Maximum Power Battery Charging from PV System Microcontroller Based

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Abstract- this paper aims to get the maximum power from the Photovoltaic generators given I-V characteristics that vary with solar insolation and temperature. Then the paper describes a technique for charging a battery from solar panel at optimum set point condition using ATmega 32 microcontroller. Simulation with Protues software is performed to be compared with practical result.

I. Introduction

Social and environmental responsibility, rising energy prices, and depleted reserves of easily attainable fossil fuels have spurred a need for developing alternative sources of energy. This has been successfully accomplished using wind, hydro, geothermal, and solar power. These sources of energy have the potential of offsetting a significant portion of the world's energy needs. Recent world energy plans have been proposed for solar power to end the world dependence on foreign oil by 2050.from enormous corporate rooftops to small off the grid residential systems, solar is guaranteed to be part of the energy solution. Inexpensive and efficient production and management of this power is crucial to making photovoltaic systems a viable solution.

The solar cell output power differs with the change of the solar irradiance, the temperature and the load. It is aimed to get the maximum power point (MPP) with the change of the weather conditions (solar irradiance & temperature) and the change of the load. This paper introduces different methods to track the MPP[1].

This paper presents a cost efficient PV charge controller with the function to disconnect and reconnect battery and load during battery overcharging or under discharging. The proposed charge controller is equipped with LCD to display the battery voltage and panel voltage. The value of the battery voltage is used to the control the charging / discharging process and the load status of the photovoltaic system. LED indicator is a feature used to show the status of the system. The source code for the ATMEGA 32 microcontroller is written in C code which is more user friendly than using assembly language.

In this paper MPPT methods will be discussed. P&O method will be used to transfer the maximum power from the PV to the battery. Charging conditions will be discussed. Finally experimental result will be compared with the simulation result.

II. PHOTOVOLTAIC CHARACTERISTIC ANALYSIS
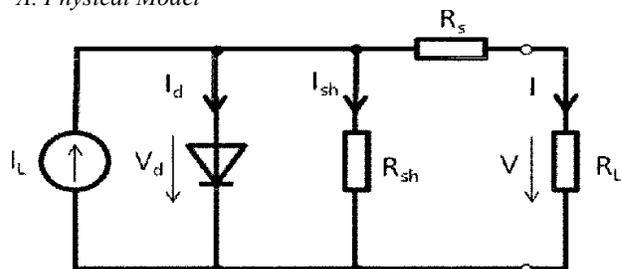
A. Physical Model

Fig.1 Photovoltaic Equivalent Circuit Diagram

Photovoltaic cells are composed of semiconductors. When light irradiates it, photovoltaic cells produce current, and the current changes with the luminous intensity. As the luminous intensity is certain, the photovoltaic can be considered as a constant-current power. Because of the contact between Photovoltaic cells' surface and back Electrode, and the resistance of material, there is a loss when the current flows through them.
As shown in fig.1, series resistance R_S is used for indicating them. On the other hand, because of the battery border leakage and the leakage of micro cracks and scratch, the current I_{sh} which should flow through the load will be short. As shown in fig.1, a parallel resistance R_{sh} is used for indicating this effect [2].

B. Output Characteristics and the Influencing Factors

Photovoltaic cells' volt-ampere characteristics and temperature characteristics are reflected through I-V and P-V characteristic curve. Photovoltaic cells' volt-ampere characteristic is the external characteristic of load when the luminous intensity and temperature are certain. It reflected the Photovoltaic cells' output power directly. Corresponding to different luminous intensity, there are different output characteristic curves.

As shown in fig.2, the photovoltaic cells' open-circuit voltage is V_{OC}, and it's short-circuit current is I_{SC}. Any point on P-V characteristic curve can be regarded as the operating point. The operating point's vertical coordinate

corresponds to the operating current, and abscissa coordinate corresponds to the operating voltage. Plot of both is the output power P, i.e. P=VI.

