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Study of Battery Charging Methods for Solar Renewable Storage Energy System

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Abstract: In this paper, a simple battery charge controller using mostly discrete components is proposed and designed to protect the battery from overcharging and deep cycle discharges. The design consists of three stages which include current booster, battery charge controller and battery level indicator. The current produce by solar panel go through the current booster in order to maximize the value. The current booster is capable to control the current to make sure it get the maximum value current. LM317 voltage regulator are used to keep the voltage constant. The battery charger control are used to control the charging of the battery. This circuit are used the Integrated Circuit LM358 to control the charging process. The battery level indicator are used to indicate the battery if the battery is fully charged. This circuit are used operational amplifier and light-emitting diode (LED) to indicate the battery. The voltages are measured in the three stages of the circuit. The voltages are measured according to the time to detect the value through the circuit. The output voltages at 12 pm are measured to be 0.18 V, 0.27 V and 0.22 V for current booster, battery charger controller and battery level indicator, respectively. Normally, the higher the heat of the sunlight, the higher output voltage will be produced. The battery take about 5 hours to reach a full charge from 7.00 V to 12.34 V. This study is using locally sourced and available components that has developed a low cost, reliable and practical solar charge controller.

Keywords: Solar Panel, Current Booster, Battery Charger Controller, Battery Level Indicator, Rechargeable Battery

1. Introduction

Solar energy is produced by sunlight as an environmentally sustainable, non-vanishing, renewable energy source. Enough energy from sunlight reaches the earth every hour to satisfy the world's electricity demand for a whole year. This solar power is generated for industrial, commercial and residential applications [1]. Power undoubtedly plays a crucial role in the growth of human life and energy is one of the main issues for every nation's growing future. Most of which are the amount of solar radiation that influences the surface of the photovoltaic modules, which in turn depends on local

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climatic conditions and mounting modules [2]. The main problem of this solar charging is to avoid the battery from overcharging or deep charging that can damage the battery. So, battery charge controller is developed. If the controller does not have in the solar charging controlled, the battery that used for stored the energy from the solar panel can drastically reduce its lifetime due to the overcharging or deep charging. Until recently, photovoltaic systems have been primarily designed to provide the electricity generated created at a fixed feed-in remuneration directly into the grid that was typically assured for 20 years. As a buffer for solar energy, lithium-ion (Li-Ion) batteries can store excess photovoltaic (PV) generation in the battery for self-consumption during periods when demand exceeds supply. [3]. Cell lithium-ion battery costs are decreasing steadily although their duration life is gradually rising. Investing in a battery storage Li-Ion would thus more appealing financially for the future [4]. There are two types of batteries which are used for PV systems are lead acid and cadmium nickel. Their usage is mainly based on their long service life with reduced maintenance, and their ability to stand deep discharge without damage [5].

This study is about to controlled the charging of the battery in order to prevent the reduction of battery lifetime [6]. The charging controllers block reverse current and avoid overcharging of batteries. Preventing overcharging is essentially about rising energy transfer to the battery as the battery exceeds a certain voltage [7]. Solar controllers also known as charging controllers which play a significant role in the operation of solar chargers. Their aim is to ensure that the batteries operate preferably, specifically disconnecting solar panels to avoid overcharging when the batteries are fully charged. A charge controller plays a key role in shielding the battery in this regard [8].

2. Literature Review

2.1 Battery charge controller

Series, shunt, pulse with modulation (PWM) and maximum power point tracking (MPPT) charge controllers are the most widely used types of solar PV charge controllers [9]. The series controller uses a kind of control feature that links the PV array to the battery in sequence. Generally, series regulators connect and disconnect the solar array through a relay or transistor. Since the relay or transistor can be mounted either in the negative or positive side, series regulators can be used in both positive and negative grounding systems. The battery voltage drops until the reconnect voltage is reached without any charge current, at which time the regulator allowed the current to flow back into the battery again [10]. The voltage of the battery rise, and repeated the cycle. Unlike shunt regulators, multiple relays or transistors may be controlled by some series regulators, allowing multiple disconnect or reconnect set points and stepped charge current. When the series regulator opens the array during regulation, during this time the measurement of the voltage of the array would yield the voltage of the array that should be near the open circuit. During normal charging, the voltage in the array should be slightly higher than the voltage in the battery. This will suggest an issue if an array voltage value is lower than the battery voltage ever measured during normal operation.

