Comparative efficiency solar panels and wind turbine DC generator as green energy sources in Bangka Island

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Abstract. Renewable energy power generation is a concept of generating electrical energy that is widely applied today. The rapid population growth is proportional to the high demand for electrical energy. There are still a lot of power plants that rely on fossil fuels as a source of energy to drive the turbines. The limitations of fossil energy provide an alternative thought for using renewable energy as electricity generation. Bangka Island is an island with great potential for solar and wind energy. The two energy sources are expected to provide a solution to the scarcity of energy that occurs on the island of Bangka. This research is expected to provide input in solving the problem of the high demand for electrical energy on the island of Bangka and provide an idea that renewable energy is a substitute for limited fossil energy. From each renewable energy generator, research is carried out to obtain the electrical energy produced. The electrical energy data generated by the two power plants will be compared in order to obtain effectiveness and efficiency values. The research was conducted in Bangka district using 50 Wp solar panels and 30 Watt DC generators.

1. Introduction
Bangka Island is an island in Indonesia which is adjacent to Sumatra Island. Bangka is one of the islands with an area of 11,910 km2 and is the largest island in the Bangka Belitung Islands Province. Electrical Energy on Bangka Island is one of them supplied by a steam power plant[1]. The use of fossil energy in producing electricity for the long term is not recommended[2]. Development of renewable energy with the concept of green energy is needed on the island of Bangka. The enormous amount of solar energy with the geographical location of Bangka Island in the tropics is very reliable. Wind energy on Bangka Island is also a renewable energy source that can be used. This much renewable energy should be used as an alternative for producing electricity[3],[4].

The use of solar panels and wind turbine generators is one way to produce electricity[5]. This study will provide an overview of the most suitable power plants used on the island of Bangka by comparing the efficiency of electricity produced between solar power plants and wind power plants[6]. The solar panel used is the Photovoltaic Module Model ST-50-P6 type polycrystalline with a capacity of 50 Wp[7]. The generator used generates a DC electric current with a maximum capacity of 30 watts. Comparison of efficiency in the form of a percentage will give an idea of the feasibility of solar panels and wind turbine generators developed on Bangka Island[8],[9].

Retrieval of energy data generated by solar panels and wind turbine generators is done in the parking lot of the Faculty of Engineering, Bangka Belitung University in 3 days in order to obtain accurate data. The data obtained are data voltage, current, power and energy with a measurement time
of 24 hours [10]. The load used is a DC lamp with a capacity that has been adjusted. The energy produced will be compared with the capacity of each generator in order to obtain the value of efficiency and then compare the level of efficiency [11].

2. Basic Theory
This study aims to produce a comparison of the efficiency of the use of solar panels and wind turbine generators as alternative green energy on Bangka Island. The results obtained will be the reason for the development of alternative green energy with high efficiency [12].

2.1. Solar Panel
The solar panel is a device that can convert sunlight energy into energy with a principle called the photoelectric effect. The main component of solar panels is silicon which functions as a photoelectric effector by converting light energy into electrical energy [13][14]. In general, solar panels have two types, namely monocrystalline and polycrystalline with their respective efficiency standards. The shape of the solar panel can be seen in the following image:

![Polycrystalline type of solar panels](image1)

Figure 1. Polycrystalline type of solar panels

The working principle of solar panels by producing voltage (V) and will produce current (A) if connected to the load. The total energy produced by solar panels depends on the capacity of the solar panels and the intensity of sunlight per hour [15].

2.2. Wind Turbine
A wind turbine is a windmill that functions as a generator driving at a speed determined to produce electrical energy [16]. Wind turbines are divided into two types according to the direction of rotation, namely Horizontal Axis Wind Turbine (HAWT) with a working turbine system rotating on the horizontal axis and Vertical Axis Wind Turbine (VAWT) with a working turbine system rotating on the vertical axis. In this research, the type of turbine used is the HAWT type as shown below:

![HAWT type of wind turbine blades](image2)

Figure 2. HAWT type of wind turbine blades

The use of HAWT type turbines is expected to provide a greater boost so that the generator rotation can be achieved in accordance with the desired rpm.

