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Application of Solar Powered Wheelbarrow for Energy Saving Cooking Process

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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 found and applied in the community. The research conducted is the application of PV mini-grid technology which is used for energy-efficient cooking processes. Solar Power Plant 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 used has an installed power capacity of 4 x 100 Wp, a Polycristaline type. Other PLTS components include 100 Ah VRLA Battery, 1000 W Inverter and 10 A Battery Control Regulator. This wheelbarrow has an electric stove with a 300 Watt power rating and is equipped with a 10 Watt lamp and a socket. This wheelbarrow is used for cooking for approximately 4 hours with continuous use and longer for light or medium use.

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/m^2 so that it has the potential to generate a total of 112,000 GWp. But the potential that is utilized is still a 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 we need a power plant that is easy to build and easy to move, namely 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 used 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, so that in the future there is no energy crisis. One solution is the use of solar energy, which is classified as renewable energy, because it has unlimited energy and is environmentally friendly. In this modern era, there are many who provide innovations in making food heating that is more hygienic and environmentally friendly. Like a food warmer using an electric stove that can be used by traders. 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 power needed and think about the energy source consumed. Solar energy as a source of electrical energy that meets the needs of an electric stove is certainly more environmentally friendly, cleaner, and a source of energy that is used sustainably. 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 an electric stove using a power source from solar panels. This stove is expected to be applied in a wheelbarrow that serves various food and beverages. In addition, with this research, it is hoped that the use of renewable energy, especially solar energy, can continue to be developed.

2. Research Method

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

a. Calculation of cooking load

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

$$W_b = P_b \times T_{lp} \quad \text{..... 1}$$

with :

W_b = Total Energy Load (kWh)

P_b = Power Load (watt)

T_{lp} = duration (hour)

b. 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.

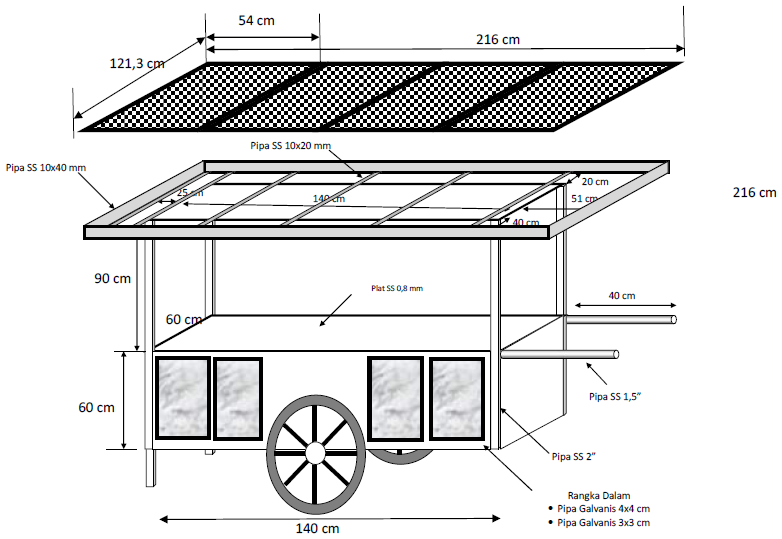

Figure 1. Wheelbarrow design

c. Install the appropriate Solar Power Plant

The type of PLTS 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 PLTS installation is based on the total electricity load that must be borne by the electric stove. The planned PLTS components 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.

$$P_t = \frac{Wb\ (Wh)}{Tp\ (hour)} \quad \text{..... 2}$$

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 :

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

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.

d. Functional and performance test
The functional test of the tool is carried out to determine whether the components of the PLTS 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:
   a. The power that can be generated and the energy supplied by PLTS
      The power and energy produced by PLTS must be able to bear the energy needs for the heating process.
   b. 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:

1. Calculation of total load energy requirements:
   It is known, the load power in the form of an electric stove is 160 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 960 Wh. The correction factor used is 15%, so the correction power becomes 1104 Wh or 1.1 kWh.
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. 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 276 W. The solar panels used have a maximum power of 100 Wp, so 3 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 Wp. The total power of the solar panels used is 400 Wp, 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 (Tlp) is carried out for 6 hours, the charging time (Tp) is 4 hours, the total battery energy used is:

