

Simulink based modeling, simulation and Performance Evaluation of an MPPT for maximum power generation on resistive load

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Abstract--Standalone photovoltaic (SAPV) systems are widely used in remote areas after development of photovoltaic cell industry in recent years. But as the load and insolation conditions vary the efficiency of the PV system decreases. A maximum power point tracker (or MPPT) is a high efficiency DC to DC converter which functions as an optimal electrical load for a photovoltaic (PV) cell, most commonly for a solar panel or array, and converts the power to a voltage or current level which is more suitable to whatever load the system is designed to drive. A PV cell has an exponential relationship between current and voltage, and the maximum power point (MPP) occurs at the knee of the curve. In this work, a MPPT has been proposed which works in conjunction with a power electronic converter to shift the operating point to obtain maximum power from a PV Panel with load and insolation conditions varying. MPPT first tracks the MPP and sets the operating point. The modeling and simulation has been done in Simulink software available with MATLAB. The efficiency of the proposed MPPT has also been evaluated. It has been shown how the efficiency of the system increases when we use MPPT for a resistive load.

Key words – MPPT, photovoltaics, converter

I. INTRODUCTION

The use of new efficient photovoltaic solar cells (PVSCs) has emerged as an alternative measure of renewable green power, energy conservation and demand-side management. Owing to their initial high costs, PVSCs have not yet been a fully attractive alternative for electricity users who are able to buy cheaper electrical energy from the utility grid. However, they have been used extensively for water pumping and air conditioning in remote and isolated areas where utility power is not available or is too expensive to transport. Although PVSC prices have decreased considerably during the last years due to new developments in the film technology and manufacturing process [1], PV arrays are still widely considered as an expensive choice compared with existing utility fossil fuel generated electricity. After building such an expensive renewable energy system, the user naturally wants to operate the PV array at its highest energy conversion output by continuously utilizing the maximum available solar power of the array. The electrical system powered by solar arrays requires special design considerations due to varying nature of the solar power generated resulting

from unpredictable and sudden changes in weather conditions which change the solar irradiation level as well as the cell operating temperature.

II. PV CELL

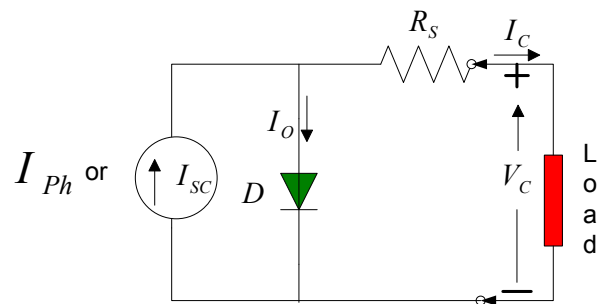


Figure.1. PV cell model

PV generators are neither constant voltage sources nor current sources but can be approximated as current generators with dependant voltage sources. During darkness, the solar cell is not an active device. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generates a current I_D , called diode current or dark current. The diode determines the $i-v$ characteristics of the cell. There are three different models of pv cells generally available. A moderate model of pv cell has been taken in this paper as shown in Figure1. The model consists of a current source (I_{SC}), a diode (D), and a series resistance (R_S). As the effect of parallel resistance R_p is negligible, it been omitted in this model.

III. PV CELL MODEL IN SIMULINK

PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model such as the one given in Fig. 1 and/or by an equation as in (1).[2,6]

$$V_C = \frac{AkT_C}{q} \ln \left(\frac{I_{Ph} + I_O - I_C}{I_O} \right) - I_C R_S \dots\dots(1)$$

Where the symbols are defined as follows:

- e: electron charge (1.602×10^{-19} C).
- k: Boltzmann constant (1.38×10^{-23} J/°K). I_c : cell output current, A.
- I_{ph} : photocurrent, function of irradiation level and junction temperature (5 A).
- I_0 : reverse saturation current of diode (0.0002 A). R_s : series resistance of cell (0.001 Ω).
- T_c : reference cell operating temperature (20 °C).
- V_c : cell output voltage, V.

