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Design of Buck-Boost Converter as Battery Charger on AC Power Usage Based on 20W Solar Cell

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Abstract

An automatic battery charging system has been designed using the Buck-Boost Converter (BBC) method based on a 20W solar cell with AC power output that can be monitored and controlled using a Smartphone. The main objective of this research is to create a stable charging system for the battery using energy sources generated from the sun, and to maintain the voltage on the battery so as not to overcharging or undercharging. The results of this study indicate that the automatic charging system on the battery has been created successfully, with the working principle of automatic cut off on the battery when the voltage reaches 14.2 V and cut off the power output on the load when the battery voltage is below 12 V. The BBC circuit is able to stabilize the input voltage from the panel to 16 V. Then it is regulated by the LM 317 regulator to 14.2 V. The LM 317 circuit which is connected to the battery through a relay is able to limit the battery voltage so that it does not exceed 14.2 V. This system is controlled by the Arduino Uno microcontroller. The data in this study is displayed on an LCD and sent to the user via the internet by IoT. Charging and output from the battery to the inverter can be controlled and monitored using the Blynk application on the Smartphone. The output of this system is a 220 V AC voltage source which is inverted by a 12 V DC – 220 V AC inverter.

Keywords: Arduino Uno; Buck-Boost Converter; IoT; Inverter; LM317 Regulator.

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1. Introduction

Solar cell is an electronic device that can catch sunlight and then convert it into electrical energy. Solar cells is the latest energy technology that is growing rapidly because it is able to produce electricity from sunlight energy [1]. However, based on the principle of use, the solar cell needs a battery that is used to store the energy which is produced from the solar cell so that it can be used at any time, such as at night when there is no sunlight, the renewable energy from this solar cell can still be used. The method of storing batteries from solar cells requires a converter that can stabilize the voltage generated by the solar cell which is fluctuating or changing. Buck-boost Converter is a DC-DC converter that is able to increase the voltage level and also lower the voltage level from the input so that this converter can be used to stabilize the input voltage to the battery. The results of Elfani's research in 2016 this converter was able to increase the voltage to 20 V and the buck converter was able to reduce the voltage to 0.5 V DC current generated by a 3W solar cell [2]. Research in 2015 conducted by Liu and his colleagues the switching frequency on the BBC was 13.56 MHz on the Wireless Power Transfer system with an efficiency of 70% [3]. In 2019, Asy conducted research on battery charging using the BBC method, which resulted in a relatively high charging efficiency of 73.9% [4]. In a study conducted by Kurniawan in 2018, found that the transient result in the BBC were 1 microsecond with a wrinkle voltage of 20 mV using a 5A load [5]. Proportional control on the BBC is obtained at a speed of 0.5s and there is a slight overshoot detected on the output of the BBC based on research who was conducted by Komaruddin in 2014 [6]. In this paper, a battery charging system with automatic charger is made using the buck-boost converter method as a voltage stabilizer which is connected with LM317 regulator as voltage protection on the battery to keep the input voltage from the panel to the battery at one point.

2. Material and Methods

In this study, an AVR-based microcontroller Arduino Uno is used as the system controller. This microcontroller controls the whole system starting from detecting panel voltage, battery voltage, battery temperature, setting the switching frequency, displaying the measured value using LCD and Smartphones. As shown in Figure 1, the microcontroller is connected by 3 sensors, there are 2 voltage sensors and 1 temperature sensor. A temperature sensor and one voltage sensor are connected to the battery to measure the output voltage of the battery, and another voltage sensor is connected to the solar panel to measure the output voltage of the solar panel. Then the measurement value from the sensor is inputted and will be displayed on the LCD and sent to the user via the internet network by IoT, so that it can be controlled and monitored using the Blynk application on the Smartphone. The working principle of this system is the microcontroller will control the driver and relay that are connected between the solar panel and the BBC as an automatic cut-off the current in the circuit when charging on the battery is detected to have reached the maximum voltage. BBC is used to stabilize the voltage generated from solar panels that is fluctuative, the voltage will be raised or lowered to 16 V and then regulated by the LM 317 Regulator to 14.2 V, that is the battery voltage when fully charged. The mosfet that is connected between the BBC and the regulator are used to adjust the switching on the battery in order to disconnect the input voltage from the panel when the battery voltage has reached the maximum specified limit. The output of the battery is 12V DC voltage that will be inverted to 220V AC by the inverter. Between the battery and the inverter is connected by a relay and a driver controlled by Arduino as an automatic cut off when the voltage on the battery is detected low.

