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PERFORMANCE EVALUATION OF ELECTRICAL ENERGY PRODUCED BY POLYCRYSTALLINE SILICON CELLS

MELONEY DIVA PATRICK[1], ARICA LEDUMIN[2], SITI AMINAH MOHAMMAD[3*]
[1, 2, 3]Faculty of Applied Science, Universiti Teknologi MARA Sabah Branch, Kota Kinabalu Campus
ct_syamin@uitm.edu.my

ABSTRACT

Energy is the ability of a physical system to perform work. Energy exists in different forms such as heat, kinetic energy, mechanical energy, and light energy. Energy sources can be classified as renewable energy, which is naturally and constantly replenished, non-renewable energy that comes from resources that are being slowly replaced by natural processes. The aim of this project is to evaluate the performance of electrical energy produced by polycrystalline silicon (poly-Si) solar panels. Solar energy is a type of energy that generates electricity from the sun's heat. By utilising solar panel technology, electricity can be generated from solar energy. The most widely utilised technologies nowadays are mono- and poly-crystalline. This project involved arranging the poly-Si solar panels in both series and parallel circuits. As a result, the relationship between voltage and current is directly proportional in both circuits, and the maximum value of voltage was 2.22 V in the series circuit and 1.12 V in the parallel circuit. The results of this study have important implications for society, as solar energy has the potential to replace non-renewable sources as the main source of generating electricity. By reducing the use of non-renewable energy, we can mitigate pollution and its harmful effects on the environment.

Keywords: energy, energy sources, renewable energy, solar panel, electricity

Introduction

There is no denying that electricity is necessary for all humans in the modern world. People depend on electricity for most of their everyday activities. Generally, electricity can be produced from two main sources of energy, namely renewable energy and non-renewable energy. Renewable energy is energy that is naturally and constantly being replenished, while non-renewable energy is energy with very limited supplies because it took a very long time to replenish. Renewable energy sources are often associated with green energy, which is energy derived from natural sources. Clean energy is energy that does not generate pollutants like carbon dioxide. The primary advantages of using green energy include its never-ending supply, environmental friendliness, and accessibility.

Fossil fuels like oil, coal, and natural gas are the most used energy sources in the world and the utilisation of fossil fuels varies widely around the world. According to the International Renewable Energy Agency (IRENA), the world's renewable energy potential is anticipated to increase by 50% between 2019 and 2024, which corresponds to a rise of approximately 1220 Gigawatts (El Hammoumi et al., 2022). According to a 2019 U.S. Energy Information Administration report, worldwide energy use will grow by nearly 50% by 2050 (Adelakun et al., 2019). Utilising solar energy using photovoltaic (PV) systems, which enable turning solar energy into electricity, is an approach to solve these challenges and meet the rising demand for electricity around the world. According to International Energy Agency (IEA), solar PV energy could provide 11% of all the renewable energy used globally (Jathar et al., 2023). The working temperature has a significant impact on the electrical efficiency of the PV panels, which is determined by the relationship between the provided electrical energy and the incident solar irradiation (Maghrabie et al., 2022).

Solar energy is the radiant heat and light that the sun emits, and it is captured by a variety of constantly changing technologies, including photolytes. Solar energy works when it obtains energy from the sunlight through a light absorption medium called solar panel, which is a collection of attached solar cells. As a source of energy to produce electricity, only about 20% of the sun's incident irradiation is converted to electricity. The remainder is reflected into the environment or converted to heat, which increases the temperature of the solar cells (Jathar et al., 2023). Other than working temperature, it is crucial to state that one of the key factors affecting the efficiency of PV cells to ensure the maximum absorption of sunlight is the selection of materials to be used in the manufacture of solar panels.

This clean technology has inspired many researchers who have studied the performance of different systems aiming to maximize the PV production with the least cost modifications. To achieve good absorption of solar energy, the material used to manufacture solar cells is very important for them to work efficiently (Charfi et al., 2018). One of the most important components of semiconductors which really turn solar energy into electricity in solar panels is silicon. Silicon is by far the most widely used semiconductor material in solar cells, representing about 95% of the modules sold today. It is the second most plentiful material on Earth (after oxygen) and mostly used in computer chips (Pivot, 2022). Silicon atoms are linked together to form a crystal lattice in crystalline silicon cells. The lattice structure enhances the efficiency of converting light into electricity. The structure of a polycrystalline silicon (poly-Si) cells is comparable to that of modern, high-efficiency manufacturing devices (Shehata et al., 2023).

