Correction Calculation of Influence of Back Pressure Change of Extraction Steam Condensing Unit on Unit Power

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Abstract. In view of the correction calculation method for the power of extraction condensing steam turbine without back pressure change at present, a simplified correction calculation method for the influence of back pressure on the power of extraction condensing steam turbine is proposed. This method can accurately calculate the influence of back pressure change on the power of extraction condensing steam turbine, so as to provide guidance for the economic operation of extraction condensing steam turbine.

Keywords: Back Pressure; Extraction Condenser Steam Turbine set; power

1. Introduction
During the operation of a steam turbine, the impact of changes in the initial and final parameters on the power of the unit is usually determined by the management of small operating indicators, and the operating efficiency of the steam turbine is improved by adjusting the operating parameters. Theory and practice show that back pressure is one of the biggest parameters affecting the power of a steam turbine[1]. For pure condensing units, the influence of back pressure on power generation can be calculated through curve correction provided by the manufacturer or thermodynamic theory, but these two methods are not applicable to extraction condenser steam turbine units. In view of the fact that there is no effective method to calculate the calculation method of back pressure on the extraction condenser steam turbine unit, this paper proposes a simplified correction calculation method for the influence of back pressure on the extraction condenser steam turbine unit power, which can be accurate Calculate the influence of the change in back pressure on the power of the extraction condensing turbine, so as to provide guidance for the economic operation of the extraction condenser steam turbine unit, and it has important practical significance for the horizontal comparison of the economic operation of the unit.

2. Type of extraction condenser steam turbine unit
The extraction condenser steam turbine unit is a machine that produces electricity and heat. It is to use the steam that has done work in the steam turbine for external heating to jointly produce two kinds of energy. The extraction condenser steam turbine unit conforms to the principle of energy consumption...
according to quality, and the high-grade thermal working medium with higher pressure and temperature is first used to produce electricity. The discharged low-grade steam is supplied to heat users [2].

The extraction condenser steam turbine unit is mainly divided into 3 types of steam extraction methods according to the different extraction locations, namely, high-pressure cylinder exhaust pipe extraction, medium-pressure cylinder perforated extraction, and medium-low pressure cylinder cross-bridge joint extraction.

3. Calculation and correction of the influence of back pressure change on unit power

Unit thermal performance test is the most accurate and easiest way to assess unit economic performance. In the thermal performance test, the allowable parameter deviation is within a certain range, but the parameter deviation will inevitably affect the test results; therefore, before comparing the test results, it is necessary to correct the effect of the parameter deviation on the results to ensure that the comparison is the same. Under the conditions of the thermal cycle. Among all the thermal parameters of a steam turbine unit, the change of back pressure has the greatest impact on the power of the steam turbine [3].

There are two main methods for calculating and correcting the influence of back pressure on the power of pure condensing units. One is the curve correction method provided by the steam turbine manufacturer; the other is the theoretical calculation method based on the principle of thermodynamics.

3.1. Calculation and Correction of the Influence of Back Pressure on the Power of Extraction Condenser Turbine Unit

Taking a 300MW extraction condenser steam turbine unit in a certain factory as an example, a simplified correction calculation method for the influence of back pressure on the power of the extraction condenser steam turbine unit is proposed. The extraction steam of this unit comes from the middle and low pressure cylinder bridge joint. The principle thermal system diagram is shown in Figure 1.

First, the steam entering the extraction unit is divided into two streams, one is condensing steam, the other is heating steam, and the two steam streams are two cycles. The difference between these two cycles is that the condensed water returns to the boiler through different regenerative heaters [2].

Then, the condensing cycle and heating cycle of the extraction condensing unit are studied respectively. The following are two cycles of analysis and calculation.

3.1.1. Calculation of the condensing steam cycle. The condensing cycle is consistent with the working fluid cycle of an ordinary pure condensing unit, that is, the new steam becomes exhausted steam after expansion and work in the high, medium, and low pressure cylinders and is discharged into the condenser for condensation, and the condensed water enters after being heated by the regenerative heaters at all levels boiler. This part of the working fluid completes a closed cycle, called the condensing cycle. The schematic diagram of the condensing steam cycle is shown in Figure 2.
The amount of electricity generated when the exhaust steam of the steam turbine condenser is 1kg. Expressed by formula (1):

\[ nK = aKL0K3600\eta j\eta d \]  

(1)

In the formula: \( a_K \) It is the water output when the water intake of the regenerative system is 1kg, that is, the boiler water intake coefficient; \( L0K \) It is the internal power of 1kg of steam inlet of the condensing cycle steam turbine;  \( \eta j \) Is the mechanical efficiency of the steam turbine unit, taking 0.98;  \( \eta d \) Is the generator efficiency, take 0.99.

