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The study of output current in photovoltaics cell in series and parallel connections

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ABSTRACT

Photovoltaic cells in solar is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. In this work, series and parallel arrangement of the photovoltaic cells in solar system were investigated over a range of voltage, current and power. The data obtained were statistically analyzed to predict the optimal energy conservation of photovoltaic cells and finally experiments were conducted for verification. The experiment designed is to observe the output current in both series and parallel PV cells arrangement with the output current of the three sets of photovoltaic cells (PV), with a minimum input supply of 18.7V DC and 8.82A respectively. Digital multimeter and current clamp meter are the main instruments used to measure the parameters in the experiment. The parameters for the circuit are analyzed based on the voltage, current, power and the efficiency of the system. Indeed, the output current and voltage for both arrangements were able to be used to derive the efficiency of the system and showed good agreement with the results from the preliminary observation. It is shown that the efficiency of parallel arrangement is higher compare to the series. Therefore, considerable investigation towards the types of arrangements is of great importance since it can determine the better system efficiency when there are any faulty panels



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Introduction

Now, renewable energy is not something new to produce electricity. These resources are needed as an alternative because energy sources such as oil and coal are declining (Lahadi, 2009). Examples of renewable energy are water, wind, geothermal, solar, biomass, waves and biofuels. These resources remain in a natural and can be replaced naturally in the short term even though it is used continuously.

In Malaysia, renewable energy has begun since 1980. It started when Malaysia introduced four fuel diversification strategies aimed at balancing mixed energy such as the use of oil, gas, coal and hydro. (Regan et al., 2019). The use of renewable energy resources in Malaysia is less than 20%, this quantity is still small. From this total, Hydro was the most contributing to the electricity production of 16.6%. While other renewable energy sources are 0.7% (Suruhanjaya Tenaga, 2019). The development of renewable energy in Malaysia is relatively slow so the Malaysian Sustainable Development Authority (SEDA) has developed many programmes to increase the renewable energy consumption by 2025 (Hamidah Haneym et al., 2019).

Solar energy is part of a renewable energy source. It is a technology created to get energy from sunlight. By using solar panels, sunlight can be collected and converted into electricity. No wonder why this solar energy becomes an important source of energy in the future. In Malaysia, PV panels have been installed in residential, industrial and commercial buildings since 2001. In the 8th Malaysia Plan (2001-2005) the Government introduced the Integrated Building Photovoltaic Technology Application (MBIPV) plan to encourage the use of renewable energy resources in Malaysia(The Enhancement of Solar Power System Implementation, n.d.). The purpose is to reduce the dependence on fossil fuels and to reduce the effects of climate change(Malaysia, 2011). It is also able to provide benefits not only in terms of environment but can also save expenses.

The solar cells also called photovoltaic (PV) cells, the name was implying from (photo meaning "light" and voltaic meaning "electricity"), it converts sunlight directly into electricity. (Toothman,Jessika et al.,2020). Some solar cells are connected together to form a PV panel. While some of these solar PV panels are connected together with other accessories to form the Solar System. This solar system is used to generate electricity. One of the basic Solar PV System is shown in the Figure 1. An Off-Grid Solar PV System, where the system is used to generate electricity for daily use but it is far from the main grid. ("Green Sarawak: Going Solar Chapter 6 Know Your Solar PV System,"2020).

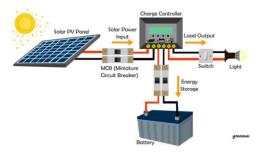


Figure 1 <Off-Grid Solar PV System ("Green Sarawak : Going Solar Chapter 6 Know Your Solar PV System," 2020)>

Basic component for Solar system is include solar PV modules, charger controller, battery and inverter. **Solar PV panel** is a main part of the system. It is like a heart of a photovoltaic system (UNIVERSITY, 2009). This PV panel are wired together in series as shown in Figure 2 or parallel as shown in Figure 3

Series PV cell arrangement

Figure 2 shows the panel connection in series. Connecting the panels in series will increase the voltage level and maintain its current value. In this case a charger controller is required as it can accept higher voltage inputs and can still charge 12V voltage. However, when one of these solar panels is shielded from the shadows then it will affect the entire panel. ("Renogy De: Your Guide to Series vs Parallel Connection,"2020)



Figure 2 < Series PV Cell Arrangement>

Parallel PV cell arrangement

Figure 3 shows the panel connections in parallel. Connecting the panel in parallel will increase the current value and maintain its voltage value. however, when the current value is high, the wire used should be thick if it travels over long distances. Also, parallel systems require additional equipment such as branch connectors or join boxes ("Renogy De: Your Guide to Series vs Parallel Connection," 2020)



Figure 3 < Parallel PV cell arrangement>

Next, the **Charger controller** is for protect the system from overcharging the batteries. Sometime it calls battery charger. **Batteries** is like the bank, store direct current electrical energy for later use. The function of **Inverter** is converted DC to AC, that come from PV panel or battery(UNIVERSITY, 2009).

The knowledge of this solar panel has been inserted into the curriculum at the Department of Electrical Engineering, Polytechnic Malaysia. However, this syllabus is still new and the existing solar panels are not enough. So, a solar system has been built in the Department of Electrical Engineering for student use as a learning aid show in Figure 4. This solar system also can directly help the lecturers, especially in the process of Teaching and Learning (T&L) (Rahim & Che, 2013). This solar system is used to measure the voltage, current and find an efficiency.