2.2 A fully integrated solar charger controller with input MPPT regulation protection for 10 V to 28 V solar powered panel [11]

The MPPT safety control feature removes voltage and current from the solar cell, and then keeps the solar cell's operating voltage above the desired amount. If the voltage of the battery is very close to the voltage level needed, the power is changed to constant voltage power and the voltage of the battery can reach and sustain the correct voltage level. Figure 1 shows the presented solar charger architecture.

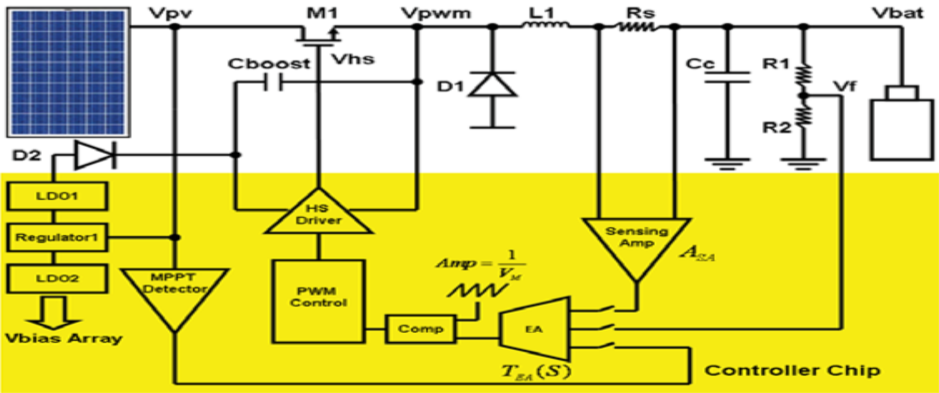


Figure 1: Solar charger architecture [11]

2.3 Design of a solar powered battery charger [12]

Liu et al. introduced the design of a solar powered battery charger with optimal controller [12]. The optimal controller consists of a microcontroller and a DC to DC converter, in which the microcontroller software implements the optimal power control. The purpose of the proposed device is to transform the solar power as much as possible into electricity under the changing environmental conditions and to charge the battery as quickly as possible according to the state of the battery life cycle. The purpose of the proposed device is to transform the solar power as much as possible into electricity under the changing environmental conditions and to charge the battery as quickly as possible according to the state of the battery life cycle. Figure 2 shows the simulation model of DC/DC converter.

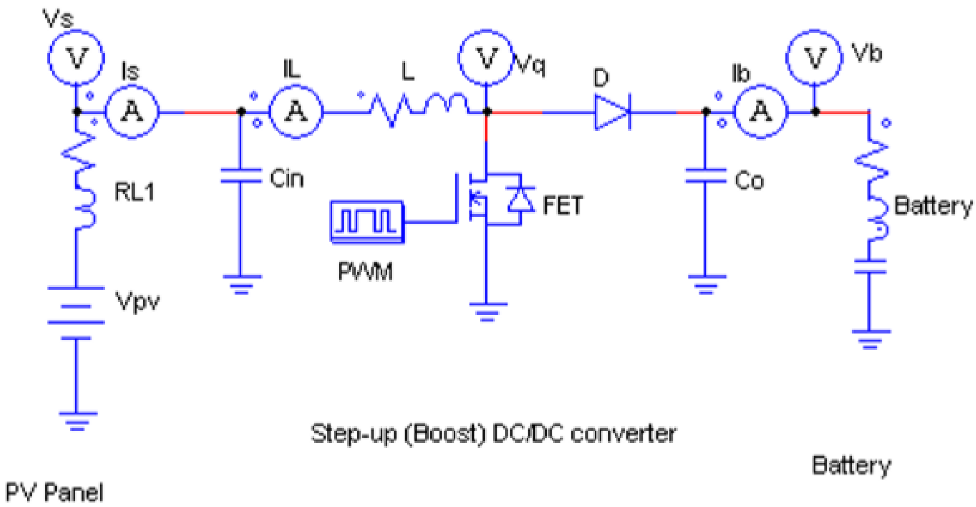


Figure 2: Simulation model of DC/DC converter [12]

2.4 Comparative study on charge controller techniques for solar PV system [13]

Reddy et al. presents a new PV charging controller based on solar technology that contains shunt, series charge controller [13]. Due of its design, the lead acid battery is used for series charging and discharging, shunt power controller. The design of shunt, series, and combined shunt and series controllers was develop by the authors using MATLAB or Simulation which gives the more benefits, further protects the battery against overloading and deep discharging conditions. Figure 3 shows functional block diagram of the system.

