



Application of Solar Powered Wheelbarrow for Energy Saving Cooking Process

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Abstract. The development of solar energy to meet the various needs of human life is currently increasing. Solar Power Plant technology has also been widely introduced and applied in the community. The research is conducted to apply Solar PV technology which is used for energy-efficient cooking processes. Solar PV is the main component of the solar power plant that is used as an energy source to supply electricity to wheelbarrows. The dimensions of the wheelbarrow used are 180 cm long, 216 cm wide, and 150 cm high. The solar panel is monocrystalline type with power capacity of 4 x 100 Wp. Other components includes 65 Ah VRLA Battery, 1000 W Inverter and 10 A Battery Control Regulator. This wheelbarrow has an electric stove and heater with an average 200 Watt power rating, also equipped with a 10 Watt lamp and a socket. This solar powered wheelbarrow is used for cooking approximately 6 hours with continuous use and longer for light or medium usage.

1. Introduction

Indonesia is a tropical country traversed by the equator which has a high irradiation rate. Solar irradiation in Indonesia averages 4.8 KWh/m² so that it has the potential to generate a total of 112,000 GWp. But the potential that is utilized is still little around 10 MWp [1]. However, many areas in Indonesia are not yet electrified, due to remote areas and not covered by PLN electricity distribution. So it need a power plant that is easy to build and easy to move, that is by implementing a Solar Power Plant (PLTS). PLTS is a power plant that converts photon energy from the sun into electrical energy. Electricity is generated using solar panels that work by utilizing the photovoltaic effect in the form of solar cells or solar cells made of single crystalline silicon. The electricity generated is in the form of DC voltage and current [2].

Food traders in Indonesia are very diverse, ranging from street food vendors, stalls to restaurants. The main equipment needed by food traders is a stove. The stoves generally use biomass charcoal and LPG gas, which is a type of fossil fuel. Fossil fuels are getting depleted and will run out in a certain period of time so that a solution is needed to replace fossil fuels in order to prevent energy crisis in the future. One of the solution is using renewable energy such as solar energy because it has unlimited amount of availability and it's environmentally friendly. In this modern era, electric stoves has been widely used for the cooking process especially in urban areas because of its practicality. However electric stoves require a lot of energy when operated, so they are less economical than fossil fuels. Therefore, the electric stove needs to be given a little modification to reduce the energy consumed. Solar energy that can be converted into electrical energy is suitable to supply electric stove and it can save more energy consumption. Utilization of solar energy can done using the panel solar (solar module). Solar panels will converting radiation from the sun into electrical energy directly, so it can be

applied to meet household electricity needs [3]. The use of solar-powered electric stoves has also been used for written batik craftsmen by using two glow plug heaters, 4 solar panels with a capacity of 120 Wattpeak each [4].

The purpose of this study is to design and built solar powered wheelbarrow for energy saving cooking process application. The wheelbarrow is using electric stove and heater to serves various food and beverages that can be applied for the food trader. Hopefully with this research, the use of renewable energy, especially solar energy, can be developed continuously.

2. Research Method

The research will be carried out at the Jember State of Polytechnic and scheduled for four months with a following stages :

2.1. Calculation of cooking load

To calculate the total load energy requirements, the following equation can be used [5] :

$$W_b = P_b \times T_{lp} \dots\dots\dots 1$$

with :

W_b = Total Energy Load (kWh)

P_b = Power Load (watt)

T_{lp} = duration (hour)

2.2. Determine the dimensions of the wheelbarrow

The wheelbarrow is designed to have dimensions of length x width x height of 140 cm x 216 cm x 150 cm, as shown in Figure 1.

