IMPLEMENTATION OF MPPT ALGORITHM ON PV PANEL USING PIC16F877 CONTROLLER

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Abstract

This paper presents the design and practical implementation of a Boost-type power converter for Photovoltaic (PV) system for energy storage application based on Perturb and Observe Maximum Power Point Tracking (MPPT) algorithm. A Boost converter is used to regulate battery charging. The major drawbacks faced by the tracking algorithm in the conventional method of tracking is overcome by the strategic utilization of a properly controlled and programmed design of Peripheral Interface Controller which helps in achieving optimized output results of MPPT algorithm.. The system is controlled by a Peripheral Interface Controller (PIC) 16F877 controller by sensing the solar panel voltage and generating the Pulse Width Modulation (PWM) signal to control duty cycle of the boost converter. This type of microcontroller was chosen is best suited as it has the necessary features for the proposed design such as built-in Analog-to-Digital Converter (ADC), PWM outputs, low power consumption and low cost. Hardware results demonstrate the effectiveness and validity of the proposed system in order to attain satisfactory results from the method. This paper mainly focuses on the effective utilization of PIC controller in the implementation of the MPPT algorithm and its constructional features which help gain the appropriate and accurate results.

Keywords: *Photovoltaic system, Analog-to-Digital Converter, Peripheral Interface Controller, Maximum Power Point Tracking, Pulse Width Modulation, Boost-type power converter, Duty Cycle.*

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1. INTRODUCTION

The major purpose of writing this paper is to obtain the maximum power point of the connected PV panel with the help of MPPT algorithm (Perturb & Observe method) during the fluctuating conditions of solar temperature and solar insolation. Perplexed conditions of solar insolation make it difficult to obtain the perfect maximum power point without the use of MPPT tracking device. In order to obtain the accurate and optimum results of maximum power point of the solar PV cell, the utilization of PIC controller (PIC16F877) is made due to its simple constructional features and easy installation with the other components of the MPPT. Thus even with the use of Perturb and Observation technique of MPPT we can obtain steady and efficient results about maximum power point on the P-V curve of the solar panel (6W). PIC controller due to its operational properties helps obstructing the distorting nature of perturb and observe algorithm and gives a pure and precise result of maximum power points even in solar fluctuating conditions. The basic aim is to charge the battery of 12V and to utilize the battery's energy to light a load, now if this battery is connected to the solar cell through a switch, then the power received by the battery will be a multiple of peak current and battery voltage. Thus the power received by the battery will be only 60-70% of the total value and the rest 30% will remain un-utilized and in order to fix this problem Pulse Width Modulation is used so that no portion of energy remains un-used or un-utilized. The surplus energy obtained as a result of PWM will be stored in the controller and whenever the need arises, this energy will be supplied to the load (Sonali Surawdhaniwar, 2012).

1.1 Basic Block Diagram of PV Cell

The main foundation of any solar panel starts from the forming of a single solar cell, which are taken in appropriate quantity and are connected in series-parallel fashion to form the solar panel of rated values of voltage and current (Solanki, 2014).

Before going into an in-depth analysis of the solar panel and the actual MPPT structure and its operation, it is very much important to know about the internal components of the solar cell, in order to obtain a basic understanding for the working of MPPT algorithm in the PIC controller in the proposed system.

The basic definition is given as "Solar cell is a basic fundamental element of a solar panel which performs the function of converting solar energy into useful electrical energy at standard values of solar insolation and temperature" (Walker, 2006).

The general block diagram of a solar PV cell includes the following things (Solanki, 2014):

1.) Current Source.
2.) Shunt Resistance.
3.) Series Resistance.
4.) A Diode.

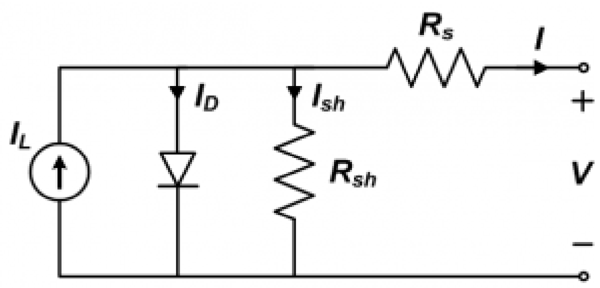

Fig-1: Equivalent diagram of solar PV cell

The above equivalent circuit diagram of solar PV cell signifies that solar cell is a current generating device with a diode connected in anti-parallel direction in order to resist the back-flowing currents and provides protection to the solar cell. Whereas the series resistance provides evidence of contact resistance i.e. between metal contacts and Silicon material, and shunt resistance provides the resistance due to the power loss caused due to manufacturing defects in a PV cell (Harjai, Bhardwaj, & Sandhibirgha, 2008).

