Simplified PV Module Simulator With MPPT

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Abstract:

This project proposes a simplified PV module simulator with MPPT. The PV model is designed in Matlab/Simulink based on various mathematical equations. This paper explains the use of MPPT technique in a photovoltaic system. The MPPT is implemented by incremental conductance or perturbation and observation methods. The overall system is designed, developed and validated by using MATLAB/SIMULINK

Keywords: Modeling, Photovoltaic Cell, MPPT, DC-DC Converters, MATLAB/Simulink

I. INTRODUCTION

The field of photovoltaic (PV) solar energy has experienced a remarkable growth for past two decades in its widespread use from stand alone to utility interactive (PV) systems. A photovoltaic (PV) system directly converts sunlight into electricity. The obtained energy depends on solar radiation, temperature and the voltage produced in the photovoltaic module. The voltage and current available at the terminals of a PV device may directly feed small loads. More sophisticated applications require electronic converters to process the electricity from the PV device [1], [2], [3], [4], [5], [14]. Unfortunately PV systems have two major problems: the conversion efficiency of electric power generation is very low (9—17%), especially under low irradiation conditions, and the amount of electric power generated by solar arrays changes continuously with weather conditions. Moreover, the solar cell V-I characteristic is non linear and varies with irradiation and temperature. In general, there is a unique point on the I-V or P-V characteristic, called maximum power point (MPP), at which the entire PV system (array, converter, etc…) operates with maximum efficiency and produces its maximum output power. Therefore maximum power point tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP. Many MPPT techniques have been proposed in literature, these techniques vary between them in many aspects, including simplicity, convergence speed, hardware implementation, sensors required, cost range of effectiveness and need for parameterization. Perturb and observe is the technique to be used in this paper, [10], [11].

II. SOLAR CELL MODELING

Solar cells consist of a p-n junction fabricated in thin wafer or layer of semiconductors, whose electrical characteristics differ very little from a diode represented by the equation of Shockly [1], [2] ,[3], [4]. Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode as shown in fig. 1. The output of the current source is directly proportional to the light falling on the cell (photocurrent **Ipv, cell**) .So the process of modeling this solar cell can be developed based on equation (1)
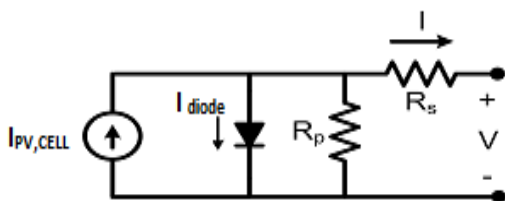

Fig 1. Equivalent Model for a Photovoltaic Cell

$$I = I_{PV,CELL} - I_{diode} = I_{PV,CELL} - I_{0,CELL}\left[\exp\left(\frac{q*V}{\alpha*k*T}\right) - 1\right] \quad (1)$$

$IPV,cell$ is the current generated by the incident light

$Idiode$ is the Shockley diode equation

$I0,cell$ [A] is the reverse saturation or leakage current of the diode [A].

q is the electron charge [1.60217646 · 10-19C].

k is the Boltzmann constant [1.3806503 · 10- 23J/K].

T [K] is the temperature of the p-n junction.

is the diode ideality constant which lies between 1 and 2 for monocrystalline silicon.

The basic equation (1) of the elementary PV does not represent the I-V characteristic of practical PV arrays. Practical modules are composed of several connected PV cells requires the inclusion of additional parameters Rs and Rp, with these parameters (1) becomes (2)

$$I = I_{PV} - I_0\left[EXP\left(\frac{V + R_S*I}{Vt*\alpha}\right) - 1\right] - \frac{V + R_S*I}{R_P} \quad (2)$$

The light-generated current of the module depends linearly on solar irradiation and is also influenced by temperature according to (3).

$$I_{PV} = (I_{PV,n} + K_I\Delta T)\frac{G}{G_n}$$

Where KI is the Temperature coefficient of ISC, G is the irradiance (W/m²) and Gn is the irradiance at standard operating conditions. The diode saturation current $I0$ dependence on temperature can be expressed as shown in (4).

$$I_0 = I_{0,n}\left(\frac{T_n}{T}\right)^3 EXP\left[\frac{q*E_g}{\alpha*k}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \quad (4)$$

Eg is the band gap energy of the semiconductor and $I0,n$ is the nominal saturation current expressed by (5)

$$I_{0,n} = \frac{I_{SC,n}}{\left[EXP\left(\frac{V_{OC,n}}{V_{t,n}*\alpha}\right) - 1\right]} \quad (5)$$

From (4) and (5) $I0$ can be expressed as shown in (6).

$$I_0 = \frac{I_{SC,n} + K_I \Delta T}{EXP\left(\frac{V_{OC,n} + K_V \Delta T}{V_t * a}\right) - 1} \qquad (6)$$

Where *VOC,n* is open circuit voltage ,*ISC,n* is the short circuit current , *Vt,n* is the thermal voltage , *Tn* is the temperature at standard operating conditions. *Vt* = Ns**kT/q* is the thermal voltage of the module with Ns cells connected in series.

