International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 10 | Oct - 2021 ISSN: 2582-3930

DESIGN & DEVELOPMENT OF A HIGH CAPACITY EFFICIENT SOLAR CHARGE CONTROLLER WITH TRICKLE CHARGING

Md. Sohel Rana [*1], Md. Habibullah [*2], Nazimul Islam[*3], Md. Abdul Momin[*4]

*1, 2, 3, 4(Ex-Student, B.Sc in Telecommunication and Electronic Engineering,
Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh)

---***---

ABSTRACT

Nowadays, there is growing scarcity of the non-renewable recourses in the developing world. Therefore in order to meet out daily energy demands we require to actively focusing on renewable resources. Among the various renewable resources solar energy is available in abundance in Bangladesh. A photovoltaic system mainly consists of four components- rechargeable battery, solar photovoltaic module, load & solar charge controller. Moreover, an inverted is used for AC system. High efficient and high capacity solar charge controllers are not being made in Bangladesh. In this point of view, this project presents designing & developing a cost efficient, high current capacity photovoltaic charge controller using locally available components. The charge controller is made using a microcontroller for controlling purpose. As switch, both relays and MOSFETs have been used. When the battery draws very large current then, it will go through relays and for trickle charging MOSFETs have been used. Moreover, to increase the life of the relays the hysteresis have been made large and a mechanism has been adopted so that the relays will be ON/OFF first then the current will go through it, The hysteresis for the MOSFETs has been kept low so that they becomes ON/OFF frequently to provide trickle charging to the battery. An LCD display has been interfaced with the system to display the different states of the controller and the battery. The system has been designed, simulated and finally implemented in the laboratory. It is found that the system works properly.

Keywords: Microcontroller, PLC Programming, Solar, Trickle charging, Relay, MPPT Charge Controller.

1. INTRODUCTION

Since the dawn of civilization, the development of mankind has been inseparably linked to the use of energy. Today with rising alarm about global warming and burning of fossil fuels, along with growing awareness that the supply of fossil fuel is running out, we are casting about for solutions. Photovoltaic power system, a promising source of energy for the future is an excellent solution.

Actually solar panels are referred by the industry as photovoltaic modules. Generally there are 30 to 36 solar panels per module. The modules can be wired as parallel or series arrays to generate higher voltage and currents. Typical small Photovoltaic systems use a single solar panel to charge a 12 volt battery. Generally, a Photovoltaic system involves of a Photovoltaic array which transforms sunlight to DC current, a control method which controls battery charging and secondary batteries.

A charge control prevents overcharging which decrease battery performance or lifecycle by interrupting the current flow from array to battery, until battery becomes fully charged and prevent completely draining a battery or overcharging by open circuiting the connection among battery & system load once the battery grasps a small state of charge situation. To prevent battery from overcharging and over discharging we use relays and MOSFETs. Figure-1 shows block diagram of our charge controller that employs hysteresis on charge and discharge, selective load disconnect.

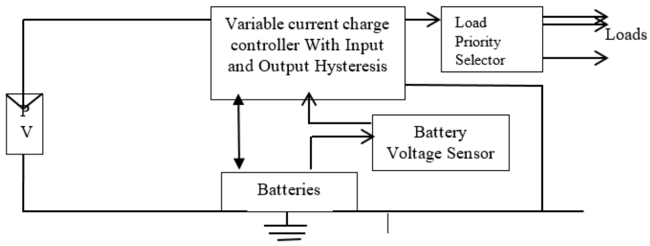

Figure 1: Block diagram of a solar charge controller

Relays are similar in function to the shunt type charge controller except instead of short circuiting the panel output they open circuit between the batteries and solar module. The hysteresis of relays is adjustable by the users and is greater than MOSFET hysteresis. But the array current remains detached for long periods for a long hysteresis. When hysteresis is tiny, the array will set on-off quickly and thus damaging relays which are electro-mechanical switching elements. In this case we use MOSFETs which enable charging in a small hysteresis. We can maximize efficient use of sunlight by using both relays and MOSFETs.

