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Design of Maximum Power Point Tracking for PV Panels

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Abstract—To minimize power crises and switching power production from conventional resources like thermal resources to renewable resources is necessary such as solar power is the main theme. The P-V characteristics are obtained for various irradiances using M-file showing MPP using Perturb and observation method. Also, the points indicating Module voltage Vmax and Current Imax at maximum power Pmax are obtained. For maximum utilization and generation of solar Photovoltaic (PV) panels maximum sun tracking is important which is referred as MPPT (Maximum Power Point Tracking), Use of efficient power converters to utilize solar power is also discussed. Theoretical and Manufactured results are compared with same results obtained.

Keywords—Photovoltaic(PV), MPPT, Power Converters, irradiance.

Abbreviations:

Iph: photocurrent of the PV Panel.

Isc: short circuit currents of the PV panel.

Rs: series resistance of the PV panel.

N: diode quality factor parameter

G: solar irradiance in W/m2

Ta: ambient temperature in °K

K: Boltzmann's constant

q: electronic charge

Voc: open circuit voltage of each cell

Ns number of cells in series

Np number of cells in parallel

Rin internal resistance of each cell

I. INTRODUCTION

MPPT is an electromechanical system which is used to operate solar PV panels to generate maximum power solar panels are capable to produce.Power produced from PV panels depends upon irradiance, temperature and current drawn from solar cells [1, 2]. Dependence on irradiance of PV cells is explained in figure 1.

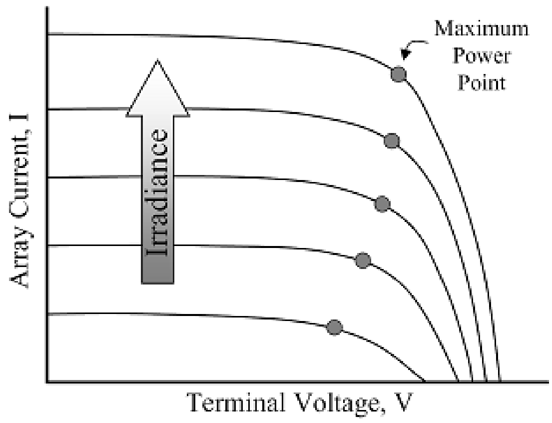

Figure 1 Irradiance Dependence of Solar Cells [5].

Nature of current and voltages of solar panels and their dependence on irradiance may vary with change in environmental conditions. Various MPPT algorithms

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have been developed some using only electronic system while others having electromechanical systems as well, the mechanism developed here is Perturb and observe which checks for MPPT level and compare it throughout to get maximum power. Power converter's duty cycle is varied for the generation of maximum power [2, 3].

Conventional energy resource is decreasing day by day with increase in cost, and now it's our responsibility to diverge power sector to renewable resources. Due to increase in oil prices, it is becoming very difficult for a normal citizen to pay high tariffs electricity bills. Electricity bills can be reduced by converting power sector to renewable resources with solar being one of the major renewable resource [1, 2].

Power Demand has increased a lot due industrial boom and use of modern electrical appliances that's why use due to declining conventional power generating resources it's becoming costly so the need for renewable resources like solar must be encouraged [3].

Various incentives are provided nationally and internationally to encourage the use of solar energy. The focal point of this Paper is Maximum Power Point Tracking (MPPT) for solar PV panels for all over the globe where there is solar potential. A MATLAB Simulink based model is designed for such a purpose to promote solar power generation [5].

II. PV MODEL

Solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pairs proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar insolation. Figure 2 below shows a simple PV panel model with Rp as parallel leakage resistance and Rs as series resistance.

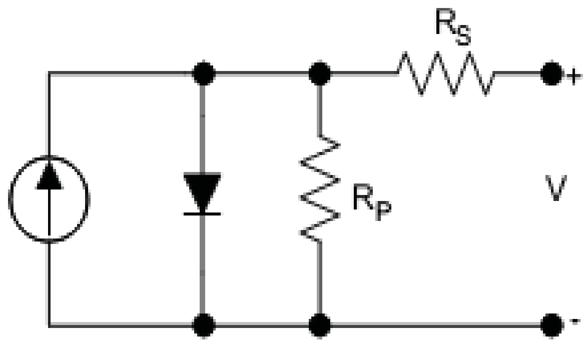

Figure 2 PV panel model Electrical [8].