As shown in fig.2, I-V curve is greatly nonlinear; it implies that there is a maximum power output problem. On the other hand, in the P-V curve, along with the voltage increases from zero to V_{MAX} gradually, the output power firstly increases and then decreases. That indicated that there is a terminal voltage value V_{MAX} (less than V_{OC}).
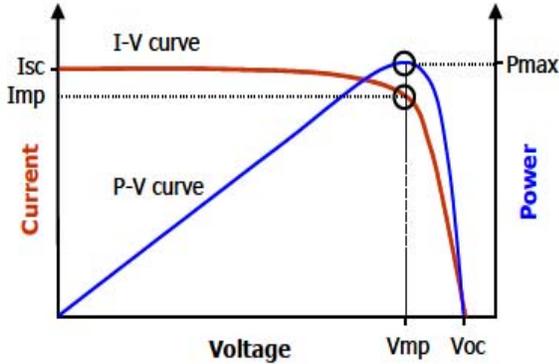

Fig.2 curve I-V and P-V characteristics

When the Photovoltaic cells' voltage is in the vicinity of this value, the photovoltaic can get the maximum output power P_{MAX}, and the current of circuit is in the vicinity of I_{MAX} (less than I_{SC}). Thus, both of the I-V and P-V curve indicate that there is a maximum output power point. This provides a direction for photovoltaic cells' maximum output power tracking in theory and practice [3].

III. MPPT CONTROL ALGORITHM

As known the output power characteristics of the PV system as functions of irradiance and temperature curves are nonlinear and are crucially influenced by solar irradiation and temperature. Furthermore, the daily solar irradiation diagram has abrupt variations during the day, as shown in Fig. 3. Under these conditions, the MPP of the PV array changes continuously; consequently the PV system's operating point must change to maximize the energy produced. An MPPT technique is therefore used to maintain the PV array's operating point at its MPPT.
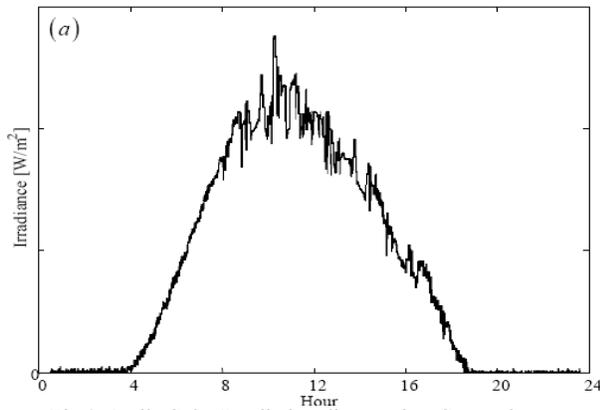

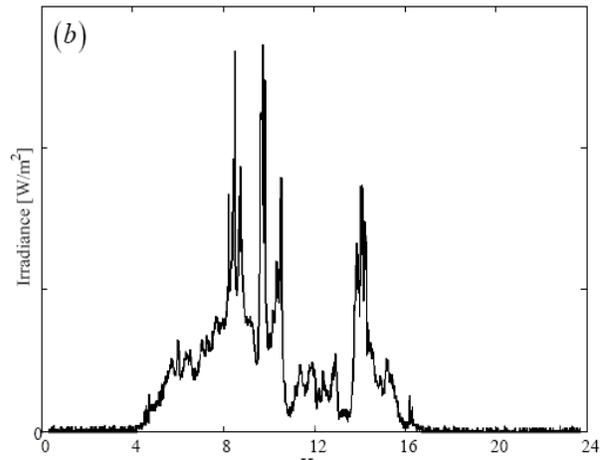Fig.3a Daily Solar Irradiation diagram in a Sunny day

Fig.3b Daily Solar Irradiation diagram in a Cloudy day

A. MAXIMUM POWER POINT TRACKING (MPPT) METHODS

There are many MPPT methods available in the literature; the most widely-used techniques are described in the following sections.

