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A Review on the Basic Mathematical Modeling of A Solar PV Module

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ABSTRACT

The world demand of power is ever increasing and with the new technological advancement new products and equipments are daily being launched in market. Electrical or Electronics products needs power to run that power which was till today created from conventional energy resources are fast depleting now. Now the need of the time is to make arrangements for alternative power sources and optimize their usefulness before our conventional energy resources gets exhausted. Two of the most promising and abundantly available resources are Wind and Solar. The challenge is get various new techniques so that maximum power could be extracted from them. In here we would try to model a mathematical power of a solar module so it's working could be better understood.

Keywords— Renewable Energy Systems, Solar Photo Voltaic,parallel and series equivalent form of solar module.

I INTRODUCTION

Now when a Hardware module is studied in its equivalent mathematical form various aspects are their which needs to be taken into consideration. Like a solar module has arrangements like series and parallel connection when current rating high is needed array parallel connection is preferred and when large voltage rating is required. Now since the cell which makes a large array when grouped in various forms. Now materials have their resistances also which comes into consideration when their equivalent form is taken for analysis. Now given here given is an equivalent mathematical for of a solar cell.

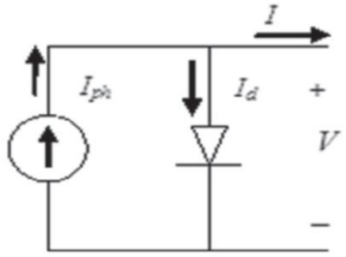

Figure 1

The given model is made such that internal losses are not considered. So applying Kirchhoff law we get the following current relation that is:

$$I = I_{ph} - I_d \qquad (1)$$

$$I = I_o\left[\exp\left(\frac{V}{A.N_s.V_T}\right) - 1\right] \qquad (2)$$

I_{ph} is the photo-current, I_d is the diode current which is proportional to the saturation current. V is the voltage imposed on the diode.

$$V_T = k.{T_c}/{q} \qquad (3)$$

I_o is the reverse saturation or leakage current of the diode. 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. V is the voltage imposed on the diode. Ns: is the number of PV cells connected in series. A is the ideality factor. It depends on PV cell technology.

Technology	Ideality factor
Si-mono	1.2
Si-poly	1.3
a-Si-H	1.8
a-Si-H tandem	3.3
a-Si-H triple	5
cdTe	1.5
CTs	1.5
AsGa	1.3

Table 1

$$a = A.N_s.k.{T_c}/{q} \qquad (4)$$

We are using this equivalent representation for variation in thermal voltage.

II MODEL OF A SOLAR MODULE USING PARAMETERS

A practical model of a solar cell can be made considering both series and parallel resistance into consideration. It is impossible to make equivalent model with resistances as they are driving factors on internal losses during working.

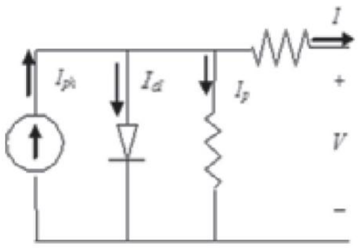

Figure 2

Considering series resistance only eqn. 2 gets modified to the form:

$$I_d = I_o\left[\exp\left(\frac{V + IR_s}{A.N_s.V_T}\right) - 1\right] \qquad (5)$$

Now considering complete fig 2 we get the following current equation

$$I = I_{ph} - I_d - I_p \tag{6}$$

$$I = I_{ph} - I_o\left[\exp\left(\frac{V + IR_s}{A.N_s.V_T}\right) - 1\right] - \left(\frac{V + IR_s}{R_p}\right) \tag{7}$$

III PARAMETERS ANALYSIS

The four parameters that have to be evaluated are also I_{ph}, I_0, R_S, R_P.

(A) I_{ph}

Now applying standard test conditions using fig 1

$$I = I_{ph,ref} - I_{o,\text{ref}}\left[\exp\left(\frac{V + IR_s}{a_{ref}}\right) - 1\right] \tag{8}$$

Now short circuiting the PV cell

$$I_{sc,ref} = I_{ph,ref} - I_{o,\text{ref}}\left[\exp\left(\frac{0}{a_{ref}}\right) - 1\right] = I_{ph,ref} \tag{9}$$

Now we know that photo current depends upon both irradiance & temperature so

$$I_{ph} = \frac{G}{G_{ref}}\left(I_{ph,ref} + \mu_{sc}.\Delta T\right) \tag{10}$$

μ_{sc} : Coefficient temperature of short circuit current (A/K), G is irradiance and all ref values are at standard test condition.

(B) I_o:

PWX 500 PV module (49 W) characteristics.

