

Mathematical Model of 72 W Cosmic Module with MATLAB/SIMULINK

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ABSTRACT: *The Earth life is dependable upon infinite source of green energy. There is an increasing trends for the use of solar cells in industry and domestic appliances because cosmic energy is expected to play significant role in future grids as non-conventional resources. The Large-scaled integration of non-conventional sources into the grid is possible by the computer simulations so there is extreme growing demand for computer simulation of non-conventional resources. The Electrical energy gained by the photon energy of the sun technically named as Photovoltaic (PV). The proposed model is based upon the maximised electric power extraction from the solar cell radiation and electrical driver interface for implementing electrical characteristic of power limited systems in power simulations. This paper gives us details steps of one-by-one procedures for the simulation of photovoltaic (PV) modules with Matlab/Simulink. Single diode equivalent circuit is processed in order to examine I-V and P-V properties are obtained for the typical 72W PV module. The suggested model is designed using a user-friendly idol and a communication box like simulink section libraries. The model is dynamic in computational multiplicity and it is easy to build for representing wide-range of photovoltaic (PV) installations.*

Index Terms: *cosmic energy, photovoltaic cell, PV module, matlab/Simulink.*

1 NOMENCLATURE

Voc is voltage output of a PV module (V)

I is current output of a PV module (A)

Tr is the temperature reference = 298 K

T is the module operating temperature in Kelvin

Isc is the generated light current in a PV module (A)

Io is the saturation current of PV module (A)

A = B is an ideality factor = 1.6

The Boltzman constant is $k = 1.3805 \times 10^{-23}$ J/K

The Electron charge is $q = 16 \times 10^{-20}$ C = 1.6×10^{-19} C

Rs is the series resistance of a PV module

ISCr is the PV module short-circuit current at 25oC and 1000W/m²

Ki is the short-circuit current temperature coefficient at Iscr = 0.0017A /oC

λ is the PV module irradiation (W/m²) = 1000W/m²

Ego is the band gap for silicon = 1.1eV

Ns is the number of cells connected in series

Np is the number of cells connected in parallel

The photovoltaic panel can be modelled mathematically as given below. [1]

2. INTRODUCTION

Among a few non-conventional energy resources, energy collecting from the photovoltaic effect is the most essential and sustainable means because of plenty and easy accessibility of cosmic radiating energy around our earth. In spite of the fluctuation of sunlight rays, solar energy is widely available during the daylight and it is freely available to use. Recently, photovoltaic (PV) system is recognized to be in the leading edge in the non-conventional electric power generation because it can generate direct current (dc) electricity without heavy environmental impacts and pollution. [2]

PV modules are the fundamental power conversion unit of a PV generator system. The output characteristic of PV modules depends upon the solar insolation, the temperature and the output voltage of the photovoltaic module. [2]

Since PV module has non-continuous properties, it is very essential to make it for the pattern and reproduction of maximum power point tracking for PV system applications. [1] Numerical designing of PV module is being continuously updated to enable analyst to have a better perceptive of its working. [1][3]

In this paper, one-by-one procedures for reproducing PV module with sub-system sections, with convenient symbols and dialog in the same way as matlab/simulink section athenaeums is developed. [1] Section 3 presents the PV module equivalent circuit and equations for Ipv, the output current from the PV module. The reference design presented in section 4 gives inputs for solkar make 72 W PV module for reproduction. In section 5 the one-by-one designing procedure of PV module is presented with reproduction results. Finally brief conclusions are drawn in section6. [1]

3. NUMERICAL DESIGN FOR A PHOTOVOLTAIC (PV) MODULE

Cosmic cell is basically a p-n junction constructed in a thin wafer of cover of semi-conductor. The

electromagnetic emission of cosmic energy easily can be directly converted to electricity through PV effect.[3]
 The PV cell equivalent circuit is as shown in Figure 1 below.

