International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.4, July-Aug. 2012 pp-2668-2671 ISSN: 2249-6645

Simulink Based Model of Photovoltaic Cell

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ABSTRACT: *The potential for solar energy as a sustainable source of energy is well understood. With the ever increasing use of solar power the necessity of a model is accentuated. The aim of this work is to study the variation of PV module main characteristic parameters as a function of shading, with a special attention to the relationship between output power lowering due to shading.*

Keywords*: pvc, mppt, solarex*

I. INTRODUCTION

India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. [1]From an energy security perspective, solar is the most secure of all sources, since it is abundantly available. The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible. To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.[1]

II. SOLAR INSOLATION IN INDIA

With about 300 clear sunny days in a year, India's theoretical solar power reception, just on its land area, is about 5 PWh.[1] The daily average solar energy incident over India varies from 4 to 7 kWh/m^2 with about 2,300–3,200 sunshine hours per year[1]. This is far more than current total energy consumption. For example, even assuming 10% conversion efficiency for PV modules, it will still be thousand times greater than the likely electricity demand in India by the year 2015[1]

III. PHOTOVOLTAIC MODULES

Solar cells consist of a p-n junction fabricated in a thin wafer or layer of semiconductor.[2] In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode.[2] .PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of PV module depends on the solar insolation, the temperature and output voltage of PV module.[2] Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications.

IV. PHOTOVOLTAIC SOLAR CELL MODELS IN REVERSE BIAS

In order to describe the electrical behavior of a solar cell, in light and darkness, the one diode model and the two diodes model, derived from physical characteristics of solar cells, are commonly used.[2] When investigations on hot spot phenomena and mismatch in photovoltaic cells association have become interesting, these models have been reviewed to deal with the reverse characteristics, when solar cells are working in reverse bias. One of the first approaches modifies the one diode model with the assumption that the avalanche multiplication affects mainly the direct current. The mathematical model of the solar cell taking into account the effect of breakdown voltage is given by the equation.

$$I = \left(I_{ph} - I_o \cdot \left(\exp\left(\frac{V}{mV_t}\right) - 1\right)\right) M(V) - \frac{V}{R_p} \quad (1)$$

Where the multiplication factor M(V) denotes the effect of the avalanche effect.[5,6] The expression of M(V) is:

$$M(V) = \frac{1}{\left(1 - \left(|V|/V_b\right)^n\right)} \quad (2)$$

where Vb is the breakdown voltage in reverse bias and n is the Miller constant. Figure 1 shows the electrical equivalent circuit including the effect of M(V) modelled by a controlled current source. Bishop[7] proposed an equation where the avalanche effect is expressed as a non-linear multiplication factor that affects the shunt resistance current term. The proposed model is given by Equation (3) and the corresponding equivalent circuit is shown in Figure 2.

$$I = I_{ph} - I_o\left[\exp\left(\frac{V + R_s I}{mV_t}\right) - 1\right] - \left(\frac{V + R_s \cdot I}{R_p}\right)\left[1 + a\left(1 - \frac{V + R_s I}{V_b}\right)^{-n}\right] \quad (3)$$

where Vb is the breakdown voltage, a and n are constants. The additional term, E(V), is added to the leakage current into the shunt resistance term modeled as a controlled current source:

$$E(V) = 1 + a\left(1 - \frac{V + IR_s}{V_{br}}\right)^{-n} \quad (4)$$

V. SIMULINK BASED MODEL FOR PV MODULE

The mathematical PV models used in computer simulation have been built for over the pass four decades [6]-[8]. Almost all well-developed PV models describe the output characteristics mainly affected by the solar insolation, cell temperature, and load voltage. Most of the above models do not take into account the effects of shading on the PV characteristics.

