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Photovoltaic Solar Energy as a Power Source for Coal Waste Measurement Equipment

Nurhalim,[a,*] Feranita [a], Yoga Pratama [a], Noveri Lysbetti Marpaung [a], Iswadi Hasyim Rosma [a], Suwitno [a]

[a)] *Electrical Engineering Department, Universitas Riau, Indonesia*

*Corresponding author: nurhalim@lecturer.unri.ac.id

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ABSTRACT

Coal mines are generally located in very remote areas and so far from the reach of the power grid. This study designs a coal waste measurement device using solar energy as the power source. The parameter being measured for coal waste is its acidity level to determine water quality standards. The test results show that the photovoltaic (PV) system is capable of supplying power to the pH meter device for a duration of 24 hours with a battery capacity of 18 Ah. The total load of this system is 5.6983 Watts. With variations in load and different weather conditions such as clear, cloudy, and overcast, the solar panel voltage can effectively meet the load requirements within the voltage range of 16.7 volts to 20.9 volts.

KEYWORDS: *Photovoltaic, Load variation, SCC, pH Measurement device.*

NOMENCLATURE

DC	Direct Current
PV	Photovoltaic
SCC	Solar Charge Controller
W	Watt
t	Time
Wh	Watt-hour
V	Volt
Ah	Ampere-hour
DOD	Depth of Discharge
A	Ampere
Wp	Watt peak
LCD	Liquid Crystal Display
LED	Light Emitting Diode

1.0 INTRODUCTION

The utilization of electrical power is one of the fundamental requirements in industries. This electrical energy is used as a power source for machinery, equipment, and measurement devices that support industrial processes [1-2]. Typically, coal mining industries are located far from the reach of the public power grid. This necessitates the availability of energy sources from nature, such as solar energy.

Currently, solar energy is one of the most widely used energy sources worldwide, particularly in photovoltaic systems. Photovoltaic technology is highly popular due to its ease of transportation, installation, and usage [3-4]. Photovoltaic systems are well-suited as an energy source in coal mining areas. In this study, a photovoltaic solar energy system is designed to supply power

to a coal waste water quality measurement device. Despite being located far from the reach of the public power grid, this measurement device will continuously receive electrical power from the natural environment.

The main components used to generate power in a photovoltaic solar energy system are solar modules, regulators, and batteries. The output of photovoltaic systems is direct current (DC) electricity, and the voltage output depends on the number of solar cells installed on the solar panel and the intensity of sunlight illuminating the panel. To utilize this electrical energy during night time, energy storage media are necessary, such as batteries. Before solar energy is directed to the batteries, it is first connected to a regulator circuit [5].

This study designs a power source for measuring the pH of coal mine wastewater. It utilizes PV module a 50 Wp as the battery charging source. A solar charge controller is used to regulate the incoming direct current (DC) to the battery. This setup allows for continuous supply of DC electrical power to the pH measurement device, even in locations far from the reach of the public power grid.

2.0 LITERATURE REVIEW

2.1 Photovoltaic (PV)

Photovoltaic (PV) is a system that converts solar energy into electricity directly using semiconductor materials. The semiconductor material consists of two layers (P-side and N-

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side) that form a PV cell. The principle of PV operation occurs when light enters the PV cell, and some photons from the light are absorbed by the semiconductor atoms, releasing electrons from the N-side to flow through an external circuit and return to the P-side. This flow of electrons generates an electric current [6], [7], [8].

PV cells can be divided into three categories: (1) inorganic cells, based on solid-state inorganic semiconductors; (2) organic cells, based on organic semiconductors; and (3) photoelectrochemical (PEC) cells, based on interfaces between semiconductors and molecules. The figure shows the structure of an inorganic solar cell based on a sandwich structure of two types of semiconductor material: one type has mobile free negative electrons (called an n-type semiconductor), and the second type has mobile free positive holes (called a p-type semiconductor). The sandwich, called a p-n junction, allows the photogenerated electrons and holes to be separated and transferred to external wires for electrical power production. PV cells have no moving parts and are silent [9].

