Pak. J. Biotechnol. Vol. 13 (special issue on Innovations in information Embedded and Communication Systems)
Pp. 261- 264 (2016)

MATHEMATICAL MODELLING OF SOLAR PV PANEL IN MATLAB/SIMULINK FOR THE APPLICATION OF HYBRID POWER SYSTEM

[1]Little Judy, A and [2]J. Karthika

Department of EEE, Sri krishna college of Engg & Tech Coimbatore, India

E-mails: [1]ajudy7@gmail.com; [2] j.kaarthika@yahoo.co.in

ABSTRACT

The physical modeling of the solar system is not that much efficient so the analysis is done through the mathematical modeling approach. The effect of irradiation and temperature is also considered. The PV module is the interface which converts solar light directly into electricity. Modeling this device, mostly requires taking weather data (irradiance and temperature) as input variables. The output parameters can be current, voltage, power or other variables. However, map out the characteristics I(V) or P(V) needs of these three parameters. Any change in the inputs immediately implies changes in outputs. This paper presents a detailed modeling of the effect of irradiance and temperature on the parameters of the solar PV module. Thus, it is important to use an accurate model for the PV module. The analysis is done in MATLAB/ SIMULINK background. This mathematical analysis approach is a so flexible to change the parameters of the system.

Index Terms: *PV Panel, MPPT Controller, Solar Array*

I. INTRODUCTION

Conventional energy sources cannot meet the increasing demand for energy worldwide. So, alter-native renewable energy sources like sunlight, wind fuel cells and biomass come into picture. Among them Photovoltaic energy is a source of interesting energy; it is renewable, limitless and non-polluting, and it is used as energy sources in various applications [1]. But because of its high cost and low efficiency, energy contribution is less than other energy sources. It is therefore important to have effecttive and flexible models, to enable you to perform easy manipulation of specific data (irradiance and temperature) investigate how to get its operation as maximum as possible. The use of these lucid models provides adequate accuracy to analyze the behavior of the solar cell and have proven to be effective in most cases. Solar cells convert solar energy into electrical energy. This observable fact occurs in materials which have the property of capture photon and emit electrons. The most important mate-rial used in the photovoltaic industry is silicon. To conserve our globe, the scientific community gave facts that mankind has to decrease the green house gases emissions, mainly CO_2 and methane, by 60 - 70% as a minimum till 2050 [2]. The main applications of PV systems are in either off grid systems such as water pumping, street lighting, electric vehicles, military and space applications [3-4] or grid- connected configure-tions like hybrid power systems and power plants [5]. The solar light generated current is serve as a constant current source supplying the current to useful load depending on its characteristics and the value of the external load resistance [6]. For the better under standing of the PV module the mathematical model is constantly updated. The output characteristics are of PV module depends on the solar Isolation. the cell Temperature and the Output Voltage of PV Module. The output quantities (Voltage, current and power) vary as a function of irradiation, temperature and phase current. The properties of these three variations are considered in the modeling, so that any alter in the temperature and solar irradiance levels should not badly affect the PV module output. So, some assumptions with respect to the physical properties of the cell beha-vior are necessary to establish a mathematical model of the PV cell and the PV module. The aim of this paper is to present constructive work to those who want to focus their application on the PV module or array as one device in a complicated ‘‘electroenergetic system’’. So, the objective is to obtain at any time, the maximum power but also the more specific, therefore, the nearest to the experimental value.

One of the major concerns in the power sector is the usual increasing power demand but the unavail-ability of ample resources to fit the power demand using the other conventional energy sources. Energy is the prime motivator of economic growth and is vital to the provision of a modern economy. Future economic growth exigently depends on the long-term availability of energy from sources that are modest, accessible and environment. Stipulation has increased for renewable sources of energy to be utilized along with traditional systems to meet the energy demand. Renewable sources like wind power and solar power are the prime energy sources which are being utilized in this regard. The continual use of fossil fuels has induced the fossil fuel deposit to be reduced and has terribly affected the environment depleting the biosphere and cumulatively adding to global war-ming. Solar energy is copiously available that has made it possible to yield it and utilize it properly. Solar energy can be an off-grid generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power remote areas where the availability of grids is very low. Another advantage of using solar energy is the portative operation whenever wherever necessary. In order to manage the present energy crisis one has to develop an systematic manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been vastly reduced in size in the past few years. The development in power electronics and material science has aided engineers to come up very small but powerful systems to hold off the high power demand. The PV module represents the fundamental power conver-sion unit of PV generator system. The output characteristics of PV module depends on the solar irradiance, the cell temperature and output voltage of PV module.

