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Maximum Power Acquisition from Photo Voltaic Module under Varying Environmental Condition

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Abstract: ***In this paper, the acquisition of maximum power from a photovoltaic module in different environmental condition like change in solar radiation and change in temperature is shown. Neural network algorithm is used for searching the optimum value of maximum power output from a simulink model of solar cell in Matlab. The result are displayed under varying temperature and solar radiation for a maximum power.***

Keywords: Solar Cell, MPPT, Photo Voltaic, Renewable Energy

1. Introduction

The search and development of new energy sources is becoming a passion for energy utilities as the conventional energy sources are either on the verge of discontinuation or are the main reason for the emission of environmental and natural pollutant thus the renewable energy sources have been a more innovative and prime focused contributor of the total energy consumed in the world. In fact the use of solar energy has risen up rapidly in the recent years [1].

Energy from the sun in the form of solar radiation is converted to electrical energy using the photocell. The dc output from the cell in then converted to ac using suitable converter to tie in the grid. This paper optimizes the output of the solar cell using Maximum power tracking algorithm under varying environmental condition as described in figure 1.

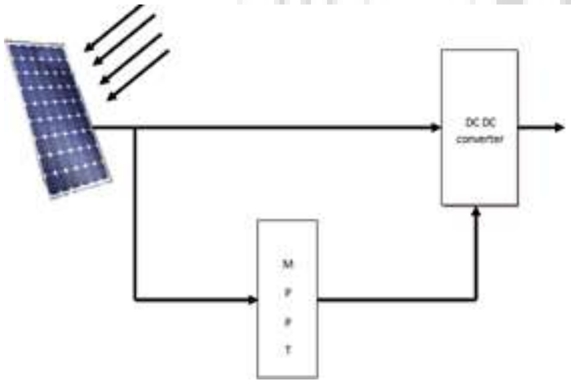

Figure 1: basic functional block diagram

2. Solar Cells

A solar cell (also known as photovoltaic cell) is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell, whose electrical characteristics e.g. current, voltage, or resistance, varies when exposed to light or electromagnetic radiation near the visible range.

2.1 Theory of solar cell

The theory of solar cells explains the physical processes by which photons are converted into electrical current when solar energy strike on them. Since the theoretical studies of solar cell predict the fundamental limits of solar cell, and give guidance on the phenomena that contribute to losses and solar cell efficiency the practical studies is very useful. The working principle of all today solar cells is essentially the same. It is based on the photovoltaic effect. In general, the photovoltaic effect means the generation of a potential difference at the junction of two different materials in response to visible or other radiation. The basic processes behind the photovoltaic effect are:

1) Generation of the charge carriers due to the absorption of photons in the materials that form a junction
2) Subsequent separation of the photo-generated charge carriers in the junction,
3) Collection of the photo-generated charge carriers at the terminals of the junction.

When a photon is absorbed, its energy is given to an electron, in valance band, in the crystal lattice, which is tightly bound in covalent bonds between neighboring atoms, and hence unable to move far. The energy due to the photon "excites" it into the conduction band, where it is free to move around within the semiconductor. The covalent bond that the electron was previously a part of now has one fewer electron which is known as a hole. The presence of a missing covalent bond allows the bonded electrons of neighboring atoms to move into the "hole," leaving another hole behind, and in this way a hole can move through the lattice. Thus, it can be said that photons absorbed in the semiconductor create mobile electron-hole pairs. The figure 2 depicts the possibility of formation of electron hole pair with its energy band.

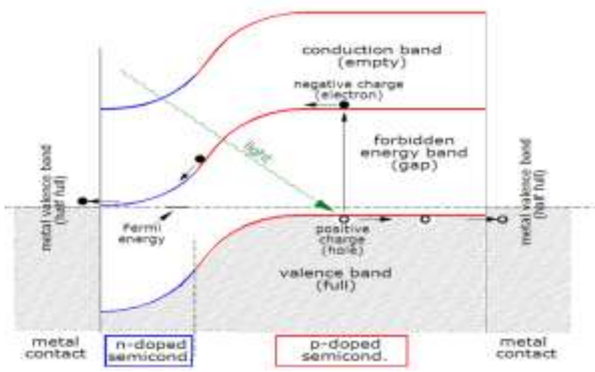

Figure 2: Formation of electron-hole pair.

2.2 Mathematical modeling of Solar Cell

Solar cell is p-n junction so a mathematical model can be derived from the physics of p-n junction of a semiconductor. The solar cell can be modeled as a single diode model or as a double diode model. Depending on the parameter to be considered and the depth of analysis the modeling can be done. However which modeling technique is applied the approximate analysis of the solar cell and be obtained. Here in this research a single diode model for modeling of a solar cell. In which a single diode is assumed to be connected parallel to a photo current that can be obtained from the solar cell diode, series resistance and a shunt resistance [1, 2].To take account of the resistance in the cell a series resistance R_s is connected in series with the current source and a shunt resistance R_{sh} for leakage current $I_{sh.}$. The models consider is shown in figure 3.