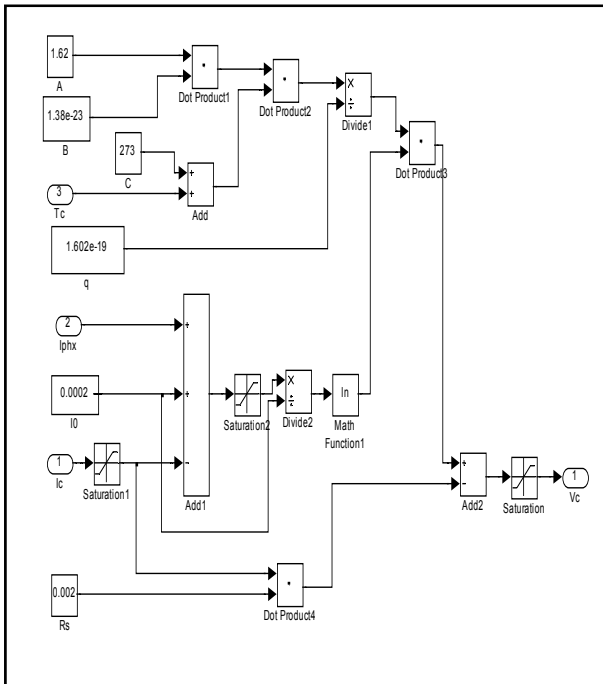


Figure 2

The variable ambient temperature affects the cell output voltage and cell photocurrent. These effects are represented in the model by the temperature coefficients CTV and CTI for cell output voltage and cell photocurrent.

$$C_{TV} = 1 + \beta_T (T_a - T_x) \dots\dots\dots 2$$

$$C_{TI} = 1 + \frac{\beta_T}{S_C} (T_X - T_a) \dots\dots\dots 3$$

Where $\beta_T = 0.004$ and $\lambda_T = 0.06$ for the cell used at 250C.

The change in the operating temperature and in the photocurrent due to variation in the solar irradiation level can be expressed via two constants Csv and Csi.

$$C_{SV} = 1 + \beta_T \alpha_S (S_X - S_C) \dots\dots\dots 4$$

$$C_{SI} = 1 + \frac{1}{S_C} (S_X - S_C) \dots\dots\dots 5$$

Where, S_c is the benchmark reference of solar irradiation level during the cell testing to obtain the modified cell model. S_x is the new level of the solar irradiation. The temperature change, ΔT_C , occurs due to the change in the solar irradiation level and is obtained using

$$\Delta T_C = \alpha_S (S_X - S_C) \dots\dots\dots 6$$

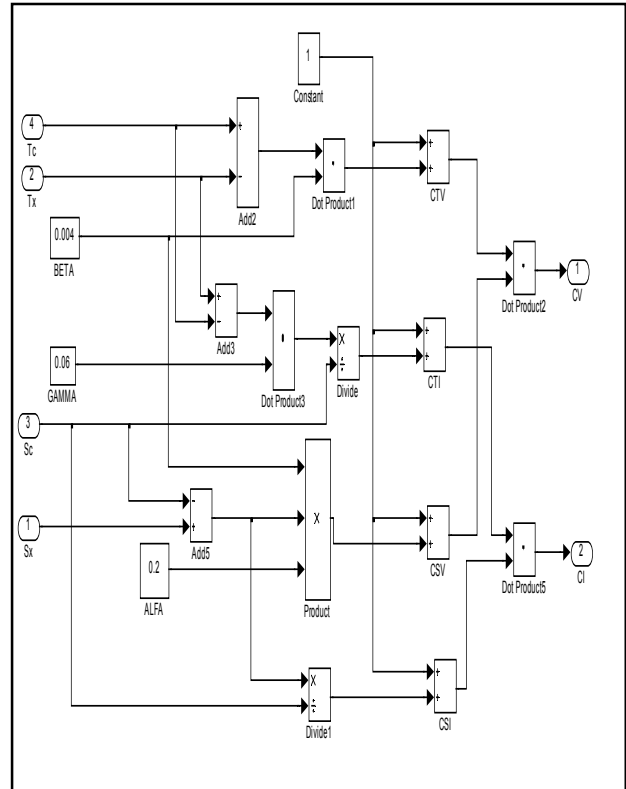


Figure 3

The simulation model of PV array from the PV cell model is presented in section 2.5. The output voltage V_c of the cell is multiplied by the number of the cells in series NSE to obtain the array voltage “Varray”. The no. of series connected cell in the array is given by $NSE = NSM \times NCN$. Where NSM is no. of series connected module in the array and NCN is the no. of cells in each module.

