Environmentally Friendly Power Generation Technology with Solar PV□Biogas in Rural Areas of Eastern Java

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Environmentally Friendly Power Generation Technology with Solar PV-Biogas in Rural Areas of Eastern Java

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Abstract. Increasing human activity has an impact on energy needs. Electrical energy is the most dominant type of energy used daily. the increase in electricity demand in East Java was due to an increase in industrial activity in several cities in East Java, such as Surabaya, Mojokerto, Sidoarjo. Meanwhile, the electrical energy needs of several rural areas in East Java, such as in Bodowoso, Bangkalan, Sumenep have not been fulfilled due to geographical factors. The solution to fulfillment of electricity in rural areas can utilize the potential of alternative energy, such as solar energy and biogas. The high potential of solar energy and biogas can be used as an energy source for solar PV-biogas hybrid power plants. The aim of the study was to study the application of a solar PV-biogas power plant model in rural areas. The research method of the solar PV-biogas hybrid power plant is carried out in several stages to assess the potential for the application of hybrid power plants in rural areas in eastern Java. The research method uses a 100 Wp solar PV hybrid system model and 1 KW biogas generator set by analyzing the potential of electricity produced on average per day. The results of the study of the analysis of the potential application of solar PV-biogas power plants show the configuration of the power plant model of generating solar PV-biogas generators produced by solar PV electric power 1.260 kW per day and 0,379 kW KW biogas generator with a total electrical energy of 1,639 kW / day. Electric energy consumption per family head is an average of 1 kWh / day. the application of a solar PV-biogas hybrid power plant still with a surplus of 0,639 KW. the model of solar PV-biogas generator has a good effective and efficient to be applied in rural Java east.

Keywords: Environmental, electricity generation, solar PV, biogas, rural

1. Introduction

Electrical energy is one type of energy that is widely consumed in everyday human activities, while others are used for lighting, cooking, production activities. The level of welfare of the population in an area is determined by the availability of electrical energy. Electricity consumption needs can be used as an indicator to measure the level of community welfare. The electricity consumption of the people of East Java experienced an increase of around 15.2 percent from January to September 2017. The largest electricity consumption was in West Surabaya, Pasuruan, Mojokerto, Bojonegoro, Sidoarjo, the amount of electricity consumption due to the industrial area in East Java. (wisnu yulianto Manager of Legal Communication and Administration of PT PLN Distribution of East Java). Meanwhile, there are still some villages that have not been electrified, including in Bangkalan there is one village that has not been electrified, in Bondowoso 3 villages and in Sumenep 29 villages. In percentage, currently only 99.61 percent of villages have electricity. Constraints faced in the provision of energy; energy in rural areas of East Java, one of them is the geographical location factors, such as the difficulty of access roads, the absence of an electrical installation network. The problem of electrical energy needs in rural areas in East Java can be overcome by utilizing renewable energy power plants. Utilization of renewable energy PV-biogas solar hybrid power plants is very potential seen from the intensity of sunlight in East Java in the range of 800-900 W / m^2, while biogas energy can be produced from cow manure with a population of 60% [1].

The process of using livestock manure becomes an energy source including gasification technology and anaerobic fermentation technology [2]. Anaerobic fermentation is a reliable process for producing methane gas, the anerobic process is very suitable for livestock manure and algae [3-4]. Biowaste processing into biogas is the most effective technology in managing waste into renewable and environmentally friendly energy. This process can provide green energy and improve environmental pollution [5]. The use of anaerobic mixture of livestock fermentation and poultry manure with straw, refining grains, pear residues and leaves to produce biogas can increase the level of utilization of sewage waste [6-8].

Making biogas from lemongrass, cow dung and poultry manure is used for the substrate. Six (6) kg of each pre-fermented substrate mixed with water in a ratio of 1: 1 to form slurry and digested for 30 days. each biogas produced from Lemon grass, cow dung and poultry manure 0.125 m^3, 0.191 m^3 and 0.211 m^3 showed that lemon grass produced less volume but quality biogas that was better than cow manure and poultry manure. [9].

