Automatic Design of Battery Charging System Power Supply from Photovoltaic Sources Base on Voltage

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Abstract. Short charging times are desirable from a battery powered system. However, the short charging time must also be considered the reliability of the system. Where the short charging time does not cause damage to the control system and battery. The battery has an important role as a source of power supply when the sun is not bright. By minimizing battery charging time, the battery can be maximally utilized as a power store. So the minimum charging time is obtained, but with maximum storage power. We present battery charging control method and auto switch off on this system. The controller is based on a constant voltage (CV) charge control scheme. In order to keep the parameters constant, this research prototype uses a DC-DC controller. The experimental results show that, the new controller charging period is significantly reduced. Moreover, the proposed controller has high accuracy and minimized battery overcharging.

1. Introduction
Electrical energy had an important role in human life. Humans use energy to do their life activities every day. Because each of these activities requires a device with an electrical energy power supply. Meanwhile, most of the energy consumption to produce electrical energy uses fossil energy. The higher rate of energy consumption can cause the depletion of fossil energy reserves available on Earth. To suffice the increasing energy needs, various alternative energies are developed as a substitute for it, one of which is Photovoltaic. However, in its application there are obstacles in the use of solar energy, namely the nature of the energy produced is Intermittent. Intermittent is a phenomenon of the inability of renewable energy power plants to produce energy continuously. As an example of application solar energy, solar energy uses solar panels to convert sunlight into electrical energy. The panels will generate electricity as long as there is sunlight, and they cannot generate electricity when there is no sunlight (eg at night). This is because renewable energy generation is very dependent on the source of the generator, such as the case of solar panels above. This variation in the presence or absence of energy is called intermittent. One of the effects of intermittent is the occurrence of blackouts when the plant is unable to produce electricity. To overcome this problem, it solved by overcoming energy shortages by supplying energy from other sources, for example from natural gas. This is done to balancing between demand and energy production (demand = production). Another alternative solution is to utilize energy storage technology. Energy storage makes it possible to store excess energy obtained at a certain time, then use it as backup energy when energy production is low.

Energy storage is a way to store energy that can be used at a certain time. Batteries are a form of energy storage consisting of one or more electrochemical connected to electrodes to store electrical energy known as Battery Energy Storage (BES). BES can be used as a storage source or energy for mobile applications such as electric vehicles (electric motors, electric cars, etc.) and stationary applications such as data center equipment, telecommunications, and renewable electricity generation.
In BES operation it is affected by charging and discharging process. The lifetime of BES will be disturbed when it gets overcharging, under discharging, and continuous charging time. But on the other hand, it is necessary to optimize charging of BES so that the charging time is faster but does not reduce the lifetime of the BES[1].

Charging control is an important issue to battery management systems. Its aim to feeding external electrical energy sources into batteries in a fast, safe, and efficient. Fast Charging is a method to regulate charging faster. It contributes to reducing time charging. Charging with safe not only assures the safety of users by preventing battery burning during the charging process but also increases the battery life by minimalizing overcharging and overheating damage. Effective charging can convert as much electrical energy as possible from a charger to electrochemical energy stored in a battery so as to increasing energy efficiency[2].

There are many methods for charging batteries. The earliest charging method is the constant trickle current (CTC) method. It has a simple circuit structure and very low cost. There are many methods for charging batteries, The earliest charging method is the constant trickle current (CTC) method. It has a simple circuit structure and very low cost. But it provides a small current, so the charging time to be extremely long. The constant current constant voltage (CCCV) method has been proposed to minimize CC charging disadvantages. A CC period is applied till the charging voltage reaches a predetermined value, and then the charging process goes to the CV period. In the CV period, the charging voltage is fixed to a cutoff value; therefore, the charging current will be automatically reduced as soon as with the increase of SOC. Fuzzy control has been applied to solve the charging control problem[3], [4]. Optimal control with considering power loss model was adopted to enhance the charging efficiency[5], [6]. In [4], neural networks and genetic algorithms are introduced to design the membership functions and rules table of the fuzzy controller.