The following equations will calculate the value for series resistance, PV output current and irradiance.

$$Id = Io\left(e^{\frac{q.Vd}{\gamma kT}} - 1\right)$$

and

$$Iph - Id = Il$$

$$Iph - Io\left(e^{\frac{q.Vd}{\gamma kT}} - 1\right) = Il$$

so

$$Iph - Io\left(e^{\frac{q(Vl+IlRs)}{\gamma kT}} - 1\right) = Il$$

I_o is constant here and I_{ph} is dependent on variable solar energy. Mostly the photovoltaic cell means a single cell, which has voltage of 0.8 volts. Panel is the collection of the cells and cell mean a single cell so here we Assumes as both cell or a panel so now we write its equations as

$$Iph - Id - Ish = Il$$

Putting the values then

$$Iph - Io\ \left(e^{AVd} - 1\right) - \frac{Vd}{Rsh} = Il$$

Here

$$A = \frac{q}{\gamma kT}$$

III. MPPT TRACKING ALGORITHM

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Algorithm that has been implemented is Perturb and Observe where current is checked repeatedly by a fixed amount in direction provided, with current direction changing with change in power drop. The algorithms detect the change and perform operation accordingly to optimize power. Flow charts shown in figure 3 will explain algorithm and MPPT process.

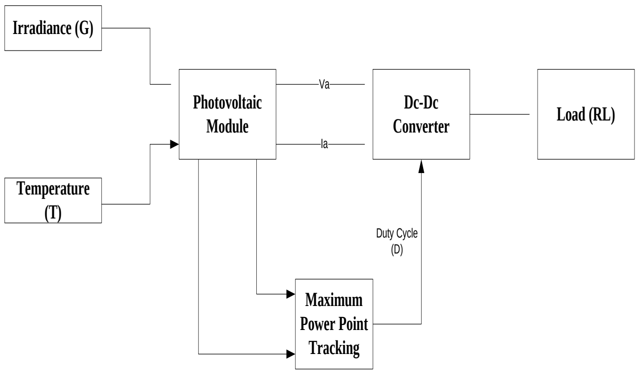


Figure 3 MPPT Algorithm.

With change in Temperature and Irradiance, power of PV cell is changed,when power reduction is detected by MPPT controller it sends signal to DC converters which in turn change the duty cycle to re-adjust power by adjusting the position of PV panel.
Algorithm will be explained in detail in figure 4 and figure 5 respectively.
Output voltage of the buck-boost converter is [6,7]

$$Vo = Vs\left(\frac{T_{on}}{T_{off}}\right) = Vs\left(\frac{T_{on}}{T-T_{on}}\right) = Vs\left(\frac{\frac{T_{on}}{T}}{1-\left(\frac{T_{on}}{T}\right)}\right)$$

