General situation of heating transformation of thermal power units in Shandong Power Grid

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Abstract. This paper introduces the basic situation of thermal power units in Shandong power grid, the mode of unit heating transformation, the results of installed capacity and heating area after the transformation of heating, and the main work of Shandong power grid in ensuring people's livelihood heating and promoting the peak load adjustment of thermal power units.

1. Introduction
In recent years, with the development of the city and the increase of heating demand, combined with the replacement demand brought by the coal-fired reduction and shutdown of small thermal power and small boilers, the heating transformation, installed capacity and heating area of direct dispatching public units in Shandong power grid is increasing year by year. In terms of installed capacity, it is 45.88 million kW in 2018, 51.82 million kW in 2019 and 52.34 million kW in 2020. In terms of heating area, it is 248.740 million square meters in 2018, 366.71 million square meters in 2019 and 379.29 million square meters in 2020. At present, the heating capacity of direct transfer public heat power units has not been fully released, and the actual heating area of some power plants is far lower than the design capacity. In the future, with the promotion of heating substitution, the heating area of direct transfer public heat power units will continue to increase.

At present, the heating transformation of the thermal power units mainly focuses on the improvement of heating capacity, but does not pay enough attention to the flexibility of peak shaving. The peak shaving of the thermal power units will be limited in the heating season [1]. First, a large number of pure condensing units are converted into heat supply units by drilling and extracting steam through medium and low pressure connecting pipes, which can not meet the peak shaving of 50%-100% rated capacity under the full extraction condition, and the peak shaving will inevitably occur when the extraction volume is large. Second, the large-scale and centralized pure condensing units are changed to high back pressure heating, the peak shaving capacity of high back pressure units is basically lost, which increases the peak shaving pressure of power grid, and the centralized overhaul and replacement of rotors before and after the heating period also has an impact on the power grid dispatching arrangement. Third, the demand for industrial steam supply is increasing, and a number of power plants are seeking industrial steam supply as a new profit growth point, but industrial users have higher requirements for steam supply pressure and temperature, which will affect the peak shaving capacity of the unit itself.
2. General situation of thermal power units in Shandong Power Grid

The heating forms of thermal power units mainly include regulating extraction condensing heating units (condensate extraction unit for short), low pressure cylinder zero output heating units (cylinder cutting unit for short), back pressure heating units (including high back pressure circulating water heating unit, optical axis transformation unit and pure back pressure heating unit) [2], etc.

As of December 2020, Shandong power grid has 160 direct dispatching public thermal power units (above 100000 kW), with a total capacity of 60.805 million KW, including 139 thermal power units, accounting for 86.88%, which capacity is 52.34 million KW, accounting for 86.08%.

According to the power generation mode, the direct regulating public thermal power units are divided into thermal power units and nuclear power units, and the proportion of their quantity and capacity is shown in Table 1.

Table 1. Classification of thermal power units according to power generation mode.

| Numble | Unit type             | Quantity(unit) | Proportion(%) | Capacity (10000 kW) | Proportion(%) |
|--------|-----------------------|----------------|--------------|---------------------|--------------|
| 1      | Thermal power unit    | 137            | 98.56        | 4984                | 95.22        |
| 2      | Nuclear power unit    | 2              | 1.44         | 250                 | 4.78         |
| 3      | Total                 | 139            | 100          | 5234                | 100          |

The number and capacity of condensing unit, back pressure unit and cylinder cutting unit classified by heating form are shown in Table 2.

Table 2. Classification of thermal power units according to heating mode.

| Numble | Unit type                  | Quantity (unit) | Proportion (%) | Capacity (10000 kW) | Proportion (%) |
|--------|----------------------------|-----------------|---------------|---------------------|---------------|
| 1      | Condensate extraction unit | 90              | 64.75         | 4187.5              | 80.00         |
| 2      | Back pressure unit         | 33              | 23.74         | 587.5               | 11.23         |
| 3      | Cylinder cutting unit      | 16              | 11.51         | 459                 | 8.77          |
| 4      | Total                      | 139             | 100           | 5234                | 100           |

According to the capacity classification, the thermal power units can be divided into 1 million KW series, 600000 kW series, 300000 kW series and below 300000 kW series, and the proportion is shown in Table 3. At present, 300000 or less units are still the main type of heat supply, but in recent years, heat supply has begun to develop to large capacity and high parameters.