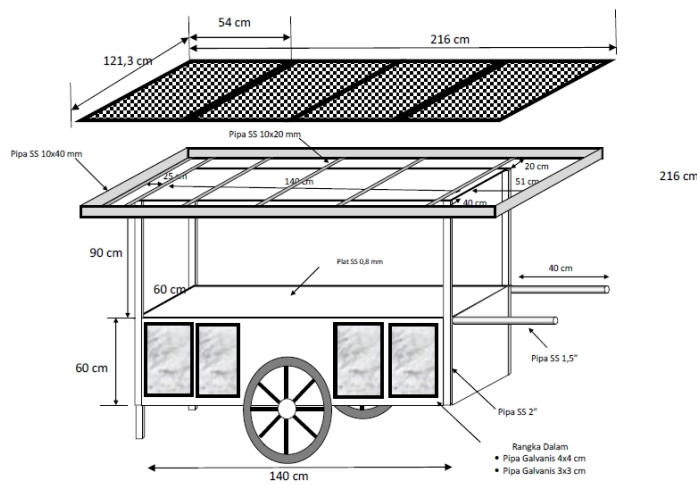


Figure 1. Wheelbarrow design

2.3. Install the appropriate Solar Power Plant

The type of Solar Power Plant installation is an Off-Grid system, where this system uses solar panels (photovoltaic panels) to produce electricity that is environmentally friendly and emission-free. The installation of this Solar Power Plant is based on the total electricity load that must be borne by the electric stove. The Solar Power Plant design include :

- Requirement of Batteries and Solar Panels

Batteries are used to store electrical energy from solar panels. To find out the battery requirements, it is necessary to determine the value of the power generated from the solar panels needed by using equation 2.

$$P_t = \frac{W_b (Wh)}{T_p (hour)} \dots\dots\dots 2$$



with :

- Pt = Generated Power from solar panel (watt)
- Wb = total energy load (Wh)
- Tp = charging periode (hour)

Battery energy requirements are calculated using equation 3 :

$$Wbt = Wb \cdot \left(\frac{Tlp - Ts}{Tlp} \right) \dots\dots\dots 3$$

with :

- Wbt = total battery energy usage (Wh)
- Wb = total energy of load (Wh)
- Tlp = using periode (hour)
- Ts = charging periode (hour)

- Inverter Requirement
Inveter changes the DC voltage of the battery to AC voltage, with the power requirement of 3 to 4 times the load power.
- Design of Solar Power Plant System
The Solar Power Plant design is an Off Grid system with the main components including 100 Wp solar panels, BCR, batteries, inverters. BCR functions as a controller for the entry and exit of electrical energy into batteries and loads.

2.4. Functional and performance test

The functional test of the tool is carried out to determine whether the components of the Solar Power Plant as mentioned are functioning properly. While the performance test is to determine the level of efficiency of the tool. The material used in the testing tool is clean water for cooking. The parameters used in testing tools include:

2.4.1. The power that can be generated and the energy supplied by Solar Power Plant.

The power and energy produced by Solar Power Plant must be able to bear the energy needs for the heating process.

2.4.2. Battery life testing

This test is conducted to see the durability of the battery supplied by the solar panels to be able to overcome the energy load required.

3. Result

Research activities that have been carried out have obtained the following results:

3.1. Calculation of total load energy requirements:

It is known, the load power in the form of an electric stove and heater is 200 W and it is turned on for approximately 6 hours in one day for the needs of boiling water, so that the total energy required is calculated according to equation 1, which is 1200 Wh. The correction factor used is 15%, so the correction power becomes 1380 Wh or 1,38 kWh.

3.2. Wheelbarrows Dimensions

The wheelbarrow has been made to have dimensions of length x width x height of 140 cm x 216 cm x 150 cm. The solar panels are placed on the roof of the cart which also functions as a protection in case of hot sun or rain. The center of the cart is placed for cooking utensils and ingredients and an electric

socket as a place for electrical terminals. The lower part is used to store the supporting components for PLTS such as batteries, inverters and solar controllers.

3.3. Determination of the Off Grid Solar Power Plant installation

– Requirement of Batteries and Solar Panels

Batteries are used to store electrical energy from solar panels. The cooking process takes place with an average duration of 6 hours of use per day. It is assumed that the charging process is only 4 hours, so that if there is an overcharging the system will get additional power. The total power generated by solar panels is 345 W. The solar panels used have a maximum power of 100 W_p, so 4 solar panels are needed. The type of solar panel used is monocrystalline which has an efficiency of 20%. To maximize the power generated, 4 solar panels are installed in parallel, each having a power of 100 W_p. The total power of the solar panels used is 400 W_p, so the total energy that can be supplied by the solar panels with a 4 hour irradiation time is 1600 Wh.

