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DESIGN OF A BACKUP ENERGY SIMULATOR AND ANALYSIS OF SOLAR CELL OUTPUT

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ABSTRACT

Solar thermal energy is an endless source of natural energy and can be converted into a source of electrical energy with a solar cell module. The solar cell system components work to absorb solar thermal energy and convert it into a DC electric power supply with a voltage of 12–18 V and a maximum current of 2.34 A. Monocrystalline solar cells have an efficiency of about 15%–25%. This means that they can convert only about 15% at 50°C, while the efficiency decreases to 15%–12% at 30°C. From the data studied on three 50 Wp solar cell modules, the efficiency value is 21%. By using three 50 Wp solar cell modules arranged in series, an energy of 870 Wh can be produced. With a fully charged battery, a 48 W lamp load can be powered for more than 18 hours. Even when the solar cells receive no sunlight and the battery is charging, the battery is still able to supply the 48 W lamp load for up to 6 hours.

1. INTRODUCTION

1.1. Background

Solar energy is the largest source of energy on earth and can be converted into electrical energy. This electrical energy can be used by people to meet their daily needs, which are indispensable now and in the future. The goals of utilizing solar electricity are electrification for the whole world as an equal distribution of development outcomes, the use of local energy in implementing the government's energy policy, especially non-fuel (non-BBM) energy, and an alternative energy source for backup energy needs of electricity consumers.

Backup systems that use solar energy have also been widely applied. In order to produce enough solar energy to meet daily needs, research is first required to examine the characteristics of the electrical energy produced by solar energy through solar cell modules. These characteristics are influenced by several factors, including weather conditions, the duration of sunlight that can be absorbed by the solar cell module, and the values of voltage (V), current (I) and power that can be produced.

The problem formulation is how to maximize the use of solar cell modules as a medium for generating and storing backup energy so that it can run well, and to determine the analysis of the voltage produced by the solar cell (source + load), monitor the solar cell temperature, and manage the backup energy.

1.2. Literature Review

A solar cell is a device or component that can convert sunlight energy into electrical energy using the photovoltaic effect. The photovoltaic effect is a phenomenon in which an electric voltage appears because of the contact between two electrodes connected to a solid or liquid system when exposed to light energy. Therefore, a solar cell is often also called a photovoltaic (PV) cell.

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The discovery of the solar cell began with the discovery of what is now known as the photovoltaic effect by the French physicist Alexandre Edmond Becquerel in 1839, who accidentally found that certain materials can produce a small amount of electric current when exposed to light (Alexandre Edmond Becquerel, 1839).

2. METHODS

2.1. Research Stages

The steps used in this research are as follows:

1. Design and build an electrical power generation system using solar cells.
2. Apply 50 Wp solar cell panels connected in series to charge a 60 Ah battery.
3. Analyze the solar cell output, including temperature, light intensity, current and voltage.
4. Calculate the solar cell load.
5. Calculate the solar cell efficiency.

2.2. Tools and Materials

The tools and materials used are as follows:

1. 3 solar cell panels, each rated 50 Wp / 12–18 V.
2. One 60 Ah / 12 V battery.
3. One 12/24 V solar charger controller module.
4. One 500 W inverter (DC–AC).
5. 4 energy-saving (LED) lamps, each rated 12 W.
6. Sufficient installation cable.

2.3. Device Design

The block diagram of the circuit applied in this work is shown in Figure 1.

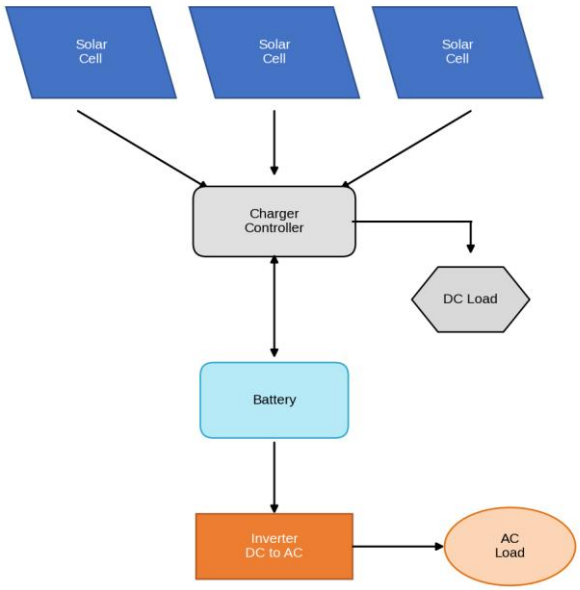


Figure 1 Block diagram of the device design

2.4. Data Analysis

In this research, several equations are used to analyze the data, including:

1. The duration for which the module receives global radiation:

$$\text{Duration of global radiation (h)} = \text{Total global radiation (Wh/m}^2\text{)} / \text{Maximum global radiation (1000 Wh/m}^2\text{)} \quad (1)$$

2. The energy produced by the solar module [6]:

$$\text{Energy produced (Wh/day)} = \text{Nominal module power (W)} \times \text{Duration of global radiation (h)} \quad (2)$$

3. The minimum number of modules [7]:

Minimum number of modules = [Daily electrical energy required by the load (Wh/day) × Daily module output (Wh/day at 12 V)] / Battery charging efficiency (%) (3)

4. Module efficiency:

$$\eta = P_{out} / P_{in} = (V_{oc} \times I_{sc} \times FF) / (S \times F) \quad (4)$$

where V_{oc} is the open-circuit voltage (V), I_{sc} is the short-circuit current (A), FF is the fill factor, S is the module surface area (m^2), and F is the incident solar radiation intensity (W/m^2).

