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Off Grid Solar System without Using Battery Storage (Solar Part)

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Abstract

Electricity is one of the important factors of a country where the power plant is built to generate electricity by using fossil fuel sources. Thus solar energy was first introduced to reduce the dependency rate on fossil fuels. Battery storage for renewable energy like solar and water has high costs and significant environmental impacts. Therefore the implementation of the project is aim to utilize solar panels to capture and convert sunlight into electricity, provide a consistent and reliable power supply and Develop a cost-effective solar-powered system. The project has involved two kind of system which is solar powered water pump system and hydroelectric system which both of this system operate at different times to complement each other purpose. The solar system is being operate during the day, while for the hydroelectric system is being operate during night by using water flow from upper tank to generate electricity. Based on the data collected of this project, it was found that the 25W monocrystalline solar panel shows the best performance of overall testing where it can produce and maintains a high output voltage and current. The envision of the small-scale solar water pump system is a physical project that represents of the conceptualized system, the development of this system also has the potential to generate development in a new technology sector that is able to have a positive impact on the world's ecosystem.

1. Introduction

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Electricity plays an important role in economic growth and Malaysia is heavily dependent on fossil fuels such as coal, natural gas and oil for energy generation [1]. However, the use of this fuel can have a negative impact on the environment and the quantity of this fossil fuel will decrease over time [1]. To reduce dependence on fossil fuels, solar energy, a renewable source, has been introduced [2]. However, the use of solar systems also requires the use of batteries which are a material made of rare earth metals, which pose a risk to the environment because of mining and disposal activities [3]. Therefore, another alternative is needed to eliminate the need for batteries in renewable energy systems to maintain effectiveness in energy generation systems this. For the project that will be implemented, it has two different systems, namely a solar-powered water pumping system with an electric micro-hydro system. Both systems are used for an energy generation cycle for the construction of this project and because of that, both are interconnected with each other.

In terms of operating time, the two systems will operate at different times where for the solar system, it is highly dependent on the source of sunlight to enable it to generate electricity. Because of this, this solar system will be operated during the day only and it also depends on the rate of peak sunlight. Meanwhile, for the micro-hydro system, although this system can be implemented during the day, but it will be operated at night because the load used in this system is a light bulb to show a high rate of traceability for this micro-hydro generation system to generate electrical energy through kinetic energy resulting from the flow of water sources from the upper tank in this project system. This cycle system in energy generation will be able to continue operating if the water source used will always be available. For this reason, these two generator systems are closely related to each other for the operating system in this project.

The main goal of this project is to utilize solar panels to capture and convert sunlight into electricity for water pumping by concentrate on developing substitute techniques for electrical energy storage, provide a consistent and reliable power supply by integrating solar power with efficient storage solutions, and also develop a cost-effective solar-powered system that can be widely adopted by individuals and communities. Main point covered this research is to conduct detailed calculations and design work to create a small-scale prototype of a solar power system, to construct a working prototype of the solar-powered water pumping system, and to Perform comprehensive testing to assess the system’s performance, efficiency, and reliability under various conditions, and evaluate the environmental impact and cost-effectiveness of the powered system compared to traditional energy solutions.

2. Literature Review

This topic is to explain the components used in the solar panel system and discuss journals or previous project studies related to the prototype of the project to be implemented.

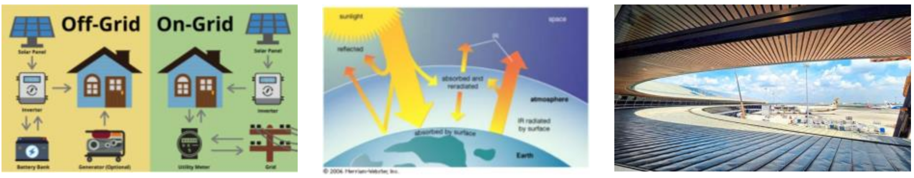
2.1 Off-Grid Solar System with Additional Information of Solar and Renewable Energy

An off-grid solar system has been shown in figure 1 (a) is a self-sufficient power system that generates and stores electricity separately from the main electrical grid [4-7]. This system is perfect for isolated areas without connection to the main grid [6,2]. Off-grid solar offers several benefits, such as decreased environmental impact, protection from power outages, and energy independence [5,7]. Daily energy needs, solar panel efficiency, inverter and battery specifications, installation logistics, and maintenance needs are all things to take into account when designing an off-grid system [4].