The water output when the water intake of the regenerative system is 1kg, that is, the boiler water intake coefficient. Expressed by formula (2):

\[ a_K = \frac{1}{a_K} = \frac{1}{a_{G1}d_{G2}} \]  

(2)

In the formula: \( a_K \) It is the water intake when the regenerative system is 1kg, that is, the exhaust steam coefficient; \( d_{G1} \)  \( d_{G2} \) They are the feed water inlet coefficient of the unit I boiler and the condensate inlet coefficient of the unit II.

Assuming that the boiler water inlet coefficient and the total condensate flow coefficient are 1, and the shaft seal leakage is ignored, the water intake coefficient of each unit is obtained. Expressed by formula (3-4):

\[ dG1 = 1 - d1 - d2 - d3 - d4 \] \n
(3)

\[ dG2 = 1 - d5 - d6 - d7 - d8 \] \n
(4)

In the formula: \( d1 \)  \( d2 \)  \( d3 \)  \( d4 \) Respectively, the ratios of #1, #2, #3 high-pressure heaters, deaerator steam intake and boiler water intake; \( d5 \)  \( d6 \)  \( d7 \)  \( d8 \) Respectively are the ratios of #5, #6, #7, #8 low-pressure heater inlet steam to total condensed water in the condensing cycle.

The internal power of the steam turbine is kJ/kg for 1kg of steam. Expressed by formula (5):

\[ L0K = i0 - t1 + \Delta t p + \alpha zr \Delta i zr - aK iK - tK - aFK \gamma FK \]  

(5)

In the formula: \( i0 \) Is the inlet steam enthalpy of the steam turbine; \( i_1 \) Is the feed water enthalpy of the steam turbine boiler; \( \Delta i p \) Is the enthalpy rise of the feed water pump; \( \alpha zr \) Is the reheat coefficient; \( \Delta i zr \) It is the heat absorption of 1kg steam in the reheater; \( i_K \) Is the exhaust enthalpy of the steam turbine; \( i_K \) Is the condensate enthalpy at the outlet of the condenser; \( aFK \) It is the amount of draining to the condenser when 1kg steam inlet steam; \( \gamma FK \) It is the heat release of 1kg drain in the condenser.
3.1.2. Calculation of heating cycle. The heating cycle refers to that the new steam expands in the cylinder to perform work to be extracted at the location of the steam extraction port. The extraction steam releases heat and condenses at the first station of the heating network to return to the thermal system and return to the boiler through part of the regenerative heater. This part of the steam also completes a closed cycle, called the heating cycle. The schematic diagram of the heating cycle is shown in Figure 3.

![Schematic diagram of heating cycle](image)

Fig. 3 Schematic diagram of heating cycle

The amount of electricity generated when the amount of steam supplied by the steam turbine is 1kg. Expressed by formula (6):

\[ nT = aT L \frac{\eta_j}{\eta_d} \]  \( (6) \)

In the formula: \( aT \) is the water output when the water intake of the regenerative system is 1kg, that is, the boiler water intake coefficient; \( L \) is the internal power of 1kg of steam intake for the heating cycle steam turbine; \( \eta_j \) is the mechanical efficiency of the steam turbine unit; \( \eta_d \) is the generator efficiency.

The water output when the water intake of the regenerative system is 1kg, that is, the boiler water intake coefficient. Expressed by formula (7):

\[ aT = 1 + \frac{\alpha_T}{\delta_T} \]  \( (7) \)

In the formula: \( \alpha_T \) is the amount of water inflow when the output water of the regenerative system is 1kg, that is, the extraction coefficient; \( \delta_T \) is the boiler feed water inlet coefficient of unit I, which is obtained by formula (3), and the parameters remain unchanged; \( \delta_T \) is the return water coefficient of the heating heater.

