Designing and Implementation of Maximum Power Point Tracking(MPPT) Solar Charge Controller

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Abstract— **Solar-energy utilization is growing in demand since the past decade due to the increase in energy needs and depletion of non-renewable sources. But the problem with solar energy is that it's not constant; it keeps on fluctuating depending upon the weather conditions such as, solar irradiation, temperature, thus a battery is always connected between the load and the solar panel so as to act as a secondary source. Since, brighter the sunlight, more voltage the solar cells would produce and excessive voltage could damage the batteries. MPPT is a method for extracting maximum power from PV module and also to protect the battery from overcharging. MPPT charge controller serves two main purpose battery protection and energy metering. This paper provides details of maximum power point tracking solar charge controller device and dc energy-meter.**

Keywords— Solar Energy, Charge controller, Arduino, Proteus

I. INTRODUCTION

Solar energy is a promising source of energy for the near future. PV modules are connected in series and parallel manner so as to collect and harness the solar energy obtained convert it into electrical energy. Generically stating, an independent PV system consists of PV arrays which convert sunlight into DC electricity. In addition, it also includes a charge controller to regulate the battery charging and discharging. A charge controller is one of the major functional components in PV systems which maintains the accurate charging voltage on the batteries. As solar energy is not evenly distributed, research is being done on various methods of collection such as thin-film devices, concentric collectors etc. [1].

In this technical paper, we present the operation of a PV solar panel. A power electronics device, Maximum Power Point Tracker (MPPT), which increases the efficiency of the system effectively is used here. By using it, the system always operates at its Maximum Power Point (MPP), thereby producing its maximum power output. Thus, an MPPT maximizes efficiency of the array and reduces the overall cost of the system. Additionally, we attempt designing the MPPT with the help of the algorithm of a selected MPPT method, which is called, the "Perturb and Observe" and we implement it by using a DC-DC Converter. We have researched about the various types of DC-DC converters and we have selected the most suitable converter, the "BUCK" converter, amongst them, for our design. Each and every solar cell, has a point at which, the current (I) and voltage (V) outputs from the cell, result to provide the maximum power output of the cell. In the diagram below, *Fig.1*, the curve is an example of the output which is expected from a solar cell, the position of Maximum Power Point, is also marked on the diagram [2].

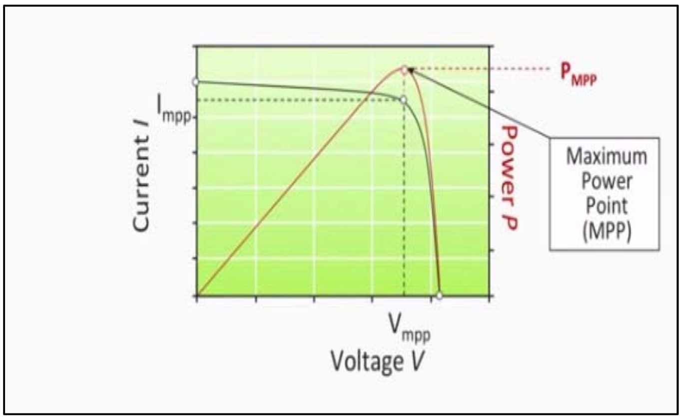

Fig. 1 MPPT IV versus PV Curve

Arduino Nano microcontroller is used to control the buck converter operations. It changes PWM duty cycles as per the algorithm used in its code and by the current and voltage sensed by the sensors and the values fed to the Arduino. One good charger controller is required for the better efficiency of the complete solar PV standalone system and the micro-controller provides the efficient operation of the charger controller.

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II. MAJOR COMPONENTS

A. Solar Panel

Solar panel is formed by connecting many solar cells in series and parallel so as to get the desired output power under nominal conditions. While designing the panel on Proteus a solar cell is considered in its equivalent form.

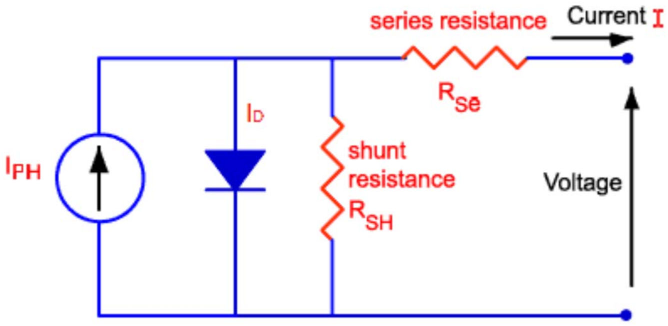

Fig. 2 Equivalent circuits of solar cell

Consider the above *Fig.2*, Applying node equation in where, I_{PH}, R_{SE} and R_{SH} diodes are meeting together. The current equation is given as:

$$I = I_L - I_0\left\{\exp\left[\frac{q(V+IR_S)}{nkT}\right]-1\right\} - \frac{V+IR_S}{R_{SH}}. \quad (1)$$