$$= Vs\left(\frac{k}{1-k}\right)$$

Where

$k = \frac{T_{on}}{T} = T_{on}/(T_{on}+T_{off})$

so

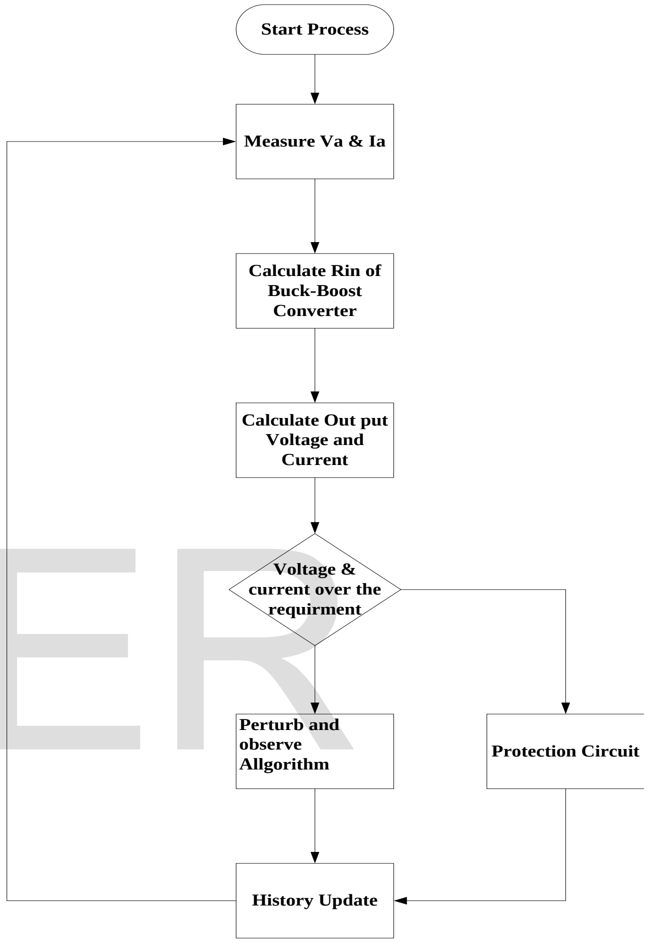
$$Vo = \left(\frac{1}{1-D}\right)Va$$

And

$$Io = (1-D)Ia$$

Perturb and Observation algorithm designed to achieve the goal of gaining maximum power from the Solar PV panel, by adjusting the duty cycle (D) Boost of the Buck-converter [7].

Figure 4 Perturb and Observe Algorithm.



<u>STEP 1:</u>

MPPT Point is observed and Iph is approximately equal to Isc.
Maximum power of the PV panel is

$$Pmax = Imax * Vmax$$

$$Pmax = n(Voc * Isc)$$

Where n is quality factor of solar cell.

Step 2:

Measuring values of current and voltage at different Irradiance and temperature.

Step 3:

Power Calculation.
Compare power of panel obtained (Pa) with Maximum power point (MPP).

Step 4a:

If output power of the system is on Maximum Power Point then controller will have no operation.

Step 4b:

MPPT not achieved then controller will perform operation by adjusting duty cycle which will in turn value for DC converters and their switching to improve power.

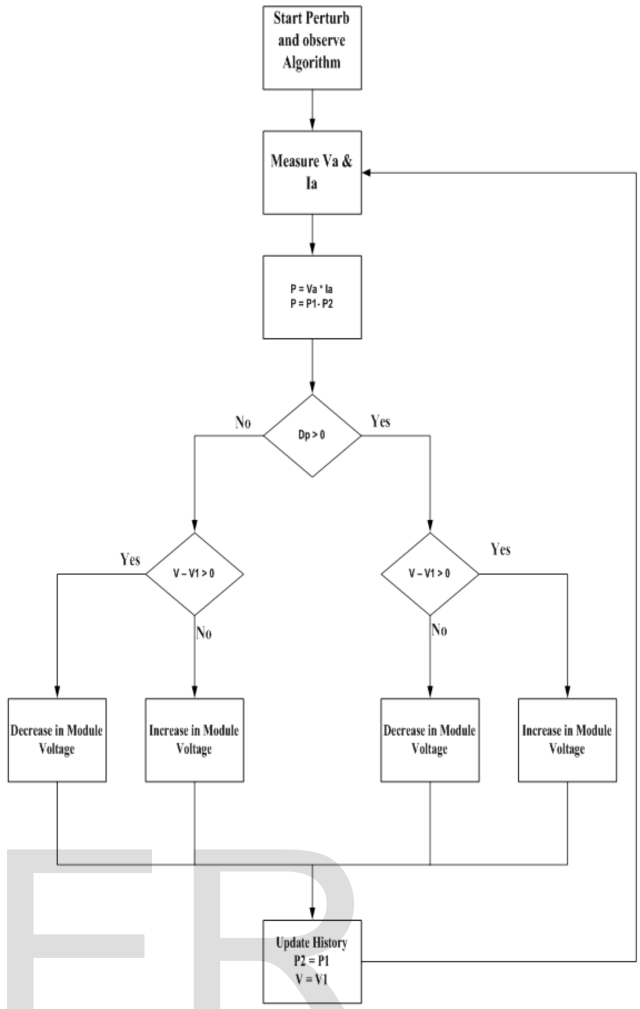


Figure 5 MPPT Algorithm B.