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

  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:
  $n = Wbt / Wb = (533\ Wh) / (780\ Wh) = 0.68\ pieces \approx 1\ piece$
  The battery used in this installation has a specification of 1 12 volts 65 Ah.
- Inverter Requirement
  The load power requirement used is 276 W so an inverter is used which has a power value above the load power value, which is 500 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 60 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 PLTS, as shown in Figure 2

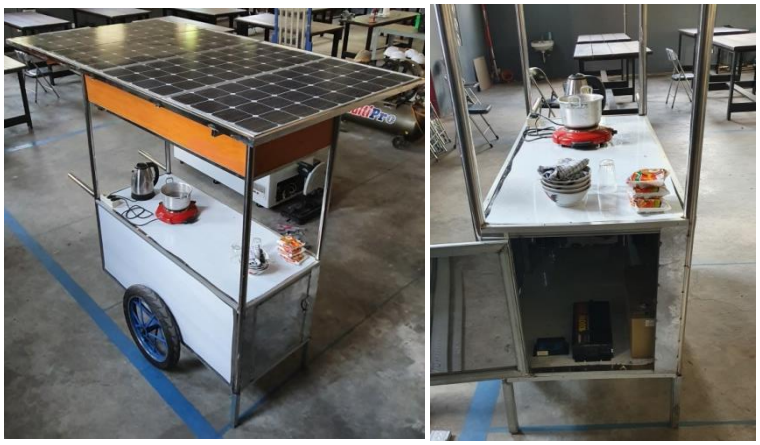

Figure 2. Solar Powered Wheelbarrow

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 PLTS and the cooking utensils used. When pushed, the cart also remains stable and easy to move. The integrated PLTS 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 PLTS system that have been made are strongly influenced by the conditions of solar radiation intensity. Solar irradiation when testing the 400WP Off Grid PLTS can be seen in Figure 3.

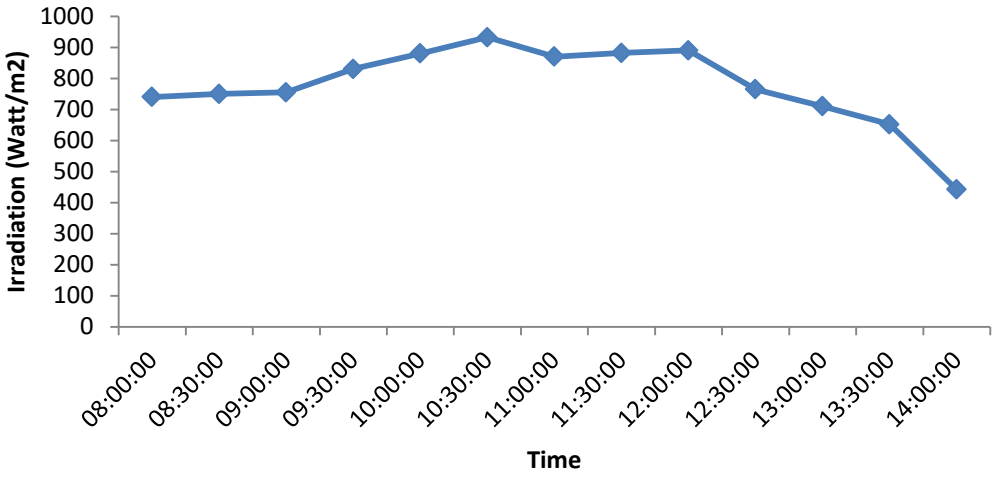

Figure 3 The radiation intensity at the time of measurement

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 PLTS with the energy consumed by the electric stove and water heater for 6 hours of work can be seen in Figure 4.

