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Buck-boost converter in photovoltaics for battery chargers

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ABSTRACT

Alternative energy is energy that is widely developed by scientists nowadays, especially in terms of electricity. Currently, the alternative energies that are widely developed are wind power, hydropower, geothermal energy, and solar power. Solar power is a promising energy source in Indonesia. The utilization of solar energy requires photovoltaics to convert solar energy into electricity, while for charging 12V/7Ah battery, a buck-boost converter is used. However, the use of the buck-boost converter still has some shortcomings, such as reversed voltage polarity. To address this issue, it is proposed to use a2-switch buck-boost converter. With the2-switch buck-boost converter, it is capable of charging the battery with an initial voltage of19V, which is then reduced to 14.25V to charge the battery with an initial voltage of 10.08V to 11.16V within 60 minutes, maintaining the same polarity as the initial input and with a maximum current from the photovoltaic of3.48A. In this thesis, Atmega16 is used to control the2-switch buck-boost converter and a50Wp photovoltaic with a maximum voltage of 21V and a current of 3.48A.

Keywords: anodic oxidation, anodizing, titanium, corrosion, biomedical

1. INTRODUCTION

In the context of Indonesia's abundant solar energy potential, photovoltaic technology emerges as a pivotal solution for harnessing renewable energy sources [1]. Situated in a tropical region with consistent sunlight throughout the year and significant solar energy potential of 156,487 MW, Indonesia stands primed for the widespread adoption of photovoltaic systems. Photovoltaic, commonly referred to as solar cells, serves as a crucial medium for converting sunlight into electricity, offering a sustainable and environmentally friendly power generation alternative [2][3].

However, the inherently fluctuating nature of solar energy necessitates efficient energy storage solutions to ensure continuous and reliable power supply [4]. This is where battery/accumulator systems come into play, storing the electrical energy generated by photovoltaic panels to mitigate the effects of variable sunlight intensity. To optimize the battery charging process and maximize energy utilization, an optimal charging circuit is indispensable [5][6][7]. The Buck-Boost Converter 2 Switch circuit presents a viable solution, capable of adjusting output voltage levels to match the power requirements of electronic systems efficiently [6].

Solar cells, composed of thin semiconductor layers typically made of silicon, form the backbone of photovoltaic systems [7]. Arranged in solar panels, these solar cells facilitate the conversion of solar intensity into clean electricity, free from pollution and waste. The performance of photovoltaic systems is highly nonlinear and subject to external influences such as solar irradiance, environmental temperature, and wind speed [8][9][10]. Parameters such as short-circuit current (ISC), open-circuit voltage (Voc), maximum voltage (Vmax), and maximum power point (MPP) current are instrumental in characterizing the behavior of photovoltaic systems, as reflected in their I-V and P-V curves [11].

In essence, the utilization of photovoltaic technology holds immense promise for Indonesia's sustainable energy future, offering a viable pathway towards reducing reliance on fossil fuels and mitigating environmental impact [9]. However, effective integration of photovoltaic systems necessitates comprehensive understanding and optimization of charging circuits, alongside meticulous consideration of external factors influencing system performance [12]. By leveraging solar energy through photovoltaic technology, Indonesia can pave the way for a greener and more sustainable energy landscape.

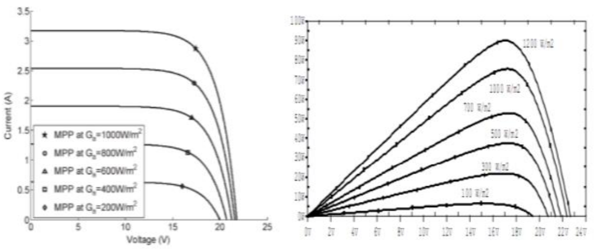

Fig 1. Characteristics Curve of Photovoltaic Panel (a) I-V Curve (b) P-V

In Figure 1, it shows the curve of the I-V characteristics with the function of solar irradiance at a temperature of 25°C obtained through simulation and the P-V characteristics curve. Changes in solar cell irradiance will cause the solar panel's MPP to shift along the P-V curve [13].