II. OPERATION AND CHARACTERISTICS OF PV OR SOLAR CELLS

A. Principle of Operation of Solar Cell

An array of solar cells transfers solar energy into a usable amount of direct current (DC) electricity. The solar panels are mainly made of semiconductor material and silicon being the most richly used semiconductor. Solar cells are connected in series to raise the output voltage. Similarly, the cells in parallel will yield a higher current. Series connected cells are called as PV modules and the inter-connection series and parallel combination of solar cells is an array**.** The function of solar cells may be described from a PN junction where there are diffusion currents and drift currents for the direct and reverse polarization, respect-tively. Generally, the cells operate in reverse direction so that the current drift is desirable. When the PN junction is exposed to light, photons with energy greater than the gap of energy are absorbed, causing the emergence of electron-hole pairs. These carriers are separated under the influence of electric fields within the junction, creating a current that is propor-tional to the incidence of solar irradiation [7]. The electric field within the semi-conductor itself at the junction between two regions of crystals of different type, called a p-n junction [8, 9]. When the PV cell delivers power to the load, the electrons flow out of the n-side into the connecting wire, through the load, and back to the p-side where the electrons recombine with holes [13].

B. Characteristics of Solar Cell:

Solar cells naturally exhibit a nonlinear I-V and P-V characteristics which vary with the solar irradiation and cell temperature. The typical I-V and P-V characteris-tics of solar cell are shown in figure 1.

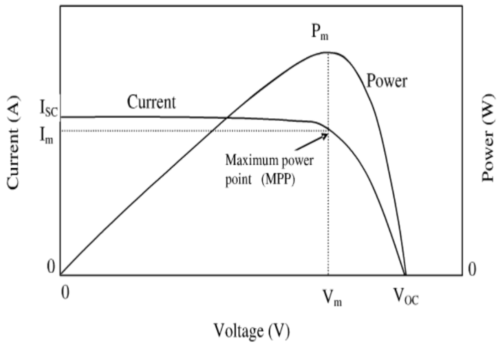

Fig 1. Characteristics of solar cell

The fundamental parameters related to solar cell are short circuit current (*Isc*), open circuit voltage (*Voc*), maximum power point (MPP), efficiency of solar cell and fill factor.

Short Circuit Current is the current corresponds to the short circuit condition when the impedance is low and it is calculated when the voltage equals to zero.

$$I\ (at\ V=0) = Isc \qquad (1)$$

Isc occurs at the beginning of the forward-bias sweep and is the maximum current value in the power quadrant. For an ideal cell, this maximum current value is the total current produced in the solar cell by photon excitation.

Open Circuit Voltage is the voltage when the open circuit occurs and there is no current passing through the cell. The Open circuit voltage is calculated when the voltage equals to zero.

$$V\ (at\ I=0) = Voc \qquad (2)$$

VOC is also the maximum voltage difference across the cell for a forward-bias sweep in the power quadrant. *Voc= Vm* for forward-bias power quadrant.

Maximum Power Point is the operating point at which the power is maximum across the load.

$$Pm = VmIm \qquad (3)$$

where, *Vm* is the maximum voltage and *Im* is the maximum current.

Efficiency of solar cell is the ratio between the maximum power and the incident light power.

III. MODELING OF PV MODULE

A. Presentation of PV Module

The model does not take into account the internal losses of the current. A diode is connected in anti-parallel with the light generated current source. The output current I is obtained by Kirchhoff law:

$$I = Iph - Io \qquad (4)$$

Iph is the photocurrent, Id is the diode current which is proportional to the saturation current and is given by the equation(13)

$$Id = Io[\exp\left(\frac{V}{Æ*Ns*Vt}\right) - 1 \qquad (5)$$

V is the voltage imposed on the diode.

$$Vt = k * \left(\frac{Tc}{q}\right) \qquad (6)$$

Io is the reverse saturation or leakage current of the diode (A), V_{Tc} = 26 mV at 300 K for silisium cell, Tc is the actual cell temperature (K), k Boltzmann constant 1.381 · 10^-23 J/K, q is electron charge (1.602 · 10^-19 C). V_T is called the thermal voltage because of its exclusive dependence of temperature. Ns: is the number of PV cells connected in series. A is the ideality factor. It is necessary to underline that A is a constant which depends on PV cell technology. All the terms by which, V is divided in equation (5) under exponential function are inversely proportional to cell.

