A COST EFFECTIVE SOLAR CHARGE CONTROLLER

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Abstract

This paper contains the design, construction and implementation of an efficient solar charge controller at low cost. The charge controller is implemented using an inexpensive PIC microcontroller with the help of solar panel and battery. It is also simulated by using Proteus ISIS ® Professional package for different PV cell and battery voltage levels. This solar charge controller (SCC) has the properties to disconnect as well as reconnect the battery during battery overcharging condition or under discharging condition. LCD is used here as the battery voltage level indicator and to display load connection and disconnection status. LED is used to show the condition of the charge controller. This charge controller deals with the PIC16F73 microcontroller and MOSFET to control the system and coordinate with the activity in the SCC. The source code for the PIC16F73 microcontroller is written in the professional programming language Proton IDE to obtain very accurate and effective connecting or disconnecting action automatically. The low cost construction and practical implementation of this smart solar charge controller indicates that it functions properly .

Keywords: *Microcontroller, Solar Charge Controller, MOSFET, SCC, Low cost etc…*

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1. INTRODUCTION

Power plants in Bangladesh are mostly dependent on gas which is not renewable. The reserve of the gas or bio-fuel is very much limited and may be consumed in the future, so it is not a sustainable power generation source. Sustainable sources like solar photovoltaic are becoming efficient as well as environmentally friendly relative to fossil fuels [1]. PV arrays produce power when it is illuminated; PV systems often use battery to capture the electrical energy which can be used at later time. In addition, storage batteries can also provide transient suppression and voltage regulation [2]. The providers of solar panel in Bangladesh are trying to reduce the price of batteries and the associated accessories. Sustainable sources are favorable for the environment, but they aren't easy to apply. Application of sustainable energy sources can be successful if power conversion and energy storage are made efficient. Charge controller is an important part of all power systems that charge the batteries, whether the source is photovoltaic, wind, hydro or utility grid. Its sole purpose is to keep the batteries safe for the long term. In other terms, it is a regulator that goes between the solar panels and the batteries. They are used to keep the batteries charged at peak without overcharging the batteries.

2. SYSTEM DESCRIPTION

Some charge controllers are relay-operated. These charge controllers seldom meet the exact requirements of PV systems and their current flow capabilities are also not good [3]. So in this case PIC microcontroller based designs are favorable for intelligent control with an internal program written in it.

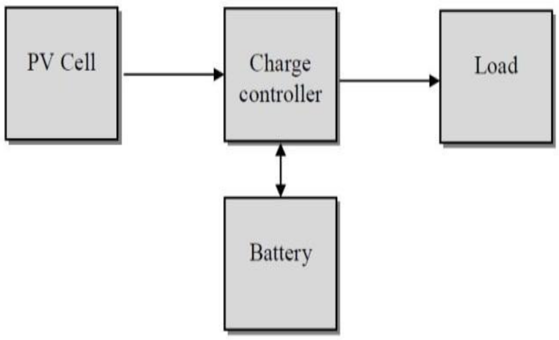

Fig -1: A typical standalone system showing a solar charge controller.

Fig -1 shows a typical standalone PV system. There are two switches in a charge controller. The first switch is used for the connection or disconnection between the PV array and battery and the second switch is used for the connection or disconnection between battery and the load. Now when the first switch connects, the battery starts charging. When the 2nd switch connects, the battery starts discharging. When both the switch is connected the system is in the charging and discharging mode state. To eliminate overcharge and over discharge, resulting from the oscillatory process, hysteresis control has been introduced into the circuit so that the array will not reconnect to the batteries until the batteries have discharged somewhat or load will not reconnect to the batteries until the batteries have some prescribed voltage left. The Sulfation effects occur when a battery is fully charged frequently. Proper battery and array sizing with the periodic equalization charges can reduce the onset of sulfation effects [4].