1) PERTURB AND OBSERVE METHOD

The P&O algorithms operate by periodically perturbing (i.e. incrementing or decrementing) the array terminal voltage or current and comparing the PV output power with that of the previous perturbation cycle. If the PV array operating voltage changes and power increases ($dP/dV_{PV}>0$), the control system moves the PV array operating point in that direction; otherwise the operating point is moved in the opposite direction. In the next perturbation cycle the algorithm continues in the same way.

A common problem in P&O algorithms is that the array terminal voltage is perturbed every MPPT cycle; therefore when the MPP is reached, the output power oscillates around the maximum, resulting in power loss in the PV system. This is especially true in constant or slowly-varying atmospheric conditions. Furthermore, P&O methods can fail under rapidly changing atmospheric conditions (see Fig. 4).

Starting from an operating point A, if atmospheric conditions stay approximately constant, a perturbation ΔV the voltage V will bring the operating point to B and the perturbation will be reversed due to a decrease in power. However, if the irradiance increases and shifts the power curve from P_1 to P_2 within one sampling period, the operating point will move from A to C. This represents an

Increase in power and the perturbation is kept the same. Consequently, the operating point diverges from the MPP and will keep diverging if the irradiance steadily increases.
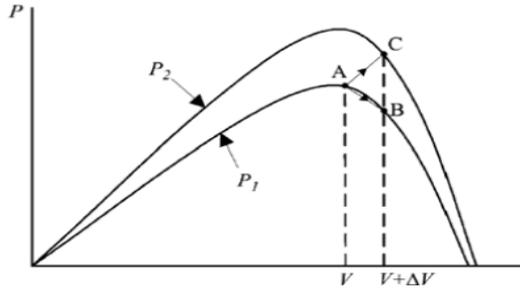

Fig.4 Divergence of P&O from MPP

There are many different P&O methods available in the literature. In this paper we consider the classic, the optimized and the three-point weight comparison algorithms.

In the classic P&O technique $(P\&O)_A$, the perturbations of the PV operating point have a fixed magnitude. In our analysis, the magnitude of perturbation is 0.37% of the PV array V_{OC} (around 2V) In the optimized P&O technique $(P\&O)_B$, an average of several samples of the array power is used to dynamically adjust the perturbation magnitude of the PV operating point.

In the three-point weight comparison method $(P\&O)_C$, the perturbation direction is decided by comparing the PV output power on three points of the P-V curve. These three points are the current operation point A, a point B perturbed from point A, and a point C doubly perturbed in the opposite direction from point B.

All three algorithms require two measurements: a measurement of the voltage V_{PV} and a measurement of the current I_{PV} (see Fig. 5) .
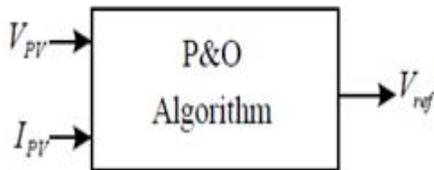

Fig.5 P&O Block Diagram

2) CONSTANT VOLTAGE METHOD

The Constant Voltage (CV) algorithm is the simplest MPPT control method. The operating point of the PV array is kept near the MPP by regulating the array voltage and matching it to a fixed reference voltage V_{ref}. The V_{ref} value is set equal to the V_{MPP} of the characteristic PV module.

This method assumes that individual insulation and temperature variations on the array are insignificant, and that the constant reference voltage is an adequate approximation of the true MPP. Operation is therefore never exactly at the MPP and different data has to be collected for different geographical regions.

The CV method does not require any input. However, measurement of the voltage V_{PV} is necessary in order to set up the duty-cycle of the dc/dc converter by PI regulator, as shown in the block diagram of Fig. 6.

