Research of Thermoelectric Decoupling of Cogeneration Unit Based on Absorption Heat Pump

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Abstract. Due to a large number of new energy power generation, the contradiction of heat-electricity is prominent in the period of winter in north China. In order to effectively eliminate the renewable energy power generation and promote the healthy development of the electric power industry in China, it is urgent to improve the peak load capacity of cogeneration unit. In this paper, a new method of thermoelectric decoupling was proposed for traditional coal-fired power generation unit, which was the transformation of thermoelectric decoupling system of integrated absorption heat pump. The comparison tests before and after the transformation of the absorption heat pump was carried out for a pilot unit. Then, the thermal power decoupling capability, energy saving benefit and special advantages of this method were analysed. The result showed that this method can both improve the energy-saving and thermoelectric decoupling. Furthermore, it also can improve the thermal efficiency of the unit and maintain the characteristics of safe and stable operation and responsive of the power load.

1. Introduction
In recent years, with the strong support of a series of policies, China's new energy power generation has developed rapidly. By the end of 2017, the wind power installed capacity is about 164 million KW, accounting for 9.2% of the total power capacity, and solar power installed capacity is about 130 million KW, accounting for 7.3% of the total power capacity, both the first in the world [1]. However, because of the geographic restriction of new energy, wind and solar energy abandoning is more and more general, which causes a lot of energy waste. Especially during the heating period, the contradiction of heat-electricity is prominent in north China. In order to effectively eliminate the renewable energy power generation and promote the healthy development of the electric power industry in China, It is urgent to improve the peak load capacity of cogeneration unit.

In November 2016, the national development and reform commission and the national energy administration issued the 13th five-year plan for electric power development, which indicated that it would comprehensively promote the transformation of thermoelectric decoupling of coal-fired power units. Refer to the international related experience of thermoelectric decoupling, the capacity improvement project of coal power unit will be carried out. Several thermoelectric decoupling measures were put forward for improving operational. A series of studies about thermoelectric
decoupling were conducted by domestic and foreign scholars. Zheyi Pei et al. [2] put forward four thermoelectric decoupling measures for improving operational flexibility of cogeneration units, and wind power accommodation and coal consumption for different measures were calculated. Fei Xu et al. [3] analysed the match of energy production and consumption in the combined electricity and heat system containing large capacity thermal energy storage. Quan Lv et al. [4] proposed that cogeneration plants can participate in regulation of curtailed wind power through decoupling the constraint of “power determined by heat”. The operation mechanism, technical characteristics and available scopes of peak regulation by cogeneration units are introduced. Guangcai Zhang et al. [5] discussed the main operation and transformation technologies of deep peaking for coal-fired power plants from three aspects: improving the combustion stability at low loads, conducting thermoelectric decoupling under heating conditions, and improving the adaptability of main auxiliary equipment and its environmental protection devices at low loads.

2. Heat pump system
As an example of a 330MW heat-supply unit, in order to further improve the heating efficiency, the power plant Choose 8 absorption heat pump to recycle waste heat from circulation water with extraction steam as drive steam. It can reduce the flow of the extraction steam from the heat-supply unit with enough heating load. In other words, the heat-supply unit can supply more heat with same extraction steam. Thus, the purpose of energy-saving emission reduction is achieved. Figure 1 shows the system of absorption heat pump recycling thermal power plant circulating water.

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

3. Experimental Section
Two series of experiments were carried out before and after transformation of heat pump system. Each experiment had two kinds of test conditions, as shown in Table 1. The Upper limit test condition of electrical load means that the cogeneration unit can achieve the maximum generation load at a given heating load. On the contrary, the lower limit test condition of electrical load means that the cogeneration unit can achieve the minimum generation load at a given heating load. Thus, the peak load regulation capacity of the cogeneration unit was achieved. The relevant parameters of steam turbine system and heat pump system are recorded in all the tests.
Table 1. Experimental conditions.

| Before transformation of heat pump system | Upper limit test condition of electrical load |
|------------------------------------------|-----------------------------------------------|
|                                          | lower limit test condition of electrical load |
| After transformation of heat pump system | Upper limit test condition of electrical load |
|                                          | lower limit test condition of electrical load |

4. Result and discussion

4.1. Analysis of thermoelectric decoupling capability

For the experimental unit, the unit was tested for two heating periods of heating period before and after the transformation of the absorption heat pump. Figure 2 shows the comparison diagram of heating capacity before and after the transformation of the unit, be able to see, the heat supply increased obviously, the maximum heating capacity of the unit reached 1700GJ/h, the maximum heating capacity of the unit increases by 400GJ/h, the total heating period is expected to increase by 1.2 million GJ, the increase in heating capacity can be up to 30% compared with that before the transformation of the unit.

Figure 3 shows the comparison diagram of the maximum thermoelectric ratio of the unit under the same load. The thermoelectric ratio can be maintained at 190-200% after the operation of the heat pump, the average thermoelectric ratio is about 195%, when the heat pump is not put into operation, the thermoelectric ratio can only reach 64-137%, the average thermoelectric ratio is about 105%, and it is increased by about 90%.

Through the above analysis, it is indicated that the pilot unit is reformed after the heat pump, due to recover the residual heat of large amount of circulating cooling water, the heating capacity increased significantly, in particular, under the low power load rate, the increase of heat is more prominent, for example, when the power load rate is 40%, the maximum heat supply capacity of the unit is three times that of the former. It provides the heating basis for the thermoelectric decoupling of the unit.