The voltage that we get across the PV cell is known as the PV cell voltage and that will increase with the increase of cells connected in series, whereas the current can be maximized by connecting PV cells in parallel fashion. By this series-parallel combination we can obtain a solar panel on which we track the maximum power point and utilize its energy for power generation and other purposes (J.Surya Kumari, 2012). The basic building block of any solar panel depends on the series-parallel configuration of the individual solar cells which decides its current, voltage, and power ratings.

1.2 MPPT Structure and Working

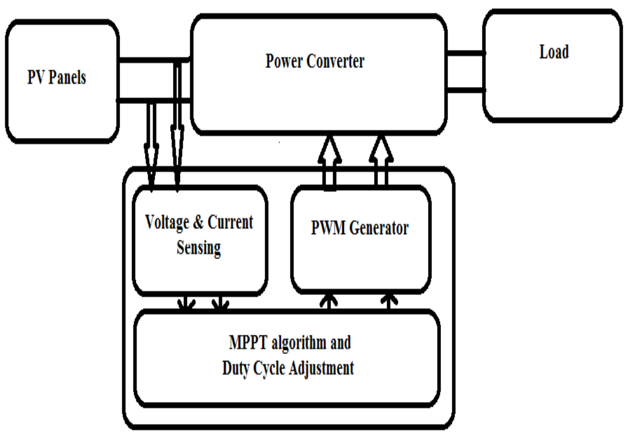

Fig- 2: Basic Block Diagram of MPPT

The above block diagram shows the basic connection diagram when the solar panels are connected to the MPPT circuitry. Here after the voltage and current generated by the solar panels are sensed by the appropriate sensors connected in shunt to the panel and is fed to the microcontroller (here PIC controller) in which the Perturb and Observe algorithm sequence is embedded as a program. This controller verifies whether the input voltage and current values are matching with the reference values set by the user and according to these values sends pulse signals to the PWM (Pulse Width Modulator). PWM on receiving these signals provides accurate triggering pulses for the power switch (MOSFET) which in turn performs the operation of boosting the voltage. Finally the output voltage is supplied to the load connected in series with the converter.

1.3 Actual MPPT Block Diagram

It is quite obvious to predict that there are minor differences between the theoretical and the actual or real time block diagram of MPPT. These differences vary from application-to-application and the type of features adopted with it. The actual project block diagram in our case is shown below which includes all the components as discussed in the previous topics.

