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Study on Flexible Transformation Mode of Cogeneration Unit

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Abstract

Most of the units installed in the "three north" areas of China are cogeneration units. When there is a large demand for heating in the heating season, the cogeneration units in the power plant adopt the operation mode of "setting power by heat" to meet the heating load. Under this operation mode, not only the unit's regulation ability is poor, but also the power plant unit is difficult to obtain profits from it. At the same time, a large amount of "abandoned wind" will be generated and the environment will be polluted. Based on this, it is particularly important to extend and renovate the adjustable range of the existing units in the cogeneration power plant, and the economic analysis before and after the renovation is an important choice factor for the power plant to choose the renovation method. This article enumerated nowadays common cogeneration unit transformation technology, analyzes its modified equivalent figure of power generation, heating unit, thermoelectric power adjustable range of the unit before and after transformation is given, to analyze its thermoelectric decoupling ability, at the same time for different transformation way of economic analysis are summarized, the hope for cogeneration unit enterprise flexibility provide certain help.

Keywords

Cogeneration of Heat and Power; Flexible Transformation; Economy; Wind Abandonment; Thermoelectric Decoupling.

1. Introduction

With the continuous progress of a series of renewable energy generation technologies such as solar energy and wind energy, the use of such energy to replace coal-fired power generation has been developed and applied to a certain extent in China, which leads to some changes in the structure of China's power system. Based on this, the National Energy Administration issued and implemented a series of relevant documents, which not only guaranteed the safety, stability and economic operation of the power system in Northeast China, but also promoted the consumption of renewable and new energy such as wind power. On September 28, 2014, Northeast Regulatory Bureau of National Energy Administration issued for the first time the Supervision Measures for Northeast Power Peak Shaking Auxiliary Service Market to encourage the renovation of thermal power plants. It was changed on November 18, 2016, August 18, 2017, December 29, 2018, and September 22, 2020.

In the latest change, power generation enterprises and electricity sales enterprises are encouraged to actively participate in the flexible transformation of units and invest in the construction of electric energy storage and other facilities. It is clear in the rules that electric energy storage facilities can participate in the auxiliary service market of peak regulation. If relevant electric energy storage facilities are built at the side of thermal power plants and the units participate in peak regulation, the compensation benefits can be calculated according to the depth peak regulation compensation mode of thermal power plants. Relevant electric energy storage facilities shall be built at the side of wind power plants and photovoltaic power plants, and the specific benefits shall be compensated by the relevant new energy power plants and the investors of the electric energy storage facilities through

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negotiation. At present, the expansion trend of depth peak regulation capacity for cogeneration units has been formed, and the main expansion forms are as follows: electric boiler expansion, heat storage tank expansion, and electric heat pump expansion.

2. Expansion method

2.1 Electric boiler expansion method

For a cogeneration power plant, the actual generating load of the unit is the sum of the generating power of the original thermoelectric unit and the electricity consumed by the operation of the newly added electric boiler after the addition of a certain scale electric boiler. For heating load, the actual heating load is the sum of the heating power of the original hot spot unit and the heating power of the electric boiler. The schematic diagram of power generation and heating load after adding electric boiler is shown in the figure:

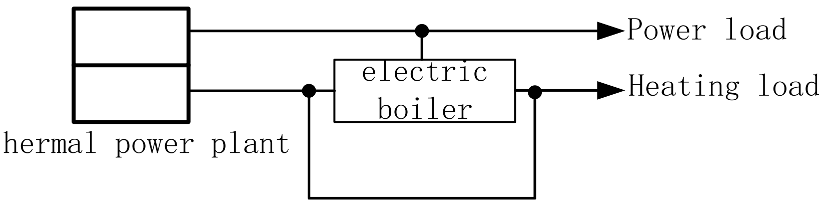

Figure 1. Electric boiler expansion equivalent unit

If the pumping and condensing CHP unit expands the regulation range by installing an electric boiler, the schematic diagram of the power generated after installation varies with the heating and steam extraction rate is shown as follows. The change of its adjustment range is the part of the shadow area, that is $BB'C'D'DC$ the interval. According to the analysis of the points C in the figure below, when the heating extraction rate, namely the heating load, remains constant, the minimum power generation load that the unit can bear will be reduced. This is because when the electric boiler is put into operation, part of the electric energy will be consumed, which makes the unit unable to provide the original power generation load. By comparison B with the point B', it can be seen that after the unit is operated with the electric boiler, the maximum heating power of the system has been improved, and it can bear more heat demand from the outside world. Therefore, the thermoelectric output regulation range of cogeneration units can be extended by installing electric boilers in the units.

