Journal of Energy and Environment Technology ISSN 2392-5701
http://jeet.siamtechu.net Review Article

Small Scale Biomass Gasification Power Plant Management

Thakrit Panklib*

School of Energy and Environmental, Graduate College Siam Technology College, Thailand

***Corresponding author; E-mail:** drthakrit@gmail.com

Abstract

There are several agricultural residues in the country that can be used for biomass energy. At present, biomass is being used in the small electricity generation. It is an effective way to eliminate agricultural waste and simultaneously to reduce fossil fuel consumption. Recently, there are many incentives from the government for small and very small electricity producers. For examples, these electricity producers are allowed to sell the power to the grid under long term contracts, the government provides an "adder" on top of the normal tariff, assists in finding soft loans and investment subsidies, etc. With the aforementioned benefits, a prototype of small biomass gasification power plant of 200 kW capacities was installed at Prachinburi province of Thailand. The plant uses local agricultural residues such as corn cob, cassava, eucalyptus bark and chip wood as fuel. Total cost of electricity generated is estimated at 1.97 Baht/kWh. The electricity is then sold to the electricity authority of Thailand (EGAT) at 3.44 baht/kWh (in 2010). Thus, the power plant makes a profit of 1.48 baht for every kWh. If the plant is operated at 80% of its full capacity, the total electricity of 1,401,600 kWh will be generated per year. The annual profit of selling the electricity is amounted to 2,070,451 Baht. Impressively, at this profit, the payback period is approximately 5.8 years. Moreover, the small biomass gasification power plant does not only eliminate agricultural waste effectively in the surrounding area, but also reduces the customary process of the disposal by burning. The emission to the atmosphere is thus reduced. In addition, the plant creates jobs and income for local people.

Keywords: Biomass gasification, biomass power plant, biomass energy, agricultural residues

Introduction

The total energy consumption in Thailand has been continually increasing. Most of the fuel used in Thailand is imported such as petroleum products. Although Thailand can provide some of its own energy resources such as natural gas and crude oil, the domestic energy resources are not sufficient because of the increasing demand and the limitation of these energy resources. Over 80% of the total energy consumption of the country was absorbed by three main economic sectors namely the power, transport, and manufacturing sectors [5]. Thailand is one of the world leaders in agricultural production. Biomass resources, especially agricultural residues, are abundant in the country. Sajjakulnukit et al [1]. EC-ASEAN Cogen Program studied biomass residues from 10 main agricultural residues which possess energy potential. In 1997 the country's total agricultural waste was 61 million tons, which is equivalent to about 426×10^9 MJ of energy. The study further estimated an amount of 41 million tons of biomass residues was unused [2]. Another independent study by EC-ASEAN COGEN Program estimated that energy potential from 4 main agricultural residues, namely bagasse, rice husk, palm oil wastes, and wood residues, was 11,200 GWh/yr or 2,985 MW of power capacity [6]. There are several other agricultural residues in the country that can also be used for energy. At present, biomass is used to generate electricity in the small power plant. It is an effective way to eliminate agricultural waste and to reduce fossil fuel consumption. Currently, there are many incentives from the government for small and very small electricity producers. They can sell all their generated electricity to the grid under long term contracts. The government offers an "adder" on top of the normal tariff, assists in finding soft loans and investment subsidies. Although the demand of electricity increases continuously, the large power plant is difficult to be built since large area of land is not easy to be obtained and, moreover, the local people are against the project. On the contrary, a small biomass power plants use less space for installation, life cycle of the biomass is relatively short, the process is not complicated and the local people can manage by themselves [7]. Consequently, the small biomass power plants look more attractive as another way to solve the energy crisis in the future. Biomass power generation helps to reduce energy imports and also greenhouse gas emissions to the atmosphere. This paper presents the planning, implementing, economics and monitoring of biomass gasification for electricity generation in a community in Thailand.

Biomass gasification power plant

The biomass gasification for electricity generation is a technology which converts any kind of biomass energy with low heat value such as waste from agriculture and forest into combustible gas, which is then fed into an electricity generator. Biomass gasification for electricity generation can solve both problems of effective use of renewable energy and environmental pollution. For this reason, the technology of biomass gasification for electricity generation attracts more and more research as well as applications. Today, commercially successful technologies for biomass gasification for electricity generation using internal combustion gas engines (BiG/ICE) get wide application because of their small system capacity, nimble arrangement, low investment, compact structure, reliable technique, low running cost, simple operation and maintenance and their low demand for gas quality. So biomass gasification for electricity generation systems equipped with an internal combustion gas engine should be appropriate technology for community [8-9]. The prototype of the system was installed at community, which is in Kabinburi amphoe and in Prachinburi province of Thailand. The capacity of the system is 200 kW. A downdraft fixed bed gasifier is used. The construction of power plant is shown in Figure 1.

