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A PROPOSED MATHEMATICAL MODEL OF SOLAR PV MODULE IN MATLAB/SIMULINK

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Abstract *—This paper present the Mathematical model of the ELPS CS6P-260MM solar photovoltaic module using MATLAB Simulink, and it is validated comparing the developed PV performance characteristics curves with those of manufacture's data sheet. The I-V & P-V characteristics are obtained for both various value of solar insolation keeping the cell Temperature constant and vice versa. The proposed model relates the electrical output of the PV system to various input environmental parameters.*

Keywords*-Photovoltaic modules, MATLAB/Simulink*.

I. INTRODUCTION

In this modern world fossil fuels are fast utilizing and also pollute our environment which will result in global warming. Limited reserves of conventional sources with their impact on environment led us to use green energy i.e. non-conventional energy sources like solar energy, wind energy, biomass, tidal energy etc. Among all these sources Photovoltaic systems are becoming popular because of its decreasing cost, low maintenance because there are no moving part, pollution free, distributed throughout the world and recyclable. It also has some demerits viz. high setup cost, low efficiency. Although such demerits government try to implement it by launching different promotion schemes, subsidies so it will lead to its competitiveness in future era.

Basically PV Power generation use the principle of the photovoltaic effect. It is basically made up of silicon cells. This solar cells can give around 0.5 to 0.7 V under open condition which can be increased by connecting them in series which is known as solar module and further we can connect them in parallel for more output Power [1-3].

II. EQUIVALENT ELECTRICAL CIRCUIT OF PV CELL

Equivalent Electrical circuit of PV cell is shown in Figure 1

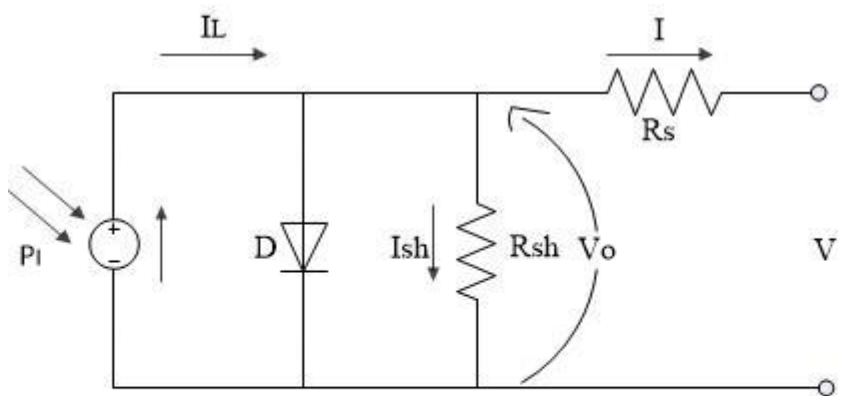

Figure 1. Equivalent electrical circuit of PV cell

The circuit parameters are as follows

- I is the output-terminal current
- I_L is the light-generated current
- I_d is the diode current
- I_{SH} is the shunt-leakage current
- R_S is the series resistance which represent internal resistance to the current, and depends on the p-n junction formation, the impurities and the contact resistance.
- R_{SH} is the shunt resistance which is inversely related with leakage current to the ground.

In ideal PV cell we take $R_S = 0$ and $R_{SH} = \infty$. The PV module efficiency is very sensitive to small variation in series resistance and independent on variation of shunt resistance [3].

III. MATHEMATICAL MODEL FOR A PV MODULE

From the equivalent circuit in Figure 1 the load current is given by the expression:

$$I = I_L - I_d - \frac{V_0}{R_{sh}} \quad (1)$$

The cell could be represented by a voltage-current Equation as follow

$$V = V_0 - R_S I \qquad (2)$$

Where:
$V_0 = V_{sh}$ = voltage on the diode and the shunt resistance
I_d = diode Current (A).
V = cell output voltage (V).
I = load (cell) output current (A).
I_L = Photocurrent (A).
I_0= Reverse diode saturation current (A).

The two most important parameters widely used for describing the cell electrical performance are the open-circuit voltage V_{oc} and the short-circuit current I_{scc} . The short-circuit current is measured by shorting the output terminals, and measuring the terminal current under full illumination. The maximum photo-voltage is produced under the open-circuit voltage. The open circuit voltage V_{oc} of the cell is obtained when the load current is zero, i.e., when I = 0.