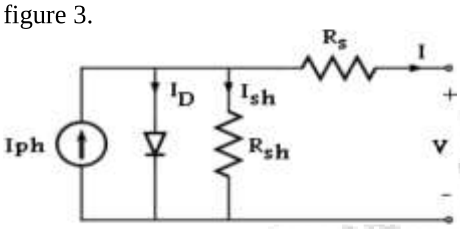

Figure 3: mathematical solar cell model

The current through the diode I_d can be given by

$$I_d = I_s\left(e^{\frac{q(V+R_sI)}{NKT}} - 1\right) \quad (1)$$

While the current through the shunt resistor is given by

$$I_{sh} = \frac{(V+R_sI)}{R_{sh}} \quad (2)$$

And hence the load current is given by [1,2]

$$I = I_{ph} - I_d - I_{sh} \quad (3)$$

$$I = I_{ph} - I_s\left(e^{\frac{q(V+R_sI)}{NKT}} - 1\right) - \frac{(V+R_sI)}{R_{sh}} \quad (4)$$

Where,

I_{ph} = photo current

I_s = reverse saturation current of diode

q=electron charge density = 1.6 x10^{-19} C

V = voltage across diode

K = Boltzmann's contant =1.38 x 10^{-23} J/K

T= temperature at junction in kelvin

N= non linearity of diode (1 for ideal and >2 for real conditions)

Rs = series resistance of cell

R_{sh} = shunt resistance of cell

2.3 Effect of solar Radiation.

For variation with solar radiation the governing equation is given by [3]

$$I_{ph} = \frac{I_{sc} - K_i\,(T-298)}{\frac{G}{1000}} \quad (5)$$

Where

K_i = short circuit temperature coefficient = 0.0017 A/^{o}C

G = Solar radiation W/m^2

2.4 Effect of Temperature Variation

For variation of temperature the mathematical relationship governing is given by. [4]

$$I_s(T) = I_s\left[\frac{T}{T_{norm}}\right]^3 e^{\left[\frac{T}{Tnorm}-1\right]\left[\frac{E_g*q}{NKT}\right]} \quad (6)$$

where,

T= actual Temperature

T_{norm} = Normal Temperature

E_g = Band gap energy of semi conductor

V_t = Thermal Voltage

3. Maximum power point tracking (MPPT)

The V-I and P-V characteristic of solar cell is non linear and is dependent on solar irradiation and temperature. In general there is a specific value of V-I and P-V, where the output of the solar cell is maximum and this point is called maximum power point. Maximum power point trackers (MPPTs) maximize the power output from a PV system for a given set of conditions, and therefore maximize the array efficiency. Thus, an MPPT can minimize the overall system cost also. MPPTs calculate and maintain operation of the PV system at the maximum power point, using an MPPT algorithm [5]. Most common MPPT algorithm are described in [5-13]

3.1 MPPT Design

The main purpose of this research is to design a suitable Neural Network based MPPT algorithm and optimize the output of the PV system. In order to solve the non linear equation of the solar cell characteristic Newton Rapson method is used as it converges rapidly for both positive and negative values [4]. The following algorithm and flowchart has been followed to obtain the maximum power points.

3.1.1 Algorithm for purposed MPPT

The following steps are executed in a Matlab in order to obtain the maximum power for different test data.

1) Start
2) Read solar cell parameter Isc, Voc, Ki, Tnorm, K, n, q, Is, Rs, Rsh
3) For different solar radiation G measure photo current I_{ph}.
4) With the help of photo current calculate I using newton raphson method of solving non linear equation. In this case we consider temperature to be constant.
5) Find the maximum value of the current.
6) Draw I-V curve from the calculated value of voltage and current and store values of values of voltage and current at maximum current.
7) Calculate the power from calculated values of voltage and current.
8) Find the maximum value of the power, this is the maximum power point
9) Store the values of voltage and power at this point which corresponds to the maximum power point.

The similar algorithm works with different solar temperature except we calculate the reverse diode saturation current Is(t) for a range of temperature variation T. and we proceed to calculate the current assuming solar radiation to constant.