Objectives

1. To measure the voltage and current stored in polycrystalline silicon (poly-Si) solar panels.
2. To determine the electrical energy produced by polycrystalline silicon (poly-Si) solar panels.

Methodology

The equipment used in this experiment included a multimeter, a multimeter cable, a complete circuit consisting of four polycrystalline silicon cells (poly-Si) with dimension 6.0 cm X 2.0 cm each and four connectors. The solar panels and connectors were arranged in a series connection and a parallel connection, as shown in Figure 2 and Figure 3, respectively. Voltage, V(V) and current, I(A) readings were observed and recorded. The data was collected at the period of maximum sunlight intensity (between 11.00 a.m. and 1.00 p.m.) and the solar panels were positioned to ensure maximum exposure to sunlight to trap heat and light efficiently. The electric power produced by the solar panels was calculated using the following equation (1):

$$E = VIt$$

where:

E = electrical energy (J)

V = Voltage (V)

I = Current (A)

t = time (s)

(1)

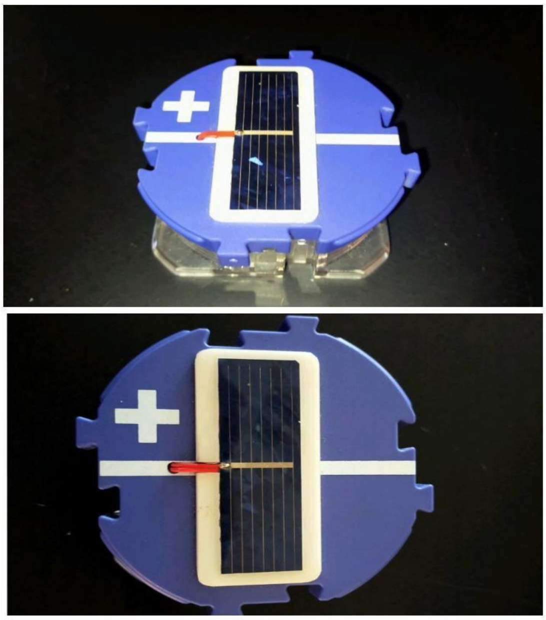


Figure 1: Solar panel (polycrystalline silicon cell)