We have chosen the Matlab/Simulink[12]environment to study the effects of shadowing in PV module performance because Matlab is today a universal tool for mathematical applications and has been used before in PV systems' simulation and solar cell parameters' extraction with success.[13,14]

The I–V characteristic simulation, in Matlab/ Simulink environment, of a photovoltaic module under different shadow rates was carried out using Bishop's model described in the previous section. The Solarex MSX60 PV [Table 1]module under study is formed by 36 serially connected solar cells and one of the solar cells is assumed to be shaded with variable rate of shadow: α (0≤ α ≤1) We consider that a full shadow corresponds to α =0 whereas α =1 indicates no shadow present on the solar cell. The PV module output voltage is the sum of voltages generated across the individual cells, illuminated and shaded:

$$V = \sum_{i=1}^{35} V_{\text{ill\_cell}} + V_{\text{sh\_cell}} \qquad (5)$$

where Vis the total PV module voltage, and V_{ill}_cell and V_{sh}_cell are the voltages across the illuminated cells and the shaded one, respectively. The current through all the cells is the same:

$$I = I_{\text{ill\_cell}} = I_{\text{sh\_cell}} \qquad (6)$$

where I is the current through the PV module, Iill_cell and Ish_cell are the currents through the illuminated cells and the shaded one, respectively.The following expression, obtained from Equation (3) for the simulation of the I–V characteristic of the PV module has been used:[3]

$$V = \frac{R_p}{E(V)}\left[I_{ph} - I_o\left(\exp\left(\frac{V + R_s I}{mV_t}\right) - 1\right)\right] - I\left(\frac{R_p + E(V)R_s}{R_p}\right) \qquad (7)$$

The same equation is governing the shaded cell with the assumption that the photogenerated current is proportional to the rate of shadow denoted by a. Thus the expression of the photogenerated current at the shaded cell is given by[7]

$$I_{ph} = I_{sco} \cdot \frac{\alpha \cdot \Phi}{\Phi_N} \qquad (8)$$

where Φ_N and Φ are the standard and incident irradiance, respectively.

The output power of the whole PV module is always less than the sum of the values of the individual power cells due to dispersion of the parameters. These losses are accentuated in the case of partial or full shadow of one or several cells serially connected to form the PV module. We have tried to report the amount of power lowering due to shadow effect. The power loss is given by the following expression

$$\text{Power loss } (\%) = \frac{P_{\max\_unsh} - P_{\max\_sh}}{P_{\max\_unsh}} \times 100 \qquad (9)$$

where Pmax_unsh and Pmax_sh, are respectively the maximum powers corresponding to the unshaded cells of the PV module and the shaded one. A single solar cell totally shaded does not cause a significant maximum power loss; it is less than 10% at lower irradiation. Therefore, the power losses increase with increase of irradiation and shadow rate.

VI. CONCLUSION

An attempt has been made to model a photo voltaic cell under the influence of shadow. The proposed model is found be showing appreciable results in comparison with the data being supplied by the manufacturer It can also be applied to study the reverse characteristics of shadowed solar cells forming part of the PV module. The reduction in the output power of a PV module due to shadowing has been evaluated taking into account the influence of irradiance level and the shadow rate over a cell of the PV module.

