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STEP BY STEP MODELING AND SIMULATION OF PHOTOVOLTAIC (PV) SYSTEM

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***Abstract*— this paper studies a unique step-by-step procedure for the simulation of photovoltaic (PV) modules in Matlab/Simulink. One-diode equivalent circuit is used to investigate I-V and P-V curve of a typical solar (PV) module and equivalent circuit with a series resistance and a parallel resistance is discussed.**

***Keywords*— Photovoltaic module, Matlab/Simulink.**

I. Introduction

Among all the renewable energy resources, energy due to the photovoltaic system effect can be considered as the most vital and prerequisite sustainable resource due to the abundance, ubiquity, and sustainability of solar energy. PV cell presents the essential power conversion unit of a photovoltaic system. The P-V and I-V characteristics of a PV module depend on the cell temperature, solar insolation and output voltage of the PV module. Since PV module has nonlinear characteristic, it is required to model PV system applications for the design and simulation of maximum power point tracking (MPPT).

In this paper, a step-by-step process for simulation of PV module with subsystem blocks is explained and shown in Matlab/ Simulink. And also presents the PV module equivalent circuit and equations for Ipv, the output current from the PV module. Finally, brief conclusions are drawn in the last section. [1][2][3]

II. Modelling of PV module

The electromagnetic radiation of solar energy can be directly converted to electricity via photovoltaic effect. And the equivalent circuit of a PV cell is shown in Figure 1.

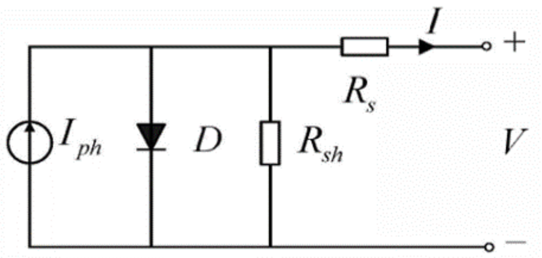

Fig.1 circuit diagram of solar cell

The current source I_{ph} presents the cell photocurrent. R_{sh} and R_s are the intrinsic shunt and series resistances of the cell, respectively. Generally for the ideal PV cell the amount of R_{sh} is very large and R_s is very small.

PV specification

V_{pv}: output voltage of a PV module (V)
I_{pv}: output current of a PV module (A)
T_r: reference temperature = 298 K
T: module operating temperature in Kelvin
I_{ph}: light generated current in a PV module (A)
I_o: PV module saturation current (A)
A, B: ideality factor = 1.6
k: Boltzman constant = 1.3805×10^{-23} J/K
q: Electron charge = 1.6×10^{-19} C
R_s: the series resistance of a PV module
I_{SCr}: the PV module short-circuit current at 25°C
Ki: the short-circuit current temperature co-efficient at
I_{SCr}: 0.0017A /°C
λ: PV module illumination (W/m^2) = 1000W/m^2
E_{go}: band gap for silicon = 1.1 eV
N_s: number of cells connected in series

N_p: number of cells connected in parallel

The photovoltaic cell can be modeled mathematically as given in the following equations.

Module photo-current is given as,

$$I_{ph} = [I_{scr} + K_i(T - 298)]\frac{\lambda}{1000} \quad (1)$$

Module reverse saturation current is given as,

$$I_{rs} = \frac{I_{scr}}{\left[\exp\left(\frac{qV_{oc}}{N_s KAT}\right) - 1\right]} \quad (2)$$

Module saturation current is given as,

$$I_0 = I_{rs}\ [\frac{T}{T_r}]^3 \exp\left(\frac{qE_{g0}}{\text{Bk}}\right) \quad -\left\{\frac{1}{T_r} - \frac{1}{T}\right\}] \ (3)$$