The intensity of solar radiation is influenced by the Earth's rotation cycle, weather conditions including cloud quality and quantity, seasonal changes, and latitude position. In Indonesia, the intensity of solar radiation lasts for 4-5 hours per day. The solar energy production in a region can be calculated as follows [10], [11]:

$$E = I \ x \ A \tag{1}$$

Where:
E = Generated solar power (Watt)
I = Avarage solar insolation (Watt/m^2)
A = Area (m^2)

For solar power systems with a capacity of 1000 Watts or below, a 20% factor needs to be added to the load to compensate for system losses and for safety factors. Therefore, the load determined in ampere-hours should be multiplied by 1.20, resulting in [12]:

$$E_T = E_L \ x \ losses \ and \ safety \ factor \tag{2}$$

Where:
E_T = Load energy (watt-hour per day)
E_L = the total load energy (watt-hour per day)

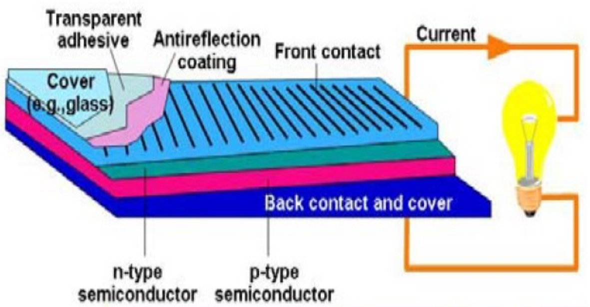

Figure 1: A Solar cell structure [9]

To determine the load energy requirement, you can refer to Equation 3 [13].

$$E = P \ x \ t \tag{3}$$

Where:
E = the total load energy (watt-hour)
P = the total power of load (W)
t = time (h)

2.2 Solar Charge Controller (SCC)

The charge controller functions to regulate the flow of electricity from the solar module to the battery. The SCC also serves to protect the battery. It regulates the overcharging and overvoltage of the solar panel to the battery [14]. The SCC controls the maximum battery voltage limit at 13.8 volts. Once this voltage is reached, the current supply will be reduced to zero or less than 1 ampere. The SCC implements Pulse Width Modulation (PWM) technology to control the battery charging function and the release of current from the battery to the load.

2.3 Battery Rating and Sizing

The battery in a solar power generation system functions to store the electrical current generated by the solar panels before it is used to operate the load. The load can be in the form of lights or electronic equipment and other devices that require DC power [15].

$$Q = \frac{E \ x \ A}{V \ x \ T \ x \ \eta_{inv} \ x \ \eta_{cable}} \tag{4}$$

Where:
Q = minimum battery capacity required (Ah)
E = daily energy requirement (Wh)
A = number of days of storage required (Ah)
V = system DC voltage (V)
Q = minimum battery capacity required (Ah)
T = maximum allowed DOD of battery (indicatively 0,3- 0,9)
η_{inv} = inverter efficiency (1,0 if there is no inverter)
η_{cable} = efficiency of the cables delivering the power from battery to loads

3.0 METHODOLOGY

3.1 System Block Diagram

The operation of this system is to absorb sunlight as an energy source, and then the PV module converts it into voltage. The voltage generated will be used to supply the battery before it is connected to the battery through the SCC. Then, the voltage will be provided to the load, which consists of a pH meter and LED lights. The overall system block diagram is shown in Figure 2.

The system block diagram is shown in Figure 2. When sunlight emits photon energy, the solar panel absorbs this energy and converts it into DC electrical energy. Once there is DC electricity generated by the solar panel, the SCC serves as a connector and protector between the panel, battery, and load. The SCC will allow the voltage to flow to the battery/load when it reaches 7.8 volts. Then, the battery will be charged, and the load will receive the supply from the solar panel.