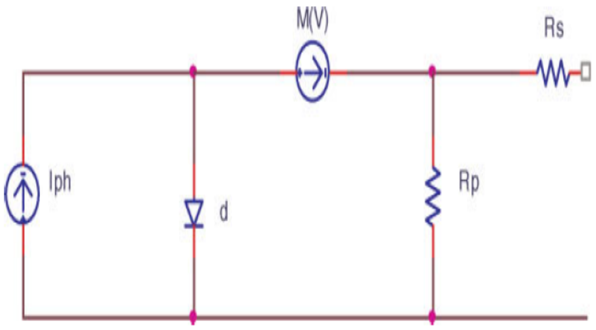

Figure 1: Solar cell equivalent circuit considering the avalanche effect

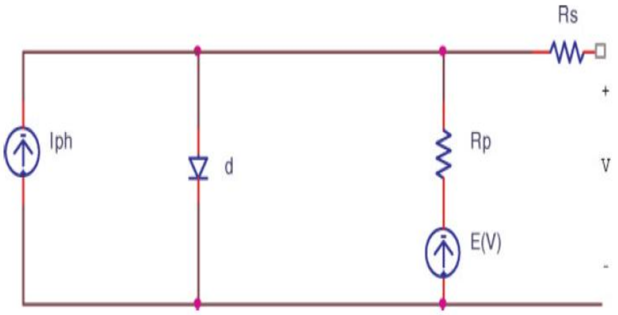

Figure 2: Bishop's equivalent circuit

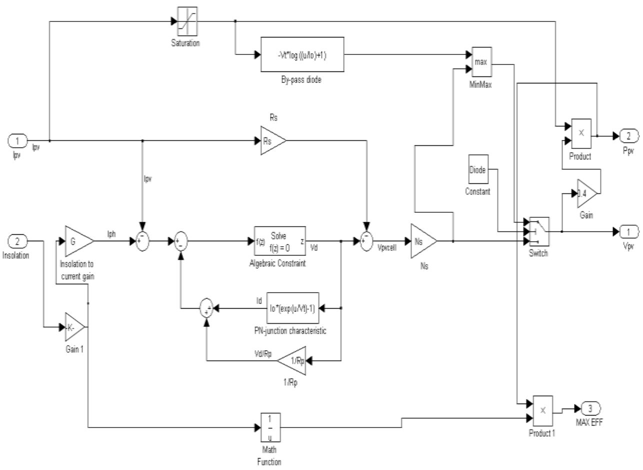

Figure 3: A part of Simulink block used in simulation

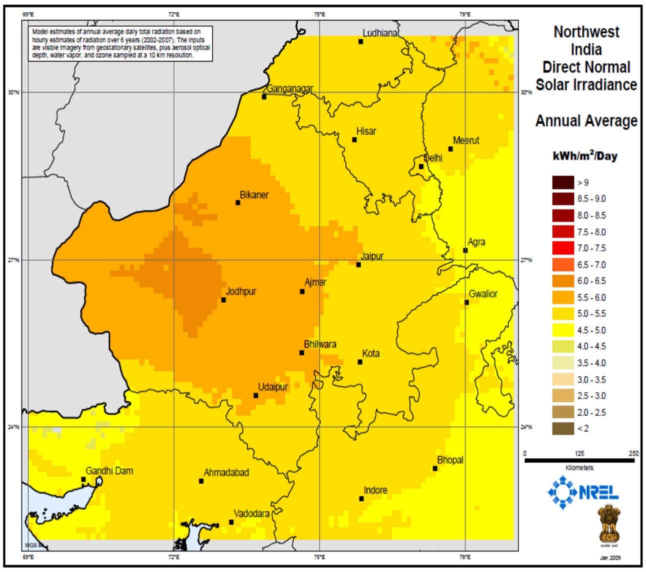

Figure 4: NW India Direct Normal Solar Irradiance Annual Average [16]

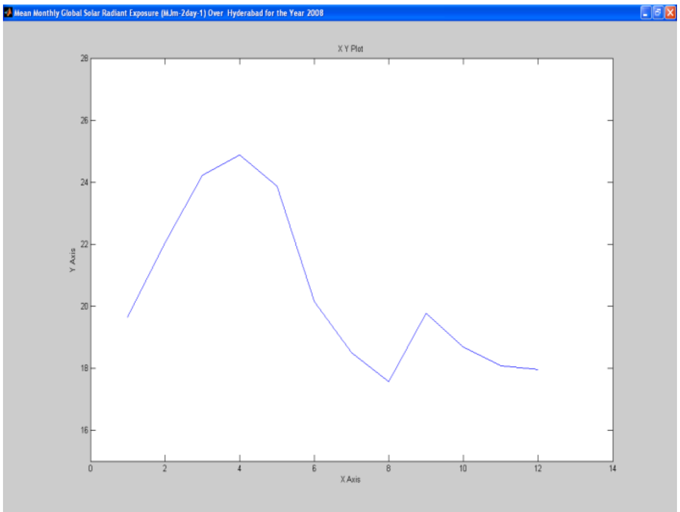

Figure 4: Monthly mean irradiance for Hyderabad[16]