The algorithm of a battery charge controller determines the effectiveness of battery charging and the ability of the system to suffice the electrical load demands. The most usual approaches for charge controllers are the shunt, series, pulse width modulation (PWM), and MPPT charge controllers. The shunt controls the charging of a battery from the PV array by short-circuiting the array internal to the controller. The series controller utilizes some type of control element connected in series between the array and the battery. While this type of controller is mostly used in small PV systems, it is also the practical choice for larger systems in consequence of the current limitations of shunt controllers. The MPPT battery charge controller incorporates a DC-to-DC converter such that the PV array can operate at the maximum power point at the effective solar irradiance[2], [7]–[10].

This paper provides the design and practical implementation of a new charge controller that keeps on the good features and resolves the limitations of the traditional controllers. The proposed battery charge controller uses the constant current–constant voltage as a charging scheme in order to reduce the charging time. In addition, the proposed controller has great accuracy.

2. Methods
There are intensive and continuous research efforts in the design and implementation of solar charger regulators to increasing their performance parameters. The targets are: increasing their efficiency and reducing the period of charging. In this section, the design and implementation of charger controllers will be observed to show their main features, drawbacks, and limitations. This would assist to achieve advancements in the solar charger controller.

The methods of battery charging control are classified into two classes: single stage, and multi-stage method. The constant current charging is an optimal example for single stage method, while the constant current, constant voltage technique is an optimal example for multistage charging method. Studies show that multi-stage charging is the most efficient and effective for battery charging regardless of the battery type[7], [8].

The structure of battery charge controllers relies on the type of controller. In the series and shunt controllers, it only consists of a switching element, such as a relay that is switched on/off based on the value of a predefined set point. In PWM and MPPT controllers, the circuits are more sophisticated. In PWM generator circuits or microcontrollers are needed to drive the switches of a DC–DC
converter[9]. However, the MPPT controller consists of a controller that set the maximum power point tracking process and DC-DC converter]

2.1. The Basic of Photovoltaic
The use of solar energy to electrical energy was first introduced by Alexander - Edmund Becquerel in 1839. His findings were the pioneer of solar cell technology. The discovery changed the perspective on energy and provided a new way to obtain electrical energy without the need to burn fossil fuels as in oil, natural gas, or coal, nor by taking the path of nuclear fission reactions. Solar cells have unique characteristics that can generate electrical energy directly and are easily moved as needed. It’s made of tiny pieces of silicon coated with a special chemical to form the basis of the solar cell. It is made of semiconductor material with positive and negative poles. To be able to more easily understand the construction of photovoltaic, it can be done by reading and understanding figure 1[1], [8], [10].

Basically, a solar cell is a photodiode that has a large surface. The large surface area for this solar cell makes this solar panel device more sensitive to incoming light and produces a stronger electric current than photodiodes in general. The minimum thickness of the solar cell is 0.3 mm. For a simple example, a solar cell made of semiconductor material is able to produce 0.5 volts and a maximum current of 0.1A when exposed to direct sunlight.

2.2. DC to DC controller
There are two types of voltage in electricity, namely alternating current (AC) and direct current (DC). The two types of voltage have different characteristics. These characteristics can be seen from the waveform and the resulting response. AC voltage is a voltage or current with a polarity that changes with time. So the AC voltage can be known frequency and period in a certain period of time. While the DC voltage is defined as a voltage that has a fixed polarity each time. DC voltage can be generated by DC generators and some energy generators from renewable sources (i.e. photovoltaic).

![Figure 1. Basic Construction of Solar Cells](image)

To supply DC loads (i.e. laptops, mobile phones, etc.) from photovoltaic, a dc to dc converter is needed. The DC-to-DC converter functions to convert direct voltage to direct voltage output by adjusting the duty cycle in the control circuit. DC to DC converters are power electronic circuits that intended to convert dc voltage to a different voltage level. In this study, the variable voltage generated by PV will be stabilized by a dc to dc converter[10].