The production of deer biogas, the addition of deer slurry as an inoculum during anaerobic fermentation of deer manure with different amounts of biogas slurry can increase total biogas production, and the highest total amount of biogas when the amount of biogas slurry added is 30% of mixed fermentation. Although the addition of biogas slurry can cause an increase in ammonia nitrogen content in the fermentation mixture, it was found that changes in ammonia nitrogen content caused by the addition of biogas slurry did not have a clear effect on methane production [10]

The potential of large energy sources of solar PV-biogas cannot be utilized by the community as a source of electrical energy in rural areas. Biogas energy produced from livestock manure can produce ± 2 m^3 of biogas per day for one cow / buffalo. Energi biogas for energy sources is highly dependent on the amount of methane gas. Methane gas from fermentation is the main content of biogas which has a calorific value between 590 - 700 K.cal / m^3. Another source of heat from biogas is from H_2 and CO in small amounts, while carbon dioxide and nitrogen gas do not contribute to the heat value. The heating value of biogas is greater than other energy sources, such as coal gas (586 K.cal / m^3) or water gas (302 K.cal/m^3). The biogas heating value is smaller than natural gas (967 K.cal / m3). Each cubic of biogas is equivalent to 0.5 kg of liquefied natural gas (liquid petroleum gases / LPG), 0.5 L of gasoline and 0.5 L of diesel oil. Biogas can generate electricity of 1.25 - 1.50 kilo watt hour (kwh). [11]

Solar biomass hybrid systems need a cost ($ 0.328 / kWh) is not cost effective and less attractive to users. while considering changes or variations in the cost of technology and the availability of energy resources need to be explored to increase the penetration of renewable energy in the energy mix and to reduce the cost of generating electricity from renewable energy systems [12]. The system uses the strategy of operating solar energy during the day and biomass energy at night, with a model operating strategy like this. biomass energy and solar energy can complement each other. In addition, the capacity of TES has a significant impact on total revenue

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with costs from the solar field. This is due to the fact that large solar energy must be prioritized at TES for high utilization at night [13].

Actual power system of the grid compared to two new renewable power systems: (1) grid solar systems tied: solar PV / grid / power inverter systems, and (2) Off grid solar power systems: PV / diesel generators / batteries / power systems inverter. PV / grid / inverter solar power systems offer the best performance compared to PV / diesel generators / batteries / inverters. while the total energy from the hybrid grid connected to diesel can be used to meet the AC load from the desalination plant with almost no excess electricity and lack of power. Hybrid power systems are more economical and environmentally friendly: high renewable fractions (47.3%), low excess power (0.15%), low energy costs (90 $ / MWh), and low emission CO2 gas (264.25 kg CO2 / MWh) [14].

The design of a solar PV-biogas electric energy generating unit in rural areas in East Java aims to meet the electricity needs in rural areas. The PV-biogas hybrid solar power generation model requires a study and analysis of its potential in rural applications.

1.1. Solar PV power plants

Energy released by sunlight is actually only received by the earth's surface by 69% of the total solar emission energy.energy supply *Solar cell* from sunlight received by the earth's surface is very large, reaching 3 x 10 joules per year, this energy is equivalent to 2 x 10^{17} Watts.

Solar module PV power capacity is denoted in watt peak (Wp). This standard refers to the intensity of solar radiation of 1000 W / m² which is perpendicular to the solar cell at a temperature of 25 ° C. The photovoltaic module has a relationship between current and voltage represented in curve IV. When the variable resistance is infinite (open circuit), the current is worth a minimum (zero) and the voltage in the cell is at the maximum value, known as open circuit (Voc) voltage. In other circumstances, when the variable resistance is zero (short circuit), the maximum current is known as short circuit (Isc). If the variable resistance has a value that varies between zero and infinity, the current (I) and voltage (V) will get a variable value as shown in Figure 1, known as the IV characteristic curve in solar cells.