III. PHOTOVOLTAIC MODULE

A. Photovoltaic Module Characteristics

MSX-50 solar array PV module is chosen for a MATLAB simulation model. The module is made of 36 multi-crystalline silicon solar cells in series and provides 50W of nominal maximum power. Table 1 shows its electrical specification from data sheet.

TABLE 1. ELECTRICAL CHARACTERISTICS DATA OF THE MSX-50 SOLAR AT 25 °C, 1.5AM, 1000W/M2. TAKEN FROM THE DATASHEET

Electrical Characteristics	
Maximum Power (Pmax)	50W
Voltage at Pmax (Vmp)	17.1V
Current at Pmax (Imp)	2.92A
Open-circuit voltage (Voc)	21.1V
Short-circuit current (Isc)	3.17A
(K_I)Temperature coefficient of Isc	(0.0032±0.015)%/°C
(K_V) Temperature coefficient of Voc	– (80±10)mV/°C
NOCT	47±2°C

Fig.2 shows the modeling circuit of the PV module by Matlab/simulink. The modeling of the PV is done applying the equations seen before, (1),(2),(3),(4),(5) and (6) .Irradiance and temperature are the inputs of the system. In fig. 3 the three remarkable points *Voc=21.1V, Isc=3.17A* and maximum power point (Pmax=50W,*VMP* =17.1V, *IMP* =2.92A) are shown

and are identical to the values given by the datasheet. Shows the effect of irradiance variation (1000, 800, 600,400) w/m2 at constant temperature (T=25° C) on V-I and P-I characteristics respectively where results are much closed to the real data. In fig. 7 the simulation results are shown for different values of temperature (T=25° C, T=50 ° C, T=75° C).
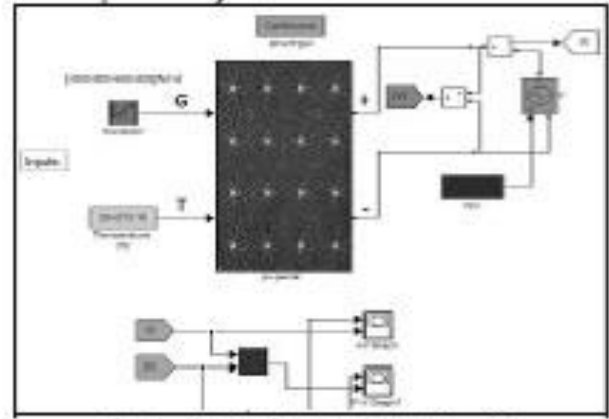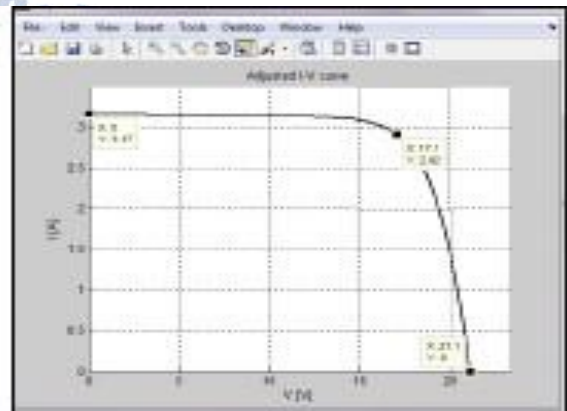

Fig. 2. PV Module Model in Simulink

Fig. 3. I-V Characteristics at T=25° C, Irradiance 1000W/M2 By Simulink.

IV. MAXIMUM POWER POINTING TRACKING

When a PV module is directly connected to a load, see fig. 4, the PV module's operating point will be at the intersection of its I-V characteristic and the load line which is I-V relationship of the load [11]. In general this operating point is not at the PV array's MPPT.
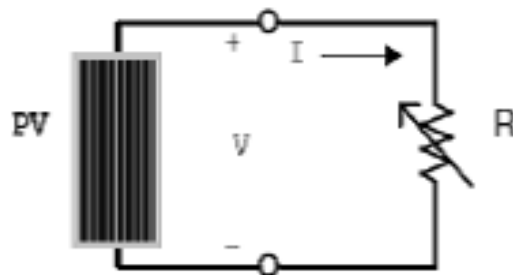

