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Approach Method to Evaluate the Output Voltage of Crystalline Silicon Photo voltaics at Different Cell Operating Temperatures

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Abstract— ***The electrical system Photovoltaic (PV) modules are 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. This paper, a mathematical model of a PV cell used matlab-simulink environment, is developed and presented. The model is developed using basic circuit equations of the photovoltaic solar cells including the effects of solar irradiation and temperature changes. The main objective is to evaluate the output crystalline silicon PV voltage at different ambient temperatures.***

Keyword— Photovoltaic, crystalline silicon, cell operating temperature, matlab-simulink, output voltage.

I. Introduction

A photovoltaic system converts sunlight into electricity. The basic device of a photovoltaic system is the photovoltaic cell. Cells may be grouped to form panels or modules. Panels can be grouped to form large photovoltaic arrays. The term array is usually employed to describe a photovoltaic panel (with several cells connected in series and/or parallel) or a group of panels[1,2].

. Most of time one are interested in modeling photovoltaic panels, which are the commercial photovoltaic devices. Three heat transfer processes occur in a PV module: conduction of the heat losses through the encapsulants, heat convection at the module front and back surfaces and radiation to the surroundings. PV modules have a good conversion coefficient as long as they operate at not too high temperatures. The rise of the module temperature is due to the heat released when photons carrying too much energy are absorbed.

Module temperature is a parameter that has great influence in the behaviour of a PV system, as it modifies system efficiency and output energy. This paper focuses on the assumed mathematical equation to determine the value of the output crystalline silicon PV voltage at different ambient temperatures[3].

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A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes.

The monocrystalline and polycrystalline silicon cells are the only found at commercial scale at the present time. Silicon PV cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form the p–n junction. A thin metallic grid is placed on the Sunfacing surface of the semiconductor.

The incidence of light on the cell generates charge carriers that originate an electric current if the cell is shortcircuited. Charges are generated when the energy of the incident photon is sufficient to detach the covalent electrons of the semiconductor, this phenomenon depends on the semiconductor material and on the wavelength of the incident light.

II. Photovoltaic Modeling

PV is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material.

The solar cell equivalent circuit is demonstrated by Fig,1.

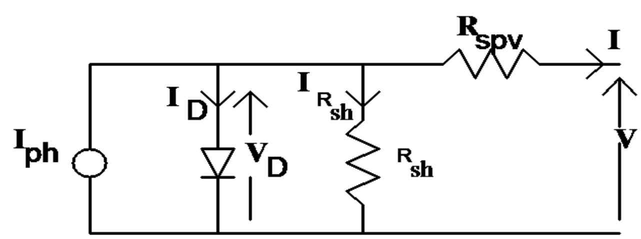

Figure (1): solar cell equivalent circuit

The equation designing the photovoltaic cell operation may be written as follows [4-6]; taking into consideration the following assumption:

The shunt resistance is too high, and consequently Ish may neglected.

$$I_D = I_O\{\exp[u_{PV}(V_{pv} + I_{pv}R_{Sr})] - 1\} \quad (1)$$

Where

$$u_{pv} = \frac{qV}{uKT}$$

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q: electron charge
K: Boltzmann's constant
u: completion factor

The completion factor A is dependent on PV technology and is listed in Table (1):

Table (1): factor A dependence on PV technology

Technology	A
Si Mono	1.2
Si – Poly	13
a-Si:H	18
a-Si:H tandem	3.3
a-Si:H triple	5
CdTe	1.5
CTS	1.5
AsGa	13

$$I_{R_{sh}} = \frac{V_{PV} + I_{PV} R_{sr}}{R_{sh}} \qquad (2)$$

$$I_{pv} = I_{Ph} - I_D - I_{R_{Sh}} \qquad (3)$$

Numerical methods have been used to calculate the cell parameters [7-10] by using the experimental data at three different points on the I-V characteristics,.namely, the short circuit current (0, Isc), the open circuit voltage (Voc, 0) and the maximum power point (Vp, Ip)