Parameters	Values
P_{mp} (W)	49
I_{mp} (A)	2.88
V_{mp} (V)	17
I_{sc} (A)	3.11
V_{oc} (V)	21.8
R_S (Ω)	0.55
Noct °C	45
μ_{sc} (K°)	$1.3 \cdot 10^{-3}$
K_d (K°)	$-72.5 \cdot 10^{-3}$
N_S	36

Table 2

This above table shows some standard values as provided by the manufacturer.

Now calculation to I_o can be found out by applying following test conditions: the voltage at open circuit $(I = 0, \mathrm{V} = \mathrm{V}_{oc,ref})$, current at short circuit $(\mathrm{V} = 0, \mathrm{I} = I_{sc,ref})$, voltage and current at maximum power ie. $\mathrm{V}_{mp,ref}$, $I_{\text{mp},ref}$. By the above given conditions following equation can be written such as:

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$$I_{sc,ref} = I_{ph,ref} - I_{o,\mathrm{ref}}\left[\exp\left(\frac{I_{sc,ref}.R_s}{a_{ref}}\right) - 1\right] \qquad (11)$$

$$0 = I_{ph,ref} - I_{o,\mathrm{ref}}\left[\exp\left(\frac{V_{oc}}{a_{ref}}\right) - 1\right] \qquad (12)$$

$$I_{\mathrm{pm},ref} = I_{ph,ref} - I_{o,\mathrm{ref}}\left[\exp\left(\frac{V_{pm,ref} + I_{pm,ref}R_s}{a_{ref}}\right) - 1\right] \text{(13}$$

Now using equ 8 to 13 we get

$$I_{\mathrm{o},ref} = I_{\mathrm{sc,ref}}\left[\exp\left(\frac{-V_{oc,ref}}{a}\right)\right] \qquad (14)$$

The reverse saturation current is defined by:

$$I = D.T_c^{\,3}.\exp\left(\frac{-q.\in_G}{A.k}\right) \qquad (15)$$

Where, D is diffusion factor of diode and $\in_G$ band gap energy. Using eqn 15 aa T_c & $T_{c,\mathrm{ref}}$ and taking ratio of both eqns we get

$$I_o = I_{\mathrm{o},ref}\left(\frac{T_c}{T_{c,ref}}\right)^3 \exp\left[\left(\frac{-q.\in_G}{A.k}\right)\left(\frac{1}{T_{c,ref}} - \frac{1}{T_c}\right)\right] \text{(16)}$$

Substituting $I_{\mathrm{o},ref}$ we get:

$$I_o = I_{\mathrm{sc,ref}}\left[\exp\left(\frac{-V_{oc,ref}}{a}\right)\right] \times \left(\frac{T_c}{T_{c,ref}}\right)^3 \exp\left[\left(\frac{-q.\in_G}{A.k}\right)\left(\frac{1}{T_{c,ref}} - \frac{1}{T_c}\right)\right] \qquad (17)$$

(C) R_s & R_p :

They are computed such that the computed max power is equal to exp maximum power at standard test conditions so we get:

$$I_{\mathrm{mp,ref}} = \frac{P_{\mathrm{mp,ref}}}{I_{\mathrm{mp,ref}}} = \frac{P_{\mathrm{mp,exp}}}{I_{\mathrm{mp,ref}}} \qquad (18)$$

$$= I_{ph,ref} - I_{o,\mathrm{ref}}\left[\exp\left(\frac{V_{\mathrm{mp},ref} + I_{\mathrm{mp},ref}R_s}{a_{ref}}\right) - 1\right] - \left(\frac{V_{\mathrm{mp},ref} + I_{\mathrm{mp},ref}R_s}{R_p}\right) \quad (19)$$

Using various substitution from above we get R_p :

$$\mathrm{R_P} = \frac{V_{\mathrm{mp,ref}} + I_{\mathrm{mp,ref}}\mathrm{R_S}}{I_{\mathrm{sc,ref}} - I_{\mathrm{sc,ref}}\left\{\exp\left[\frac{V_{\mathrm{mp,ref}} + \mathrm{R_S} I_{\mathrm{mp,ref}} - V_{\mathrm{oc,ref}}}{\mathrm{a}}\right]\right\} + I_{\mathrm{sc,ref}}\left\{\exp\left(-V_{\mathrm{oc,ref}}/\mathrm{a}\right)\right\} - \left(\mathrm{P_{max,ex}}/V_{\mathrm{mp,ref}}\right)} \quad (20)$$

IV CONCLUSION

Various parameters and standard test condition values are used for finding these various parameters that are essential for successful modeling of a PV module.

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