The general Equation describing the I_V & P-V characteristics are as follow.
Module output current is given by following Equation [Egypt]

$$I = I_L - I_O\left(e^{\frac{q(V+IRs)}{nKTr}} - 1\right) \quad (3)$$

Where:
q = electron charge = 1.6×10^{-19} Coulombs.
n = ideality factor = 1 to 2.
K = Boltzmann constant = 1.38×10^{-23} Joule/K
Tr = rated cell temperature in Kelvin.
Rs = cell series resistance (ohm).

The value of the saturation current Io at different operating temperatures is calculated as follow:

$$I_o = I_{o\,(Tr)} * (T/Tr)^{\frac{3}{n}} * e^{\frac{qVg}{nk} * \{\frac{1}{T} - \frac{1}{Tr}\}} \qquad (4)$$

$$I_{o\,(Tr)} = I_{SC\,(Tr)} / \left[e^{\frac{qV_{oc\,(Tr)}}{nKTr}} - 1\right] \qquad (5)$$

Where:
V_g = The band gap voltage
$V_{oc\,(Tr)}$ = Open Circuit voltage at rated operating conditions.
$I_{SC\,(Tr)}$ = Short circuit current at rated operating conditions.

The photocurrent I_L (A) is directly proportional to solar radiation level G (W/m2), as follow:

$$I_L = I_{L(Tr)}(1 + \alpha_{I_{SC}}(T - Tr)) \qquad (6.1)$$

$$I_{L(Tr)} = G * I_{SC\,(Tr,nom)} / Gr \qquad (6.2)$$

$$\alpha_{I_{SC}} = d_{I_{SC}} / dT \qquad (6.3)$$

Where, α_{Isc} = the short circuit temperature coefficient (A/sec).
The open circuit voltage is varied with temperature as illustrated follow:

$$V_{OC\,(T)} = V_{OC\,(Tr)}(1 - \beta_{V_{OC}}(T - Tr)) \qquad (7)$$

Where, β_{Voc} = the open circuit temperature coefficient (V/sec).

All the constant in above equations are provided for standard condition of 25C temperature and 1000w/m^2 radiation level, and zero angle of incidence [3].

IV. SIMULATION OF SOLAR PV MODULE IN MATLAB/SIMULIMK

In this section equations (3)-(6) for the PV module is implemented in Matlab Simulink as shown in figure3. The parameters for modeling is chosen from the datasheet of ELPS CS6P260-MM as shown in Table 1.

Table 1. Key specification of ELPS CS6P260-MM[4]

Parameter	Value
Typical Maximum Power (Pmax)	260W
Voltage at Pmax (Vmp)	30.7V
Current at Pmax (Imp)	8.48A
Short circuit current (Isc)	8.99A
Open circuit voltage (Voc)	37.8V
Module efficiency	16.16%
Temperature coefficient for Isc = α_{Isc}	0.00060/C
Temperature coefficient for Voc = β_{Voc}	0.0035/C