Dynamic resistances $R_{SO} = -\left(\frac{\partial V}{\partial I}\right)_{V=V_{oc}}$ and $R_{shsc} = -\left(\frac{\partial V}{\partial I}\right)_{I=I_{sc}}$ are obtained at the respective points. The equation of the generator current which consists of Ns cells in series and Np cells in parallel, is given by equation (4):

$$I_{pv} = I_{phg} - I_{og}\{\exp[u_g(V_{pv} + I_{pv}R_{srg})] - 1\} - \frac{V_{pv} + I_{pv}R_{srg}}{R_{shg}} \qquad (4)$$

Where for an array of a series combination:

$$I_{phg} = I_{ph} \qquad I_{og} = I_o$$

$$u_g = \frac{u_{PV}}{N_s} \qquad R_{srg} = N_s R_{spv}$$

$$R_{shg} = \frac{R_{sh}}{N_s} \qquad (5)$$

And for an array of parallel combination

$$I_{phg} = N_P I_{ph} \qquad I_{og} = N_p I_o$$

$$u_g = u_{PV} \qquad R_{srg} = \frac{R_{srpv}}{N_s}$$

$$R_{shg} = N_p R_{sh} \qquad (6)$$

Finally, the following equations can be written, in considering that when $V_{PV}=V_{oc}$, $I_{PV}=0$

$$I_{phg} = \frac{V_{oc}}{R_{shg}} + I_{og}\{\exp(u_g V_{oc}) - 1\} \qquad (7)$$

$$V = -I_{pv}R_{Srg} + \frac{1}{u_g} Ln\left(1 + \frac{I_{phg} - I_{pv}}{I_{og}}\right) \qquad (8)$$

III. modified mathematical model of a PV cell

Taking as a referance the curves of the crystalline silicon photovoltaics manufacturer for the temperature level current (I) versus voltage (V) curves of the PV panel are depicted under different temperature and irradiation levels as shown in fig. (2).

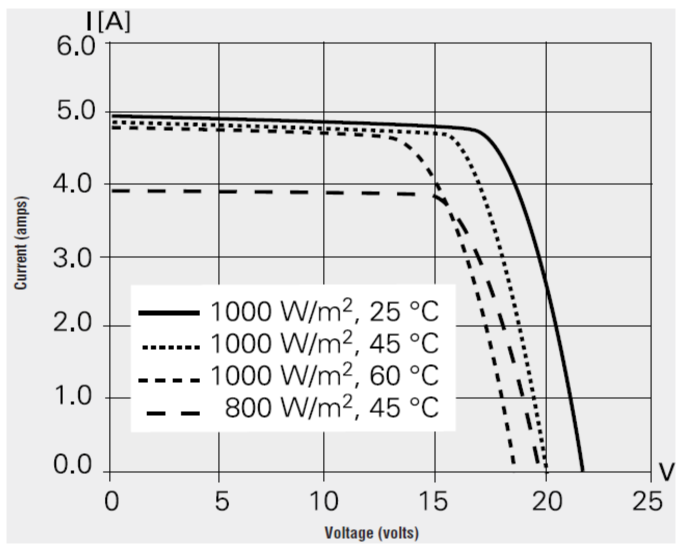

Figure (2): The simens solar module SP75 voltage-current characteristic for various temperature and irradiation levels.

A table produced from manufacturer curves as shown in table (2).

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Table (2): voltage (V) value versus Current (I) of the simens solar module SP75 under different temperature and irradiation levels

S.N.	I_{PV} (Amp)	V_{PV} (Volt) at the following levels			
		1000W/m^2 & 25^{o}C	1000W/m^2 & 45^{o}C	1000W/m^2 & 60^{o}C	800W/m^2 & 45^{o}C
1	0.0	21.7	20	18.6	19.7
2	1	21.1	19.5	18	19
3	2	20.5	18.7	17.2	18
4	3	19.6	18	16.9	17.9
5	3.4	19.3	17.6	15.9	16.3
6	3.6	19.1	17.4	15.7	16
7	3.8	18.9	17.2	15.4	15.3
8	3.85	18.8	17.1	15.3	15
9	3.92	18.7	17	15.2	0.0
10	4.4	18.5	16.9	15.1	-
11	4.4	17.9	15.3	14.3	-
12	4.6	17.5	16	13.5	-
13	4.8	15.5	10	0.0	-

Using the mono crystalline silicon for module production. [10-12]. Solar cells were connected in series and in parallel in a matrix form of 1*36 cells (one module Simens Solar Module SP75) using flat, thin tinned silver strips. With its 36 series connected solar cells, module (SP75) has a peak power of 75 Wp.

