Thesis Report

Design of a charge controller circuit for multilevel solar panels for solar home system

A report submitted to the department of Electrical & Electronic Engineering (EEE), BRAC University.

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Declaration

We do hereby declare that the thesis titled "Design of a charge controller circuit for multilevel solar panels for solar home system" is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

Date: 4th September, 2012

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Abstract

This work aims to design an efficient charge controller circuit for a multilevel solar panel systems intended for its use in urban residential solar home system. The stacked panel system will consist of panels stacked on top of one another to minimize the floor area and maximize the power generation. The charge will control the flow of charge from the panels to the battery as well as from the battery to the load.

Acknowledgement

We are greatly thankful to our supervisor Dr. Mosaddequr Rahman for his proper guidance and support during this project. His inspiration, support and encouragement made it easier for us to finish the thesis work properly in proper time.

1.Introduction:

Photovoltaic (PV) or more commonly known as solar power, is one of the renewable energy resources that recently has become broader in nowadays technology. PV has many benefits especially in environmental, economic and social.

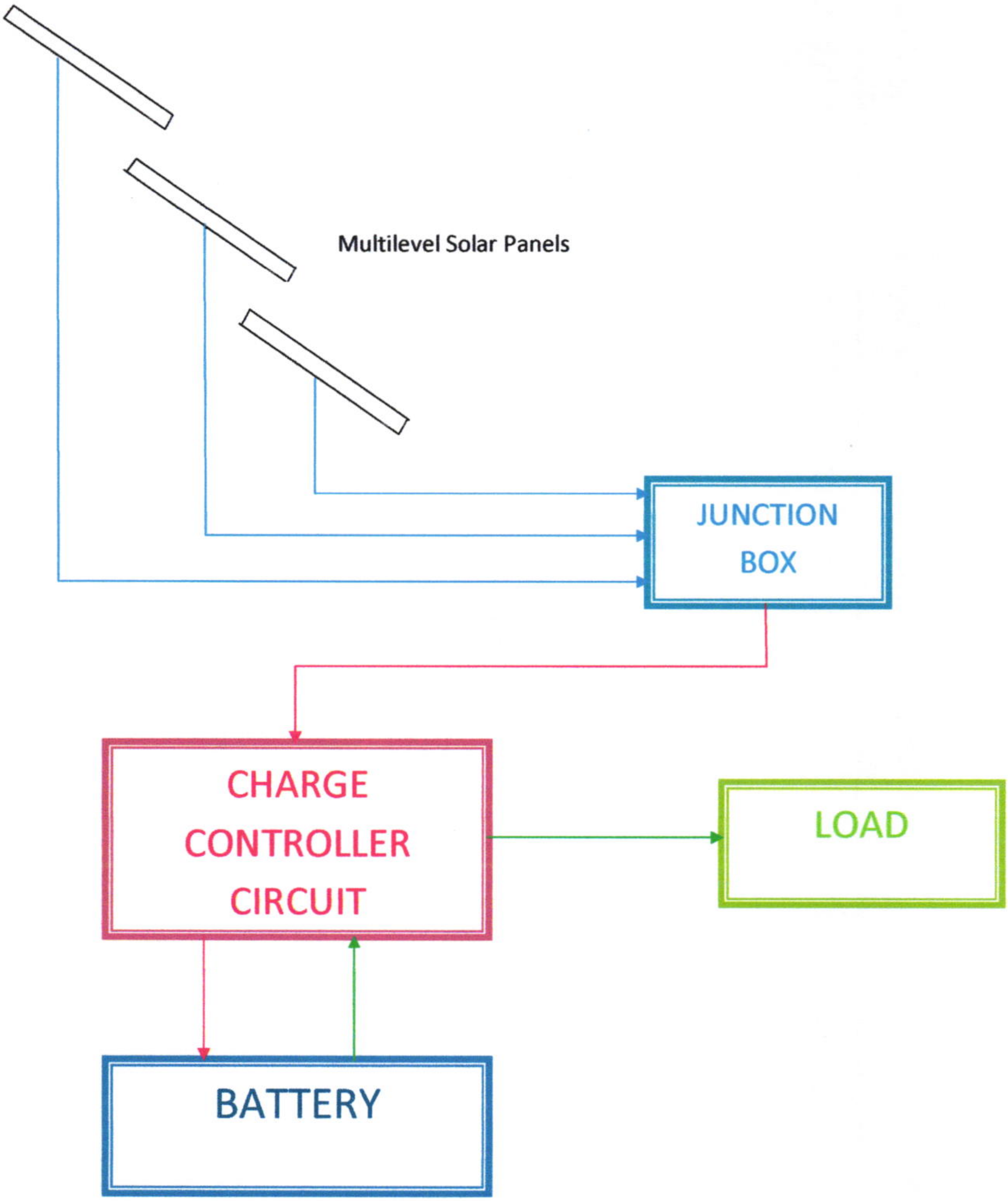
In general, a PV system consists of a PV array (solar panel/s) which converts sunlight to direct-current (DC) electricity, a control system (Charge controller) which regulates battery charging by the PV array and discharging by the load.