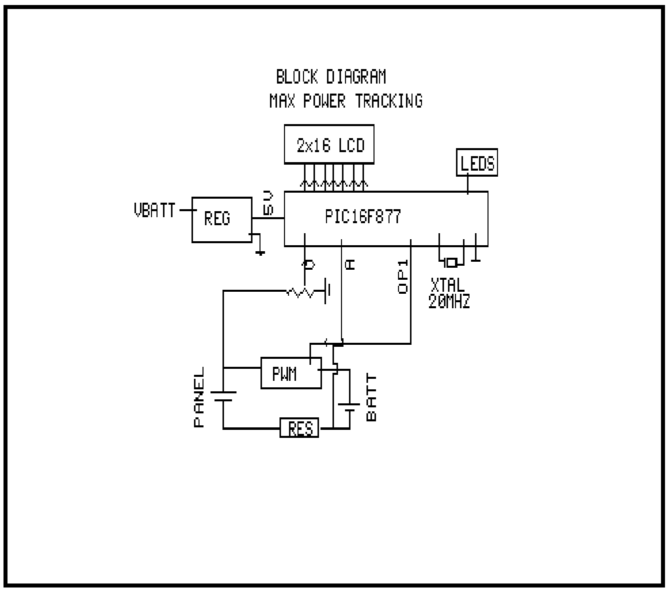

Fig- 3: Actual Block Diagram of MPPT

Here in this present diagram, solar panel is considered as a battery, also there are two voltage regulators connected to which a 5V supply is provided, so that the voltage level is maintained and a proper voltage is given to the PIC controller for its functioning. A 2*16 LCD is provided across the microcontroller which provides with the real-time data of the tracking voltage and current of the solar panel. There are 3-4 LEDs used in the circuit to let know the user about the proper functioning of MPPT device and if some violation is found then the LED instantaneously lights ON showing that some serious problem has occurred in the circuit. There is a quartz crystal attached with the microcontroller to generate 20MHz frequency for the operational purpose of PIC controller. The batteries are connected in the circuit for the major purpose of taking the boost voltage from the converter and get charged, acting as a load in our case. This diagram gives the basic outline about the modeling of project.

The model presented above is for the special application of MPPT that operates in an autonomous mode with the PIC controller connected in the circuit. Here it is possible to connect a load with the battery, which can supply the power stored in it to the load when required. Any type of lighting load or a small rated motor can be connected here for satisfying the load applications in the present MPPT system.

2. PV ARRAY CHARACTERISTICS

There are basically different types of characteristics obtained from the PV module, which actually determines the various aspects such as maximum power point, maximum voltage, temperature relation with current-voltage, etc. which gives us the correct idea about the information obtained from the photovoltaic characteristics. Here we have obtained the Power v/s Voltage, Power v/s Current and Voltage v/s Current characteristics for the solar panel of 6 watts rating (11.5 volts, 0.61 ampere).

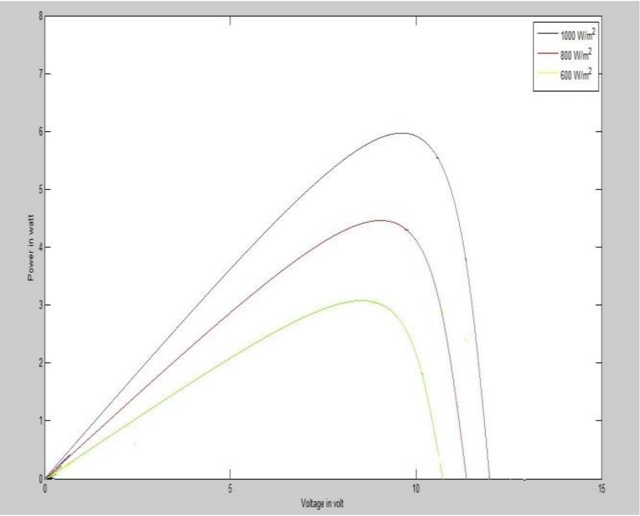

Fig -4: Power v/s Voltage Characteristics

The characteristic shown above is the power versus voltage curve for a 6 watt panel at different sun values of 1000W/m^2, 800W/m^2 and 600W/m^2. The above curve shows that the panel operates efficiently and reaches the peak point of 6W at a voltage of 10.46volts. If voltage is further increased the n power will significantly drop down to lower values. Same can be applied for sun values of 800W/m^2 and 600W/m^2.

These characteristics are important from the point of view that it helps us in determining the maximum power point range of any given solar panel.

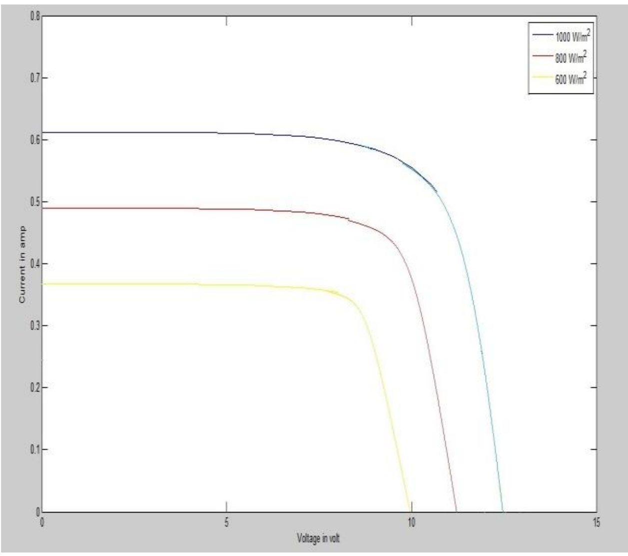

Fig -5: Current v/s Voltage Characteristics

The above characteristics show the current versus voltage relationship of a 6 watt solar panel.

