Analyze the application of thermal test in thermal power plants [J].China Science and Technology Wealth, 2012, 000 (014): 214-214.
6. Li Hening.Optimal operation of electric heating combined system based on new energy consumption [D]. Shenyang University of Technology.