We use the trickle charging to charge battery of PV system using MOSFETs. A trickle charge is a constant current charge at a low rate which is used to keep the solar battery in a fully charged condition. Trickle charging is used to boost a battery for losses from self-discharge plus to restore the energy

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 10 | Oct - 2021 ISSN: 2582-3930

discharged during discontinuous use of battery. Therefore, a good and reliable solar charge controller is a vital component of any solar battery charging system to reach low cost and the advantage that the user can acquire from it. The control strategy or algorithm of a PV charge controller governs the efficiency of battery charging, Photovoltaic array utilization and the capacity of the structure to come across the load demands.

In our project, we are designing a series controller. The best modest series controller is series –interrupting type, rotating the array point charging current whichever on or off. The charge controller continuously monitors PV battery voltage, and separates or open-circuits the array point in series when the PV battery touches the directive voltage set point. When battery voltage falls to the ARV (Array Reconnect Voltage) set point, battery and the array are rewired, and the sequence repeats.

Generally, charge controller is distributed into three main parts, which are PIC16F72 microcontroller, input parts and output parts. The input part of any charge controller is solar battery voltage sensing circuit. It is used to detect the voltage of battery and send information to the PIC microcontroller to analyze and PIC microcontroller will work rendering to the program written within its memory. For the output, it consist panel-battery connect/disconnect circuit, load connect/disconnect circuit, battery voltage indicator, charging condition indicator. Internal oscillator of PIC16F72 clocks the microcontroller. Circuit power at 5V is derived from a voltage regulator connected to the battery. Six power MOSFETs and two relays are used as solid-state switch for the panel-battery line and battery-load line. An LCD display is used to demonstration the system status.

Here, PIC16F72 microcontroller is used to control the whole operation of charging control and data collecting task in this project. PIC16F72 microcontroller contains 5 I/O ports which are fit for the development of solar charge controller. Port-A is used to execute the ADC conversion that used in input portions like current sensing circuit and battery voltage identifying circuit. Port D is used to controls reconnect or disconnects operations for photovoltaic panel or load. Port C is used to display various battery voltage conditions on LCD display. Block diagram of charge controller is exposed in figure-2.

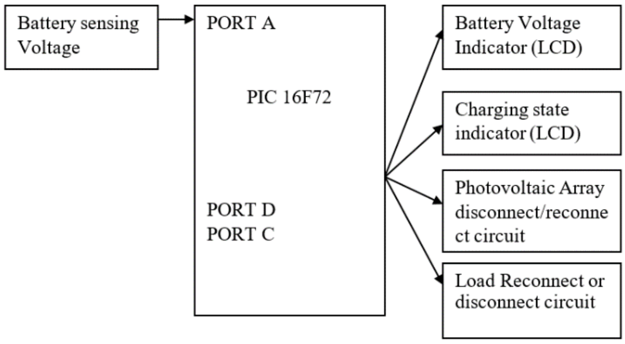

Figure-2: Block Diagram our solar charge controller

Other options of our designed charge controller are shown in below:

- Solar charging current :120 Amps continuous
- Nominal battery voltage:24V
- PV panel voltage ratings: up to 3 KWP
- Battery type: lead-acid
- Hysteresis control option
- Over voltage and under voltage protection
- Battery voltage status indication by LCD display

2. Theory of Charge Controller

In our project, we used a series on/off charge controller, also known as two stage charge controller. Theory behind two-stage charge controller is given below.

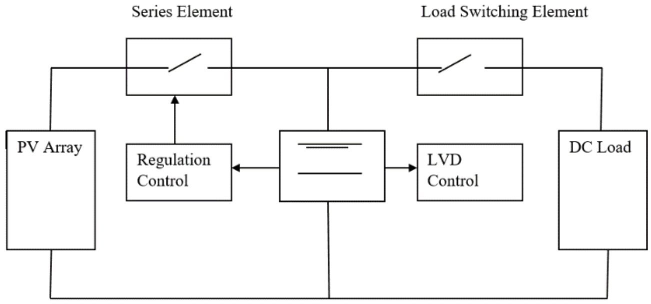

Figure 3: Two stage series charge controller

2.1 Solar Charge controller set points

The PV battery voltage level where a charge controller executes switching functions is known as charge controller set points (Figure 4).