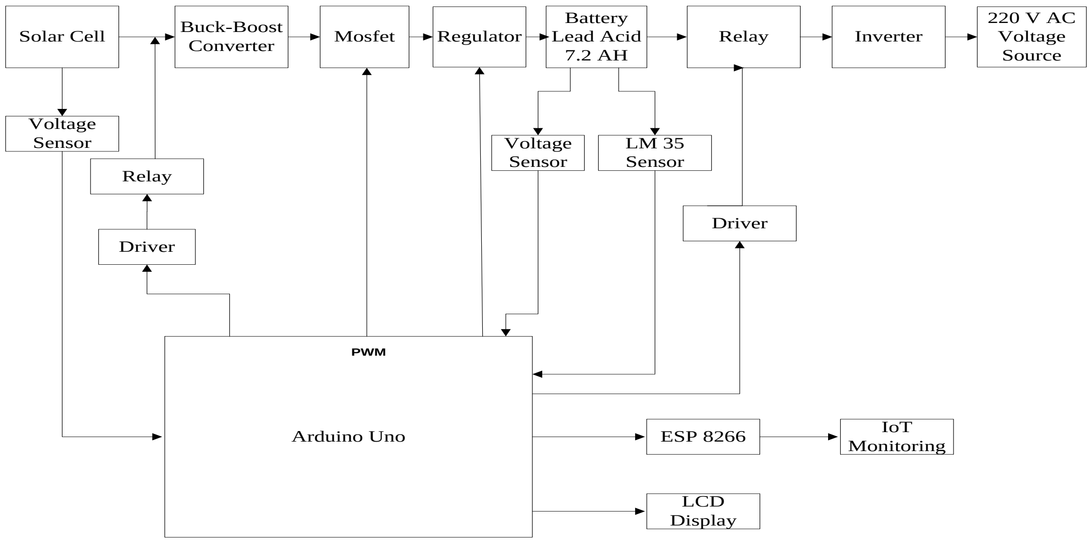

Figure 1: Block Diagram

3. Results and Discussions

The design of the tool is a system for converting solar energy into electrical energy as an effort to develop renewable alternative energy. There has been a lot of research in this field and there have been many products sold in the market. From the author's research and observations on a PV (Photo Voltaic) system where a PV system or solar panel always produces a voltage that fluctuates depending on the intensity of light. Higher voltages can be regulated, but if the resulting voltage is too low then the voltage cannot be regulated and will remain low. Based on these facts the authors examine how to overcome these problems. The voltage must be able to be increased when the panel output is relatively small. The only way is to use a series of dc to dc converters called Buck-Boost Converters. BBC is a voltage step up and step down circuit with with high frequency switching principles. Switching is done on a ferrite core induction coil. Switching on a coil will result in voltage induction. Voltage induction makes the voltage higher than the source voltage. The magnitude of the induced voltage depends on the given switching frequency. Thus, the voltage can be regulated by adjusting the switching frequency by the microcontroller. The design is built with electronic components and a solar panel. The output of the solar panel is given to the boost converter circuit to be regulated before being used to charge the battery. The battery as an energy storage medium will store the energy generated by the panel before it is used in the load. The microcontroller controls the whole system starting from detecting panel voltage, battery voltage, adjusting switching frequency, displaying LCD and so on. The system is also equipped with a data sender module, that is the node mcu so that system parameter data can be accessed by users via the internet with a smartphone application.