3. CHARGE CONTROLLER BASED ON PIC MICROCONTROLLER

Microcontroller is used for performing various complex tasks. Relatively low cost PlC16F73 series microcontroller is used in this charge controller for the center of coordinating all ongoing system's activity and it is most economical than any other pic based microcontroller. It is designed in 28 pin DIP package while other microcontroller has greater pins and it has 8-bit RISC CPU [5]. PlC16F73 microcontroller is used here for the charging and discharging control mechanism. It is also used for battery data acquisition task which is the prime requirement in this project. PlC16F73 microcontroller contains 3 or input/output ports which are useful for the development and designing of the charge controller.

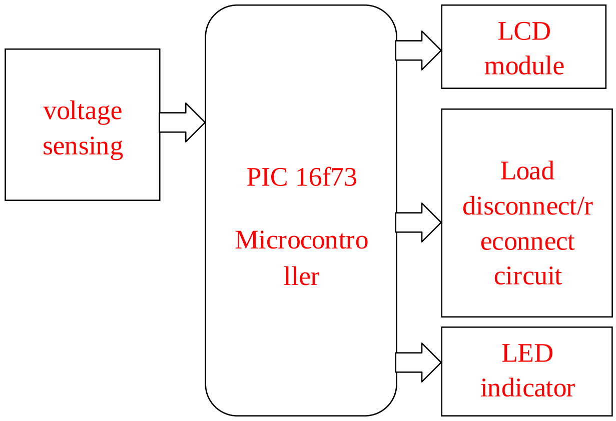

Fig -2: Block diagram of charge controller

Fig-2 shows the block diagram of this charge controller. ADC operation is performed by Port A by which microcontroller can sense the battery voltage using voltage divider. To interface with the LCD module display, which shows the battery voltage, port B is used. Port C is used to control disconnect or reconnect operations between PV panel or load or battery. It is also used for the LED indicator which indicates the various battery voltage conditions.