The different values of solar insolation help us to determine the values of voltage when the current is varied. It can be perfectly said from the graph that at the current value of 0.61 Amp we get a perfect value of voltage of 11.5 volts according to the specifications given for the solar panel.

After reaching a certain value, the voltage starts to decrease and reaches to a zero value for the value of sun =1000W/m^2. These are similarly obtained for other values of sun of 800W/m^2 and 600W/m^2.

2.1 Boost Converter: In-Depth Analysis

The major use of DC-DC boost-converter in MPPT is that it improvises the voltage profile of the main system that comes through the solar panel after passing through the MPPT controller, so that an output voltage which is greater in value as compared to the input solar panel voltage can be obtained (Sonali Surawdhaniwar, 2012). Due to its effective duty cycle ratio and efficient working when connected in series with the solar panel, it is majorly utilized in this circuit. Boost converter like buck converter works in two modes, which defines the actual working that takes place in the boost converter circuitry. In our boost converter application, we have implemented MOSFET as our power switch in the circuit due to its efficient power and voltage characteristics. The switching time required for MOSFET is sufficient for the operation of boost converter.

The two modes of boost-converter operation are defined as below:

2.1.1 Mode 1 Operation of Boost Converter

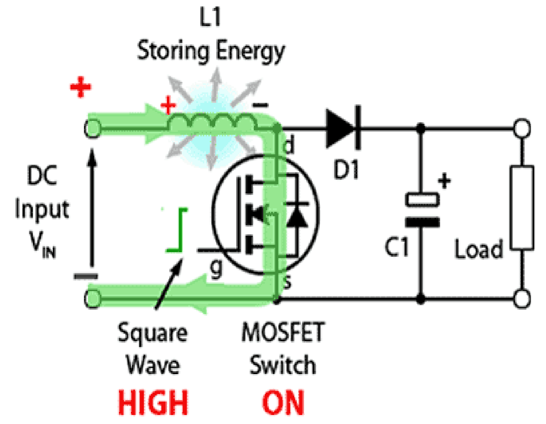

Fig- 5: Mode 1 Operation of boost converter

Fig.6 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up (Harjai, Bhardwaj, & Sandhibirgha, 2008). During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent much higher impedance than the path directly through the heavily conducting MOSFET.

The other mode of boost converter is further explained in further topic.

2.1.2 Mode 2 Operation of Boost Converter

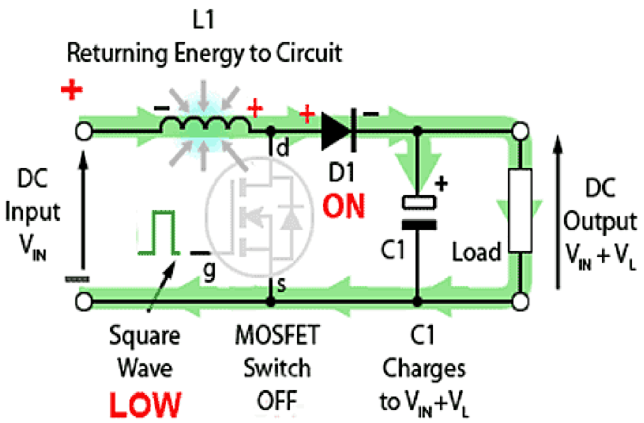

Fig- 6: Mode 2 operation of boost converter

Fig. 7 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off the sudden drop in current causes L1 to produce a back e.m.f. in opposite polarity to the voltage across L1 during the on period, to keep current flowing (Harjai, Bhardwaj, & Sandhibirgha, 2008). This results in two voltages, the supply voltage VIN and the back e.m.f. (V_L) across L1 in series with each other. This higher voltage (V_{IN} $+V_L$), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to V_{IN} $+V_L$ minus the small forward voltage drop across D1, and also supplies the load.

2.2 Brief Details about PIC16F877A Controller

The current recent trends in microcontroller are the usage of more advanced microcontrollers in major applications. The mostly utilized controller in majority of the applications is the PIC controller, due to its advanced modeling and easy installation. The PIC16F877A features 256 bytes of EEPROM data memory, self -programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit bus and a Universal Asynchronous Receiver Transmitter (USART).