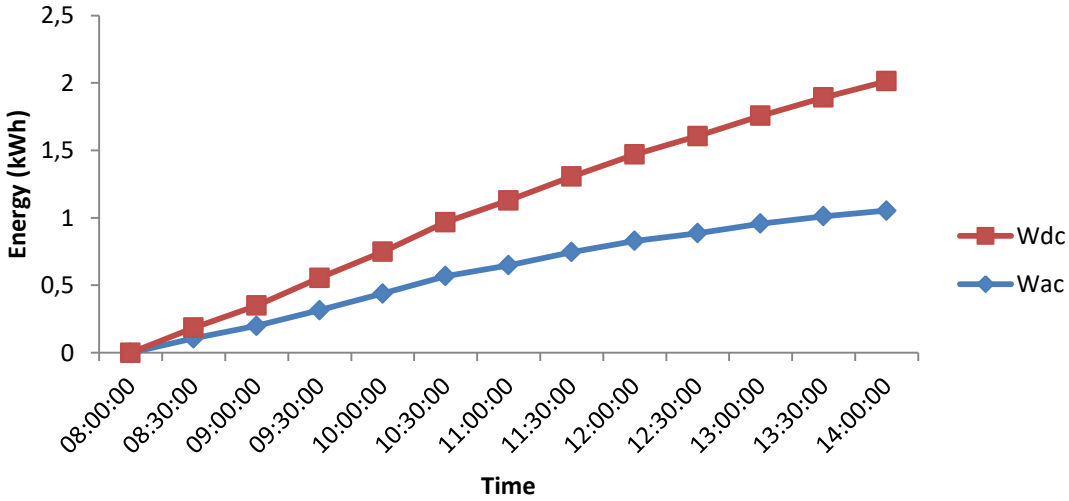

Figure 4. Comparison chart of energy produced by 400WP Off Grid PLTS with the energy used by electric stoves and heater

Figure 4 shows a graph of the energy produced by the 400WP Off Grid PLTS 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 PLTS 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 400WP Off Grid PLTS for 6 hours is 1.053KWh and the electric energy needed by the electric stove for 6 hours is 0.96KWh. The excess electrical energy produced by PLTS is 0.093KWh 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 400WP Off Grid PLTS can be seen from the results of the DC side inverter input voltage in Figure 5 that the results from PLTS can charge electrical energy to the battery.

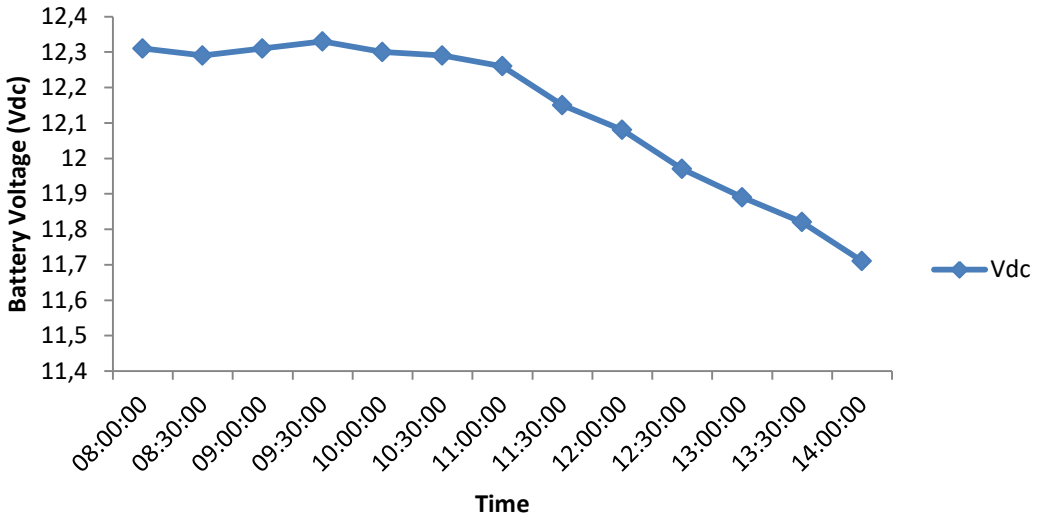

Figure 5 Graph of battery testing on the PLTS system

In Figure 5 it can be seen that the voltage on the battery has decreased and increased. 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 can be seen starting 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 the number 12.15 Volt. After that the voltage has decreased until 14:00 which shows the lowest number, namely 11.74, 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:

a. The solar powered wheelbarrow is able to support the load of the PLTS components and the cooking utensils used, besides that the cart also remains stable and easy to move.
b. The PLTS 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.
c. The energy produced by the 400WP Off Grid PLTS can exceed the energy used by electric stoves and heaters. Excess electrical energy generated by solar panels can be stored in batteries.
d. The battery used can survive the cooking process for 6 hours of use in one day.

5. Refference

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