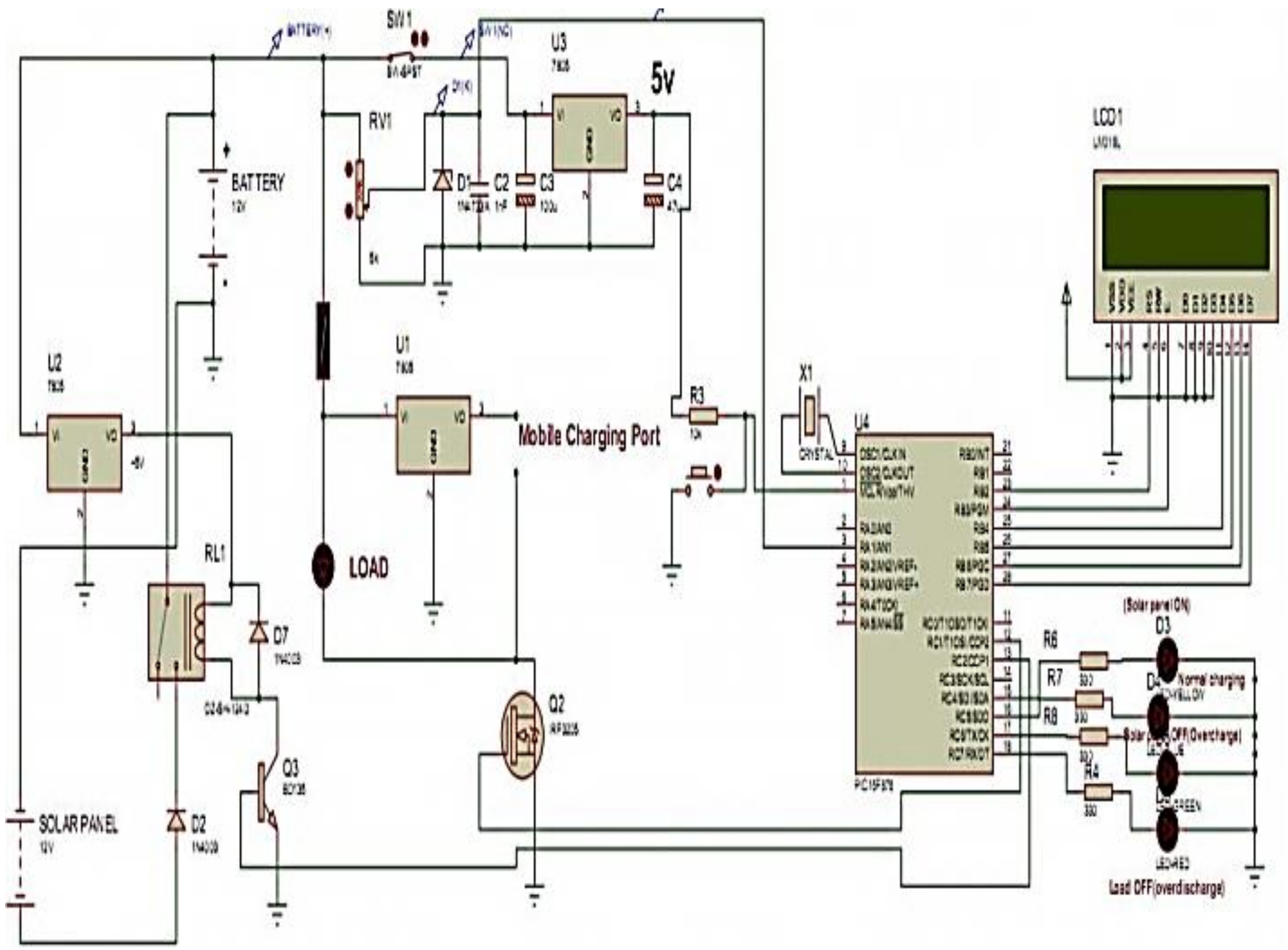

Fig -3: Schematic diagram of solar charge controller

Circuit diagram is shown in Fig-3. A 20 MHz crystal oscillator clocks the microcontroller. Microcontroller and LCD gets 5V power from 7805 voltage regulator which is derived from the battery. One power MOSFET (IRF3205) is used in the battery to load line for performing as a solid-state switch [6]. A relay and transistor combination is used for the switching purpose between the panel and battery line. LEDs are used to display the charge controller's different status. LCD display shows the battery voltage.

3.1 Voltage Sensing and Hysteresis Control mechanism

Microcontroller cannot sense the voltage greater than 5V that's why the battery voltage is reduced to less than 5V by a potential divider and then microcontroller sense this voltage. When the battery voltage comes to low then LED gives a signal which warns that battery is draining charge. Normally the hysteresis of the charge controller cannot be changed by the user. Load hysteresis should not be too small, if it is small then the load on and off would occur rapidly between load reconncect voltage (LRV) and low voltage load disconnect (LVD) voltage, which can damage the charge controller. Load hysteresis should not be too larger also, if it is larger then the load connection would remain off for longer periods, which is bad, until the solar panel fully recharges the battery. With a resonable large load hysteresis, the battery condition can be improved by the help of reduced battery cycling[4]. So it is important to select proper load hysteresis which depends upon batery chemistry, specification, PV and load condition also. Load hysteresis for the experiment is selected as: LRV is 11V and LVD is 10V. But still with simple hysteretic control there is a disadvantage that is, the frequency variation is very large under load variations; hence this charge controller is designed to avoid such large variations. The lead acid batteries needs lower charge current which means PV energy is required less because oxygen recombination cycle limits their ability to accept the further charge[7].

3.2 Switching Section

For the output part, it consists with the switching section, whose function is to connect or disconnect panel-battery and battery-load. The controlled load distribution and it's all featuring equipment is shown in Fig-3. Positive end of the battery is connected with the positive ends of the load. Negative ends are switched by the use of power MOSFET (IRF3205) which is established here . The combination of microcontroller and mosfet is used to control the load operation of the charge controller . Positive end of the battery is connected to microcontroller. Microcontroller then verifies it with the program written on it. If all the requirements are fulfilled then a signal is sent out to the MOSFET unit of what to do. Now positive switching is established by this MOSFET and the load [8]. Circuit is now closed. So load operation can be done by this way.

