Analysis of Hybrid Diesel-Biogas for Palm Oil Mill Electrification and Environmental Sustainability

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Submission date: 26-Feb-2022 07:59AM (UTC+0800)
Submission ID: 1771057310
File name: lm_Oil_Mill_Electrification_and_Environmental_Sustainability.pdf (753.61K)
Word count: 2479
Character count: 12753

2021 3rd International Conference on High Voltage Engineering and Power Systems (ICHVEPS)

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2021 3rd International Conference on High Voltage Engineering and Power Systems (ICHVEPS) | 978-1-6654-4354-8/21/$31.00 ©2021 IEEE | DOI: 10.1109/ICHVEPS53178.2021.9601006

***Abstract*—This paper presents an economic analysis of the hybrid diesel-biogas plant for the electrification of palm oil mills and the reduction of greenhouse gas emissions. A palm oil factory load in remote Sumatra area is used as a case study. The optimization configuration, economic and environmental aspects were analyzed using HOMER software. The optimization result obtained 78.7% of total electricity is supplied by hybrid diesel-biogas generators with net present cost (NPC) of IDR 130,693 million and cost of energy (CoE) of IDR 2,142 /kWh. The operating cost of the system is relatively low due to a reduction of diesel fuel consumption. The hybrid system also reduced greenhouse gases emission compared to non-renewable power system. Environmental sustainability is obtained through efforts to increase biogas power generation and reduce the use of non-renewable power system.**

Keywords— optimal design, hybrid diesel-biogas, economic feasibility, and environment sustainability

I. Introduction

The need for energy in the world in general and in Indonesia in particular continue to increase due to the increasing of population and economic development. Meanwhile, fossil energy, which has been the main source of energy, has very limited resources and continues to deplete. Natural processes take a very long time to be able to provide fossil energy again. In addition, electricity production from fossil fuels produces high carbon dioxide and other substances that pollute the environment [1]. Thus, alternative energy generation based on renewable energy is needed. However, the availability of renewable energy for power generation is still limited and expensive. To overcome this issue, it is necessary to combine (hybrid) renewable and non-renewable energy power plants [2].

In accordance with the Indonesia government regulation No. 79 year 2014 on National Energy Policy to utilize new and renewable energy [3], one of the renewable energy sources that can be used is biomass. The Sumatra region has a tremendous growth of oil palm plantations over the last decade. The increase of oil palm plantations area has encouraged the growth of processing industries, including palm oil mills that produce crude palm oil (CPO) or have biomass waste. The biomass waste can be proceed further to be biogas fuel for electricity of palm oil mills [4].

Considering that there is quite a lot of waste material from shells and excess fibers that really need to be utilized and the use of generators which require high fuel costs, it is necessary to adjust the boiler scheduling without having to use generators. Many methods can be used to design a power generation system, one of which is using the HOMER software to design a biomass power generation system.

Based on the description above, research on the design and economic analysis of hybrid diesel-biogas for Indonesia remote palm oil factory electrification needs to be carried out. The results of this study will be presented in the following section.

II. Biomass Resources

Indonesia's oil palm plantations are growing fast and reflect the oil palm revolution. Indonesian oil palm plantations are growing in 22 of the 33 provinces in Indonesia. The two main islands of oil palm plantation centers in Indonesia are Sumatra [5][6] and Kalimantan [7]. Oil palm is a plant that has a high selling value in the community. The results of oil palm plants can be used, including as a producer of oil and also Palm oil waste [8]. The Palm oil waste consist of empty fruit bunch, shell, and fiber are palm biomass waste that can be used to be processed into biogas to generate electricity.

Biomass power plants are power plants whose fuel is biomass in the form of plants, grass and so on. Biomass power plants have 2 ways to make biomass as fuel to produce electrical energy: (a) by burning solid biomass directly so that the boiler produces steam, or (b) by fermenting (anaerobic digestion) which later can produce biogas with 20 to 28 m^3 of CH_4 m^{-3} biogas from 1 m^3 of palm oil mill effluent [9]. About 1 m^3 of biogas is capable of producing electrical energy equivalent to 1.8 kWh, which is equivalent to 25 % power generation efficiency [10].

Biogas usually has a lower heating value compared to fossil fuels, especially if it contains large amounts of nitrogen, which is non-flammable. However, biogas has several advantages over solid biomass, including cleaner combustion, higher efficiency, and better control. In this study, biomass from gasified biomass was used based on Homer simulation model.

