



Design and Implementation of MPPT for a PV System using Variance Inductance Method

Engr Zainab Huma, Dr Abdul Basit

Abstract—Earth receives huge amount of solar energy which is thousands times more than the world's yearly demand. Solar energy is very cheap reliable and pollution free source of energy. Solar energy is converted into electrical energy with the help of solar panels made of solar cells. Various methods have been developed to extract maximum power from these solar panels. Those methods are conventional and they lose huge amount of solar energy causing failure in extracting maximum power. This paper presents very efficient method to extract maximum possible power which a solar panel may deliver. Here MPPT charge controllers are used instead of conventional charge controllers which always keep on tracking maximum possible power. This paper involves designing and implementing Maximum Power Point Tracking System for a Solar Photovoltaic Panel (150 Watt). The efficiency of solar cells is low in general. So the impact of being able to extract maximum possible power out of the PV System is huge. The technique used in this paper to track maximum power point is Variance Inductance Method. This technique compares the actual value of $\Delta P/\Delta V$ in the circuit with zero on regular intervals to generate a PWM Signal using a microcontroller. This PWM signal then dictates the switching frequency of a buck regulator connected to the solar panel and the load/batteries. Through this switching the values of V and P in the circuit are maintained such that maximum power keeps on getting transferred. This technique is designed and implemented in proteus and output is observed.

Keywords— Maximum Power Point Tracking (MPPT), Variance Inductance, Solar Photovoltaic (PV), Efficiency, Pulse Width Modulation (PWM)

I. INTRODUCTION

Now-a-days, power is being generated using hydro or thermal power plants which use fossil fuels like coal, oil and gas. The ever-increasing depletion of fossil fuels and risk of

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climate changes and environmental crisis are a major source of concern for most of the developing countries. Due to this, the modern world is inclining towards the usage of renewable energy sources to produce electricity among which wind and solar are the emerging renewable sources. Renewable energy comes from a source which does not get depleted with usage and time. In our country Pakistan, the energy crisis is severe so solar energy would present itself as a worthy replacement of non-renewable energy resources.

II. PHOTOVOLTAIC SYSTEM

A. Solar Energy

Solar energy has found vast use in modern times. Its use is now ever increasing given the long life of solar panels and very low maintenance cost after installation. With recent development in technologies, the efficiency of the solar cells used in panels is increasing. An advantage of using the solar energy is that it can be used to produce electricity and power applications on small to medium scale. Ease of transportation and easy installations (from rooftops to mini-grids) of solar are some added advantages. Low maintenance and longer life of the equipment are also some attractive features. The major disadvantage of using solar or wind energy is the high cost of installations and use of expensive energy-storing technologies. Solar can also be used to provide energy to the areas that still have no access to electricity and it is costly and difficult to connect them to the national grid. It would be a good and feasible solution till the transmission lines are extended to those areas. The use of solar is slowly growing with the increase in general awareness of people about the advantages of renewable energy. Solar panels are being used to generate electricity on very small scales to run solar water heaters, solar lamps, fans, solar pumps etc.

Sun light is a form of energy. This solar energy can be captured and converted into other forms of energies for example electrical energy (to meet our energy demands). Photovoltaic (PV) is the method of converting solar energy into electricity. This is based on photovoltaic effect. The photovoltaic effect is a physical and chemical phenomenon in which voltage or electrical current is produced once a material is exposed to sunlight. The emergence of photovoltaic as possible energy sources came in 1958 yet it was 1980 when they began to commercialize on the basis of high efficiencies and lower costs. Photovoltaic cells are

designed that act as devices for this conversion of solar energy to electrical energy.

B. Photovoltaic Cells

Photovoltaic cells are made up of silicon. These cells are connected in series and parallel combinations to increase the overall voltage and current respectively. A specifically designed arrangement of a number of PV cells forms a PV Module. An orderly grouping of PV Modules forms a PV Array.