There are several types of DC converters including buck converter, boost converter and buck-boost converter. Boost Converter is an electronic circuit for power supply purposes. Boost Converter is also known as DC to DC voltage boost converter. Buck-converter is an electronic component that can lower the DC voltage to a lower voltage level, for example lowering the 12V DC voltage to 5V DC.
Buck Converter is a converter that is able to increase and decrease the voltage according to the expected voltage level. The circuit of the buck converter is represented in Figure 2. Where the circuit requires components that make up the circuit, namely diodes, capacitors, inductors and switches. The diode used is adjusted to the input voltage rating. As for the inductor (L) and capacitor (C), the value is determined by calculating using equation (1) - (4) and for the switch used is a MOSFET. Where this duty cycle will regulate the switching process to be carried out. The waveform of the buck converter can be seen in Figure 3. In this study using a buck converter to reduce the voltage generated by PV to the load. The setting in the DC to DC Converter is done by controlling the duty cycle which is represented in figure 4 [8], [10].

\[
D = \frac{t_{on}}{T} \quad \text{instead of} \quad T = \frac{t_{on}}{D} \\
\]

\[
T = \frac{1}{f} \\
\]

\[
L = \frac{V_{0}(1-D)}{\Delta i_{L}f} \\
\]

\[
C = \frac{V_{0}(1-D)}{8\Delta i_{L}f} \\
\]

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Figure 2. Buck Converter Circuit.

Figure 3. Buck Converter waveform

Figure 4. Block diagram of system control with DC to DC Converter
2.3. Power Supply

Electrical device that function to supply an electrical load is known as a power supply. The main function of a power supply is converting the electric current from the source into the voltage, current, and frequency according to the load requirement. The power supply system in a circuit must be considered carefully. This is related to the amount of damage because of overheating the power devices, so several studies proposed switching power supplies by adjusted according to the operating temperature. In order to improve the performance of the power supply, a temperature, power, and output current control unit is added to the conventional switching power supply technology. Besides that, the system added a temperature monitoring unit to test the operating temperature and also input-output power in every powered device in the system. So the state diagnosis will affect switching power supply to reduces the temperature by reducing the output current and reducing the loss of power. Thereby achieving the purpose of extending the lifetime of the power supply and improving the reliability of the power supply. So it shall improve the performance of the system [2].

2.4. Automatic Battery Charging System

Electrochemical energy storage devices are known as Batteries. In the battery there is an electrolyte as a place to store energy. In the process of charging the battery, electrical energy is stored in the electrolyte. Furthermore, in the discharging process, the energy stored in the electrolyte is released into DC power. Batteries are one source of energy that is still very commonly used, because it is portable and can be used anytime when needed. However, charging the battery with a high current supply will cause excessive heat so that it will increase the temperature. Where high temperatures can reduce battery life. Another thing that can reduce battery life time is that the battery is full but the battery is still supplied or the voltage used to charge the battery is above or below the proper voltage range.

In this study, automatic control charging is presented. It is a tool used to regulate the charging current of the battery. So, It can minimize the occurrence of overcharging. Overcharging is excess charging of the battery because the battery is full. Overcharging can result in reduced battery life so that the battery will be damaged quickly. It gives an order to stop the battery charging system if the battery is full.
3. Proposed System Design
The block diagram of this research is shown in Figure 6. It is composed of six main unit that should be considered. Photovoltaic used to convert sunlight into electricity, Current sensor to detect the electric current flowing in the load, Voltage sensor to detect DC voltage flowing in the load, liquid crystal display (LCD) as a medium for displaying the results of the readings made by the sensor and as a provider of the status of the battery condition, and the most important unit in this study is the controller, where the controller here functions to control the charging process of the battery and give orders to charge or stop charging if it is full. In this controller there is a buck boost converter to adjust the input voltage from the intermittent PV and adjust the output voltage of 14.2 Volts To manage the process of charging the battery, control is carried out in the charging process, namely by automatically disconnecting charging if the battery is full. The hardware design in making the monitoring and automatic charging system is represented in fig 5.

