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Analysis of A Portable DC to DC Solar Power Supply

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Abstract: This paper presents the analysis process of a small-scale, cost-effective portable solar power supply. Photovoltaics or PV for the short term is a type of renewable energy that has lately gained popularity in modern technology. The demand for future work is for great efficiency, reliability, and low cost. PV charge controllers that are small enough to carry about have become highly common in PV systems. PV systems typically include a photovoltaic array, charge controller, rechargeable battery, and DC load. In a PV system, the charge controller is important. PV is often acknowledged as one of the most environmentally beneficial and widely available alternative energy sources. A solar panel is included in the final product to convert solar energy to electrical energy. The electrical energy was stored in a rechargeable battery that was regulated by a solar charge controller. To keep track of the battery storage capacity, a battery level indicator was shown on the controller. A solar charge controller is built to cut down the maximum output of an 18 V DC voltage solar panel to a regulated 12 V DC power supply for charging handheld devices such as smartphones and tablets and as well as a DC power supply source.

Keywords: Photovoltaic, Charge Controller, Solar Power

1. Introduction

Renewable energy plays an increasingly essential role in the provision of social utilities such as potable water and electricity in many parts of the world. Solar energy has received special attention among the numerous sources of renewable energy since it is freely available. solar energy is the driving force behind numerous renewable energy sources. Solar energy is an excellent alternative energy source since it is abundant and renewable [1].

Developing a portable device that can capture this solar energy and supply it when needed is a crucial approach to meeting the growing demand for portable gadgets. Also significant is a portable device that can provide power for non-portable equipment that can be useful when used outside. An electric fan, a projector for watching movies, and a computer printer are examples of non-portable devices that can be useful when used outdoors. A portable solar power supply has a wide range of

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applications. It can be used to supplement a fuel-powered portable generator in a mobile home. It can be used to power electronics when camping in the great outdoors [2].

PV cells and a battery pack are the two power sources for the system. A solar-powered system can only provide electricity during the day, and especially only on clear days. They are unable of producing the power required by the load on a cloudy day or at night. As a result, the system will require more voltage sources, such as batteries to meet the increased load requirement [3]. This is especially important when the solar array or panel is used in a stand-alone arrangement and is unable to provide a stable load voltage [4].

2. Materials and Methods

The study about the project to develop DC to DC solar portable power supply was very helpful to find the suitable design and method in build this project. Several parts do the research in this project such as the design, the method that using and more. From the previous study, for this project choose the PWM charge controller and use a monocrystalline type of PV solar because it is easy to get and easy to maintain. The two most prevalent charge controller methods in today's solar power systems are pulse width modulation (PWM) and maximum power point tracking (MPPT). Both adjust charging rates based on the battery's maximum capacity and keep an eye on the temperature of the battery to avoid overheating [5].

2.1 Materials and Specification

The main component is an important thing that use to build it. The project’s main components are a PV Solar panel, a solar charge controller, a rechargeable 12V battery, a battery breaker and DC loads. in Table 1.

Table 1: List of specific materials and specification

Parts	Materials	Specification
PV Solar Panel	Polycrystalline A-Grad Solar panel	10 W 18V 0.55A
Solar Charge Controller	Pulse With Modulation	Distinguish between a 12V and 24V lead acid and gel battery.
Battery Breaker	Sealed and Waterproof	40A 12-48V DC 3000A@30V
Sealed Lead Acid Battery	Sulfuric Acid Electrolyte	• Low-Pressure Venting System •Low Self Discharge •Operation Sealed
USB Output	high-temperature, low-temperature, flame-retardant,	-25°C~80°C, 240W DC 12V/24V

2.2 Methodology

To settle and complete the project, the flowchart in figure 1 is used to guide the flow of the process of developing the prototype of a portable DC to DC power supply. In the first phase, it must decide the title of the project. This project mainly focuses on the design and development of a DC-to-DC solar portable power supply. The function of this project is to evaluate the potential of a DC to DC power supply on the voltage, current, and power output of the project. So that it can monitor by the solar charge controller. The type of solar charge controller was chosen because this type of controller is required input voltage to be always higher than the output voltage, is the same polarity, and is not isolated from the input.