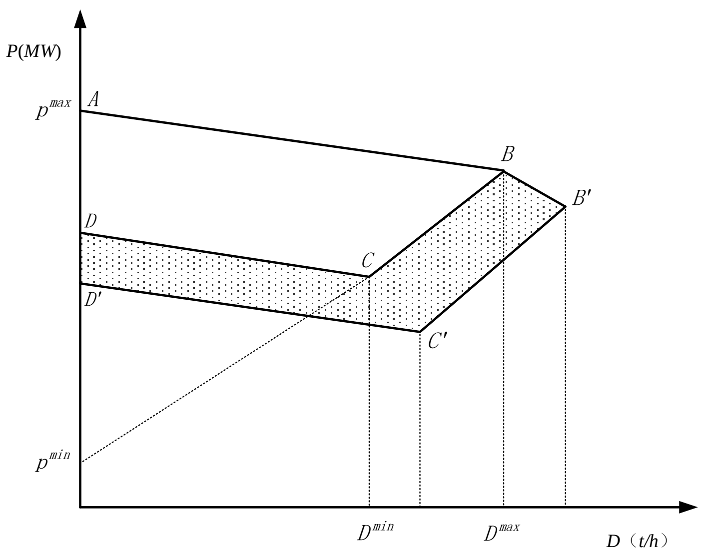

Figure 2. Electric boilers extend the equivalent range

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As shown in the figure above, after the expansion of the cogeneration unit through an electric boiler, the operating area of the unit is shown as follows:

$$AB{:}P = P^{max} - b_H D \tag{1}$$

$$BB'{:}P = P^{min} + b_L D^{max} + \frac{P^{max} D^{max} \triangle H}{1000 Q^{max}} - \frac{P^{max} \triangle H}{1000 Q^{max}} D \tag{2}$$

$$B'C'{:}P = P^{min} - P^{max} - \frac{1000 b_L Q^{max}}{\triangle H} + b_L D \tag{3}$$

$$C'D'{:}P = P^{min} - P^{max} + (b_L + b_V) D^{min} - \frac{1000 b_L Q^{max}}{\triangle H} - b_V D \tag{4}$$

In on type: D^{max} is the upper limit of heating extraction rate of thermoelectric unit, the unit is t/h; P^{max} is the upper limit of electric power of electric boiler, unit is MW; Q^{max} is the upper limit of thermal power output of electric boiler, and the unit is MW.

Literature [1] analyzes the feasibility of using electric boiler heat storage technology in district heating from the aspects of wind power development and heating demand in areas with "electrothermal characteristics" in power generation and heating in China, and calculates and analyzes the economic and environmental benefits of this technology.

Literature [2] introduced solid regenerative electric boiler system with strong heat storage capacity, which not only improved the effective heat storage of the boiler to a certain extent. It is also proved that the multi-objective optimization scheme has the best economic feasibility in the same investment recovery period.

Literature [3] introduces the design scheme and characteristics of the heating system of the electric heating boiler through the analysis of an example of the transformation of an atmospheric pressure electric heating boiler system in a unit in Shanxi, compares the actual operating cost of the system with the central heating cost, and points out the technical advantages and economy of the electric heating boiler.

Literature [4] introduces the development status of electric boilers, the research results of relevant scholars at home and abroad, the classification and principle of electric boilers. By analyzing four typical application scenario electric boiler, confirmed the electric boiler cogeneration heating projects have fully the feasibility of peaking in the wind load of heating, commercial users or the preparation of life regenerative heating hot water projects have a certain feasibility, heat storage in heat supply network company projects there is a greater risk of loss.