Figure 5 above shows the other half of MPPT algorithm With same operation as performed in first half this time Algorithm will check for minimum power production level.

$$Iph = G * Isc$$

$$Isc = \mathrm{Isc_{Tr}} * [1 + \left(a * (Ta - Tr)\right)$$

and

$$\mathrm{I = Isc - Io}\left(e^{\frac{q(V+IRs)}{nkT}} - 1\right)$$

$$\mathrm{dI = 0 - Io.q}\left(\frac{(dV + Rs.dI)}{nkT}\right).\left(e^{\frac{q(V+IRs)}{nkT}}\right)$$

so

$$\mathrm{Rs} = -\frac{dI}{dV} - \frac{\frac{nkT}{q}}{Io.\left(e^{\frac{q(V+IRs)}{nkT}}\right)}$$

At open circuit condition V=Voc and I=0 then equation

$$Rs = -\frac{dV}{dI} - \frac{\frac{nkT}{q}}{Io.\left(e^{\frac{q(Voc)}{nkT}}\right)}$$

IV. Results

Figure 6 below will show the graphical results for temperature and irradiance for the data provided by AEDB in Pakistan.

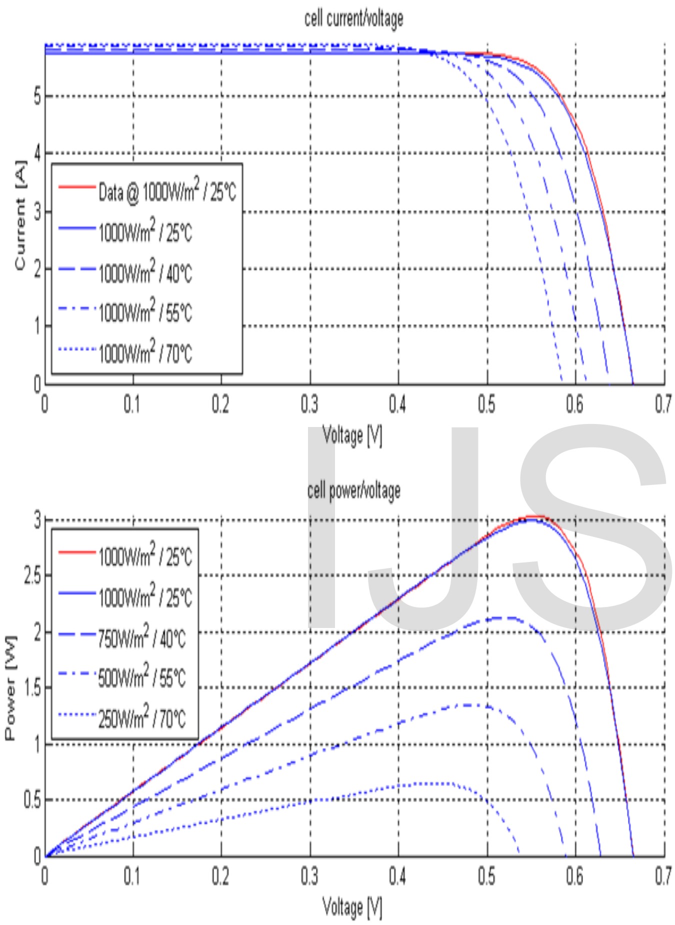


Figure 6 Effect of Temperature and Irradiance.

The output waveform for DC converter power simulated in MATLAB is shown in Figure 7 which shown stability in power for MPPT.