It is important to observe that when the PV panel is in low insulation conditions, the CV technique is more effective than either the P&O method or the IC method (analyzed below). This characteristic, CV is sometime combined together with other MPPT techniques [4].
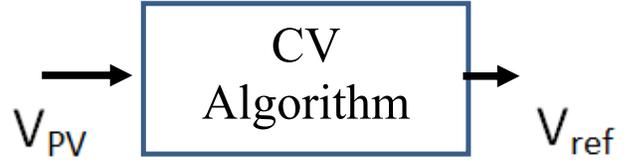

Fig.6 CV Block Diagram

3) OPEN VOLTAGE METHOD

An improvement on this method uses V_{OC} to calculate V_{MP}. Once the system obtains the V_{OC} value, V_{MP} is calculated by Equation 1:

$$V_{MP} = K * V_{OC} \tag{1}$$

The k value is typically between 0.70 to 0.80, it is necessary to update V_{OC} occasionally to compensate for any temperature change, Figure 7 show that V_{OC} also changes with (irradiance).
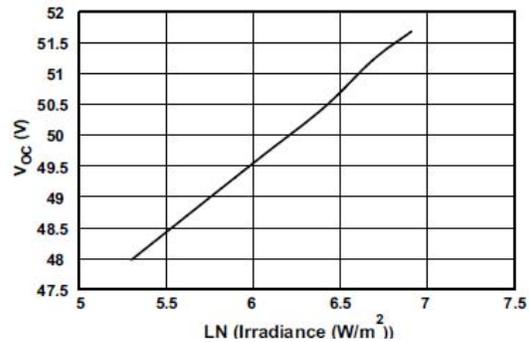

Figure 7: V_{oc} vs In (irradiance)

Sampling the V_{OC} value can also help correct for temperature changes and to some degree changes in irradiance. Monitoring the input current can indicate when the V_{OC} should be re-measured. The k value is a function of the logarithmic function of the irradiance, increasing in value as the irradiance increases. An improvement to the V_{OC} method is to also take this into account. Figure 7 gives an example of how input current can also be used to adjust the k value for indoor lighting PV systems. As the V_{MP} value is adjusted, I_{PV} becomes closer to the I_{MP} [5].
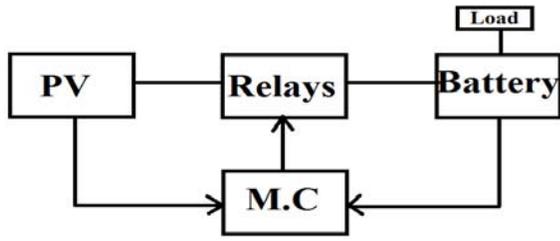
IV. HARDWARE IMPLEMENTATION

Fig.8 circuit diagram for maximum power point battery charge using ATmega 32

As shown in fig.8 the system consists of a microcontroller (ATmega 32) with on-chip multichannel Analog-to-Digital Converter (ADC). The used Battery: 7.0 AH, 12V Sealed Lead-Acid Battery. Fig.9 shows the simulation using Proteus software and the ATmega 32 code written by code vision software, there are three input analog signals to the microcontroller represent the sensed voltage , the sensed current from the PV cell and the sensed voltage of the used battery. In the code vision program, the sensed voltage and current from the PV cell are multiplied to calculate the power of the PV cell until reaching the maximum power point MPP using perturb & observe method then maintaining the operating voltage & current at the MPP. In order to cascade the PV cell with the battery & the load, it is mandatory to compare the operating voltage of the PV cell with the battery voltage. If the battery voltage is greater than the PV panel voltage, the battery is connecting with the load. Otherwise the load is connecting with the PV panel and the battery is recharging.
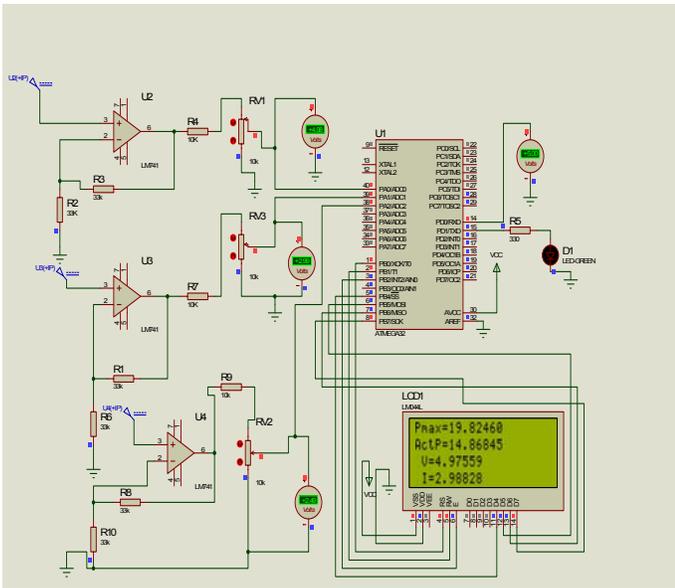