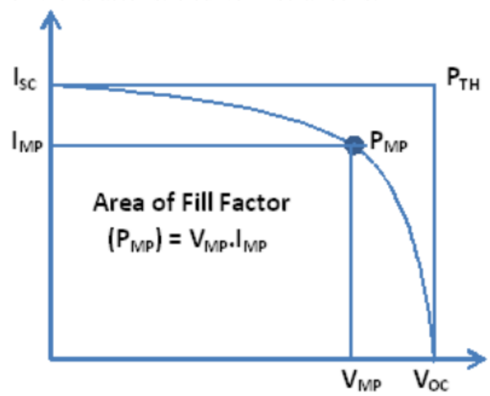

Figure 1. Characteristic curve of IV solar cells

The working principle of Solar PV if the sun's light affects the solar panel, then the electrons in the solar cell will move from N to P, so that at the output terminal of the solar panel will produce electrical energy. The amount of electrical energy produced by solar PV varies depending on the number of solar cells. Output from direct current solar panels (DC) whose voltage outflow depends on the number of solar cells installed in the solar panel and the sunlight's intensity illuminating solar PV.

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Solar PV input power is the multiplication between the intensity of solar radiation which is widely accepted by PV modules.

$$Pin = Ir \times A \qquad (1)$$

with,

Pin: Input power due to solar irradiance
Ir: Solar radiation intensity (Watt / m2)
A: The surface area of the photovoltaic module (m2)

While solar PV output is an open circuit voltage (Voc) , Short circuit current (Isc), and Fill Factor (FF) produced by Photovoltaic cells.

$$Pout = Voc \times Isc \times FF \qquad (2)$$

with,

Pout: Power generated by solar cell (Watt)
Voc: Open circuit voltage in solar cell (Volt)
Isc: Short circuit current on solar cell (Ampere)
FF: Fill Factor

Value FF can be obtained from the formula:

$$FF = Voc\text{-}\ln (Voc + 0.72) / Voc + 1 \qquad (3)$$

Efficiency of solar PV is a ratio of power that can be generated by solar PV with input energy obtained from solar irradiance. The efficiency used is the instantaneous efficiency of data retrieval.

$$\eta = Output / Input \times 100\% \qquad (4)$$

The electrical energy produced by solar panels can be used directly to a load that requires DC voltage source with a small current consumption. Electrical energy produced by solar PV can be used in cloudy or night conditions, where solar PV cannot be sunlight. Solar PV is connected to electrical energy storage media using batteries. Stability of the storage of electrical energy in the battery is installed a regulator that serves to regulate the charging voltage and control the charging of the battery automatically.

1.2. Biogas power plant

Biogas is a gas produced from anaerobic (fermentation) processes of organic materials such as human waste, household waste and animal waste. Materials that are needed in making biogas are methane and carbon dioxide contained in organic matter. The process of making biogas is organic impurities mixed with clean water, a ratio of 1: 1 water and dirt or can use a ratio of 1: 1.5. The temperature that takes place during the process is 27-38^0 C. The source of the suitable biogas raw material is used in Indonesia, such as; animal and human waste, organic waste, and liquid waste. Biogas generating equipment. There are two types of biogas or digester generating equipment, namely floating type and fixed dome type.

The process of making biogas with the following steps:

1. Mixing cow dung with water until it forms a slurry with a ratio of 1: 1 in a temporary reservoir.
2. Flowing the sludge into the digester through the intake hole. In the first filling the gas faucet above the digester is opened so that the input is easier and the air inside the digester is pushed out. In this first filling, a large amount of cow manure is needed until the digester is full.
3. Adding a starter of 1 liter and fresh rumen contents from cow dung for digester 3.5 - 5.0 m^3. After the digester is full, the gas faucet is closed so that the fermentation process occurs.

4. Disposing of the first gas produced on days 1 to 8 because COis formed2. Whereas on the 10th to 14th days methane is formed (CH_4) and CO_2 begins to decline. At composition CH_4 54% and CO_2 27%.
5. On day 14, the gas formed can be used for generator fuel. Starting on day 14, the digester can produce biogas energy that is always renewable. Furthermore, the digester continues to be filled with cow dung continuously to produce optimal biogas.