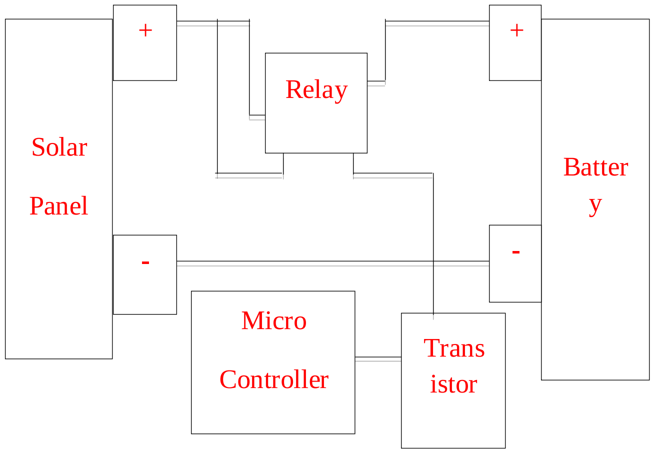

Fig -4: Battery-Panel switching circuit

Fig-4 shows battery-solar panel connection to charge the battery. In this way transistor and relay are used to control the charging process. Positive end switching is also used here which is shown in this figure. So negative end of battery is connected to negative end of solar panel. Microcontroller takes the decision whether to connect or disconnect these two by the help of the program written on it. If everything is okay then a signal is sent from the microcontroller to establish the connection between battery and panel. By this way battery is charged to its full state. If the condition is not fulfilled then a signal from the microcontroller is sent to the transisitor that implements one terminal of relay is not grounded. Because one terminal of Relay must be higher potential and other should be lower potential so that the Relay can be energized. So the circuit is now open and there is no charge flow to the battery from solar panel.

3.3 Control Section

The purpose of this section is to control the whole hardware. A microcontroller (PIC16F73) has been used to control the system. PlC16F73 contains 3 I/O ports. Port A is the input port which is used at the input stage to sense the battery voltage and to control hysteresis level. PORTC performs connecting or disconnecting operations between PV panel or load or battery and also shows status using LED. PORTB is used to provide the information of battery charging status in LCD display. RC4, RC5, RC6 and RC7 indicates solar panel-on, load-on, solar panel-off, load-off condition respectively. Data can be transmitted to remote displays by some charge controller also [9]. Normal condition refers to both charging and discharging of battery simultaneously. PORT B is used to show different battery voltage level indicated by LCD. LED level indicator has been used here to minimize cost in PORT C [10].

4. CONSTRUCTION OF THE SMART SOLAR CHARGE CONTROLLER

To construct a smart solar charge controller, one needs to do the following task.

4.1 Voltage Control Algorithm

Microcontroller analyzes data and it operates by the program written on it. To construct a charge controller, the first thing that needs to be done is to write a program for the MCU. The program gives instruction and as well as controls PIC16F73 microcontroller to execute various tasks, such as to control battery voltage. For writing the program for MCU, Proton IDE software is used. Proton IDE is a high level programming language also it provides more efficient and intelligent control. Control program has been developed according to the algorithm shown in Fig-5.