Figure 9 Hardware implementation using ATMEGA 32

Fig 10 shows the real hardware implementation for the system where Fig 10.a shows the battery connected to the load and there is no charging while fig 10.b shows the panel charging the battery
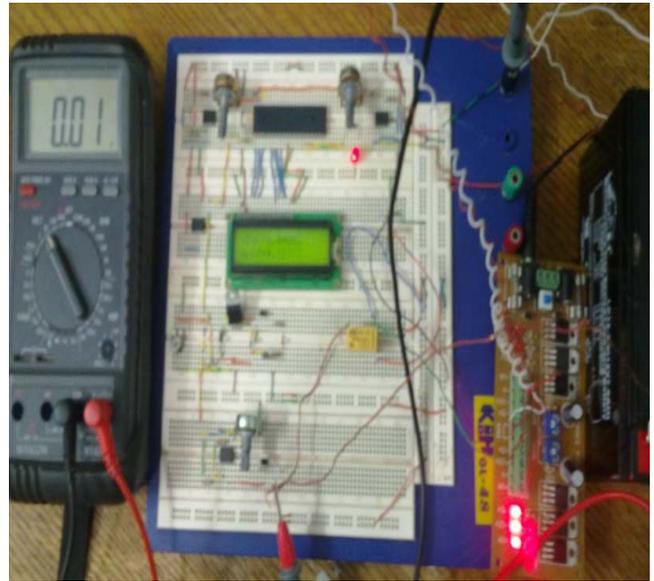

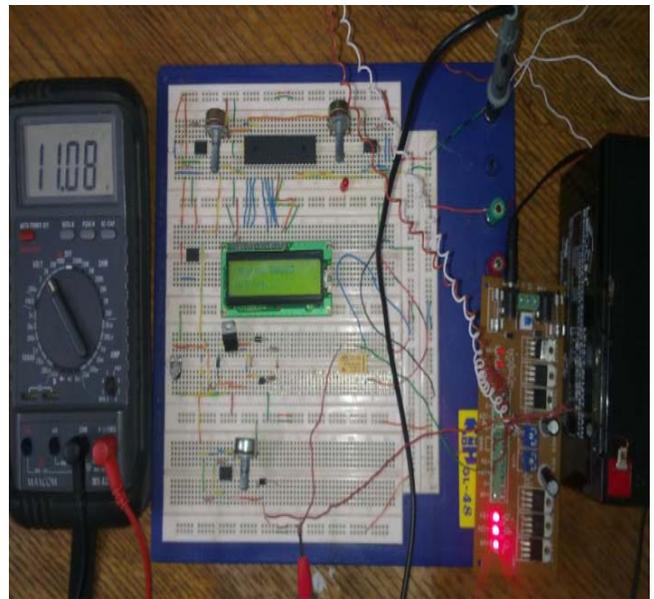Figure 10.a the battery is connected to the load

Figure 10.b the panel is charging the battery

V. CHARGING CONDITION

Figure 11 shows the battery charging and load connection set points, where the PV used is 18v ,30w and the battery is 12v.
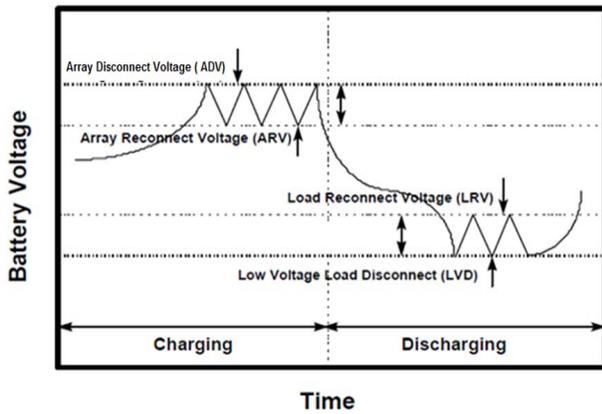
Figure 11.charger controller set points