In this paper a brief introduction about PIC controller is provided to get information about its implementation in the main circuit. Only the major features which are mainly required and utilized are described here. All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

PIC controller is utilized in our application so as to obtain smooth results of maximum power from perturb and observe technique algorithm.

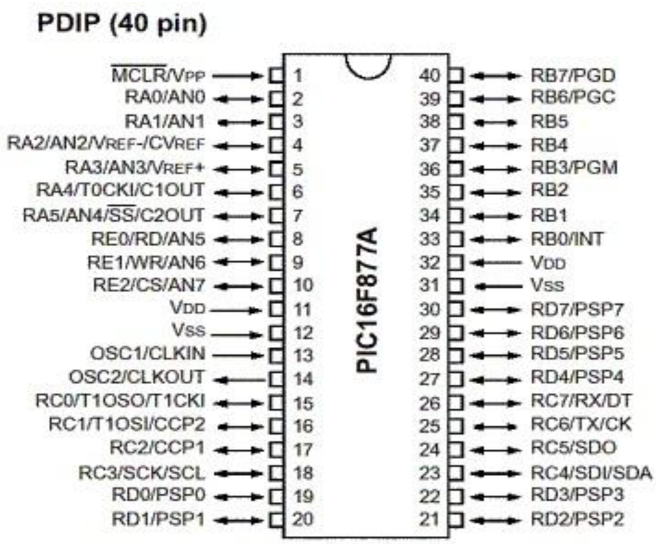

Fig- 8: Pin diagram of PIC16F877 controller

Fig.8 given above gives us the basic idea about the PIC controller circuit which contains 40pins to which various input and output ports can be connected. This microcontroller is used in the implementation of perturb and observe algorithm in order to attain stable maximum power point of the solar panel in a short time duration. PIC controller because of its multi-operational parameters and easy implementation in the circuit improves the fluctuating nature of power v/s voltage curve of the 6W solar panel.

2.3 Flowchart for Perturb AND Observe Technique in Application with PIC Controller

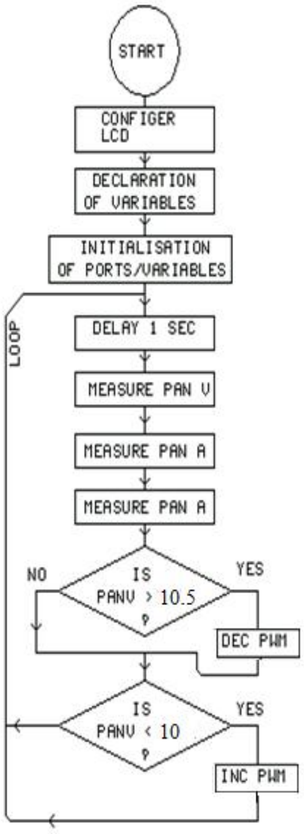

Fig- 9: Flowchart for PWM generation (J.Surya Kumari, 2012)

The diagram above signifies the actual structure of algorithm which is used for PWM generation in Perturb & Observe algorithm. This algorithm program will first configure all the accessories connected with it i.e. LCDs and LEDs. Afterwards will introduce all the variables that are necessary for the algorithm to run and then after a 1minute delay will measure the panel voltage and panel current. If the panel voltage that is accessed by the controller is greater than 10.5V (set value) then the controller will decrement the pulses given to the PWM and if the value is less than the pre-set value then it will monitor the next condition. If the panel voltage is checked in the next iteration is less than 10V then the controller gives signals to increment the PWM and so PWM generation takes place. If the voltage is lower than 10V then the algorithm starts again its monitoring from the start by measuring the panel voltage and current. Here the range of 10V to 10.5V in the algorithm is taken as per the requirement of application. Any random value can be taken and can be set as a pre-set value which becomes the decisive function for the controller whether to generate PWM or not. If the values are set at any other voltage values say 15V to 15.5V then also the controller will generate PWM only that this time it will generate pulses of different magnitude as compared to the previous one. In this way it is found that setting the values for PWM generation is quite flexible in the operating ranges of the load in case of Perturb & Observe technique of MPPT.

