Application Prospect of Coal-fired coupled Biomass in Technical Transformation of Thermal Power Unit

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Abstract: The development of thermal power units in China is restricted. In the process of transformation, coupled biomass power generation is the main direction of the transformation in the fuel sides. This paper introduces the constraints of thermal power units, the main ways of coal-fired coupled power generation, the technical route of coupling biomass in all of 84 pilot thermal power units and the problems faced by coupled biomass power generation. On this basis, some suggestions on the application of coal-fired coupling power generation in enterprises are put forward.

1. Preface
The development of thermal power units is currently restricted by three major constraints. They include the shackles of coal consumption, the restraint of water resources and the bondage of the ecological environment. The 13th five-year Plan for controlling greenhouse gases requires that carbon dioxide from thermal power units emissions at 500 grams. The pressure on carbon emission from thermal power units is very great. In order to improve the power generation efficiency of thermal power unit, reduce coal consumption and reduce CO₂ emission intensity, the fuel side of thermal power plant has been modified flexibly. In the aspect of fuel flexibility transformation, coal-fired coupled biomass is the main direction of power generation. Coal-fired coupled power generation can not only promote the substitution of coal energy, increase the supply of biomass energy, promote the development of low-carbon emission technology of thermal power units, but also solve the environmental protection problems such as direct incineration of agricultural, forestry waste, disorderly stacking of sludge and waste, and so on. Coal-fired coupled power generation has been listed as an important supporting development industry in our country. In order to realize the transformation, development of thermal power units and make full use of biomass, it is inevitable to develop coupling power generation on a large scale.

2. Present situation of application of coal-fired coupling power generation in domestic thermal power units
In order to alleviate the energy pressure caused by the oil crisis, Denmark has become the first country in the world to develop biomass power generation. Denmark promotes biomass power generation and has been developing the power generation technology coupled with coal in the traditional biomass-based power generation technology. Most projects are used in small-sized and medium-sized coal-fired units. The earliest coupled biomass power generation project in China is the gasification power generation of waste crops such as rice husk, straw and so on. Based on the current installed capacity of coal-fired units in China, most of the domestic biomass coupling power generation is used in 300 MW
and 600MW large units. According to the form of biomass combustion, coupling-biomass power generation technology is divided into 3: 1. Direct blending of biomass. 2. Indirect blending of biomass 3. Biomass boilers operating independently\textsuperscript{[1]}

2.1. Direct blending of biomass
Biomass fuel is pretreated and mixed with pulverized coal in the boiler. The high moisture and low calorific value of biomass reduce the combustion temperature and combustion efficiency of the boiler directly. At the same time, the increase of moisture in the flue gas will cause corrosion to the heating surface of the tail of the boiler. Chen\textsuperscript{[2]} calculated the boiler efficiency of mixed combustion of coal and three kinds of biomass (rice straw, sawdust, valley shell) in different proportions. The results showed that when the mixing ratio of grain shell and pulverized coal was 40%, the combustion efficiency of boiler decreased by about 0.25%, and the effect of mixing with sawdust was relatively small. The results of Ma\textsuperscript{[3]} showed that when the ratio of dry sludge with the moisture content of 30% to 35% to pulverized coal was 5%, it had little effect on the operation of boiler. The biomass directly mixing with pulverized coal was prone to increase of combustible fly ash and slagging in furnace because of its different properties and composition from pulverized coal. When the proportion of mixing was too high, the ash recycled after combustion could also be affected\textsuperscript{[4]}, Mao\textsuperscript{[5]} thought that the boiler suitable for direct mixing was circulating fluidized bed boiler, which could burn high moisture and low calorific value fuel efficiently, and could mix biomass in a large proportion, and the proportion of mixing could be changed and adjusted. The results of Xu\textsuperscript{[6]} and other studies showed that the mixed combustion of biomass and coal could effectively reduce the emission of SO\textsubscript{2} and reduce the emission of pollutants.

In the early stage of biomass coupling power generation in China, direct mixing was the main mode of power generation, and the investment cost was low. There was a number of biomass blending demonstration projects in China. Wheat straw mixed pulverized coal directly in Huadian International Shiliquan Power Plant. The mixing ratio of straw to pulverized coal was not more than 40%, which had little effect on the fly ash properties of boiler, and did not cause great corrosion, blockage and wear on the heating surface of boiler tail. At present, the mode was used in Guodian Baoji second Power Generation Co., Ltd., Baoying Xiexin Biomass Power Generation Co., Ltd., Fengxian Xinyuan Biomass Environmental Thermal Power Co., Ltd., Guangzhou Huarun Thermal Power Plant and Fuzhou Power Plant.