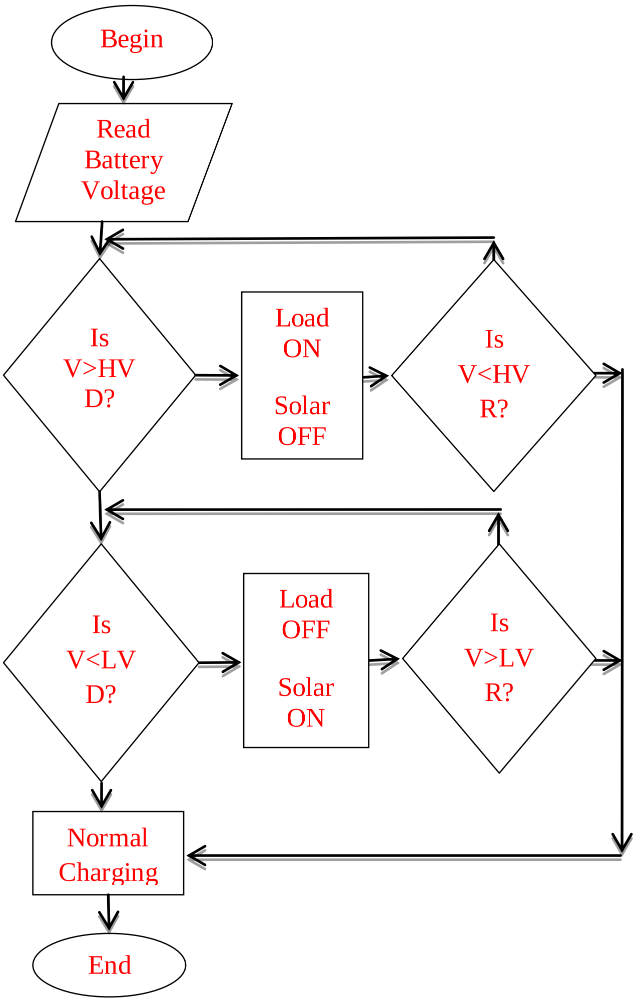

Fig -5: Flow Chart of charge controller circuit

Decision taking plan is shown in the flow chart of fig-5. It indicates how a microcontroller program takes decision. At first microcontroller reads the battery voltage via voltage divider. Then it takes first decision whether voltage is greater than 14.1 V or not. If yes then load is on and solar panel off. So voltage will be decreasing. If battery voltage is below 13.5 V then it starts normal charging conditions. If voltage is still above 13.5 V then solar panel is off for preventing hysteresis. Again if the battery voltage is less than 10.3 V then load is off solar panel is connected. Load will be off till 11.3V which is low voltage reconnect point (LRV). Above 11.3 V load and solar both are connected normally.

Table -1: Control set points with measured voltage

Control set points	Corresponding Voltage set points
HVD -High Voltage Disconnect	14.1V
HVR -High Voltage Reconnect	13.5V
LVR -Low Voltage Reconnect	11.3V
LVD -Low Voltage Disconnect	10.3V

Four regulation set points of the solar charge controller for the experiments are listed avobe in table -1. The set points are chosen by the help of battery charging/discharging datasheet. The upper set point diconnect the battery from the solar panel from further charging. The low voltage disconnect point prevents battery from further draining charge.

4.2 Hardware Circuit

The whole circuit is mounted on the Vero board for the experiments. For commercial purpose SCC should be mounted on PCB board.