3. HARDWARE IMPLEMENTATION OF MPPT ALGORITHM

Before performing the hardware implementation of MPPT on a practical basis, there is a need to design the whole hardware structure according to the practical design of MPPT which is provided in the diagram given below:

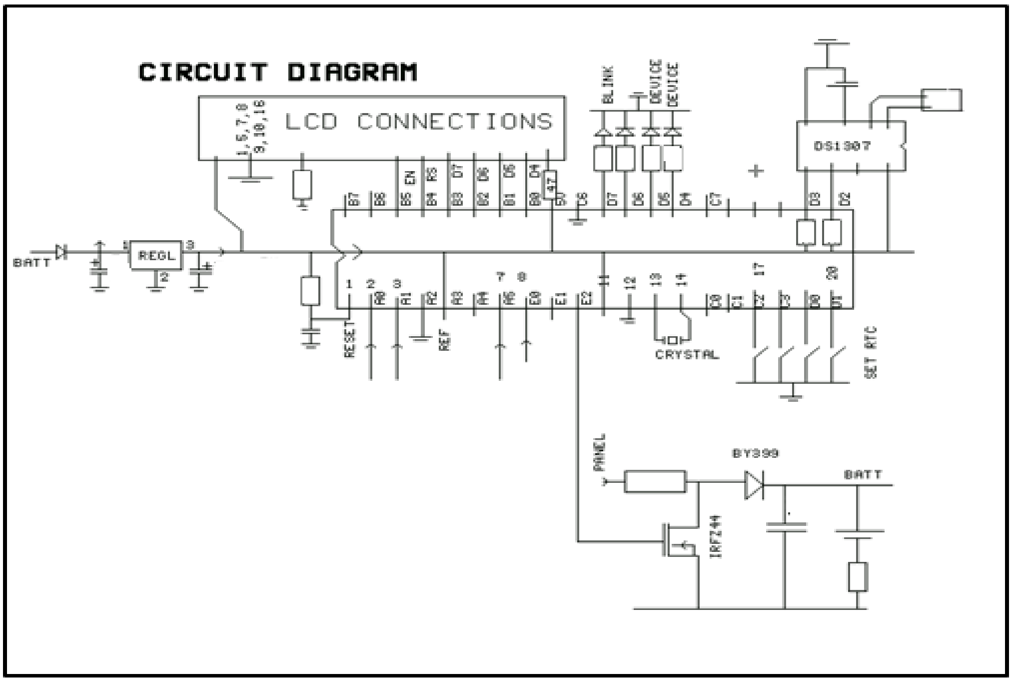

Fig- 10: Circuit Diagram of MPPT Implementation

By observing the circuit diagram we can say that the power supply is derived from 12V DC battery in per unit. 3 pin regulator gives 5V DC fixed voltage. The circuit works on 5V DC supply. The microcontroller works on 5V DC and its crystal frequency is 20 MHz which is clock for our microcontroller. We have used PIC16F877 as microcontroller and so it has got 33 input/output pins, 8K flash memory, 256 ram and 256 EEPROM and it has got 10bit built-in ADC (Analog-to-Digital Converter).We measure the panel voltage from AD input connected on pin 2 of microcontroller. PWM output is of 100microseconds (10kc)is given on pin 21 which drives bc547 which drives MOSFET (IRFZ44), diode (5408) is used as a free-wheeling diode in the circuit. 470 microfarad capacitors are used as filters diode (4007) is used for blocking reverse current flow that comes from the battery.

A 0.5ohm current sensing resistance is used for sensing current and this operation of current sensing is done on pin number 9 of the microcontroller. In our case the reference voltage is 5V DC on pin number 5 of the microcontroller. If the measured value of the panel voltage is greater than 10.5V DC then the microcontroller will increase the PWM and if the measured value of the panel voltage is less than 10V DC then the microcontroller will decrease the PWM. In this format almost all the time the maximum power range of the solar panel is maintained. The connections for LCD is done on the PORT B of the microcontroller and also the LCD that is connected as an external accessory displays panel voltage and panel current at all times.