2.2. Indirect blending of biomass
Biomass is burned in circulating fluidized bed, and the gas is sent directly into the furnace of coal-fired boiler to generate electricity by mixed combustion\textsuperscript{[7]}. This method has little effect on the original combustion system, and the mixed gas has little effect on the operation of the boiler when the calorific value ratio is less than 10\%\textsuperscript{[8]}. The gas can also be used as the secondary fuel to reduce NO\textsubscript{X} emissions, which can be used as the secondary fuel for graded combustion, and the power generation efficiency is high. The coupled power generation with oxygen rich and pressurized gasification has high investment, large scale and flexible combustion of biomass, and the gasification efficiency. Gas quality has been greatly improved, which is more beneficial to the safety function of the boiler\textsuperscript{[9]}. Biomass gasification coupling power generation has significant advantages in technology maturity, treatment scale, operation and so on\textsuperscript{[10]}

In Changyuan Jingmen Power Plant, the earliest coal-fired coupling project in China, rice husk and straw were mixed with coal, with 640MW unit of coupled 10.8MW biomass to generate electricity. The other project was Datang Changshang 660MW Supercritical Coal-fired Generator unit coupled 20MW Biomass, which is the first national pilot demonstration project of coal-fired coupled biomass gasification power generation technology transformation\textsuperscript{[11]}, and biomass fuel was corn straw. At present, the mode was used in Huaneng Yingkou Thermal Power Co., Ltd. and Hubei Huadian Xiangyang Power Generation Co., Ltd.
2.3. Biomass boilers operating independently
Biomass combustion has a separate operation of the boiler. The steam generated by the boiler into the steam network of the thermal power unit, and the original thermal power unit share steam turbine power generation. The type of boiler is mainly water-cooled vibrating furnace and circulating vulcanized bed boiler. Water-cooled vibrating furnace can adapt to most agricultural and forestry waste and some straw containing high alkali metal and chlorine content. The furnace can not only burn some biomass, but also mix a variety of biomass. Boiler heating surface is vulnerable to high temperature corrosion. Circulating vulcanization bed has high particle requirements, so biomass needs to be pretreated. From the comprehensive consideration, water-cooled vibrating furnace is obviously better than that of circulating fluidized bed. The coal-fired coupled waste power generation technology developed by Harbin Power Group fully combines the technical characteristics of waste incinerator and coal-fired unit, and makes use of the advantages of high efficiency thermodynamic circulation system of coal-fired unit, which is not only limited to steam side coupling, but also coupling on the fuel side. The tail flue gas produced by waste incinerator is introduced into coal-fired boiler, which saves the investment of incinerator flue gas purification system and thus reduces the investment of adding biomass boiler.

3. The direction of coal-fired coupling power generation in the technical transformation of domestic thermal power units
On November 27, 2017, the State Energy Administration and the Ministry of Environmental Protection jointly issued the Circular on the Construction of Pilot Projects for Technical Reform of Coal-fired Coupled Biomass Power Generation. The Circular determined that the pilot projects covered a total of 84 units in 23 provinces and autonomous regions. There was 1 each in Tianjin, Shanxi, Chongqing, Sichuan, Guizhou and Ningxia, 2 each in Gansu, Guangxi, Fujian and Shanghai, 3 each in Zhejiang and Shaanxi, 4 each in Jilin, Anhui and Henan, 5 each in Shandong, Hubei, Hunan and Guangdong, 6 each in Hebei and Heilongjiang, 7 in Liaoning and 13 in Jiangsu. The Circular explicitly required that the main project of the pilot project should be completed on May 1, 2019. The routes of coupling biomass technology transformation of 84 thermal power units were divided into the following ways according to the different types of biomass.

3.1. Coupling waste residues from agriculture and forestry
Most of units in coupling agricultural and forestry waste residues use coupled gasification power generation, 2 units use direct power generation blending coal powder, and 1 unit uses additional biological furnace to generate electricity. Among them, Liaoning Tiaobingshan Coal Gangue Power Generation Co., Ltd. uses 2×300MW coal-fired unit coupling 2×30MW agricultural and forestry waste to generate electricity; Jiangsu Huamei Thermal Power Co., Ltd. with 2×350MW coal-fired unit coupled with 2×22MW agricultural and forestry waste, directly mixes with agricultural and forestry waste residues for combustion to generate electricity and Huarun Power (Heze) Co., Ltd. with 2×300MW coal-fired unit coupling 1×30MW agricultural and forestry waste residue, adds biomass boiler. The resulting steam is transported to the original steam system to generate electricity. Dust removal and desulphurization facilities are shared and denitrification facilities are added.