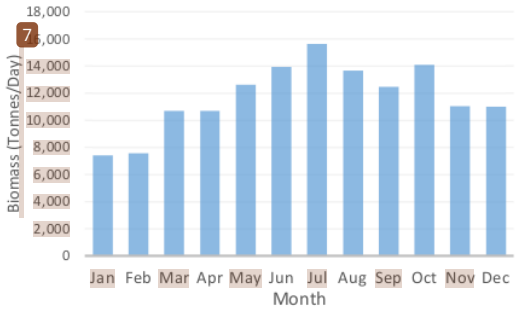

Fig. 1. Biomass resources

One of the oil palm plantations located at the end of Sumatera island, namely PT. Perkebunan Nusantara I, Cot Girek Unit was used in this study. The unit's oil palm plantations contain a lot of palm oil waste in the form of shells, fibers and empty fruit bunch. The potential for palm oil waste is seen in Fig.1. Based on Fig.1, it can be seen that Cot Girek plantation area has biomass waste potential that can be used as fuel with a total fresh fruit bunches of 317,731 tons/year.

III. System Study Preparation

A. Palm Oil Factory Load Profile

This research uses load data of palm oil factory at remote palm plantation area which have no public grid utility electrification. The load consists of seven stations as shown in Table I.

TABLE I. POWER REQUIRED AT EACH STATION

Station	Power (kW)
Loading ramp	29
Thressing	93.65
Pressing	75
Kernel plant	192.55
Classification station	142
Boiler takuma	225.4
Water treatment	64
Total	821.60

The average factory energy consumption per day is 8,730 kWh/day with 821.77 kW peak. Fig. 2 demonstrates monthly factory load profile for one year of operation in two different climates.

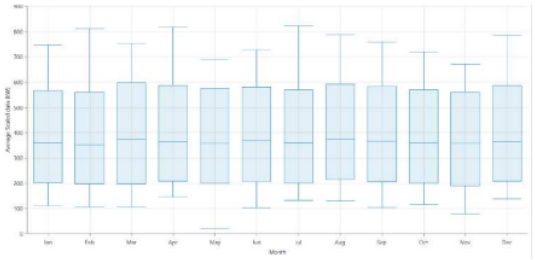

Fig. 2. Mothly Palm Oil Factory Load Profile

B. System Architecture

Two electrification scenarios are used, using the base case only for diesel generators and using hybrid generators with biogas. The capacity of the diesel generator is designed to be able to serve the entire load so that a capacity of 1000 kW is chosen. While the biomass generator model uses a capacity that corresponds to the biogas potential that can be produced from palm waste. The schematic diagram of a hybrid diesel-biogas for palm oil factory electrification in the HOMER software to serve the load demand 8,730 kWh/day is shown in Fig. 3.

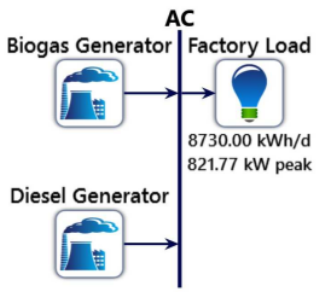

Fig. 3. Schematic diagram of hybrid diesel-biogas

C. Components input parameters and costs

Table II shows the input parameters and costs of diesel generator as non-renewable generator combine with gasified biomass generator as renewable power system. The biomass generation cost is referred to ref [11]. The price of biomass, including transportation, storage and labor charges is considered to be IDR 35,000/ton. Economical and technical parameters associated with components used in this study have been presented in Table 2. The lifetime of the project and the nominal discount rate are considered to be 25 years and 3.7%, respectively.

TABLE II. COMPONENTS COSTS IN HOMER SIMULATION.

Diesel Generator	
Type	Generic 1000 kW
Initial capital cost	IDR 5,180 million
Replacement cost	IDR 4,144 million
Fuel cost (IDR/L)	8,000
O&M Cost (IDR/op.hour)	700
CO (g/L fuel)	13.56
Biogas Generator	
Type	Generic 500 kW
Initial capital cost	IDR 16,100 million
Replacement Cost	IDR 10,500 million
Fuel cost (IDR/ton)	35,000
O&M Cost (IDR/op.hour)	700
CO (g/kg fuel)	2

Biogas fuel cost have been cheaper because palm oil mill effluent (POME) is being used as biomass. The other biogas fuel process assumed including in biomass initial capital cost as shown in Table II.