Figure 4 < Solar System>

Method

Figure 5 shows the main parts of the solar system. The parts are solar panels, charger controllers and also battery. This experiment will focus on these 3 main parts and the connection at PV solar panel. Table 1 show the specification for each part.

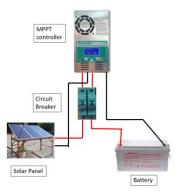


Figure 5 < Part of Solar System>

This testing is only conducted in open areas and it can receive sunlight without the interference of shadows, which is in the parking area of the Electrical Engineering Department, Omar's Polytechnic. This study starts at 10 a.m. to 2 p.m (Khairool Anwar bin Alias, n.d.). This test is limited to measuring voltage, current and calculating the efficiency of the solar system in series as well as parallel PV arrangement. The measuring tool used is a digital multimeter and also a clamp meter.

For the first test, solar panels are arranged in series and left exposed to sunlight. The data will be taken every 1 hour and will be recorded in the tables provided. Once the data is obtained, the system efficiency will be calculated based on the formula below

$$\eta = \frac{Pout}{Pin} \times 100$$

Next test, solar panels are arranged in parallel and left exposed to sunlight. The data will also be taken every 1 hour and will be recorded in the tables provided. Once the data is obtained, the system efficiency will be calculated based on the above formula.

Results and Discussion

Series PV cell arrangement

The value of voltage and current for Series PV arrangement are show on Table 1. From the result, the voltage is higher than the rated PV voltage. This is because the PV are arranged in series. While, the current value for series are higher.

Table 1 < Result for Series PV Arrangement>

Time	V solar (V)	V battery (V)	I solar (A)	I battery (A)
10.00 - 11.00 am	40.8	14.6	0.7	1.6
11.00 - 12.00 pm	41	14.59	0.88	1.9
12.00 - 1.00 pm	41.5	14.6	1.36	1.31
1.00 - 2.00 pm	41.9	14.58	1.44	1.5

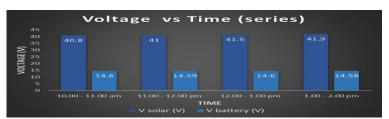


Figure 6 < Graph Voltage vs Time for Series PV Arrangement>

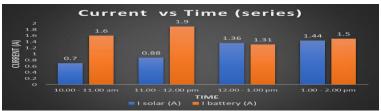


Figure 7 < Graph Current vs Time for Series PV Arrangement>

Parallel PV cell arrangement

The value of voltage and current for Parallel PV arrangement are show on Table 2. From the result, the voltage is almost similar to the rated PV voltage. This is because the PV are arranged in parallel. However, the voltage and current for parallel PV arrangement are lower than series PV arrangement.

Table 2.<Result for Parallel PV arrangement>

Time	V solar (V)	V battery (V)	I solar (A)	I battery (A)
10.00 - 11.00 am	20.5	14.5	0.7	0.86
11.00 - 12.00 pm	20.3	14.6	0.66	0.77
12.00 - 1.00 pm	20.2	14.6	0.64	0.76
1.00 - 2.00 pm	20.4	14.6	0.67	0.75

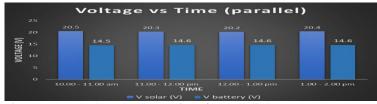


Figure 8 < Graph Voltage vs Time for Parallel PV Arrangement>

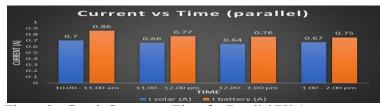


Figure 9 < Graph Current vs Time for Parallel PV Arrangement>

i) Efficiency for series and parallel PV cell arrangement

The efficiency of parallel PV arrangement and series PV arrangement for solar system are derive and showed in Table 3. From the table the efficiency for series arrangement decreases as the time approaches in the evening. However, the efficiency for parallel arrangement is more stable. This value of efficiency also shows in the graphs on Figure 10.

Table 3.<Result Efficiency for Series / Parallel PV Arrangement>

	Efficiency (%)					
	Series			Parallel		
Time	Power	Power	Series	Power	Power	Parallel
	solar	battery	Efficiency	solar	battery (W)	Efficiency (%)
	(W)	(W)	(%)	(W)		
10.00 - 11.00 am	28.56	23.36	81.79	14.35	12.47	86.90
11.00 - 12.00 pm	36.08	27.72	76.83	13.40	11.24	83.91
12.00 - 1.00 pm	56.44	19.13	33.89	12.93	11.10	85.83
1.00 - 2.00 pm	60.34	21.87	36.25	13.67	10.95	80.11
Average			57.19			84.19



Figure 10 .<Graph Comparison of Efficiencyfor Series or Parallel vs Time>

Conclusions

Experiments on this solar system have shown that the value of the output current in the series connection is higher than in parallel. In addition, the output voltage values in series and parallel are the same. However the efficiency for parallel connections is better, fewer module will be required to get more power and more stable than the series (UNIVERSITY, 2009). So with this solar system can be used as a teaching aid and can also be carried out appropriate experiments on it.

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