A charge controller is one of the key major components in PV systems. A good, efficient and reliable PV charge controller is crucial for any PV battery charging system to ensure greater battery life and smooth operation to achieve the maximum benefit that user can get from it.

The main function of a charge controller in a PV system is to regulate the voltage and current from PV solar panels into a rechargeable battery. The minimum function of a PV charge controller is to disconnect the array when the battery is fully charged and keep the battery fully charged without damage. A charge controller is important to prevent battery overcharging, excessive discharging, reverse current flow at night and to protect the life of the batteries in a PV system.

In this project, we have designed a charge controller circuit consisting of a microcontroller (PIC16F876A) which is able to carry out the above mentioned functions in a sequential manner. A block diagram of the overall system is illustrated in the next page.

2.BLOCK DIAGRAM OF OVERALL SYSTEM



3. System Components:

3. Solar Panel:

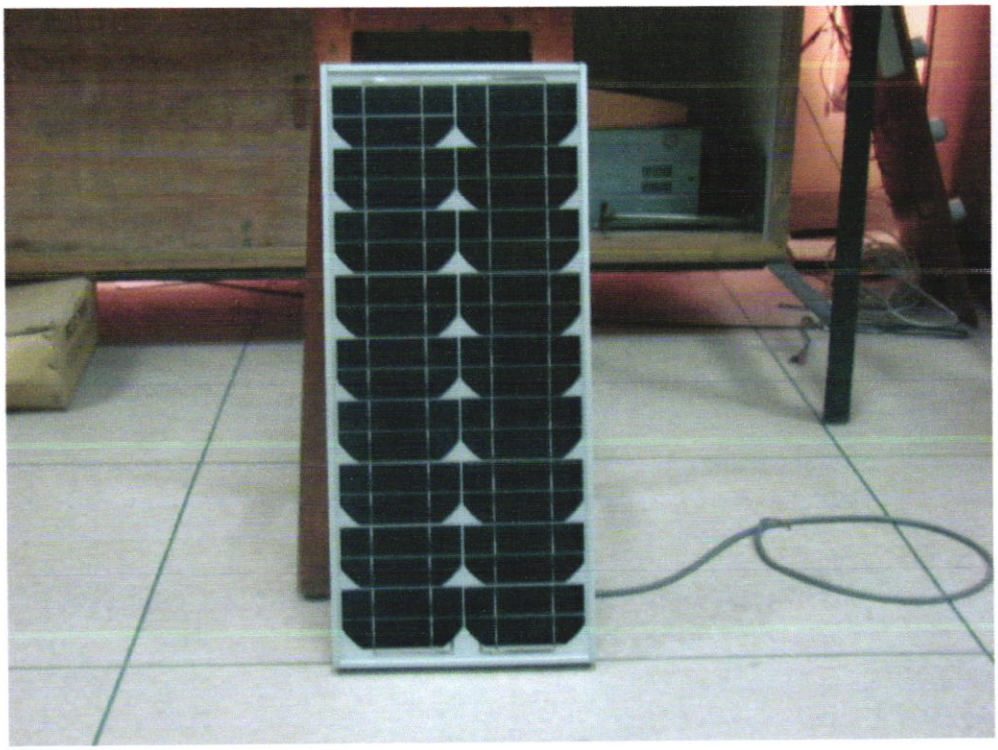


Figure 1 : Solar panel

The type of solar panel used is a mono-crystalline solar panel manufactured by Akash Solar. It is composed of 18 crystalline cells connected in series. The rating of the solar panel is as follows:

Open circuit voltage (Voc) = 21.8 Volts

Short Circuit Current (Isc) = 1.15 Ampheres

4. Battery:

The battery used to carry out the experiment is a 12V *sealed lead-acid* rechargeable battery of capacity of 7.5 amphere-hours (Ah).

This project mainly emphasizes on constructing an efficient charge controller circuit. The battery used is only for testing and experimental purposes of the charge controller, hence a smaller capacity battery is included rather than large lead acid battery so that charging and discharging time of the battery is sufficiently smaller.