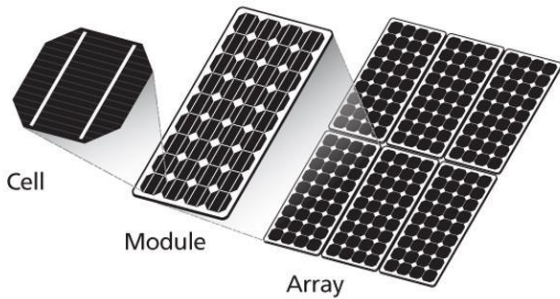


Figure 1. PV cells, modules and Array

C. Equivalent Circuit

A PV cell can be represented by an equivalent circuit comprising of a current source, a diode in parallel, a shunt resistance and a series resistance.

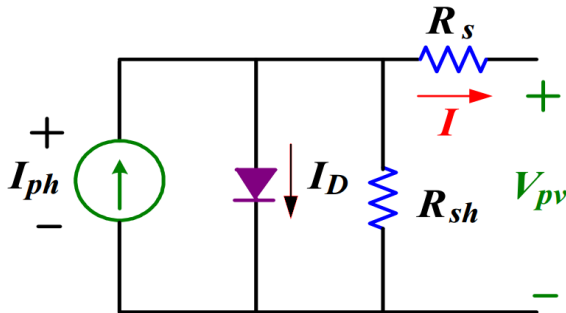


Figure 2. Equivalent circuit of PV Cell

Where,

- $I_{ph} = I_{sc}$ is the short circuit current of the PV cell
Ideally its magnitude is dependent upon the solar irradiation.
- I_D is the diode current
- R_s is the series resistance
- R_{sh} is the shunt resistance
- V_{pv} is the voltage obtained across the panel

D. Power & I-V Curves

A graph between terminal voltage and power produced by a solar module is called a PV curve. A graph between terminal current and terminal voltage of a solar module is called an I-V curve. Although different solar panels have

different PV and I-V curves but their curve shape is very similar.

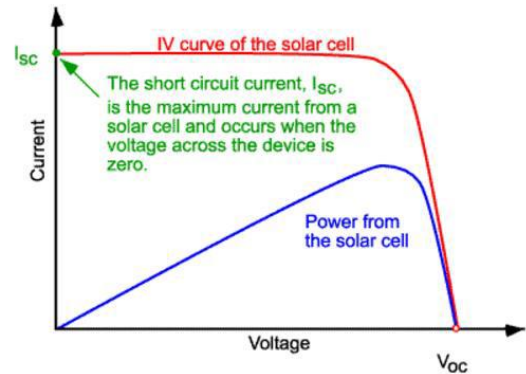


Figure 3. Power & I-V Curve of a Solar Panel

E. Specifications of PV Module

TABLE I. PARAMETERS OF PV MODULE

Model
Open Circuit Voltage (V_{oc})
Short Circuit Current (I_{sc})
Optimum Operating Voltage
Optimum Operating Current
Maximum Power at STC
Standard Test Conditions

These specific parameters of PV modules are specified by the manufacturer.

III. MAXIMUM POWER POINT (MPP)

In the PV Curve shown previously, there is observation that the graph has a peak in it. This is the operating point where the solar cell provides maximum power output. The PV module possesses maximum efficiency at this point. It is usually at the knee of I-V curve of a PV panel.