B. Solar Array Characteristics

The solar array characteristics profoundly influence the converter and control system, and therefore these will be briefly reviewed here. More generally, the array cell static characteristics, as a function of light intensity and temperature, are given y the equation

$$I = I_{ph} - I_o\{\exp[\frac{q}{(AKT)}(V + I_aR_s)]\} \quad (7)$$

Module saturation current I_0 varies with cell temp.

$I_{sc}=I_{or}[(T/T_r)]^3 \exp[qE_{go}/(BK)\{(1/T_r)-(1/T)\}]$ (8)

solar photo - current

$I_{ph} = [I_{scr} + K_1(T_c - 28)] * G$ (9)

NOMENCLATURE

All the symbols in (1)-(3) can be defined as I Cell output current,

V Cell output voltage,

Io Cell saturation current,

T Cell temperature in K,

K/q Boltzmann's constant divided by electronic charge 8.62 x 10-5 eV/K,

Tc Cell temperature in °C,

K, Short circuit current temperature Coefficient 0.0017 A/°C,

G Solar irradiance (W/m^2),

Iscr Cell sort circuit current at 28°C and 100 m 2.52 A,

Iph Light-generated current,

Ego Band gap for silicon = 1.11 eV, B = A, ideality factors = 1.92,

Tr Reference temperature = 301.18 K,

Ior Saturation current at Tr = 19.9693 x 10-6, Rs Series resistance = 0.001.

IV. HYBRID POWER SYSTEM Variable nature of wind and fluctuating load profiles make the opera-tion of wind based power systems risky, particularly when they operate in Grid connected mode. This paper deals with power control of a Wind and Solar hybrid generation system for interconnection opera-tion with electric distribution system. Power control strategy is to extract the maximum energy available from varying condition of wind speed and solar irradiance while maintaining power quality and Power factor at a satisfactory level. Integration of an Energy Storage System (ESS) into a wind and solar based power system provides an opportunity for better voltage and frequency response, especi-ally during wind, solar and load demand variations. Main Block diagram is shown in Fig.2. Output voltage and current waveform is shown in Fig.3