Fig 4. Direct Coupled Resistive Load

Thus in a direct-coupled system, the PV array must usually be oversized to ensure that the load's power requirements can be

supplied. This lead to an overly expensive system. To overcome this problem, a switch-mode power converter, as shown in fig. 5, can be used to maintain the PV's operating point at the MPP. The MPPT does this by controlling the PV array's voltage or current independently of those of the load. However, the location of the MPP in the I-V characteristic is not known a priori. It must be located, either through model calculation or by search algorithm. The situation is further complicated by the fact that the MPP depends in a nonlinear way of irradiance and temperature [12].
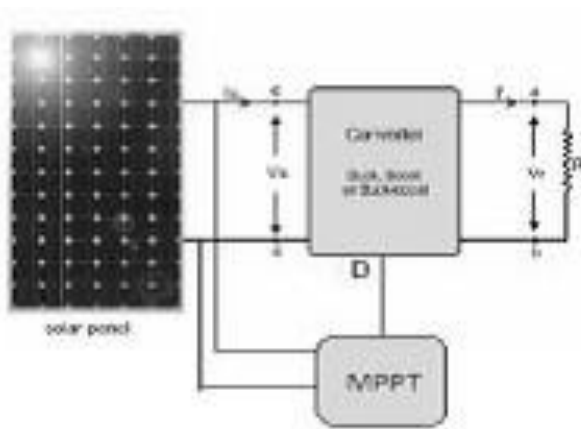

Fig.7. Simulation results for proposed circuit

Fig 5. Standalone PV System with Power Converter and MPPT Control

Fig.8. Simulation results for proposed circuit

V. SIMULATION MODEL AND RESULTS

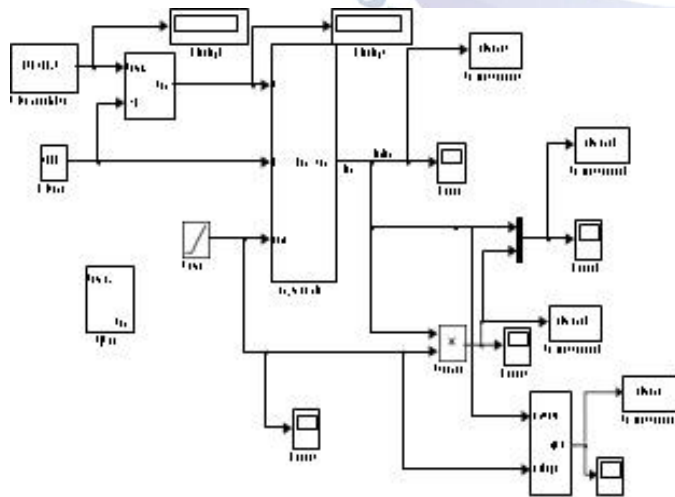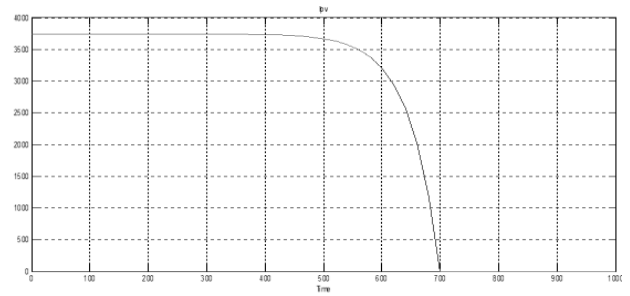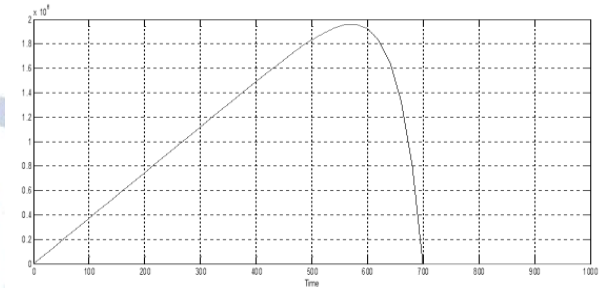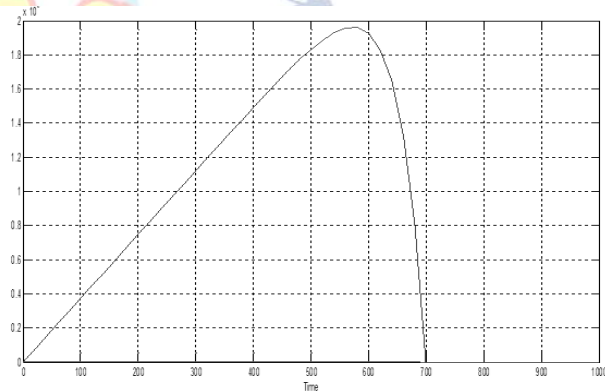Fig.9. Simulation results for proposed circuit
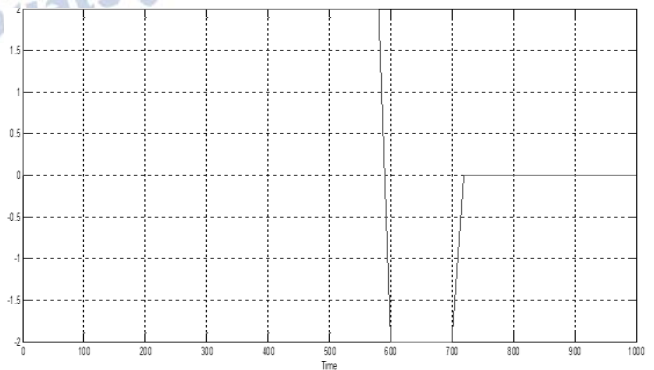