3.1.2 Flowchart of purposed MPPT

The following block diagram depicts the working principle of the tracking algorithm

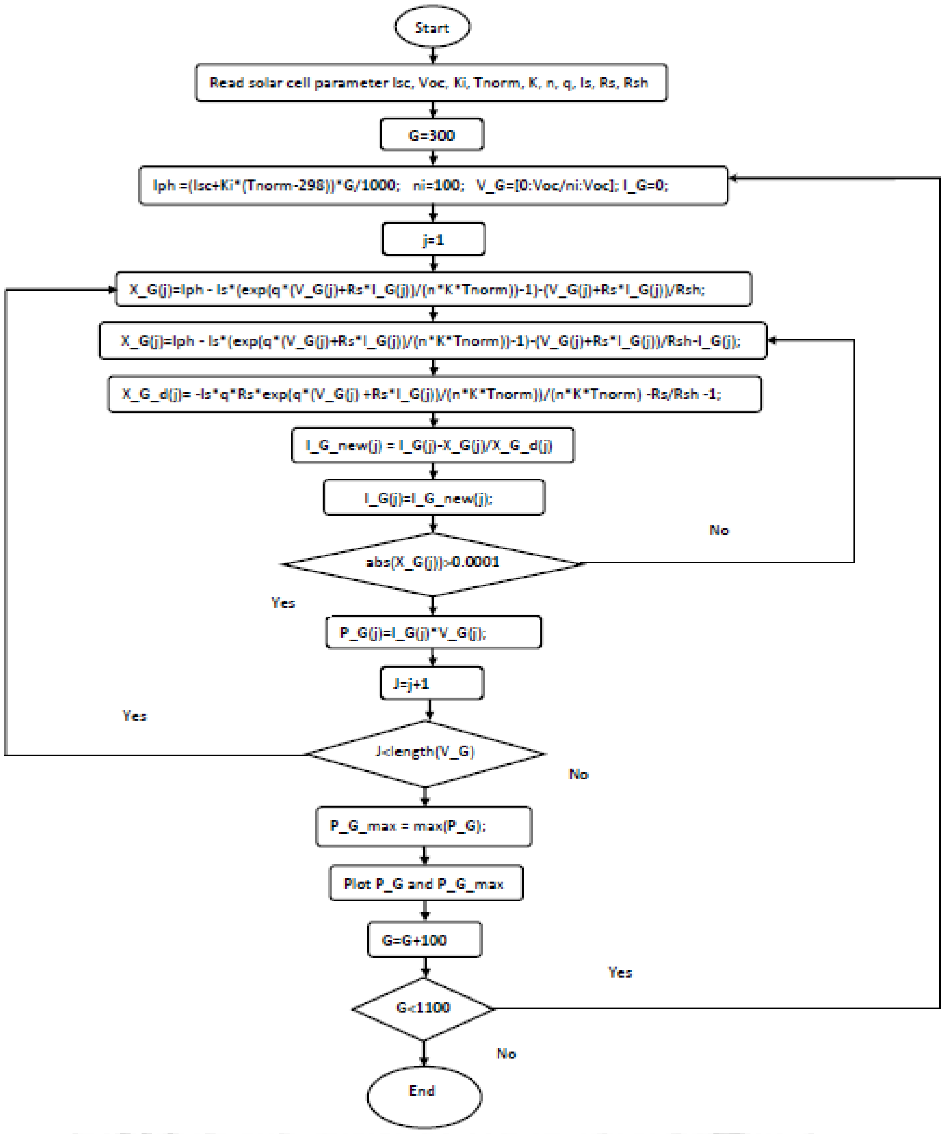

Figure 3.6: Flowchart of Purposed MPPT

4. Simulation Result

4.1 Effect of solar Radiation

The simulink model for the effect of solar radiation is as shown in the figure 4

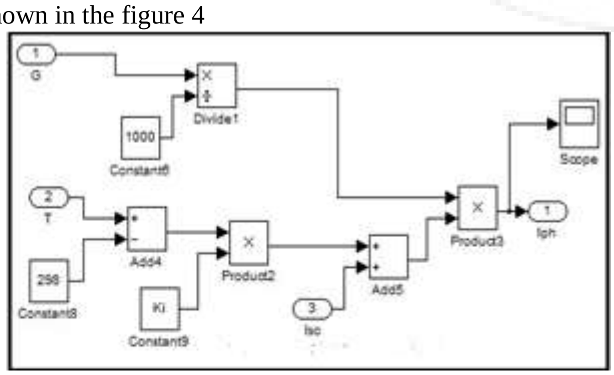

Figure 4: Simulink model for effect of solar radiation

The effect of solar radiation for a solar radiation variation of G= [300 1000] is as shown in figure 5

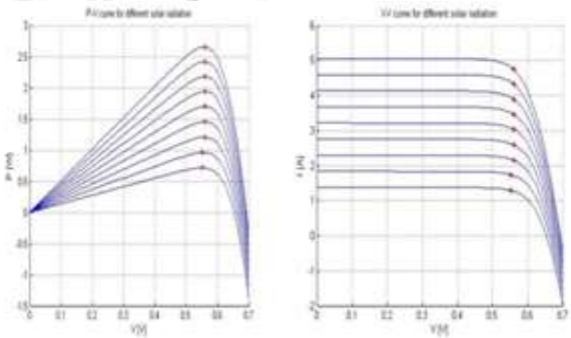

Figure 5: P-V and I-V curve for different solar radiation

The maximum power point will decrease as there is decrease in the solar radiation. Whenever there is high radiation there will be more power, even though for a specific radiation there will be a specific maximum power point. So some system uses this algorithm to track the maximum power using movable solar panel system.