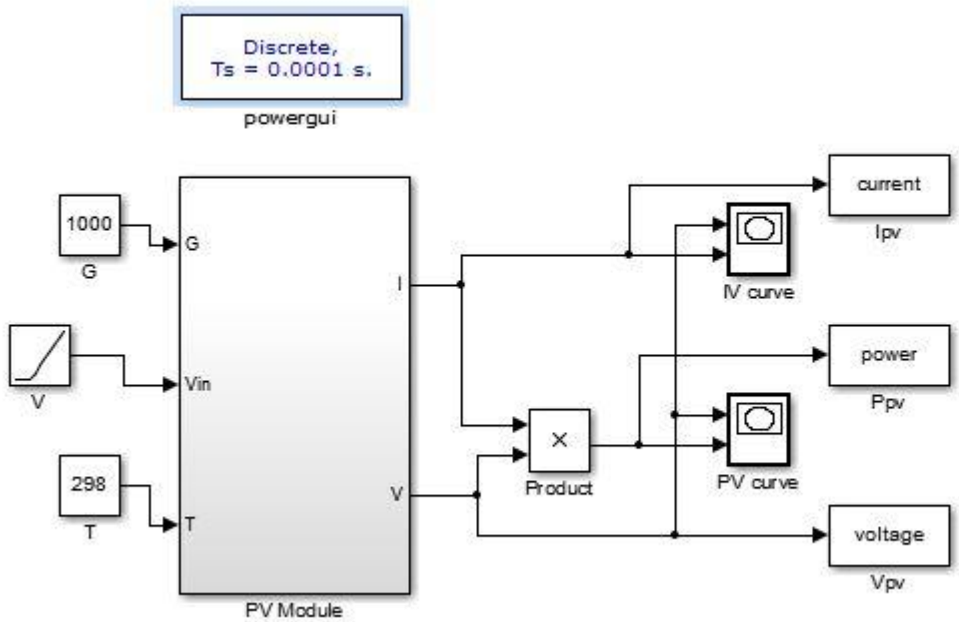

Figure 2. GUI block of CS6P260-MM

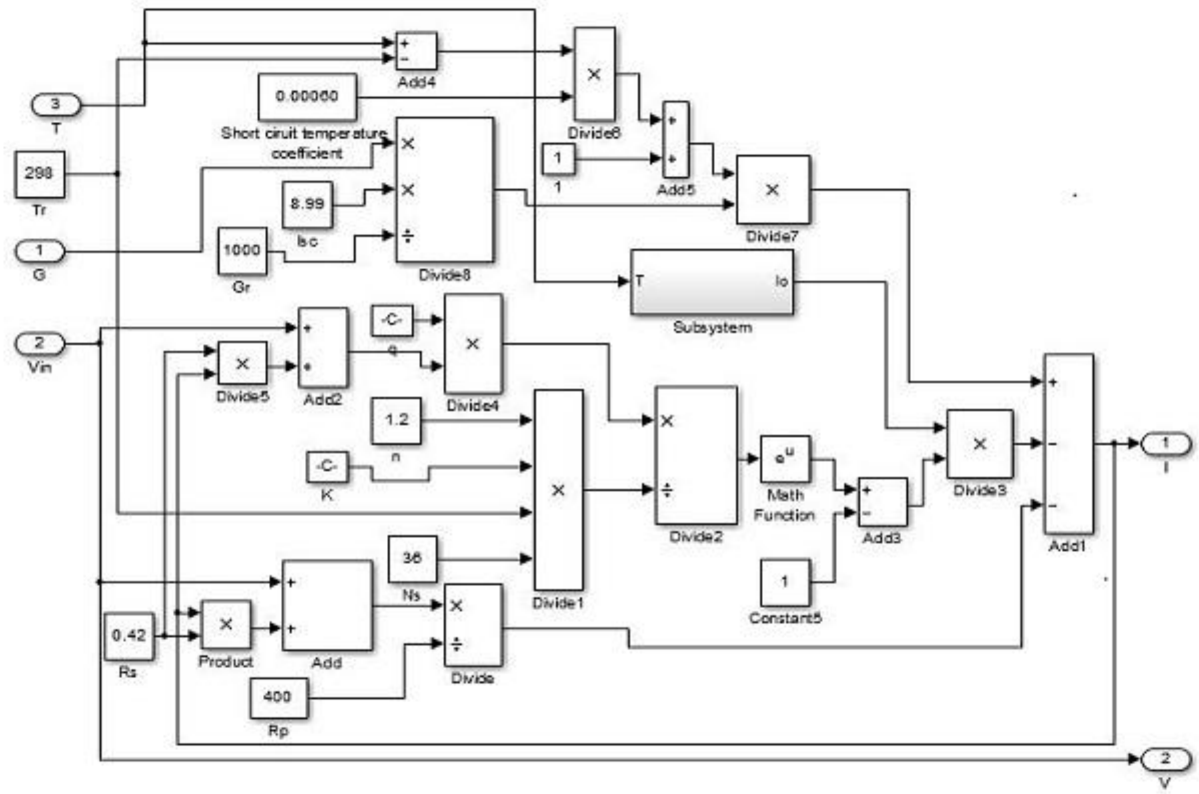

Figure 3. The complete PV module simulation

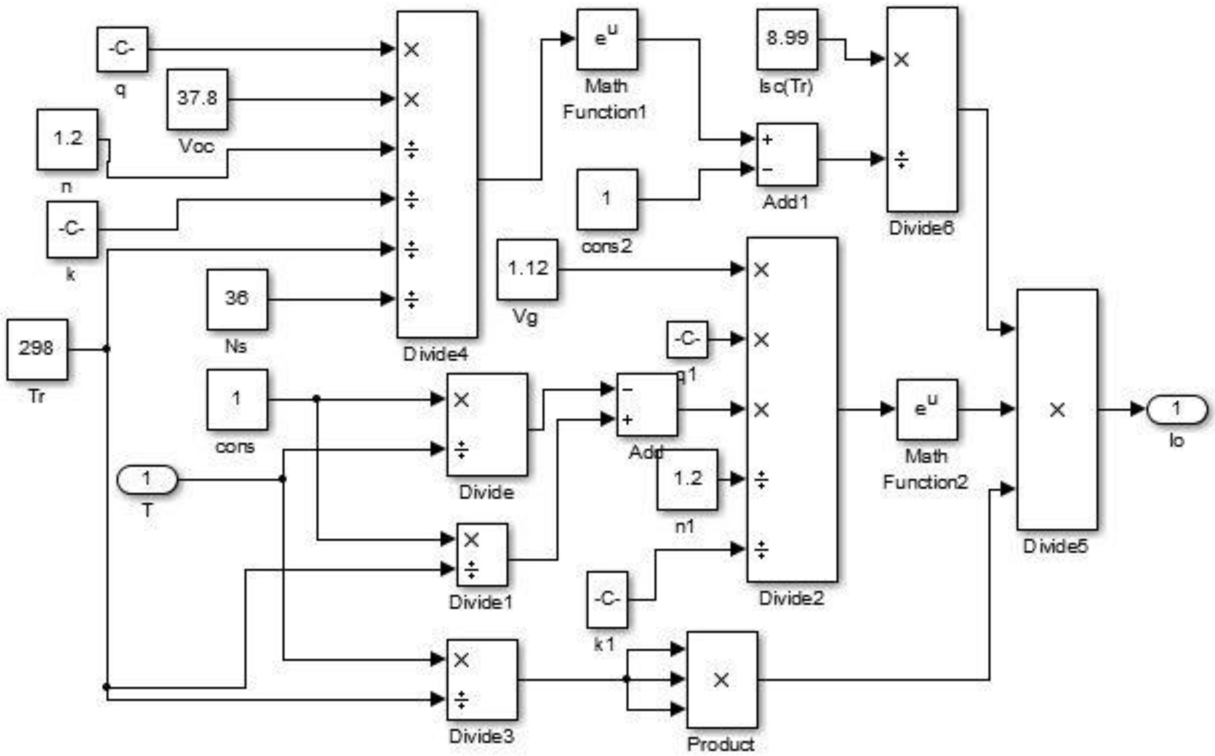

Figure 4.Unbundeled block of reverse diode saturation current

V. SIMULATION RESULTS