Solar energy is referred to as energy produced by the sun [8]. Based on the figure 1 (b) where solar radiation having the ability to ignite chemical reactions, produce heat, or produce electricity. The world's present and future energy needs are far exceeded by the total amount of solar energy incident on Earth. This highly diffused source has the capacity to meet all of the world's energy needs if properly harnessed. In the twenty-first century, solar energy has gained popularity as a renewable energy source due to its limitless supply and non-polluting nature, which sets it apart from the finite fossil fuels like coal, oil, and natural gas [9].

Photovoltaic (PV) panels also known as solar panels which use solar radiation to generate electricity. They are composed of a semiconductor that transmits energy, like silicon [10]. PV systems come in a wide range of sizes, from compact rooftop or portable units to enormous utility-scale power plants as been show in the figure (c) where the solar panel has been installed on the rooftop of the Kuala Lumpur International Airport. This article concentrates on PV systems that are connected to the utility grid, or grid-tied PV systems, even though they can function independently as off-grid PV systems [11].

Malaysia's energy mix now includes biomass, biogas, solar, small hydropower, and municipal waste since 2000, when the country implemented the Five Fuel Diversification Policy. The 2010 National Renewable Energy Policy, which established a target of 20% renewable energy in the power generation mix (also known as the installed capacity mix) by 2025, accelerated the use of renewable energy because Malaysia is situated near the Equator and enjoys six hours of sunshine per day on average, the country has enormous potential for solar energy harvesting [12].



(a) **(b)** **(c)**

Fig. 1 *(a) System component simplify; (b) The flow of sunlight towards earth, (c) Solar panels atop the Kuala Lumpur International Airport*

2.2 Previous Project Review

The first project highlighted by Gualteros and Rousse [13] which the research on solar water pumping system that has wide range of aspects including system sizing, optimization, performance evaluation, and sustainability. Next, Sontake and Kalamkar [14] provided an extensive review of (Solar Photovoltaic Water Pump System) SPVWPS literature from 1975 to 2014, discussing the classification, historical development, and performance factors. A study by Maddalena et al. [15] explored a two-stage photovoltaic water pump system that avoids using batteries for energy decoupling and large electrolytic capacitors. Other than that, the research by Chaisricharoen and Srimaharaj [16] evaluated different controllers and developed a Sine Wave Pump Controller with Maximum Power Point Tracking (SPCM). The research by Gopal et al. [17] is reviewed developments in water pumping systems powered by renewable energy sources. Meanwhile, research by Rezk et al. [18] focused on optimizing a hybrid power system design for water pumping applications that combines solar and wind energy without using batteries. A study from Elrefai et al. [19] evaluated a battery-less solar water pumping system design through a case study in El Wahat, Egypt. Research by Ghoneim [20] discussed the application of photovoltaic solar energy in water pumping, presenting a survey of the system's advantages and disadvantages. The role of solar-powered water pumps in sustainable development is being explored by T D Short [21] discussing the concept of Design for Sustainable Development (DFSD).

2.3 Formula Related to Project

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Theory calculation was also involved in this study where the energy consumption of the system, power produced by solar panel and the flow rate of water were measured using the Bucket Method by Design and Development of Prototype Solar Water Pump System.