A typical I-V curve with indication of MPP is shown in Figure 4. According to the theory of MPP, Maximum Power Point is the operating point at which:

- Power transfer is maximum
- Output Impedance is equal to input impedance (Maximum Power Transfer Theorem)
- Derivative of Input Power with respect to Input Voltage is zero ($\frac{\Delta P}{\Delta V} = 0$)

- Derivative of Input current and Input voltage is equal to the negative of the ratio of input current and voltage ($\frac{dI}{dV} = -\frac{I}{V}$)

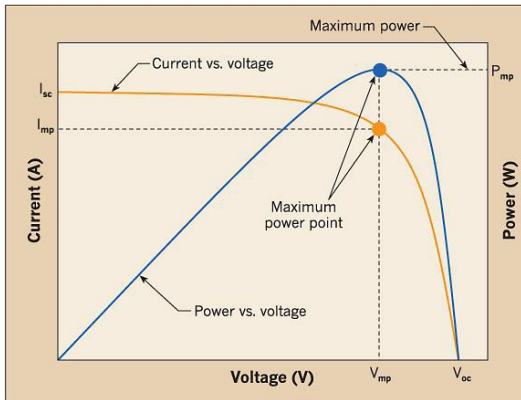


Figure 4. Visualization of Maximum Power Point

IV. DIFFERENT TECHNIQUES OF MPPT

There are several tracking techniques to implement MPPT. These techniques are briefly mentioned.

A. Perturb-and-Observe Method

In this method, voltage is perturbed (changed) and power output is observed. If change in power has the same sign as change in voltage, operating point has to move closer to MPP otherwise it has to move away from it. Although simple and easy to implement, this method fails for small changes and possesses unpredictable behaviors for rapid changes in irradiance. A simple flowchart demonstrating the principle is shown in Figure 5. Since it always has to perturb the voltage no matter the case, it encounters problems on constant irradiance.

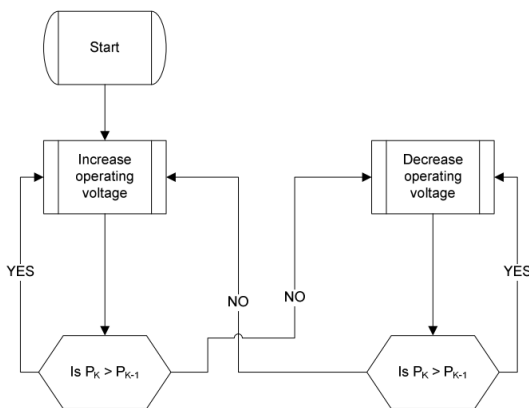


Figure 5. Flowchart of Perturb & Observe Method

B. Incremental Conductance method

In this method, the derivative of power with respect to voltage is taken into account indirectly. $\Delta P/\Delta V$ has to be zero for method to work properly. The direction of change is determined and actual MPP is tracked. It is better than

Perturb-and-Observe method because it can sense rapid changes. An equation for this method and flow chart is shown Figure 6.

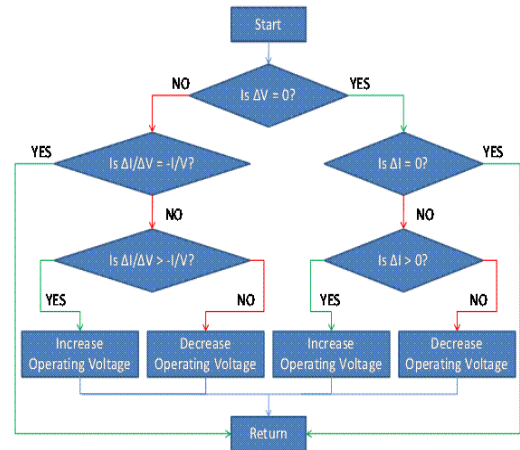


Figure 6. Incremental Conductance Method

$$\frac{dP_{pv}}{dV_{pv}} = I_{pv} \frac{dV_{pv}}{dV_{pv}} + V_{pv} \frac{dI_{pv}}{dV_{pv}} = I_{pv} + V_{pv} \frac{dI_{pv}}{dV_{pv}} = 0$$

$$\frac{dI}{dV} = -\frac{I}{V}$$

C. Pilot Cell Method

Open circuit voltage and short circuit current of solar cell are measured and it is assumed that voltage is directly proportional to MPP voltage. It is also assumed that cell exhibits characteristics similar to I-V curve of solar cell model. Hence one cell is modeled and rest of array is calibrated accordingly.