The simulation model was run for $N_S = 4$, $N_P = 2$ for different solar irradiance and temperature. Figure 4 shows the characteristics of the PV array for different insolation at constant temperature of 25 °C. The characteristics of PV array for different temperature at constant solar irradiation of 100 mW/cm² are shown in Figure5.

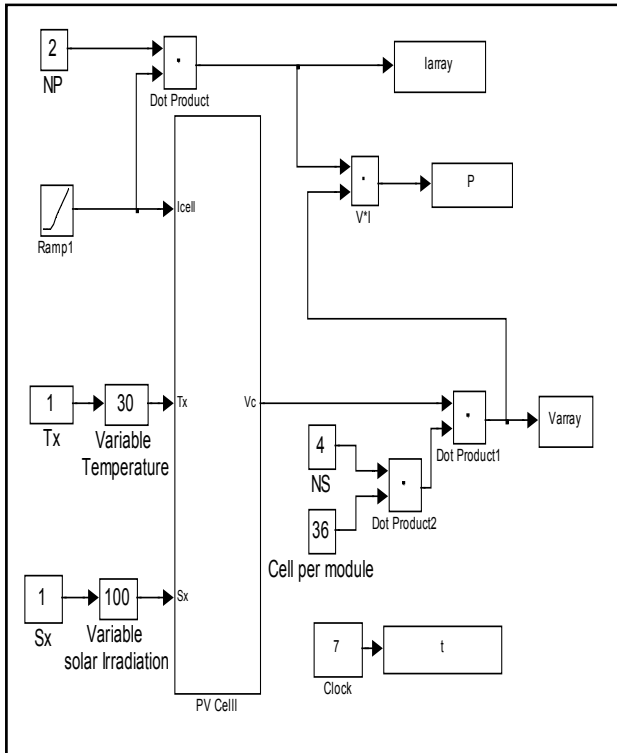


Figure 4

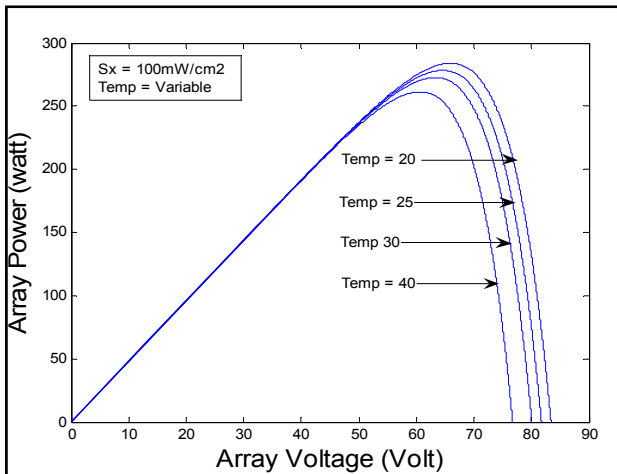


Figure 5

IV. MAXIMUM POWER POINT TRACKER

To make best use of solar PV system, the output is maximized in two ways. The first is mechanically tracking the sun and always orienting the panel in such a direction as to receive maximum solar radiation under changing positions of the sun. The second is electrically tracking the operating point by manipulating the load to maximize the power output under changing conditions of insolation and temperature [1,2,3]. The operating point of an electrical system is determined by the intersection of source

characteristics (source line) and load characteristics (load line). The operation for a solar PV system connected to a resistive load is shown in Figure 7. For a low value of resistance, R1 the system operates at Q1. As the resistance is increased to R2 and then to R3 the operating point moves respectively to Q2 and Q3. Maximum power is available from the PV system for load resistance of R2. Such load matching is required for extracting maximum power from PV system. When a solar PV system is deployed for practical applications, the I-V characteristic keeps on changing with insolation and temperature [2]. In order to receive maximum power the load must adjust itself accordingly to track the maximum power point. The I-V characteristics of PV system along with resistive loads are shown in Figure 6. An ideal load is one that tracks the maximum power point.