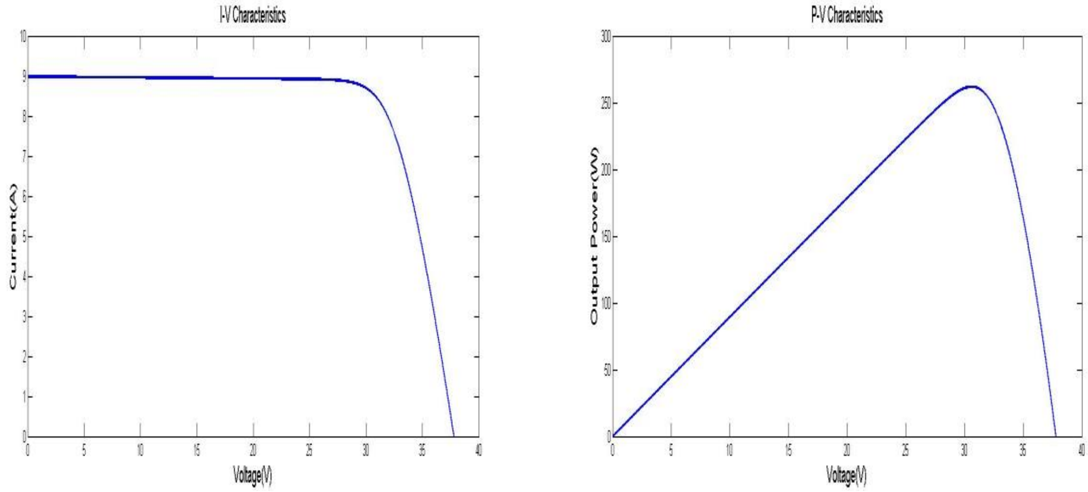

Figure 5. I-V& P-V Characteristics

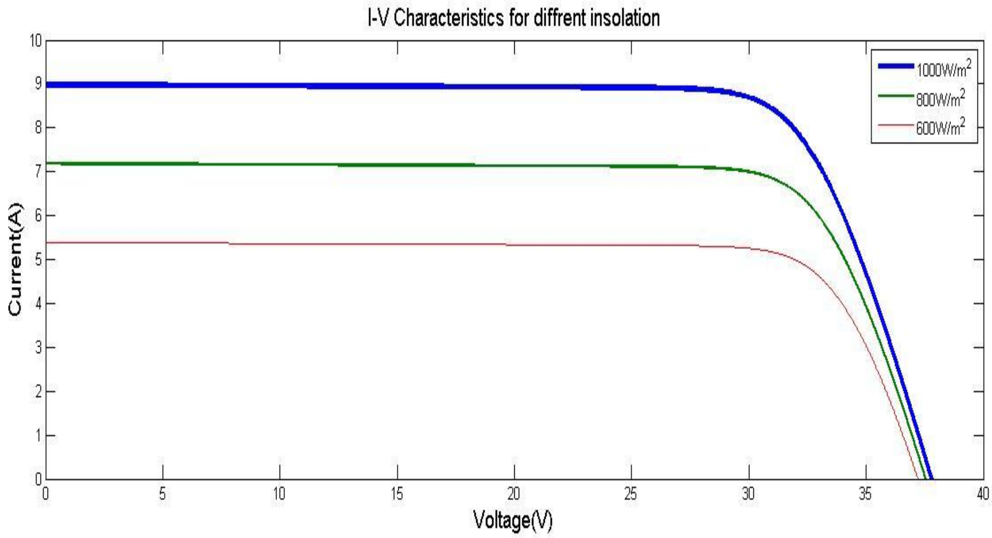

Figure 6. I-V Characteristics for different insolation

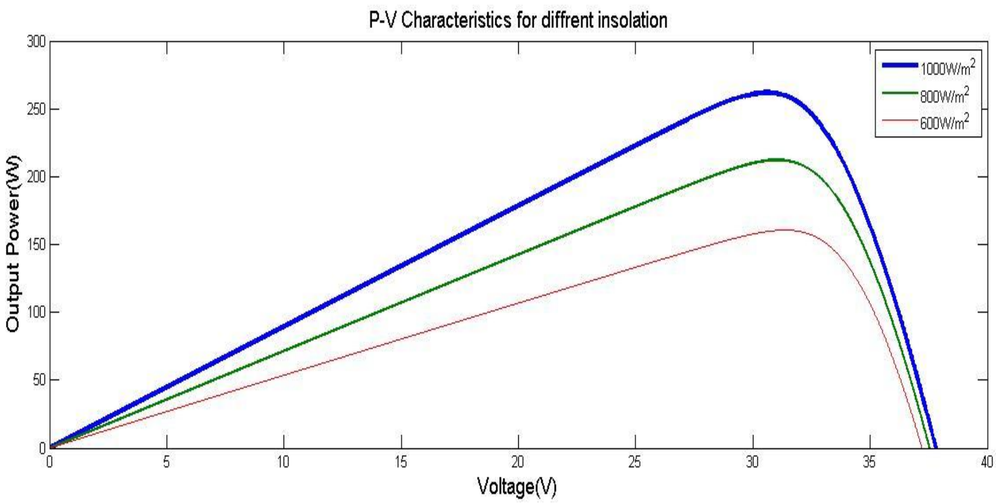

Figure 7. P-V Characteristics for different insolation

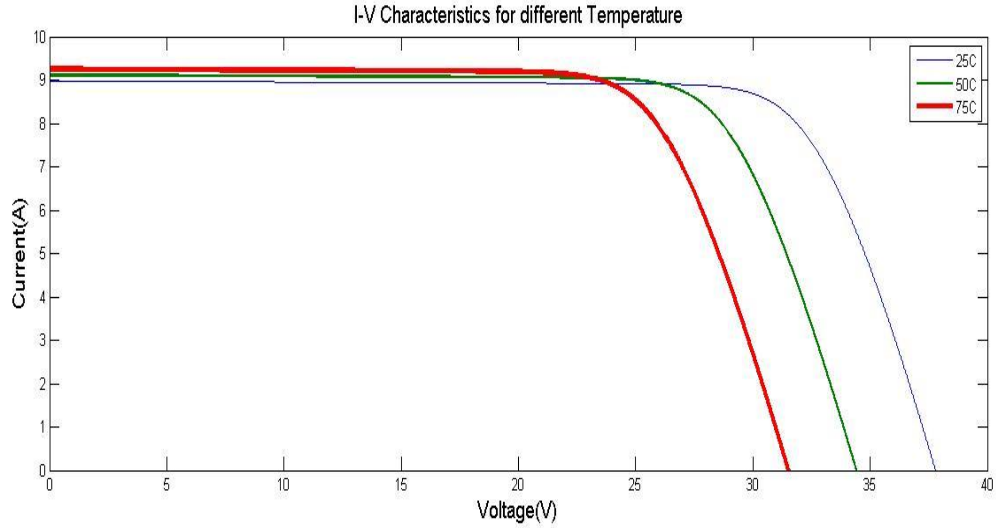