However, if the voltage reaches 7.8 volts or if the battery voltage reaches 13.8 volts, the SCC will not allow the voltage

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to flow. If the solar panel cannot provide sufficient power, the SCC will prioritize the battery as a backup power supply for the load, which includes the pH meter and an additional load of a 5-watt LED lamp.

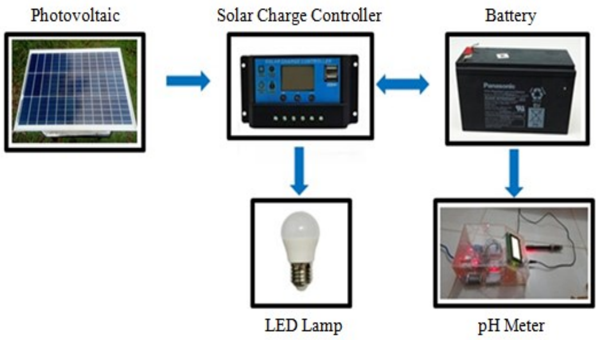

Figure 2: Power supply block diagram for ph meter

Tabel 1: PV module specifications

Merk	ST Solar (Model: SP50-18P)
Cell Type	Polycrystalline Silicon
Pmax (Maximum Power)	50 W
Vmp (Voltage at Pmax)	17.8 V
Imp (Current at Pmax)	2.81 A
Voc (Open Circuit Current)	21.8 V
Isc (Short Circuit Current)	3.05 A
Max System Voltage	1000 V
Temperature Range	-4ºC~85ºC
Dimension	540 x 670 x 30 mm

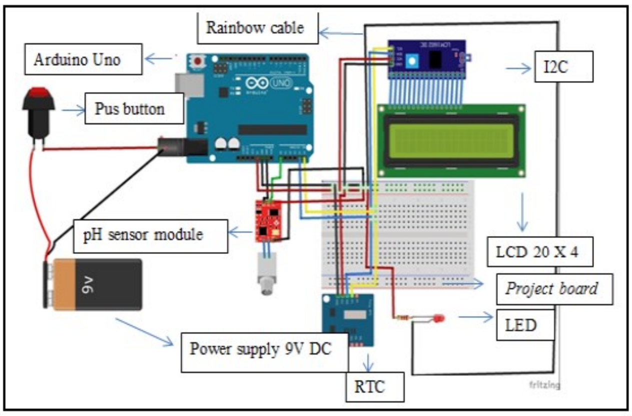

Figure 3: Circuit of pH meter based on arduino uno [5]

Figure 3 shows an installation of pH meter components consisting of Arduino Uno, pH sensor module, RTC, push buttons, LED lights, jumper cables (rainbow cables), project board, 20x4 LCD and I2C modules which are soldered directly on the LCD. The pH sensor module has 3 pins connected to the Arduino, namely the VCC pin connected to the Arduino 5V VCC, the GND pin connected to the Arduino GND, and the PO pin as the output of the pH sensor which is connected to the analog pin on the Arduino Uno, namely pin A0. The RTC has 4 pins connected to the Arduino Uno, namely the VCC pin to the Arduino VCC, the GND pin to the Arduino GND, the SDA pin to the Arduino A4 and the SCL pin to the Arduino A5. And there are four pins that are used to turn on an LCD, the four pins on the I2C LCD include VCC, GND, SDA and SCL, the Arduino VCC pin is connected to the I2C LCD VCC pin, the Arduino GND pin is connected to the I2C LCD GND pin, the SDA pin on the Arduino is connected to the SDA LCD I2C pin, the Arduino SCL pin is connected to the I2C LCD SCL pin [5].

The pH meter shown in Figure 3 will get power from solar PV. Where, this tool will be used to measure the quality of coal mine waste water. Another electrical load is the LED light. A complete arrangement of tools as shown in Figure 2.