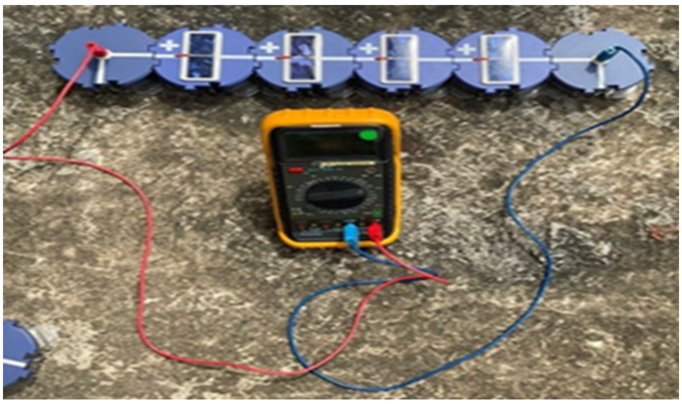


Figure 2: Solar panel cells arranged in a series circuit

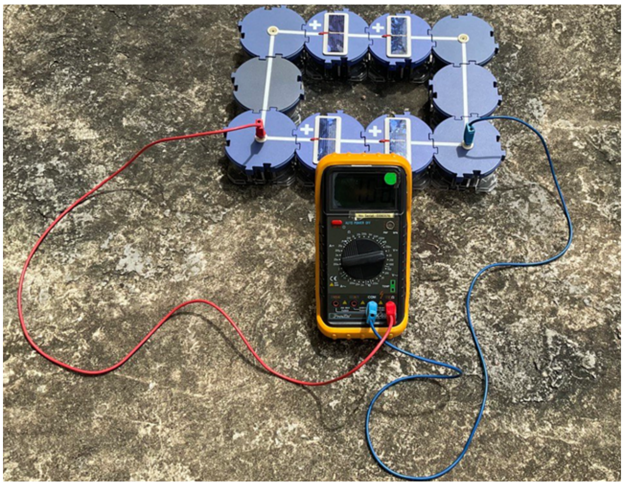
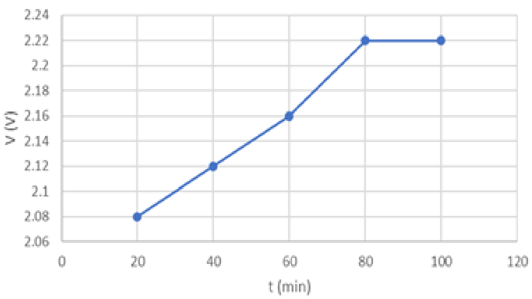
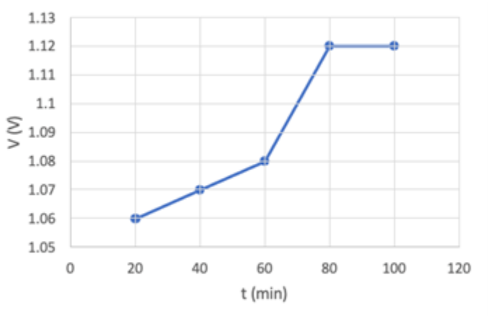


Figure 3: Solar panel cells arranged in a parallel circuit

Data Analysis and Discussion

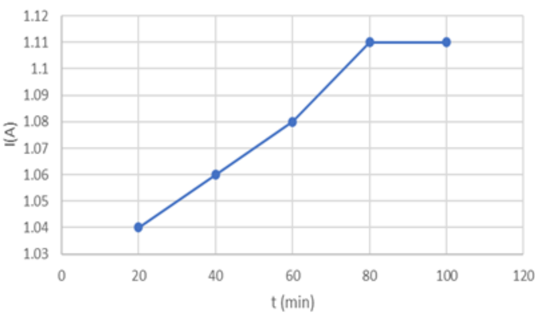


Graph 1: Voltage (V) vs Time (min) for the series circuit

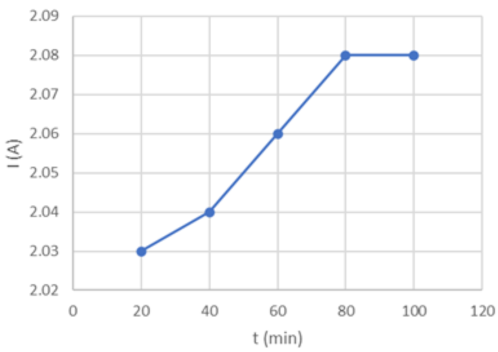


Graph 2: Voltage (V) vs Time (min) for the parallel circuit

Based on Graph 1 and Graph 2, the voltage increased from 20 min to 80 min, after which it stayed steady until the next 100 minutes. This happened due to the solar panels absorbing more sunlight as the sun intensity increased until peak hours. The series circuit had a maximum voltage of 2.22 V while the parallel circuit had a maximum voltage of 1.12 V.

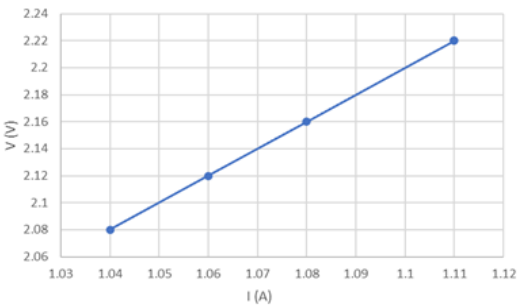


Graph 3: Current (A) vs Time (min) for the series circuit

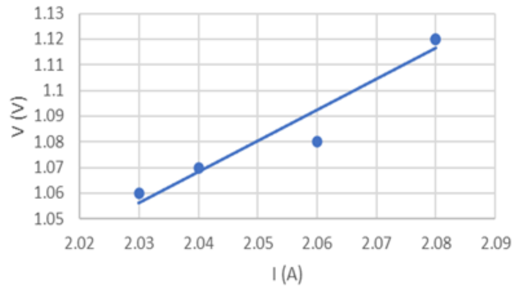


Graph 4: Current (A) vs Time (min) for the parallel circuit

Based on Graph 3 and Graph 4, the current increased from 20 min to 80 min, after which it remained steady until the next 100 minutes. This happened due to the solar panels absorbing more sunlight as the sun intensity increased until peak hours. The series circuit had a maximum current of 1.11 A, while the parallel circuit had a maximum current of 2.08 A.