Literature [5] through the electrode boiler heat storage device, solid heat storage type electric heating device, electrode boiler + low temperature phase change heat storage device, the high temperature phase change heat storage type electric heating device and so on four different electric heat storage device manufacturers as well as the actual case of research, analysis and comparison of different characteristics of electric heat storage technology, wear blah graph model is established, according to different requirements to recommend suitable electric heat storage technology.

2.2 Regenerative tank expansion method

If the existing cogeneration power plant is added with a certain capacity of heat storage tank, the actual power generation power of the unit in the power plant is the same as the power generation power before adding heat storage tank. But for the heating power, the actual heat supply of the unit after the transformation is the sum of the heat directly provided by the thermal power plant and the heat stored in the heat storage tank itself.

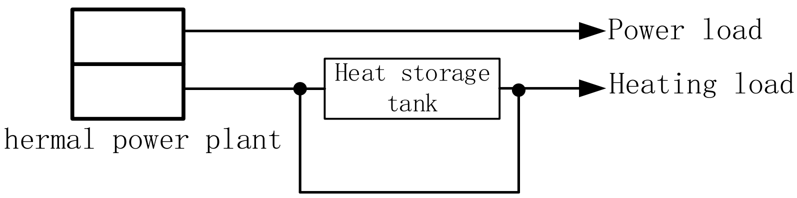

Figure 3. Heat storage tank expansion equivalent unit

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Similarly, when the heat storage tank is not added in the power plant, the operating area $ABCD$ of "electrothermal characteristics" is shown in the figure. There is a certain coupling relationship between the heating and power generation power of the unit, and there is a certain flexibility that can be adjusted within a small range. After adding the heat storage tank, the adjustable range of the unit becomes $AA'B'C'C''D'$.According to the analysis of the points C in the figure below, when the power output value of the unit is guaranteed, the operating state of the heat storage tank will have an impact on the heat output of the unit. Specifically, when the heat storage tank is in the heat storage period, the external heating power of the unit will be reduced, from the corresponding heating power at the point C'' to the corresponding heating power; When the heat storage tank is in the heat release period, the external heating power of the unit will increase, and the corresponding heating power at the point will be reduced to the corresponding heating power. Through the comparison of points B and points B', it can be seen that after the addition of heat storage tank, the maximum heating power of the system is improved, and it can bear more heat demand from the outside world. Therefore, adding a heat storage tank in the unit can also expand the thermoelectric output regulation range of the cogeneration unit.