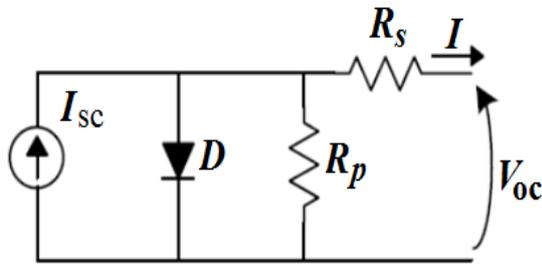


Fig-1: Single diode model of PV cell

The current origin I_{sc} represents the light generated current. R_p and R_s are the inherent shunt and series resistances of the cell respectively. Usually the value of R_p is very huge and that of R_s is very short, hence they may be ignored to simplify the investigation.

PV cells are combined in larger units called PV modules which are more attached in a parallel-series composition to form PV patterns.

The using equations (1) to (4) design of PV Module cell. [1],[4],[6],[8]-[12].
 The Module photo-current:

$$I_{sc} = [I_{SCr} + K_i(T - 298)] * \lambda / 1000 \quad (1)$$

The Modules reverse saturation current I_{rs}

$$I_{rs} = [I_{SCr} / [\exp(qV_{oc} / N_s kAT) - 1]] \quad (2)$$

Module saturation current I_s varies with the cell temperature, which is given by

$$I_s = I_{rs} \left[\frac{T}{T_r} \right]^3 \exp \left[-\frac{q * E_{go}}{Bk} \left\{ \frac{1}{T_r} - \frac{1}{T} \right\} \right] \quad (3)$$

The current output of PV module is given as below

$$I = N_p * I_{sc} - N_p * I_o \left[\exp \left\{ \frac{q * V_{oc} + IR_s}{N_s AkT} \right\} - 1 \right] \quad (4)$$

Where $N_p = 1$ and $N_s = 72$.

4. REFERENCE MODEL

The Solar BP SX 150s PV module is chosen for a MATLAB/Simulink reproduction Design. The PV Module is making of 72 many-

crystalline silicon cosmic cells in series and provides the maximum power output of 150W. [3]

Electrical Property	BP SX150S
Maximum Power(Pmax)	150W
Voltage at P _{MAX} (V _{MP})	34.5V
Current at P _{MAX} (I _{MP})	4.35A
Open-circuit Voltage(V _{OC})	43.5V
Short-circuit Current(I _{SC})	4.75A
Temperature Co-efficient of I _{SC}	-(0.065±0.015) %/°C
Temperature Coefficient of V _{OC}	-(160±20)mV/°C
Temperature Coefficient of Power	-(0.5±0.05) %/°C

Table-1: BP SX 150s PV module spec.

Note: The electrical spec are under test conditions of irradiance of 1kw/m², spectrum of 1.5air mass and cell temperature of 25 °C [1].

5. STEP ONE BY ONE METHOD FOR SIMULINK DESIGNING OF PV GROUP OF CELLS.

A design of PV module with steady intricacy that includes the temperature independence of the cosmic current source, the saturation current of the diode, and a series resistance is steady using upon Shockley diode concepts. [1]

Being lighted up with rays of sun light, PV cell changes part of the PV potential directly into electricity with both I-V and P-V output properties. [1]

Using the equations given in section 3, simulink designing is done in the following steps. [1]

A. Step1

Subsystem 1 is shown in Figure1. The design changes the group of cells performing temperature given in degrees Celsius to Kelvin.

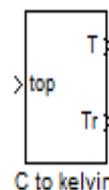
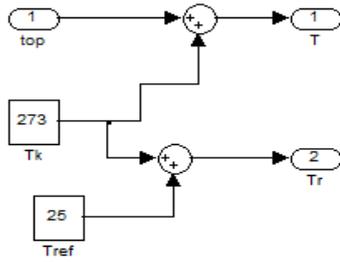


Fig-2: Subsystem1.

Figure3: Gives the circuit beneath subsystem 1



Function: To convert operating temperature-centigrade to Kelvin

Equations: 1. $T = 273 + 25(\text{ref temp.})$
 2. $Tr = 273 + Top$ (operating temp)

Fig-3: Circuit under subsystem 1.

B. Step2

The subsystem 2 is shown in figure 4. This design takes specified aids.

