Feasibility study of biomass energy application in a project

Minmin Zhao¹, Wenwen Zhang¹

¹Huadian Electric Power Research Institute, NO. 1 Xiyuan 10 Road, Xihu District, Hangzhou Zhejiang Province, 310030, China

Abstract. Combined with the characteristics of the project, this paper analyzes the application potential of biomass energy in the project area, introduces the technical route used in the project, studies the development and application of biomass gasification technology, and analyzes the economy of biomass energy application. This paper demonstrates the feasibility of biomass energy application in the project from the aspects of technology, social benefit, energy saving benefit and environmental protection benefit.

1. Introduction
The project is located in Xiangyang City, Hubei Province. The plant is located in the open space of Xiangyang power plant. In this project, biomass raw materials are crushed (briquetted) and gasified to produce high-temperature combustible gas, which will enter into large power plant boilers to replace part of raw coal. In addition to the heat brought by high temperature, the main components of gas produced by gasification are CO, H₂, CO₂, N₂ and CH₄. Compared with coal combustion, the products after combustion produce a large amount of dust, NOx and Sox, which are less harmful to the environment. After gasification of raw materials, there are 10% residues, commonly known as plant ash. It is a very good agricultural fertilizer and will form "biomass high temperature gas electricity return" The industrial chain of "farmland" circular economy. It belongs to the encouraged project in the national development and Reform Commission order "Guiding Catalogue of industrial structure adjustment (2011 Edition) (Amendment)". The planned processing capacity of the project is 205600 tons / year, with a total of four sets of gasification units with an annual processing capacity of 51400 tons. The raw material biomass resources of this project are straw, rice husk, wood waste, etc. the summary table is shown in Table 1.

| Raw material | Straw | Rice husk | Wood waste |
|--------------|-------|-----------|------------|
| Rice straw + Wheat straw | 25.7  | 19.2      | 1          |
| Corn straw + Other straw | 4.4   |           |            |
| Total (10000 tons) | 30.1  | 19.2      | 1          |

2. Project research background
Energy and environment problems are the global concerns and urgent problems to be solved. With the
exploitation of fossil energy such as conventional energy coal, oil and natural gas, these energy are consumed and gradually reduced, and at the same time, they also bring more and more serious environmental problems[1]. Especially in recent years, the global warming problem, which is widely concerned, is caused by the burning of fossil fuels and the emission of CO₂ and other greenhouse gases to a large extent. One way to change this situation is to develop and utilize new energy resources such as biomass, solar energy and wind energy reasonably[2]. In 2009, the national development and Reform Commission and the Ministry of Agriculture issued the notice on the preparation of guidance on the comprehensive utilization plan of straw. The report of the State Energy Administration on biomass direct combustion power generation also pointed out that several biomass mixed combustion power generation projects should be built in the country by selecting the appropriate regions and projects. In November 2015, Hubei Province took the lead in providing special support measures for the on-line price of straw, agriculture, forestry and biomass power generation project in China. Based on the original on-line price, the on-line electricity of enterprises increased by 0.081 yuan per kilowatt hour. The project uses biomass gasification technology to send the generated gas into large boilers for combustion, which realizes the combination of biomass energy and large power plants, not only improves the efficiency of biomass power generation, but also increases the power quota of renewable energy of the company. With the implementation of the national "renewable energy power quota assessment method" and the requirements of the guidance system for the guidance system of renewable energy development and utilization target of the Energy Bureau, the renewable energy generation capacity of power generation enterprises shall reach more than 9% of the total power generation by 2020. In terms of the development needs of the company, the proportion of new energy generation must be increased, and the project is proposed based on the experience of other companies.

3. Feasibility study on biomass energy

3.1 Available biomass energy resources
Xiangyang City belongs to the north subtropical monsoon type continental climate transition zone, which has the characteristics of mild climate, sufficient light, moderate rainfall and the same season of rain and heat, providing superior climatic conditions for agricultural production. Xiangyang is a big agricultural city with a good agricultural foundation. It has been successively identified as one of the 20 large-scale commercial grain production bases, one of the ten major summer grain production areas, one of the three sesame production areas, the national commercial beef cattle production base, and Qinba mountain high fragrant tea planting base. It has initially formed eight leading industries, mainly grain, oil, tea, cotton, fruit, animal husbandry, vegetables and forestry, with an agricultural area of more than 9 million mu. The raw material biomass resources of this project are straw, rice husk, wood waste, etc.

