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Development of a Household Solar Power Plant: System Using Solar Panels

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Abstract. The purpose of this study was to find a model system of power generation by using solar-cells for house. The research was a realization of concern in overcoming the electricity energy crisis. Solar panels, inverters, batteries, and solar charge controllers were used to support on this study. Polycrystalline solar panels with 4 × 50Wp power were chosen to generate energy. The output voltage ranges from 14.8 to 17.5 V DC (direct current) per panel with a capacity of 2 × 70 Ah. Battery capacity of 24 volts was connected in series with an inverter of 1000 watts. The result of the study showed the voltage output of the solar panels was at maximum average of 30.2 V. The distribution of batteries charging used a solar charger controller at a voltage of 24.5 volt DC. The measurement of voltage resulted at the inverter output from 24 volt DC to converse of 220 volt AC (alternating current) without load. Voltage conditions as outputs of solar panels reach maximum voltage during the day from 10:00 am to 1:00 pm Western Indonesia Time (WIB) and it begin down until 6:00 pm. The design greatly influenced the performance of solar power plants.

1. Introduction

The energy is needed to increase with the advancement of technology year to year. Excessive use of energy can lead to energy depletion such as non-renewable such as crude oil, coal, and natural gas. Human energy needs continue to increase. Humans are trying to find alternative energy that is environmentally friendly as well as solar energy. SEC (State Electricity Company) as a provider of electricity services uses fossil fuels to drive turbine generators. Until now there are still areas that have not been served electricity by SEC. so it needs to be sought by researchers to find suitable alternative energy. Therefore researchers effort to find an alternative energy source, making a system of generating electricity from solar panels. Thus dependence on SEC electricity sources can be overcome. With this phenomenon, the researchers try to use solar energy as an energy source to produce electricity. Solar cells (photovoltaic cells) are devices that can convert solar energy into electricity. The solar panels are semiconductor devices consisting of *p*-*n* (positive-negative) junction diodes. Intersections direct electrons transferred from *n*-type semiconductors to *p*-type semiconductors and vice versa for polar movements [1]. Based on the explanation, electrons and polar movements produce photogeneration as shown in Figure 1.

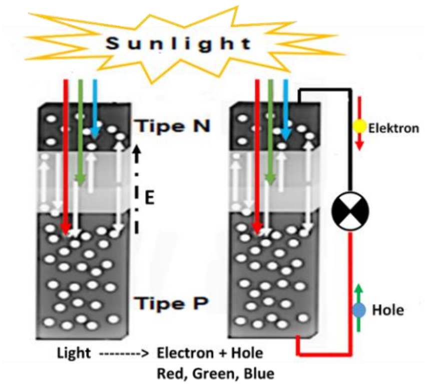

Figure 1. Photogeneration process [1].

The basic characteristics of solar panels influence parameters of solar panels or photovoltaics to produce optimal electrical energy - parameters as a reference to be used to determine the performance of solar panels in generating electricity [2]. The graph of the I-V (current-voltage) solar panel parameter is given in Figure 2.

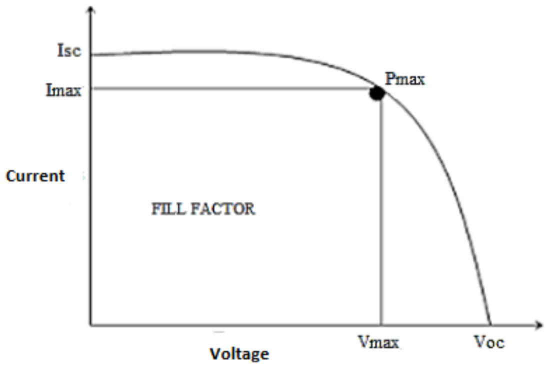

Figure 2. The relation between current (I) vs voltage (V) to get a maximum power output of a solar panel [2].

Short Circuit Current (I_{SC}) is defined as the maximum current output from a solar panel that is released without a hitch or a shortcut. On the other hand, Open Circuit Voltage (V_{OC}) is the maximum voltage that can be achieved by a solar panel without load (no current from the solar panel to load) [3]. The high temperature in solar panels, caused by waste heat generated due to absorption of solar radiation. From radiation falling to Photovoltaic (PV) panels, only 20% of the solar energy event is converted to electricity [4]. The rest of the department section is turned into heat. As a result, the accumulation of heat energy increases the operating temperature in the PV panel, due to a decrease in its electrical efficiency. PV panel conversion efficiency is reduced by approximately 0.40 to 0.50% for each increase in temperature degree [5-6].