There are four (04) elementary switching set points defined for maximum charge controllers. Those are:

- ARV: (Array Reconnect Voltage)
- VR: (Voltage Regulation)
- LRV :(Load Reconnect Voltage)
- LVD: (Low voltage Load Disconnect)

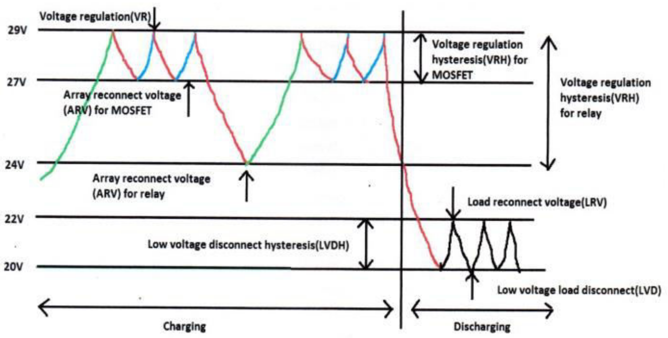

Figure 4: Charge Controller Set Points

2.1.1 VR: (Voltage Regulation)

The VR set point is clear as the supreme voltage that the PV charge controller permits the battery to touch, controlling the overcharge of PV battery. In our project it is 29 volt. When the controller reaches that the battery touches the VR set point, the charge controller will disconnect MOSFET or relays.

2.1.2 ARV: (Array Reconnect Voltage)

When the PV battery voltage losses to a prefixed voltage (in this case it is 27 volt), the array once more rewired to the battery to restart charging. This voltage where the array is recombined is defined as the ARV set point.

2.1.3 VRH: (Voltage Regulation Hysteresis)

The PV voltage variances between the arrays reconnect voltage and the VR set point is frequently called VRH. when the hysteresis is excessively peak, the array current rests disconnected for extended times, effectively lowering the array energy consumption and constructing it very tough to entirely recharge the PV battery.

When regulation hysteresis is excessively slight, the array will set on-off promptly, possibly damaging controllers which use electro-mechanical switching components.

2.1.4 LVD: (Low Voltage Load Disconnect)

If battery voltage falls too short, due to persistent bad weather for example, certain non-essential loads can be separated from the PV battery to avoid further discharge. This can be finished by a LVD device attached between non-essential loads and the battery. We selected 20 volt as the LVD set point.

The LVD is moreover a solid-state switch or relay that intersects the current from PV battery to load, and involved as part of maximum controller designs.

2.1.5 LRV: (Load Reconnect Voltage)

The PV battery voltage where a charge controller permits the load to be rewired to the PV battery is called LRV, which was selected 22 volt for our charge controller. After the charge controller detaches the load from the PV battery at the Load Reconnect Voltage set point, the battery voltage increases to the open CKT voltage. When additional charge is provided by the array, the battery voltage increases even more. At various set point, the PV controller wits that the PV battery voltage and condition of charge are great adequate to rewire the load, known as LRV set point.

2.1.6 LVDH: (Low Voltage Load Disconnect Hysteresis)

The voltage variance between the LRV set point and LVDH set point is called the hysteresis LVDH. When LVDH is excessively low, the load may round on-off quickly at low battery condition, probably damaging the controller or load, and spreading the time it receipts to fully charge the PV battery. If the LVDH is too high, the load may continue off for comprehensive times awaiting the array entirely recharges the battery. With an extraordinary LVDH, battery strength may be enriched due to abridged battery cycling, along with a decrease in load availability.