3.2 Selection of technical route
According to the utilization mode, the combination of biomass and large-scale electricity can be divided into direct utilization and gasification utilization technology. Direct utilization is the technology of mixing biomass raw materials (crop straw, rice husk, wood processing waste, etc.) into coal and transporting them to the boiler combustion chamber for combustion. At present, the combustion modes include layer combustion, fluidized bed combustion and pulverized coal furnace. It is mainly used in industry, district heating, power generation and cogeneration. For example, the straw CO combustion technology is adopted in the boiler burner of Shiliquan Power Plant in China. After the boiler transformation, the original system and parameters remain unchanged, and the straw and pulverized coal CO combustion can be realized, or the coal can be burned separately. Gasification and utilization technology is the technology that biomass is gasified in the gasification device, the low calorific value gas (mainly composed of nitrogen and CO, CO₂, CH₄, H₂, etc.) and the combustible particles carried in the gas are sent to the boiler combustion chamber through the gas delivery pipe for mixed combustion with coal. As an ideal gasification raw material, biomass can be quickly converted
into gas fuel at low temperature, and the gasified gas is easy to burn in coal-fired boiler. The temperature of gas produced by gasification is 700–730 ℃. The gas only needs to be cooled to 450 ℃ (the cooling heat is recovered through the condensate of coal-fired boiler, which is not wasted). The complete combustion time of high-temperature gas in the furnace is short, and the biomass ash and coal ash can be separated, which has certain flexibility.

The two technologies have their own advantages and disadvantages. For direct utilization, it is a feasible and effective method to solve the problem of low ash melting point of biomass, that is, ash in coal effectively reduces the concentration of alkali metals in fuel. At the same time, the existing boilers are generally designed for specific fuels, and the amount of flue gas produced is relatively stable, while the moisture content of biomass is high, and the volume of flue gas produced by combustion is large. If the volume of flue gas exceeds a certain limit, the convective heating surface is very difficult. It is hard to adapt. In contrast, gasification technology has many advantages, such as: (1) technical performance: raw material pretreatment process is simple, without using higher operating temperature and residence time, gas can be produced, because the use of circulating fluidized bed gasification technology reduces the tar content; at the same time, gas enters coal-fired boiler from Gasifier at higher temperature, tar will not condense; (2) environmental benefits: the hydrocarbon gas fuel with reducing property is produced by gasification, which will reduce NOx and other oxidizing gas pollutants and reduce NOx when entering the reburning zone of power plant boiler (3) economic type: due to the use of existing large-scale and efficient power generation system, the efficiency of biomass energy conversion into electric energy is greatly improved; the residence time of biomass in the gasification device is short, reducing the size of the gasification device; combustible particles and tar have enough time for complete combustion in the boiler furnace, so gas purification equipment is not required. In this way, the structure of gasifier is simplified and the investment and operation cost of equipment are reduced. (4) Flexibility: the technical route of this project can be applied to coal-fired power generation units of different capacity levels, which can achieve efficient and reliable combustion. Gasification technology can improve energy conversion efficiency by changing the form of biomass raw materials, and obtain high-grade energy, which provides optimization opportunities for the utilization of biomass and coal. In this project, the way of gasification utilization is selected for discussion.

3.3 Biomass gasification technology

3.3.1 Principle of biomass gasification technology Biomass gasification is a thermochemical reaction in which the combustible part of biomass fuel is converted into combustible gas (mainly hydrogen, carbon monoxide and methane) at high temperature by using oxygen or oxygenates in the air as gasification agent. In the 1970s, Ghaly first proposed the application of gasification technology to biomass, a fuel with low energy density.[3] The volatile content of biomass is generally 76% ~ 86%. When heated, a large amount of volatile matter can be separated out at a relatively low temperature. In order to provide thermodynamic conditions for the reaction, air or oxygen should be supplied in the gasification process to make the raw material partially burned. The energy should be kept in the combustible gas as much as possible, and the product after gasification contains combustible gases such as H2, CO and low molecular weight CMHN. The whole process can be divided into drying, pyrolysis, oxidation and reduction.

3.3.2 Classification of biomass gasification There are many classifications of biomass gasification technology, which can be classified from different perspectives. According to the gas production mechanism, it can be divided into pyrolysis gasification and reactive gasification. According to different gasification agents, it can be divided into dry distillation gasification, air gasification, steam gasification, oxygen gasification and hydrogen gasification; according to different gasification reaction equipment, it can be divided into fixed bed gasification, fluidized bed gasification and entrained flow gasification. In the process of gasification, using different gasifying agents and different process
operation conditions, three kinds of gasified product gas (gas) with different calorific value can be obtained: low calorific value gas with calorific value less than 8.3 \text{MJ/m}^3 (using air and steam / air); medium calorific value gas with calorific value less than 8.3 \text{MJ/m}^3 (using oxygen and steam); high calorific value gas with calorific value higher than 33.4 \text{MJ/m}^3 (using hydrogen).

3.4 Biomass gasification equipment

Biomass gasification reaction takes place in gasifier, which is the main equipment of gasification reaction. Biomass is gasified in a gasifier and converted into biomass gas.\textsuperscript{[4]} At present, the biomass gasification equipment under research and development at home and abroad is mainly divided into fixed bed gasifier, fluidized bed gasifier and entrained bed gasifier according to the principle; it is divided into direct heating and indirect heating according to the heating mode; it is divided into up suction, down suction and cross suction according to the air flow direction.