D. Variance Inductance Method

This method is an upgraded version of Perturb-and-Observe method. In this method $\Delta P/\Delta V$ is calculated. This method is better than Perturb and Observe because it involves large number of samples. $\Delta P/\Delta V$ magnitude and sign is considered. A PWM is generated and a MOSFET is used as switch in Buck converter for variation in duty cycle. The sign of this rate of change of power with respect to voltage, whether positive or negative, dictate the increase or decrease of duty cycle whereas the magnitude of this rate of change determines how much duty cycle will have to vary. A block diagram of the system is shown in the Figure 7. MPPT algorithm is stored inside a microcontroller ATMEGA328 on an "Arduino Platform" which is used because of its good frequency response. The result provided by microcontroller is PWM whose duty cycle is being varied consistently. This duty cycle is provided to MOSFET in Buck Converter which ensures tracking of MPP.

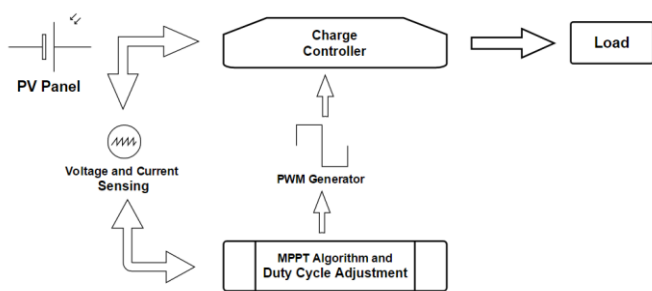


Figure 7. Variance Inductance Method

V. MICROCONTROLLER – ARDUINO UNO PLATFORM

Arduino platform allows us easy and fast prototyping. Arduino has many printed circuit boards and the one used in this project is Arduino Uno. The board consists of ATMEGA328P microcontroller from ATMEL® studios. It has 16 MHz crystal that can be programmed to generate desired Pulse Width Modulated (PWM) signals. It can be excited by DC power jack or via USB cable. There are female headers with pin numbers displayed alongside them so connections can be made using connecting wires. The LCDs can be used conveniently to display the desired quantities. Moreover, the programming of Arduino is easy to understand as it is in C language. Hundreds of coding libraries can come in handy if any circuit is to be tested.

VI. DESIGN & SIMULATION

A. Specifications of Solar Panel

The specifications of the solar panel used in this project are given in the table.

TABLE II. SPECIFICATIONS OF SOLAR PANEL

Model	Solar Land SLP150-12
Open Circuit Voltage (V_{OC})	21.6V
Short Circuit Current (I_{SC})	9.7A
Optimum Operating Voltage	17.2V
Optimum Operating Current	8.72A
Maximum Power at STC	150W
Standard Test Conditions	1000 w/m^2 Air to Mass ratio = 1.5at 25°C

B. Output Requirements

The output requirements are given in the table

TABLE III. OUTPUT PARAMETERS

Output Voltage (V_{out})	12V
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Maximum Output Current ($I_o(max)$)	$I_{sc} = 9.7A$
Output Current Ripple Percentage	30% of $I_o(max)$
Output Voltage Ripple Percentage	2% of V_{out}
Output Load Nature	Purely Resistive
Output Load value	4.61 Ohm

C. Simulation

For simulation purposes MATLAB and Proteus are selected. The choice of simulation software is based on the fact that MATLAB and Proteus both have a user friendly interface. However MATLAB does not have Arduino block. This is where Proteus is used. Proteus software tool is the best Arduino simulator. Another advantage of using Proteus over other simulation environments is that it is fast, reliable and flexible.