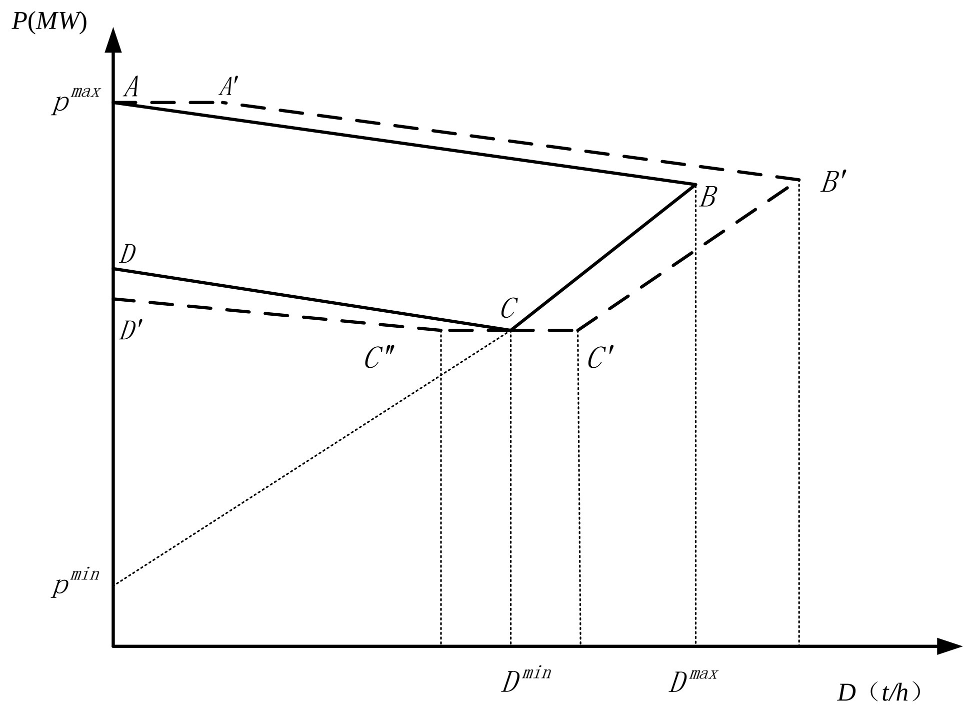

Figure 4. The regenerative tank extends the equivalent range

As shown in the figure above, after the expansion of the cogeneration unit through the heat storage tank, the operating area of the unit is shown as follows:

$$AA':P = P^{max} \tag{5}$$

$$A'B':P = P^{max} + \frac{3600 b_H h_{out}^{max}}{\triangle H} - b_H D \tag{6}$$

$$B'C':P = P^{min} - \frac{3600 b_L h_{out}^{max}}{\triangle H} + b_L D \tag{7}$$

$$C'C':P = P^{min} + b_L D^{min} \tag{8}$$

$$C''D':P = P^{min} + (b_L + b_V) D^{min} - \frac{3600 b_V h_{in}^{max}}{\triangle H} - b_V D \tag{9}$$

In on type: b_H is the maximum steam inlet working condition slope of the thermoelectric unit; b_L is the minimum condensing condition slope of thermoelectric unit; b_V is the minimum steam inlet

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working condition slope of thermoelectric unit; D is the heating extraction steam rate of thermoelectric unit, the unit is t/h; D^{min} is the lower limit of heating extraction rate of thermoelectric unit, the unit is t/h; h_{out}^{max} is the upper limit of heat release power of the regenerative tank, and the unit is MW; h_{in}^{max} is the upper limit of heat release power of the regenerative tank, and the unit is MW; $\triangle H$ is the enthalpy drop of steam, the unit is kJ/kg。

Literature [6] mainly uses numerical simulation and theoretical calculation methods to study the heat storage and release performance of the hot water heat storage tank, the influencing factors and the influence on the peak load capacity of the unit, which lays a foundation for the wide application of the hot water heat storage tank.

Literature [7] mainly studied the related problems of setting hot water storage tank in cogeneration heating system, and obtained the thermal characteristics of hot water storage tank and the operation strategy of its joint operation with cogeneration unit, providing corresponding theoretical guidance for engineering practice.

Literature [8], aiming at the optimal allocation of the capacity of the heat storage tank, added the investment and maintenance costs of the heat storage tank to the operation model of wind-wind - thermo-electric -heat storage tank -carbon capture comprehensive thermal power plant, and converted them into daily depreciation and maintenance costs, and established the objective function to achieve the lowest total investment operating costs of the comprehensive thermal power plant. The simulation results show that the optimized storage capacity is more economical and efficient than the traditional given storage capacity.

Literature [9] takes a district heating system as the research object, collects the operation data of its power co-generation unit, gas-fired boiler room and heating pipe network, and makes statistical analysis. According to the load fluctuation, the construction scale of the heat storage tank system is determined. Combined with the land use of this project, the type selection calculation of the heat storage tank system is carried out. According to the operation of the heat network, the operation control strategy of the heat storage tank system is formulated. Finally, the economic and social benefits of the construction of the heat storage tank are analyzed, and it is concluded that the project is feasible in terms of economic and social benefits, and conforms to the national resource planning layout and the policy of energy conservation and emission reduction.

Literature [10] studied the feasibility of adding heat storage devices to improve peak regulation capacity through the investigation of electric heating units. On the one hand, it can increase the peak regulation capacity of the power grid and the consumption of renewable energy. On the other hand, power generation enterprises obtain corresponding benefits by participating in renewable energy peak regulation through technical transformation, which improves the enthusiasm of peak regulation and removes the electrothermal coupling relationship.