Output PV module is given as,

$$I_{PV=} = N_P\, I_{Ph} - N_P * I_0\ [\exp\left\{\frac{q * (V_{PV} + I_{PV}\, R_s)}{N_s AkT}\right\} - 1]\ (4)$$

$$V_{PV} = V_{oc}, N_P = 1, N_s = 20$$

III. Reference model specification

Rated power (W): 345, Voltage at Maximum Power (V): 46 V, Current at maximum Power (A): 8.3 A, Open Circuit Voltage: 46 V, Short Circuit Current: 8.41 A, Total number of cells in series : 20, Total number of cells in parallel: 1

IV. All procedures for Simulink Modelling PV module

Step 1, Simulink and modelling is shown in Figure 2, converts the module operating temperature given in degrees Celsius to Kelvin.

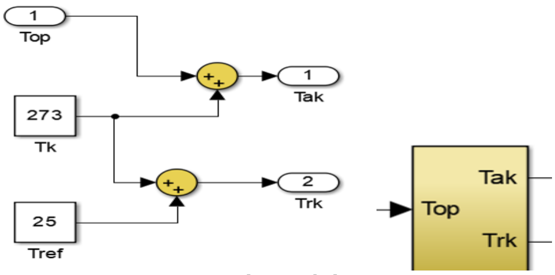

Fig.2 Celsius to kelvin

Step 2, Simulink and modeling is shown in Figure 3, this model calculates the short circuit current (I_{ph}) with respect to the temperature.

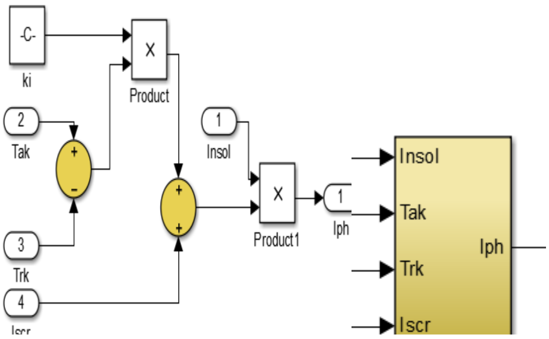

Fig.3 Photon current

Step 3, Simulink and modeling is shown in Figure 4, the reverse saturation current of the diode is calculated.

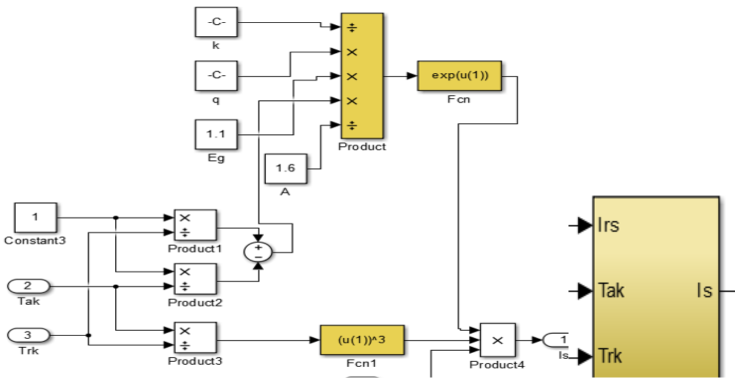

Fig.4 Saturation current

Step 4, Simulink and modeling is shown in Figure 5.This model shows reverse saturation current I_{rs}, reference temperature. T_{rK} = 250C and operating temperature T_{aK} as input and calculates module saturation current.