For this project, the output voltage that is used is limited to 12V from 18V maximum input will step down using a solar charge controller to generate an output of 12V. The first process is to convert the light energy into electrical energy using the photovoltaic cell. Light energy, which comes mainly from the sun, is transmitted by photons, small packets or quantum of light. Photons of sufficient energy create mobile electron-hole pairs in a semiconductor. Therefore, a solar cell converts light energy which is a flow of photons, to electrical energy which is a flow of electrons. This is known as the photoelectric effect. Figure 1 shows the flowchart for the project progress in completing the project from the start to the end of the project.

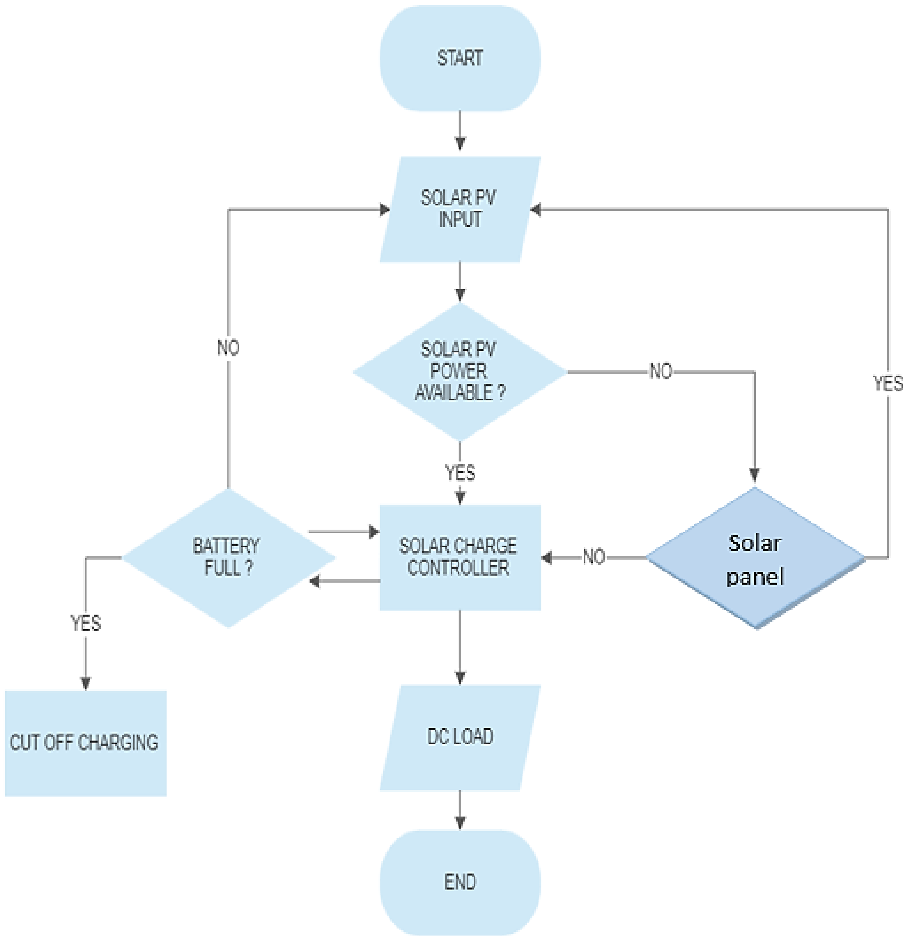

Figure 1: Overall project flowchart

2.3 Equation

The formula for Battery Sizing

The formula shows the formula for energy consumption to choose the correct sizing of the battery.