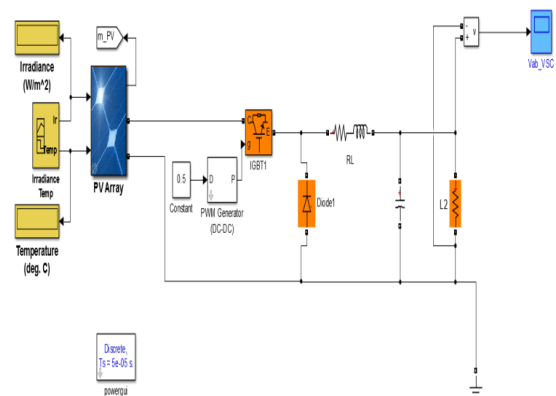


Figure 8. Schematic Circuit Diagram for using MPPT

D. Overall Project Simulation

The circuit diagram used for the general simulation of this project in SIMULINK and Current, Voltage and Power graphs for the simulation with respect to time are in the figures 9-11

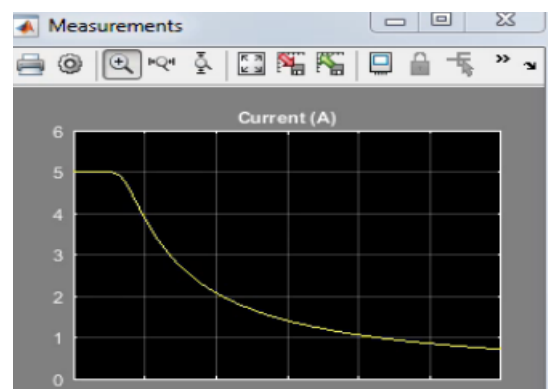


Figure 9. Current Characteristics

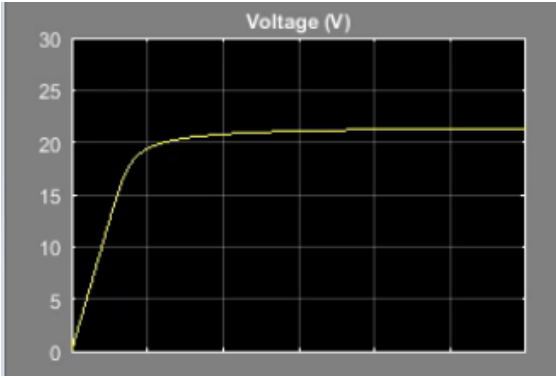


Figure 10. Voltage Characteristics

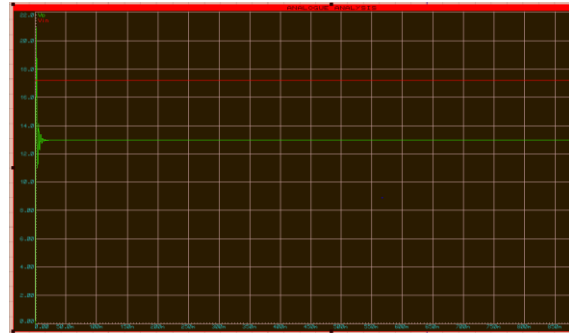


Figure 13. Input and Output Voltage

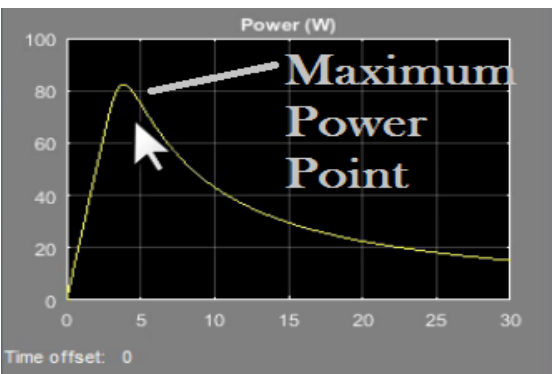


Figure 11. Power Output Characteristics

VII. PROTEUS TESTING OF THE CODE

The Arduino is programmed and the code is developed for implementation of MPPT. The developed code was tried and tested in Proteus 8. The results obtained are shown in the figure. The current sensor IC block is also employed here to check for results. An LCD is interfaced to show results of Power, Voltage and Current on the screen.