IV. Results and Discussion

The six solutions have been simulated through the HOMER software with 4 viable systems, and 2 systems are not feasible due to lack of storage capacity constraints. The optimized result is as shown in Table III.

TABLE III. OPTIMIZATION RESULT

Energy production	kWh/year	%
Biogas Generator	2,542,977	78.7
Diesel Generator	686,228	21.3
Total	3,229,205	100
Excess Electric	42,755	1.32

The optimization result show that 78.78% electricity of palm oil factory supplied by biogas generator and 21.3% supplied by non-renewable power system. The monthly electric production is shown in Fig. 4.

The electrical energy that can be produced from palm oil waste is large enough to dominate the electrification of the factory's electricity needs and can be sustainable because it is renewable. Biomass fuel which is palm oil waste can be useful for electrifying the factory and not just wasted. This can reduce dependence on fossil fuels in the future.

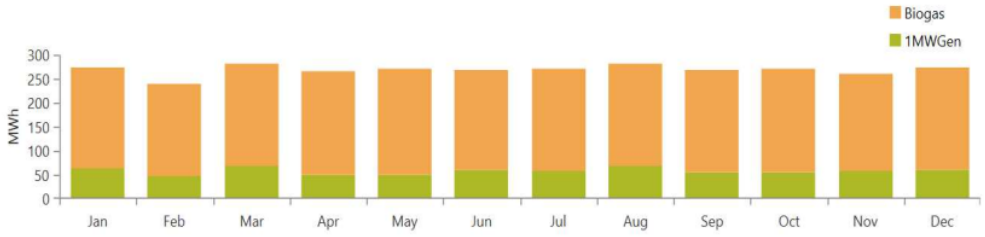

Fig. 4. Mothly electric production

The economic comparison of hybrid system to diesel generation electrification is shown in Table IV.

TABLE IV. ECONOMIC COMPARISON WITH NON RENEWABLE SOURCE

Quantity	Hybrid Diesel-Biogas	Diesel Generator
NPC	IDR 130,693M	IDR 188,324M
COE	IDR 2,142/kWh	IDR 3,087/kWh
Initial capital	IDR 21.3B	IDR 5.18B
Operating cost per year	IDR 5.72B	IDR 9.57B
Diesel fuel consumption	190,624 L/year	910,566 L/year

Net present cost (NPC) of hybrid system is IDR 130,693 billion, which is cheaper than non-renewable power system. Cost of energy (CoE) of hybrid system is IDR 2,142/kWh, also cheaper than non-renewable power system. The initial capital cost is used for biogas generator investment. Therefore, the initial capital cost for hybrid system is high to cover the construction of a gasified biomass power plant cost. However, the annual operating costs have decreased to IDR 5.44B for a hybrid system. This is due to a decrease in diesel fuel consumption from 910,566 L/year to only 190,624 L/year.

TABLE V. ENVIRONMENT COMPARISON

Emissions (Pollutant)	Unitt	Quantity	
		Hybrid	Diesel
Carbon Dioxide	kg/yr	500,406	2,387,709
Carbon Monoxide	kg/yr	2,602	12,353
Unburned Hydrocarbons	kg/yr	137	656
Particulate Matter	kg/yr	22.1	106
Sulfur Dioxide	kg/yr	1,222	5,837
Nitrogen Oxides	kg/yr	505	2,367

Table V shows environment comparison with diesel generator. The hybrid system can reduce up to 1,887 tons of carbon dioxide emission per year.

V. CONCLUSION

The design and economic analysis of hybrid diesel-biogas for Indonesia remote palm oil factory electrification has been carried out. Utilization of palm oil waste for power generation has reduced the cost of energy generation from IDR 3,087/kWh to IDR 2,142/kWh for optimal configuration. Likewise with the NPC from IDR 188,324M to IDR 130,693M. Although the initial investment costs are large for the construction of a gasified biomass power plant, the annual operating costs have decreased to IDR 5.44B for a hybrid system. This is due to a decrease in diesel fuel consumption from 910,566 L/year to 190,624 L/year. On the environmental side, the use of biogas plants has reduced all pollutant, especially for CO_2 decrease to 500 tones/year. The results of this analysis can be used as a consideration in the construction of a biomass power plant from palm oil waste from an oil palm plantation in the remote Indonesia area which there is no utility network and still depends on non-renewable power system.

ACKNOWLEDGMENT

The authors would like to thank for the publication of this article supported by Engineering Faculty of Universitas Andalas under publication grant 2021.

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