2. SYSTEM DESIGN AND TESTING

3.1 Hardware Design

The total system is divided into four subsystems

1. Hysteresis control and Voltage sensing circuit
2. Voltage regulation section
3. Control section
4. Switching section

3.1.1 Hysteresis control and Voltage sensing circuit

To capture the battery voltage a preset resistor has been used. We have designed this circuit to sense the maximum battery voltage of 35 Volts. The output battery voltage of this circuit is fed to the voltage separator bias circuit. Resister 9k and 1k are used in our voltage divider circuit. The voltage across 1k resistor is fed to the microcontroller ADC2 or pin4.

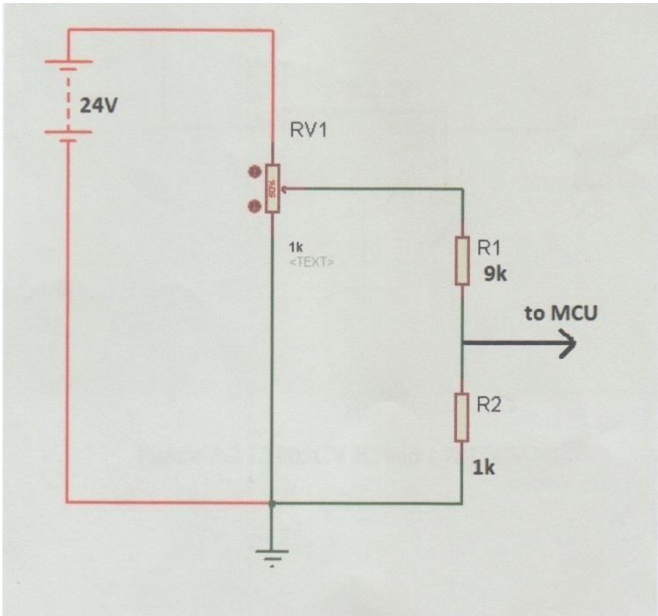

Figure 5: Voltage sensing circuit

3.1.2 Voltage regulation section

To operate the microcontroller a regulated 5V source is required. But the battery voltage our system is 24V. That’s why a voltage regulator has been designed for the microcontroller. For this purpose a regulator IC (L7805CV) has been used. L7805CV converts battery voltage (24V) to 5V. This 5V is used to activate the microcontroller & drive the MCLR pin. To operate relay a regulated 12V is required.L7812CV convert battery voltage (24) to 12V.

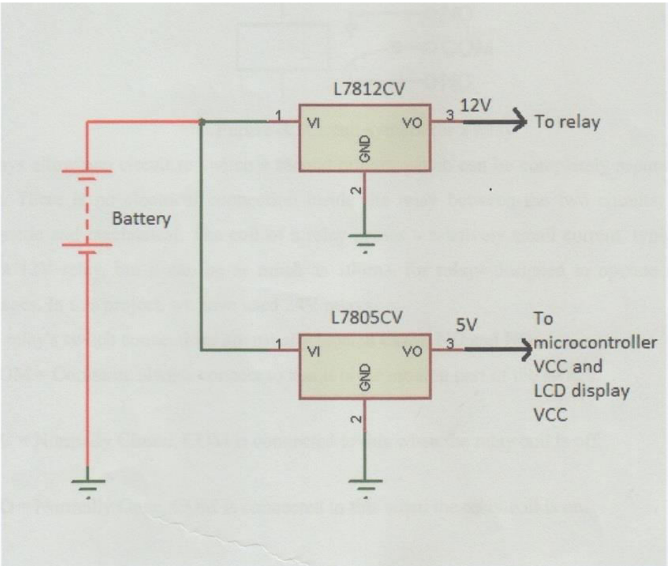

Figure 6: L7805CV IC and L7812CV IC

3.1.3 Switching section

In this charge controller two kinds of switches have been used-relays and MOSFETs.

RELAY:

A relay is an electrically operate switch. Relays are where it is essential to regulator a circuit by a less power signal with whole electrical isolation between controlled circuits and control. Current flowing over the coil relay creates magnetic fields, which appeals a lever and modifications the switch links. The relay coil current may be off or on so the relays have two switch points and maximum have double lob switch contact points as shown in following diagram.