Project assessment

Although the downdraft fixed-bed gasifier is technically preferred to other gasifies, other decisive criteria must be considered. These criteria include gasifier application, the availability of suitable equipment, biomass fuel availability and reliability, regulations, operator availability, and finally capital investment and operating cost [10-11].

Figure 1 BiG/ICE system 200 kW.

Feedstock supply

Adequate resources should be available within a 50 km radius to minimize concerns for an uninterrupted supply. The types of biofuels available are important. They should be compatible with the gasifier. Since the resource may ultimately attract other customers, one or more long term contracts guaranteeing a supply are prerequisite. Also the reputation of the suppliers to meet commitments should be thoroughly verified. Storage is required to store enough biofuels for a certain period in case the suppliers cannot supply the biofuels in time.

Regulations

Local and government regulations may influence decisions regarding the type, form and size of a gasifier installation. Currently in Thailand, there are many incentives from the government for small and very small electricity producers. For examples, the PEA buys all the electricity generated by these small and very small power plants at an agreed price for a predetermined number of years, the government provides an “adder” on top of the normal tariff, and assists in finding soft loans and investment subsidies, etc.

Labor needs

Small biomass power plant employs seven operators which are all local people. One of them is technician work 8 hours a day. The others are general workers are work two people per shift, three shifts a day, eight hour each and scheduled to run the plant every day. Each person can be easily trained to operate a batch-fed gasifier.

Logistics considerations

To ensure the success of the project, the following should be secured. All equipments should be checked that their specifications agree with proven design, they are underwritten by long term service contracts and warranties for prime power application, systems engineering should be certified by a trusted engineer. A long-term fuel purchase agreement at a fixed price with assured supply (multiple sourcing is preferred) should be secured as critical to the project's success. All zoning questions should be resolved. All permits, licenses, and approvals are acquired. Liability insurance should be available and assured. Long-term power sales contract should be in place if the project includes utility buyback.

Economics

The value of the electricity and heat produced must be included. An assessment of the overall economic feasibility of using biomass to generate electric power should consider the following factors when considering a specific project for example the cost of biomass fuel such as the cost of the gasifier system, the money at prevailing interest rates the operating labor, overhaul and replacement, life of the equipment between overhauls or replacement, the value of the power produced, retail cost of buying electricity and benefits of using renewable energy.

Energy costs

The cost of energy from biomass should be compared with the costs for all other fuels with which it might compete. The cost of various forms of biomass should be compared using a common base. Since neither moisture nor ash contributes to fuel value, biomass cost is mostly quoted in Baht per ton MAF (Baht/ton MAF), where MAF denotes moisture and ash free.

$$\text{Biomass Cost}\left(\frac{\text{Baht}}{\text{MAF ton}}\right) = \frac{(\text{Actual Cost})}{(1-\text{M}-\text{A})} \quad (1)$$

M is the fraction of moisture and A is the fraction of ash in the biomass. Freshly harvested biomass often contains a moisture fraction of 0.5 (50%). The internal ash content of most wood is less than 0.01 (1%), but as-delivered it may contain extraneous matter in fractions up to 0.05 (5%). Agricultural residues contain 0.05 to 0.20 ash fractions, so the normalization equation clearly is important in calculating biomass costs. The actual costs of various forms of biomass depend on many factors, which include quantities available, whether the biomass is a byproduct or principal product, distance that the biomass must be transported, amount of pretreatment, sizing, drying, and storage needed. Example for corn cob is containing 0.5 moisture and 0.6 internal ash fraction. The normal price is 300 Baht/ton. The actual cost of corn cob is 377 Baht/ton MAF, calculated from Eq.(1).

Equipment cost

A gasifier is not a complicate technology, it is a low-capital-cost device, ranging from 60,000 to 80,000 Baht/kW depending on the auxiliary equipments required. These auxiliary equipments include fuel storage bins, fuel drying, screening, and pretreatment systems, devices to deliver and meter fuel fed to the gasifier, the gasifier burner, ash removal, gas cleanup system, gas engine and gasifier operational controls. These factors are specific to the application, and they must be evaluated economically and technically for each application. In many cases, a gasifier might be considered simply as a retrofit to provide low-cost gas in place of more expensive fossil fuels because a boiler or other fuel-requiring device already exists.