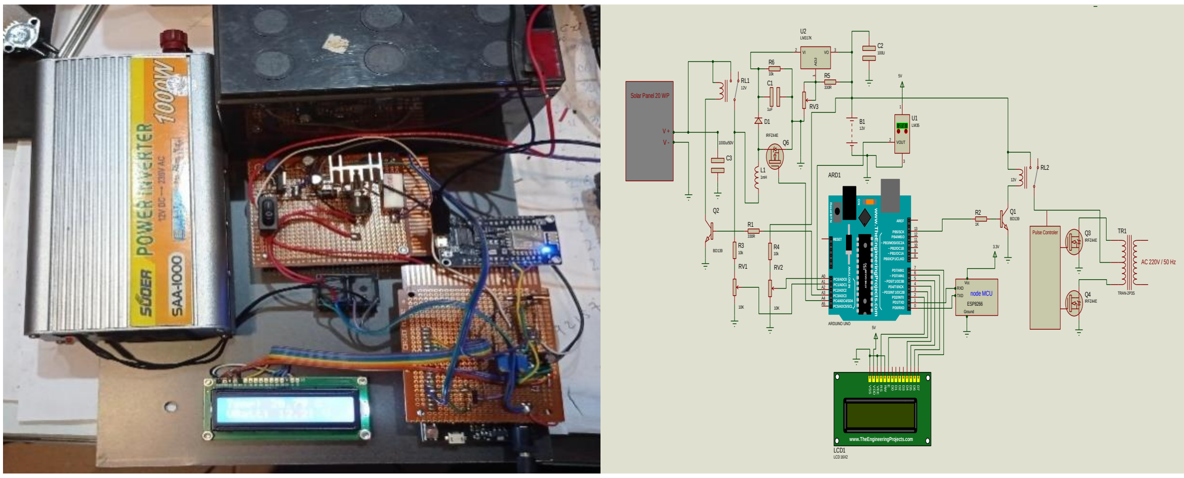

Figure 2: Charge Circuit Design

Figure 2 is a design of the BBC as a charger for the use of 20W Solar Cell-based AC power that has been successfully done. In the picture above, there are several components such as lead acid batteries 7.2 AH, inverters 12 DC – 220 AC, LCDs, Arduino microcontrollers, BBC circuit, Node mcu and so on.

3.1 Buck-Boost Converter Circuit Test

The BBC circuit is used to increase the panel voltage when the panel output is weak, which is below 12V. The buck boost converter circuit serves to raising the voltage when the panel voltage is below 12V and lowering when the panel voltage is above 16 V. BBC will adjust the voltage to 16V so that it can be regulated by the LM 317 Regulator circuit. The load in this test is a 10 Ohm 10 Watt resistor. In this test, a variable power supply is used as the input voltage so that the voltage can be adjusted from 0 to 20V.

Table 1: Buck Boost Converter Circuit Test Results

Input Voltage (V)	Output Voltage (V)	Output Current (A)	Output Power (W)
0	0	0	0
2	0,2	0,02	0
4	15,8	1,57	24,80
6	15,9	1,58	25,12
8	16,1	1,59	25,59
10	16,2	1,60	25,92
12	16,1	1,59	25,59
14	16,2	1,61	26,08
16	16,2	1,61	26,08
18	16,2	1,61	26,08
20	16,2	1,61	26,08

From the table above, it can be seen that the input voltage with a value of 0V to 6V, BBC has not been able to work optimally, that is the output voltage does not reach 16 V. In testing with input voltage of 8V to 14V the BBC is able to raise the output voltage to 16 V. when testing with input voltage value of 16 V to 20 V, the bbc is able to reduce the output voltage to 16 V. It is concluded that the minimum voltage value that can be increased is 8 V and the maximum voltage value which is tested is 20 V, can be reduced to 16 V.

3.2 Regulator Circuit Test

The regulator is used to stabilize and limit the output voltage of the solar panel. Without a panel voltage regulator will go up and down according to light conditions. This voltage will make the battery charging process unstable. The regulator works to limit the voltage at a certain voltage. In this design the regulator is set to work at a voltage of 14.2 V, which is the battery voltage when fully charged. To test the regulator, it is done by using a solar panel that is placed under the sun and measuring the input and output of the regulator. As a load a 10 Ohm 10 watt resistor is used which is installed between the regulator output and ground. Current is measured with a digital ammeter in series with the load resistor. The following is a table of measurement results made during testing.

Table 2: Test results of the LM 317

Input Voltage (Vin)	Output Voltage (Vout)	Output Current (I)
7,1	5,3	0,51
9,2	7,2	0,77
10,8	9,7	0,93
12,5	11,4	1,17
13,6	12,9	1,30
14,9	14,2	1,19
15,7	14,2	1,19
17,1	14,2	1,21
18,5	14,2	1,20
19,8	14,2	1,21
20,3	14,2	1,21

From the regulator test in the table above, it can be seen that the regulator output voltage will be maintained constant at 14.2V when the input voltage is greater than the output voltage, the voltage will be maintained even though the input voltage is continuously increased. It is concluded that the regulator is able to lower the voltage and maintain it at one point, but the regulator is not able to increase the voltage when the voltage is less than 14.2 V.