Energy consumption is the amount of energy consumption or power output that is certain in the operation of a device [22].

$$Energy\ consumption\ (E) = Power\ (W)\ \times Time\ (hrs) \tag{1}$$

A solar panel's capacity to generate power is contingent upon various aspects, such as its dimensions, effectiveness, positioning, and meteorological circumstances [23].

$$Daily\ output\ (kWhrs) = Power\ (W) \times Time\ (hrs) \times Efficiency\ (\eta) \tag{2}$$

In order to determine the design flow rate of the pump to be built, the estimated daily water requirement needs to be divided by the total number of operating hours in determining the daily water requirement rate [24].

$$Water\ Required\ in\ Litre\ per\ Minute = \left[\frac{Q\left(\frac{Litre}{Day}\right)}{T\ \times\ 60s}\right] \tag{3}$$

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3. Methodology

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This chapter will discuss the process of designing an off-grid solar system without using an off-grid solar system without using a battery storage prototype for the solar panel part, operation. Once the water tank at the top has been fully filled, it can flow through hydro electric generator which will produce electricity and the water will be stored at the lower tank. This cyclical process of electricity production can be carried out without the need for domestic energy sources. This chapter will also explain the research procedure carried out in detail which includes the components used in building this system, as well as the development of this system.

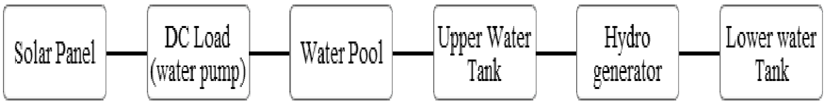

Fig. 2 *System Block Diagram*

3.1 Flowchart System

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Figure 3 shows a flow chart system designed based on logical operations. Initially, the solar PV input collects solar energy continuously and is fed to the solar charge controller. If solar power is available, directly to the DC load used in this project, which is the DC water pump and as a result the energy channeled from the PV panel will be used directly to suck water from the bottom of the water tank and then channeled to the water tank at the top.

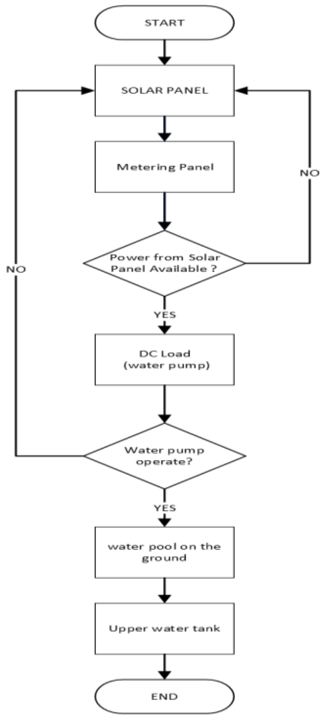

Fig. 3 *System Block Diagram*

3.2 3D System Design

Figure 4 shows the visual concept of the project which consists of two renewable energy systems which is the solar water pump system and the hydroelectric system. The solar water pump system is being used as an energy collector to transfer the water container to the upper tank which functions as energy storage to create a potential energy. The water that being stored at the upper tank will be released through the second system which flows through the hydro generator to generate electricity.

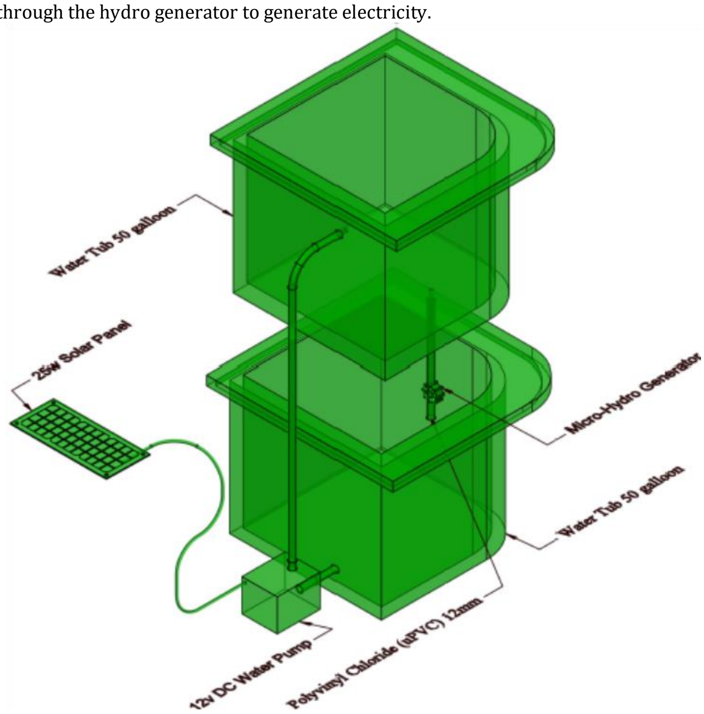

Fig 4 *3D Visualization Design of Project*

4. Result and Discussion

This chapter will explain the results and analysis obtained from the implementation of this project where the testing for this system is done in real-time to collect data in terms of voltage, current, and power output that can be produced for the prototype of this system.