Energy Consumption
Energy consumption P(Wh) = Load (W) x usage hour (hour) (2.2)

Energy consumption for reserved power including normal days

(Operating days + Reserved days) x Energy consumption (2.3)

Battery Capacity

Battery Capacity, Ah = $(\frac{P(Wh)}{V})$ (2.4)

P(Wh) = Total energy consumption that needs to be supported

V = Voltage of the battery

Ah = Battery capacity (hours)

Battery Charging Time

$$h = \frac{Ah}{A}$$

h = Hours took for the battery to be fully charged

Ah = Ampere hour rating battery

A = Discharge current battery

3. Results and Discussions

This section will explain the result theoretically based on the simulation result and data collection for DC to DC portable power supply system by manual reading based on the output and turning on the direct current load which is a 5V Led lamp and charging handphone. The circuit's connections in this project are simulated using Proteus 8 Professional. The main objectives of this project are to design a portable solar power supply for 12V Direct Current (DC) output and to develop a direct current solar power supply system with a solar charge controller.

3.1 Results

Hardware Development

Figure 2, shows the hardware installation for the DC power supply system. For hardware development, several core components are used to develop this project. The solar charge controller is the main component of this system. Next is the 12V solar panel with a maximum output of 18V that was used to supply the power from light energy to electrical energy for the system. Then, the 12V rechargeable sealed lead acid battery is for storage of the power for the 12V DC load. Lastly, the load for the test is 5V DC led lamp and charging the phone with the efficiency of the voltage. Figure 5 shows the hardware development.

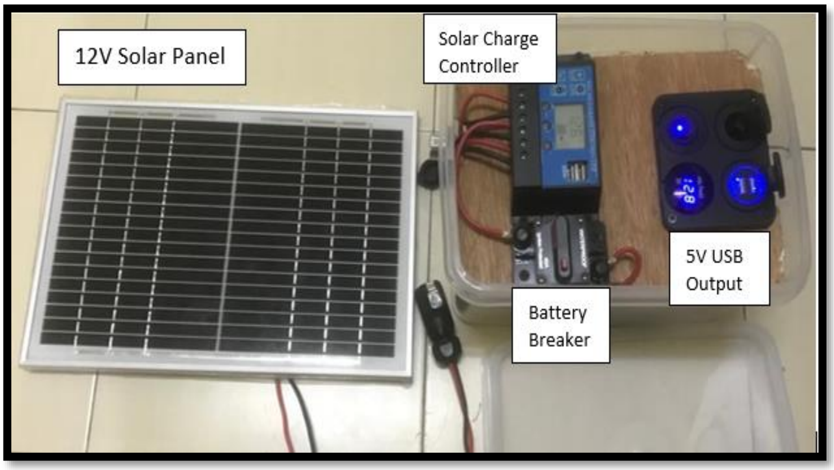

Figure 2: Hardware Development

3.2 Test a Solar Panel with Mustimeter

There are three (3) measurements for solar panels:

(a) Open circuit voltage (Voc)
(b) Short circuit current (Isc)
(c) Operating current

(a) Open Circuit Voltage (Voc)

The open circuit voltage (Voc) on the specs label on the back of a solar panel was located. For this project, a solar panel 12Volt 10 Watt was used. It has an open circuit voltage (Voc) of 21.6V.

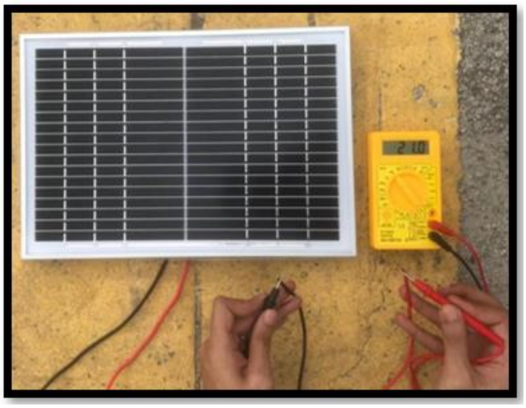

Figure 3: Measure Open Circuit Voltage

Under bright sunlight, the solar panel can achieve a voltage of about 21.0V as shown in Figure 3 which is quite close to the value stated in the design specification. If they're similar, the solar panel appears to be in good working and can proceed to the next stage of hardware testing.

