Designing a Stand-alone Solar Charge Controller for 12V System with Over Voltage and Under Voltage Protection

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Abstract—In this paper, we will design a stand alone solar charge controller for a 12 V system. The result will be discussed in two ways: in simulation obtained by Proteus software and by implementing on hardware. The overcharge and over-discharge protection conditions were maintained. We find, in this paper, the over cutoff voltage of 14.10V and the low cutoff was 10.3V.

Index Terms— stand-alone,over-voltage, under-voltage, charge controller, MPPT, PWM

1 Introduction

The sun, undoubtedly, is a reliable, pure and limitless source of energy and it is the ultimate source of energy in the form of light and heat as well. PV arrays produce power when it is illuminated; PV systems often use the battery to capture the electrical energy produced by PV arrays which can be used at a later time. In a stand-alone PV system, the PV array supplies power to the load via a power conditioning system and charges the battery when there is sunlight; otherwise, the battery powers the load using the same power conditioning system [1]. The charge controller is an imperative part of all power conditioning PV systems that charge the batteries [2]. It ensures the batteries are working in optimal conditions.

The charge controller restricts the rate of electric current added to or drawn from batteries. It prevents overcharging and thus prevents overvoltage, which is a threat and can reduce battery lifespan. It may also prevent complete discharging of a battery depending on the battery technology, to protect battery life [3].

A series charge controller stops the further current flow into batteries when they are full. A shunt charge controller deflects excess electricity to an auxiliary load [4]. Between the MPPT and PWM charge controller, PWM charge controller is the most effective means to achieve constant voltage battery charging by adjusting the duty ratio of the switches [5].

The aim of this paper is to design a solar charge controller that protects batteries from overcharging and over-discharging. The relay switch was used doing the exchange between overcharging and under discharging.

In this paper, we are designing a 12V stand-alone solar charge controller. The simplest charge controller is the series-interrupting type, turning the array charging current either on or off. The charge controller constantly monitors battery voltage, and disconnects or open-circuits the array in series once the battery reaches the set-point voltage. When battery voltage drops to the array reconnect voltage set point, the array and battery are reconnected, and the cycle repeats. Assume that the battery is fully charged when the terminal voltage reaches 12 volts with a specific charging current. Assume also that when the terminal voltage reaches above 12 volts, the array will be disconnected somehow from the batteries and that when the terminal voltage falls below 12 volts, the array will be reconnected.

Fig.1 shows the block diagram representation of the general solar system.

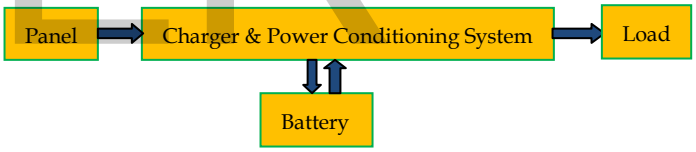

Fig. 1. Block Diagram of Solar System

2 Related Works

A lot of research works have been done around the whole world relating to the battery protection. But the researchers are not fully satisfied. For this, we have studied several journal papers, thesis works, books, web documents etc. related to the charge controller.

G. D. Rai has written the book "Solar Energy Utilization". Salient feature of this book is that it has a dedicated chapter on "Solar Photovoltaic Electric Power Generation" [6].

In a review paper titled "A Review of Single-Phase Grid Connected Inverters for Photovoltaic Modules" Soeren Baekhoej Kjaer, John K. Pedersen, and Frede Blaabjerg focuses on inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid [7].

In the paper titled "An Efficient MPPT Solar Charge Controller," maximum power point tracker battery charger is proposed by Dr. Anil S. Hiwale, Mugdha V. Patil, Hemangi Vinchurkar for extracting maximum power from a photovoltaic panel to charge the battery [8].

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2.1 System Designing

Simulation was carried out after connecting all the components to make a complete circuit. Proteus software was used to perform the simulation. Fig.2 shows the schematic diagram of solar charge controller.

