Study on Peaking Performance of 330MW Unit under Pure Condensing Condition and Extraction Condition

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Abstract. In this paper, the peaking capacity test is carried out for the 330MW unit to compare the peak shaving performance of the unit under the extraction state. The test content is divided into three parts, respectively (a) operating at minimum output under pure condensing condition, (b) minimum load with maximum steam extraction condition and (c) maximum steam extraction with minimum electric load condition. It can be seen from the test results that the minimum electrical load of the unit under 3 conditions is 128.4 MW, 128.6 MW, and 124.8 MW, respectively. Under the test conditions of industrial steam extraction at about 40t/h, the peak shaving performance of the unit has almost no change, compared with the pure condensing condition.

1. Introduction
The rapid growth of new energy installed capacity, especially the surge in distributed photovoltaics, has increased the difficulty of grid peak shaving, and the impact on Shandong power grid peak shaving has become more and more obvious. In order to maintain the power balance of the power system, grid-connected thermal power units have gradually transformed to undertake peak shaving tasks and provide auxiliary services [1-3].

At present, there are many domestic and foreign researches on the participation of thermal power units in peak shaving, either by tapping the potential of the unit's own operating capacity, or improving the peaking capacity of the unit by means of flexible technical transformation [4, 5]. Some scholars conduct research on traditional peak-shaving capacity evaluation methods of heat-supply thermal plants, using clustering analysis algorithms to classify and divide the massive operating big data of heat-supply units, and use Gaussian distribution probability density function tools to optimize the peak-shaving capacity [6]. Studies have analyzed in detail the main factors of the boiler, such as combustion stability, safety of water circulation and the influence of boiler auxiliary equipment on the peak regulation margin [7]. Aurora has established an MPC predictive control model for thermal power plants, which plays a certain role in improving peak shaving capabilities of thermal power plants [8].

At present, the research on deep peak shaving of power grid mostly focuses on theoretical and numerical simulation analysis, and lacks a large amount of field measurement data verification, which is difficult to directly use to guide the operation of the unit. For this reason, it is urgent to combine the abundant field measured data and analyze the unit peak shaving performance with the theoretical model to provide technical support for the safe and economic operation of the unit.
In this paper, the peak-shaving capability test was carried out for the thermal power unit, and we analyzed the operating conditions of the unit in the pure condensing state and heating state, giving optimization suggestions in the peak-shaving operation process.

2. Experimental apparatus and procedure

2.1. Experimental apparatus

The boiler is a sub-critical, one-stage intermediate reheat, control cycle, single furnace crucible, solid-state slagging coal-fired steam drum furnace. The combustion method is a positive pressure direct blow four-corner cut circle, using plasma ignition. The main steam temperature adjustment mode is the second-stage water spray, and the reheat steam temperature adjustment mode adopts the swinging burner swing angle and the water spray.

The steam turbine is a subcritical, intermediate reheating, high and medium pressure combined cylinder, twin-cylinder double-exhaust steam, single-shaft, condensing steam turbine. Each high and low pressure heater is equipped with a drain cooling section. The high pressure heater is also equipped with a superheated steam cooling section. The heater drain is self-flowing step by step.

Table 1. Main parameters of the unit

| Items                      | Unit | BMCR | THA | 75%THA | 50%THA |
|----------------------------|------|------|-----|--------|--------|
| Main steam flow            | t/h  | 1025 | 893.7 | 645.21 | 437.49 |
| Main steam pressure        | MPa  | 17.5 | 17.28 | 16.94  | 16.74  |
| Main steam temperature     | °C   | 541  | 541  | 541    | 534.4  |
| Drum pressure              | MPa  | 18.87| 18.34| 17.52  | 17.02  |
| Feed water pressure        | MPa  | 19.27| 18.72| 17.86  | 17.34  |
| Feed water temperature     | °C   | 282  | 273.6| 253.7  | 231.3  |
| Reheated steam flow        | t/h  | 847.27| 744.73| 548.27 | 378.63 |
| Reheated steam outlet pressure | MPa | 3.72 | 3.27 | 2.39  | 1.60  |
| Reheated steam inlet temperature | °C | 541 | 541 | 541    | 513.2  |
| Reheated steam inlet pressure | MPa | 3.92 | 3.45 | 2.52  | 1.69  |
| Reheated steam outlet temperature | °C | 329.8| 316.9| 293.3  | 265   |
| Superheater spray pressure | MPa  | 20.44| 19.58| 18.3    | 17.59  |
| Superheater spray water temperature | °C | 178.8| 173.6| 161.9  | 148.5  |

2.2. Experimental contentprocedure

2.2.1. Experimental procedure.
The following working conditions are tested on the unit: (a) pure solidification minimum load test, continuous stable running time of more than 2h; (b) minimum load, maximum steaming condition test, through adjustment, the unit's electric load is maintained Pure solidification minimum load, extraction steam flow reaches the maximum value, continuous stable operation time is more than 2h; (c) Maximum extraction steam quantity and minimum electric load working condition test, through adjustment, the unit extraction steam flow is designed maximum value and electric load is reached The lowest, continuous stable running time is more than 2h.

2.2.2. Monitoring items. In the test, we monitored the key parameters of the thermal power unit in the peak shaving operation, mainly including the negative pressure of the furnace, the flue gas temperature of the SCR device, the oxygen content of the furnace outlet, the temperature of the heating surface and the vibration of the steam turbine bearing, etc., through the above parameters In contrast, we analyze the key limiting factors of the unit in the deep peak shaving state.