- The Insolation /Irradiation- $(G/1000)1\text{kw}/\text{m}^2 = 1$
- The Module operating temperature $T = 30$ to 70°C
- The Module reference temperature $Tr = 25^\circ\text{C}$
- The Short circuit current (I_{sc}) at reference temperature= 2.55A

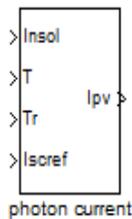
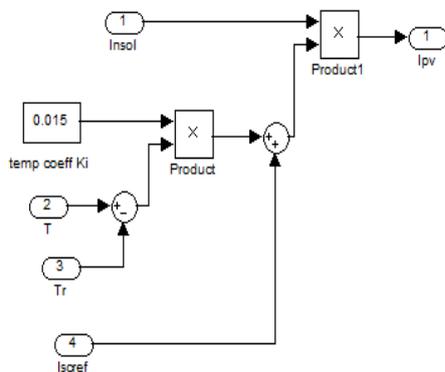


Fig-4: The subsystem 2.

This design determines the short circuit current (Isc) at given running temperature. Figure 5 provide the circuit beneath subsystem.



Function: to find light emitted photon current of PV group of cells

Equations:
 $I_{ph} = [I_{sc} + K_i(T - T_r)] * \text{where } * = \text{irradiation}$

Fig-5: Circuit beneath subsystem 2.

C. Step3

The subsystem 3 is shown in fig. 6 this design takes short circuit current I_{sc} at reference temp $= 2.55\text{A}$ and module reference temperature $Tr_k = 25^\circ\text{C}$ as aid

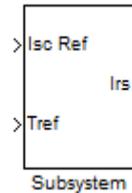
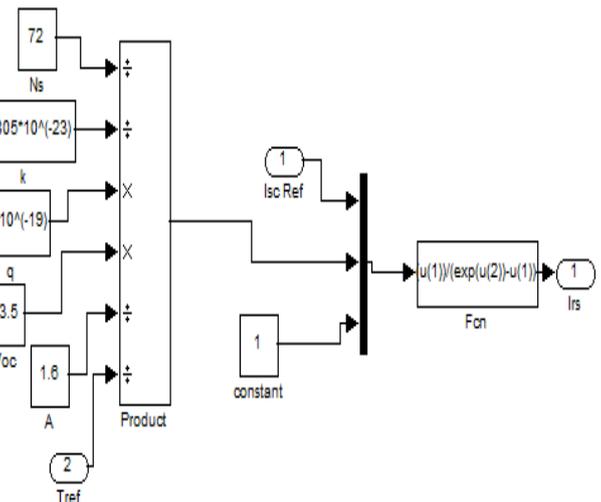


Fig-6: Subsystem3 reverse sat current.

Using equation 2, the reverse saturation current of the diode is measured in subsystem3. Figure7 provides the circuit under subsystem 3.



The subsystem 3: Reverse saturation current

Equation:

$$I_{rs} = I_{sc} / [\text{Exp}(qV_{oc}/N_s K A T_a K) - 1]$$

Fig-7: Circuit beneath subsystem 3.

D. Step4

The subsystem 4 is shown as below in figure8

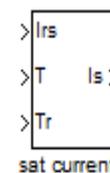
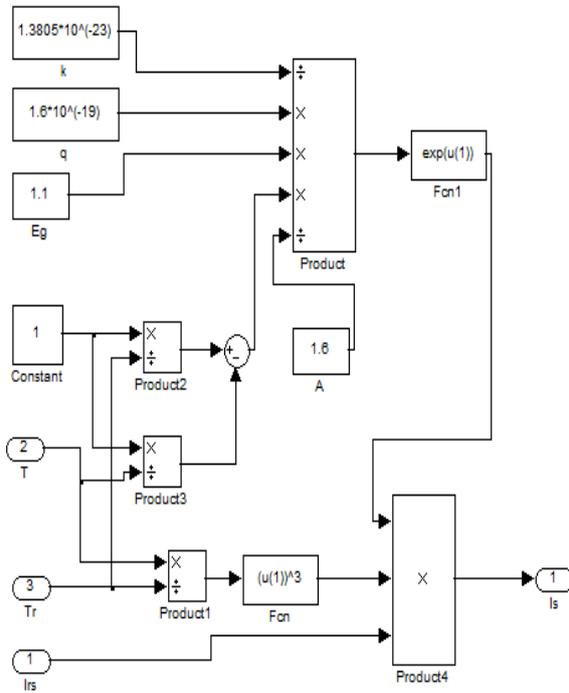


Fig-8: The subsystem4.