3.3 Overall Circuit Test

Overall testing is carried out after all components are integrated into a system, that is a battery charger with the principle of switching Buck-boost converter. This test is carried out during the day because the source of electrical energy is obtained from sunlight. Solar panels that have been connected to the appliance are placed outside the room, which is dried under the hot sun while the charger and battery circuits remain indoors. The light absorbed by the solar panel will be converted into direct current electricity, the output voltage of the solar panel depends on the intensity of the light received at that time.

Table 3: Overall Test Results

Time	Solar Cell Voltage (V)	Voltage after Regulation	Battery Voltage (V)	Charger Switch Condition	Inverter Switch Condition	Inverter Output Power (W)
11:00	17,81	14.2	12,78	OFF	ON	11,02
11:30	18,83	14.2	12,62	OFF	ON	10,98
12:00	16,71	14.2	12,49	OFF	ON	10,91
12:30	19,92	14.2	12,33	OFF	ON	10,87
13:00	18,74	14.2	12,25	OFF	ON	10,86
13:30	10,76	14.2	12,15	ON	ON	10,67
14:00	11,98	14.2	11,88	ON	ON	10,07
14:30	12,81	14.2	11,07	ON	OFF	0,0
15:00	12,29	14.2	11,98	ON	OFF	0,0
15:30	11,67	14.2	12,09	ON	OFF	0,0
16:00	12,21	14.2	12,38	ON	OFF	0,0
16:30	11,87	14.2	12,67	ON	ON	10,98
17:00	11,67	14.2	13,89	ON	ON	11,06
17:30	10,27	14.2	14,22	OFF	ON	11,12

From the overall testing of the equipment, at 11.00-13.00 the charger is in an OFF state, the battery voltage is still above 12.2 V while the inverter is ON. Then At 13.30-17.00 the charger is automatically ON because the battery voltage is below 12.2 V and the charger is ON until the battery voltage reaches 14.22 V, then the charger will turn OFF automatically because the battery has reached the specified maximum voltage. At 11.00-14.00 the inverter condition is ON, and the inverter is automatically OFF when the battery voltage is below 12 V at 14.30-16.00, the output value of the battery voltage becomes 0.0 V. The inverter can be turned ON again at 16.30 to 17.30 when the battery voltage above 12 V. In addition to being displayed on the LCD, the data will also be sent to the user via the internet network by IoT. Data can be monitored using the Blynk application on a smartphone as shown in Figure 4 below. This picture shows the results of monitoring via smartphone using the Blynk application. In order for the circuit connect to the internet, Then a WiFi hotspot is needed. The name and password of the wifi should match with the WiFi hotspot to be connected. If the internet signal is good, the connection will immediately be connected and the data can be received by the smartphone. However, if the signal is not strong enough, there will be a delay. And if connectivity is lost there will be a red sign on the top of the application so it has to restart or wait until the signal improves.

Figure 3: Screenshot of the Blynk Application on a Smartphone

From figure 3, The ON/OFF top button is for activate and deactivate the charger relay manually. While the ON/OFF buttons below it is for activate and deactivate the inverter relay. The smartphone also displays data during charging, that is the value of the panel voltage, panel current, panel power, battery temperature and battery voltage. From the results above, it can be stated that the IoT test, namely monitoring the voltage parameters, has been successfully carried out.

4. Conclusion

A charger system has been successfully designed with the BBC method which is designed with the principle of switching on a coil, it is the principle of voltage induction due to alternating current flowing in the coil with a certain frequency. This circuit consists of a series of Buck-Boost Converter which works to keep the voltage stable, when the voltage is below 12 V the boost circuit will increase the voltage by setting the switching frequency to be higher. And when the solar panel voltage is above 16 V, the Buck circuit will work to lower the voltage by setting the frequency to be lower. This tool uses the LM 317 regulator circuit to regulate the voltage so that it does not exceed 14.2V. To maintain the input voltage on the battery so that the battery is not damaged during recharging. The regulator output is connected to the battery via a relay. Where the Arduino microcontroller will read the battery voltage, if the battery voltage before being burdened is below 12.2V then the microcontroller will activate the relay so that the charger can work to flow current to the battery, and when the voltage on the battery reaches 14.2 V, the microcontroller will disconnect the relay so that charging is stopped. During the recharging process, the microcontroller will still read the battery voltage and temperature. This data is displayed on the LCD and sent to the user via the internet network, namely IoT. On the user side, the data can be monitored using the Blynk application on a smartphone. Then the output on the system is 220V AC voltage source which is inverted by a 12 V DC – 220 V AC inverter.

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