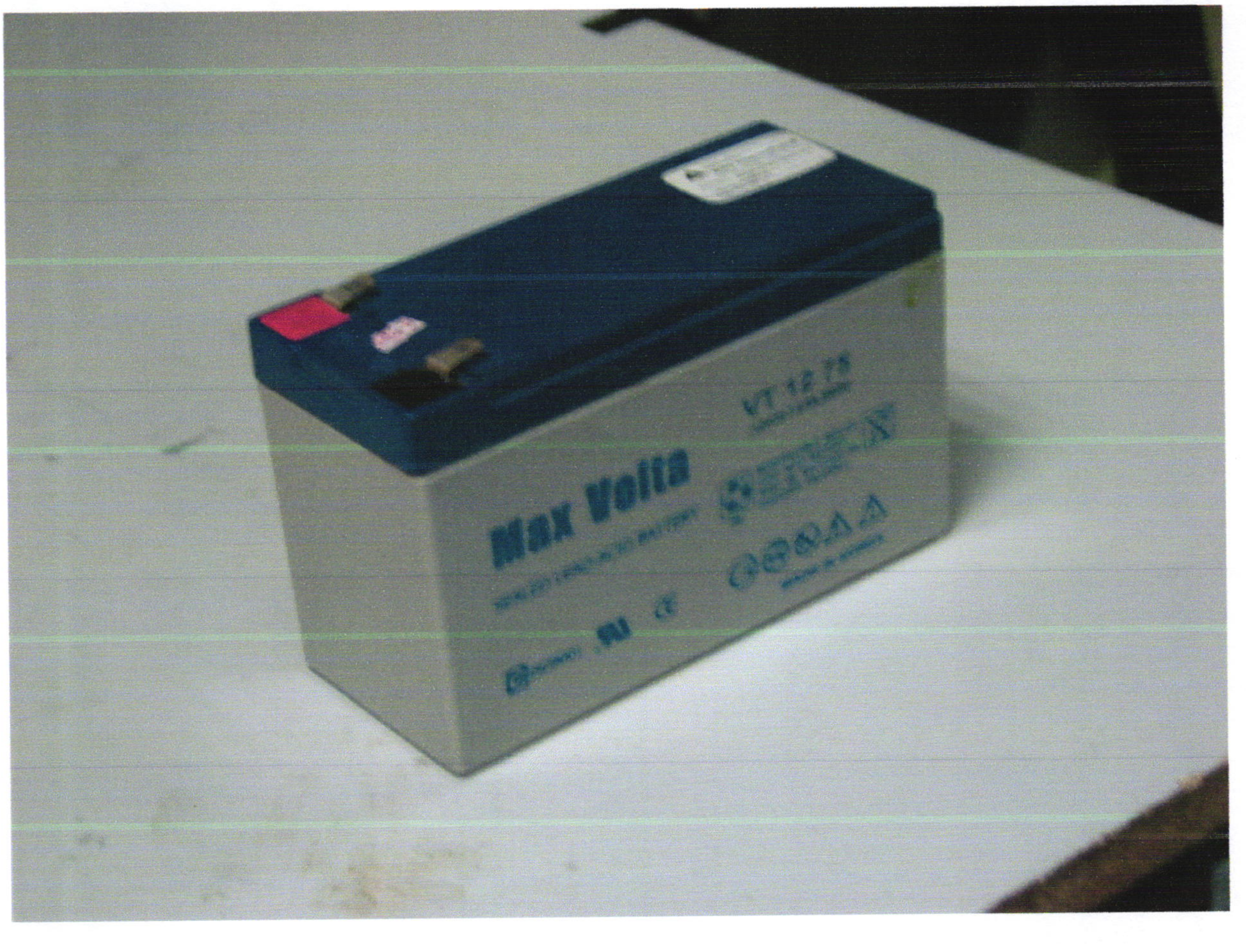


Figure 2: 12V Sealed Lead-Acid rechargeable battery

4.1 Charging Stages of Battery (Lead-acid):

A solar re-chargeable lead-acid battery consists of certain set of methods of charging to ensure optimum service when supplying to a load connected across it. It is not charged by a fixed voltage and current supply. The charging stages of a battery regime as shown below, the stages are:

- Bulk charge (Constant Current)
- Absorption (Constant Voltage)
- Float

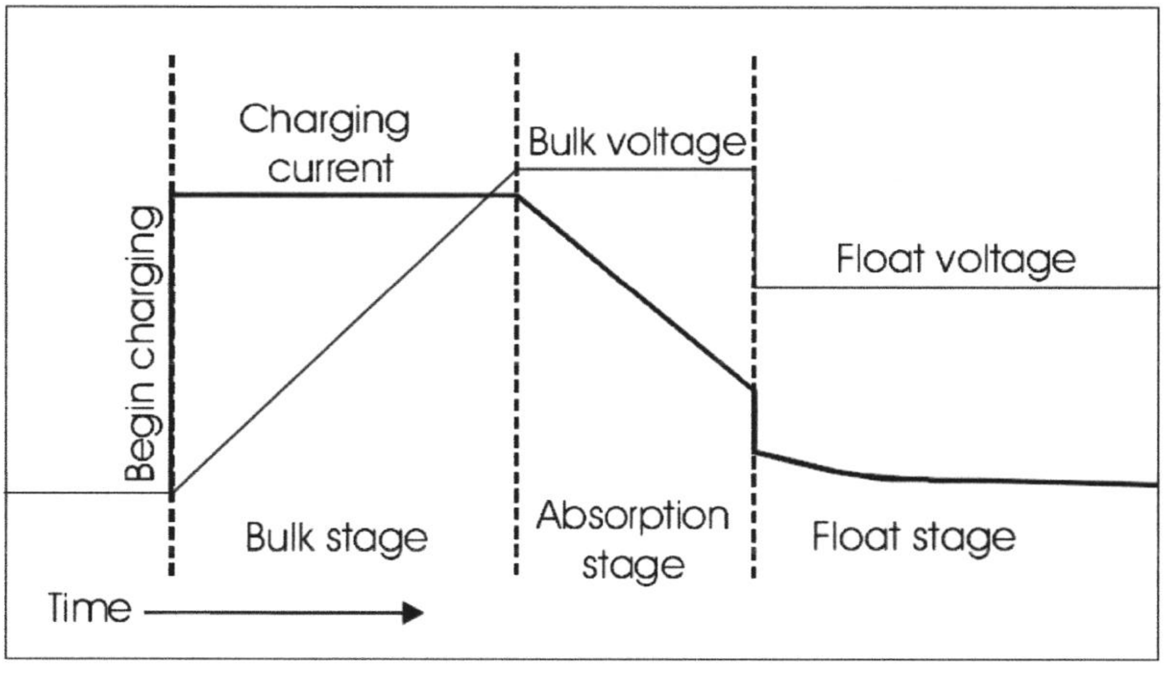


Figure 3: Three state charging system of a battery.

Bulk Charge:

The initial stage of the 4-stage battery charging is **bulk charge** also referred as **constant current (fast)** charging. In this stage the battery is charged with a constant current up to a certain voltage level. During the bulk charge, 40 percent of the total Ah (amp-hour) capacity should be used to charge the battery.

Absorption:

The 2nd stage of the 4-stage battery charging is **absorption charge** or **constant voltage charging.** In this stage the voltage across the battery remains constant while the current flow in the battery is varied. The current used here in this stage should be 20 percent of the total Ah (amp-hour) capacity of the battery. The constant voltage regulation prevents overheating and excessive battery out-gassing.

Float:

The 3rd stage of battery charging is **float charge.** This constitutes 90-100 percent charge state. After batteries reach full charge, charging voltage is reduced to a lower level to reduce gassing and prolong battery life. The current used in this stage should be only 5 percent of the total Ah (amp-hour) capacity of the battery.

Battery testing was carried out by connecting the battery to a power supply through a 50-ohms rheostat and a switch while a constant 1 amphere current was allowed to flow while charging the battery and while discharging, the battery was connected directly connected to the rheostat through a switch. Again, the rheostat was adjusted to make sure that no more than 1 amphere current was flowing through it.

A series of readings of the battery charge and discharge voltages as well as the open circuit voltages were taken at 10 minute intervals by opening the switch. The corresponding data was matched with the above State of charge (SOC) vs. percentage graph and also with the state of discharge (SODC) vs. percentage graph (in next page) to calculate the cut-off voltages of the battery and restrict overcharging and over discharging of the battery. The respective cut-off voltage while discharging is 11.6 Volts and while charging is 14.4 Volts.