Assuming that the boiler water intake coefficient and the total flow coefficient of condensate are 1, and the leakage steam of the shaft seal is ignored, the water intake coefficient of each unit is obtained. The exhaust steam of the steam turbine condenser of the heating cycle is zero. Return water coefficient of heating heater. Expressed by formula (8):

\[ dGT = 1 - \frac{\delta_5 \delta_6 \delta_7 \delta_8}{\delta_T} \]  \( (8) \)

In the formula: \( \delta_5 \), \( \delta_6 \), \( \delta_7 \), \( \delta_8 \) are the ratios of #5, #6, #7, #8 low-pressure heater inlet steam to total condensate in the heating cycle.

The internal power of the steam turbine is 1kg. Expressed by formula (9):

\[ L_{OT} = (i_0 - i_T) - \alpha_T (i_T - i_T) \]  \( (9) \)

In the formula: \( i_0 \) is the steam inlet enthalpy of the steam turbine; \( i_T \) is the feed water enthalpy of the steam turbine boiler; \( i_T \) is the steam enthalpy for the heating of the steam turbine; \( i_T \) is the outlet enthalpy of the heating heater.

According to the formula, the power of the condensing cycle and heating cycle of the extraction condensing unit can be calculated separately. The back pressure only corrects the power of the condensing cycle, and the result is that the back pressure corrects the power of the extraction condensing unit.
3.2. Calculation results
According to the test data of the thermal performance test and the above formula, there are two methods to calculate the power of the condensing unit in the condensing cycle and heating cycle. Method 1: Calculate the power of the condensing cycle and heating cycle respectively according to the above formula; Method 2: Calculate the power of one of the cycles according to the formula, and the total power can be known to find the other power. The prerequisite of the first method is that the shaft seal leakage is zero, so the calculation error is relatively large, and the calculation amount is relatively large; the second method is simple and fast, and the calculation error is small, so the second method is preferred.

Since the heat extraction volume of the condensing unit is known, and compared to the condensing cycle, the calculation of the heating cycle is relatively simple and the system is not complicated. Take a 300MW condensing unit in a factory as an example to calculate the heating cycle power of the unit.

According to the law of conservation of energy and matter, the inlet steam flow of No. #6, #7, #8 ow pressure heater is calculated to be a negative number close to 0, so 0 is taken.

See Table 3 for the work results of the heating cycle of the unit. It can be seen from Table 1: The heating cycle power of this unit is 81.653MW when the extraction steam flow is 450t/h. It is known that the active power of the generator is 248.184MW, and the condensing cycle power can be calculated to be 166.531MW. Therefore, the back-pressure correction can be performed on the condensing cycle work in the pumping condensing unit according to the back pressure correction curve, and the result obtained is the corrected calculation result of the influence of the back pressure on the power of the pumping condensing unit.

| Parameter name | Unit | Value |
|----------------|------|-------|
| Power generation when steam turbine heat supply and extraction steam is 450t | MW | 81.653 |
| Power generation when steam turbine heating and extraction steam is 1kg | kW | 0.3576 |
| $L_{ot}$ The internal power of 1kg steam inlet for the heating cycle steam turbine | kJ/kg | 455.99 |
| $d_{g1}$ Is the condensation water inflow coefficient of unit I | / | 0.77367 |
| $d_{gt}$ Is the return water coefficient of the heating heater | / | 0.875418 |
| $a_{ft}$ Is the water output when the water inlet of the regenerative system is 1kg | kg | 1.476546 |
| $a_{fr}$ It is the water intake when the regenerative system output is 1kg | kg | 0.677256 |

4. Conclusion
This paper proposes a correction calculation method for the influence of back pressure on the power of the pumping condensing unit. This method divides the extraction condensing unit into a heating cycle and a condensing cycle to study separately. Through analysis and calculation, the amount of work done by the heating cycle and the condensing cycle is determined, and then the back pressure correction curve is used to correct the power of the condensing cycle. The correction result is the correction result of the influence of back pressure change on the power of the pumping condensing unit.

Using this calculation method, the influence of back pressure changes on the power of the pumping condensing unit can be accurately and simply calculated under any working conditions of the pumping condensing unit.

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