State of The Art of Biomass Gasification Power Plants in Thailand

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Abstract— *Currently, there are 14 gasification power plants in Thailand with a total capacity of 5.4 MWe., as of today DEDE invested in 7 plants each with a capacity range of 20-400 kWe and investment cost about 8,000-100,000 baht/kWe. Furthermore, another 4 pilot plants were installed in the Universities such as Naresuan University, Prince Songkla University, Rajamangla University of Technology Thanyaburi, and Suranaree University of Technology. The investment cost of the thermal gasification plants is relatively high, ranging between 8,000- 100,000 baht/kW, because most of plants are under technology improvement for cost reduction. If technology is stable, the investment cost will be able to reduce about 1,000 baht/kW. The 10 gasification power plants are strongly examined in this investigation. It was found that most of plants have a series problem of the inability of control gas production system for both producer gas rate and gas composition resulting from the lack of a good design system for feeding system and tar content removal. In order to develop gasification plants in Thailand, the research in this area must be continuous requirement for ensuring system stability resulting in cheaper investment cos .*

Keywords— *biomass, renewable energy, gasification power plant*

1. INTRODUCTION

Research and development of gasification in Thailand have started around 20 years. Initially, a small scale of biomass gasification was designed and constructed for understanding the basic mechanism of gasification. Then, the pilot plants were constructed to study the application for using producer gas for power generation. Currently, under National Renewable Energy Development Plan (PDP 2010), Thailand promotes community based on gasification power plant and the application of gasification for industries [1].

Thailand has 14 biomass gasification power plants with a total capacity of 5.4 MWe., as of today DEDE invested in 7 plants each with a capacity range of 20-400 kWe and investment cost about 8,000-100,000 baht/kWe. Furthermore, another 4 pilot plants were installed in the Universities such as Naresuan University, Prince Songkla University, Rajamangla University of Technology Thanyaburi, and Suranaree University of Technology. Only the Supreme Renewable Gasification Power plants with a 150 kWe capacity is presently in operation. As has been shown, The main objective of this investgation is to review the status of biomass gasification plants in Thailand.

2. STUDY RESULT AND ANALYSIS

The 10 gasification power plants are selected to be strongly examined as below.

2.1 Gasification power plant of Supreme Renewable Energy Co., Ltd. located at Wiang Kaen, Chiang Rai.

Biomass gasification power plant of Supreme Renewable Energy Co., Ltd, located in Wiang Kaen, Chiang Rai. The installed capacity of the plant is 150 kW. The plant is using biomass and waste corn corps, and wood as fuel. This plant supplies electricity to grid (PEA) and receive 0.3 baht/kWh adder from PEA since April 2008.

Construction of the plant was started in 2006 and finished in 2008 with approximately 30 million baht installation cost. Nowadays, technology of this company is stable as a result of the reduction cost of new plant construction into only 12 million baht. This company plans to construct another power plant by using gasification technology with a capacity of 2 MW with 60 million baht investment.

Technological details:

The plant using down draft gasifier technology, is a modified gasification technology from Ankhur, India and North Island. 224 kg/h of feedstock (corncob) continuously feed into the top of gasifier. Moisture content of the feedstock is controlled to 20 % by drying in warehouse or sun dried. Drying and pyrolysis process occur over throat with a temperature of 600-800^{o}C. Then, in combustion zone at 1,400^{o}C, partial combustion for producer gas production is apparent because of limited of oxygen. Reduction process begins at the bottom of gasifier; producer gas is produced in this zone. Producer gas exits from gasifier with temperature of 400-500^{o}C. It's sent to the venture for reducing temperature, water is sprayed in this position resulting gas temperature decrease from 400-500^{o}C to 40^{o}C. Moisture content in gas is separated by wood chip in the first stage filter unit and saw dust in second stage filter unit. The gas flow rate is measured as 500 cfm and the calorific value as 4.5 MJ/ m^{3}. Finally, producer gas is sent to the modified Hino diesel engine to produce electricity. About 60% of the diesel is replaced by the producer gas.

Technical problems:

Modified diesel engine uses diesel mixed with the producer gas resulting in a higher combustion temperature, therefore engine has some problem related to a cooling system, pipe connection (not designed for gas)

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and pipe leakage. Under this circumstance, the system needs to be cleaned every 500 hrs of operation. It takes about 8 hrs for cleaning system.

