Abstract: Maximization of power from a solar photovoltaic (PV) module is of special interest as the efficiency of the solar PV system is very low. A maximum power point tracker (MPPT) is needed to operate the PV array at its maximum power point. The present work describes the design and implementation of a MPPT for the solar PV array connected to a resistive load. The design consists of a dc-dc boost converter (also known as step up converter) and a control section that uses an ATmega32 microcontroller. The control section obtains the information from the PV array through microcontroller’s Analog and Digital (A/D) ports and hence performs the pulse width modulation (PWM). The incremental conductance method with some modification is used as an algorithm to track the maximum power point of the PV array. By using this algorithm the MPPT is able to track the maximum power point of the PV array very quickly under rapidly changing atmospheric conditions. The simulation is carried out in PROTEUS ISIS environment. The program is written in C and then is compiled by a freeware version C compiler “WinAVR”. The power tracker is developed and tested in the laboratory. It is observed that the use of MPPT enhances the output power by 25%. The measured parameters such as the panel voltage, current, power and corresponding duty cycle are displayed on the LCD.

Keywords: Photovoltaic (PV), Maximum power point tracker (MPPT), Microcontroller, Boost converter.

1. INTRODUCTION

Bangladesh is facing energy crisis and this problem is being worse day by day and huge pressure is added on it due to increased demand of power. The people are also much concerned with the fossil fuel exhaustion and the environmental problems caused by the conventional power generation, renewable energy sources and among them PV panels and wind-generators are now widely used. Since PV modules still have relatively low conversion efficiency, the overall system cost can be reduced using high efficiency power conditioners which, in addition, are designed.

To extract the maximum possible power from the PV module [maximum power point tracking (MPPT)], PV arrays have an optimum operating point called the maximum power point (MPP) [1]-[3].

A maximum power point tracker is required to meet the following goals:

1. Tracking of maximum power from the photovoltaic array with an algorithm suitable for rapidly changing atmospheric condition.
2. Charging a lead-acid/Nickel Cadmium battery at a constant voltage.
3. Providing high conversion efficiency.

2. ROLE OF MPPT

Two important factors limit the implementation of PV system i.e. high cost and low efficiency in energy conversion. Due to the high cost of solar cells, it is necessary to operate the PV panel at MPP.
It is apparent that the (I-V) and (P-V) characteristic changes with temperature and illumination. Power output of solar PV module changes with change in direction of sun, changes in solar isolation level and with varying temperature.

3. MAXIMUM POWER POINT TRACKER

3.1 How Maximum Power Point is Obtained

The maximum power point is obtained by introducing a dc-dc converter between the load and the solar PV module. The duty cycle of the converter is changed until the maximum power is obtained [5]-[8].

5. SYSTEM CONFIGURATION

Choosing boost converter topology will maximize the efficiency of the PV array in a cloudy day, which is technically easier to fabricate and also guarantees continuous current through the array [4]. The control section is involved in the design of both analog and digital systems. It will take in analog voltages and currents proportional to measured quantities, digitize them and process them in a microcontroller. The components used in the proposed project are (1) PV array of model ET-M53865 (2) Voltage and current sensing circuit (3) DC-DC boost converter (4) Control section (5) MOSFET driver circuit (6) Load.

5.1 Hardware Design

The most critical section of the power tracker is switching converter section. It is this section that operates the PV array at its maximum efficient point. The converter will maintain the output voltage of the module at the maximum power point, has a target output of approximately 25V. This operating voltage is initially used to select an initial duty cycle for the MOSFET and also choose appropriate element values [8]-[10].

5.1.1 Inductor

The amplitude of the inductor current ripple can be varied between 10% and 20% of its dc value. The minimum value of inductance is given in (1).

\[ L = \frac{V \times D \times T}{2 \times \Delta i L} \]  

(1)

5.1.2 Output Capacitor

The selection of appropriate value of the capacitor is required to obtain a desired output voltage ripple. Assume that the output voltage ripple is 1% of its dc value can be determined using (2).

\[ C = \frac{I_o \times D \times T}{\Delta V_o} \]  

(2)

Figure 2: P-V Characteristic Curve for Different Temperature

Figure 3 shows the maximum power point of the PV module. For this particular insulation and temperature level, the maximum power approximately 75 Watts at 17.5 volts, 4.3 Amperes.

4. DESIGN OF MPPT

A block diagram of the proposed maximum point tracker is shown in Figure 4.

The MPPT consists of two basic components: (1) switch mode converter (2) control section.
5.1.3 MOSFET Driver
In order to achieve high speed switching in power MOSFET, a MOSFET driver circuit is used. Two PN2222A npn transistors are used for this driver circuit.

5.1.4 Microcontroller
ATmega32 is chosen as a microcontroller for the design. This microcontroller is responsible for all tracker functionality, operating the ADCs and DACs that deal with the analog section, computing the power point of the array.