4.2 Effect of Temperature Variation

The simulink model is given by figure 6

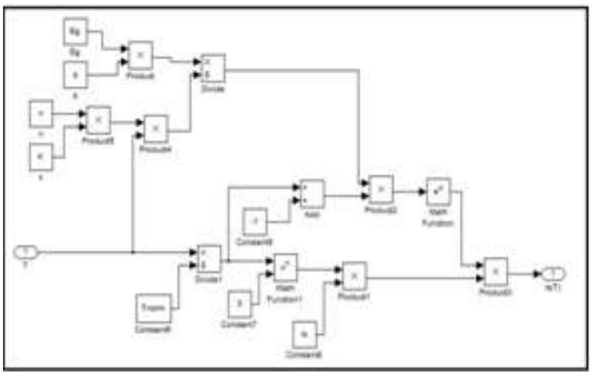

Figure 6: Simulink model of effect of temperature variation

The effect of solar radiation for a solar temperature variation of T= [25:35] degree is as shown in figure 7.

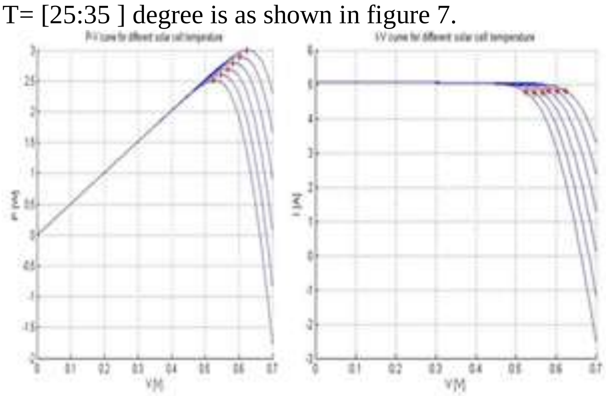

Figure 7: P-V and I-V curve for temperature variation

With the increase in temperature there will be fall in maximum power output of the solar cell.

4.3 MPPT

When simulated in the Matlab the following output has been observed. The red star represent the maximum power point when the solar panel is operated with different environmental condition. The maximum power point obtained from this algorithm is stored in a computer memory so as to give the signal to the converter. The converter than uses the control mechanism to give a maximum power output. The output of the maximum power tracking algorithm is shown below.

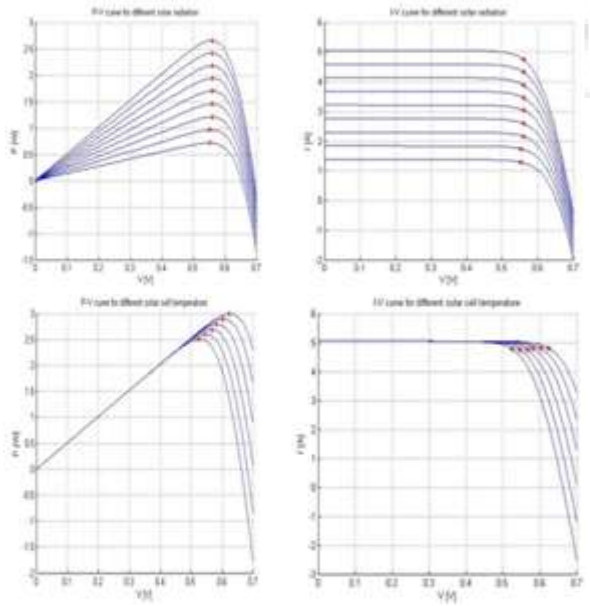

Figure 8: MPPT output

5. Conclusion

In this research maximum power from the solar under varying environmental condition especially temperature and solar radiation is observed and the maximum power is tracked using developed algorithm. A model to predict a maximum power with certain range of temperature and solar radiation is developed. The maximum power obtained using this model can then be tracked using suitable power electronics converter.

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Raju Wagle received his Bachelor degree in Electrical Engineering from Institute of Engineering, Pulchowk campus in the year 2010 and his master's degree in Electrical Engineering from Narvik University College, Norway in 2015. He is the permanent faculty of Electrical and Electronics Department, School of Engineering, Pokhara University. Besides he is also engaged in an Energy related sector in Nepal.