4.1 Actual Product

Figure 5 shows the actual product for the solar water pump system which is designed with a strong tower structure to support the entire system. The preparation of the pool is used to accommodate the volume of water that will be pumped using a 12V DC water pump and the volume of water will be pumped up with the height difference. This comprehensive setup allows comprehensive testing and analysis to be performed on solar-related experiments.

Fig. 5 *The Actual Setup of The Off-Grid Solar System Without Using Battery Storage*

4.2 Result and Analysis Comparison

The data obtained from the test session and the results of the actual practice data will be compared to evaluate and make comparisons between the components that are important in the analysis work for this project. There are three main components that are compared in this section, namely, the voltage open circuit value, the current value produced by the system and the maximum voltage value when connected to the load.

4.2.1 Voltage Open Circuit (Voc)

The data in Table 1 shows that the value of Voltage over current obtained for each solar panel is compared to show the performance of each solar panel in the daily production of energy without load. These values are also affected by the weather conditions and the amount of solar radiation available at the time of the work incident to test this system.

Table 1 *The Comparison voltage Open Circuit (Voc) of all solar panel.*

TIME	Solar Panel 25W (Mono)	Solar Panel 25W (Poly)	Solar Panel 20W (Poly)	Solar Panel 10W (Poly)	Solar panel 10W (Thin film)
10.30 am	20.7	20.7	20.4	19.63	13.2
11.00 am	21.2	21.2	20.1	18.24	13.45
11.30 am	13.7	13.7	20.7	20.75	13.15
12.00 pm	20.2	21.2	18.2	18.23	12.21
12.30 pm	19.56	21.06	19.56	15.56	12.05
1.00 pm	20.2	18.2	20.2	20.43	12.96
1.30 pm	20.5	15.5	20.01	17.12	13.02

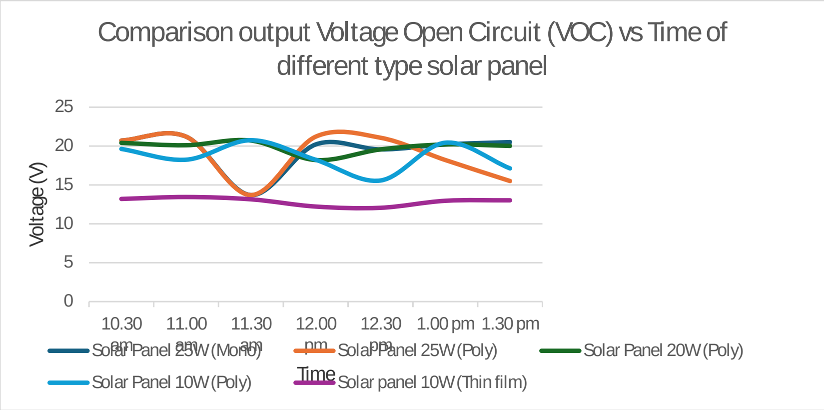

Fig. 6 *Graph comparison output voltage of all solar panel*

Figure 6 shows that the performance more clearly about the ability to produce energy provided by each type of solar panel use involved in the testing of this project.

4.2.2 Current (A) Comparison

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The data in Table 2 shows that the value of current that obtained for each solar panel is compared to show the performance of each solar panel in the daily production of energy load connected. These values are also affected by the weather conditions and the amount of solar radiation available at the time of the work incident to test this system.