However, all data rarely fulfil actual sun conditions because it depends on the specific climatic conditions of each location. This study looks at voltage, PV cells have an important role in controlling the output of temperature coefficients from V_{OC}, P_{max} and Fill Factor (FF) are recognized negatively, while positive for I_{SC} [7]. The maximum power point (V_{mpp} and I_{mpp}) on the I-V curve is an optimal operation where the optimal power is generated by solar panels when loaded. Maximum power output can be calculated by equation (1).

$$P_{max} = V_{oc} I_{sc} \mathrm{FF} \tag{1}$$

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where P_{max} is the maximum power point (MPP), V_{oc} is the open circuit voltage, I_{sc} is the open circuit current and FF is the Fill Factor, which is a parameter that affects the maximum power of the solar panel and also the quality and can be calculated according to equation (2). The important characteristic of FF is written as equation (3).

$$\mathrm{FF} = \frac{P_{max}}{V_{oc} I_{sc}} \tag{2}$$

$$\frac{V_{mpp} I_{mpp}}{V_{oc} I_{sc}} \; FF = \frac{V_{mpp} I_{mpp}}{V_{oc} I_{sc}} \; \frac{P_{max}}{V_{oc} I_{sc}} \tag{3}$$

where V_{mpp} is the maximum voltage and I_{mpp} is the maximum current. The power can be calculated using equation (4).

$$\mathrm{P} = \mathrm{V} \cdot \mathrm{I} \tag{4}$$

where P is the power in Watt, V is the voltage in Volt, and I is the current in Ampere.

Solar panels are assembled devices of photovoltaic cells that convert sunlight into electricity. However, with advancements in commercial solar panel technology having a 15% efficiency, it is one of the main reasons why the solar energy industry still cannot compete with fossil fuels. Commercial solar panels rarely exceed the efficiency of 20%. Photovoltaic cells, such as batteries, produce direct current, which is generally used for small loads (electronic equipment). When DC from photovoltaic cells is used for remote home applications, then electric utilities use alternating current networks, in this case, must be converted to alternating current (AC) using an inverter, a solid-state device that converts DC power to AC [8-9].

Many solar cells system optimization efforts have utilized factors from performance solar cells. In this study, the focus is on the factors solar panels, inverters, batteries, and solar charge controllers that were used to support the power system. This study of the solar cells panels was designated at location and time/date that play a significant role in the performance of the solar cells panels. The purpose of the study is to find a model system of power generation by using solar-cells for a house and the optimum settings to improve the performance of the solar cells panel.

2. Methodology

Solar cells can convert sunlight energy directly into electricity, in this research was focused on the design of solar panels power plant for a household where the flowchart of research is shown in Figure 3. The power density emitted from the sun in the outer atmosphere is 1.373 kW/m^2 [10].

The last incident of sunlight on the earth's surface has a peak density of 1 kW/m^2 during the day in the tropics. These cells can be grouped to form a panel, as shown in Figure 4. These panels can be grouped to form a large array of solar cells. The term array is usually used to describe solar cells panels or groups of panels. Solar Cell is an active element that converts sunlight into electrical energy. Solar Cells generally have a minimum thickness of 0.3 mm, which is made of semiconductor material slices with positive poles and negative poles. The basic principle of making Solar Cells is to utilize the photovoltaic effect, which is an effect that can convert sunlight directly into electrical energy [11].

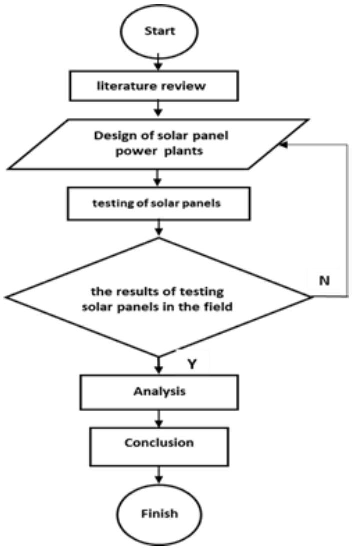

Figure 3. Research flowchart.