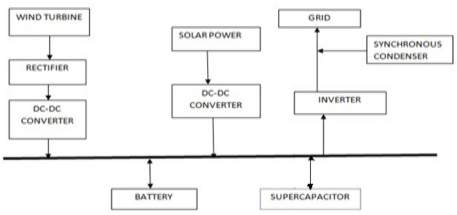

Fig. 2. Block diagram of a Hybrid Power System with grid Interfacing

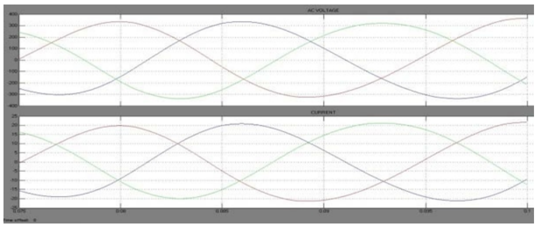

***Fig.3.* Voltage and current waveform of a Hybrid Power system**

V. PANEL MODELING IN SIMULINK

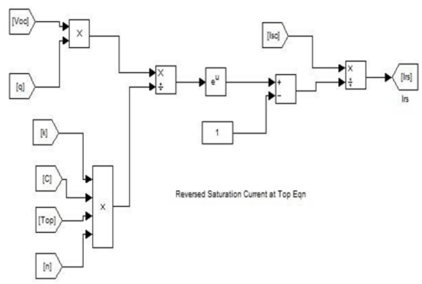

Fig.4 Reverse Saturation Current

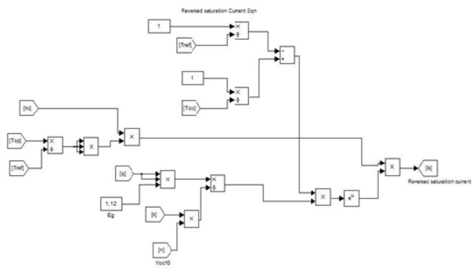

Fig.5 Total Current Equation

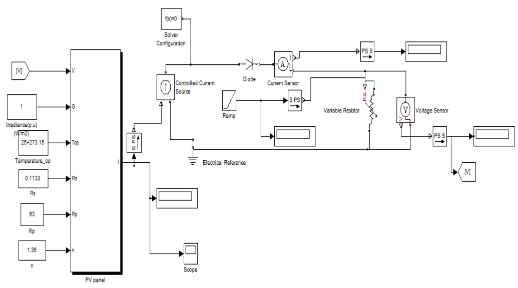

Fig.6 Overall Solar PV Panel Simulink Modeling

VI. SIMULATION RESULTS

The behavior of the proposed PV model has been implemented in Matlab atmosphere [11-12] based on mathematical equations (13-14), (15) & (16) that characterize the photovoltaic module.

The P-V characteristics are at constant irradiation 1000W/m² and at constant temperature 25°C. For the voltage generated if we plot the power develop-ped characteristics by considering power on y-axis and voltage on x-axis then the result curve is shown as in fig 7.

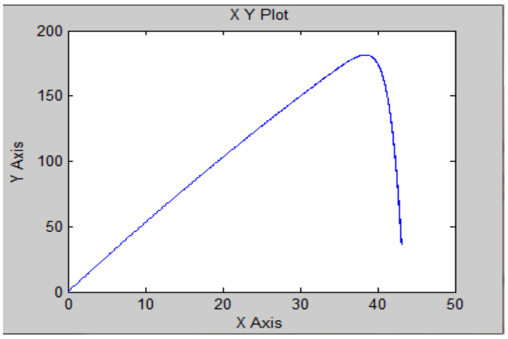

Fig.7 XY plot of PV panel

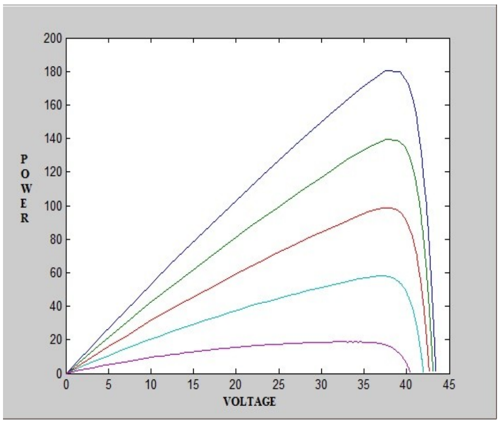

Fig. 8 PV Characteristics for different Irradiant Level

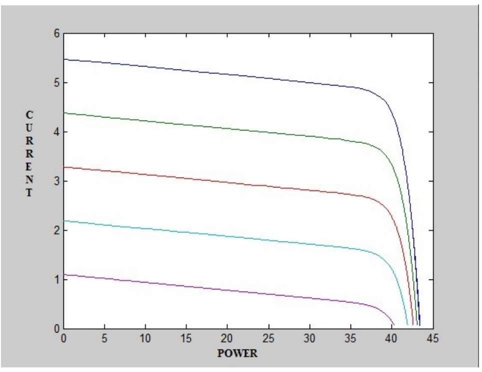

Fig. 9 IV Characteristics for different Irradiant Level

Table-1: ELECTRICAL CHARACTERISTICS DATA OF SOLAR 150W PV PANEL

PARAMETERS	VALUES
POWER	180 W
VPV	45 V
IPV	4.9 A

Table I shows the Power, Voltage and Current for the panel. It achieves the Power of about 180 W

VI. CONCLUSIONS

180-kW residential photovoltaic power conditioner has been described. It is very difficult to change the parameters of the present module in the case of physical modeling. But by analyzing the circuit with the help of mathematical model it is very beneficial to verify required parameters just by changing values. Similarly the I_V and P-V characteris-tics are observed for different irradiations and differ-rent temperatures. Photovoltaic solar plays an important role in the renewable energy domain. With the growing PV sector, it has become crucial to focus on the power conditioning for PV solar. The power conditioning unit required for a PV solar system depends upon the scale of deployment, requirements such as efficiency, reliability, flexi-bility and control. A Matlab software model for the PV panel, module and array was deve-loped and presented in this paper.

ACKNOWLEDGMENT

The authors would like to thank the management of Sri Krishna college of Engineering and Technology for their encouragement and support.

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