Table 3. Classification of thermal power units according to capacity class.

| Numble | Unit type                | Quantity(unit) | Proportion(%) |
|--------|--------------------------|----------------|--------------|
| 1      | 1 Million KW series      | 7              | 5.04         |
| 2      | 600000 KW series         | 24             | 17.27        |
| 3      | 300000 KW series         | 62             | 44.60        |
| 4      | Below 300000 KW series   | 46             | 33.09        |
| 5      | Total                    | 139            | 100          |

3. The present situation of the heat supply reform of Shandong power grid thermal power unit

The heating transformation methods of provincial direct transfer public thermal power units for people's livelihood heating mainly include middle and low pressure connecting pipe drilling steam extraction transformation, high back pressure circulating water heating transformation, optical axis heating transformation, low pressure cylinder zero output heating transformation [3]. The transformation methods for industrial steam supply mainly include cold re extraction transformation, hot RE Extraction transformation, injection confluence transformation, etc. Except for the zero output transformation of low pressure cylinder will improve the flexibility of the unit, the other modification methods will reduce
the peak load regulation capacity. There are no real ways to realize "thermoelectric decoupling" of units in the province, such as high-pressure bypass heating transformation, heat storage tank, electric boiler, absorption heat pump, etc. The main reason is that there is a big gap between the peak shaving compensation of auxiliary services and that of Northeast China, and the market incentive role is not fully played. However, the energy authorities have actively tried to use policy guidance flexibility transformation. The provincial energy bureau has given more priority to the "thermal power generation" priority power generation plan for low-pressure cylinder zero output transformation units.

In recent years, the medium and low pressure connecting pipe drilling and steam extraction transformation is the main way for pure condensing unit to change heat supply. The heat supply object is mainly heating users. The medium pressure cylinder exhaust realizes the safe external steam supply of the unit by installing a new exhaust pressure hydraulic regulating butterfly valve (or rotating diaphragm) on the medium and low pressure connecting pipe, the extraction check valve, regulating valve, quick closing valve and control system on the extraction pipe.

The high back pressure heat supply unit improves the exhaust pressure of low pressure cylinder from 4.9kpa to about 54kpa by reforming the rotor of low pressure cylinder of pure condensing unit, corresponding to the saturation temperature of about 80℃, the exhaust steam is directly used to heat the circulating water for external heating, so that all the exhaust heat of the unit is taken away by the circulating water for heating, and the loss of cold source is zero, which greatly improves the economy of the unit. In the early stage, the low-pressure rotor is transformed to remove the last two stage blades, so as to improve the exhaust pressure; in the later stage, the "double rotor and double back pressure" is proposed, that is, the special rotorthe with highly exhaust parameters is used in winter, the circulating water of heat supply network is heated in the condenser and then enters the heat supply network heater for secondary heating to meet the requirements of heat users. The original pure condensing rotor is restored in summer to meet the needs of pure condensing condition.

The zero output transformation of low-pressure cylinder is aimed at the extraction condensing thermal power unit with bridge pipe heating. The maximum steam extraction capacity is limited by the minimum steam inlet capacity of low-pressure cylinder. For the sake of safety, the manufacturer reserves a large margin for the minimum steam inlet capacity of low-pressure cylinder, which can not give full play to the heat supply capacity of the unit. Through checking and calculation, generally, the steam inlet capacity of low-pressure cylinder with 3% rated main steam flow is enough to take away the blast heat. Cylinder cutting overcomes the problem of insufficient steam extraction capacity of the condensing unit. There is no need to reform the main equipment of the unit. It only checks the strength of the last two stages of blades, and then adds a bypass pipe on the medium and low pressure connecting pipe to inject a small amount of cooling steam to take away the blast heat generated by the rotation of the low pressure rotor. After cylinder cutting, the exhaust steam of intermediate pressure cylinder is basically used for heat supply, which is equivalent to back pressure machine. The heat supply capacity is greatly increased, and the cold source loss and the coal consumption rate of the unit is also reduced. Under the condition of constant heat supply, the generating power of the unit can be reduced to a certain extent, and the deep peak shaving can be realized. The reformed unit can switch between back pressure operation and condensate extraction operation flexibly, which makes the unit have the characteristics of large heat supply capacity of back pressure unit and flexible operation mode of condensate extraction unit.