5.1.5 Voltage Sensing Circuit
Since the ATmega32 can only process digital information, A/D conversion is required. Analog signals, either the voltage from the voltage divider network or from the differential amplifier must be converted to binary numbers that is digestible by ATmega32.

5.1.6 Current Sensing Circuit
The current signals from the PV array are monitoring by using by the current sensing circuit. The sensing acts as a transducer that converts the current to the voltage signals so that the microcontroller can understand and used use the information to process and hence performs the PWMs.

5.2 Software Design
With the hardware circuit design completed, the next step in the design is the on-board software control. The incremental conductance is chosen as a tracking algorithm for the MPPT. The ATmega32 microcontroller operating at a speed of 8MHz is used to carry out the algorithm. The program is written in C and then is compiled by freeware version C compiler ‘WinAVR’. The MPP determination technique is shown in figure 5.

The program starts by initializing the A/D module and sets the duty ratio at 50%, since it is likely that the MPP can found. The program flowchart for this algorithm is shown in fig. 6. The incremental conductance method is selected and certain changes are made in the present work. The incremental conductance method is used with some modifications as a MPPT algorithm. This method of tracking MPP is more efficient than the P&0 method.

6. SIMULATION OF MPPT
The simulation studies are carried out in Proteus ISIS interactive circuit simulation environment. The program is written in C and then is compiled by a freeware version C compiler ‘WinAVR’. The simulation setup of the MPPT system and its running status is shown in figure 7. The simulation was carried out for duty cycle starting from 50% since it is likely that the MPP can be found.
The LCD information for different values of input power is shown in figure 8. It has been observed from fig. 8 that the duty cycle decreases with input power and the controller tracks the MPP.

Figure 8: LCD Readout for Different Values of Input Power

7. EXPERIMENTAL SETUP

Figure 9 shows the hardware setup of the MPPT system. The experiment was performed in various environments i.e. temperature and irradiance levels. The experimental reading was carried out at different times of the day.

Figure 9: Photographs of Hardware Setup

8. EXPERIMENTAL RESULTS

The open circuit voltage and short circuit current found in laboratory were 19V and 3.7A respectively, whereas their ratings are 21V and 5.29A respectively. This may be due to the increase in temperature (55°C) and reduce in irradiance (0.72 W/m²). Comparative results found in experiment for different temperature and irradiance is noted in Tables.

Table 1
The Experimental Results were Found at Temperature 51°C and Irradiance 0.85kw/M²

<table>
<thead>
<tr>
<th>Parameters</th>
<th>From Data Sheet</th>
<th>From Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Circuit Voltage, $V_{oc}$</td>
<td>21.9V</td>
<td>19V</td>
</tr>
<tr>
<td>Short Circuit Current, $I_{sc}$</td>
<td>5.29A</td>
<td>4.74A</td>
</tr>
<tr>
<td>Voltage at MPP, $V_{mpp}$</td>
<td>18.05V</td>
<td>16.37V</td>
</tr>
<tr>
<td>Current at MPP, $I_{mpp}$</td>
<td>4.71A</td>
<td>4.03A</td>
</tr>
<tr>
<td>Max. Power, $P_{max}$</td>
<td>85W</td>
<td>66 W</td>
</tr>
</tbody>
</table>

Table 2
At Temperature = 51°C and Irradiance = 0.72 W/M²

<table>
<thead>
<tr>
<th>Experiment type</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without MPPT</td>
<td>1.8A</td>
<td>17.8V</td>
<td>32.04W</td>
</tr>
<tr>
<td>With MPPT</td>
<td>2.59A</td>
<td>15.6V</td>
<td>40.42W</td>
</tr>
</tbody>
</table>

Table 3
At Temperature = 52°C and Irradiance = 0.83 W/M²

<table>
<thead>
<tr>
<th>Experiment type</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without MPPT</td>
<td>2.10A</td>
<td>17V</td>
<td>35.7W</td>
</tr>
<tr>
<td>With MPPT</td>
<td>2.92A</td>
<td>15.1V</td>
<td>44.92W</td>
</tr>
</tbody>
</table>

The result from tables shows that with the use of MPPT the output power increases about by 25%. The module with MPPT gives the output peak power of 66W at noon time(12:00 noon) while it gives only 55W without MPPT.

9. CONCLUSIONS

The aim of this research work is to develop a suitable method to optimize the energy extraction from a proposed renewable energy generation system. To achieve this, MPPT design was implemented and modeled in PROTEUS ISIS environment. The simulation result showed that the tracker was able to maintain the operating of the photovoltaic module at the maximum power point. Experimental results have shown that the MPPT has the capability to track the maximum power point. This results in improved efficiency for the generation of renewable energy systems.

REFERENCES


Maximum Power Point Tracker for Photovoltaic System”, Rajshahi University of Engineering and Technology, Bangladesh. September 2009.