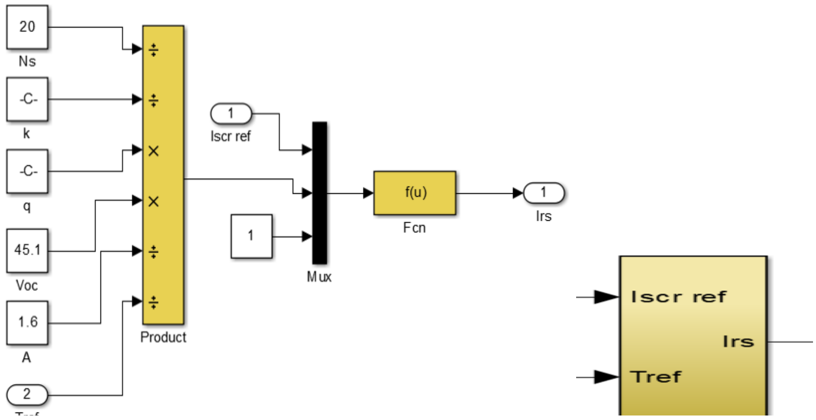

Fig.5 Reverse saturation current

Step 5, Simulink and modelling is shown in Figure 6.This model shows operating temperature in Kelvin T_{aK} and calculates the product N_sAkT subsystem.

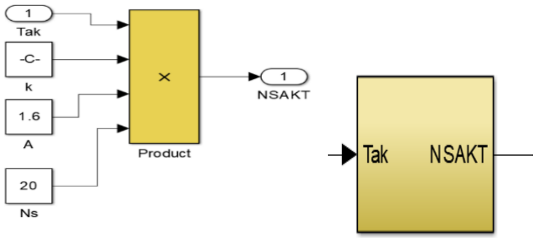

Fig.6 N_sAKT subsystem

Step 6, Simulink and modelling is shown in Figure 7. This model implements the function given by the equation (4). The following equation is used.

I_{PV} = u(3)-u(4)*(exp((u(2)*(u(1)+u(6)))/(u(5)))-1) (5)

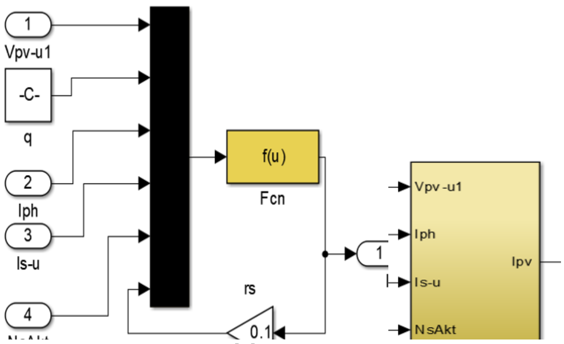

Fig.7 module output current

Step 7, all above six modules are connected as shown in Figure 8.

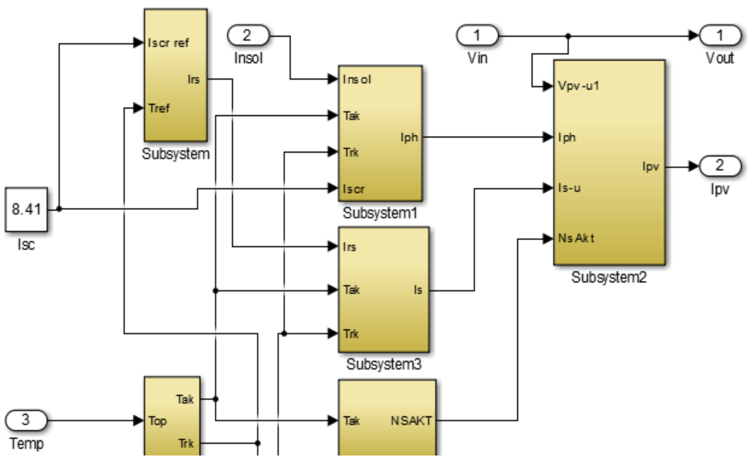

Fig.8 Interconnection of six subsystems

The last model is shown in Figure 9. The workspace is added to measure I_{pv}, V_{pv}, P_{pv} and also irradiation variation and operating temperature in Celsius shown as input and give the output current I_{pv} and output voltage V_{pv}.