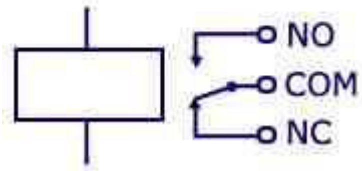

Figure 7: Circuit symbol for a relay

Relays permit one circuit to switch another circuit, which can be entirely separate from the first. There is no electrical joining on the relay among circuits; only the connection is mechanical and magnetic. The coil of a relay passes a relatively minor current, typically 30mA for a 12V relay, but it can be high as 100mA for relays designed to function from lower voltages. In our project, we used 24V relays.

The relay's switch contacts are typically labeled NC, COM and NO:

#COM=Common, continuously join to this, it is the touching portion of the switch

#NC = Typically Closed, Common is attached to this while the relay loop is off.

#NO = Generally Open, Common is attached to this while the relay loop is on.

MOSFET:

We have also used MOSFET as a switch in parallel with the relays. MOSFETs enable at a small voltage and draw an extremely small current to control a much larger current up to service amps for a power MOSFET. It has some other benefits such as:

- Very high (near infinite) input resistance.
- Very speedy switching.
- Small output resistance.
- Able to switch high currents (up to 09amps with a heat sink and a power MOSFET).
- 0V (Zero Volts) on the gate will turn the switch off.
- Small drain voltage when saturation(0.1 Volts)

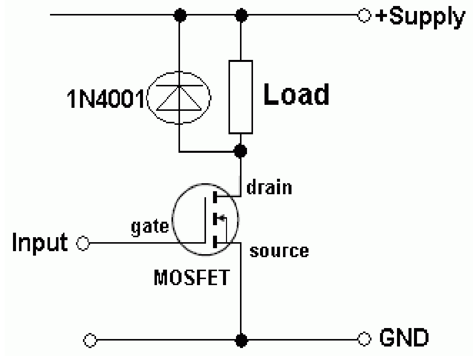

Figure 8: MOSFET Switching Circuit

For driving load we use only relay. But when we connect PV array with the battery we use both relay and MOSFET. Battery is charged either through MOSFET or through relay.

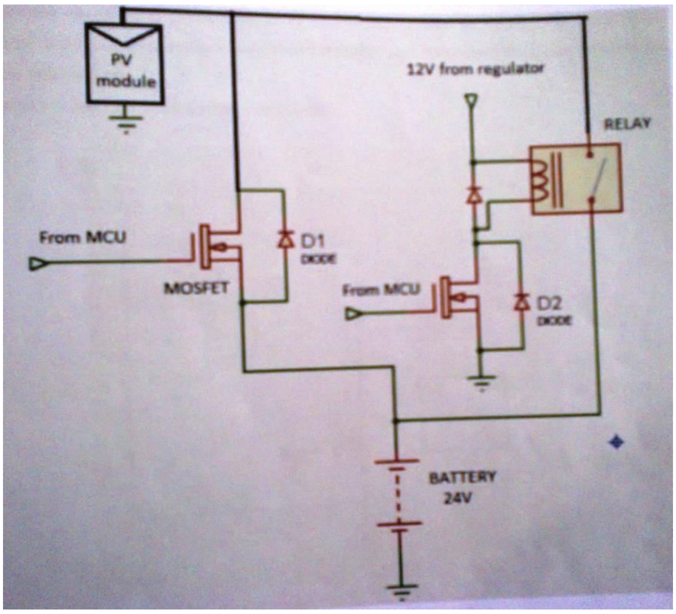

Figure 9: Connection of PV module with battery

When battery voltage is smaller than 24V then it is charged through relay up to 29V and then relay will be turned off. Again when battery voltage falls down below 27V MOSFET will be changed ON, also battery will be charge up to 29V So voltage regulation hysteresis for relay is 5V (from 24V to 29V) and for MOSFET is 2V (from 27V to 29V).If we use too small hysteresis for relays then the relays will cycles ON and OFF frequency which causes damage to them. So for relays we use larger hysteresis. But for larger hysteresis the battery will remain disconnected for a long period which is inefficient of use of energy. So MOSFETs are introduced for small hysteresis. Using both MOSFET and relays will facilitate efficient use of available soar energy. To control our load we use only relay as a switch.