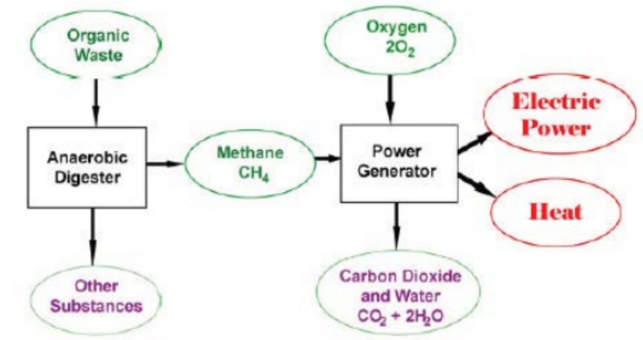

Figure 2. Model of biogas power plant

Calculations to obtain cow manure per day in wet conditions are used with the equation of m-wet dirt = an, where m-wet dirt is the amount of cow dung in wet conditions (kg / day), a is the amount of manure produced by one cow per day (kg / day), and n is the number of cows. Based on the data obtained, the average cow produces as much as 25-30 kg of manure / day. so the minimum m-wet dirt equation is obtained.

$$\text{m-wet dirt} = 25\ n \tag{5}$$

Biogas generator consumption can be calculated to determine how long the biogas generator operates.

$$\text{Operation of biogas generators} = \frac{\text{biogas production}}{\text{biogas generator consumption}} \tag{6}$$

2. Research Method

The research method of the solar PV-biogas hybrid power plant is carried out in several stages to assess the potential for the application of hybrid power plants in rural areas in eastern Java, including; (a) analyze the potential intensity of solar energy that can be converted into electrical energy with a photovoltaic module, (b) analyze the potential of biogas energy sources in the area of East Java, (c) design a solar PV-biogas power plant model, solar PV design using solar modules PV 50 Wp is 2 pieces, so the total power generated is 100 Wp, with a 10 ampere battery charging control. Whereas to convert DC current to AC current for the use of load with an DC / AC 12V / 220V inverter with 900 watts of power capacity (d) design a biogas power plant system, using a digester capacity of 2 m^3 with biogas raw material for cow dung waste. Composition of a mixture of water mixture: cow dung using a ratio of 1: 1 with a temperature of the digester room between 20-45^0 C. Biogas products are converted to using biogas generators with a power capacity of 1000 watts. (e) analyzing the electrical energy produced by solar PV-biogas power plants.

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(a) (b)

Figure 3. Research instrument (a) solar-PV, (b) Biogas power plant

3. Results and Analysis

3.1. Solar PV power plant

Solar PV power plants using solar PV 100 Wp receive sun rays on average for 8 hours (8.00 AM-04.00 PM), but effectively receive optimal sunlight for 4 hours. The intensity of sunlight received by the solar PV surface has an impact on the electricity produced by solar PV. Changes in the electrical power produced by solar PV every hour are not the same which is greatly influenced by the weather and the angle of movement of the sun on the surface of the solar PV. Solar PV electricity in the dry season (April-August) with sunlight intensity (123-1075 W / m^2) produces an electric power variation of 8.12 – 65,63 Watts (figure 5). The lowest electric power of 8,12 watts produced in the morning (08.00 AM) continues to increase until the peak condition is 65.63 watts (12.30 PM), then decreases to the lowest power of 28.19 watts in the afternoon (04.00 PM). The total electricity produced by solar PV during one day irradiation (08.00 AM-04 PM) reaches 1,26 kW. Electrical energy produced by solar PV can be stored in batteries, so that it can be used according to the electrical energy needs of rural communities. The use of solar PV as a hybrid power plant in rural areas in East Java can reduce the use of diesel generators, save on the use of diesel fuel, reduce air pollution due to diesel engine exhaust emissions and are environmentally friendly.