Table 2 *Comparison current (A) of all solar panel*

TIME	Solar Panel 25W (Mono)	Solar Panel 25W (Poly)	Solar Panel 20W (Poly)	Solar Panel 10W (Poly)	Solar panel 10W (Thin film)
10.30 am	0.853	0.43	0.346	0.335	0.235
11.00 am	0.886	0.52	0.314	0.296	0.278
11.30 am	0.150	0.046	0.377	0.368	0.324

12.00 pm	0.794	0.52	0.046	0.046	0.142
12.30 pm	0.733	0.51	0.068	0.068	0.128
1.00 pm	0.652	0.19	0.359	0.351	0.197
1.30 pm	0.247	0.068	0.095	0.095	0.154

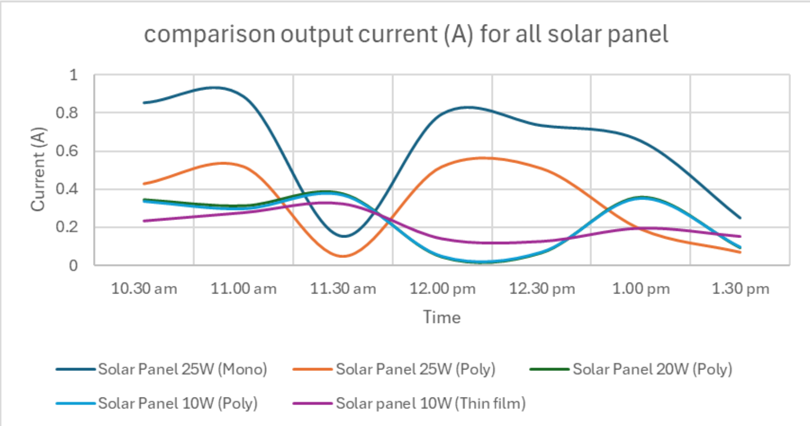

Fig. 7 *Graph comparison output current of all solar panel*

Figure 7 shows that the performance more clearly about ability to produce output value of each type of solar panel that being involved in the testing of this project.

4.2.3 Voltage Maximum Comparison (Vmax)

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The data in Table 3 shows that the change in terms of value of voltage output that obtained for each solar panel is compared to show the performance of each solar panel in the daily production of energy load connected. The change of value happened due to the connection with the load which is the 12V DC water pump. These values are also affected by the weather conditions and the amount of solar radiation available at the time of the work incident to test this system.

Table 3 *Comparison Voltage Maximum (Vmax) of all solar panel*

TIME	Solar Panel 25W (Mono)	Solar Panel 25W (Poly)	Solar Panel 20W (Poly)	Solar Panel 10W (Poly)	Solar panel 10W (Thin film)
10.30 am	19.46	8.36	16.52	16.52	9.52
11.00 am	19.9	9.73	15.02	15.02	10.09
11.30 am	4.2	4.2	15.03	15.30	11.35
12.00 pm	13.4	9.82	4.65	4.67	6.31
12.30 pm	10.3	9.65	7.53	7.53	6.03
1.00 pm	12.0	7.98	14.55	14.55	9.67
1.30 pm	8.6	4.63	11.13	11.13	9.38

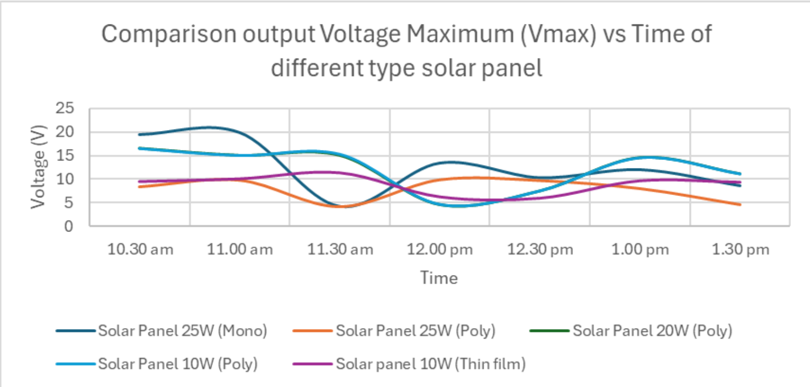

Fig. 8 *Graph comparison output current of all solar panel*

Figure 8 shows that the waveform performance more clearly about ability to produce output value of each type of solar panel that being involved in the testing of this project.