TABLE I. SOLAR PANEL SPECIFICATIONS

Maximum Power Pm	50 W
Voltage at Maximum Power (V_{MP})	17.2 V
Current at Maximum Power (I_{MP})	2.90 A
Open Circuit Voltage (Voc)	21.5 V
Short Circuit Current (Isc)	3.16 A

36 solar cells are used to get the following output. The designing done on Proteus ISIS. It is shown below:

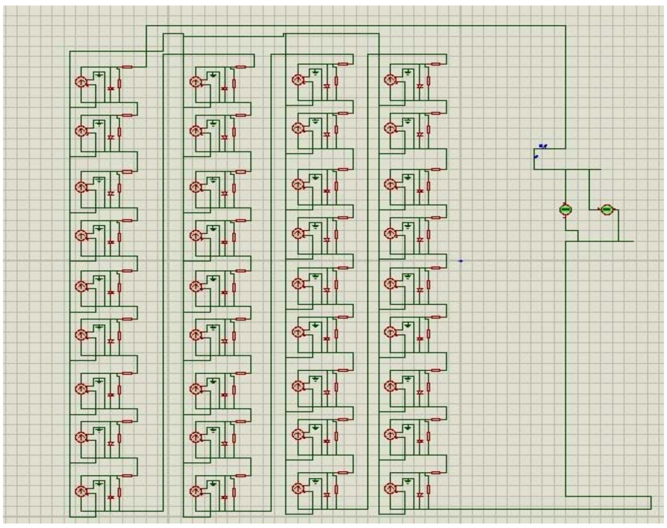

Fig. 3 Solar Panel Design on Proteus

B. DC-DC Buck Converter

A buck converter is a DC - DC converter in which the output voltage is always lower or same as the input voltage. It is MOSFET's switching is controlled by Arduino in this project.

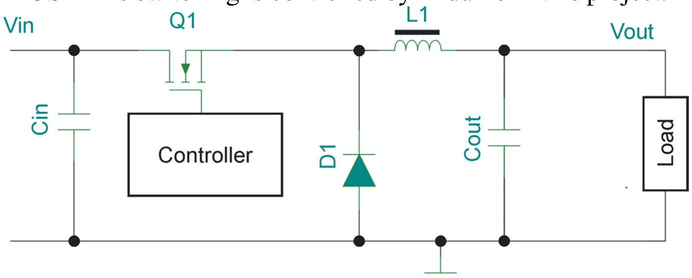

Fig. 4 Buck converter

While designing the buck converter we need to find out the values of capacitor and the inductor used in it. It is a very crucial part in designing since the efficiency of the converter depends upon these values. The value of inductance and capacitance that calculated assuming the panel is working at full capacity, value of inductance L=33uH and value of capacitance C=220uF [3].

C. Arduino Nano

Arduino Nano is a device which has an integrated USB. It is surface mounted breadboard with an embedded version. It is small in size and the most complete. It is completely breadboard friendly. It has all the features of Duemilanove and has more number of analog inputs when calculated electrically. It has an onboard AREF Jumper which is +5V, but has a missing power jack. Since the Nano is automatically sensed and is switched to a higher potential source of power, the need for a power select jumper is abolished. Arduino Nano has the breadboard ability of Boaruino and the Mini+USB, with a smaller footprint than either. Thus, as a result, it has more breadboard space. Its pin layout works well with Mini or the Basic Stamp. TX, ATN, GND, RX on one of the top sides and Power and Ground is on the other. This new version comes with ATMEGA328 which offers more programming space and also data memory space. It consists of layers which are two in number when examined. This is what makes it easy to be hacked and affordable.