Temperature of solar PV panel has effect on its efficiency. we can observe in figure 5,6 that the voltage are become low at higher temperature. The terminal voltage increases with decreasing temperature. It is due to mobility of electrons and holes in semiconductor material. Therefore, when temperature increases then electrons and holes mobility in semiconductor material is decreases [9].The band gap energy of semiconductor material is also varies with temperature variations. Band gap will increase by increasing temperature at semiconductor material. If energy gap is increased then electrons and holes required more energy to move from valance band to conduction band, it means more photons will absorbed by electrons in the valance band but few electrons move towards conduction band and efficiency of solar cell is decreased. In general, silicon crystal PV cell efficiency will be decreases almost 0.5% for every degree C° increase in temperature [9, 10].

Irradiance is also a very important changing factor in solar PV panel's performance. Irradiance is amount of solar energy, which is absorbed by a PV panel over its area. Unit of Irradiance is Watt/m² and in ideal condition Irradiance of solar PV panel is obtain 1000W/m² or 1KW/m²,this value of irradiance is depend on location and angle of the sun rays.

It can be observe in figure 5-2 that irradiance directly effect on output power of PV panels, in other words output power of the PV panel directly proportional to the Irradiance of solar. In solar PV panels the output current is directly proportional to the flux of photons, it means if the light intensity is low then the output current is also low but there is minimal change in output voltage by varying irradiance and that is negligible change in voltage. If the light intensity will increase then output current will also increase. Therefore, we can observed, if the sun is bright an intensity of light is high then performance of PV panels will increase [9, 11].

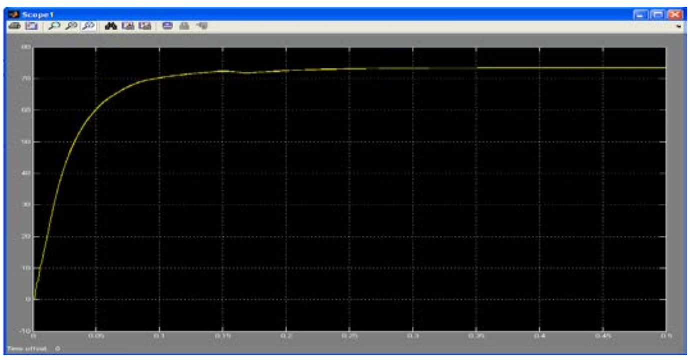


Figure 7 DC Converter output power.

Waveform in Figure 8 will show MPPT output for algorithm working for maximum power generation.

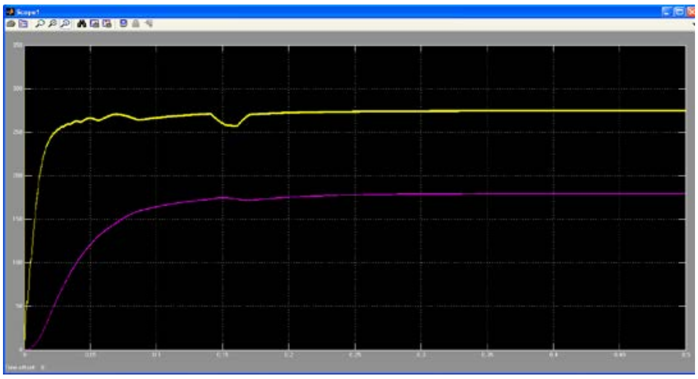


Figure 8 MPPT final Output.

V. CONCLUSIONS

The I-V and P-V characteristic of Solar PV module is obtained using the MATLAB/Simulink for different values of irradiance and temperature. The P-V characteristics are also obtained using the M-file with Perturb and Observation method. It is observed that the characteristics obtained usingboth methods are matching with the theoretical Characteristics. Also the module voltage Va and Current Ia at the maximum power Pa are obtained which are fairly same as indicated. MPPT algorithm can be used with DC-DC Buck-Boost converter to obtain the required dc voltage to supply the dc load.

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