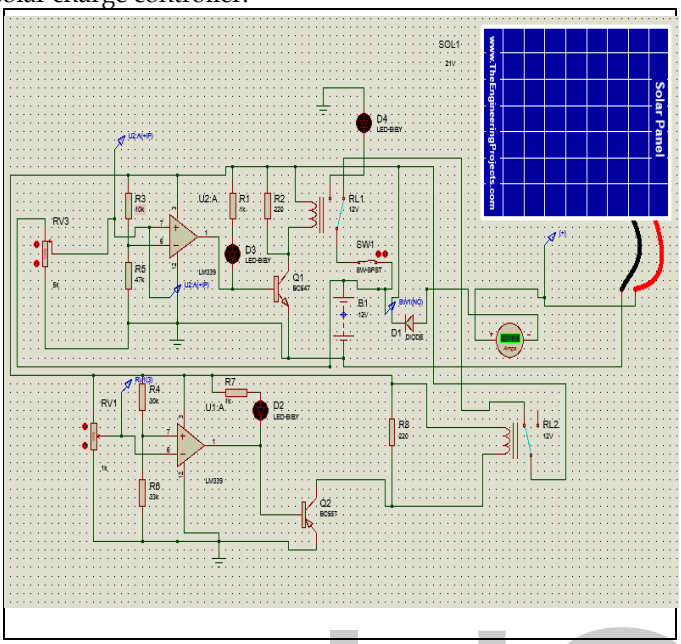

Fig. 2. Schematic diagram of Solar Charge Controller

Solar panel is connected to the charge controller circuit. We use two comparator op-amp LM-339 to continuously monitor the battery voltage. The variable resistors are used to determine the reference voltage of the comparator. By this we can easily determine the upper voltage and the lower voltage of the battery according to the battery parameter. The two transistors are used for energized the relay. The relays are used as a switch for the circuit.

2.2 Simulation Result

After the all components are connected in Proteus, we run the simulation in Proteus. Now we can see the output from the figure.

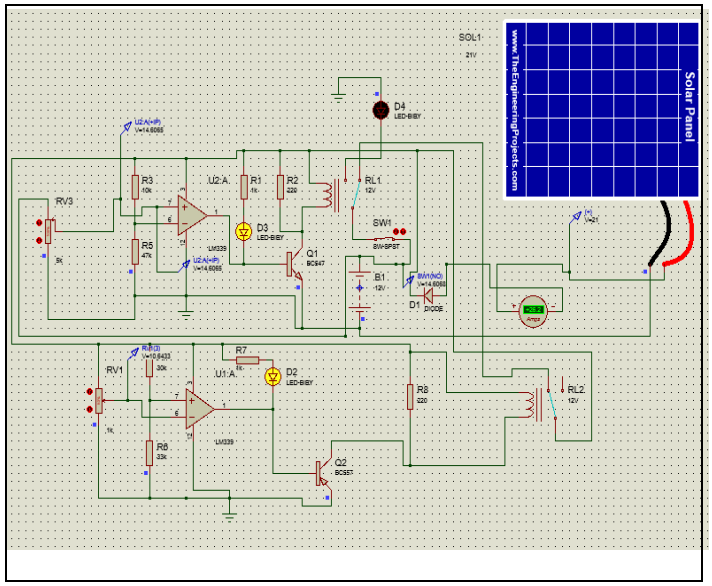

Fig .3. Schematic diagram of Solar Charge Controller

From this figure we can see that the upper cut voltage in comparator U2: A is 14.605V and lower cut voltage is 10.64V. This circuit simulation in Proteus is running properly. Now we implement the circuit in practically.