Figure 2. Comparison of heating capacity.
Figure 3. Comparison of ratio of heat to electricity.

Figure 4 shows the comparison of peak load regulation capacity before and after the transformation of heat pump system, it can be seen that after the transformation, the range of peak adjustment is significantly enlarged. The maximum peak range is expanded from 180MW-280MW to 132MW-300MW, the lower limit load rate was reduced from 55% to 40%, the capability of depth peak adjustment of unit heating period is realized, and in addition, the maximum heating capacity of the unit can reach up to 900GJ/h under 40% of the power load rate. It can realize high heating capacity under low load, and can meet the basic heating demand of heating period.

The above analysis shows that, after the transformation of the absorbing type heat pump, the experimental unit's capacity of heat supply and peak load regulation capacity increased greatly, the purpose of thermoelectric decoupling is achieved, it is therefore possible to keep a large amount of new energy consumption in that heat supply period, it's consistent with national energy development, a new method of thermoelectric decoupling is provided for traditional coal-fired cogeneration units.

Figure 4. Comparison of peak load regulation capacity.
4.2. Analysis of energy-saving benefit
After the transformation of absorption heat pump, we know that it can achieve the thermoelectric
decoupling. Furthermore, because of recycling large amount of waste heat from circulating water, it
also can obtain considerable economic benefit, which mainly includes three aspects:

1. Recycling waste heat from circulating water, improve heating benefit;
2. During the heating period, the unit can operate with depth peak load regulation, which can
achieve the peak load regulation compensation benefit;
3. Because of a large amount of circulating cooling water do not need to cool for passing cooling
tower, it can save water consumption and obtain corresponding benefit.

Table 2 shows the details of the benefit for the three aspects. It shows that the heating benefit is
33,600,000 RMB/year, the compensation benefit is 1,240,000 RMB/year and the saving water benefit
is 1,600,000 RMB/year. A total of 36,440,000 RMB/year can be obtained, with remarkable economic
benefits.

| Heating benefit | Heating capacity increase | Heating supply increase | Heating unit price | Heating benefit |
|----------------|--------------------------|------------------------|-------------------|----------------|
|                | GJ/h                     | GJ/year                | RMB/GJ            | RMB /year      |
|                | 416                      | 1200,000               | 28                | 33,600,000     |

| Peak load regulation compensation benefit | Compensation standard | Compensation power | Compensation benefit |
|-------------------------------------------|-----------------------|--------------------|----------------------|
|                                           | RMB /MW.h             | MW/year            | RMB /year            |
|                                           | 50                    | 24,800             | 1,240,000            |

| Saving water benefit | Saving water capacity | Saving water amount | Water unit price | Saving water benefit |
|----------------------|-----------------------|---------------------|-----------------|---------------------|
|                      | t/h                   | t/h                 | RMB /t          | RMB /year          |
|                      | 140                   | 400,000             | 4               | 1,600,000          |

4.3. Analysis of advantage
From some research in references [2-4], it can be concluded that four thermoelectric decoupling
measures for improving operational flexibility of cogeneration units were proposed. Table 3 shows the
advantages and disadvantages of these four methods. It can be seen that the first three methods all
have the disadvantages of lower thermal efficiency and the fourth method has the disadvantage of
worse responsive capacity. For transformation of absorption heat pump method, it can not only both
significantly improve the energy-saving and thermoelectric decoupling, but also can maintain the
characteristics of safe and stable operation and responsive of the generation load. Therefore, this
method is a worth promoted measure.
Table 3. Advantages and disadvantages of thermoelectric decoupling measures.

| Method                        | Advantages                                      | Disadvantages                              |
|-------------------------------|------------------------------------------------|--------------------------------------------|
| Thermal storage heating       | Fewer transformation of unit                    | Larger investment, heat loss               |
| Electric regenerative heating | Fewer transformation of unit, larger degree of thermoelectric decoupling | Larger investment, worse thermal economic |
| Steam turbine bypass heating  | Fewer investment                                | Worse thermal economic                     |
| Remove low-pressure cylinder heating | Fewer investment, better economy                | Worse responsive capacity of generation load |

5. Conclusion

In this paper, a new method of thermoelectric decoupling was proposed for traditional coal-fired power generation unit, which was the transformation of thermoelectric decoupling system of integrated absorption heat pump. According to the contrast tests before and after transformation of heat pump system of cogeneration unit, the main conclusions are as follows:

(1) The transformation of thermoelectric decoupling system of integrated absorption heat pump can significantly improve the peak load regulation capacity and the heating capacity, which leads the cogeneration unit achieve the purpose of thermoelectric decoupling.

(2) The transformation also can recycle waste heat from circulating water, save water consumption and increase large amount of power generation absorption of new energy. Thus, it has considerable economic and social benefits, which both improve the energy-saving and thermoelectric decoupling.

(3) Compared with other methods of thermoelectric decoupling, the transformation of thermoelectric decoupling system with integrated absorption heat pump has its unique advantages. It can not only both significantly improve the energy-saving and thermoelectric decoupling, but also can maintain the characteristics of safe and stable operation and responsive of the generation load.

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