Study on Operating Economy of Ultra-supercritical Units

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ABSTRACT

Under the same peak-regulating load rate, the economical efficiency of ultra-supercritical unit is superior than supercritical unit and subcritical unit. By comparing the ultra-supercritical unit, supercritical unit and subcritical unit, the bestload point of ultra-supercritical units could be achieved, which has a certain and positive effect to improve and maintain the steady and high economical efficiency operation state of the ultra-supercritical unit.

KEYWORDS

Ultra-supercritical Unit, Load Curve, Heat Consumption

INTRODUCTION

The number of 1000MW units in China is more than the total amount of global ultra-supercritical units, China's ultra-supercritical power generation technology has reached the top level of worldwide. It not only has played a key role to achieve China's efficient and clean energy development leap, but also for coal-fired power generation field in China to realize energy saving and emission...
reduction and protection of the environment and resources. But with the optimization of the economic structure, residential electricity and commercial electricity ratio have increased year by year, the gap electricity peak and valley load in power grid has become larger and larger, which leads to the fact that large capacity coal-fired power generating units with the basic design of the adjustable peak load have to participate in peak operation in a low load level operation. The decrease of unit load means lower efficiency and coal consumption increased, which leads to the fact that it is unable to make the full use of the large capacity ultra-supercritical units. How to improve the efficiency of ultra-supercritical unit in low load operation is a difficult problem for coal-fired power generation industry to solve.

OPERATING ECONOMY OF SUBCRITICAL UNIT

With the development and importation of technology independency, optimization of design and updating of technology, the economical efficiency and reliability of subcritical unit have almost met the international standard. Till 2014, the 300MW and 600MW subcritical units had still been widely applied in peaking operation of each power grid.

For example, in 2016 the average coal consumption of Taishan 600MW subcritical unit was 310g/kWh. Compared with the average coal consumption level of whole nation subcritical units in 2011, which was 326 g/kWh, the coal consumption has decreased by 16g/kWh after optimization of five years: the energy utilization rate has obviously improved.

The test result reveals that the variation of load states of the subcritical unit has a very small influence to the turbine efficiency of the steam turbine. On the contrary, the throttling loss of air valve adjusting has a great impact on the efficiency of HP cylinder. The efficiency of HP cylinder varies greatly with the change of load. The decrease of the HP cylinder efficiency is the main reason that leads to the increase of the heat consumption rate.

With the gradual implementation of the national policy of developing large scale units and suppressing small ones, the subcritical unit faces double pressure of environmental protection and the demand of high efficiency of energy utilization. After serving as main units for decades, subcritical unit shave gradually retreated from the historical stage of coal-fired power generation.

OPERATING ECONOMY OF THE SUBCRITICAL UNIT

Similarly, the coal consumption of the subcritical unit and the auxiliary power rate have gradually decreased year by year. For example, the average coal con-
The heat load curve of this unit shows in Fig. 1 below. The performance test shows that when the load rate is lower than 70%, the efficiency of HP cylinder will be evidently decreased, which leads to the rise of the unit’s heat consumption rate.

**OPERATING STATUS OF ULTRA-SUBCRITICAL UNIT**

![Heat Consumption Rate Curve of the Supercritical Unit](image)

Figure 1. Heat Consumption Rate Curve of the Supercritical Unit.

At present, China’s coal-fired generating units installed capacity accounted for nearly 70%. For the peaking operation, oil and gas generation and pumped storage generator installed capacity accounted for only 8%. Due to the load peak valley difference, although most of 300MW the following small and medium-sized coal-fired power generating units have participated in peak shaving, but by its installed capacity, its peaking operation capacity is limited. Therefore, 600 MW and 1000 MW ultra-supercritical units act as the main force for peaking operation tasks in order to meet the requirements of power grid dispatching. The data shows that in 2015 the national wide 600 MW and above coal-fired power generation units average utilization hours is only 4329 hours(Fig.2), which reaches the lowest level since year 1978. According to the existing 1000MW ultra-supercritical unit operation statistics, about 35% units are operating under the load rate of 70%.

Although 600MW and 1000MW ultra-supercritical unit are designed with the basic load, but often operate in a low load rate: not in the design of the "economic zone" caused by operation, coal consumption increased about 8~9 g/(kWh). Therefore, the development of efficient wide load rate of ultra-supercritical unit is very necessary. In addition, the installed capacity of wind power and solar power in the power grid is increasing year by year. By the end of 2015, the installed capacity of China’s grid connected wind power and solar power generation plants have reached 129000 MW and 43180 MW respectively, and the installed capacity of these two kinds has reached 11.3% of the total installed capacity of all the
power generation units. Because wind and solar power generation has strong randomness and fluctuation of the output characteristics, it is difficult to guarantee stability which leads to the characteristics of strong anti-peak operation, peak of large scale grid brings the difficult problem is very prominent, the peak daily load curve of power grid is increasing. The difference is shown in Fig.3 that Jingjinji grid in winter the typical daily load curve the difference between peak and valley, which has reached 30.6%. Therefore, in the future, coal-fired generating units become the leading new energy complementary power grid. Enhancing the ability of large capacity units peaking operation is the foundation to ensure the safe and stable operation of power system.