5. The equation used to determine the fill factor (FF):

$$FF = (V_m \times I_m) / (V_{oc} \times I_{sc}) \quad (5)$$

where V_{oc} is the open-circuit voltage (V), I_{sc} is the short-circuit current (A), V_m is the nominal voltage (V), and I_m is the nominal current (A).

6. The total usable battery capacity (Ah at 12 V):

$$t_{load} = P_{load} / P_{battery} \quad (6)$$

where t_{load} is the battery usage time (ampere-hours, Ah), P_{load} is the lamp power (W), and $P_{battery}$ is the battery power.

7. The minimum number of batteries required:

Minimum number of batteries = Total capacity × current / Nominal capacity for 14.5 V × 60 Ah = total power (7)

8. The load current:

Load current (A) = Total load power (W) / System voltage (V) (8)

3. RESULTS AND DISCUSSION

3.1. Solar Cell Module Specifications

In this research, 3 modules connected in parallel were used, giving a total panel power of 50 Wp, with the following specifications:

Table 1 Specifications of the Solar Cell Module

Description	Specification
Model	GH50P-18
Rated Maximum Power (Pm)	50 W
Voltage at Pmax (Vmp)	18 V
Current at Pmax (Imp)	2.78 A
Open-Circuit Voltage (Voc)	22.4 V
Short-Circuit Current (Isc)	3.24 A
Normal Operating Cell Temperature (NOCT)	47 ± 2°C
Maximum System Voltage	1000 VDC
Maximum Series Fuse Rating	15 A
Operating Temperature	−40°C to ±85°C
Application Class	Class A
Cell Technology	Poly-Si
Weight	4.3 kg
Dimensions	540 × 670 × 30 mm

3.2. Solar Cell Module Test Data

The test was carried out to determine the voltage output of the solar cell module from 8:00 a.m. until 4:00 p.m. (afternoon to evening) on 5 July 2018 (sunny) at a height of 3 m, as shown in Table 2.

Table 2 Test Results of the Solar Cell Module by Time (Thursday, 5 July 2018)

Time	Voltage, Vmp (V)	Current, Imp (A)	Temperature (°C)	Light intensity (cd)
8:00	16.3	0.6	32	10914
9:00	17.5	1.3	43	21120
10:00	18.42	1.5	50	32768
11:00	18.92	1.5	50.2	32768
12:00	19.12	2.1	51.4	32768
13:00	19.15	2.2	51.2	32768
14:00	18.57	1.5	49.6	32768
15:00	17.48	1.2	42.8	6258
16:00	17.47	1	38	761

Source: Research results, 2018.

Based on Table 2, it can be seen that the nominal voltage (V_{rated}) of the module fluctuates depending on light intensity and time. This means that the hotter the sun, the higher the nominal voltage. At 08:00 WITA (Central Indonesia Time) the measured nominal voltage was 16.3 V, but at 10:00 it reached 18.42 V. Then, from 10:00 WITA to 13:00 WITA there was a fairly drastic increase, to 19.15 V, followed by a slight decrease at 13:00 WITA, to 19.17 V.

3.3. Load and Storage Data

Load data. The LED lamps used as the load in the cattle farm are 12 W LED lamps distributed over 4 points.

Table 3 Load Data

Description	Specification
Type of lamp	LED lamp
Power	12 W
Voltage	12 V
Number of lamps	4
Total power	48 W

Source: Research results, 2018.

Battery data. The battery used is of the lithium-ion polymer type. In general, a battery has a voltage rated in volts and a capacity rated in ampere-hours (Ah), and the batteries commonly used by the public have a voltage of 12 V/24 V.

If a storage period of 1 day is specified, then using Equation (7), the total usable battery capacity is 14.5 V × 60 Ah = 870 Wh.

Then, using Equation (6), the remaining battery (accumulator) energy after 12 hours of use with a 48 W load can be determined as follows:

$$870\ \text{Wh} - (48\ \text{W} \times 12\ \text{h}) = 870\ \text{Wh} - 576\ \text{Wh} = 294\ \text{Wh}$$

3.4. Discussion of Research Results

From the data obtained, it can be analyzed that the lighting of the cattle farm shed uses solar cells.

Table 2 shows that in the morning the solar cell produces a voltage of 12 V and a current of 0.1 A. At midday, when the sun is high and the light intensity is at its maximum, it produces a voltage of 19.15 V and a current of 2.2 A. Likewise, in the afternoon, as the light intensity decreases, the voltage produced also decreases.

By using three 50 Wp solar cell modules arranged in series, the solar cells can produce an energy of 870 Wh. With a fully charged battery, a 48 W lamp load can be powered for more than 18 hours. Even when the solar cells receive no sunlight and the battery is charging, the battery is still able to supply the 48 W lamp load for up to 6 hours.

4. CONCLUSION

1. One way to optimize the absorption of the sun's thermal energy and light intensity is to position the solar cell module facing the sun, because the position of the module also affects the absorption of heat and solar intensity. In the solar cell system, the solar cell components work to absorb the sun's thermal energy and convert it into a DC electric current with a voltage of 12–18 V and a maximum current of 2.34 A, and the electrical energy produced by the solar cell depends on the intensity of the sunlight absorbed. The electrical energy produced by the solar cell is then stabilized by the charger controller module and stored in the battery so that it becomes a backup energy source that can be used when needed.
2. After the analysis, it was found that the solar cell module works when it is illuminated by the sun. In data collection, the solar cell produced a voltage of 16.3 V with a current of 0.6 A at 08:00 at a temperature of 25.2°C, and the highest result was a voltage of 19.15 V with a current of 2.2 A at 13:00 at a temperature of 51.2°C. These results are not yet optimal, because the solar cell works at temperatures of 40°C up to ±85°C.

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