2.3. DC Generator
The generator used generates DC electric current so that the hybrid system with solar panels is simpler and does not require an inverter[17]. The capacity of this DC generator is 30 watts with the required rpm is 500 - 1000 rpm and can produce a voltage of 12 - 90 volts. The power generated depends on the rpm obtained by the generator according to the load used. Generator and turbine synchronization is carried out horizontally without the use of gearbox as regulator of the generator rotation. Tuggi wind turbine generator pole about two meters from the ground level so that it allows the propeller on the turbine can get enough wind pressure to turn the generator. The generator used is as shown below:

![Figure 3. DC generator](image)

The electricity generated by the generator will be channeled to the solar charger controller using the same device as the solar panel as an output voltage to the load regulator.

2.4. Measurement Equipment
Other equipment used is measuring the output of each power plant such as a volt meter, amperes meter, energy meter, solar charger controller (SCC) and several other mechanical equipment. This supporting equipment functions to provide the value of the electrical energy output of each power plant so that it can compare the efficiency of the two power plants for future development.

In calculating the output of each generator, the following simple calculation is used:

\[ P = V \times I \]  \quad \text{(1)}

Description: \( P \) = Power; \( V \) = Voltage; \( I \) = Current; \( W \) = Energy

Meanwhile, to find the resulting current is to provide a load according to the ability of the generator as in the following calculation:

\[ I = \frac{V}{R} \]  \quad \text{(2)}

Description: \( R \) = Resistance

In this case the load used is in the form of resistors or lamp loads according to the ability of the generator to avoid overload or less maximum current.

3. Results and Discussion
Solar power plants are divided into two systems, namely stand alone generator systems and generators which are connected to the user grid (utility grid)[18]. The scheme of solar electricity generation can be described as follows:

![Figure 4. Schematic of a solar power plant](image)

Figure 4. Schematic of a solar power plant

![Figure 5. Schematic of wind power generation](image)

Figure 5. Schematic of wind power generation
The scheme used in this study is a stand alone solar panel scheme that is not connected to the user's network. The energy produced by solar panels will be stored in batteries. The wind turbine generator system scheme is the same as the solar power generator scheme because the generator used produces DC electric current. For schematic drawings can be seen in Figure 5 above.

Retrieval of voltage, current, power and energy data is carried out for three days at the same time. The data obtained will be accumulated as a percentage of the efficiency of each plant. The first data is a graph produced by solar panels for three days as follows:

![Figure 6. (a) Graph of voltage over time, (b) Graph of current against time](image)

The chart data above illustrates the voltage and current that a solar panel produces over three days compared to time. The colored lines contained in the graph are described as the day of data collection. The blue line is the first day's data, the red line is the second day's data and the green line is the third day's data. The average voltage generated the first day is 13.134 Volts with an average current of 0.657 Amperes. Whereas on the second day the average voltage generated was 12.356 with an average current of 0.303 Amperes. The average voltage on the third day is 14.329 Volts with an average current of 0.941 Amperes. Power and energy produced by solar panels can be seen in the following graph:

![Figure 7. (a) Power graph based on time, (b) Graph of total energy](image)

The power and energy produced by the solar panel is an output that determines the efficiency of the solar panel. Similar to the line code on the voltage and current data, the blue line represents the first day, the second day red, and the third day green. From the picture above it appears that the energy data generated by the third day is higher compared to other days. The average power produced on the first day is 8.76 watts with total energy is 83.5 watts with an average energy / hour is 8.35 watt / h with a measurement time of 10 hours. So that the efficiency of the comparison of solar panel specifications with measured data in the field on the first day as in the following calculations:
The second day measurement the average power produced by solar panels is 3.77 watts with a total energy of only 34.6 watts with an average energy / hour of 3.46 watt / h with a measurement duration of 10 hours. So that the efficiency of the comparison of solar panel specifications with measured data in the field on the second day as in the following calculation:

\[
\% \text{ Efficiency of Day 1} = \frac{\text{Measured data}}{\text{Solar Panel Specifications}} \times 100\% = \frac{8.35}{50} \times 100\% = 16.7\%
\]

The third day measurement obtained the highest data from the previous day ie the average power produced by the solar panel was 13.38 watts with a total energy up to 124 watts with an average energy / hour was 12.4 watts / h with a measurement length of 10 hours. So that the efficiency of the comparison of solar panel specifications with measured data in the field on the third day as in the following calculation:

\[
\% \text{ Efficiency of Day 2} = \frac{\text{Measured data}}{\text{Solar Panel Specifications}} \times 100\% = \frac{3.46}{50} \times 100\% = 6.92\%
\]

From the overall measured data obtained the efficiency of solar panels by doing an average of three percentage measurements and the percentage obtained efficiency of solar panels on Bangka Island is 16.14%.