3.2. Coupled garbage power generation
There are only 2 coupling garbage power generation projects, and both of the technical routes adopt the addition of garbage incinerator to generate electricity. Shanghai Waigaoqiao Power Generation Co., Ltd. with 4×320MW coal-fired unit coupling 6×750t/d garbage and Guangzhou Huarun Thermal Power Co., Ltd. with 2×330MW coal-fired unit coupling 1000t/d waste, use additional waste incinerator. The resulting steam is transported to the original steam system for coupling power generation. Flue gas is transported to the original denitrification, dust removal, desulphurization facilities for pollutant removal.
3.3. Coupled sludge power generation
All coal-fired coupled sludge projects adopt drying of sludge first, and the sludge after drying is transported to the boiler of the original thermal power unit, mixing with pulverized coal for combustion and power generation.

In the Circular, it is put forward that "gasification coupling scheme is given priority which is convenient for electricity monitoring and metering" in the technical reform project of coal-fired coupling agricultural and forestry waste residue. From the pilot scheme of 84 units coupling biomass selection, gasification coupling is the main direction in the coupling scheme of coal combustion and agriculture and forestry waste, and the technical scheme of direct mixing burning is adopted for the coupling of coal combustion and sludge. The technical scheme of adding incinerator is adopted in the combination of coal combustion and garbage.

4. Problems in the application of coal-fired coupled power generation in the technical transformation of domestic thermal power units

In terms of technological transformation, thermal power enterprises should not only consider reducing coal consumption and low carbon emissions, but also consider the continuous and stable operation and profitability of enterprises. Biomass raw materials has increased on the fuel side, therefore enterprises need to face the instability of biomass raw materials supply, the rising cost of biomass raw materials, accounting electricity quantity scientifically and related compensation policies and so on.

4.1. Instability of biomass feedstock supply
Most of the biomass comes from rural areas. The domestic agricultural production is mainly "small farmers". Agricultural and forestry waste residues distribution is loose. It is difficult to adopt industrial collection, acquisition, transportation and storage, resulting in unstable supply of biomass resources. Biomass collection and raw material support restrict the large-scale development of coal-fired coupled biomass.

4.2. Cost of biomass feedstock
As the main body of the technical transformation, The enterprise considered the load of the unit, the cost of coal raw materials and the structure of the local power grid in the site selection, and did not consider a series of problems such as the acquisition, transportation, storage and pretreatment of biomass raw materials. If the raw materials of the enterprise change, they will face the problem of the change of the raw material cost. The cost of biomass raw materials varies according to the characteristics of raw materials and pretreatment methods, and the price fluctuates greatly. The high cost of biomass raw materials also limits the development of coal-fired coupled biomass to a certain extent.

4.3. Biomass power generation metering
The metering problem of biomass power generation is how to solve the scientific measurement of mixed biomass power generation\textsuperscript{[15]}. It is suggested that biomass resources should be set up and the utilization of biomass resources should be recorded in detail. The direct measurement of biomass blending is generally vulnerable to the interference of human factors, and scientific measurement is difficult for enterprises. There is still a lack of regulatory mechanisms. The indirect measurement of biomass blending, only through on-line monitoring of gas flow, calorific value, gas temperature and coal-fired boiler power generation efficiency, is to achieve separate accounting of biomass power generation. In the measurement and accounting of biomass fuel coupling power generation, there is still a lack of relatively perfect standards, norms, technologies, methods and so on.

4.4. The imperfections of the relevant supporting policies
The government has not yet been formulated the relevant policies for coupling biomass power generation. The electricity price policy of pure biomass power generation, which was issued earlier, is
referred. The electricity supply only has a certain degree of policy tilt. The relevant policies have not formulated for coupled biomass projects, such as the biomass mixed burning incentive policy, the penalty measures for failing to complete the "green" power generation index, the monitoring and verification system of biomass blending unaffected by man-made and the compensation mechanism of biomass resource absorption.

5. Conclusion
Government encouragement and policy support have promoted enterprises to carry out the transformation of coal-fired coupled biomass, but enterprises themselves should also comprehensively analyze the advantages and disadvantages of biomass resources, establish a management model suitable for their own biomass power generation according to local conditions, ensure the stable supply and price of biomass raw materials, ensure the stable operation and profitability of enterprises and strive to transform the enterprise into a green development of characteristic power generation enterprises. In addition to encouraging and policy support, the government should speed up the introduction of electricity prices, electricity subsidies and other supporting rules, promote the large-scale development of coal-fired coupled biomass, and achieve the goal of ultra-low CO$_2$ emissions from thermal power units.

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