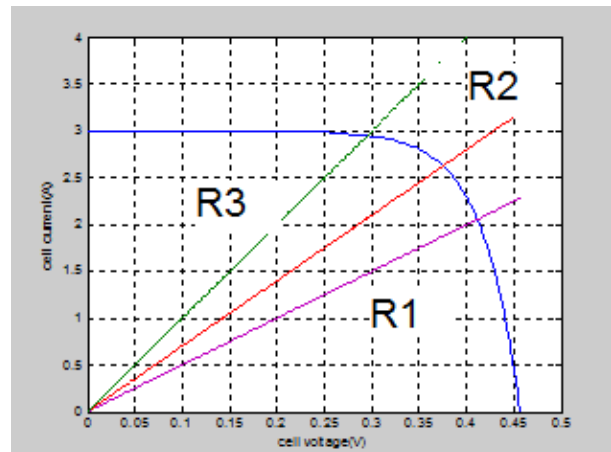


Figure 6

If the operating point departs significantly from maximum power point, it may be desirable to interpose an electronic maximum power point tracker (MPPT) between PV system and load. A maximum power point tracker is a high efficiency DC to DC converter which functions as an optimal electrical load for a photovoltaic (PV) cell, most commonly for a solar panel or array, and converts the power to a voltage or current level which is more suitable to whatever load the system is designed to drive.

The power output of a PV system is given by:

$$P = V.I \quad (3)$$

With incremental change in current and voltage, the modified power is given by:

$$P + \Delta P = (I + \Delta I).(V + \Delta V) \quad (4)$$

which, after ignoring small terms simplifies to:

$$\Delta P = \Delta V.I + \Delta I.V \quad (5)$$

ΔP must be zero at peak point. Therefore, at peak point the above expression in the limit becomes:

$$\frac{dV}{dI} = -\frac{V}{I} \quad (6)$$

It may be noted here that $\frac{dV}{dI}$ is the dynamic impedance of the source, which is required to be equal to negative of static impedance, $\frac{V}{I}$.

There are three possible strategies for operation of an MPPT:

- (i) **By monitoring dynamic and static impedances:** A small signal current is periodically injected into the array bus and the dynamic as well as static bus impedances (Z_d and Z_s respectively) are measured. The operating voltage is then adjusted until the condition $Z_d = -Z_s$ is achieved.
- (ii) **By monitoring power output:** From the shape of P-V characteristic given in Figure 6, it is clear that the slope, dP/dV is zero at maximum power point. This property is utilized to track the maximum power point. Voltage is adjusted and power output is sensed. The operating voltage is increased as long as dP/dV is positive. That is, voltage is increased as long as we get increased output. If dP/dV is sensed negative, the operating voltage is decreased. The voltage is held unaltered if dP/dV is near zero within a preset dead band.
- (iii) **By fixing the output voltage as a fraction of V_{oc} :** This method makes use of the fact that for most PV cells the ratio of the voltage at maximum power point to the open circuit voltage, is approximately constant (say k). For high quality crystalline silicon cell $k = 0.72$. An additional identical unloaded cell is installed on the array to face same environment as the module in use, and its open circuit voltage V_{oc} is continuously measured. The operating voltage of the array is then set at $k.V_{oc}$. The implementation of this scheme is simplest among all the available schemes. [3]

V. SIMULINK MPPT MODEL

In this work, a MPPT has been proposed which works in conjunction with a power electronic converter to shift the operating point to obtain maximum power from a PV Panel under varying load and insolation conditions. MPPT first tracks the MPP and sets the operating point. The modelling and simulation has been done in Simulink software available with MATLAB..

VI. COMPARISON OF TWO SIMULINK MODEL TO SHOW WORKING OF AN MPPT

The pv model is directly coupled to a resistive load in fig 7 and by varying the resistance output power is recorded.

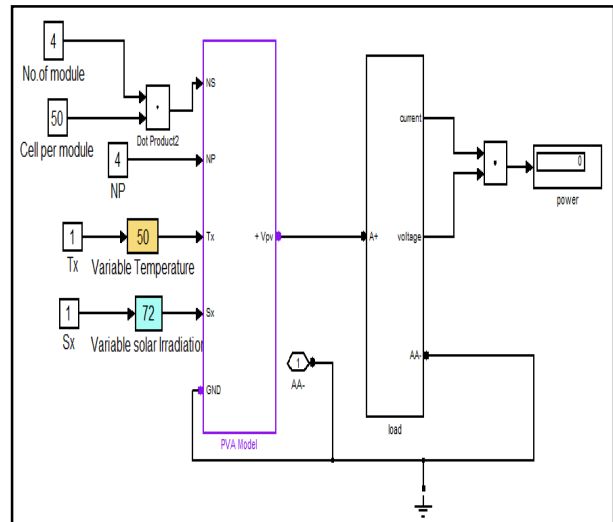


Figure 7

Simulation was carried out upto 20 seconds for $N_s=4$, $N_p=4$, insolation (S_x) = 72W/CM², temperature (T_x) = 500C for different value of resistance. The result is tabulated in Table 5.1. It is seen that it gives maximum power for 4.1 ohms.