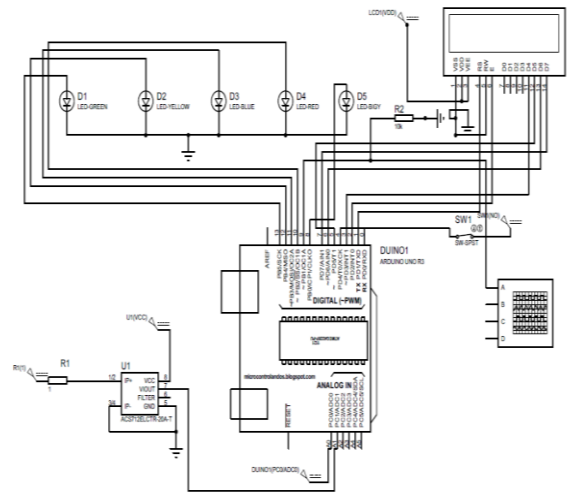


Figure 14. Proteus simulation circuit for MPPT code

E. Buck converter simulation

The following circuit is implemented in Proteus. The values of the components are according to the calculations.

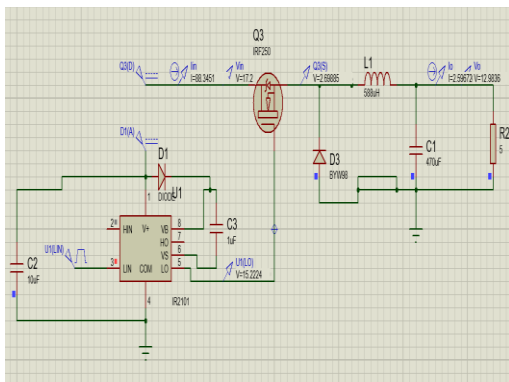


Figure 12. Buck Converter Simulation

a. Results:

The red line shown in the figure is input voltage which is 17.2V and the green line showing is output voltage which comes out to be 12.9V. The desired value for the output voltage is 12-13V. The result of the simulation is 12.9V which lie within the required range.

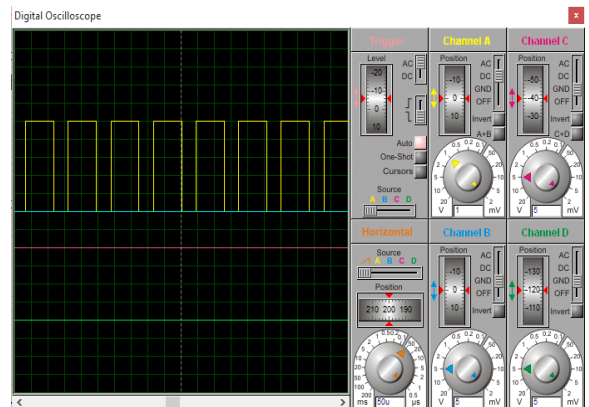


Figure 15. PWM Signal

The main objective is to calculate $\Delta P/\Delta V$ which is achieved and an increment according to this value is added or subtracted from previous value of duty cycle to calculate new duty cycle. For MPPT to occur, $\Delta P/\Delta V = 0$. If this calculated value is greater than 0, we subtract the increment to get it back at 0 and vice versa.

CONCLUSION

The several different methods have different algorithms which can be traded for complexity and computational cost. Efficiency and reliability are two features which are extremely important for us to work with. Out of these methods, we have designed and implemented MPPT via variance inductance method. After a series of tests we have come to conclude that the efficiency of the solar panels is very low so there is a need for MPP tracking to harness the maximum available power. To obtain the maximum power, the panel has to be operated at the MPP which was controlled by the duty cycle of the varying PWM generated by the microcontroller. The Variance Inductance method is an upgraded form of Perturb and Observe method and a better methodology to track and obtain the maximum power.

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