Interest Cost

In these cases, the economic analysis is greatly simplified because the operation and economics of existing equipment are already well understood. If the gas is to be burned directly, then an equipment comparison should be based on the cost per kilowatt hour. For example at 60,000 Baht/kW equipment cost, 6.5% interest and operating at 80% duty cycle, the cost of interest is 0.56 Baht/kWh, , calculated from Eq. (2)

$$C_{int} = \frac{(\text{Equipment Cost}, \frac{\text{Baht}}{\text{kWh}})\ (\text{Loan Interest}, \%)}{(\text{Duty Cycle}, \%)\left((360\frac{\text{days}}{\text{year}})(24\frac{\text{hr}}{\text{day}})\right)} \tag{2}$$

Conversion efficiency and fuel consumption

The efficiency with which the gasifier converts biomass fuel to a final product is an important factor for calculating operating costs. Overall efficiency is the product of the efficiencies of drying the biomass, operating the gasifier, and use of the product gas. Drying efficiency varies widely, depending on the equipment design and heat source. Typical fuel consumption for corn cob with 20% moisture is roughly 1.35 kg/kWh. The price is 300 Baht/ton, we get fuel cost 0.57 Baht/kWh, calculated from Eq. (3)

$$C_{fuel} = \frac{(\text{Fuel Price}, \frac{\text{Baht}}{\text{ton MAF}})\ (\text{Fuel Consumption}, \frac{\text{kg}}{\text{kWh}})}{\left(1{,}000\frac{\text{kg}}{\text{ton}}\right)[1-(\text{Moisture}, \%)]} \tag{3}$$

The cost of operating labor

Batch-fed gasifier can be used in the lowest cost system designs. Batch-fed gasifiers are suitable for many situations, especially in the context of the workplace where change of shifts, lunch, and breaks serve as natural intervals for fueling and ash removal. If the gasifier requires continual monitoring by a skilled attendant, this cost introduces a significant economy-of-scale factor against very small systems. It should be possible in many situations to operate batch-fed gasifier with minimal attention. However, if round-the-clock operation or minimal attendant labor is desired, then automatic operation may be more suitable. Automatic fuel feeding and ash removal require additional equipment. The labor cost for small biomass power plant 200 kW employ 2 labors per 8 hours shift at 190 Baht/labor/shift wage rate is 0.24 Baht/kWh, , calculated from Eq. (4)

$$C_{laber} = \frac{(\text{Wage Rate}, \frac{\text{Baht}}{(\text{LaberxShip})})\ (\frac{\text{Laber}}{\text{Shift}})}{(\text{Capacity}, \text{kW})(\frac{\text{hr}}{\text{Shift}})} \tag{4}$$

Utility cost

These are the cost of electricity and water used in the production process. Approximately 15% of all electrical power produced is used in the production process such as blower chiller and circulation pump. Approximately, 0.1 m3/hr of fresh water is required to fill up the loss of circulating water used to cool the fuel gases and equipments in the plant. The cost of electricity is 0.44 Baht/kWh and the cost of water is 0.01 Baht/kWh, , calculated from Eq. (5) and (6).

$$C_{elect} = \left(\text{Unit Price}, \frac{\text{Baht}}{\text{kWh}}\right)(\text{Electricity Used}, \%) \quad (5)$$

$$C_{water} = \frac{\left(\text{Unit Price}, \frac{\text{Baht}}{m^3}\right)\left(\text{Water Used Rate}, \frac{m^3}{hr}\right)}{(\text{Capacity}, kW)} \quad (6)$$

Maintenance cost

Normal maintenance costs are 8,000 Baht for 60 liter lubricant oil capacity, 1,000 Baht accessory parts include wage for 500 hr maintenance interval. The maintenance costs is 0.09 Baht/kWh, calculated from Eq. (7)

$$C_{maint} = \frac{(\text{Parts and Wage} + \text{Oil Lubricant})}{(kW)(\text{Maintenance Interval})} \quad (7)$$

The cost of engine wear for a gas engine with 2,000 hr engine life and 25,000 Baht rebuild cost is 0.06 Baht/kWh, calculated from Eq. (8)

$$C_{wear} = \frac{(\text{Rebuild Gost}, \text{Bah t})}{(kW)(\text{Engine Life})} \quad (8)$$