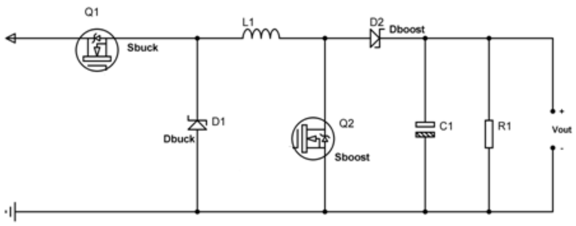

Fig 2. Buck-boost Converter with 2 Switches

In Figure 2, it shows the buck-boost converter is a type of DC-DC converter that can both step up and step down the DC voltage by adjusting the duty cycle of its switch [14]. However, the polarity produced by the converter is opposite to the voltage from the source. To overcome this, an additional switch is added to the buck-boost converter circuit along with two diodes. The operation principle of the buck-boost converter circuit is divided into two phases: when the switch is closed and when the switch is open [15].

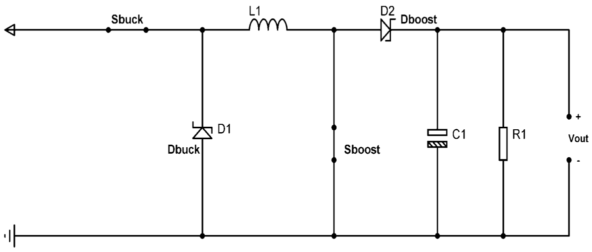

Fig 3. Switch Close

In Figure 3, it shows the buck-boost circuit with the analysis of the closed switch where the Sbuck and Sboost switches are on or closed [16]. This causes the buck diode to work in reverse-bias, so the current will flow towards the inductor and the inductor current will rise until it reaches the maximum current of the inductor [15].

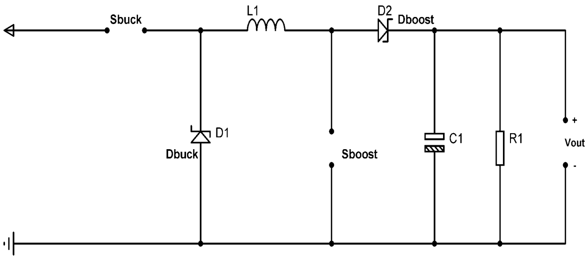

Fig 4. Open Switch

In the depicted buck-boost circuit, showcased in Figure 4, both switches are in the open position, leading to the activation of both the buck diode and the boost diode in forward-bias configuration. Consequently, the current stored in the inductor L is directed towards the load, ensuring a steady flow of power [17][18].

Within this system, several integral components collaborate seamlessly to facilitate efficient battery charging. The primary components include the photovoltaic panel, buck-boost converter, voltage sensor, battery, and supplementary monitoring elements [19][20]. Fundamentally, the battery charging system operates on the principle of converting solar energy captured by the photovoltaic panel into usable electricity [21].

The buck-boost converter assumes a pivotal role in stabilizing the input voltage derived from the photovoltaic panel, thereby ensuring optimal charging conditions for the battery [22]. Concurrently, the voltage sensor serves as a critical intermediary, detecting the voltage output of the photovoltaic panel, which is subsequently transmitted to the Analog-to-Digital Converter (ADC) [23]. The ADC processes the voltage signal, enabling the microcontroller to ascertain whether the charging process necessitates the implementation of a buck or boost converter [24]. Moreover, the current sensor plays a crucial role in measuring the current generated by the converter during the battery charging process, providing essential feedback for optimal system performance [25][26].

To charge the battery using photovoltaic, an electrical design is required. In the design of the buckboost converter circuit with2 switches, it is important to determine the values of the inductor and capacitor [27]. Determining the Duty Cycle

$$V_{out} = -V_{in}\left[\frac{D}{1-D}\right]$$
$$14 = -10\left[\frac{D}{1-D}\right]$$
$$1.4 = \left[\frac{D}{1-D}\right]$$
$$1.4 = 2.4D$$
$$D = 0.583$$

Current capability of the inductor

$$I_{L(avg)} = \frac{V_o}{V_{ln}RD}$$
$$I_{L(avg)} = \frac{14^2}{10 \times 1000 \times 0.583}$$
$$I_{L(avg)} = \frac{196}{58.30}$$
$$I_{L(avg)} = 3.362\ A$$