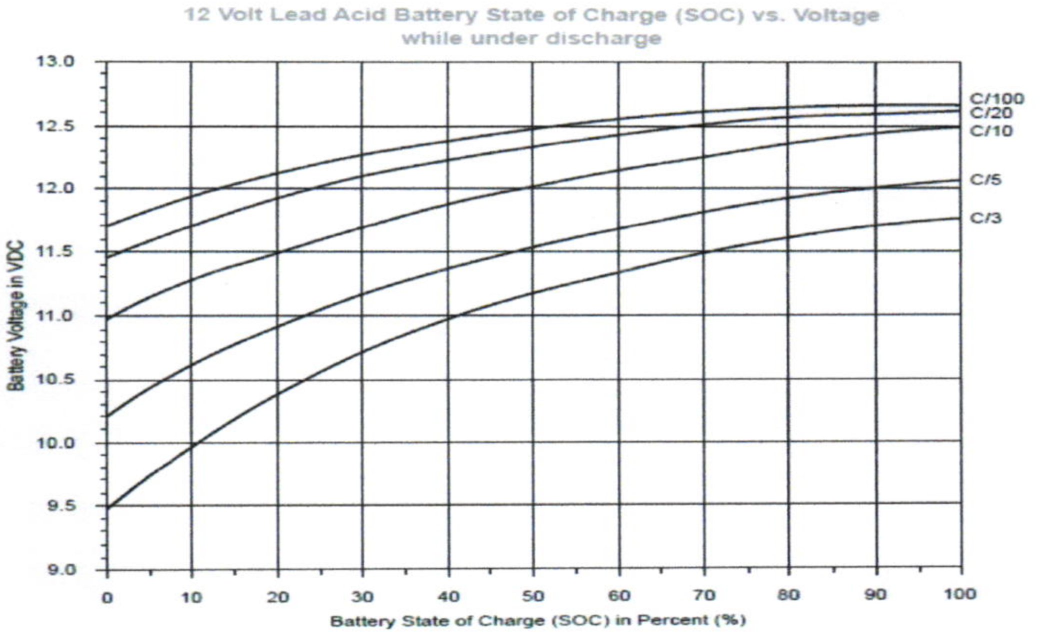


Figure 4: A standard graph for discharging a lead-acid battery.