Data generated by the wind turbine generator during three measurements produced different data variations. Graphs of voltage and current measurements produced by wind turbine generators can be seen in the following figure:

![Figure 8. (a) Time-based voltage graph, (b) Time-based current graph](image)

Measurements made to obtain voltage and current data generated by wind turbine generators are carried out for three days. Voltage and current data obtained vary according to the state of the wind at the time of data collection. The blue line on the voltage and current graph is the measurement made on the first day, the red line on the second day and the green line on the third day. The first day the average voltage generated by the wind turbine generator was 6.36 volts with an average current of 0.13 amperes and an average generator rpm of 292.4 rpm. The average voltage, current and rpm produced on the second day are 5.09 volts, 0.08 amperes and 236.4 rpm. While on the third day it was 3.34 volts, 0.06 amperes and 145.1 rpm.

The voltage and current data above will produce voltage and total energy data generated by the wind turbine generator as shown in the following graph:
Figure 9. (a) Time-based power graph, (b) Time-based total energy graph

Similar to the voltage and current graph produced by the wind turbine generator, the blue line on the power and energy graph is the result of measurement on the first day, the red line is the measurement data of the second day and the green color line is the measurement data on the third day. Energy graph displays the total energy produced on the first day is higher than other days. This can be seen from the average power produced on the first day is 2, the total energy produced during 24 hours is 56 watts so that the average energy / hour is 2.3 watts / h. The efficiency value of the comparison of generator specifications with measured data in the field on the first day as in the following calculation:

\[
\% \text{ Efficiency of Day 1} = \frac{\text{Measured data}}{\text{Generator Specifications}} \times 100\% = \frac{2.3}{30} \times 100\% = 7.6\%
\]

Measurements made on the second day give lower results than the first day. This is evidenced by the total energy produced on the second day measurement for 24 hours amounting to 33.7 watts with an average energy / hour of 1.4 watts / h in order to obtain the value of the comparative efficiency of the generator specifications with measured data in the field on day two as in the following calculation:

\[
\% \text{ Efficiency of Day 2} = \frac{\text{Measured data}}{\text{Generator Specifications}} \times 100\% = \frac{1.4}{30} \times 100\% = 4.6\%
\]

The results of the third day wind state measurement are less than the first day measurement so that the energy produced is the lowest than the previous day's measurement. This can be seen in the total energy obtained for 24 hours is 27.6 watts with an average energy / hour of 1.15 watts so that the efficiency of the generator specifications compared with the data measured in the field on the third day as in the following calculation:

\[
\% \text{ Efficiency of Day 3} = \frac{\text{Measured data}}{\text{Generator Specifications}} \times 100\% = \frac{1.15}{30} \times 100\% = 3.8\%
\]

From the overall measured data, the efficiency of the wind turbine generator is obtained by making an average of three percentage measurements and the percentage of efficiency of the wind turbine generator on Bangka Island is 5.3%.

4. Conclusions
This study only discusses the comparison of the percentage of efficiency between solar panels with a capacity of 50 Wp with a 30 Watt DC generator capacity. Measurements were made in one place by assuming that the state of the sun's intensity and wind speed were the same throughout the Bangka Island. From the results of the comparison between each power plant, it was found that the energy efficiency produced by solar panels is greater than the use of wind turbine generators. This is evidenced by the percentage of energy efficiency produced by solar panels amounting to 16.14% and the percentage of energy efficiency produced by wind turbine generators is 5.3%. It can be concluded that a renewable power plant that is feasible to be developed on Bangka Island is a solar power plant.
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