This design takes reverse saturation current I_{rs} , module reference temperature $T_r = 25^\circ\text{C}$ and module performing temperature T as input and determination module saturation current. The circuit beneath subsystem4 is as given below in fig.9.



The subsystem -4 saturation current of PV module Equation3 is in subsystem

Fig-9: Circuit beneath subsystem4.

E. Step5

The subsystem 5 is shown as below in figure 10.

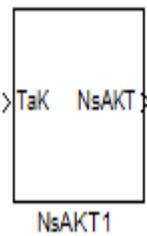


Fig-10: The subsystem5.

This model takes performing temperature in Kelvin T_{ak} and determines the product N_sAKT , the dominator of the exponential function in equation (4). Figure 11 gives the circuit subsystem5.

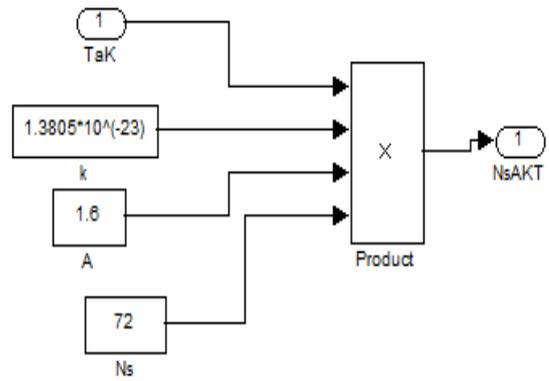


Fig-11: Circuit beneath subsystem 5.

F. Step6

The subsystem 6 is shown as below in fig 12.

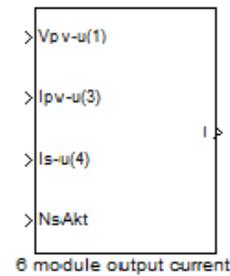


Fig-12: The subsystem6.

This model executes the function given by the equation (4).The following function equation can be used in design of the subsystem6.

$$I_{pv} = I - u(3) - u(4) * (\exp((u(2) * (u(1) + u(6))) / (u(5))) - 1)$$
 Figure 13 gives the circuit subsystem6.

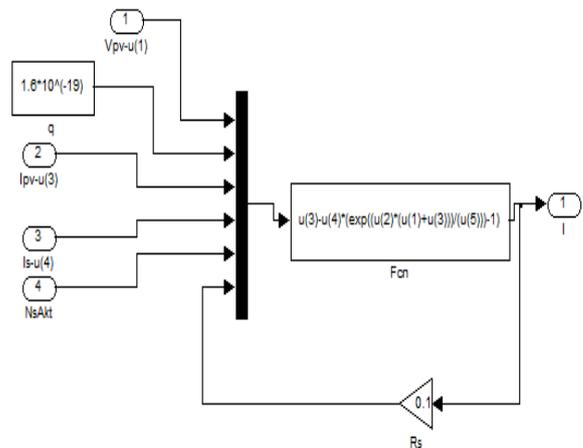


Fig-13: Circuit under subsystem6.

G. Step 7

All above six designs are interdependent as given in figure 14.

