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Mathematical Modelling of Single Diode Model of Solar PV Cell using Matlab/Simulink

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Abstract—*This paper focuses on modeling and simulation of single diode model of solar Photovoltaic cell using matlab/simulink. The PV module is the interface which converts light into electricity directly. The various factors like temperature, solar irradiance, series and shunt resistance influence the output characteristics of PV cell. The output can be voltage, current, or power. The P(V) and I(V) characteristics are being plotted by varying the given parameters. Results are compared for greater accuracy. The detailed model is studied and simulated step by step using matlab/simulink.*

Keywords*: Diode, PV Charactersics, PV Module, Matlab/Simulink.*

1. INTRODUCTION

With no pollutant emission, Photovoltaic cells convert sunlight directly to electricity. They are basically made up of a PN junction. Figure 1 shows the photocurrent generation principle of PV cells. In fact, when sunlight hits the cell, the photons are absorbed by the semiconductor atoms, freeing electrons from the negative layer. This free electron finds its path through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one.

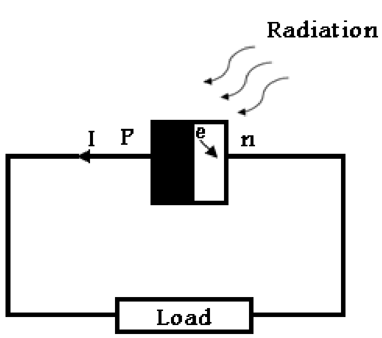


Fig. 1: Photocurrent generation principle.

Typically, a PV cell generates a voltage around 0.5 to 0.8 volts depending on the semiconductor and the built-up technology. This voltage is low enough as it cannot be of use. Therefore, to get benefit from this technology, tens of PV cells (involving 36 to 72 cells) are connected in series to form a PV module. These modules can be interconnected in series and/or parallel to form a PV panel. In case these modules are connected in series, their voltages are added with the same current. Nevertheless, when they are connected in parallel, their currents are added while the voltage is the same.

Three major families of PV cells are monocrystalline technology, polycrystalline technology and thin film technologies.

2. SINGLE DIODE MODEL

Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.

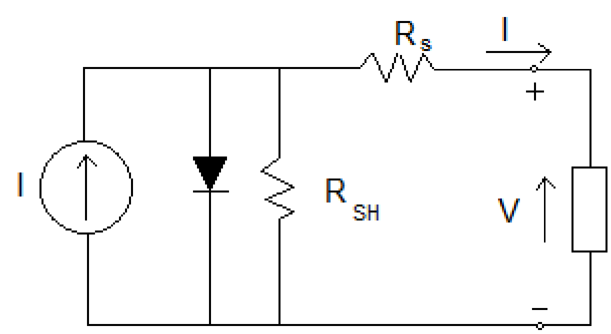


Fig. 2: Single diode model of a PV cell.

In this model we consider a current source (I) along with a diode and series resistance (Rs). The shunt resistance (RSH) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array is

$$I=Iph-Id \quad (1)$$

where Iph is the photocurrent, Id is the current of the diode which is proportional to the saturation current and is given by

$$Id=Io[\exp(qV/ANskTc)-1] \quad (2)$$

where q is the electron charge, V is the voltage across the diode, k is Boltzmann constant (1.38 * 10^{-19} J/K), Ns is the no. of PV cell connected in series, A is the ideality factor, and T is the junction temperature in Kelvin (K).

Table 1: Ideality factor (A) Huan- Liang et. Al., 2008.

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

In this work take

$$a = Ns.A.k.Tc/q \quad (4)$$

where this 'a' can be termed as "the modified Ideality Factor".

By connecting Rs and Rsh and applying KCL in the circuit , equations obtained are

$$I=Iph-Io\{\exp[(V+IRs)/a]-1\}-[(V+RsI)/Rsh] \quad (5)$$

Determination of Iph

Output current at STC

$$I=Iphref-Ioref[\exp(V/aref)-1] \quad (6)$$

In short circuit condition

$$Iscref=Iphref-Ioref[\exp(0/aref)-1]=Iphref \quad (7)$$

The photocurrent depends on both irradiance and temperature:

$$Iph=(G/Gref)(Iphref+\mu sc\Delta T) \quad (8)$$

G=irradiance(W/m^2), Gref=irradiance at STC=1000 W/m^2

ΔT=Tc-Tcref(Kelvin),Tref=cell temperature at STC=25+273=298K,

μsc=coefficient temperature of short circuit current (A/K)

in open circuit condition,

$$Iscref=Iphref-Ioref[\exp(Iscref.Rs/aref)-1) \quad (9)$$

$$0=Iphref-Ioref[\exp(Voc/aref)-1) \quad (10)$$

$$Impref=Iphref-Ioref[\exp(Vmpref+Impref.Rs/aref)-1) \quad (11)$$

Where mp is for maximum power.

With both Rs and Rp

$$Impref=Iphref-Ioref[\exp(Vmpref+Impref.Rs/aref)-1)-[(Vmpref+RsImpref)/Rp] \quad (12)$$

3. SIMULATION MODELS

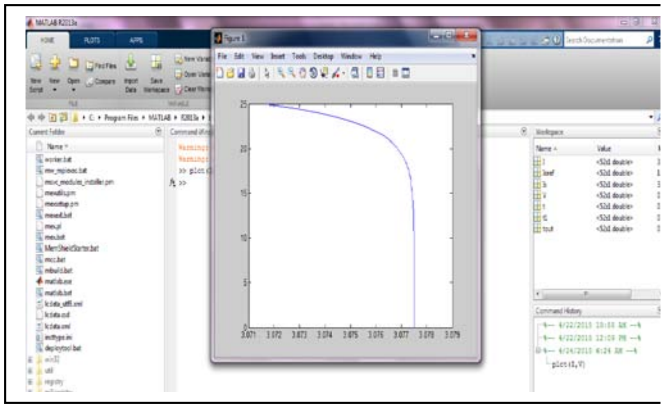
Simulation Of PV model

-firstly photocurrent Iph is implemented in MATLAB/Simulink. The result is represented in Fig.3

-The reverse saturation current at STC is also implemented in MATLAB/Simulink. The result is represented in Fig.4,

-It allows the simulation of Io which is represented in fig. 5.

-system is also modeled with and without Rp and the corresponding results are represented in Fig. 6, and Fig. 7 respectively.



4. CURVES AND INTERPRETATION

Firstly I(V) characterstics is plotted for Rs=0 and Rs=0.55. the last value of series resistance is provided by manufacturer. It is confirmed that manufacturer didn't take into consideration the parallel resistance, because the peak power Rs model is more accurate. But for Rp model the peak power is logically less ha the experimental one.

The proposed Rp model is now used to simulate the PVmodule at different values of irradiance and temperature. The I(V) characterstics and the P(V) characterstics are then presented by varying the values of temperature and irradiance.

5. CONCLUSION

The presented work is a detailed modeling and simulation of the pv cell. Included effects are: temperature effects, irradiance effects, series and shunt resistance effects and diode ideality factor effect. The experimental results exhibited a good agreement with the simulation results. This paper also provides a clear and concise understanding of the, I-V and P-V characteristics of PV module and the effect of change of Temperature and Irradiance on these characteristics. The proposed model is expected to serve as the basis model for carrying out study by the researchers in the field of PV modeling.

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