3.4.1 Fixed bed gasifier

The biomass raw material is added from the top, and the gasification air flows from bottom to top in the furnace body to provide gasification agent for biomass gasification reaction.\textsuperscript{[5]} As the flow direction of the gas is from bottom to top, it is convenient for the thermal decomposition and drying of materials, the heat utilization efficiency in the furnace body is high, and the temperature of the gas generated in the furnace body is low. The updraft biomass gasifier can adapt to some wet biomass materials. However, the tar content of the generated gas is high, and it is inconvenient to put biomass materials into the furnace. This type of furnace is suitable for the situation where the gas can be used directly without cooling and purification.

3.4.2 Fluidized bed gasifier

1) Circulating fluidized bed gasifier

The main difference between the circulating fluidized bed gasifier and the single fluidized bed gasifier is that the solid particles in the generated gas pass through the cyclone separator and then return to the fluidized bed through the feeder to continue the gasification reaction. Compared with single fluidized bed gasification, the main advantages of CFB gasification are as follows: (1) the operating gas velocity can be significantly increased without reducing the carbon conversion rate; (2) smaller material particle size can be applied. The main disadvantage is that it is difficult to control the system, and it is difficult to cut the material.

2) Double fluidized bed gasifier

The double fluidized bed gasifier is divided into two-stage fluidized bed reactors. In the first stage fluidized bed reactor, the biomass material is pyrolyzed, and the generated gas carries the carbon particles and bed materials such as sand into the separation device; in the second stage fluidized bed reactor, the carbon particles are oxidized to increase the bed temperature, and the high temperature flue gas enters the separation device, and the separated bed materials re enter the first stage fluidized bed reactor through the foot. Double fluidized bed gasifier separates combustion and gasification in two reactors. The combustible gas produced by pyrolysis will not be diluted by the flue gas produced by combustion. The generated gas has high calorific value and can be used as the raw material of city gas or chemical synthesis gas, but the investment cost is high.

3.5 Furnace type selection

In order to realize industrial production and improve reaction efficiency, combined with the requirements of this project, circulating fluidized bed gasifier is selected. At present, most of the biomass gasification systems are managed by the Ministry of agriculture, and few of them are connected with industrial systems. At present, the largest processing capacity in China is 8 ~ 10t. In order to ensure the reliability of the equipment, the project is still designed according to this capacity. The project plans to treat 51400 tons of biomass annually (including 22000 tons of rice husk and 29400 tons of straw), and the annual utilization hours are 5500h, equivalent to an hourly processing
capacity of 8t/h (50% rice husk and 50% briquette fuel). Gasifier type: circulating fluidized bed gasifier; gasifier feed port raw material: 50% less than 3cm briquette and 50% rice husk; biomass feed rate: 8t/h; gasification efficiency: about 80% unit average gas production: 1.85nm3/kg (generally 1.48 ~ 2.2nm3 / kg); gasification temperature: 720 ~ 750 ℃, exhaust temperature: 730 ℃ Average power of biomass power generation of supercritical unit: 10.8mw (thermal efficiency of supercritical unit is 41%)

4. Conclusion
1) The annual power supply can reach 54.58 million kwh, which is equivalent to saving about 22500 tons of standard coal, saving primary energy; due to the clean fuel, low sulfur content and small amount of ash, the project reduces about 218 tons of SO2 generated by coal combustion and 67000 tons of CO2, which improves the ecological environment.
2) By using biomass gasification technology, the generated gas is sent to large boilers for recombustion, realizing the combination of biomass energy and large power plants, which not only improves the efficiency of biomass power generation, but also increases the electricity quota of renewable energy of the company.
3) According to the analysis of fuel, transportation, site and other conditions, Xiangyang power plant construction of biomass power plant conditions are good and feasible. The project is technically feasible, with good site conditions, good social, energy-saving and environmental benefits, in line with the national industrial policy. The project construction is necessary and feasible.

References
[1] Ma longlong. Research and development of biomass energy utilization technology [J]. Chemical industry, 2007, 25 (8): 9-14
[2] Wang Yelin. Biomass energy development in Nordic countries and Its Enlightenment [J]. Journal of Anhui Vocational College of electrical engineering, 2006, 11 (3): 72-75
[3] Berndes G, Hoogwijk M, Broek R. The contribution of biomass in the future global energy supply: a review of 17 studies[J]. Biomass and Bioenergy. 2003, 25(1): 1-28
[4] Fischer G, Schrattenholzer L. Global bioenergy poten-tials through 2050 [J]. Biomass and Bioenergy, 2001, 20(3): 151-159
[5] Wu lile, Zheng Yuan, Wang Aihua, Ren Yan. Research status and Prospect of comprehensive utilization of renewable energy [J]. Journal of North China University of water resources and hydropower, 2015, 3 (36): 182-85