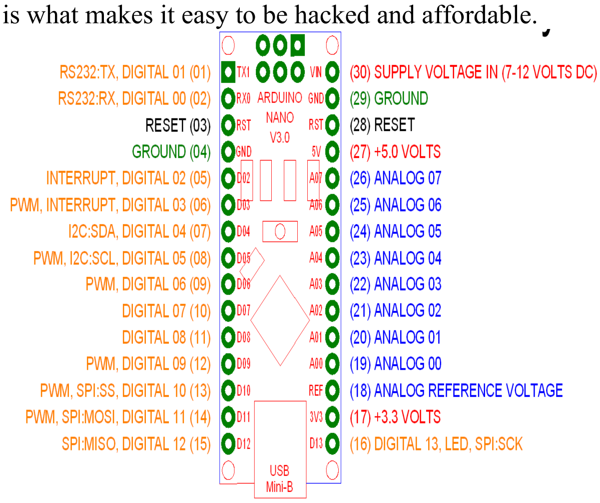

Fig 5 Arduino Pin Configuration

III. Block Diagram

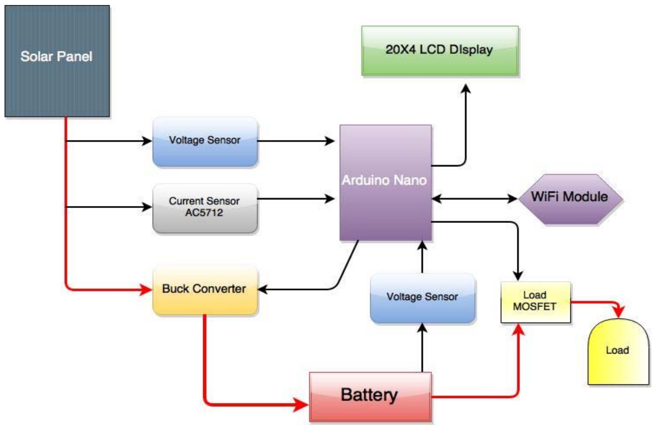

Fig. 6 Block Diagram

In this block diagram the Arduino microcontroller is the heart of this system. The solar panel provides the input to voltage and current sensor. The microcontroller measures the current and voltage and displays on the LCD screen. Then depending upon the power level it gives PWM input to buck converter which decides whether the solar panel is to be connected to battery or not for charging. The battery is connected to the load, the load MOSFET is given input by the microcontroller whether to connect the load to the battery or disconnect it depending upon the battery level which is sensed by the voltage sensor and its output is provided to the microcontroller. The Wi-Fi module is connected to the microcontroller so as to log the statistical data into a computer or mobile wirelessly.

IV. Perturb and Observe Method

In the method of Perturb and Observe method, the power is measured by change in the voltage by a diminutive amount from the array by the controller. If incase, the power increases, adjustments are tried to be done in that particular direction until the power cease to increase. This is what we call the Perturb and Observe method. This method can result into an increase in the oscillations of power output, but still it is the most commonly used method. Since this method depends upon the rise in the power curve against voltage below its maximum power point and the fall which is above that particular point, this is referred to as the Hill Climbing Method. This algorithm of Perturb and Observe (P&O) increases or decreases the output terminal voltage of the Photo Voltaic Cell periodically and then it simultaneously compares the power obtained in the current cycle with the power obtained in the previous cycle. If the power is comparatively more than the previous value, then it indicates that it has moved the operating point closer to the maximum power point (MPP). Thus, further voltage perturbations if in the same direction, should move the operating point, even closer to the MPP. If the power decreases, the operating point moves away from the Maximum Power Point (MPP), and the direction of the perturbation has to be changed and reversed to move back towards the MPP [4].

