Effect of Absorption Heat Pump System on Peak Load Regulation of Cogeneration Unit during Thermoelectric Decoupling Transformation

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Abstract. The integrated absorption heat pump in the cogeneration unit can realize thermoelectric decoupling, create the conditions for the absorption of electric energy for the new energy unit, and solve the problem of wind and light abandoning in the region. This paper presents a calculation model for cogeneration heating depth peak load test data, complete the heat pump unit load range and heating can contrast before and after the transformation, to verify the cogeneration unit based on the heat pump running can effectively realize the thermoelectric decoupling, run the heat pump capacity is higher, the greater the load range and heating capacity to ascend.

1. Introduction
The cogeneration unit has a high energy utilization efficiency, but the electric load and the heat load have a certain coupling effect, and the electric load needs to reach a certain degree to meet the requirement of the heat load. In recent years, the excessive proportion of cogeneration units leads to the insufficient peak regulation capacity of the power grid. In addition, the large-scale grid connection of wind energy, solar energy and other intermittent new energy sources further increases the peak-valley difference and peak regulation pressure of the power grid system load, leading to the more prominent heat-electricity contradiction in winter heating period [1]. Thermoelectric decoupling can effectively improve the flexible operation level of cogeneration units, so as to improve the peak shaving performance of power grid system and improve the absorption capacity of new energy [2]. Thermoelectric decoupling of cogeneration units is an inevitable choice of energy under the new situation. Through thermoelectric decoupling, the cogeneration unit can adjust the peak depth of adaptability and operate under the electric load. In the heating season, the space for generating electricity will be moved out to create the conditions for the absorption of electric energy for the new energy units, which can solve the problems of wind abandoning and light abandoning in the region.

Heat pump takes heat extraction as driving heat source, and uses waste heat from circulating water of condenser to increase heat supply, so as to reduce steam extraction of steam turbine, increase power generation capacity of steam turbine and improve overall energy efficiency of the system.

2. The engineering application
The 2×350MW unit of Power Plant A in Tianjin area is the heat-supply unit. In 2016, the condenser and related circulating cooling water system of No.2 unit of Power Plant A were reformed, and the heating
and steam extraction of No.2 unit was taken as the driving heat source, and four absorption heat pump (4× 27.29 MW) units were taken as the main body to recycle the waste heat of circulating water from the high-temperature side of the condenser and heat the return water of the urban heat network. Before the unit transformation, the heating system only has the heating heater to heat the heat-supply backwater; After the transformation of the heat pump, the heat-supply backwater enters the heat pump and the heating heater for series heating. The heat pump was put into operation in November 2017. The system diagram of heat pump application in cogeneration unit is shown in figure 1.

![Heat pump recycling waste heat recovery system diagram of heat and power plant.](image)

**Figure 1.** Heat pump recycling waste heat recovery system diagram of heat and power plant.

### 3. Experimental analysis

In order to quantitatively compare the influence of two heating modes on power generation load before and after the transformation of absorption heat pump in Power Plant A, In this paper, the No.1 and No.2 unit of Power Plant A are tested for deep peaking capacity during the heating period (No.2 unit is based on heat pump operation). Test the maximum and minimum electrical load that the unit can achieve under a certain heating load. The curves of the maximum and minimum electrical loads of the two units varying with the heating load are drawn respectively. According to the curve graph, compare the range of peak load capacity of electrical load before and after unit transformation. Table 1 shows the experimental conditions.

| No.1 unit | Operation without heat pump | Upper limit test condition of electrical load |
|-----------|-----------------------------|-----------------------------------------------|
|           |                             | Lower limit test condition of electrical load |
| No.2 unit | Operation based on heat pump| Upper limit test condition of electrical load |
|           |                             | Lower limit test condition of electrical load |
3.1. Calculation model

Based on the original experimental data, using the equivalent heat drop theory, correcting the actual work capacity of the main steam and heating extraction of the steam turbine, the relationship between the electrical load of the unit and the main steam flow and the heating and steam extraction flow is obtained as follows:

\[ N = \frac{(A \times G_0 - B \times G_{CN})}{3600} \]  

(1)

Where, \( N \) represents the electrical load of the unit, kW. \( A \) represents the actual work capacity of the main steam after modification, kJ/kg. \( G_0 \) represents the main steam flow of the unit, kg/h. \( B \) represents the actual work capacity of heating extraction after modification, kJ/kg. \( G_{CN} \) represents the heating and steam extraction flow of the unit, kg/h.