(b) Short Circuit Current (Isc)

On the back of the panel, look for the short circuit current (Isc) on the specs label. The Isc of the panel is 0.6A. PV circuits are tested to short-circuit current tests to ensure that proper readings are obtained and that the circuits are free of major problems. These tests are just meant to ensure that the system is working properly, not to measure performance. It is necessary to have test equipment capable of safely short-circuiting high-voltage DC circuits. Most digital multimeters can measure DC current up to 10 A but must be used with an appropriate shorting device to do so securely. Figure 4 shows measure short circuit current testing.

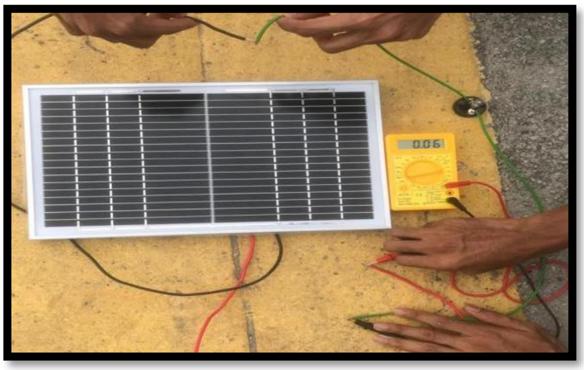

Figure 4: Measure Short Circuit Current

After measuring the solar panel, the result obtained is 0.6A, so these results are acceptable. It's good if the measurement matches the Isc indicated on the back of the panel. The solar panel is functioning properly. To ensure that a solar panel is in good working order, most individuals only need to measure open circuit voltage and short circuit current.

(c) Operating Current (PV Current)

Using a multimeter, the amount of current produced by the solar panel is measured. Solar charge controller (PWM charge controller) and battery are used to measure 12V 7Ah sealed lead acid battery). Connect the charge controller to the adapter. Figure 5 shows the measure operating current testing.

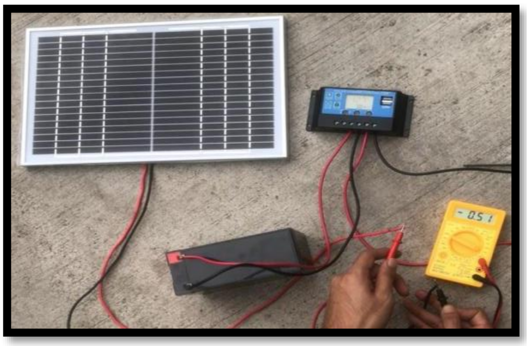

Figure 5: Measure Operating Current

We can compare this value to the current at maximum power (Imp) on the rear of the panel to discover how near the solar panel is at its maximum output right now. My panel, for example, has an Imp of 0.55A, yet I measured a current of 0.51A.

While this may appear to be a long way off, it is not that bad. Solar panels typically produce 70-80 percent of their rated power output, with optimum conditions producing close to 100 percent.

3.3 Load for the System

For the proposed system, the load has been applied to the power supply system which is the charging phone and 5v led lamp. The charge controller will be connected to the load with a 12V output voltage with dual 5V USB output. As this is an off-grid system, it means that the loads are fully dependent on the solar system and battery. Energy consumption must be calculated based on the load applied as shown in Table 2 below.

Table 2: Calculation for load consumption

Description	Parameters and Calculation
Energy Consumption for 5V charging phone	2.4Ah × 5V = 12Wh
Energy Consumption 5V led lamp	1Ah × 5V= 5Wh

The energy consumption must be calculated by its operating time per day which is calculated at 17Wh. A reserved power must be applied which is 1 day of reserved power as a backup for the system if any power shortage happens such as bad weather. Total energy consumption including power reserved is calculated at 34Wh.

3.4 Battery Sizing

Battery sizing is essential to support the energy consumption of the system. This proposed battery sizing will be able to support the energy consumption for the load every day with a precaution if any accident occurs for example bad weather conditions. The calculation for the battery sizing is shown in Table3.

Table 3: Battery sizing

Description	Parameter and Calculation
Nominal Battery Voltage	$12V$
Efficiency of Battery	0.85
Depth of Discharge	0.5
Battery Capacity	$2 \times (\frac{12Wh}{0.85\times0.5\times12}) = 4.7Ah$ / 7Ah
Battery Charging Time	$\frac{7Ah}{0.7A}$ =10 hours

3.5 Result for Monitoring Solar

The charge controller is now connected to a solar panel to demonstrate the charge controller's higher efficiency. The data in Table 4 were collected over some time with no load applied.