– Battery energy requirements

Calculation using the formula in equation 3 shows the battery energy requirement of 1600 Wh. Assuming the usage time (T_{lp}) is carried out for 6 hours, the charging time (T_p) is 4 hours, the total battery energy used is:

$$W_{bt} = 1600 \text{ Wh} \cdot ((6 \text{ h} - 4 \text{ h})) / (6 \text{ h}) = 533 \text{ Wh}$$

The battery used has a capacity of 12 V - 65 Ah which has a storage energy of 780 Wh. So the number of batteries used using equation 4 results:

$$n = W_{bt} / W_b = (533 \text{ Wh}) / (780 \text{ Wh}) = 0.68 \text{ pieces} \approx 1 \text{ piece}$$

The battery used in this installation has a specification of 12 volts 65 Ah.

– Inverter Requirement

The load power requirement used is 345 W so an inverter is used which has a power value above the load power value, which is 1000 W.

- The PLTS installation integrated with a wheelbarrow has the following specifications The 100 WP solar panels are 4 pieces, A Battery with capacity of 12 V - 65 Ah, The inverter which has a power of 500 Watts, and The solar controller that is capable of flowing currents of up to 10 A

The wheelbarrow that has been made is then integrated with the appropriate Solar Power Plant system so that the cooking process uses an electric stove and water heater with a source originating from Solar Power Plant, as shown in Figure 2



Figure 2. Solar Powered Wheelbarrow

The results of the functional tests that have been carried out show that all the components of this solar powered wheelbarrow are functioning properly. This cart is able to support the weight of the Solar

Power Plant and the cooking utensils used. When pushed, the cart also remains stable and easy to move. The integrated Solar Power Plant system is also capable of supplying electricity for cooking utensils in the form of electric stoves and water heaters. The battery used is also capable of storing electrical energy generated by solar panels so that during cloudy conditions or at night when there is no sun it can still supply electrical energy.

The performance test results of the Solar Power Plant system that have been made are strongly influenced by the conditions of solar radiation intensity. Solar irradiation when testing the 400WP Off Grid Solar Power Plant can be seen in Figure 3.

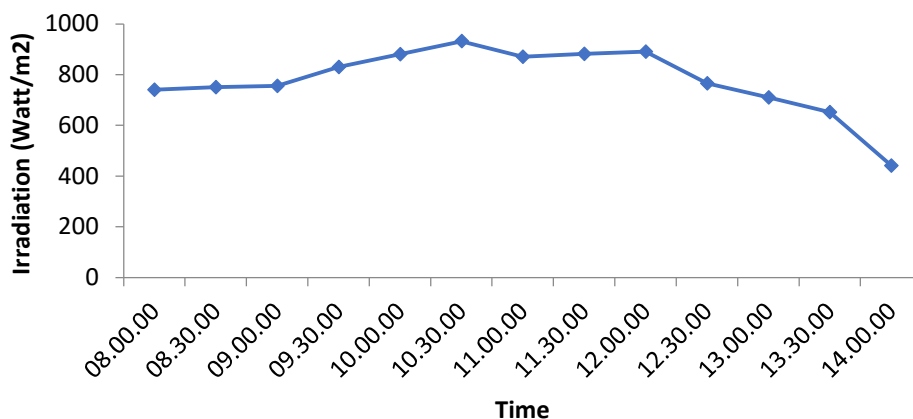


Figure 3 The radiation intensity at the time of measurement

The solar irradiation at the time of this test was classified as bright, it was possible that the solar panels could produce optimum electrical energy. The highest irradiation value was at 10:30 with an irradiation amount of 932 W / m² and the lowest irradiation value was at 14:00 with an irradiation amount of 442 W / m². The intensity of solar radiation in this test is quite good because it can be stable above 800 W / m² for about 3 hours.

The comparison of the energy produced by the 400WP Off Grid Solar Power Plant with the energy consumed by the electric stove and water heater for 6 hours of work can be seen in Figure 4.