3.2 Load Calculation

Total Load This device utilizes several components, including a pH sensor, Arduino UNO microcontroller, and an LCD. These components will be operational for 24 hours. The load calculation is based on the datasheets of each component, as shown in Table 2.

Table 2: Total power of ph meter

No	Components	Current (Ampere)	Power (Watt)
1	Microcontroller	0.028	0.14
2	SCC	0.01	0.05
3	pH Sensor	0.1	0.5
4	LCD	0.00165	0.00825
5	LED lamp	0.471	5.00
	Total	0.61065	5.6983

Source: Datasheet of unit

Based on Table 2, the total current of the measuring device is 0.61065 amperes and the total load is 5.6983 watts. Therefore, according to Equation 3, we have the total load energy for 24 hours:

$$E = 5.6983 \ x \ 24 = \ 136{,}8 \ Wh$$

The daily energy requirement can be calculated according to Equation 2 as follows:

$$E_T = 136.8 \ x \ 1{,}2 = 164{,}2 \ Ah$$

The battery capacity can be rounded up to a larger value to ensure optimal service to the load in the PV system. Generally, batteries have a Depth of Discharge (DOD) capability of 80%. Equation 4 can be used to calculate the battery current divided by the factor of 0.8, as follows:

$$Q = \frac{164{,}2 \ x \ 1}{12 \ x \ 0{,}8 \ x \ 1 \ x \ 1} = 17{,}1 \ Ah$$

The total load of the pH measuring device, which is 5.6983 Watts, requires a battery capacity of 17,1 Ah (rounded up to 18 Ah) to supply the load for 24 hours.

4.0 RESULT AND DISCUSSION

4.1 Overall Design

The complete power supply system for the coal waste pH measuring device consists of a 50W solar panel, SCC (Solar Charge Controller), pH meter, 12V/18 Ah battery, and a 5W LED lamp. The complete arrangement of the measuring device components and its power supply is shown in Figure 4.

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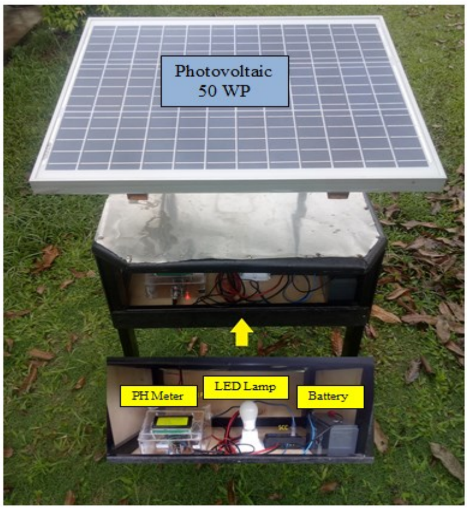

Figure 4: Complete arrangement of measuring instruments and their power sources

This device is tested with load variations. The purpose of the load variation test is to determine the solar panel's ability to supply the load under changing weather conditions. The testing is conducted three times in a day. In the first test, the pH sensor is turned on while the lamp is off. In the second test, the pH sensor is turned off while the lamp is on. Finally, in the third test, both the pH sensor and the lamp are turned on. During the testing, the weather conditions are observed, and the ambient temperature is measured.

4.2 Photovoltaic Testing with Load Variation

Data collection was conducted from December 22, 2020, to December 28, 2020, at the Electrical Engineering laboratory, Universitas Riau. Solar radiation and environmental temperature are important factors to consider during this testing. Solar radiation measurement was carried out using the Ambient Weather WS-1002-WiFi.