**OPERATING ECONOMY OF ULTRA-SUBCRITICAL UNIT**

Compared with the supercritical and subcritical units, the ultra-supercritical unit has higher efficiency and operation reliability, which is established in the high level operation load of rated main and reheat steam temperature. When the ultra-supercritical unit is operating in a wide range of load ratio, it is difficult to guarantee the efficiency of the unit: boiler, steam turbine, water pump and blower and other auxiliary equipment would deviate from the optimum design operating condition, which will lead to the increase of the throttle, steam leakage and moisture loss. It would result in the decrease of circulating heat efficiency and the increase of the coal consumption. Usually, system design, equipment structure, operation environment (backpressure), operation mode and the technical level of operators are main factors that affect the operation economics.
Economical Operation Load of the Ultra-Supercritical Unit Boiler

Under the reasonable adjustments and designs of the boilers of ultra-supercritical and supercritical unit, the main steam temperature can reach the rated value when the load rate is over 35% to 50%. The reheat stream temperature, can also reach the rated value[1] when the load rate is over 70%. Therefore, when the unit operates between 70% and 100% rated load, the reheat steam temperature doesn’t affect the unit’s operational efficiency. The main steam temperature does not affect the unit’s operational efficiency when the unit operates between 50% and 100% rated load. When the change is within the range mentioned above, which means the rated load is between 50% and 100%, only steam pressure influences the unit’s efficiency[2].

Economical Operation Load of Ultra-Supercritical Unit Steam Turbine

![Figure 4. Heat Rate Curve of the Ultra-Super Critical Unit Design.](image)

After two years’ energy saving and polluting control, Shanghai Shangdian Caojing Power Plant 2×1000 MW unit have achieved great improvement in energy utilization. The heat consumption rate design values of the system in different loads shows in Table 1 and the heat consumption rate curve shows in Fig 4. It can be seen that the decrease of the load leads to the increase of the heat consumption rate of the ultra-supercritical unit evidently. Operating on the rated load ratios of 80%, 75%, 50%, 40% and 30%, the heat consumption rates of the unit respectively rises about 0.5%, 0.8%, 4.1%, 6.7% and 12.1%. When the actual load is lower than half of the rated load, the heat consumption rate tends to evident acceleration.

When ultra-supercritical unit with load changing is operating mode of steam turbine with fixed pressure operation, sliding pressure operation and composite sliding pressure operation, the steam temperature in steam turbine has a great change. The low-load operating rate leads to a significant throttle loss of the main
steam which finally leads to the decrease of thermal efficiency. When system is operating at Sliding pressure load changing mode, steam turbine steam temperature changes very small or even remains unchanged, while the initial steam pressure decreases with the load decreases. The steam heat capacity is reduced, superheated steam and reheat steam are easy to maintain the stability, so that the operation conditions of intermediate pressure and low pressure cylinder is improved, which has less influence on the operation of steam turbine.

**TABLE 1. HEAT RATE OF THE DESIGN OF THE 1000 MW-UNIT OF ULTRA-SUPER CRITICAL OF CAOJING POWER PLANT.**

<table>
<thead>
<tr>
<th>Project</th>
<th>Load (TMCR)%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Main Steam Pressure</td>
<td>10</td>
</tr>
<tr>
<td>Main Steam Temperature</td>
<td>600</td>
</tr>
<tr>
<td>Heat Rate Of The Design</td>
<td>8222</td>
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**Economical Operation Load of Ultra-Supercritical Unit Auxiliary Equipment Efficiency**

Air blower and other auxiliary equipment of coal fired power plant are very important. When the load changes, it has a great influence on the efficiency of the air blower. The main auxiliary equipment for ultra supercritical units, even under rated load, the air blower would not operate in the high efficiency region and still suffers the increase of power consumption and energy loss.

**DISCUSSION AND ANALYSIS**

The curve of the heat consumption rate designed value of the subcritical unit, supercritical unit and ultra-supercritical unit shows in Fig 5. When the load rate of the ultra-supercritical unit is lower than 65%, its heat consumption rate will be higher than the rated 800MW supercritical. When the load rate of the ultra-supercritical unit is lower than 35%, its heat consumption rate will be higher than rated 600 MW subcritical unit.
CONCLUSIONS

According to the data analysis above, under the same peak load regulation, the operation efficiency of ultra-supercritical units is apparently higher than supercritical units and subcritical units. When the load rate of ultra-supercritical unit is lower than 35%, the heat consumption rate will be higher than rated 600MW subcritical unit. When the load rate of ultra-supercritical unit is lower than 65%, its heat consumption rate will be higher than rated supercritical. When the actual load is lower than half of the rated load, the heat consumption rate tends to evident acceleration.

Coal-fired units have to face the great pressure of current environmental protection. On one hand, it is necessary to enhance the technical equipment reformation of the existing subcritical unit and supercritical unit to lower the fuel consumption. On the other hand, it is necessary to guarantee the utilization rate of the ultra-supercritical unit, which means the economical operation load would not less than 60%-70% rated load. So that it would achieve the final purpose of the optimization of economical operation, environmental protection and the high utilization efficiency of energy.

REFERENCES