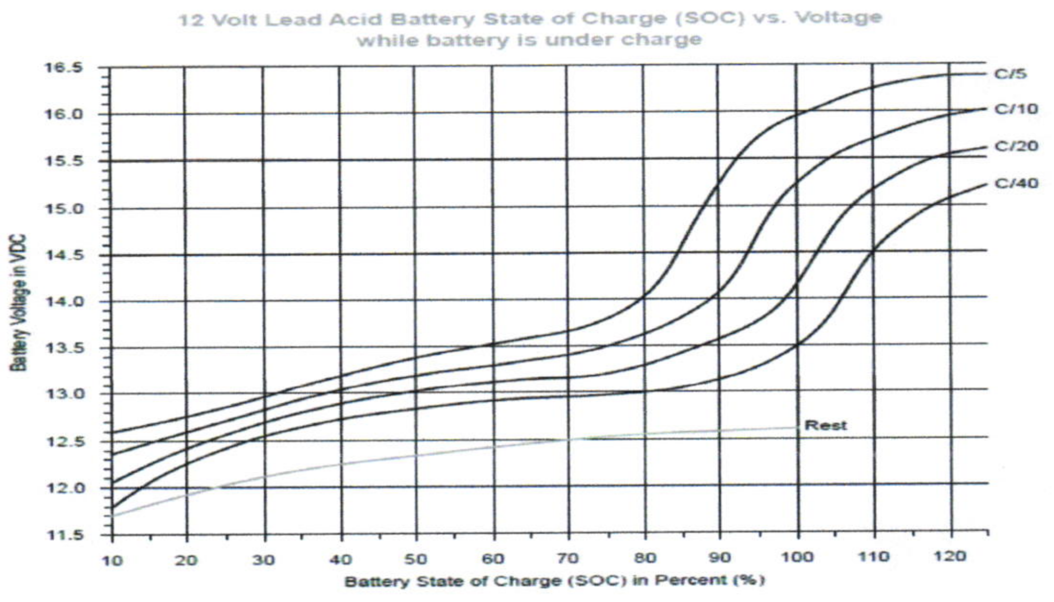
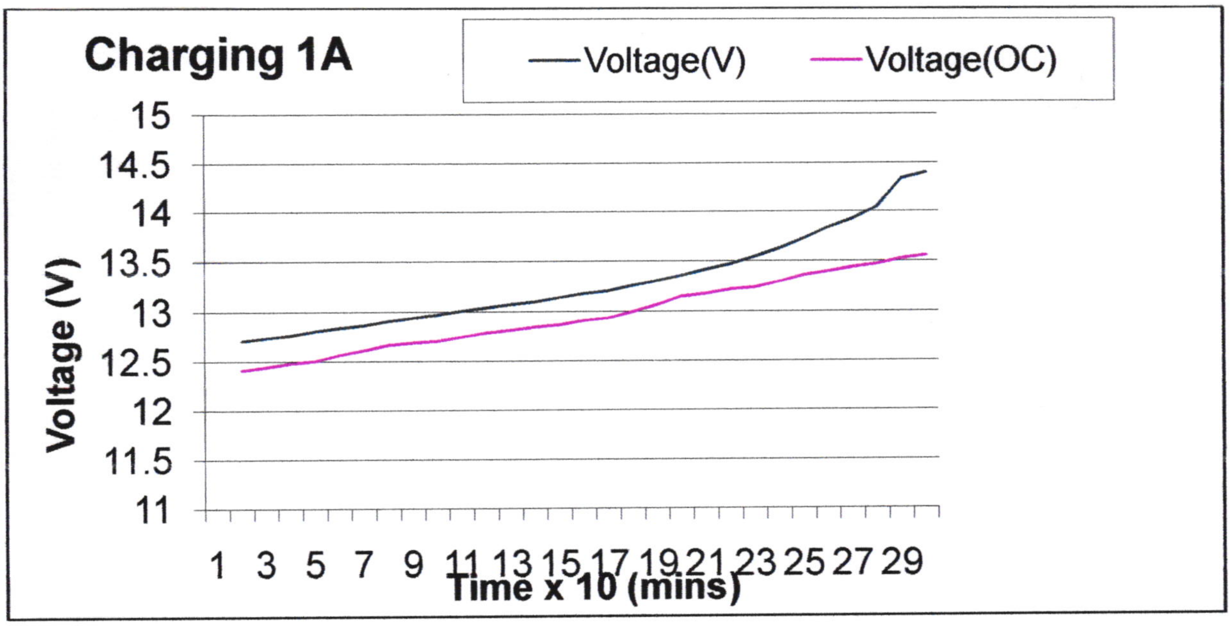
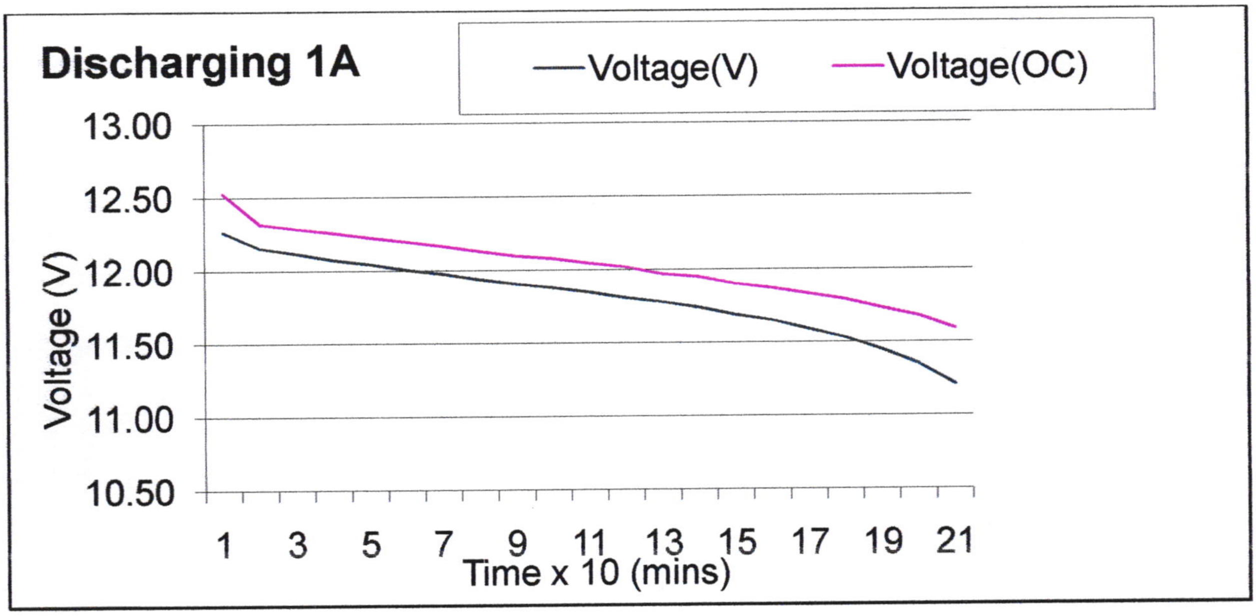


Figure 5: A standard graph for charging a lead-acid battery

4.2 The following results were obtained after battery testing:





5. Charge Controller

5.1 Reason for Charge Controller and its functions:

The primary function of a charge controller in a stand-alone PV system is to maintain the battery at highest possible state of charge while protecting it from overcharge by the array and from over discharge by the loads. The algorithm or control strategy of a battery charge controller determines the effectiveness of battery charging and PV array utilization, and ultimately the ability of the system to meet the load demands. Additional features such as temperature compensation, alarms, meters, remote voltage sense leads and special algorithms can enhance the ability of a charge controller to maintain the health and extend the lifetime of a battery, as well as providing an indication of operational status to the system caretaker. Important functions of battery charge controllers and system controls are:

· ***Prevent Battery Overcharge:***

To limit the energy supplied to the battery by the PV array when the battery becomes fully charged.