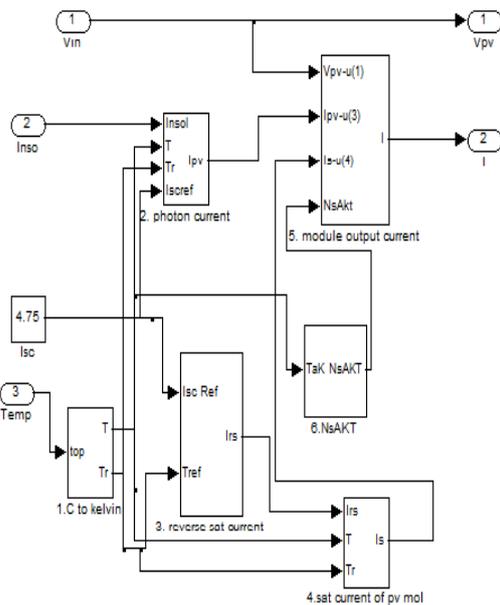
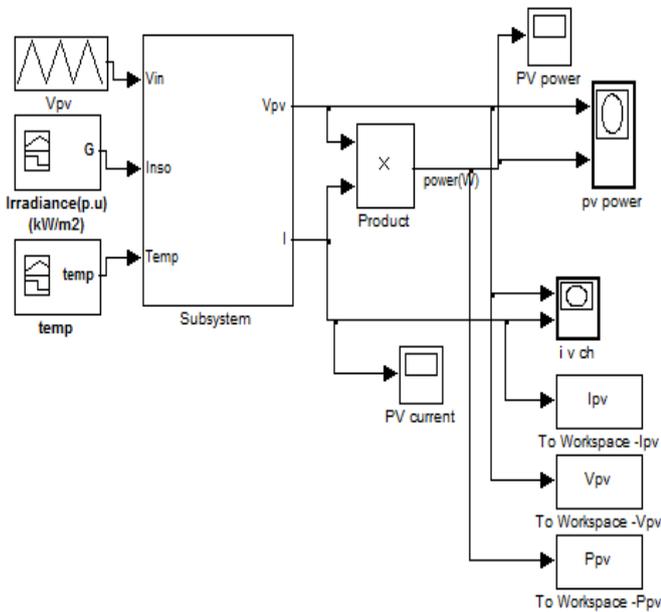


Fig-14: Interdependent of all six subsystems.

The final design is shown in Figure 15 as below. The workspace is joint to measure Ipv, Vps, and Ppv in this design. The time tout is stored in workplace with scope design can be used to draw graph.



Matlab code to XY graph;
 The Plot (Vpv, Ipv)
 The Plot (Vvp, Ppv)
 The Plot (tout, Ipv)

Figure15. The Simulink design of PV group of cells.

The final model uses as input illumination, operating temperature in Celsius and module voltage and gives the output current Ipv and output voltage Vpv.

For designing BPSX 150S the subsystem section in figure 15 as above will be a basic PV module design of MATLAB/Simulink. This subsystem is simulated in MATLAB/Simulink. [3]

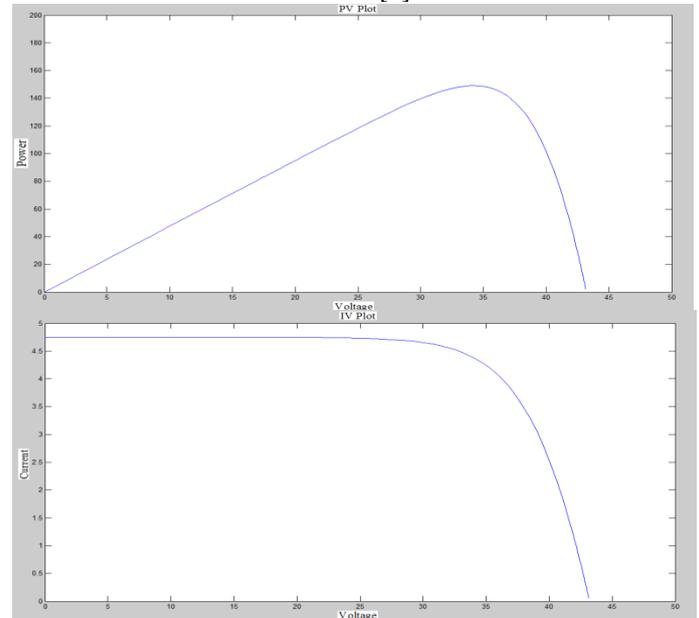


Fig-15.1: The simulated result of PV module at given temperature and cosmic irradiation (a) P-V property (b) I-V property

H. Performance Estimation

1. The Effect of Variation of Irradiance

The P-V and I-V curves of a PV module are extremely dependent on the cosmic irradiance data. The cosmic irradiance as a result of the environmental variations which keeps on oscillating, but control mechanisms are also accessible that can record this change, can alter the working of the PV module to meet required load need. Higher is the cosmic irradiance, higher would be the cosmic input to the PV module and hence power would increase for the same voltage value. The Open circuit voltage increases with increase in cosmic illumination. This is fact that, when more sun rays incidents on to the PV group of cells, the electrons are equipped with higher stimulation energy, thereby increasing the electron immovability and thus more power is gained. [5]