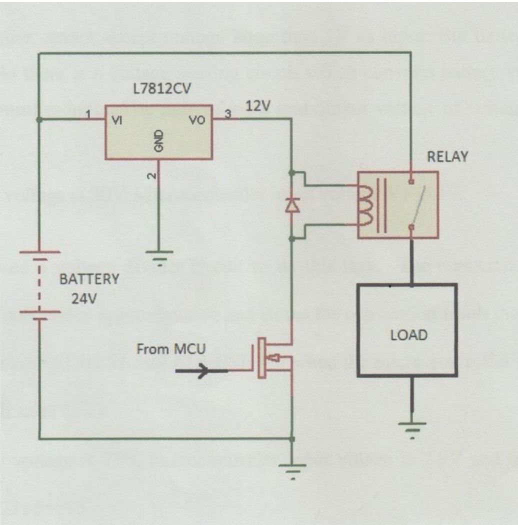

Figure 10: connection of load with battery

3.1.4 Control Section

The aim of this unit is to control the total hardware. So a microcontroller (PIC16F72) is used to manage the system. Output of the voltage detecting circuit is fed to PORT-A (pin-4) of the microcontroller. Thus PORT-A is designed as input port and PORTC and PORTD is configured as output port. We use an LCD display the voltage stage of the battery. The output of PORTC is fed to LCD display's data input. Output of RD0 and RD1 are connected with RS and E pin of the LCD display. The output of RD4 pin drive the MOSFET and output of RD3 pin drive the relay. The output of RD2 pin is fed to the load.

3.2 Complete Circuit Diagram:

The following figure shows complete circuit drawing of solar Charge controller.

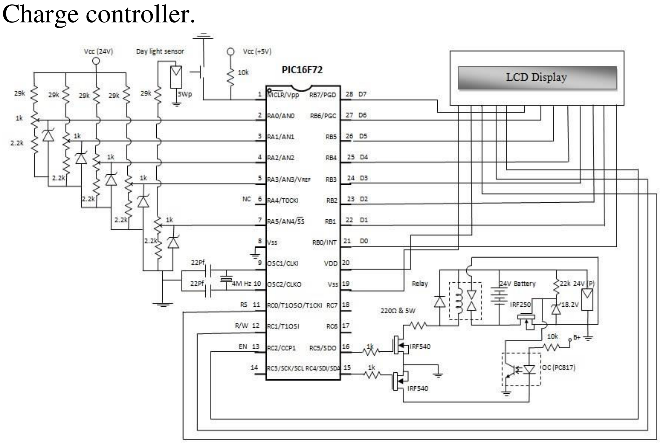

Figure 11: Complete circuit diagram

In this work, series regulation technique is utilized but instead of killing the charging battery current as heat, when the battery is completely charged, the energy is converted into pulsed signal and useful to the battery to retain the battery high. Once power is on, the controller read out the battery voltage with the support of the ADC conversion and shows the data on the LCD. It observes the input sign from the evening-to-morning sensor and starts the load system otherwise charging relay RL accordingly.

3.3 Software design:

3.3.1 Programming Language

Programming on PIC can be done in several languages such as Assembler, C, BASIC & FLOWCODE, which are most commonly used languages. In our case we have used C programming language. For writing C code we use MPLAB IDE v8.84 software. When the code is written in C language then it is assembled to HEXADECEMIL file by using HI-TECH ANSI C compiler. Then the HEXADECEMIL file with the support of microcontroller burner is burned/ programmed to the microcontroller chip and the programmed micro controller is ready for use.