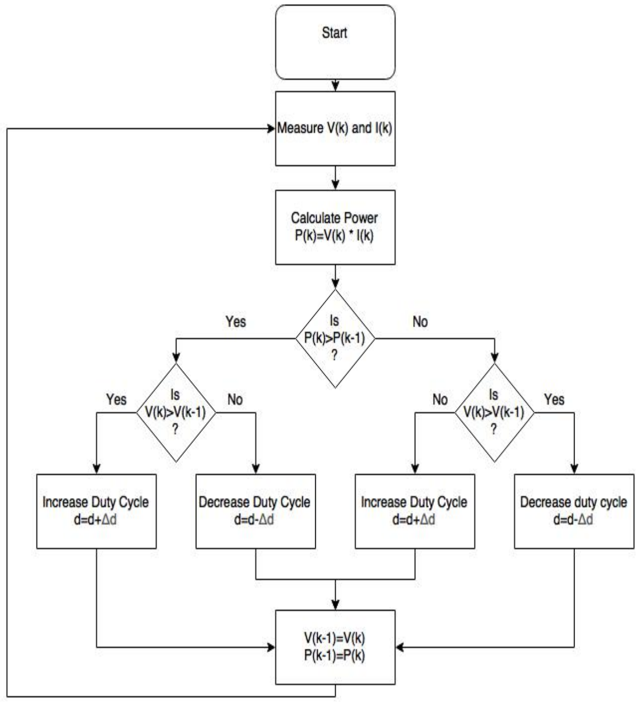

Fig. 7 MPPT Algorithm

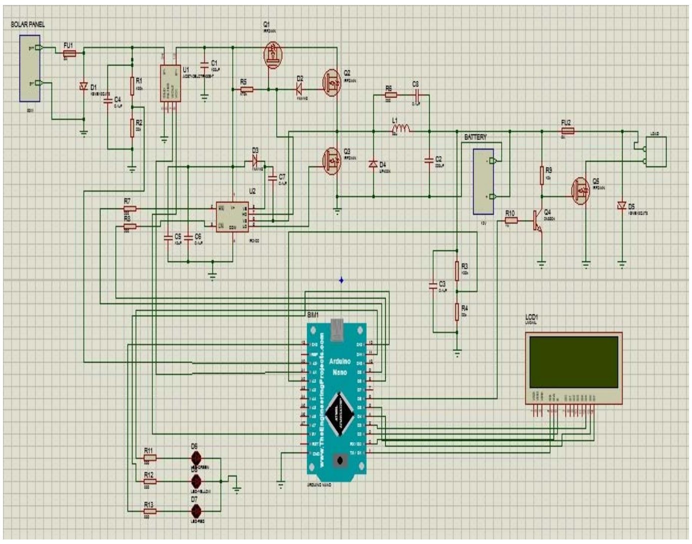

Fig.8 Complete Circuit Diagram

The *Fig.8*, shows the complete schematics of MPPT solar charge controller designed on the Proteus software. It shows the various connections that are made between the major components of the complete project.

V. SIMULATION OF BUCK CONVERTOR

A. Input Data For Simulation of Buck Convertor:

The *Fig.9,* shows the MATLAB simulation of a buck convertor. The details of it are as follows: Input Voltage=12V, Duty Cycle=25%, Frequency=25 KHz, Inductance= 80μH, Capacitance= 20μF, 20V.

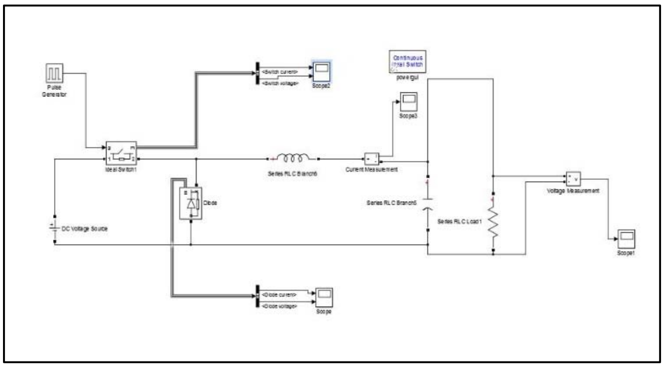

Fig. 9 MATLAB Simulation of Buck Convertor

A. *Output Characteristics of Buck Convertor:*

The *Fig.10*, shows the output characteristics of the buck convertor. The main function of the buck convertor being stepping down the DC Voltage from the reference voltage (12V in this case), to the required necessary Voltage (3V in this case). Consider *Fig.10*, the Yellow region in the *Fig.10* indicates the maximum voltage of 3V obtained after Buck convertor comes into action with an input voltage of 12V.

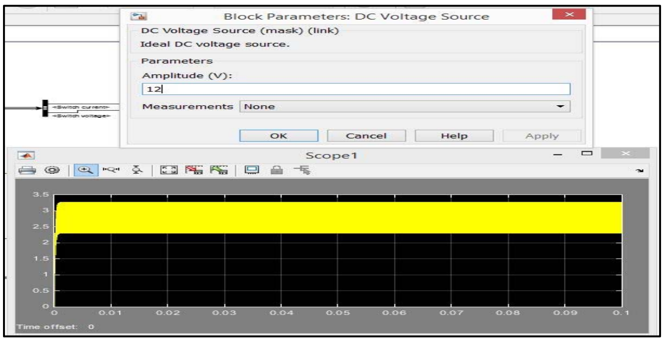

Fig. 10 Output Voltage Characteristics of Buck Convertor

VI. HARDWARE PROTOTYPE

A hardware prototype was built using various electronic components having the values which were tested and approved by the simulation process. LCD screen was used to display the results obtained. The observations ahead show the results of hardware implementation.