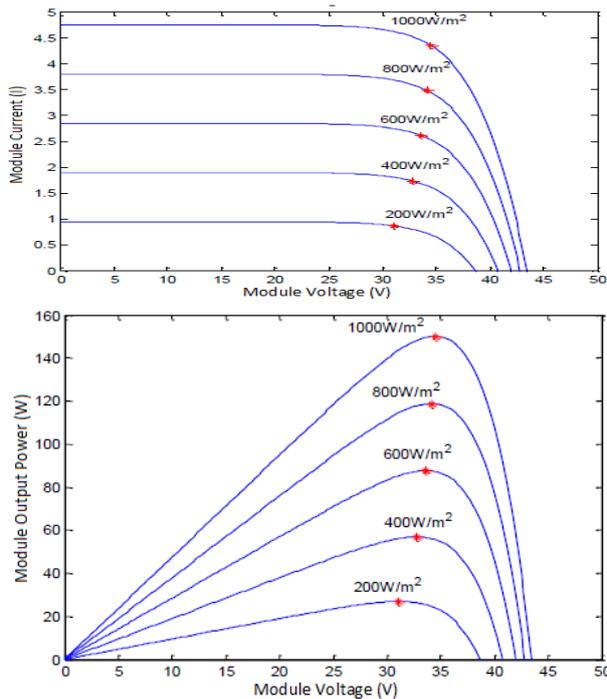


Fig-16: Simulated result of P/ Fig. 16 Simulated result of PV module at various cosmic irradiances and constant temperature (25°C) (a) I-V property (b) P-V property.

2. The Effect of change of Temperature

The Negative impact on the power generation capability is gained while the temperature increases around the PV module. The value of increase in temperature results decrease in the open circuit voltage. Increase in temperature causes increase in the band energy gap of the material, so the barrier level increases and thus more energy is required to cross this barrier. Hence the efficiency of the PV module is reduced. [5]

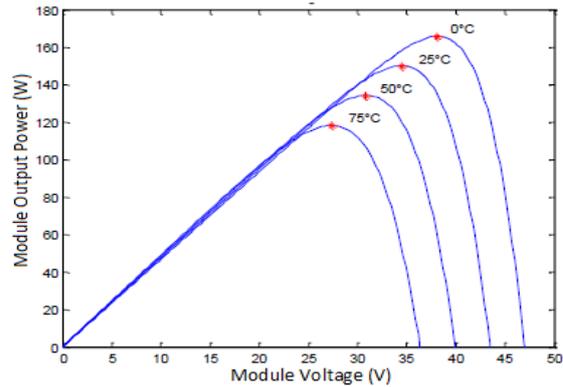
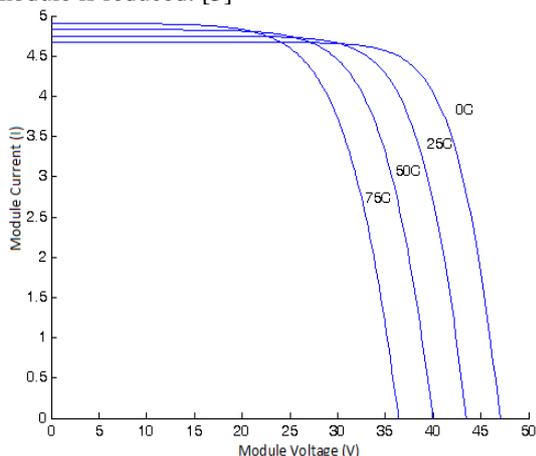


Fig. 17: The simulated result of PV module at constant cosmic illumination (1000W/m² and various temperatures) (a) I-V property (b) P-V property.

6. CONCLUSION

The numerical step one-by-one method for designing the PV module is presented. This designing method serves as a gift to bring about more people into PV investigation and to gain a closer understanding of I-V and P-V properties of typical 72 W PV modules.

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