3.4 Algorithm:

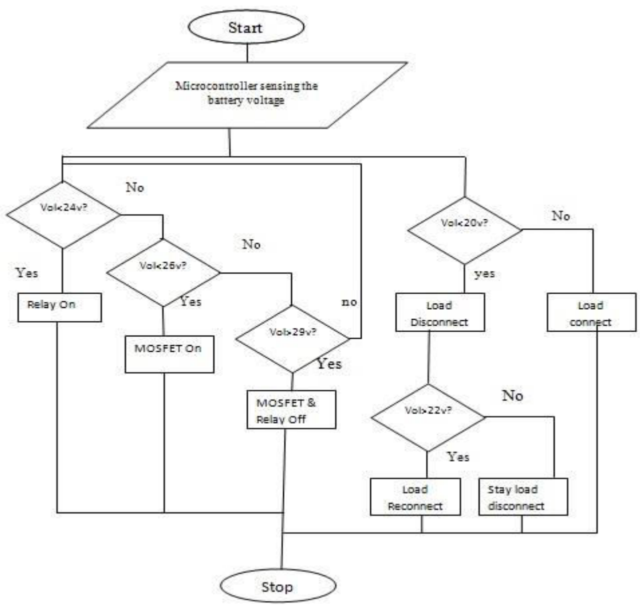

Figure 12: Flowchart of c code

3.5 Prototype Testing

After designing the hardware architecture and software part, we implement the working circuit diagram on the breadboard/project board for testing purpose. Here input voltage generated by power supply (representative of battery) and see that 44microcontroller output state changes according to the application of input voltage. In addition, we can see battery voltage levels indicating by LEDs are also operation properly. If we change the preset we see that the hysteresis band changes. All the output condition matches with the change in the input condition, so our prototype testing is successful, and the device is ready to be implemented on PCB.

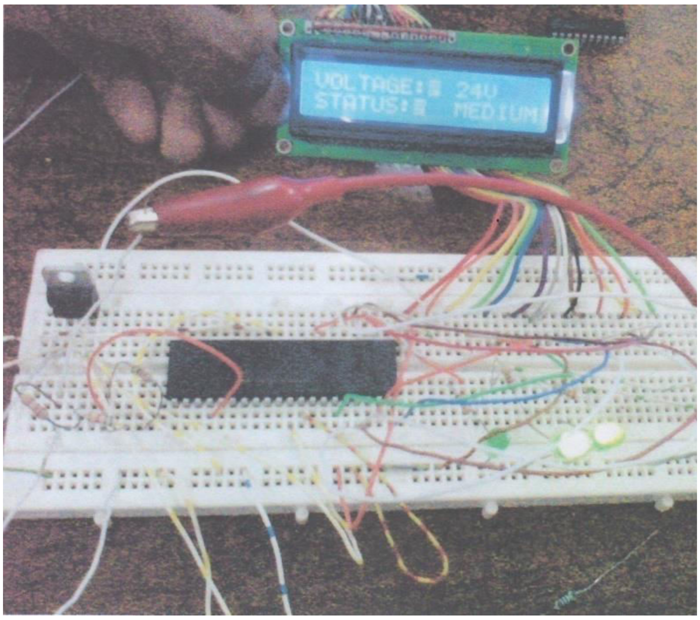

Figure 13: Prototype testing

4. FUTURE ASPECT

In our project a charge controller capable of voltage regulation photovoltaic System is presented. In future we want to expand it with current specification along with terms used by PV industry for battery charge controllers to compare it with commercially available charge controllers. An outline of battery performance characteristic is also needed for successful commercialization of our product. Also we want to use microcontrollers with fewer pins than PIC16F887. But it was not possible due to unavailability of microcontrollers in the market. So in future we would want to use microcontroller with less pins like PIN16F690 to reduce the overall cost and want to integrate with Internet of Things (IOT) based monitoring system.