Figure 8.I-V Characteristics for different Temperatures

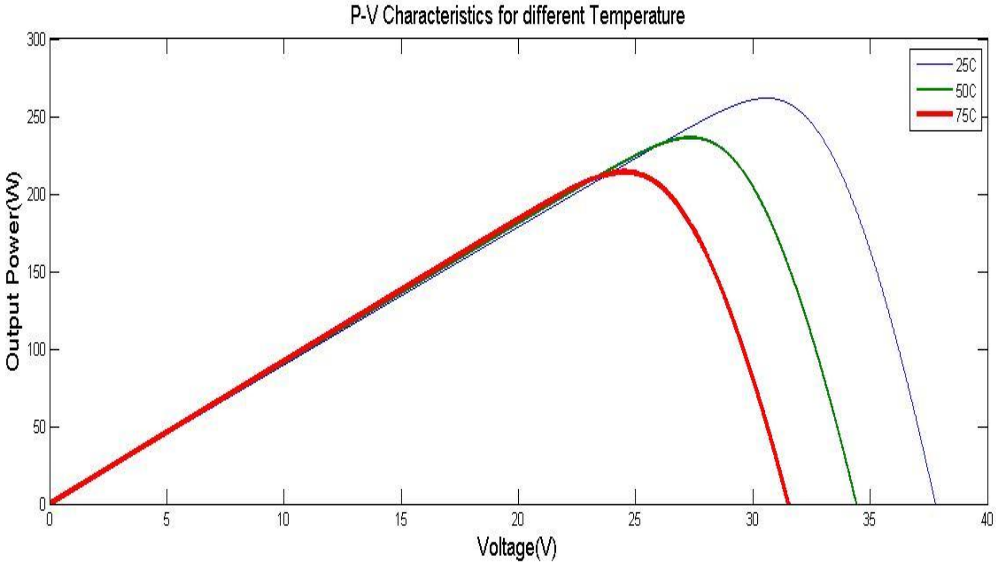

Figure 9. P-V Characteristics for different Temperatures

VI. CONCLUSIONS

This paper represent a mathematical model of PV module in Matlab/Simulink. The I-V & P-V characteristics at different environment conditions are developed and also compared with those available from datasheets. So such type of model can be used to for performance testing of different PV module in future.

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Example:

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