2.2 Three stage down draft gasifier 400 kW, the Tha-khlong Agricultural Cooperation, Amphur Tha-woong, Lopburi Province

The Tha-khlong Agricultural Cooperation has been selected as the commercials site for using crop residue (rice husk) as feedstock to produce producer gas for electricity generation. The plant locates at Amphur Tha-woong in Lopburi Province, about 150 kilometers from north of Bangkok. The system installed at the Tha-khlong Agricultural Cooperation with "Three Stages Gasifier" and 400 kW capacity and power generation system utilizes gas engine from China.

This plant is designed for generating electricity 400 kW with 40 million baht of the investment cost. Currently, according DEDE report, this plant is under improvement because of instability in gasifier led to inability of engine working. In addition, the environmental problems results from a lack of water treatment[2].

2.3 Rice Mill and Central Market, Agricultural Cooperative, Lam Luk Ka, Pathum Thani Province

This plant was installed under the development of biomass gasification for community project. It is the cooperation between Energy and Environmental Engineering Center, Faculty of Engineering, Kasetsart University and DEDE. It's located at Rice Mill and Central Market, Agricultural Cooperative Lam Luk Ka, Pathum Thani Province

There are four parts used to produce producer gas. Firstly, the producer gas provided heat needed to perform pyrolysis and drying at the outside of gasifier by using waste heat recovery system from the engine. Secondly, combustion and reduction process occur inside the gasifier. Thirdly, the producer gas sent to cyclone to separate solid particle and then, it is sent to heat exchanger and scrubber to remove tar and reduce temperature before to the power unit. Fourthly, the power unit is a diesel modified engine 80 kW capacity used for the production of the electricity to be used in rice mill.

The flow rate of the producer gas at 240 m^3/h with the average heat rate of 4.5 MJ/m^3 and the feeding rate of 85 kg/h rice husk. According to economic analysis, investment cost is 5 million bahth whereas payback period is 7 years. Currently, this plant is not operating because of the inability to control reaction inside gasifier led to the instability of producer gas compositions.

2.4 20 kW Community Demonstration Plant at Ban Non Muay, A. Chumphon Buri, Surin.

Firstly, pyrolysis process use a screw conveyer sending the rice husk by heating with LPG for increasing temperature about 450-600 ^oC for gasification process. Subsequently, the rice husk flows into the gasifier at the throat to perform re-combustion by filling the air releasing the heat as the exothermic reaction resulting in the higher temperature into approximately 1,050 ^oC. The process produces the producer gas containing approximately 17.23% of CO, 4.05% of CH_4, 6.86% of H_2, 19.43 % of the others such as gas carbon dioxide, and 50.49% of N_2 with the 5.6 MJ/m^3 of the heating value.

Producer gas then flows through a series of cyclones to trap dust mixed with gas to clean up with wet scrubber. Finally, the producer gas is fed though a series of filtered dry (Bag house filter) for another gas cleaning at about 45 ^0C before passing to the diesel engine to generate the electricity. The engine applies dual, i.e., about 30% of diesel and 70% producer gas.

2.5 Downdraft gasification plant, 10 kWe Naresuan University

The 10 kWe of downdraft gasification plant was installed in 2007 and developed by School of Renewable Energy Technology, Naresuan University.

The woodchip as feedstock is cut into 7 cm length of standard size and then fed at 35 kg/h. The producer gas is used in the engine to generate electricity. It was found that the biomass gasifier power generation system consumes about 50 kg/h fuel or 2 kg/kWh. Gasifier can generate around 135 m^3/h of producer gas and about 5.05 MJ/m^3 of heating value. The gas consist of CO, CH_4, CO_2, H_2, N_2, and O_2 is around 29.4%, 0.2%, 9.71%, 9.34%, 50.4% and 0.22%, respectively. Gesifier efficiency is about 73%. The generator used in the plant is about 14% efficiency, so the overall system efficiency is 10%[2].