The parameter values of a PV module:

R_{sr} = 0.411383 ohms,

u_g = 0.8083 1/volts at 273.15^o K (i.e. 0^o C),

I_o = 2.35E-8 Amp,

I_{ph} = 4.11383 Amp at 100% insolation.

By using the trial & error method a suitable equation which consider as a modified mathematical model of a PV cell is fit the manufacturer curve is given by the next eq. (9),

$$V_{pv} = -0.411383\ I_{pv} + \frac{1}{0.8083\ T_r} Ln\ \left(1 + \frac{4.82 * \Phi - I_{pv}}{2.35 * 10^{-8}}\right) \qquad (9)$$

where,

I_{pv} : Current of the PV cell.
V_{pv} : Voltage of the PV cell.
Φ : Solar insolation in watt/m^2.
T_a : Is equal to 273.15 °C.
T : Ambient temperature in °C.
T_r : Is equal to $(T_{a+}\ T)/\ T_a$
I_{ph} : Photocurrent
I_D : diode current.

A modified mathematical model of a PV cell used matlab-simulink block model as shown in fig. 3.

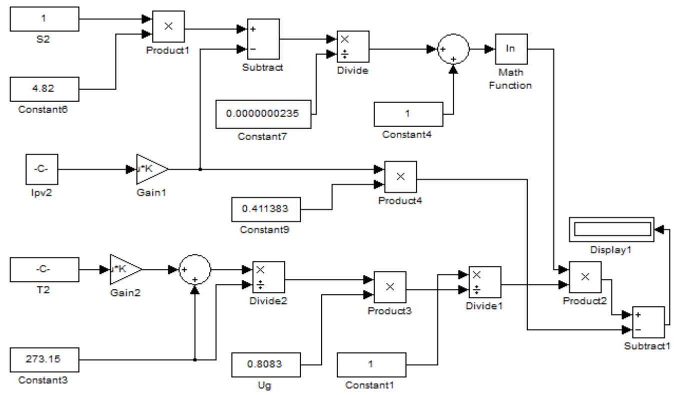

Figure (3): Matlab/Simulink block model of overall system

IV. Simulation and results

Fig. 4 shows the PV panel I-V curves for various temperature levels at 1000W/m^2 irradiation level.

While, Fig. 5 shows the PV panel P-V curves for various temperature levels at 1000W/m^2 irradiation level

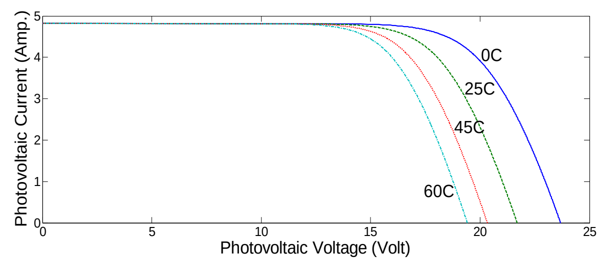

Figure (4): The PV panel I-V curves for various temperature levels at 1000W/m^2 irradiation level.

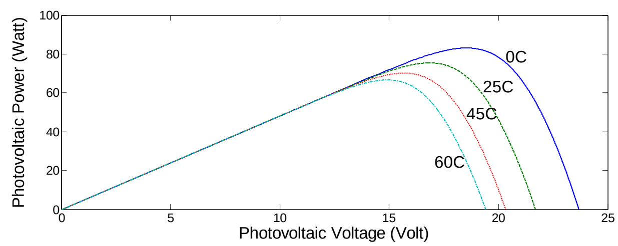

Figure (5): The PV panel P-V curves for various temperature levels at 1000W/m^2 irradiation level.

V. Conclusions

During this paper, a new approach is presented for determine the PV output voltage at different temperatures for certain value of solar irradiation by assumming a suitable equation. This equation gives us the same results as the crystalline silicon photovoltaics curves of the manufacturer for the output voltage at different cell operating temperatures. A modified mathematical model of a PV cell used matlab-simulink environment, is developed and presented. The individual system performance of PV system is studied through simulation for solar insolation and temperature.

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