5. ACKNOWLEDGEMENTS

At first we respectfully remember the almighty creator and thank Allah to give us a chance to complete this project and to give us the good health to complete this report. We respectfully remember our beloved parents, who always encourage and support us. We also thankful to Dr. Jahid Hassan Mahmud & Dr. Md. Habibur Rahaman, Professor, Department of Applied Physics, Electronics & Communication Engineering, University of Dhaka. It would not have been possible to finish this project without his help and support, not to mention his advice and vast knowledge. We are also grateful to the laboratory staffs for their fast response and cooperation with us to get all materials we needed for our project. At last, we would like to express our thanks to all of our friends for whom the projects were moved to the success. They always help us.

6. CONCLUSION

In our work, the application of microcontroller with improve algorithm of extended specifications has improved the proficiency of charge controller also simplifies the circuit. This solar charge controller was designed to withstand high current. A high amp system needs high voltage, so we have used a 24 V battery (two 12 volt batteries in series) in our system. Because it is a series type there would be loss of 0.7V in the diode, but here in the series type there is no diode, only loss is in the MOSFET switch (0.5). In this work, this loss has also been removed by passing the current over the relays. Suitable ON-OFF voltage for both MOSFETs and relays were selected carefully which resulted in good simulation as well as excellent output response.

7. REFERENCES

[1] Microcontroller-Based Solar Charger, KS Project Manual EFY September 2009

[2] James P. Dunlop, P.E., Batteries and charge control in stand-alone Photovoltaic Systems-Fundamentals and Application, Florida Solar Energy center.

[3] http://en.wikipedia.org/wiki/Microcontroller [last access 20.01.2014]

[4] Iovine, John, PIC Microcontroller project book, eBook, McGraw-Hill

[5]http:/www.engineersgarage.com/electronic/7805-voltage-regulator-ic, [last access 10.01.2014]

[6] http://electronicsclub.info/relays.htm, [last access 23.01.2014]

[7] NowshadAmin, Lam Zi Yi and Kamaruzzaman Sopian, Master's Thesis, Microcontroller Based Smart Charge Controller for Standalone Solar Photovoltaic Power System, National University of Malaysia, 2009.

[8] PIC16F72 PDF Datasheet (http://www.wvshare.com/product/PIC16F72.htm) [last access 22.01.2014]

[9]Working principles of solar system, solar cell [online] http://www.windwaerts.de/en/topics/solar-energy/operating-principle-of-a-solar-cell.html [last access 29.07.2013]

[10] Solar Charge Controller, working of charge controller [online] http://www.dgsolarpower.com/ennew_93.html [last access 29.07.2013]

[11] Sunshine Works, Solar Calculations Math, a Simple Load Analysis. [Online]. Available:

http://www.sunshineworks.com/solar-calculation-math-tutorial.htm [last access 30.07.2013].
[12] Battery Selection. [Online] Available: http://www.battery2000.com/spec.html [last access 20.8.2013]
[13] http://www.slideshare.net/SohelRana23/savedfiles?s_title=mini-grid-and-solar-home-system&user_login=Jupiter276 [last access 06.12.2013]
[14] Roger A. Messenger, Jerry Venture, Photovoltaic System Engineering, Second edition, CRC Press, 2005
[15] http://www.cs.ucr.edu/~dalton/i8051/ [last access 06.11.2013]
[16] http://www.futurlec.com/Microchip/PIC16F72.shtml, [last access 31.12.2013]
[17] http:/www.edaboard.com/thread24199.html, [last access 19.12.2013]
[18] www.microchip.com/downloads/en/devicedoc/39597b.pdf, [last access 08.11.2013]
[19] www.answers.com/topic/circuit-board, [last access 05.11.2013]
[20] P.J McChesney, Solar Electric Power for Instruments at remote sites, open file report 00-128, 2000, USGS.
[21] Hund, Tom, no date, Battery Testing for Photovoltiac Applications: Albuquerque, Sandia, National Laboratories, p.1 (Sandia National Laboritories website: http://www.sandia.gov/pv/lib/bospub.html)
[22] http://www.bdchargecontroller.com/2stage3stage.php [last access 22.01.2014]
[23]http://www.microchip.com/stellent/idcplg?IdcService=SS_GET_PAGE&nodeId=1406&dDocName=en019469&part=SW007002 [last access 23.01.2014]