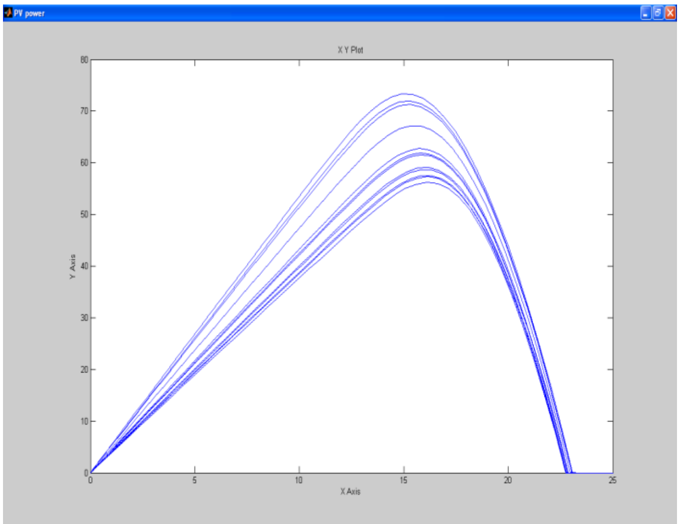

Figure 6 :P-V characteristics of the photovoltaic cell under different isolation

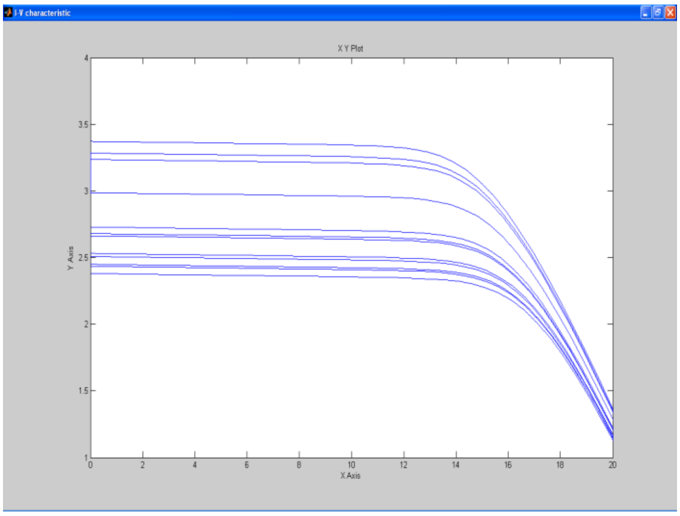

Figure 7 :I-V characteristics of the photovoltaic cell under different isolation

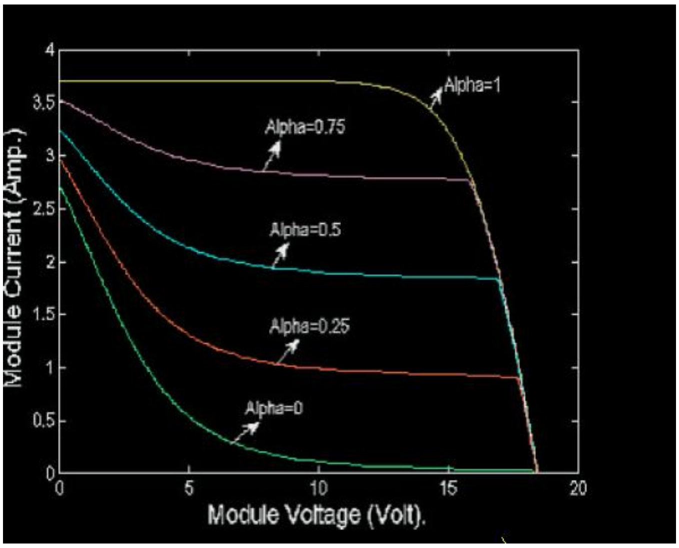

Figure 8 :I–V characteristics of the photovoltaic cell under shadow

Solarex MSX 60 Specifications (1kW/m^2, 25°C)

Characteristics	SPEC.
Typical peak power (P_p)	60W
Voltage at peak power (V_{pp})	17.1V
Current at peak power (I_{pp})	3.5A
Short-circuit current (I_{SC})	3.8A
Open-circuit voltage (V_{OC})	21.1V
Temperature coefficient of open-circuit voltage	-73mV/°C
Temperature coefficient of short-circuit current (K_I)	3mA/°C
Approximate effect of temperature on power	-0.38W/°C
Nominal operating cell temperature (NOCT)	49°C

Table 1; Specifications of solarex MSX 60

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