Figure 4. Solar cells panels..

The Solar Charge Controller is an electronic device used to adjust direct current which is charged to the battery and taken from the battery to the load [12-14], as shown in Figure 5. The solar charge controller regulates overcharging (excess charging - because the battery is 'full') and excess voltage from the solar panel. Overvoltage and charging will reduce battery life. The goal is to maintain the battery when given DC voltage supply correctly and safely for a long time. The controller fills the battery, prevents excess battery discharge, protects against excessive electricity, and displays battery status and power flow [15-16].

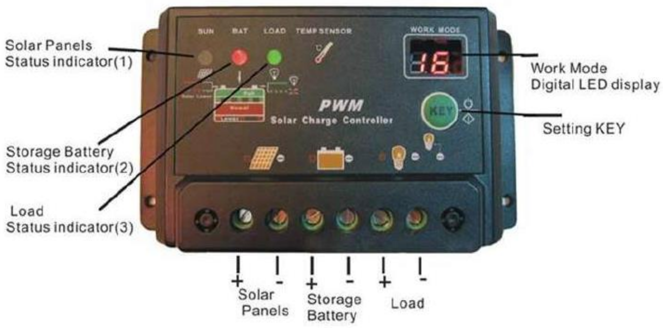

Figure 5. Solar charger controller.

Figure 6. Accumulator (battery).

Accumulators or batteries are one of the direct current (DC) source elements. The battery was used in the design is 2 x 70 Ah, including electrochemical elements. The electrochemical elements is a current source system that converts chemical energy into electrical energy.

Inverters were used in solar power plants for converting DC (direct current) to AC (alternating current) [17-19]. Inverters used in electrical devices, with a capacity of 1000 watts 24 volts, as shown in Figure 7.

Figure 7. Power inverter

2.1. Electric Motor

In this design, the load used is a 125 watt and 200 watt electric motor. The electric motor was used to operate a water pump. The specifications of the water pump motor are shown in table 1.

Table 1. Load specifications, in the form of 125 watts and 200-watt water pump motors.

Model	PWH137C	PWH236C
Electric Motor	1 phase induction	1 phase induction
Voltage Source	220 Volt AC/50 Hz	220 Volt AC/50 Hz
Power Output	125 watt	200 watt
Current input	1.55 Ampere	2.3 Ampere
Number of Poles	2	3
Suction Power	9 meter	9 meter
Maximum Flow Height	30 meter	30 meter
Maximum Water Capacity	30 litre/minute	45 litre/minute
Suction Pipe / Push	1 inci	1 inci
Size	210 x 170 x 225 mm	225 x 175 x 225 mm
Net / Gross Weight	5,3 kg/5,8 kg	7.2 kg/7.7kg

3. Results and Discussions

The results of the study show that solar cells produce a voltage by converting solar energy into electricity. The voltage produced by 17.5 Volt DC solar cells. The solar cells used four pieces the type of Polycrystalline (Poly-crystalline) with 50 WP per piece, so that it can fill the 2 × 70Ah battery connected in series.

3.1. Battery capability testing.

The current and voltage distribution of the installed solar panels produce a voltage of ±17.5 V per panel, but their distribution of charging batteries is very stable at an average of 13.5 V. The distributions are regulated by the solar charge controller (SCC). The flow will start to increase in the morning at 07.30WIB; then it will reach the maximum level at noon at 10:00-14.00 WIB, then begins to drop at 18.00 WIB. Figure 8 shows the ability of battery with AC 125-watt during the day and night.