Literature [11] introduces the type and working principle of heat storage tank. Combined with a central heating system of combined heat and power supply, the determination of storage tank volume, the connection mode with heat network and the economy are discussed. Conclusion It can be concluded that using the heat storage tank (atmospheric hot water storage tank) in the combined heat and power supply district heating system can prolong the full load operation time of the thermoelectric unit and improve the economy, and the heat storage tank can be used as an emergency water supply tank to improve the heating quality and the safety of the heat network.

2.3 Electric heat pump expansion method

Compared with the former two expansion methods, the way to expand the existing cogeneration units with electric heat pump is relatively complicated. The heating principle of the heat pump is to recycle the waste heat of the circulating water in the unit. The waste heat before recycling is difficult to be used directly. After it is converted into heat energy with higher value through the heat pump, it can be directly supplied to the heat demand users, so as to realize the heating function of the device.

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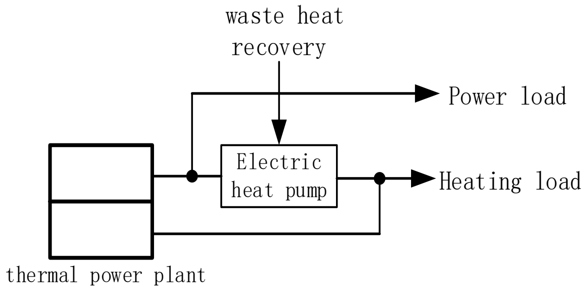

Figure 5. Electric heat pump expansion equivalent unit

For the use of electric heat pump to expand the thermoelectric output adjustment range of the cogeneration unit, the adjustable range is consistent with the use of electric boiler expansion method. After the addition of an electric heat pump device, the influence caused by the recovery of the waste heat of the circulating water in the unit on the cogeneration unit is ignored. The actual generating power of the reformed power plant unit is the sum of the generating power of the original thermoelectric unit and the electricity consumed by the newly added electric heat pump operation. Different from the expansion method of electric boiler, for heating load, the actual heating power of the reformed power plant unit is the sum of the heating power of the original thermoelectric unit and the heat power generated by the newly added electric heat pump.

When the unit expands the cogeneration unit through the electric heat pump, the operating area of the unit is the same as that obtained by the expansion of the unit through the electric boiler, but at this time, the maximum values of P and Q are the power consumption and output thermal power values of the electric heat pump, and the unit is MW.

Literature [12] heat pump heating system of the whole thermal power relations and the thermal efficiency, explore the heat pump in power plant flue gas waste heat recovery in the field of application, provide a reference for power plant operation and energy saving reconstruction and the suggestion.

Literature [13] takes a 300 MW thermoelectric unit as an example to analyze the feasibility of using the absorption heat pump to recover these low-temperature waste heat. It is believed that the absorption heat pump can recover the waste heat of the circulating water in the power plant and reduce the emission of pollutants at the same time, which has significant economic, social and environmental benefits.

Literature [14] is put forward based on the absorption heat pump circulating water waste heat utilization technology, extract the generating set of the waste heat of circulating water for urban heating, lithium bromide absorption heat pump stations are installed in thermal power plant, using circulating cooling water as heat source of heat pump water, water extraction of waste heat heating network, which significantly improve the heat capacity and thermal efficiency of thermal power plant, further reduce the integrated power supply coal consumption, to achieve the purpose of energy saving and emission reduction.

Literature [15] somewhere in 350 mw cogeneration unit as an example, the heating unit variable condition calculation model is established and mechanical calculation model of heat pump heating, compared the cogeneration unit using extraction steam heating and compression heat pump heating when the minimum electric load rate and the difference of coal consumption quantity, and studies the heat pump performance coefficient, electric load rate, heat load rate on the influence law of unit energy consumption characteristics.

3. Conclusion

This paper enumerated nowadays common cogeneration unit transformation technology, analyzes its modified equivalent figure of power generation, heating unit, thermoelectric power adjustable range

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of the unit before and after transformation is given, the analysis of the thermoelectric decoupling ability, at the same time for different transformation way of economic analysis are summarized, the unit for cogeneration enterprise flexibility provide certain help. However, there are still many deficiencies and improper considerations in this paper, which I hope can be improved and perfected in the future study and research.

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