Fig 6. Simulink Model for Proposed Circuit

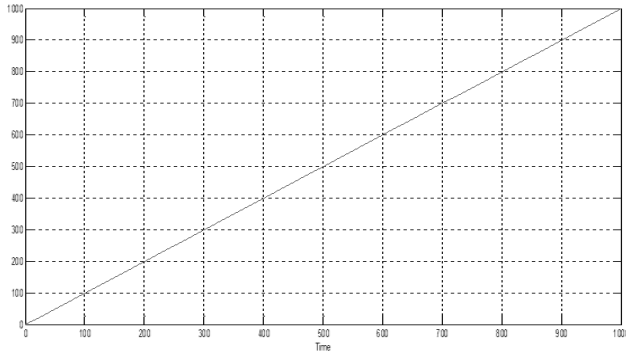Fig.10. Simulation results for proposed circuit

Fig.11. Simulation results for proposed circuit

VI. CONCLUSION

The design and modeling of PV module is obtained in MATLAB/SIMULINK based on mathematical equations. The design consists of PV model block and MPPT block. The simulation results for voltage, current and power is obtained.

REFERENCES

[1] Ramos Hernanz, JA. Campayo Martin,JJ. Zamora Belver,I., Larranga Lesaka,J. , Zulueta Guerrero,E. p―Modeling of photovoltaic module‖, International Conference on Renewable Energies and Power Quality (ICREPQ'10) Granada (Spain), 23th to 25th March, 2010.

[2] Francisco M. González-Longatt, ―Model of photovoltaic Module in Matlab™‖, (II CIBELEC 2005).

[3] Huan-Liang Tsai, Ci-Siang Tu, and Yi-Jie Su, Member, IAENG, ―Development of generalized photovoltaic model using MATLAB /SIMULINK‖, Proceedings of the World Congress on Engineering and Computer Science 2008,WCECS 2008, October 22 - 24, 2008, San Francisco, USA .

[4] M.G. Villalva, J.R. Gazoli and E.R. Filho, ―Comprehensive approach to modeling and simulation of photovoltaic array‖, IEEE Trans on Power Electronics, Vol. 24, n°5, pp. 1198-1208,May 2009 .

[5] Savita Nema, R.K.Nema, Gayatri Agnihotri, ―Matlab / simulink based study of photovoltaic cells / modules / array and their experimental verification‖, International Journal of Energy and Environment, Volume 1, Issue 3, 2010 pp.487-500.

[6] S. Rustemli, F. Dincer, ―Modeling of photovoltaic panel and examining effects of temperature in Matlab/Simulink‖ Electronics and Electrical Engineering, ISSN 1392 – 1215, 2011. No. 3(109).

[7] Sera, Dezso, Teodorescu, Remus and Rodriguez, Pedro, ―PV panel model based on datasheet values,‖ International Symposium on Industrial Electronics, 2007. ISIE 2007. IEEE, November 2007,pp. 2393 - 2396.

[8] Syafrudin Masri, Pui-Weng Chan, ―Development of a microcontroller-based boost converter for photovoltaic system‖, European Journal of Scientific Research ISSN 1450-216X Vol.41 No.1 (2010), pp.38-47 ©

[9] Matlab and Simulink, The Math works, Inc. as of September 2010, http://www.mathworks.com.

[10] D.P Hohm and M.E. Ropp, ―Comparative study of maximum power point tracking algorithms‖, Progress in Photovoltaic: Research and Applications, 2003, 11:47-62.

[11] Manoj Kumar, F. Ansari, A.K. Jha ―Maximum power point tracking using perturbation and observation as well as incremental conductance algorithm‖,IJREAS , ISSN 2294-3905, Vol.1,Issue 4 (2011), pp.19-31.

[12] Pandiarajan N., Ramaprabha R., Ranganath Muthu, ―Application of circuit model for photovoltaic energy conversion systems‖, research article.

[13] Vikrant A. Chaudhari, ―Automatic peak power tracker for solar pv modules using dspace software‖, Master thesis.,Maulana Azad National Institute of Technology, Deemed University, 2005.