2.2.3. Coal quality parameters

| Table 2. Coal quality parameters |
|----------------------------------|
| Item       | Unit | Condition a,b | Condition c | Design coal | Check coal |
| Mad (%)    | 2.29 | 2.03          | 8.00        | 3.09        |
| Aad (%)    | 19.16| 20.62         | 7.63        | 21.20       |
| Vdaf (%)   | 37.49| 37.36         | 35.00       | 32.31       |
| F Cad (%)  | 49.1 | 48.45         | —           | —           |
| Stad (%)   | 0.73 | 0.72          | 0.46        | 0.68        |
| Had (%)    | 4.40 | 4.32          | 4.00        | 3.60        |
| Qb,ad MJ/kg| 25.40| 24.88         | —           | —           |

3. Results and discussion

3.1. Furnace negative pressure

During the peak-shaving operation of thermal power units, the stable combustion of the boiler is an important factor affecting the stable operation of the unit. The heat sources of the pulverized coal air flow include high-temperature flue gas entrained and refluxed by the pulverized coal air flow, the radiation of the pulverized coal airflow and the heat released by the chemical reaction of the fuel such as the flame furnace. The reaction heat of the fuel can be ignored before the fire, and the high-temperature reflux flue gas convection and radiation are dominant, and the decrease of the average flue temperature in the furnace has a great influence on the fire heat. Pulverized coal is difficult to ignite,
flame stability is poor, and the ability to adapt to changes in working conditions becomes poor. Small disturbances may cause unstable combustion and even fire in the furnace. The negative pressure in the furnace is an important parameter that reflects the stability of the combustion conditions, and the fluctuation indicates the degree of combustion stability. Once the combustion conditions in the furnace change, the furnace negative pressure changes accordingly.

It can be seen from Figure 2 that under the three working conditions, the average values of the boiler furnace negative pressure are not much different, which are -49.87Pa, -50.77Pa, -49.77Pa, and the fluctuation rates are 9.26, 8.80, and 10.23 respectively. However, it can be seen from Figure 3 that when operating under the first condition, the negative pressure of the furnace fluctuates significantly, and even has a positive value, and the combustion stability is significantly worse. This is because under working condition 1, although the electrical load of the unit is not much different from the other two working conditions, the unit is in a pure condensing state, and the boiler evaporation is obviously small, that is, the boiler load is small, and the combustion stability becomes worse.

3.2. SCR flue gas temperature

When the load of the coal-fired unit decreases, the fuel consumption of the boiler will decrease, and the temperature field in the boiler will also change accordingly, resulting in a change in the radiation heat exchange in the furnace. The change in heat caused by fuel consumption is greater than the change in radiant heat transfer in the furnace, so the flue gas temperature change is mainly determined by the fuel consumption. When the load decreases, the fuel consumption decreases and the flue gas temperature decreases. Therefore, the SCR flue gas temperature also decreases.

When the temperature of the SCR device is lower than the condensation temperature of NH₄HSO₄, NH₄HSO₄ will precipitate and easily adhere to the surface of the SCR reactor catalyst. When dust adheres, the catalyst will be deactivated. In order to protect the catalyst, the denitrification device is generally set to automatically exit the temperature.

It can be seen from Figure 4 that the flue gas temperature deviations on both sides A and B of the SCR are relatively large under the three working conditions, and the flue gas temperature on the A side is close to 320°C under low load, which is similar to the automatic withdrawal of the denitrification device. The temperature difference is similar to peak shaving limited temperature, especially in the case of large deviation of the smoke temperature on both sides, the smoke temperature on both sides should be monitored strictly.

Under the three working conditions, the denitrification temperature of working condition a is the lowest, which is related to the operating load of the boiler. The boiler evaporation capacity under the three working conditions are 445.87t/h, 463.56 t/h, and 458.55 t/h, although three
the unit under working condition is close, but the boiler under working condition a has the lowest load. Therefore, when the unit participates in peak shaving under the heating state, the boiler operation is better, but the operating pressure of the steam turbine extraction is higher.

3.3. SCR flue gas temperature

Figure 4 shows the desuperheater and reheater desuperheater water volume under different working conditions. It can be seen from the figure that during the peak-shaving operation, both the superheater and the reheater are put into operation with desuperheating water, indicating that there is an over-temperature phenomenon. The desuperheating water volume of the three working conditions is similar, but the highest desuperheating water volume appears in both working conditions a and b, which shows that the superheater has a higher wall temperature under low load. When the unit is running under low load, the pipe wall temperature of each heating surface should be closely monitored to avoid the occurrence of over-temperature pipe explosion.

4. Conclusion

(1) The negative pressure fluctuations in the furnace increased significantly during the peak-shaving operation of the unit, indicating that the stable combustion performance of the boiler decreased.

(2) SCR flue gas temperature is an important parameter that affects the peak shaving operation of the thermal plant.

(3) When the thermal power plant participates in peak shaving under the heating state, the boiler and auxiliary equipment can maintain good operating conditions, while the steam turbines are prone to operational hazards due to extraction steam heating.

(4) When the unit is running under low load, the pipe wall temperature of each heating surface should be closely monitored to avoid the occurrence of over-temperature pipe explosion.

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