Where the battery is disconnected from charging once its voltage reaches the array disconnect voltage set point (ADV), while during loading the battery and its voltage goes down the array reconnect voltage set point (ARV) it will be recharged. With respect to load, it is disconnected once the low voltage load disconnect set point(LVD) is reached and the load is reconnected when the voltage rises up to the load reconnect voltage set point (LRV)

Figure 12 shows the charger controller set point operation modes, where figure 12.a   shows the case of ADV as the battery is fully charged so the charging is stopped to protect the battery from the overcharging and the load is on.

Figure 12.b Array reconnect voltage case

Figure 12.c   shows the case of LVD as the battery voltage goes down to its minimum value so the load is disconnected to protect the battery from the over discharging
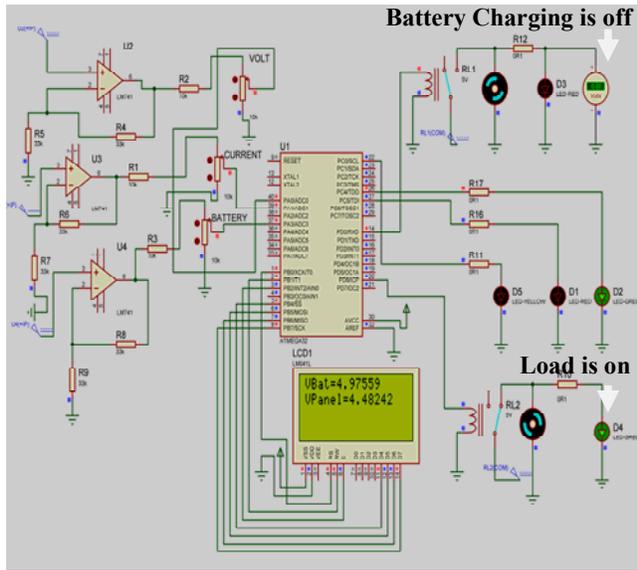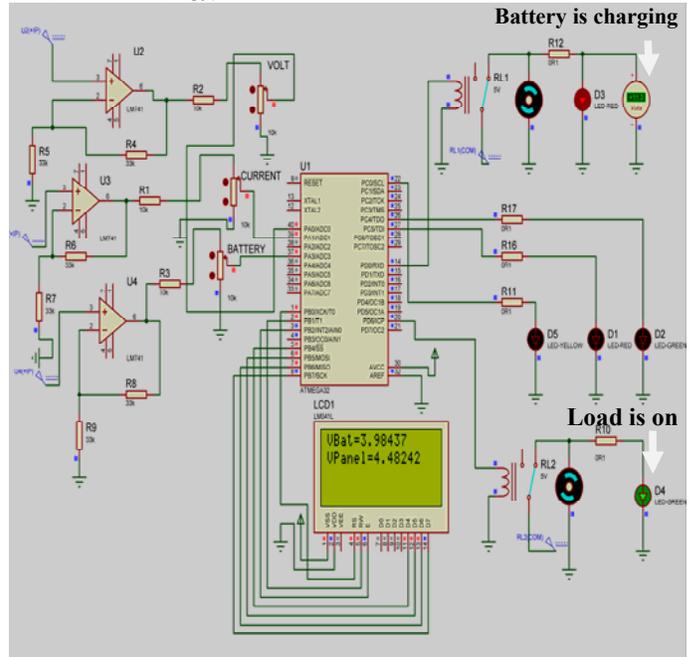