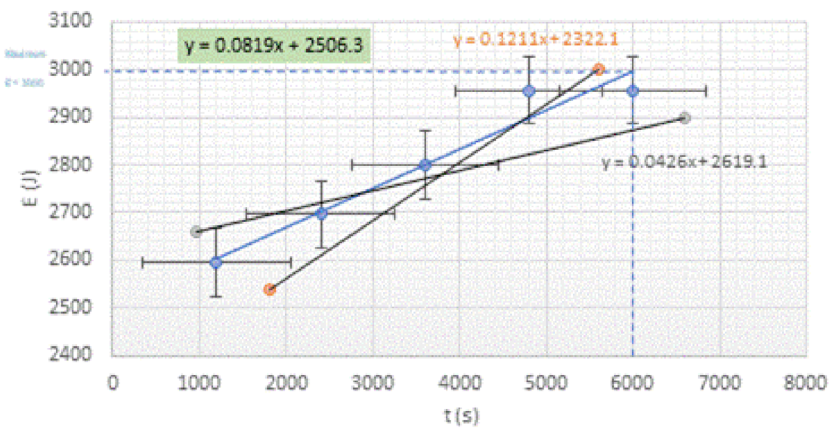


Graph 5: Voltage (V) vs Current (A) vs for the series circuit

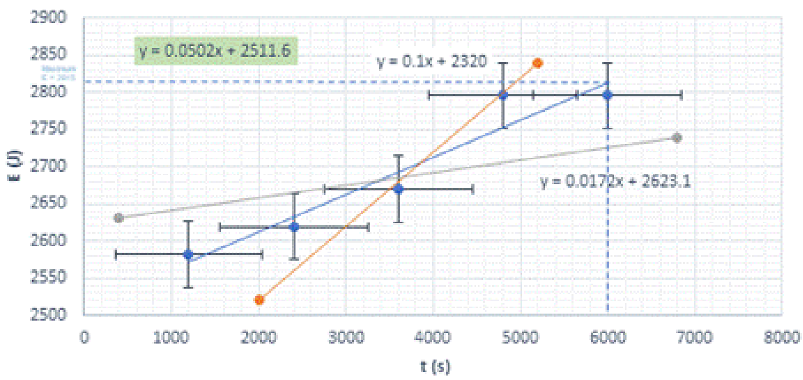


Graph 6: Voltage (V) vs Current (A) for the parallel curcuit

Based on Graph 5 and Graph 6, the voltage, V (V) is directly proportional to current, I (A) for both series and parallel circuits. This means that as the voltage increases, the current also increases, in accordance with Ohm's Law, which states that the applied voltage is directly proportional to the current flowing in the circuit (Brown & Musil, 2004).



Graph 7: Electrical Energy (J) vs Time (s) for the series circuit



Graph 8: Electrical Energy (J) vs Time (s) for the parallel circuit

Based on Graph 7, the gradient of the best fit line is m = 0.0819 Js^{-1} with a max gradient of mmax = 0.1211 Js^{-1} and a min gradient of mmin = 0.0426 Js^{-1}. The gradient represents the power generated by the solar panels in Js^{-1} or Watts. Therefore, the electric power, P, generated by the solar panels arranged in series is 0.0819 W with an uncertainty of 0.04. In addition, the graph also shows that the electrical energy, E (J), is directly proportional to the time, t (s). This means that as the time increases, the electric energy, E (J), also increases. The maximum electrical energy produced is 3000 J while the minimum is 2506.3 J.