During the heating period, the original low-pressure rotor is replaced by the optical shaft without blades, so that the blowing heat loss of the low-pressure rotor is reduced to nearly zero. During the heating period, the low-pressure cylinder does not enter the steam, and the exhaust steam of the medium pressure cylinder enters the heat supply network heater, which is equivalent to the back pressure machine so as to maximize the external heat supply. In the non heating period, the original unit's low-pressure rotor is replaced and the low-pressure cylinder's condensing operation is restored. After the optical shaft is put into operation in the heating period, in order to prevent the low-pressure cylinder's optical shaft rotor from blowing, a low-pressure cylinder cooling device is equipped to lead a way of steam from the middle exhaust to the low-pressure cylinder after temperature and pressure reduction, so as to take away the heat generated by the optical shaft blowing. The optical shaft transformation needs to replace the
rotor, the cost is higher, and an overhaul is added, but the safety is greatly improved, and the water erosion of the last stage blade of the low pressure cylinder in long-term operation is avoided.

The comparison of advantages and disadvantages of each transformation mode and the transformation quantity are shown in Table 4.

**Table 4.** Comparison of advantages and disadvantages of main heating transformation modes of thermal power units.

| Number | Transformation mode                                      | Advantages                                                                 | Shortcomings                                                                 | Transformation cost |
|--------|----------------------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------|
| 1      | Revamping of steam extraction by drilling middle and low pressure connecting pipes | The operation mode is flexible, and it has a certain peak shaving capacity under the premise of ensuring the heat supply. | Compared with the pure condensing unit, the peak shaving capacity is reduced, and the peak shaving interval becomes narrower with the increase of steam extraction capacity. | Within 10 million   |
| 2      | Heating transformation of high back pressure circulating water | 1. The exhaust steam of low pressure cylinder is used for heating, with strong heating capacity and no cold source loss. 2. Low pressure cylinder is still in steam, normal work, high thermal power generation rate, low coal consumption, using waste heat heating, heating economy is the best. 1. There is no need to reform and replace the rotor, only need to check the strength of the last stage and the last stage blade, so the reform cost is low. 2. It can be switched freely in back pressure condition and condensate extraction condition. 3. After cutting the cylinder, the middle exhaust is almost full of heat supply, and the heat capacity is strong. Low pressure cylinder does not work, increase 30% of low load peak shaving capacity. | 1. The rotor needs to be replaced, the cost is high. 2. The power supply is determined by heat, and the peak load regulation capacity is basically lost on the premise of keeping the heat supply unchanged. | 50-100 million       |
| 3      | Low pressure cylinder zero output transformation          | The LP cylinder has only optical axis, and the middle row is basically used for heating, with strong heating capacity. | 1. Long term operation of water erosion, blast loss may cause damage to the blade. 2. After cutting the cylinder, the power is set by heat, and the load cannot be adjusted. | 10-20 million        |
| 4      | Optical axis transformation                              |                                                                           | 1. The low pressure cylinder does not work basically, which affects the high load of the unit. 2. It is necessary to replace the rotor once and add an overhaul. 3. The peak adjustment capacity is poor when the power is fixed by heat. | over 50 million      |

4. Improvement of operation management of thermal power unit
In recent years, Shandong power grid has carried out a lot of work in ensuring people's livelihood heating and promoting peak load regulation of thermal power units. One is to improve the operation management of thermal power units with the help of thermal power online monitoring system. Through the
establishment and improvement of online monitoring organization of cogeneration units, centralized check of uploaded data of cogeneration monitoring system before and after heating season, data audit of new and retrofitted units connected to the main station, monthly, semi annual and annual heating report analysis, and special verification of heating sub station, the reliable operation of thermal power online monitoring system and priority power generation plan of direct regulating public thermal power units are ensured fair and reasonable. Second, relying on the development of grid source platform, the research on peak load regulation capacity of thermal power units is explored. In recent years, with the rapid development of foreign power into Shandong and new energy, thermal power units need to give priority to heating in heating season, and the peak shaving capacity is limited, which seriously affects the new energy consumption and the real-time balance of power grid. Shandong power grid focuses on the peak shaving capacity of thermal power units, modifies the calculation model of upper and lower limits of peak shaving of thermal power units to improve the function of power load dispatching interval of thermal power units, and verifies the minimum startup mode of thermal power plants online. By improving the practical level of peak shaving module of thermoelectric units on grid source platform and dynamically carrying out peak shaving capacity test of thermoelectric units, the peak shaving pressure of power grid is effectively alleviated and new energy consumption is promoted.

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