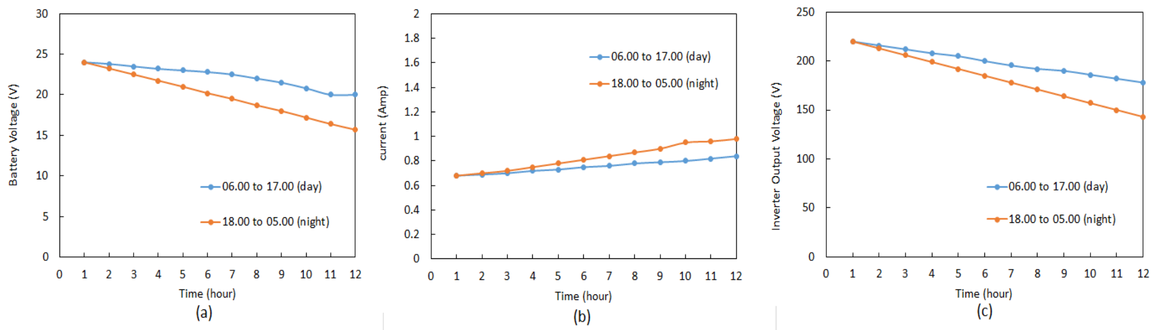

Figure 8. The ability of battery in AC 125-watt load during the day and night with measurement of (a) battery voltage (b) current of the battery and (c) Inverter output voltage.

The system designed is, electrical energy derived from solar energy sources can be used for solar power plants. Also, it can be used to drive a water pump motor, with electrical energy that has been converted through an inverter from 24.5 volts DC to 220 volts AC. The conversion of electric DC to AC could not achieve 100%, it may be lost to converse. Vinay (2015) reported, that AC power in overall the conversion DC to AC in actual field condition is an efficiency of about 82-89% [2]. The electrical energy from solar panels can be flowed and stored into batteries; the process of storing and using electricity is regulated by using a Solar Charge Controller (SCC). The stored electrical energy can be used to drive loads in the form of lighting and electric motors, through an installed inverter requiring a voltage of 220 volts AC with a frequency of 50 HZ. The ability of battery with 200-watt AC during the day and night is shown in Figure 9. At the day the measurement of voltage and electric current more than higher at the night, it corresponded to Amelia (2016). Amelia reported that high solar irradiation may increase output power [7].

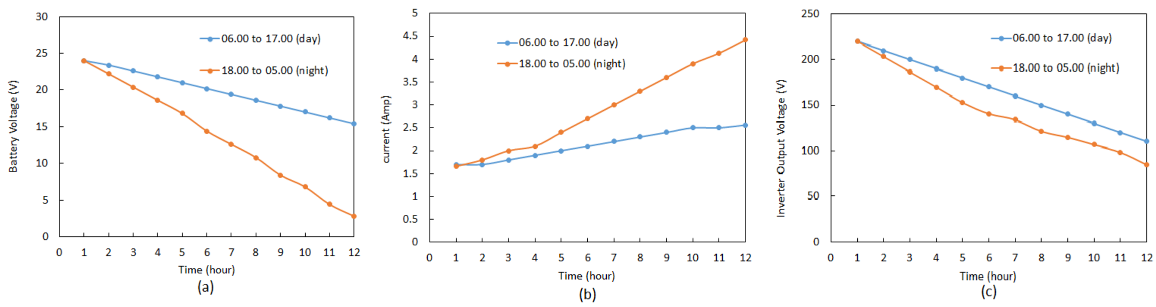

Figure 9. The ability of battery with AC 200-watt load during the day and night with measurement of (a) battery voltage (b) current of the battery and (c) Inverter output voltage.

4. Conclusion and recommendation

4.1. Conclusion

Based on the results of measurements and testing of data retrieval and the overall analysis that has been carried out, it can be concluded that:

i. The working principle of PLTS is to convert solar thermal energy into electrical energy using solar panels which are then stored in batteries.

ii. To change the 24 volt DC voltage from the battery/battery to a 220 volt AC voltage using an inverter circuit.

iii. In the current and voltage distribution of solar panel sources, the resulting ± 30.2 V is in series, but its distribution of charging the battery is very stable with a maximum average of 24.5 V where a solar charge controller regulates all distribution.

iv. The voltage and current will begin to increase in the morning at 06.00 WIB to 10.00 WIB, then will reach the maximum level at noon at 10:00 to 12:00 WIB, and begin to decrease until the afternoon.

4.2. Recommendation

The disadvantage of this Solar cells system is the lack of power efficiency in very changing weather conditions. If the weather is sunny, the filling process is very good, it all also depends on the characteristics of the type of solar cells that used.

For further development, to get a large amount of energy in the panel, it is better to install an automatic solar tracking system that can follow the direction of sunlight.

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