Total Cost

Total cost of electric generation is the sum of the above components of production cost. The total cost of electric generation is 1.97 Baht/kWh, calculated from Eq. (9)

$$C_{total} = C_{int} + C_{fuel} + C_{labor} + C_{elect} + C_{water} + C_{maint} + C_{wear} \quad (9)$$

Cost benefits

Value of power produced is an important factor to consider for the project. The regulation to purchase power from small power producers has been approved and announced in Thailand. The program allows private investment in the generation of electricity using renewable energy to sell excess power to the Provincial Electricity Authority (PEA) and requires utilities to buy back power generated from private sector investment in power generation at a price of 2.94 baht/kWh equal to the utility (in 2010) and the government was provided an “adder” on top of the normal tariff 0.5 baht/kWh which the total amount 3.44 baht/kWh for 7 to 10 years contact.

Total cost of electricity generated is estimated at 1.97 Baht/kWh. Thus, the power plant makes a profit of 1.48 baht for every kWh.

Financing

Besides subsidies of government, several potential funding sources exist for implementing a project. Thailand is highly dependent upon imported oil. It is estimated that the value of net energy import will reach 900,000 million Baht in 2008. The high dependence on imported oil together with the abundance of agricultural sources leads Thailand to be one of the earliest Asian countries having policies in supporting renewable energy [7]. The existing policies are:

- Since the cost of power generation from renewable energy is much higher than that from fossil fuels, the government has provided various forms of financial support.
- Ministry of Energy through Energy Conservation Fund (ENCON Fund) has subsidized many renewable energy project investment cost, e.g. ENCON Fund has sponsored 44-50% of investment cost of biogas projects in pig farms and 20% of that in industrial sector since 1995.
- Preferential finance, the 2,000 million-Baht budget from ENCON Fund allocated to financial institutions as revolving fund for granting soft loan with the maximum of 50 million baht each project and 4% interest in renewable energy and energy efficiency projects since 1993.
- Investment tax incentive, exemption of import tax and 8-year corporate tax as well as other BOI privileges in renewable energy business, approved by the board of investment since 2005
- Competitive bidding, having been launched twice for determining the lowest adder for renewable SPPs in 2002 and 2007.

Feed-in tariff, employed for SPP and VSPP in 2006 by purchasing power at fixed adder for each type of renewable energy for 7 – 10 years since its commercial operating date (COD).

Other consideration

The factors considered in this chapter directly influence the viability of the project. Other factors, although peripheral, are worth noting because such important considerations as bank loan approvals can hinge on their perceived value. These factors include job creation and economic benefit to the community. New jobs can be expected because of a biomass gasifier electric project. Also most of the operating expenses of biomass gasifier electricity generation involve payment directly to individuals in the local community through fuel purchases (including collection, preparation, handling, and transport) and equipment operation and maintenance. Engine overhaul and investment earnings also may be retained in some local economies. In such cases, virtually all the expenses of electricity generation may generate local wages and income to the benefit of the local economy.

Conclusion

For this project the total cost of electric generation is 1.97 Baht/kWh and power plant can sell the power to electricity authority 3.44 baht/kWh (in 2010). So, the power plant has profitable on sales of 1.48 baht/kWh. If operating at 80% duty cycle which the plant generate electricity 1,401,600 per year. The profit of selling the electricity is about 2,070,451 Baht per year and approximately 5.8 years payback period. Today, commercially successful technologies for biomass gasification for electricity generation using internal combustion gas engines get wide application because of their small system capacity, nimble arrangement, low investment, compact structure, reliable technique, low running cost, simple operation and maintenance and their low demand for gas quality. Due to the current energy crisis, energy electricity demand and fuel prices continually increasing every year and the government's issuance of policies to promote energy efficiency and renewable energy, it can be seen that biomass-based power generation seems to be quite possible in both the technological aspects and the potential of biomass. However, for sustainable achievement, the Thai government does not only create confident mechanisms but also continually encourages the VSPP, IPPs and SPPs with power purchase agreements, incentive investments, as well as research for new pilot plants. Small electricity production from biomass agricultural residue is one solution to solve the domestic demand for the electricity in the future. It is feasible because small biomass power plants can be installed throughout the country, the local people can manage them by themselves and agricultural residues are plentiful in rural areas. In addition it would considerably decrease the burning of our forests and the disposal of agricultural residue saving the environment from SO_2 and NO_X emissions emitted into the atmosphere [11]. Although energy policies adopted by the government are in the right direction, the pace of implementation is slow. It is very important for the government to disseminate information through public campaign to educate the public about alternative energy.

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