Table 2: Testing of equipment with load variation

Date	Weather	Solar Radiation (W/m^2)	Temp. (°C)	Load		PV	
				Ph	Lamp	V	A
22/12 /20	Cloudy	398.9	33.5	V		16.8	0.48
					V	16.9	0.50
				V	V	16.7	0.52
23/12 /20	Sunny	605.5	33.9	V		18.8	0.75
					V	18.7	0.62
				V	V	18.9	0.77
24/12 /20	Cloudy	382.9	30.6	V		17.6	0.66
					V	17.3	0.73
				V	V	16.8	0.73
25/12 /20	Sunny	695.0	32.1	V		20.9	0.97
					V	19.2	0.97
				V	V	19.5	1.20
26/21 /20	Cloudy	421.6	31.7	V		17.6	0.68
					V	17.9	0.71
				V	V	17.5	0.69
27/12 /20	Sunny	801.5	34	V		20.2	1.01
					V	20.1	1.25
				V	V	19.9	1.42
28/12 /20	Overcast	362.5	30.9	V		17.0	0.67
					V	17.2	0.63
				V	V	16.9	0.57

4.3 Test Results and Graphic Image

The measuring instrument was tested under three load conditions: instrument load only (Ph), lamp load only (L), and combined load of instrument and lamp (Ph + L). The test results graph can be seen in Figure 3 and Figure 4.

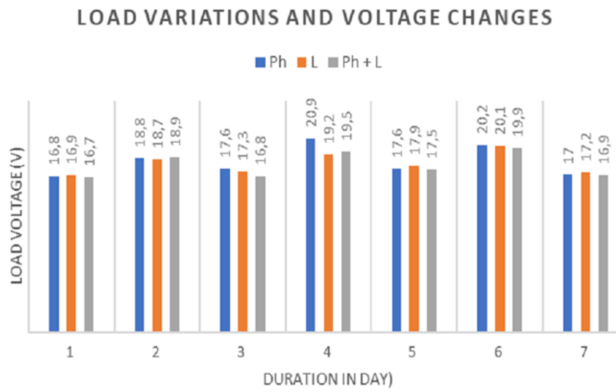

Figure 5: Changes in load variations and voltage variations

Figure 5 dan Figure 6 show the results of testing pH meter with a solar energy source. In this case, there is a change in voltage and current due to change in load. But all these changes are still within safe limits.

In this case, Figure 5 shows test results that the voltage supply of solar PV to the pH meter fluctuates between 16,7 volt and 20,9 volts. This condition shows that the energy source supplies the pH meter properly.

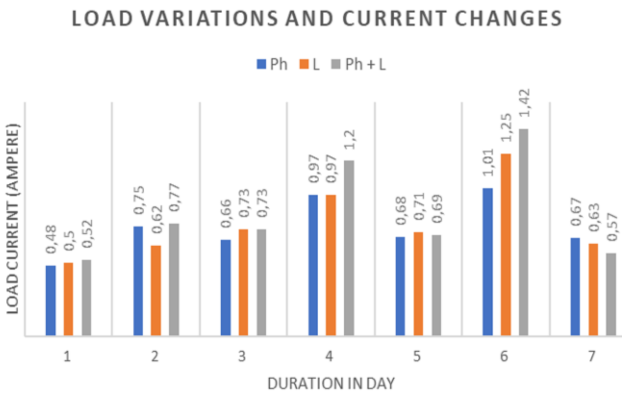

Figure 6: Changes in load and current variations

Likewise, the results of testing the current capability of energy sources are shown in Figure 6 where the maximum current reaches 1.42 amperes. This current is still below the current capability of the solar PV module.

5.0 CONCLUSION

The conclusions drawn from this research: the PV POWER source can continuously serve the pH meter energy for 24 hours. Testing under cloudy, sunny, and overcast weather conditions showed varying out voltages ranging from 16.7 Volts (lowest) to 20.9 Volts (highest). The maximum current of the pH is 1.42 amperes, this current is smaller than the current

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capability of solar PV module, which is 2.81 amperes. Based on the load variation test result under sunny, cloudy, and overcast weather conditions, the voltage supplied from the solar panel to SCC still effectively serve the load.

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