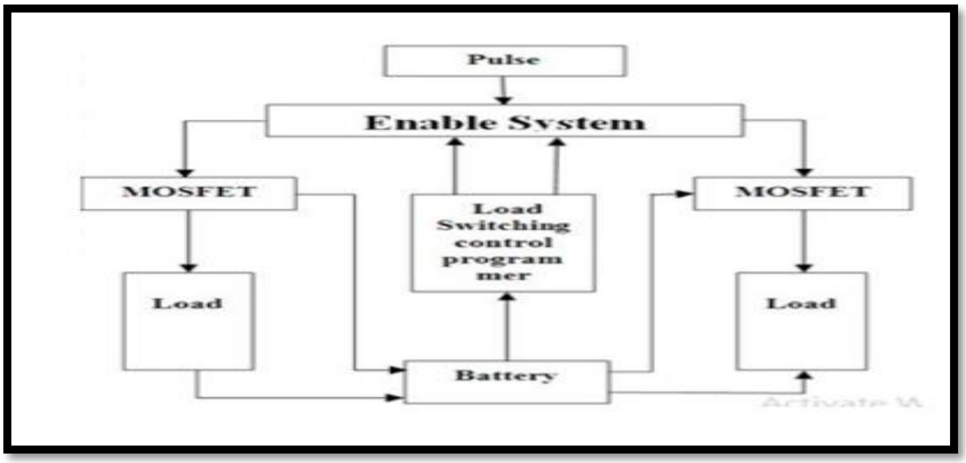


Figure 3: Functional block diagram of the system [13]

2.5 Portable solar charger with controlled charging current for mobile phone devices [14]

Hussain et al. has made studied to propose an electronic design which can be used for charging purposes on mobile devices [14]. The first design was made from an IC, and the charging power of a mobile battery depends entirely on the MPPT algorithm. Other design represents a 3.7 V and 2000 mAh solar charger for battery. Again the design and construction relies on integrated circuits as a major part of the controlling circuit. Other design is solar charger controlled by shunt-mode charging. This circuit was used to avoid overcharging the battery, and when the battery reaches maximum voltage, this mechanism is performed by interrupting the current flow by the charge controller. Figure 4 shows the electronic circuit of portable solar charger.