3 Hardware Implementation

First, we set up all components in breadboard. Solar panel is connected to the charge controller. A diode which is used for block the reverse current from the battery. The comparator IC determines the upper cut and the lower cut of the battery. The relay switch is used for switching the charge controller for the battery. Four LEDs indicate the switching state of the circuit. The working of the controller in this design is explained with three cases Case 1: When the requirement of the load can be supplied by the solar, then the load is supplied by the solar and the battery is charged using the remaining energy from the solar. Case 2: Now when the battery is fully charged it is disconnected from the system and the load is still supplied from the solar panel. Case 3: When the solar cannot supply the load, i.e., when the load requirement is more than the energy produced by the solar then the supply to the load is given by the battery and the battery is charged from the solar.
The practical circuit is given below

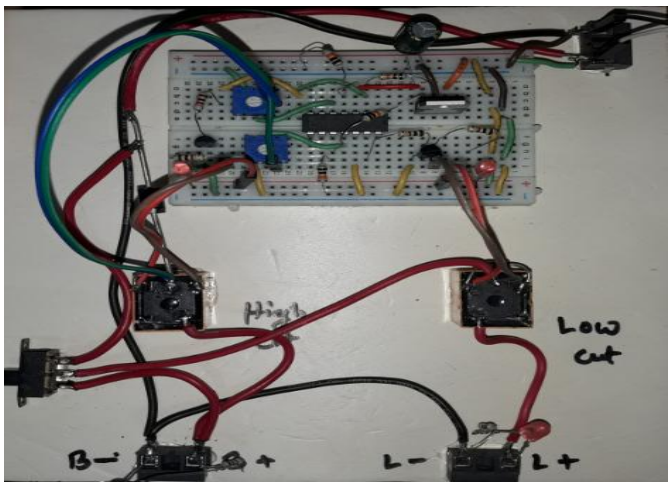

Fig. 4. Practical circuit

4 Result and Discussion

In practical, we use voltage generators a source and resistive load as a battery. We use voltage generator that produce 18V to the charge controller and this voltage is passing to the resistive load through the charge controller circuit. After connecting the entire probe to charge controller, voltage generator and resistive load, we can see the output below. When the solar panel produces 18v the current passes through the charge controller circuit and it charges the battery until the battery charge is full.

Fig. 5. Total setup

Overcharging Protection

When the battery voltage reaches to its upper limit, in this case 14.1V, the high cut relay will turn on that will turn off the circuit from charging the battery. The solar charge controller charges the battery until the battery voltages reaches14.1V. Above this value battery is disconnected from the circuit but conducting current to the load. It will protect the battery from overcharging. From the lab experiment we can see the result in fig. 6.

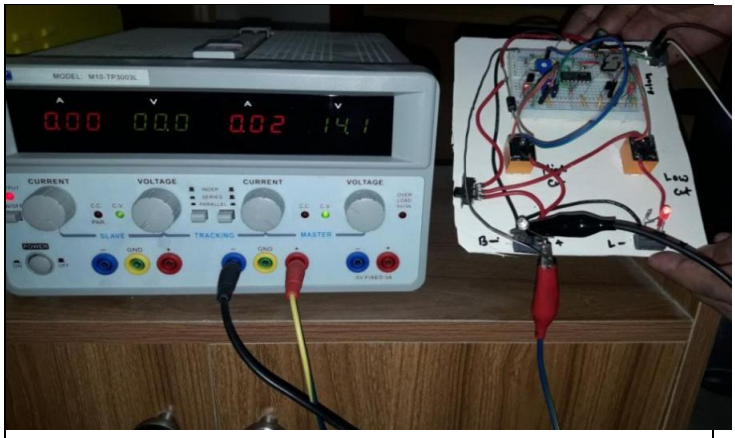

Fig. 6. Over voltage protection

Over-discharging Protection

When the battery voltage is 10.3V the second relay is turn off that will cut off the load and continue charge the battery. In this case circuit protects the battery from over discharging. The load will be connected to battery until the charge is accumulated in the battery. From fig. 7 we can easily see the result.

Fig. 7. Over discharging protection

5 Conclusion

Energy crisis is a hard nut to crack now a day to the modern world. We are running out of fossil fuel day by day. In future we have to depend on renewable energy. We can easily convert the sunlight into electrical energy by using solar cell. This work has produced a low cost, reliable and functional solar charge controller, using locally sourced and available components and can be used to charge a 12V battery only. The product worked satisfactorily and can be used in a solar home system to solve problems of power supply in Bangladesh.

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