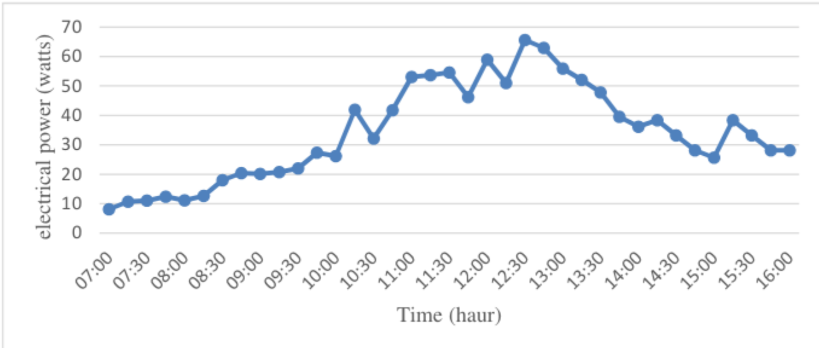

Figure 4. Solar PV power

3.2. Biogas power plant

Utilization of cow manure from rural livestock for raw material for biogas production, the use of biogas as a potential energy source for biogas power plants. Biogas production with a ratio of cow dung and water (1: 1) for raw materials that are fed into the digester. 0.5 m^3 Slurry (cow dung and water) is put into the biogas digester with a capacity of 2 m^3. The biogas production process in the digester begins with the fermentation process by anaerobic bacteria in the digester influenced by several factors, such as; Dilution of cow dung waste as raw material for biogas production, type of bacteria, pH (degree), temperature in the digester, inhibiting elements (detergents, heavy metals, disinfectants, antibiotics) can inhibit bacterial growth in the digester, Comparison of C and N ingredients) Biogas began to be produced on the seventh day, measurement of biogas production for 12 hours produced biogas 0.044 m^3 in the first hour and continued to increase until the 12th hour of 0.127 m^3 (table 1), increase in biogas production because the fermentation process was more perfect. Accumulation of biogas production for 12 hours can produce 0.9678 m^3. While from table 1 biogas production can be calculated per day which can be used as fuel for biogas generators $^{24}\!/_{12}$ x 0,968 $m^3 = 1.936\ m^3$.

Table 1. Biogas production

Time (h)	Biogas Increase (m^3)	Gas Accumulation (m^3)
1	0.044	0.044
2	0.067	0.111
3	0.062	0.173
4	0.061	0.234
5	0.059	0.293
6	0.065	0.358
7	0.067	0.425
8	0.086	0.511
9	0.085	0.596
10	0.120	0.716
11	0.125	0.8408
12	0.127	0.9678

The average biogas production per day (Table 1) from cow dung waste produces biogas 1,936 m^3. While the accumulation of biogas production for 30 days reached 42.92 m^3 (Figure 6). Biogas production began to stop on day 33. The factors that influence biogas production for 30 days are the decrease in water content in the digester, because water plays an important role in microbial movement and growth, nutrient transport, and increases mass transfer of substrate particles. Other study reported that the long fermentation time will cause less biogas produced due to the reduced substrate which is a nutrient for microorganisms [15].

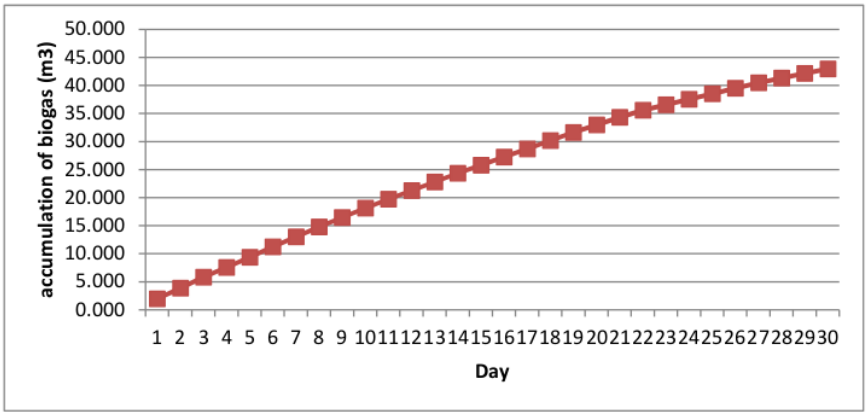

Figure 5. Accumulation of biogas production

The test results biogas power plants using biogas generators using light load of 200 watts, 300 watts, 500 watts and 800 watts require average biogas consumption of 0.22 m^3/min. No-load fuel consumption 0,018 m^3/ minute and increased biogas fuel consumption with the additional load used in the electrical system. While the electrical energy that can be produced from biogas production is,

$$1{,}936\ \mathrm{m}^3\ x\ 4{,}7\ kWh = 9{,}09\ kwh\ /\ day\ ,\ \frac{9{,}09\ Kwh}{24} = 0{,}379\ kW$$