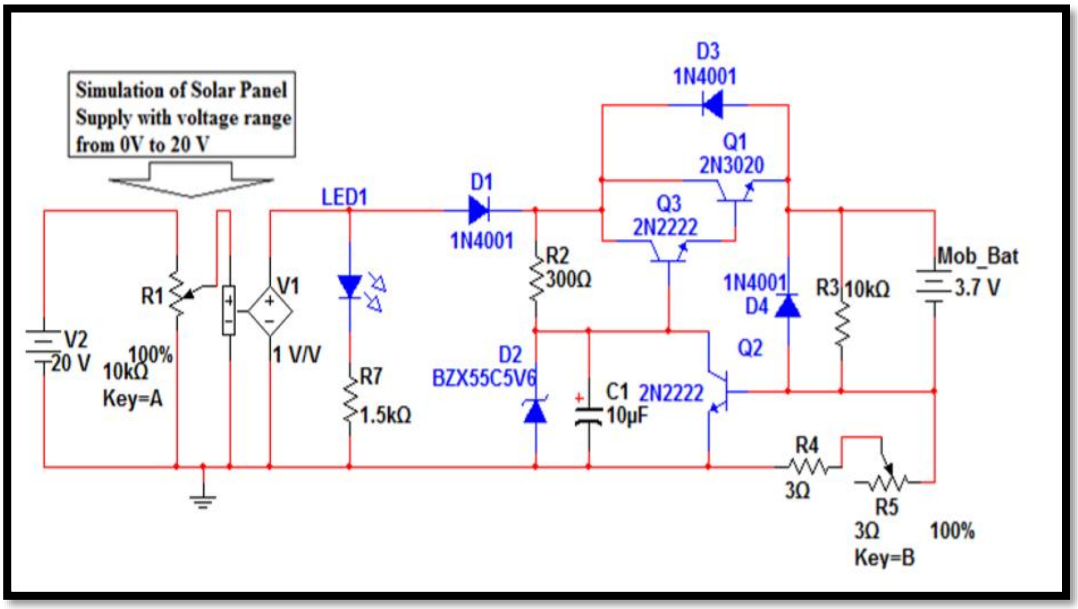


Figure 4: Electronic circuit of portable solar charger [14]

2.6 Analysis and design of a solar charge controller using cuk converter [15]

Riawan et al. presents a scheme that uses a solar charger controller based on a Cuk DC/DC converter to transfer the power from the PV modules to the battery [15]. To achieve greater efficiency, in parallel power transfer (PPT) mode, the converter is configured. For extracting maximum power from the PV modules, PWM control with maximum power point tracking algorithm is used. The controller was designed on the basis of stability requirements for the Bode study implemented using a lag compensation network in PWM chip voltage mode. Lastly, experiments are performed to verify the system's overall performance in the extraction of power from PV modules. Figure 5 shows the Cuk converter in PPT configuration for solar charge controller application.

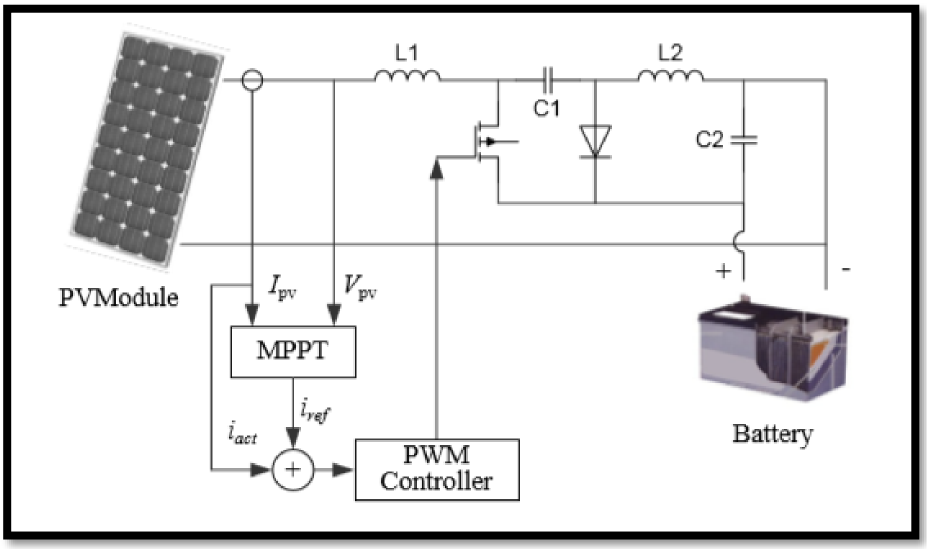


Figure 5: Cuk converter in PPT configuration for solar charge controller application [15]