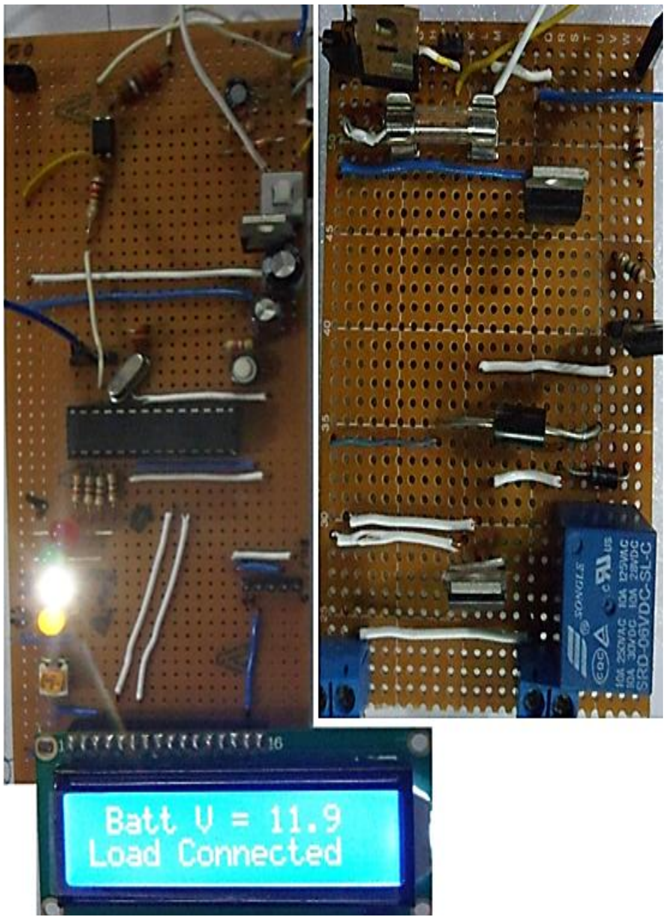

Fig -6: Implemented hardware circuit in Veroboad

The veroboard of fig-6 is chosen because it is low cost than any other board. Some charge controlllers use PCB board for the commercial use but we selected it because it is much lower costly and easy to implement.

4.3 Implementation

The charge controller is now attached with a solar panel to prove that the efficiency of the charge controller is high. The data was taken in Bangladesh time without load is connected.

Table -2: Data taken without load connected condition

Time 24-11-13	Battery Voltage (V)	Solar Panel Current (A)	Remarks
9:20 am	10.2	1.53	Charging on
9:40 am	11.3	1.42	Charging on
10:30 am	12.5	1.30	Charging on
11:00 am	13.0	1.24	Charging on
12:00 pm	14.0	1.08	Charging on
12:10 pm	14.1	0	Charging off

From table 2 it is seen that the efficiency of the charge controller is good. While taking the data, a solar panel of 40 watt, 3 watt bulb as load and 7.6Ah battery is used. The solar panel being small, the current is less than the theoretical value shown in the table. The power consumption of the charge controller is less than 1 watt. It would suffice to say that the charge controller will operate smoothly and accurately if a solar panel of higher watt is used.

5. RESULTS AND ANALYSIS

This SCC system can be controlled independently by PIC16F73 microcontroller as well as it is incorporated with various status display functions. The internal components are also independent. For this reason the controlling program is written on the microcontroller. Our main objective is to make this charge controller as low cost so that the mass people of Bangladesh can afford to buy it. That’s why our charge controller is not equipped with MPPT feature because it is so much costly. This charge controller can be made as PWM controller as well just by writing a program on it. But we cannot do it here because we are using relay which operates bad as PWM controller.

A blocking diode or the schottky diode is used here for blocking the charge flow from battery to solar panel at night which could damage the panel. For overvoltage protection a Zener diode is placed in parallel to the voltage divider. For overcurrent protection a 10A fuse is used before the load connection.

For load controlling operation the positive end switching method has been introduced here. For the set points the manufacturer’s instruction is being followed. At first the source code is not working which was written in Micro c language. Then we changed it and written it with the proton IDE which works best. MOSFET rating was carefully chosen and a power MOSFET is chosen for the system purpose. The crystal oscillator frequency is chosen as 20 MHz which gives best microcontroller operation.

Several practical implementations have been done with this charge controller at CUET. It works well and the person was satisfied with the performance of our solar charge controller. This charge controller can be made commercially after making some changes. This is done on veroboard but for commercial purpose it should be implementing on PCB board. Thus it can be economical as well as commercial solar charge controller.

6. CONCLUSION

PV system is required for our country. As we are not economically solvent the price of the accessories of solar system are too much high. For this purpose we did our work and research on solar charge controller. The cost is so much low as it is less than 350 BDT and would be small in size. It is so much lower than any other charge controller which is found in Bangladeshi market. The algorithm used here is efficient for the charge controller operation. The charge controller also has hysteresis control and battery voltage indicator by both LCD display and LED. So it is useful for commercial purpose.

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