Graph 8 shows that the gradient of the best fit line is m = 0.0502 Js^{-1}, with a max gradient of mmax = 0.1 Js^{-1} and a min gradient of mmin = 0.0172 Js^{-1}. The gradient represents the power generated by the solar panels in Js^{-1} or Watts (W). Therefore, the electric power, P, generated by the solar panels arranged in parallel is 0.0502 W with an uncertainty of 0.04. The graph also shows that electrical energy, E (J), is directly proportional to the time, t (s). This means that as the time increases, the electric energy, E (J) also increases. The maximum electrical energy produced is 2815 J, and the minimum value produced is 2511.6 J.

Based on the data obtained from the experiment, the solar panels arranged in series produced more electric power than solar panels arranged in parallel. The electrical power produced in the series circuit is 0.0819±0.04 W while electrical power produced in the parallel circuit is 0.0502±0.04 W. In series the circuit, the maximum electric energy, Emax, produced is 3000 J while the minimum electric energy, Emin, produced is 2506.3 J. Then in parallel circuit, the maximum electric energy, Emax, produced is 2815 J while the minimum electric energy, Emin, produced is 2511.6 J. This happened because the voltage produced in the series arrangement was higher than in parallel arrangement. However, the current produced in parallel arrangement was higher than in the series arrangement.

Furthermore, the electric power, P, generated in the series arrangement is 0.0819±0.04 W and in the parallel arrangement is 0.0502±0.04 W. This is due to the open circuit voltage and short-circuit current of the solar PV cell that increase over time as the light intensity increases. Solar panels in the parallel arrangement are better than series arrangement, and the PV performance in the parallel shading was still greater than the series shading, even though the results showed there were more shaded cells in the parallel shading than series shading (Shalaw et al., 2015). Series connections are less reliable and require more modules; therefore, the parallel connections are more efficient (Norlinda & Annuar, 2020). In addition, based on our observation, the electric power produced in the series circuit only had a slight difference from the electric power produced in the parallel circuit. Thus, solar panels arranged in parallel work better.

The PV cells on a solar panel capture the energy from the sun's rays as they shine on the panel. In reaction to an internal electrical field within the cell, this energy generates electrical charges that move, resulting in the flow of electricity. The PV cells on a solar panel are made from silicon. This is due to silicon being available, non-toxic, and has high and consistent cell efficiencies. In addition, the production infrastructure for silicon is mature, and there is a broad and deep level of expertise in silicon devices (Blakers et al., 2013). Silicon acts as a semiconductor of the PV cell, with two layers: p-type and n-type. There are three types of silicon solar cells: monocrystalline, polycrystalline, and amorphous. In this experiment we used polycrystalline solar cells. Polycrystalline solar cells consist of multiple silicon crystals, which results in lower efficiency due to their lower purity level and lower heat tolerance. In contrast, monocrystalline solar cells have higher power generation yield due to their perfect lattice structure, higher purity level and weak internal resistance. Therefore, monocrystalline solar cells produce more electrical power compared to polycrystalline solar cells (Jiang et al., 2020).

Conclusion

In conclusion, the maximum voltage, V, that is produced from the solar panels is 2.22 V in the series circuit and 1.12 V in the parallel circuit. Meanwhile, the maximum current, I, produced from the solar panels is 1.11 A in the series circuit and 2.08 A in the parallel circuit. The voltage, V, is directly proportional to the current, I, which obeys the Ohm's Law. Furthermore, in the series circuit, the maximum electric energy, Emax, produced is 3000 J while the minimum electric energy, Emin produced is 2506.3 J. In the parallel circuit, the maximum electric energy, Emax, produced is 2815 J while the minimum electric energy, Emin, produced is 2511.6 J. Additionally, the electric power, P, generated in the series circuit is 0.0819 ± 0.04 W and in the parallel circuit is 0.0502 ± 0.04 W. This is due to the open circuit voltage and short-circuit current of the solar PV cell that increase over time as the light intensity increases. The findings of this project are beneficial to society, considering that solar energy can substitute non-renewable energy as the main source of electricity generation. Therefore, the use of non-renewable energy can be reduced, and pollution that may lead to adverse effects on the environment can be avoided.

Future Studies

To optimise the performance of solar panels in producing electricity, parameters such as the capacitance and resistance of solar panels need to be determined. These two parameters are essential for the stability of electricity production in solar power systems.

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