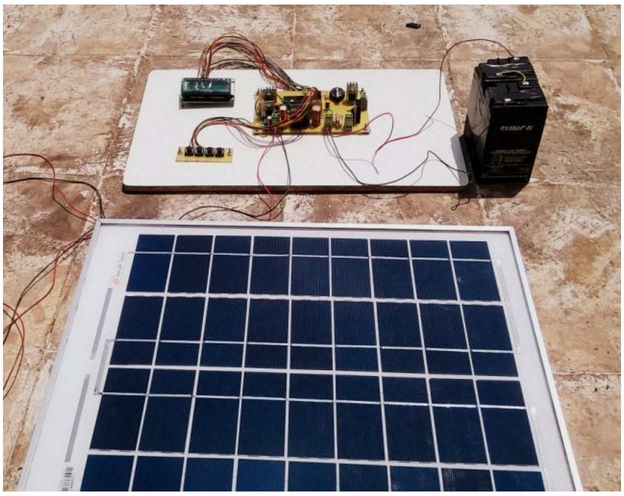

Fig- 7: Hardware implementation of MPPT(with panel**)**

The images shown below are of the hardware implementation of MPPT with solar panel connected as an input to the hardware circuit. There is a battery of 12V (two batteries of 6V in series) connected to the on-board MPPT circuit implementation which is the load in our application. The main working parameters in our application are the temperature of 30°C with solar insolation of 1000W/m^2.

The image above is showing the solar panel as the input given to the controlling circuit (including PIC controller, PWM, boost converter, resistors and capacitors, LCDs and LEDs, with timing circuit) and the control circuit after generating maximum power by running the algorithm gives the voltage supply to the battery which charges the battery (here battery should be considered as load application). The panel used here is of 20 W and the battery connected across the controller output is of 12V (two 6V batteries) connected in series with each other.

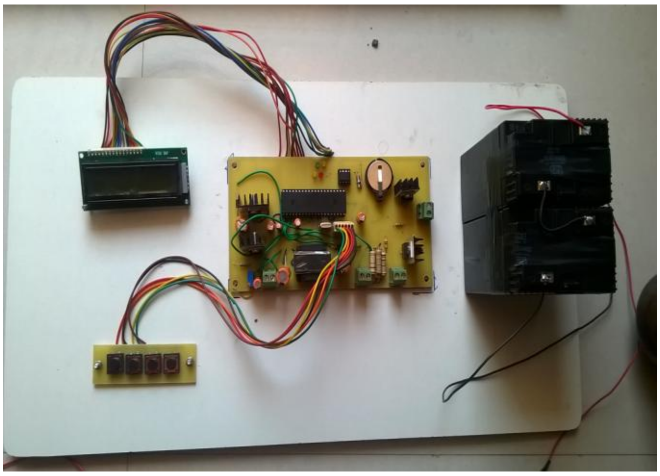

Fig- 8: Hardware Implementation of MPPT(without panel)

The upper two diagrams depicts the values of voltage (in volts) and current (in milli-amperes). The LCD display of 2*16 shows the output values of voltage and current from which we can evaluate the values of maximum power. The value of voltage here fluctuates between 11.6V to 12V, whereas the current varies in the ranges of 560mA to 600mA.

Whereas the lower two diagrams, depicts the tracking of power at variable time interval with the values of voltage varying in between 11.2V to 11.5V and the current ranging from 560mA to 600mA; this signifies that the controller after reaching the maximum power point, oscillates between certain pre-determined values of voltage on the P-V curve of the solar panel.

The value of maximum power is obtained after the controller performs numerous oscillations around the peak point.