The difference between the average current

$$\Delta I_{L(avg)} = 20\% \times I_{L(avg)}$$
$$\Delta I_{L\Delta(avg)} = 0.2 \times 3.362$$
$$\Delta I_{L\Delta(avg)} = 0.67\ A$$

Inductor value

$$L = \left(\frac{1}{F}\right) \times [V_{out} \times V_F] \times \left(\frac{V_{in\,min}}{V_{out} + V_F + V_{in\,min}}\right) \times \left(\frac{1}{\Delta I_L}\right)$$

$$L = \left(\frac{1}{20000}\right) \times [14 \times 1] \times \left(\frac{10}{14 + 1 + 10}\right) \times \left(\frac{1}{0.67}\right)$$
$$L = 0.75 \times 10^{-3} \times 0.4 \times 1.452$$
$$L = 4.356 \times 10^{-4} H$$
$$L = 4.356\ mH$$

Capacitor value
$$\Delta V_o = \pm 0.1\% \times V_o = 0.001 \times V_o$$
$$\Delta V_o = 0.001 \times 14$$
$$\Delta V_o = 0.014$$
$$\Delta V_o = \frac{V_o \times D}{R \times C \times f}$$
$$0.014 = \frac{14 \times 0.583}{1000 \times C \times 20000}$$
$$C = \frac{14 \times 0.583}{1000 \times 0.014 \times 20000}$$
$$C = \frac{8.165}{2800}$$
$$C = 0.002915\ F$$
$$C = 3000\ \mu F$$

2. RESEARCH SIGNIFICANCE

The research focuses on the design and testing of a buck-boost converter circuit with 2 switches for efficient battery charging using photovoltaic systems. The components like the voltage sensor, current sensor, and microcontroller are crucial for measuring and processing data during the battery charging process. The buck-boost converter plays a vital role in stabilizing the input voltage from the photovoltaic panel, ensuring optimal charging conditions for the battery.

3. RESEARCH METHODS

In this system, there are several components, namely Photovoltaic, buck-boost converter, voltage sensor, and battery. The working principle of the battery charging system is when the photovoltaic converts solar energy into electricity. To charge the battery, a buck-boost converter is used to stabilize the input voltage from the photovoltaic. The voltage sensor functions to read the voltage on the photovoltaic and then enters the ADC. The ADC signal processed by the microcontroller is then used to determine whether the charging is done using a buck or boost converter. Current sensor is used to determine the current produced by the converter for the battery charging process. The details of the system is shown as block diagram in Figure 5.

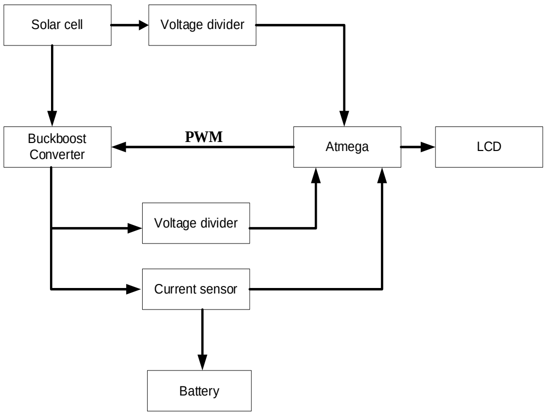

Fig 5. Block diagram of the system

4. RESULTS AND DISCUSSION

In this chapter, testing and analysis of the device will be discussed. The testing of the device includes overall performance testing to determine whether the system is functioning properly and as expected in Figure 6.

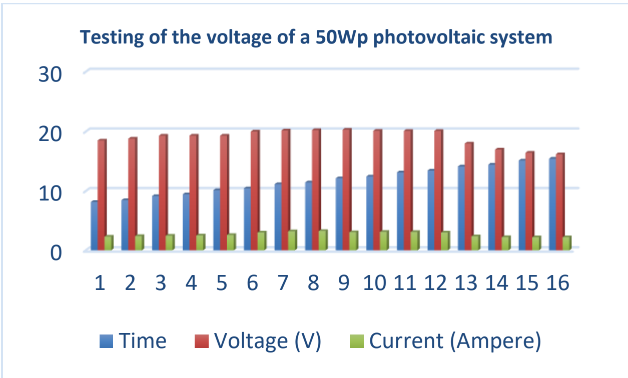

Fig 6. Testing of the voltage of a 50Wp photovoltaic system

Based on the test results, the output of the photovoltaic system is in accordance with the specifications of the 50Wp photovoltaic system. At maximum sunlight intensity, the voltage can reach up to 21VDC.