2.6 Down draft gasification plant, 100 kWe Suranaree University of Technology

In 2008, Suranaree University of Technology co-operated with Satake Corporation (Japan) for the establishment of the gasification power plant capacity 100 kW. The type of Suranatree Gasification Power plant is downdraft gasifier and designed to use flexible fuel such as rice husk and wood. The process of gas production consists of drying process at 100-300^oC, pyrolysis process at 300-900^oC. The combustion appearance is a partial combustion at the throat with the highest temperature about 900^oC whereas reduction reaction is apparent at ranging between 400-900^oC. The producer gas is sent to the gas treatment unit for tar reduction and temperature reduces for closing to the ambient temperature for increasing the volumetric efficiency of the engine.

The feed stock fed on the top of reactor and the moisture content of the feed stock should be less than 15%. This gasifier uses air as gasification agent. To control the combustion reaction as a partial reaction, the air is limited by using the flow control valve around the throat. The gas treatment unit with cyclone collector is used to trap the solid particle in producer gas. Water scrubber and chiller scrubber are used to reduce the temperature and remove tar. Flocculation tank is used to waste heat recovery. When use a wood as a feed stock, It produces 5.52 MJ/Nm^3 of the producer gas at 80.45 kg/h of feedstock rate. The gasifier efficiency is 80.29 % while the engine efficiency is 22.07 %. Consequently, the overall efficiency of this plant is 17.72 %. When rice husk is used as feed stock with a rate of 120 kg/h, the overall efficiency is 14.54%.

2.7 Fixed bed down draft gasification plant 100 kW, A. Tubsakae, Prachuap Khiri Khan Province

This plant is under the study of gas production and development of biomass for power generation in internal

combustion engines by the Department of Alternative Energy Development and Efficiency, Ministry of Energy. The gasifier used in this plant is designed by The Energy and Resource institute (TERI), India. Investment cost by 5.4 million baht.

The gas production uses the wood chip as the feed stock. This system can produced 250Nm^3/h of the producer gas with 4.6 MJ/Nm^3 of heating value and 70-75% efficiency. The producer gas can replace approximately 65% of diesel fuel. This plant has the water treatment system for the eliminating the water pollution.

2.8 Downdraft Gasifier 30 kW, Rajamangala University of Technology Thanyaburi

This is a pilot plant installed at Mechanical Engineering Department, Faculty of Engineering, Rajamangala University of Technology Thanyaburi in 2005 and designed by Assistant Professor Suppawit Lawanasakol. The 30 kWe downdraft gasifier as shown in Figure 3.38 has 60 cm diameter bed and use charcoal as a feed stock and producer gas is used for electricity generation. The heating value of feed stock is 30 MJ/kg and the feeding rate is 6 kg/h. The temperature of reaction in gasifier is controlled by air fuel ratio. The advantage of using charcoal as a feed stock is no tar is generated in the producer gas. Air is used as a gasification agent. Under such circumstance, CO is a major of gas composition of the producer gas i.e. about 15%, and the heating value of the producer gas is about 6 MJ/Nm^3.

A gasoline engine is used for driving a 30 kW generator. The producer gas is sent to mix with gasoline at the intake manifold in 60% of original used without modified the engine.

2.9 80 kW, Double throat downdraft gasifier for water pumping system, Ubonratchthani province.

This plant was designed by Ubonratchthani University's research team and installed in 2009. 80 kW of double throat downdraft gasifier used for irrigation at Phibunmangsahan, Ubonratchthani province The 80 kW fixed bed downdraft gasifier in the Figure 3.39 has 1 m diameter and 4 m height. The gasifier can use a variety of feed stock such as wood chip and corn cob, to prevent feed stock shortage problem. For effectiveness of gas production, the feed stock size should be reduced as 5x5 cm and the moisture content less than 15%. Subsequently, the feed stock is fed at rate of 83 kg/h by manual feed system. The calorific value of feed stock is about 15 MJ/kg.

The reaction temperature is about 1,100-1,400 ^oC and controlled by adjusting the quantity of air that injected at the throat. The major composition gas of the producer gas is CO at 19%. The heating value is 5 MJ/Nm^3 and the gas flow rate is 240 m^3/h. The approximately producer gas flows out of the gasifier at the bottom of gasifier and sent to cyclone to trap dust then sent to scrubber for reducing temperature from 400^oC to 40^oC before combustion in the engine**.** The problems of this plant are slagging and overheat of engine because of high temperature in combustion zone resulting ash become slag. To solve this problem, the cooling system is modified by adding electric fan in front of the radiator.