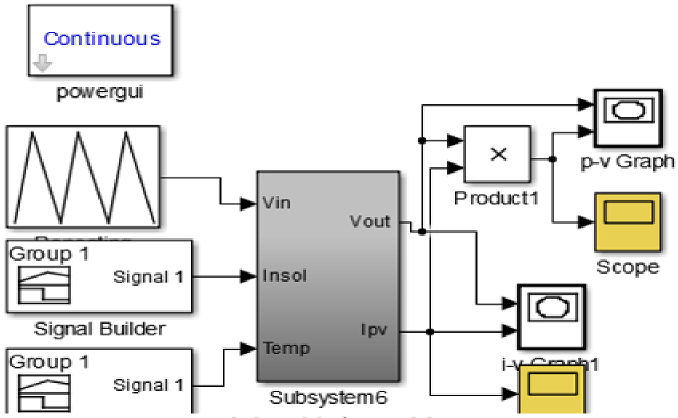

Fig.9 simulink model of pv module

The I-V & P_V output characteristics of PV module with varying irradiation at different temperature are shown in Figure11, 12, 13, 14.

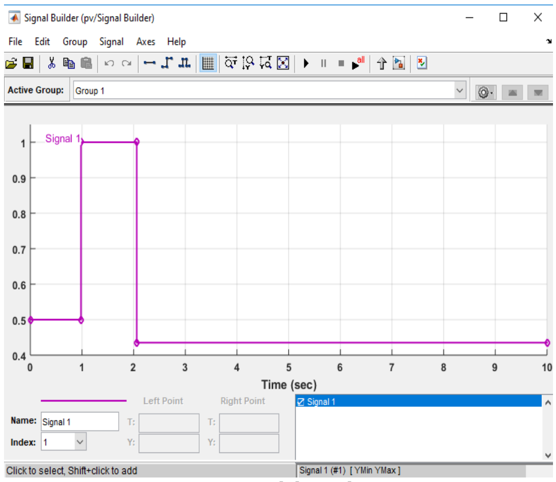

Fig.10 PV module irridiation

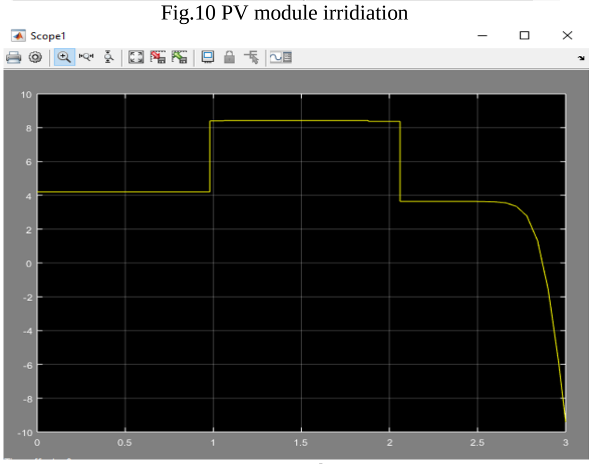

Fig.11 Output power with respect to time

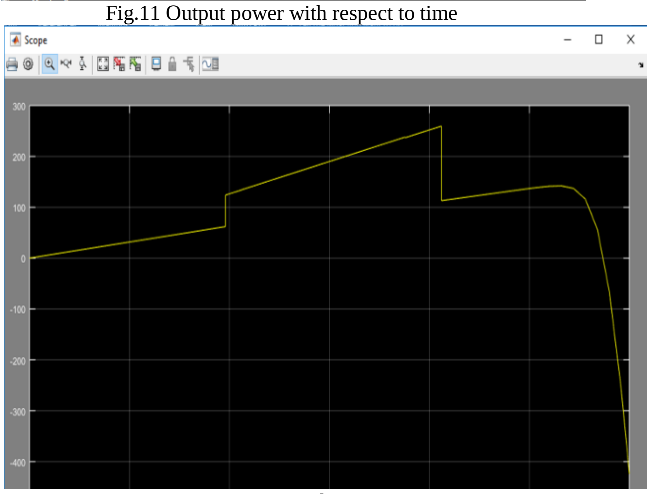

Fig.12 Output current with respect to time

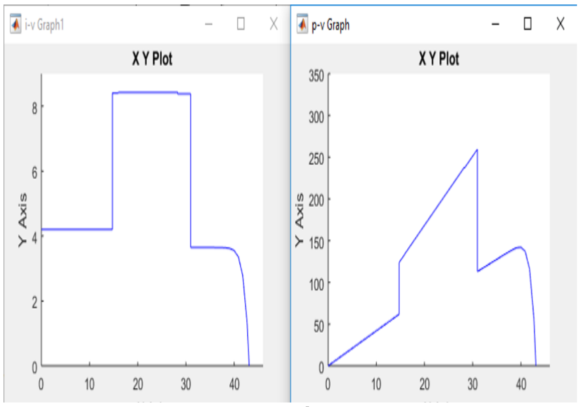

Fig.13 I-V & P-V characteristic

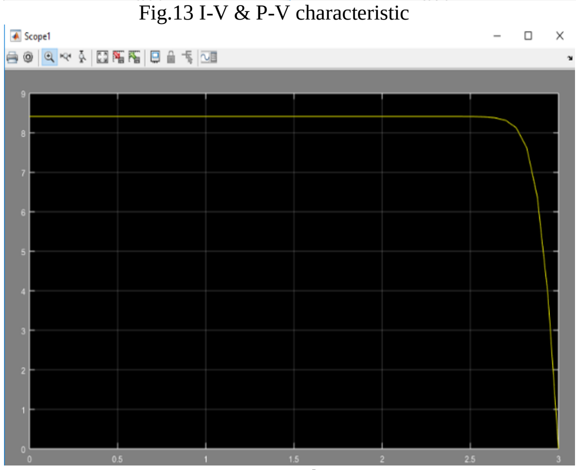

Fig.14Output current with respect to time

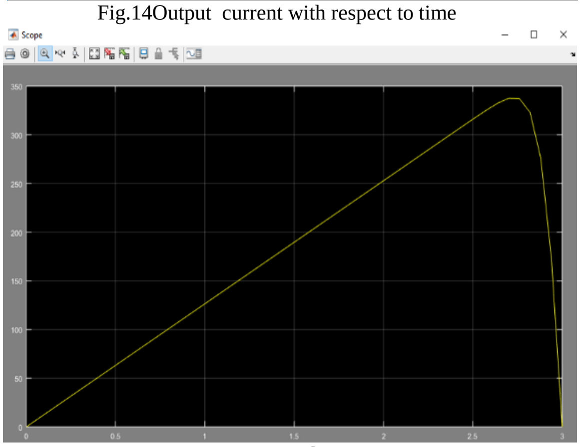

Fig.15 Output power with respect to time

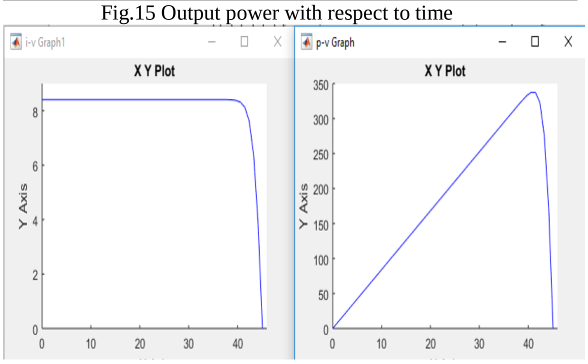

Fig.16 I-V & P-V characteristic

V. CONCLUSION

The procedure for the modelling of the PV module, has analysed the development of a method for the mathematical modelling of PV arrays. The objective of the method is to fit the mathematical I–V equation to the experimental remarkable points of the I–V curve. This mathematical modelling procedure can be used as an aid to induce more people into photovoltaic research and understanding of the I-V and P-V characteristics of PV module as well.

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