Table 4: Shows Times Versus Voltage

No of Testing	Time (hour)	Solar Output Voltage
1	0700	17.00V
2	0800	17.60V
3	0900	17.80V
4	1000	18.00V
5	1100	18.50V
6	1200	18.80V
7	1300	19.50V
8	1400	19.30V
9	1500	19.10V
10	1600	18.70V
11	1700	18.00V
12	1800	17.00V
13	1900	16.50 V

A 10Watt solar panel and a 7.0Ah battery were utilised to collect the data. Due to the modest size of the solar panel, the current is lower than the theoretical value stated in Table 4. The charge controller consumes less than 1 watt of power. It should go without saying that if a higher-wattage solar panel is utilised, the charge controller will run smoothly and accurately.

We can observe from the results in Figure 6 that sun radiation increases from 9 a.m. to 12 p.m. At roughly 1 p.m., solar radiation reaches its greatest value of 19.5V. Then, until the completion of the experiment, the solar radiation began to decrease. The sun insolation fluctuates throughout the experiment, as can be seen. Because of the shading effect induced by clouds, dust, and pollutants, this is the case. We can also see that the voltage value fluctuates, with the morning value being slightly greater than the afternoon value. This is related to energy loss caused by the hot weather in the afternoon. A high insolation value and a temperature of 25 degrees Celsius were required for the PV panel to provide the rated voltage. This experiment demonstrates the need of having a good sun-tracking system to achieve the best possible insolation value. As the rated voltage and power output are dependent on the insolation value, this benefits the SEGS.

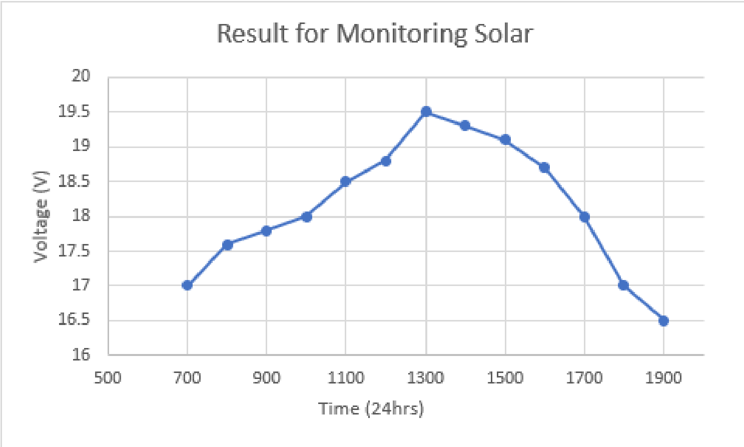

Figure 6: Graph Voltage VS Time

4. Conclusion

In conclusion, the prototype of the system achieves maximum efficiency which reduces power dissipation and heat. Output voltage regulation and efficiency of the charge controller are independent of the number of DC input sources. All the DC input sources share current well as long as their voltages are close to one another. The product can support simultaneous operation of low-power rated electrical appliances and charging of mobile phones. The product makes use of a 12V solar panel to capture the sunlight and convert it to electrical energy. A charge controller is in place to regulate the charging process of the 12V rechargeable battery. To support the charging of handheld devices such as smartphones and tablets, a solar charge controller was implemented to step down the maximum output of an 18V solar panel to a regulated 12V load.

A portable solar power supply that met the requirements was successfully constructed. The product can enable the operation of low-power rated electrical equipment as well as the charging of mobile phones at the same time. A 12V solar panel is used to gather sunlight and convert it to electrical energy in the device. The charging procedure of the 12V rechargeable battery is regulated by a charge controller. A charge controller was designed to facilitate the charging of handheld devices such as smartphones and tablets by stepping down the 12V battery voltage level to a regulated 5V. The finished product includes a USB port and a regulated 5V DC 1W power supply and a 12V power socket.

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