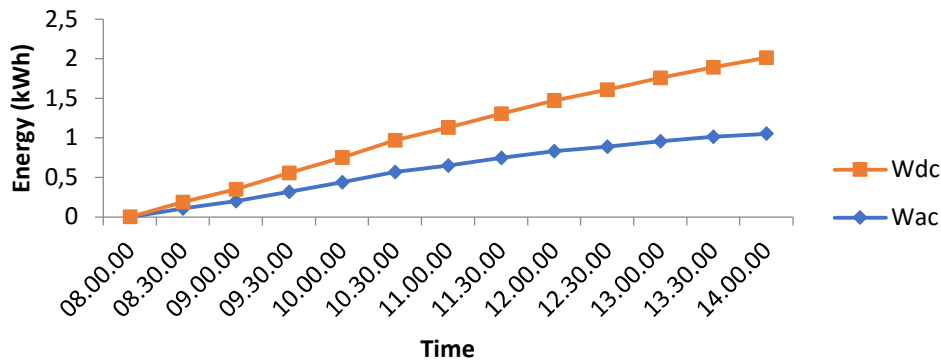


Figure 4. Comparison chart of energy produced by 400WP Off Grid Solar Power Plant with the energy used by electric stoves and heater

Figure 4 shows a graph of the energy produced by the 400 WP Off Grid Solar Power Plant and a graph of the electrical energy consumed by the electric stove and heater. The graph above shows that the energy produced by the 400WP Off Grid Solar Power Plant can exceed the energy used by electric stoves and heaters. Excess electrical energy generated by solar panels can be stored in batteries. Storage of electrical energy in batteries for backup energy on the next day of use in case of less sunny weather. So that the electrical energy stored in the battery can be used at that time. The electrical energy produced by the 400 WP Off Grid Solar Power Plant for 6 hours is 1.053 kWh and the electric energy needed by the electric stove for 6 hours is 0.96 kWh. The excess electrical energy produced by Solar Power Plant is 0.093 kWh and this electrical energy is stored in the battery. With these conditions, the electric stove and heater can produce heat as desired.

Testing the resistance of the battery on the 400 WP Off Grid Solar Power Plant can be seen from the results of the DC side inverter input voltage shown in Figure 5. It shows that Solar Power Plant can charge electrical energy to the battery.

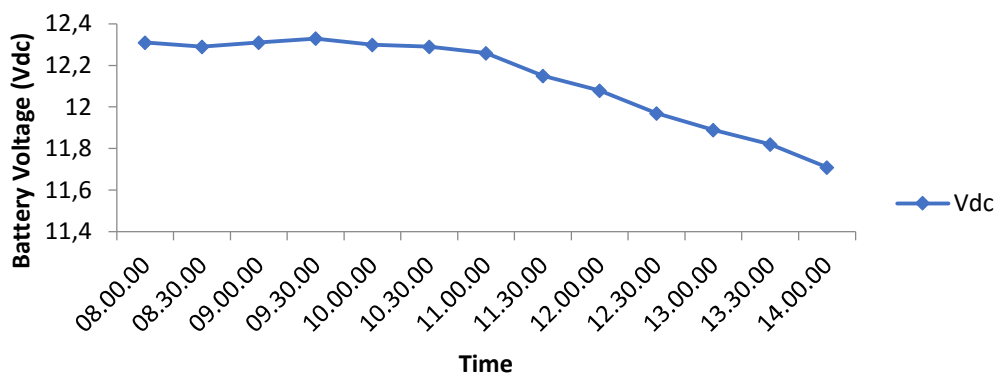


Figure 5 Graph of battery testing on the Solar Power Plant system

In Figure 5 it can be seen that the voltage on the battery is experience fluctuation. The battery voltage is greatly influenced by the output voltage of the solar panel, the greater the panel output voltage, the higher the battery voltage and vice versa. The inverter input voltage at 08:00 having a voltage of 12.47 volts and at 14:00 having a voltage of 11.74 volts. Charging the battery by the solar panel lasts until 11:30 a.m., where the inverter input voltage shows 12.15 Volt. After 6 hours the voltage has decreased until 11.74 Volt at 14:00 which is the lowest number, this is because the intensity of the sun has also decreased.



4. Conclusion

Based on the results of the research that has been done it can be concluded that:

- The solar powered wheelbarrow is able to support the load of the Solar Power Plant components and the cooking utensils used, besides that the cart also remains stable and easy to move.
- The Solar Power Plant installation integrated with a wheelbarrow has specifications, including 4 solar panels of 100 WP, batteries with a capacity of 12 V - 65 Ah, inverters with a power of 500 watts, and a solar controller capable of flowing currents of up to 60 A.
- The energy produced by the 400WP Off Grid Solar Power Plant can exceed the energy used by electric stoves and heaters. Excess electrical energy generated by solar panels can be stored in batteries.
- The battery used can survive the cooking process for 6 hours of use in one day.

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