3.2. Test results and analysis

The test data is substituted into the calculation equation (3.1) for calculation and correction, and the upper and lower limit electrical loads of the unit under different heat supply are obtained. According to the test results, the curve of the adjustable peak range of the unit's power generation load is plotted (Figure 2). It can be seen that since the No.2 unit has been added to the heat pump operation, the peak-shaving range of the unit is significantly higher than that of the No.1 unit, especially the lower limit of the power generation load is significantly reduced. The specific analysis is as follows:

![Figure 2. Curve of adjustable peak range of electric load before and after heat pump reform](image)

After the operation of the heat pump, the upper limit of the heating load of the unit is obviously improved. The maximum heat supply of the No.2 unit based on the heat pump operation is 1435GJ/h, and the maximum heat supply of the No.1 unit without the heat pump operation is about 1150GJ/h, and the No.1 machine phase Compared with the No.2 unit, the heating load ceiling has been increased by 24.78%, and the heat supply has increased by 285 GJ/h. According to the heating index of buildings with a heating capacity of 60W per square meter, the heat supply area increased by about 1.319 million square meters after operation.

After the operation of the heat pump, the lower limit of electrical load of the unit corresponding to the same heat supply is significantly reduced. In the heating region of 750GJ/h-1150GJ/h, the lower limit of electrical load of the unit is reduced between 42MW -68MW. The minimum load of unit No.1
is 212MW (60% of the rated load), unit No.2 is 147MW (42% of the rated load), and unit No.2 can provide deep peak shaving service for the power grid.

4. Comparison of engineering application effect

In 2014, Power Plant B in Tianjin tried to realize thermoelectric decoupling through heat pump transformation technology. In order to maximize the recovery and utilization of waste heat from circulating water, Power Plant B choose eight absorption heat pumps (8×38.96 MW) to heat water return in urban heat network.

Kun Wang et al. [3] studied the thermoelectric decoupling of cogeneration unit based on the transformation of absorption heat pump, and analyzed the thermoelectric decoupling capability of the unit after the transformation of heat pump in Power Plant B. The comparison of peak load regulation capability of the unit before and after the transformation of heat pump in Power Plant B is shown in figure 3.

![Figure 3. Peak adjustable range of electrical load before and after the transformation of plant B](image)

As can be seen from figure 3, under the condition that the heating capacity is 830GJ/h, the lower limit of peak load regulation of the unit is reduced from 194MW to 132MW, and the load rate is reduced from 58% to 40%. Under this heating capacity, the B power plant can achieve deep peak regulation and provide energy consumption "space" of up to 62MW. Under this heating capacity, the upper limit of generating load of the unit was increased from 275 MW to 291MW. The transformation of heat pump improved the generating capacity of the unit, and the peak shaving range of the unit increased significantly after the transformation.

The installed capacity of heat pump of Power Plant B (8× 38.96 MW) is larger than that of Power Plant A (4× 27.29 MW). By comparing figure 2 and figure 3, it can be seen that after the transformation of heat pump, when the electrical load of the unit is all 160MW, the heating capacity of plant A is 729GJ/h, while that of plant B is 1122GJ/h. When the heating capacity of both units is 1000 GJ/h, the minimum electrical load of plant A is 199MW, the minimum electrical load of plant B is 144MW, and the lower limit of generation load of plant B is reduced by 55MW. It can be seen that when the power plant increases the number of heat pumps and the installed capacity of heat pumps, the unit will recover more waste heat of circulating water, further reduce the loss of cold source, increase the heat supply of the unit under the same electrical load, and improve the peak load regulation range of the electric load.
under the same heat supply load. The minimum load rate of units in Power Plant A and Power Plant B at the same heating load is shown in figure 4.

![Bar Chart](image)

**Figure 4.** The lowest load rate of the unit at the same heat supply

5. Conclusion

   (1) This paper proposes a calculation model for correcting the actual functional force of steam turbine main steam and heating extraction steam based on the data of heat peaking test. According to this formula, the power generation load of the unit under different heat supply can be calculated. Evaluate the retrofit effect of the unit's thermal electrolysis and provide support for the balanced thermal-electric load during the heating period.

   (2) After the system modification based on the absorption heat pump, the heating capacity and peak load range of the unit during the heating period increased significantly, and the lower limit of the peak load of the unit under the same heat supply was significantly reduced.

   (3) The transformation of absorption heat pump can effectively realize thermoelectric decoupling of the unit. The larger the installed capacity of heat pump, the better the effect. It is suggested that during the transformation of thermoelectric decoupling, the number of heat pumps should be increased, the installed capacity of heat pumps should be increased, the waste heat of circulating water should be recycled to the maximum extent, and the loss of cold source should be further reduced.

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