Meanwhile, the efficiency of biogas energy conversion into electrical energy is influenced by the performance of biogas generator generators and the quality of biogas.

Biogas consumption of 0.25 $m^3/_{min}$ with an 800 watts load produces output power of

$$\frac{1{,}936\ m^3}{0{,}25\ m^3}\ x\ 800\ watts = 6{,}195\ kw\ .$$

Increased production of electric power that can be done to increase biogas production according to the needs of electricity used every day.

Table 2. Generator fuel consumption

Load (W)	Biogas consumption (m^3 / min)
0	0.018
200	0.019
300	0.020
500	0.022
800	0.025

3.3 Solar PV-Biogas Hybrid System

Two models of power generation systems that can be used for renewable energy generation systems, solar energy and biogas energy (1) solar PV / solar / grid inverters and (2) solar grid PV / biogas / battery generators / inverters. Solar PV / Grid / inverter power systems can meet the annual electricity demand from every home in rural areas. Solar PV / Grid / Inverter hybrid systems that are used to have excess electricity to the network can be the best choice for electricity generation in rural areas compared to PV systems / biogas / battery / inverter generators. Other sudy, the hybrid solar energy and biomass power plant system uses the strategy of operating solar energy during the day and biomass energy at night is very optimal, where biomass and solar energy plants during operation can complement each [13]. While the hybrid solar PV-biogas model, the use of solar PV 100 Wp produces electricity per day of 1.26 kW enough to meet the electricity needs of every home in rural areas with an average electricity consumption of 1 kWh / day. Whereas to increase solar PV electricity production can be done by adding solar PV panels according to electrical energy needs. The model of solar PV power plants in the eastern Java region of Indonesia can be optimal in the dry season, whereas in the rainy season the performance of solar PV decreases by 50-70%, this is because the production of solar PV electricity is very dependent on the intensity of sunlight. Conditions that are not optimal solar PV systems caused by weather conditions and low sunlight intensity can be overcome using a hybrid system.

The use of biogas power plants from the processing of cattle manure in rural areas as an energy source of electricity generation with an average capacity of cattle waste 125-250 kg / day. The potential of biogas energy produced 1,936 m^3/ day can be converted into 0,0645 kW of electricity. The utilization of the solar PV-biogas power plant model in rural areas in East Java can supply the total electricity needs of 1.26 kW (solar PV) and 0,379 kW (biogas) per day, so that the total electricity supply is 1,639 kW. While the benefits of utilizing renewable energy sources for electricity generation in rural areas, namely; fulfillment of electrical energy needs in rural areas, reduce environmental pollution, and can increase energy independence in rural areas.

The minimum power of the hybrid PV-biogas model is very effective and efficiently applied as a model for small-scale power generation in rural areas. Electric energy consumption per family head is an average of 1 KWh / day with the application of solar PV-biogas hybrid power plants still surplus energy.

4. Conclusion

Utilization of renewable and environmentally friendly energy sources as an energy source for electricity generation in rural areas can reduce environmental pollution. The utilization of cow manure in the countryside as a source of biogas raw material for hybrid solar PV-biogas power plants is very potential to be applied in rural areas of East Java Indonesia. the performance of solar PV power plants is optimal during the dry season, while in the rainy season solar PV performance decreases by 50-70%, so a source of biogas hybrid power plants is needed to support the work of PV solar generation systems. Utilization of renewable energy sources for electricity generation in rural areas can provide benefits to rural communities, such as; fulfillment of electricity needs in rural areas, reduce environmental pollution, and can increase energy independence in rural areas.

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