Table 1. Testing of the Buck-Boost Converter 2 Switch

No	Vin	Duty	Vout	Mode
1	12.78	5	12.28	Buck
2	12.78	10	12.28	Buck
3	12.78	15	12.29	Buck
4	12.78	20	12.29	Buck
5	12.78	25	12.3	Buck
6	12.78	30	12.87	Boost
7	12.78	35	15.36	Boost
8	12.78	40	16.96	Boost
9	12.78	45	17.29	Boost
10	12.78	50	17.21	Boost

Table 2. Battery Charging Test

No	Vin Photovoltaic	Vout Converter	Initial Battery Voltage	Final Battery Voltage	Charging Time
1	19V	14.25V	10.08V	11.16V	60 Minutes
2	21V	11.30V	11.50V	11.97V	58 Minutes
3	11V	11.50V	10.30V	11.68V	74 Minutes

Based on the testing and analysis conducted, it can be concluded that the Buck-Boost Converter 2 Switch circuit is capable of stepping down and stepping up voltage. In Table 1, the charging process using the Buck-Boost Converter 2 Switch circuit with a 7AH battery load, an initial voltage of 10.08V in 60 minutes increased to 11.16V with an input voltage of 19V then lowered to 14.25V with a current of 12mA (Buck Mode). When the initial battery voltage is 10.30V in 75 minutes it increased to 11.68V with a source voltage of 11V then raised to 11.50V with a current of 7mA (Boost Mode). In the future, for utilizing photovoltaic as a battery/accumulator charger, Maximum Power Point Tracking (MPPT) control can be used so that the position of the photovoltaic can move following the direction of the sun.

After testing using the charger in Table 2, it was found that the Buck-Boost Converter 2 Switch is capable of charging a battery with an initial voltage of 19V and lowering it to 14.25V, it is able to charge a battery with an initial voltage of 10.08V to 11.16V in 60 minutes with a maximum current from the photovoltaic system of 3.48A.

5. CONCLUSIONS

In conclusion, this study demonstrates the feasibility and effectiveness of utilizing photovoltaic systems for electricity generation and battery charging in Indonesia's tropical climate. By harnessing solar energy through photovoltaic panels, it is possible to convert sunlight into environmentally friendly electricity, which can be stored in batteries for later use. The implementation of a Buck-Boost Converter 2 Switch circuit provides an efficient means of charging batteries by adjusting voltage levels as needed, maximizing the charging process's effectiveness. Through testing and analysis, it is evident that the Buck-Boost Converter 2 Switch circuit effectively steps up or steps down voltage levels as required, facilitating the charging process efficiently. The results indicate that the circuit successfully charges batteries within reasonable timeframes, with varying initial voltage levels and solar intensities.

Moving forward, the integration of Maximum Power Point Tracking (MPPT) control can further enhance the system's performance by optimizing the photovoltaic panel's positioning to track the sun's direction. This advancement can lead to even more efficient energy generation and battery charging, maximizing the utilization of solar resources. Overall, the findings of this study underscore the potential of photovoltaic systems as a sustainable energy solution in Indonesia, offering a reliable source of electricity generation and battery charging in remote or off-grid areas. Further research and development in this field can contribute to the widespread adoption of renewable energy technologies, fostering a more sustainable and environmentally friendly energy landscape

When the Titanium was anodized at 5,10, 20, 30, and 40 V, it resulted in the color variety of gold, violet, dark blue, and light blues. The anodic film's pore density grew when the voltage was applied, resulting in a lighter tint. The change in voltage also resulted in the pores density of the film to alter, which caused light interference in the film thickness and gave protection to the metal from corrosion. When we apply a greater voltage to anodize the titanium, the corrosion rate increases. It has been discovered that utilizing 10V provides the best corrosion resistance. The coating thickens in the surface due to the high voltage employed in anodizing the titanium, which influences the roughness. corrosion rate and surface roughness are inversely proportional.

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