TABLE-1 $N_s=4$, $N_p=4$, $S_x=72W/CM^2$, $T_x=50^0C$

S.NO	RESISTANCE(OHMS)	LOAD POWER(WATTS)
1	1	214.7
2	2	425.9
3	3	605.2
4	4	673.5
5	4.1	673.6
6	4.2	672.7
7	4.5	665.9
8	5	644.9

The pv model is connected to an mppt and then to a resistive load is shown in fig 8.

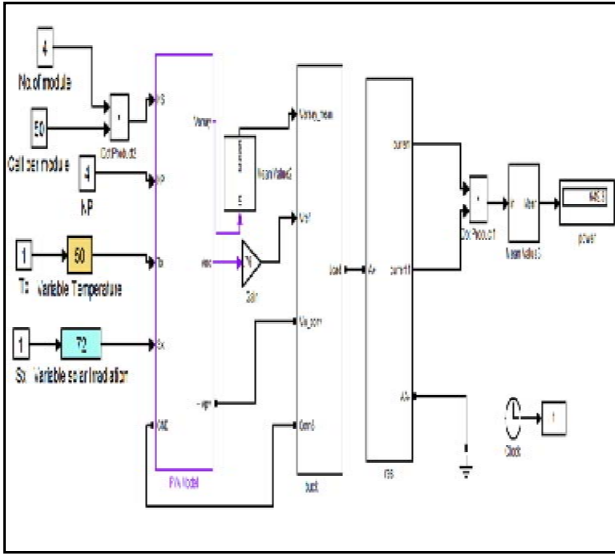


Figure-8

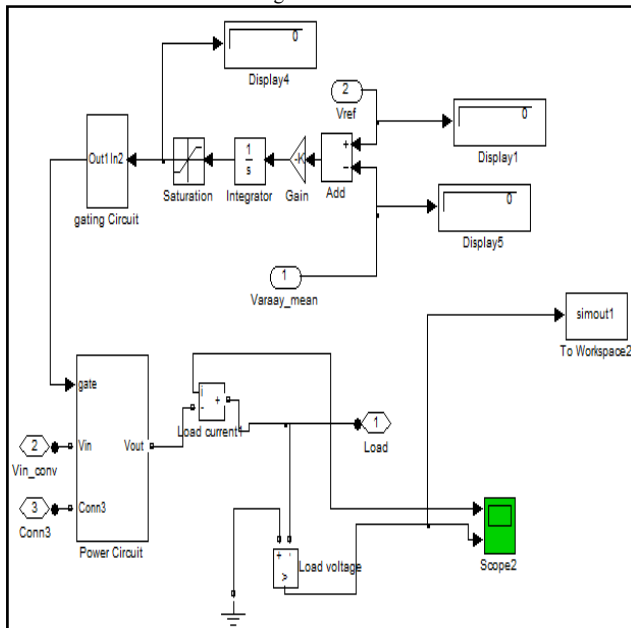


Figure-9

Simulation was carried out upto 20 seconds for $N_s=4$, $N_p=4$, insolation (S_x) = 72w/cm^2 , temperature (T_x) = 500C for different value of resistance. The results are tabulated below in the Table 5.2. Following observations may be made from the results obtained.

TABLE 2

$N_s = 4$, $N_p = 4$, $S_x = 72\text{w/cm}^2$, $T_x = 30^\circ\text{C}$

S.NO	RESISTANCE (OHMS)	POWER(WATTS)
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1	1	613.2
2	2	638.4
3	3	652.2
4	4	658.5
5	4.1	658.6
6	4.2	657.2
7	4.5	649.3
8	5	627.4
9	6	623.2

The above simulink model of an mppt shows that when rating of the load is greater than the supply then mppt comes into play and draws maximum power from the supply (PV ARRAY) and when rating of the load is less than supply then mppt does not come into play and whole of the supply voltage is transferred to the load.

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