· ***Prevent Battery Overdischarge:***

To disconnect the battery from electrical loads when the battery reaches low state of charge.

· ***Provide Load Control Functions:***

To automatically connect and disconnect an electrical load at a specified time, for example operating a lighting load from sunset to sunrise.

5.2 Reason for Microcontroller:

A microcontroller is a sophisticated microchip which allows the direct interface of the software program and the hardware operation. It enables the circuit components to carry out the commands of the program embedded inside with accuracy and simultaneously. The program embedded in the microcontroller is designed by the user and then compiled and written. It also includes other features such as voltage & current sensing, conversion, switching, etc.

5.3 Charge Controller Set Points:

To execute the charge controller functions, it is programmed to connect and disconnect the solar panels as well as the load at certain voltage levels of the battery. The voltage levels at which this cut-off and reconnection occurs are called **set points.** All solar charge controllers are associated with certain **set points** for safe and efficient operation of the system.

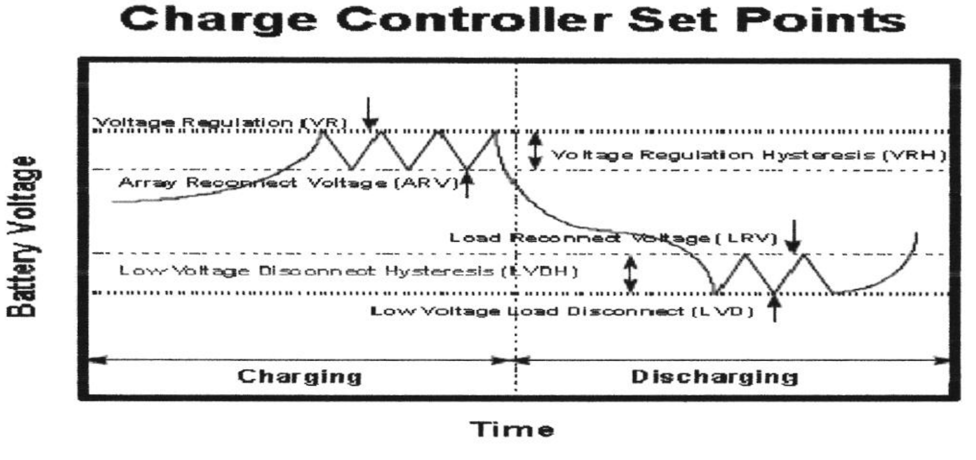


Figure 11. Controller set points

Figure 6: A graph of different charge controller set points and their variations with time.

Set points are an important factor while designing a solar charge controller circuit. The charge controller set points for thesis circuit are:

Array Disconnect Voltage: 14.4V

Array Reconnect Voltage: 13.8 V

Load Reconnect Voltage: 12.6V

Load Voltage Disconnect: 11.6 V

6. Circuit Components:

The following components were used to construct the circuit:

- Microcontroller (PIC16F876A)
- Voltage Regulator (LM7805)
- Bi-polar Junction Transistor (BJT) npn-type (BC547)
- MOSFET p-type (IRF9540N)
- 12V DC relay
- Darlington pair BJT npn-type (TIP122)
- 24V Zener diodes
- 3A schott-key diode
- 5A semiconductor diode
- Resistors (1k, 4.7k, 8.2k, 10k, 47k & 100k)
- Capacitors (1uf, 47uf, 100uf)
- LED indicators
- 20 MHz crystal oscillator.

7. Circuit Operation:

7.1 Voltage Sensing:

The basic operation of the circuit is to sense the voltage provided by the solar panel and also the battery voltage. If the panel voltage is sufficient enough and the battery is required to be charged, then the battery is allowed to be charged by the panel, else not. Similarly, if the battery voltage is enough to operate a load then the relay is activated to connect the load to the battery.

All the above functions are carried out by a specific defined program burned inside the microcontroller (PIC16F876A). It can be said that the microcontroller is the heart of the whole charge controller circuit. Its function includes sensing both the panel and battery voltages and take decisions to activate different components of the circuits such as, transistors, relays and LED indicators. It is powered up by the lead-acid battery connected to it through a voltage regulator (LM7805) which converts the 12V into 5V and is connected at pin no.1 (through a 10k resistor) and 20 (directly connected to the regulator). Pin 19 & 8 is ground and pin 9 & 10 is connected to the crystal oscillator.