3. Research Method

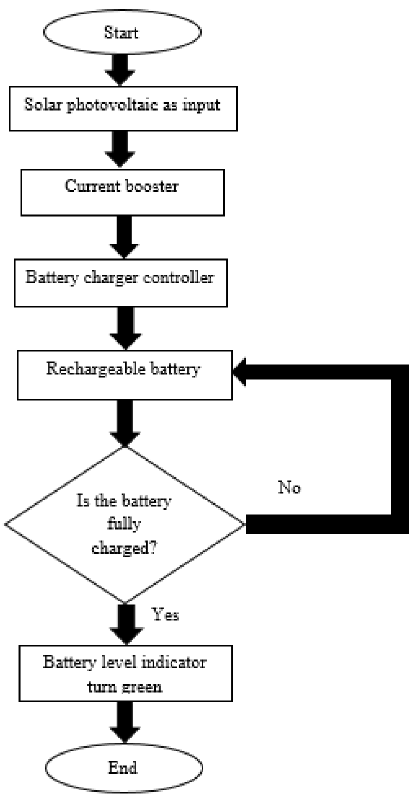


Figure 6: Flowchart of the study

The system layout and structure involved in this study are represented by a flowchart as shown in Figure 6 with solar has been used as an input. The solar photovoltaic generates DC voltage. Then, the current booster enables the maximum current value from the solar panel to flow through to the battery. The battery charge controller keep the battery at the highest charge possible. The charge controller guards against overloading of the battery and disconnects the load to avoid deep discharge. The battery level indicator monitors the level of charge of the battery. It shows that it is fully charged and that charging needs to stop and is cut off with the aid of the charging controller circuit. All the charging energy stored in the battery. Table 1 shows the list of the component for electrical parts and mechanical parts. The software development is required to be a part of the collecting data and information for this project. The software that are used in this project are Proteus software. The Proteus software is used as a platform to construct and design the schematic circuit to do the simulation.

Table 1: Bill of materials

No.	Components		Quantity	Cost(RM)
1	Solar Panel		1	RM85.00
2	Breadboard		3	RM16.50
3	Resistors	220 ohm	1	RM0.20
		Variable resistor 1k ohm	2	RM2.00
		1k ohm	1	RM0.10
		2k ohm	2	RM0.20
		2.2k ohm	1	RM0.10
		10k ohm	2	RM0.20
4	Transistor	BC547	1	RM1.80
		BC557	1	
5	Diode		7	RM1.26
6	Integrated Circuit LM358		2	RM4.00
7	Voltage Regulator	LM317	1	RM1.30
		LM7812	1	RM0.70
8	Contact Relay		1	RM8.00
9	Light Emitting Diode (LED)	Red	1	RM0.60
		Green	2	
10	Capacitor 100µF		1	RM0.90
11	Battery		1	RM75.00
Totals				**RM197.86**

4. Results and Discussion

4.1 Simulation Result

Table 2 shows that the voltage of the three stages when connected with the 12.00 V solar panel. It is measured by the voltmeter to show the value. The results show that the voltages 2.50 V that through in current booster does not have voltage drop because the LM317 works to ensure that the voltage keep constant. The voltages of the solar panel from sunlight before the current booster is set to 2.50 V because to equate it with the real situation of the sunlight. It shows that the current booster is acts to keep the voltages constant and avoid any voltages drop happens.

Table 2: Voltages of the three stages

Circuit	Current Booster	Battery Charger Controller	Battery level indicator
Voltages (V)	2.50	1.18	0.27

Figure 7 shows the complete circuit of the simulation solar charger controller. There are three stages in the circuit that is current booster, battery charger controller and battery level indicator.