This plant has less environmental impact because of good of waste management. Waste water from system is treated by water treatment system therefore it is not effect on environment. Also, ash is mixed with soil and used as soil condition. The total investment cost is 1,000,000 baht

2.10 Biomass gasification plant at A+ Power Co., Ltd., Lopburi

A+ power CO., Ltd, gasification power plant located at Lopburi province since 2010. Satake installed 2x950 kWe down draft gasifier to generate electricity and sell to grid. About 7 cm standard of the Wood chip is automatically fed into the gasifier.

Eucalyptus wood chip is used as a feedstock at a rate of 1 ton/h, the cost of feedstock is 300-400 baht/ton which relatively cheap when compared to other feedstock. The feedstock is dried before feed into gasifier. In rainy season the feed stock is dried by waste heat recovery from boiler and drying summer the feed stock is dried by solar energy.

Waukesha gas engines the plant use to generate the electricity. The gas properties or gas rate is checked by igniting at the pipe of flair gas before start the engine. The waste from plant such as ash and tar could be sold where ash is made to charcoal briquette and sold at a rate 1-2 kg per week. In addition, this plant can sell carbon credits under CDM. The total investment cost is 120 million baht but the gasifier cost is 80 million baht.

3. CONCLUSION

The difficulties of the gasification plant both thermal process and power generation are related to three majors sectors, technology, economic and environment. These can be concluded as:

Technology:

1. High tar content in producer gas: More efficient system needed to reduce the tar content in the producer gas.
2. High moisture content of feed stock: Feed stock often stored in the open area which lead to the high moisture content.
3. Control of feeding system: Most plants use screw conveyor to feed stock to gasifier with the fixed speed rate difficult to optimize the control of feeding.
4. Control of temperature in combustion zone: the temperature zone is controlled by feeding rate, air flow rate and moisture content. When the moisture content and feed rate change it is difficult to control the temperature in combustion zone.
5. Lack of skill in operator is causing breakdown of plant frequently.

Economics:

1. High investment cost becaus of most plants are imported from aboard.
2. High maintenance cost, become most spare parts are not readily available.

Environmental:

1. Large amount of waste water generated. Without the good water treatment causes water pollution problem.
2. Ash removal disposal air pollution such as most of plants have CO leak from system.

4. RECOMENDATION

In term of economic analysis, most plants for this study is only under investigation stage and far to be the commercial resulting in expensive installation cost as about 8,000- 100,000 Bath/kW. To reach the commercial technology stages, the investment cost should be reduced into 1,000 Bath/kW approximately (Supreme Renewable Energy Co.,Ltd.,2010). Besides, on environment side, a good of water treatment and gas production controls are necessarily requirement. In addition, the several factors of producer gas production need to be controlled such as a moisture control, a feeding rate, a reaction in gasifier. This control can carry out by a regulation of the combustible gas production rate, the tar content in gas compositions. The tar content can be decreased by the application of the water chiller system to condensed tar in vapor phase.

In order to be the optimization of the combustible gas production rate and gas compositions, the main improvement strategies can be recommended as follows;

Firstly, gasification plant should control temperature in combustion zone between 900-1,200 [3] in order to get high quality of producer gas needed.

Secondly, the moisture of feed stock should be controlled less than 20% for maintaining high temperature in the combustion zone of gasifier. However, this control is difficult in Thailand because of high humidity. However, the moisture control can be carried out by an installment of variable speed control system to regulate feeding rate relating to moisture of feed stock.

Finally, the most of commercial biomass thermal gasification in Thailand is only the first stage of the maturity. Therefore, the biomass technology is commercial. Continuous research and development is strongly requirement to reach the public cost capacity. In addition, the adder campaign in power generation based on biomass technology is a good promotion plan for an interesting stimulation for private sectors. However, human resource development for gasification plants is needed to fulfill the maturity completion of the gasification technology. Eventually, to achieve goal target of 6.95% of the total fuel mix as the biomass share in 2030[4], the policies and plans must keep the integral part of subsidies and adder campaign for biomass technology promotion.

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