![Block Diagram of Proposed System Design](image)

**Figure 6.** Figure with short caption (caption centred).

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![Flow Chart of Automatic Charging](image)

**Figure 7.** Propose flow chart of Automatic charging

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Figure 7 represents the proposed flowchart which can be used to control battery charging. It starts with initializing the initial value, namely the battery reference voltage. Then the current sensor and voltage sensor read the output of the charging system connected to the battery. Then check the condition of the battery whether the battery is full or not. The battery is said to be full if there is no current flowing in the battery and also the comparison between the measured battery voltage (\(V_{\text{bat}}\)) and the reference voltage (\(V_{\text{bat,ref}}\)). If the battery is not fully charged, then charging continues.

![Solar cell test](image)

Figure 8. Solar cell test

4. Results and Discussion
This chapter will be discussed about the results of the tests that have been carried out. Tests in this study were carried out to determine the level of success of the system created. There are 2 (two) tests carried out, namely testing on photovoltaic and automatic chargers.

4.1. Photovoltaic Testing
First, the research results that must be seen are the output voltage test data from the solar cell. The data of output voltage from the solar cell is obtained from testing for 1 day on May 20, 2021, from 08.00 AM to 01.00 PM. Figure 8 shows the process of taking solar cell test data. The solar cell test data can be seen in Table 1. Table 1 explains that the solar cell output voltage data changes according to the amount of sunlight received by the solar cell. The maximum output voltage of the solar cell is 13.2 Vdc.

| No | Time  | Output Voltage (V) |
|----|-------|--------------------|
| 1  | 08.13 | 13.1               |
| 2  | 08.20 | 13.1               |
| 3  | 08.37 | 13.0               |
| 4  | 09.30 | 13.0               |
| 5  | 10.30 | 12.9               |
| 6  | 11.10 | 12.9               |
| 7  | 12.20 | 12.9               |
| 8  | 12.50 | 13.2               |
Table 2. Automatic charger test data

| Charger Voltage | Battery Voltage | Indicator Light Condition |
|-----------------|-----------------|---------------------------|
| 13.1            | 13.0            | On                        |
| 13.1            | 13.0            | On                        |
| 13.0            | 12.96           | On                        |
| 13.0            | 12.87           | On                        |
| 12.9            | 12.81           | On                        |
| 12.9            | 12.77           | On                        |
| 12.9            | 12.7            | On                        |
| 13.2            | 12.00           | Off                       |

Figure 9. DC lamp not connected to source

Figure 10. Image of DC light on

4.2. Automatic Charger Test

The next test is the automatic charger test. The charging system on the battery will automatically cut off or disconnect if the battery is full. The load used in this test is a 12 Vdc lamp load with a power of 9 Watt. Figure 10 shows the DC lamp load inflaming condition. After the DC light load is on, the automatic charger test can be carried out. The automatic charger test data is shown in table 2.

The image of the battery voltage during the charging process can be seen in Figure 11 and 12. The automatic charger can be applied to this system that shown in table 2. This is evidenced by the indicator light that turns off when the battery is full. The picture of the indicator light turns off when the battery is full can be seen in Figure 13. While the picture of the battery voltage can be seen in Figure 14.

Figure 11. Indicator light is on

Figure 12. Battery voltage during the charging process
5. Conclusion
In this paper, an automatic design of a battery charging system from photovoltaic sources based on constant voltage (CV) to keep the parameters constant has been successfully created. The proposed technique can control the voltage which is applied to the converter. It can be seen from the experimental results where the charging indicator light goes out and the charging process will automatically stop when the battery voltage has been reached, which is 12 Vdc. And the charging process will continue until the voltage value is obtained according to the set point.

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