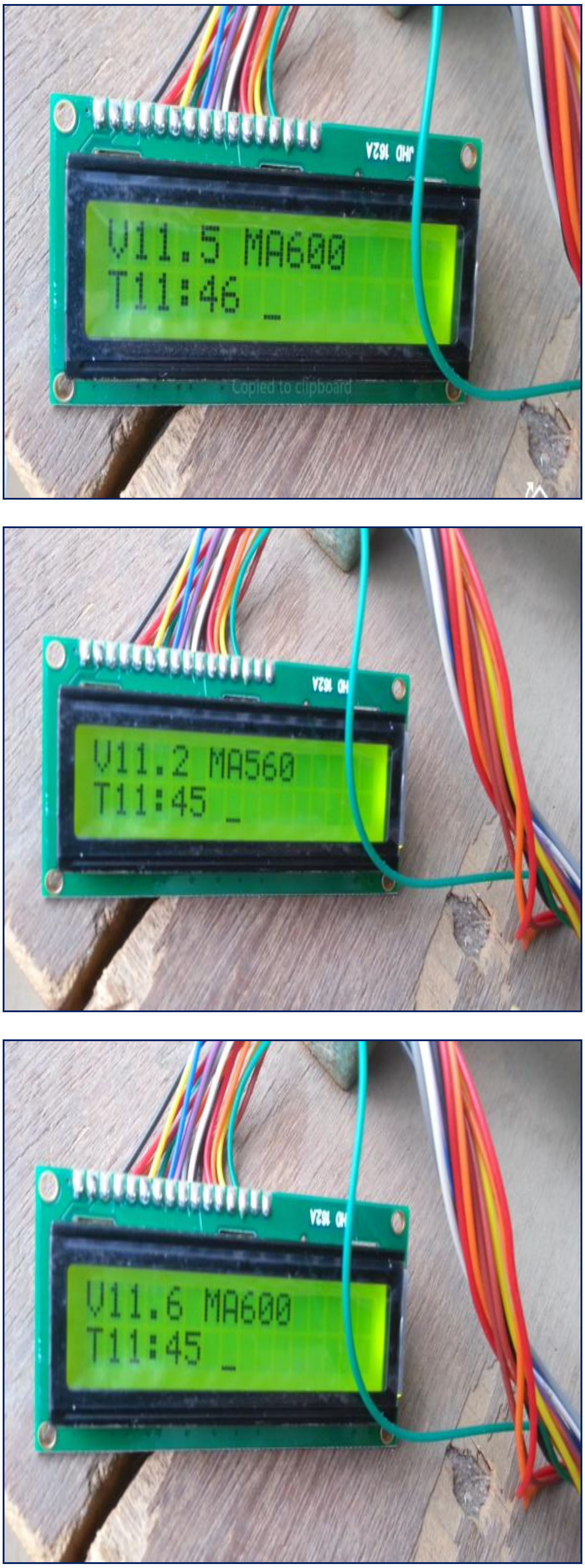

Fig- 13: Different values of voltage and current while tracking the maximum power.

Fig- 14: Value of maximum power achieved after the oscillations performed by the controller

The diagram shown above signifies that the maximum power point tracking conditions that are required for our conditions are fully satisfied and thus it is verified that with the help of perturb and observe technique we can obtain the required value of maximum power of the panel.

4. CONCLUSION

From the above performance of Perturb and Observe algorithm it is clear that the MPPT power obtained after the boost converter varies the voltage level, will result in the power nearly as same as the power which is obtained from the PV panel. This means that by controlling the PWM of the boost converter, we have obtained the maximum power. By using the PIC controller, the maximum power is delivered by the panel and 12V battery is charged respectively and results are obtained smoothly and accurately.

REFERENCES

[1]. Geoff Walker, "*Evaluating MPPT Converter Topologies Using A MATLAB PV Model"* , University of Queensland, Australia, 2002.

[2]. ArjavHarjai, AbhishekBiswajit, and MryutunjaySandhibirgha, "*Evaluation of Maximum Power Point Tracking Methods In Solar Photovoltaic Array*," Project Report, National Institute of Rourkela, Orissa, 2008.

[3]. A. Dolara, R. Faranda, S. Leva. "*Energy Comparison of Seven MPPT Techniques for PV Systems"*. Electromagnetic Analysis & Applications, 2009, 3: pp-152-162.

[4]. BiswajitSethy, "*Application Of Sliding Mode Technology In PV Maximum Power Point Tracking Systems* "PhD Thesis Report, National Institute of Rourkela, Orissa, 2010.

[5]. SonaliSurawdhaniwar, RiteshDiwan. *An Improved Approach of Perturb and Observe Method Over Other Maximum Power Point Tracking Methods*. International Journal of Recent Technology and Engineering (IJRTE)

ISSN: 2277-3878, Volume-1, Issue-3, August 2012.pp- 137-144.
[6]. S.ZahraMirbagheri, SaadMekhilef, S. Mohsen Mirhassani. *MPPT with Inc. Cond method using conventional interleaved boost converter*. Mediterranean Green Energy Forum 2013 (MGEF-13).Energy Procedia 42 (2013) pp 24 – 32.
[7]. \Shridhar Sholapur, R.Mohan, T. R. Narsimhegowda. *Boost Converter Topology for PV System with Perturb And Observe MPPT Algorithm.* IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 4 Ver. II (Jul – Aug. 2014), pp- 50-56.
[8]. Chetan Sinh Solanki, "*Introduction to Photovoltaic Array",* Eastern Economy Edition, Chapter 4-8, 2014.

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