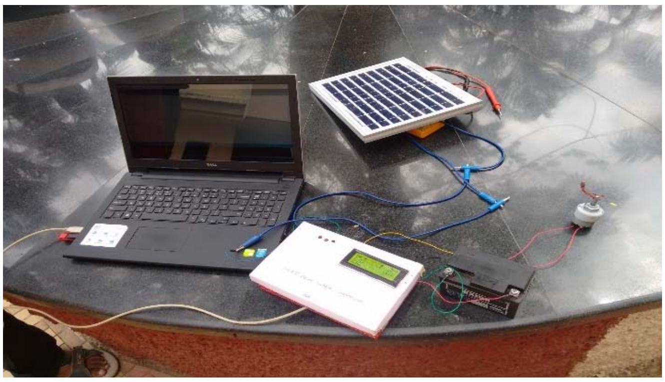

Fig. 11 Hardware Prototype

VII. OBSERVATIONS

A. *Charge Controller:*

Fig.12, shows the charge controller demonstration. The two columns talk about the process in which either a battery or a load come into action.

Sr No.	Conditions	Results Expected	Output Observed
1.	Battery volt >10v Solar power>1w	Load ON Battery Charging OFF	
2.	Battery volt <10v Solar power<1w	Load OFF Battery Charging ON	

Fig. 12 Charge Controller Demonstration

The 1st Horizontal Row shows that when the Battery Voltage is greater than 10V and the Solar Power is greater than 1W, the entire supply reaches the load i.e. Load is turned ON and the battery charging remains OFF.
The 2nd Horizontal Row states that when the Battery voltage is less than 10V and the Solar Power is also less than 1W, the Load turns OFF and the Battery charging gets turned ON, is less than 10V and the Solar Power is also less than 1W, the Load turns OFF and the Battery charging gets turned ON.

B. *Duty Cycle:*

Sr No	V_{in} (v)	I_{in} (A)	R_i (Ω)	R_L (Ω)	Duty cycle (Calculated) (%)	Duty cycle (Observed) (%)
1.	13.8	0.34	40.58	67	64	
2.	12.73	0.4	31.8	67	75	
3.	14.2	0.49	28.98	67	79	

Fig. 13 Duty Cycle Observations

For maximum power point tracking, Input Impedance R_i should be equal to the load impedanceR_L. But since the input voltage fluctuates continuously, it is not possible to keep the input resistance R_i steady. That is why the Duty Cycle is worked upon in order to get $R_i = R_l$ as per the algorithm. The input impedance is given by,

$$R_i = \frac{\eta R_L}{d^2} \quad (2)$$

Here, R_i = Input Impedance

R_l = Load Impedance

η = Efficiency

d = Duty Cycle

Here, the Efficiency of the panel is assumed to be 25%.

VIII. RESULT

The MPPT curve was successfully achieved at different times of a day. The PV curve was plot against the resistive load characteristics and the maximum power point was tracked. Operations of charge controller were successfully achieved as shown in the observations.

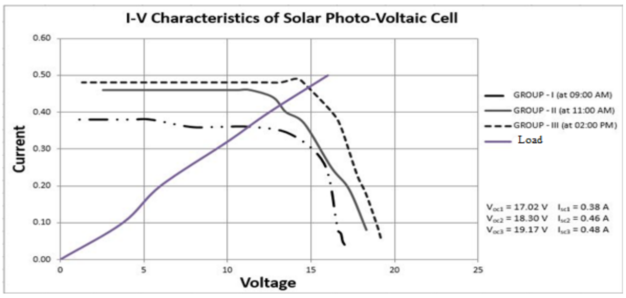

Fig. 14 IV and Load Characteristics of Photo Voltaic Cell

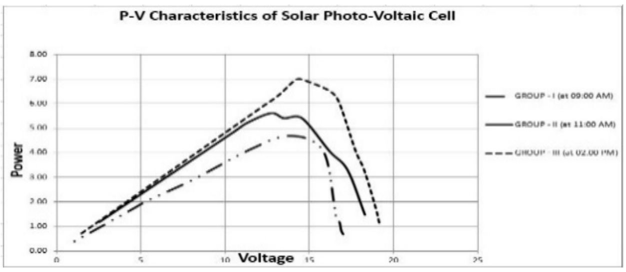

Fig. 15 PV Characteristics

IX. CONCLUSION

In this project a simple low cost but effective solar PV power generation system for small DC loads; prototype model is designed in Proteus software. Plans are been made to implement it on hardware in near future.

Hall Effect base current sensors are very efficient, simple in connections and easy in use but it is little bit expensive in the India only. For MPPT circuit implementations always have to use complete development board kit for microcontroller otherwise its circuitry will complex and less efficient.

In all DC-DC buck converter have additional advantage that if suppose MPPT circuit is fail then MOSFET will not be switching in that condition also load is directly connected to the panel and panel still supply the load at less efficiency other DC-DC converter can't do that.

The complete circuit is also composed of various protective measures are taken. For overcurrent protection a 5A fuse is installed and for overvoltage protection a TVS diode is connected at both panel and load side.

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