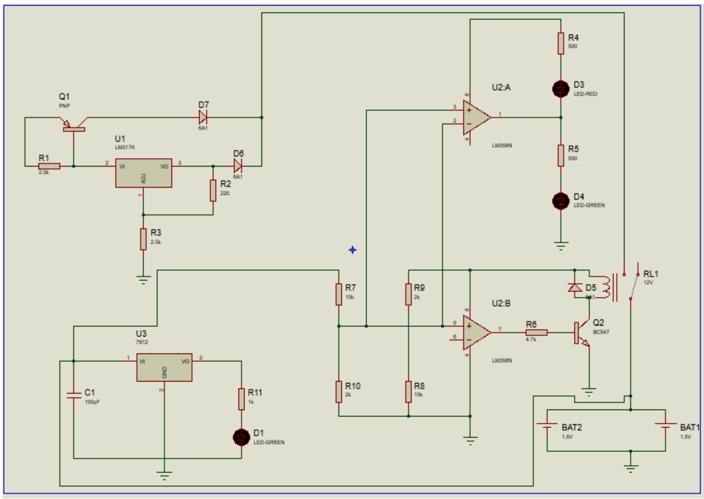
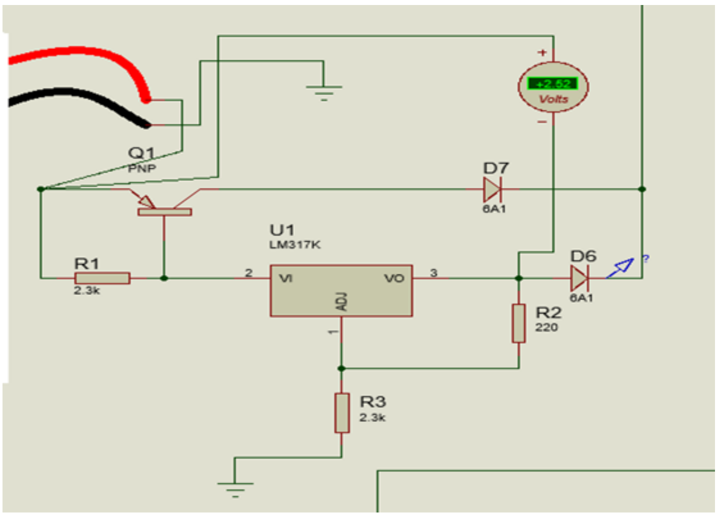
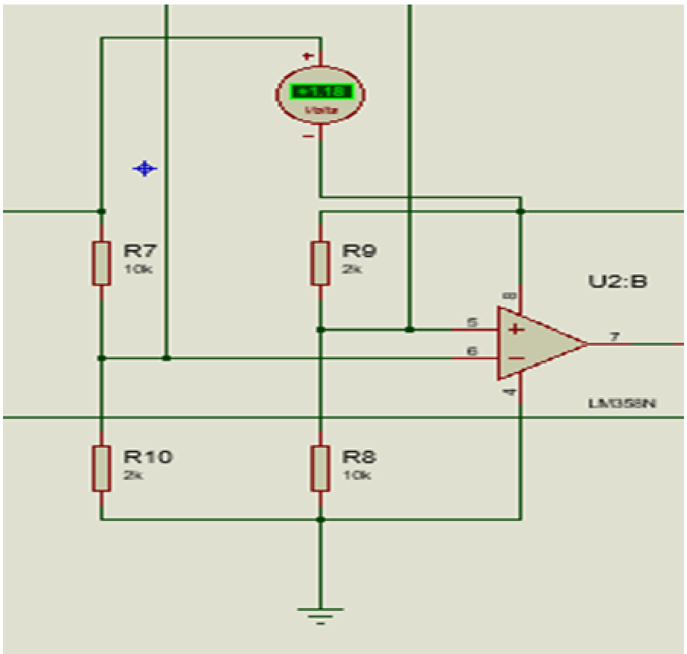


Figure 7: The complete circuit of the solar charger controller

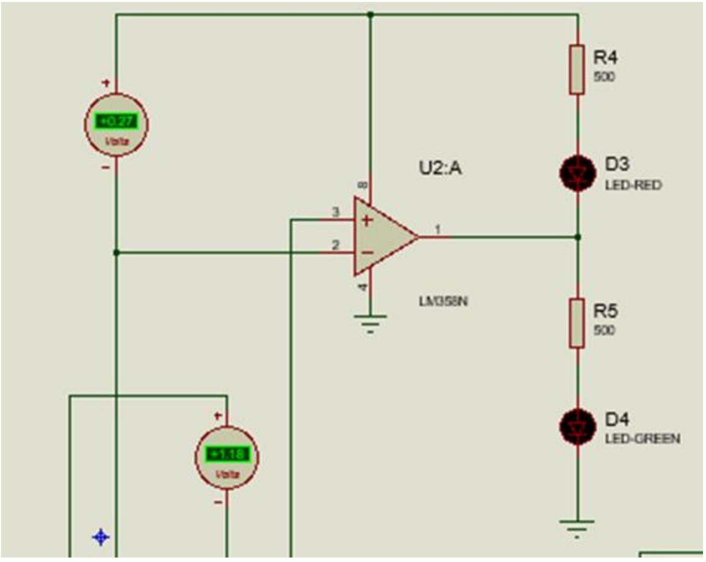
Figure 8 shows the voltage of (a) current booster, (b) battery charger controller and (c) battery level indicator when connected with 12.00 V solar charger.



(a)



(b)



(c)

Figure 8: The voltage of (a) current booster, (b) battery charger controller, (c) battery level indicator when connected to 12 V solar panel

4.2 Experimental result

Table 3 shows the results that get from this study in every stages in the circuit which is current booster, battery charger controller and battery level indicator. Through the photovoltaic effect, solar panels transform energy from the sun into electron flow. Then, it goes through the 3 stages in the circuit to charge the rechargeable battery charged. The data shows the value of voltage that goes through the 3 stages according to the time. This energy store in a rechargeable battery 12.00 V.