4.2.4 Summary

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Based on all the data obtained from this study, it was found that the 25W monocrystalline solar panel shows the best performance among other solar panels. Table 4 shows where this solar panel produces the highest voltage output value when connected to the load which is around 19.46V and maintains a high current which is around 80.2mA. These solar panels also show efficient energy conversion and consistent and stable power output. The rate of water suction carried out by the water pump is also quite high which is around 0.0186 to 0.0204 liters per second and recorded the shortest time to pump an amount of water with a capacity of 125 liters. Because of this, this solar panel shows good energy consumption compared to other solar panels and these factors prove that this 25W monocrystalline solar panel has high efficiency and is the most effective choice to apply in this project.

Table 4 *Comparison Voltage Maximum (Vmax) of all solar panel*

Time		10.30 am	11.00 am	11.30 am	12.00 pm	12.30 pm	1.00 pm	1.30 pm
Volume of Water (Gallon)		8	17	18	26	32	35	39
Current (A)		0.853	0.886	0.150	0.794	0.733	0.652	0.247
Irradiance		867	934	205	934	923	645	469
Temperature PV (°C)		53	52	52	50	52	52	56
Temperature Ambient (°C)		45	47	46	45	48	51	49
Load Voltage	With	19.46	19.9	4.2	13.4	10.3	12.0	8.6
	Without	20.7	21.2	13.7	20.2	19.56	20.2	20.5

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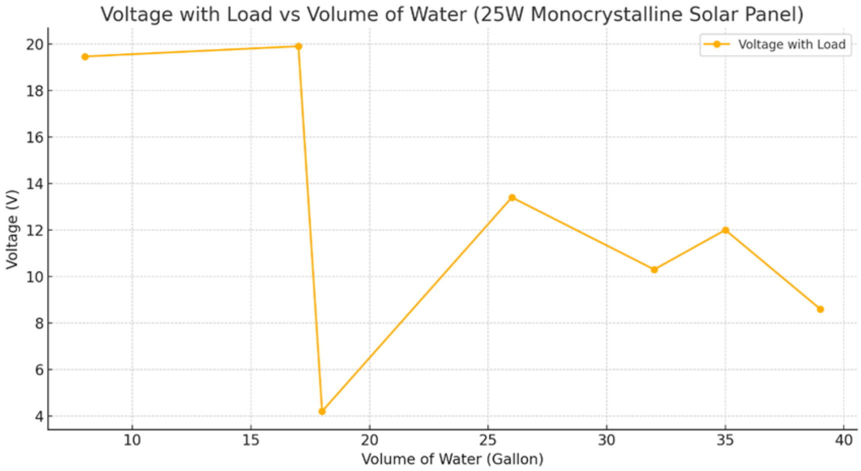

Fig. 9 *Graph output of voltage vs volume of water*

Based on figure 9, where it shows the performance graph for 25W Monocrystalline solar panel and found at 11.30 in the morning, the value of the energy output produced dropped and this happened due to the weather factor and the initial thickness that occurred when the project was tested. Based on the irradiance value found at 11.30 am also low due to the poor weather factor at the time the test was carried out and it directly affects the performance of this solar panel.

5. Conclusion

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Based on the small-scale solar water pump project developed for off grid solar system without battery, there is some lack of this prototype which can be used to considering the future advancement of the small-scale solar system which can be implemented the benefiting from the unique insights and control capabilities that can be offered by IoT devices and remote monitoring systems. With the advance technology of IoT, the collection of data can be done in real-time situations for surveying the efficiency, performance and maintenance of the system.

The envision of the small-scale solar water pump system is a physical project that represents of the conceptualized system, this project is being implemented to develop a system that can reduce pollution and be efficient in meeting the needs equivalent to the current technological advances. Not only that, the development of this system also has the potential to generate development in a new technology sector that is able to have a positive impact on the world's ecosystem.

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