The microcontroller (PIC16F876A) consists of a built-in analog to digital converter (ADC). Two out of 6 of these ports are required to sense the voltages. One is for sensing the panel voltage and the other for battery voltage. The panel and battery voltages are fed to the microcontroller in the same manner. The panel is connected to a series of resistance network of (47k and 8.2k) and the battery to another separate and similar network of resistances (4.7k and 1k).

The ADC of the microcontroller divides 5V into 1024 quantized levels. The node voltage in between the two resistances is fed as input to the microcontroller ADC ports from the battery and also from the panel. Hence, in this manner both the panel and the battery voltage sensing are achieved.

For example, if battery voltage is 11.6V the corresponding node voltage can be found by applying voltage divider rule i.e. {(1k x 11.6V)/5.7k} which is 2.03 V. Now the corresponding quantization level is {(2.03 x 1024)/5} or 416.

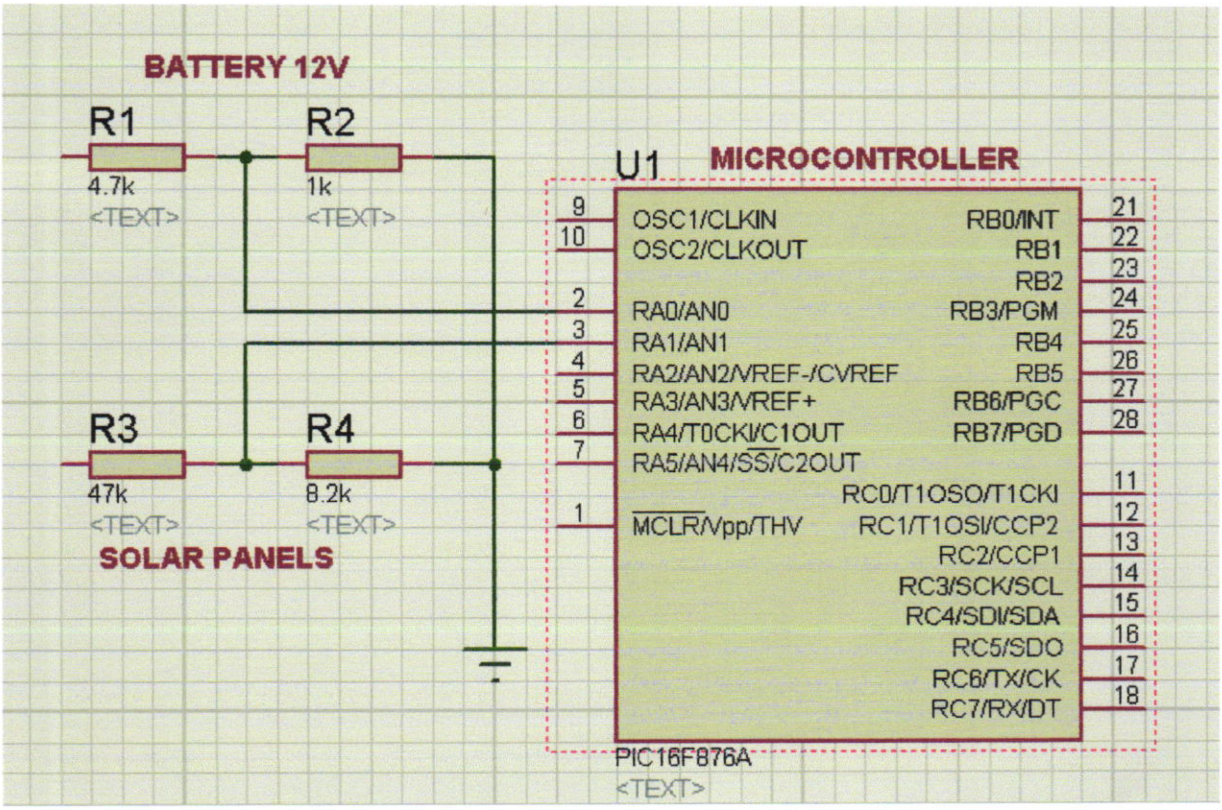


Figure 7: Circuit diagram for the voltage sensing. The battery (+) is connected with the 4.7k resistor and the panel (+) is connected with the 47k resistor. The negative terminals are connected to ground. The node voltages are taken as input in the ADC ports AN0 and AN1 of the microcontroller.

7.2 Battery Charging Operation:

The battery is charging is carried out by the process of pulse width modulation (PWM), instead of direct charging from the panel. There are three different charging methods to be followed while charging a lead-acid battery. They are:

- **Bulk Charging**
- **Absorption**
- **Float**