Figure 12.a Array disconnect voltage case

Figure 12.b   shows the case of ARV as the battery is recharged after its voltage goes down to the array reconnect voltage set point and the load is still on
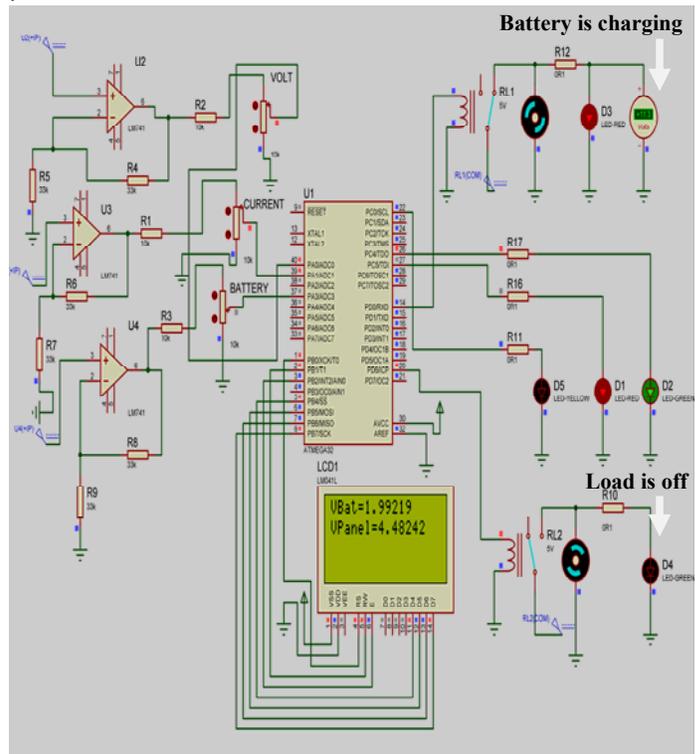

Figure 12.c low voltage load disconnect case

Finally figure 12.d shows the case of LRV as the battery voltage reaches up to a certain value higher than the LVD so the load is permitted to be connected
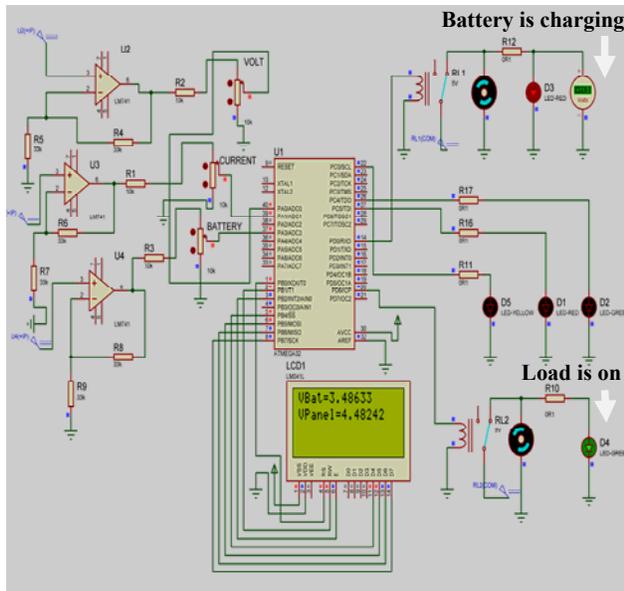

Figure 12.d Low voltage load reconnect

Comparing with previous work, Noshad Amin has used microcontroller based smart charge controller for standalone solar photovoltaic power system [6].Md. Imran Khan has studied the photovoltaic maximum power point tracking battery charge controller using microcontroller [7]. Nurul Izzatul has used six stages for battery charger using PIC microcontroller [8]. Ashwin has used microcontroller based on resistive control [9].Gazi Mohammad describes in the design and construction of microcontroller based maximum power point using PWM charge controller [10].Our result fulfilled the objective of battery charging close to the result of the previous work.

VI. CONCLUSION

In this paper, a simple and fast practical method for keeping maximum output power generated from PV panel to charge a battery. Hardware implementation has been built to validate the results using ATMEGA 32. It is based on the simple idea that the output power of the solar cell can be used for charging a battery & feeding certain load. All precautions for overcharging & over discharging have been taken into consideration. Practical results have been compared with simulated results running out of Proteus software.

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