Table 3: Voltage of the 3 stages in the circuit according to the time

Time	Current Booster (V)	Battery Charger Controller (V)	Battery level indicator (V)
11.00 a.m	0.16	0.25	0.20
12.00 p.m	0.18	0.27	0.22
1.00 p.m	0.16	0.25	0.20
2.00 p.m	0.16	0.25	0.20
3.00 p.m	0.17	0.26	0.21
4.00 p.m	0.15	0.24	0.19

Table 4 shows that the voltage of the rechargeable battery charged according to the set time. Every half hour, the voltage will increase when battery is charged. The value of the voltage followed the rate of the sunlight.

Table 4: Continuous voltages charging of battery from solar panel

Time	Voltage, V
11.00 a.m	7.00
11.30 a.m	7.12
12.00 p,m	7.23
12.30 a.m	7.89
1.00 p.m	8.54
1.30 p.m	9.34
2.00 p.m	9.77
2.30 p.m	10.51
3.00 p.m	11.01
3.30 p.m	11.69
4.00 p.m	12.34

Based on the experimental result, it shows that the value that get is lower than the value in the simulation. There are several factors that have caused this condition to occur. One of the factors is the level heat of the sunlight that occurs when the result is made. The hotter the sun, the higher the voltage value that can be achieved. Figure 8 shows the prototype for solar charger controller. This project is placed on the wooden board as its base and the solar panel acts as the supply from the sunlight. Multimeter is used to show the voltage through the circuit.

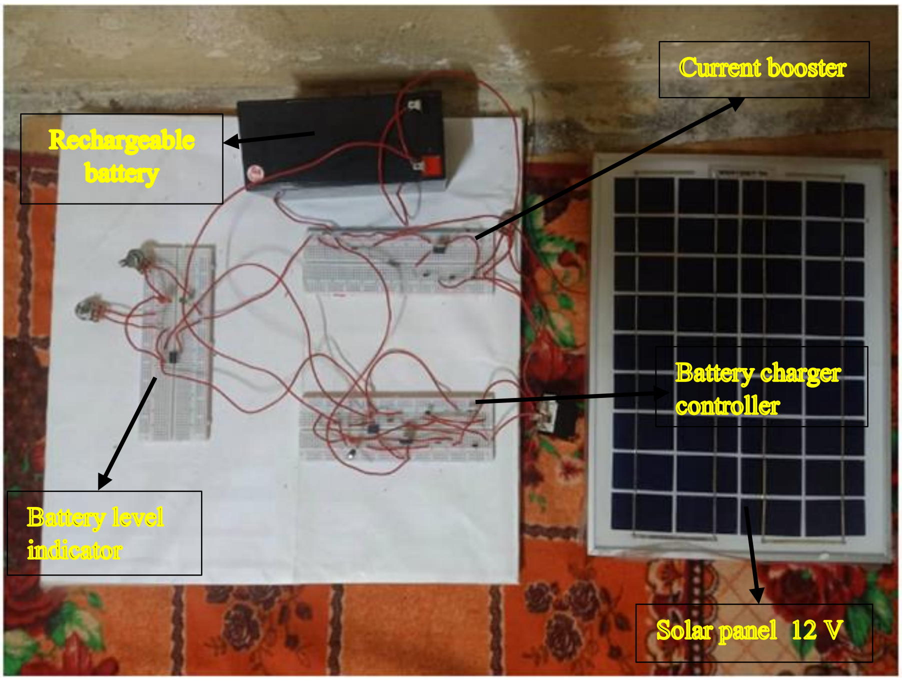


Figure 8: Prototype of the study

5. Conclusion

Solar control charger is very useful to human because it can save the cost of the electricity. All the charging battery requires the battery charge controller to prevent any damage to the battery. The main goal is to deliver power from an array of solar panels to a Li-ion battery in order to charge it. In order to make the battery safe, the battery charger controller is used to make sure it cut off the charging when fully charged. The solar panel need to choose wisely which is must be suitable to charge the battery and the greater the power of solar, the faster the charging of the battery. This study is using locally sourced and available components that has developed a low cost, reliable and practical solar charge controller.

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