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Modeling and Simulation of Photovoltaic Module and Array based on One and Two Diode Model Using Matlab/Simulink

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Abstract

This paper presents the modeling and simulation of photovoltaic module and array based on one and two diode model using the software Matlab/Simulink. Also, two fast and accurate methods are used to obtain the parameters of photovoltaic panel. The experimental validation of one and two diode model under STC condition and the simulation of P(V) and I(V) Characteristics of ISOFOTON 75 panel under different values of temperature and irradiation are presented .

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Keywords:Modeling,Simulation,I-V and P-V Characteristic,STC condition ,Matlab/Simulink

1. Introduction

the renewable energy resources is becoming an essential factor in power electric generation in many countries [1], There are various renewable sources which utilized for the production of electric power, such as solar energy, wind energy and geothermal etc. Solar energy is the best choice for electric generation in the countries which is

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characterized by an high solar radiation intensity [2,3], since the solar radiation is converted directly into electrical energy by the photovoltaic effect. A photovoltaic module is composed of cells connected in series. The nominal current of the modules increases when the area of the individual cells is increased. The output power of photovoltaic module is proportional to the solar radiation emitted by the sun.

Nomenclature

I	the output current of PV cell
V	the output voltage of PV cell
I_{ph}	the photocurrent
I_0, I_{01} ,I_{02}	the reverse saturation current of diode
V_d	the diode voltage
I_d	the diode current
I_0	the reverse saturation current of diode
a,a_1,a_2	the diode ideality factor
k	the Boltzmann constant
T	the p-n junction temperature
q	the electron charge
K_i	the short-circuit current/temperature coefficient
K_v	the open-circuit voltage/temperature coefficient
G	actual sun irradiation
G_{STC}	nominal sun irradiation (1000W/m^2)
ΔT	the difference between Actual temperature and nominal temperature (25°C)
$I_{Ph,STC}$	the nominal photocurrent(25°C and 1000W/m^2)
N_s	the number of cells connected in series
N_{ss}	the number of modules connected in series
N_{pp}	the number of modules connected in parallels
V_{oc}	open Circuit Voltage
I_{sc}	short Circuit Current
MPP	maximum Power point

2. Modeling of photovoltaic systems

2.1 The ideal model of photovoltaic cell

The equivalent circuit of photovoltaic cell consists of a single diode connected in parallel with a photocurrent source, this model described by the equation 1.

$$I = I_{ph} - I_0(\exp(\frac{qV_d}{akT}) - 1) \tag{1}$$

2.2 Photovoltaic module modeling using single and two diode models

The single diode model which includes the series resistance R_s and shunt the resistance R_p , where the output current can be written as [4]

$$I = I_{Ph} + I_0(\exp(\frac{V + IR_s}{aV_T}) - 1) - \frac{V + IR_s}{R_p} \tag{2}$$

With

$$V_T = \frac{N_s KT}{q} \tag{3}$$

The photocurrent is given by

$$I_{Ph} = (I_{Ph.STC} + K_I.\Delta T).\frac{G}{G_{STC}} \tag{4}$$

And the reverse saturation current

$$I_0 = \frac{I_{sc,STC} + K_I \Delta T}{\exp\left[(V_{oc,STC} + K_V \Delta T)/aV_T\right] - 1} \tag{5}$$

The two diode model takes into consideration an additional diode in the equivalent circuit of a single diode, this diode connected in parallel with the first diode. The output current is given by the following expression in this case [6,7,8]

$$I = I_{Ph} + I_{01}\left[\exp(\frac{V + IR_s}{a_1 V_{T1}}) - 1\right] - I_{02}\left[\exp(\frac{V + IR_s}{a_2 V_{T2}}) - 1\right] - \frac{V + IR_s}{R_p} \tag{6}$$

where I_{Ph} is the same with the equation 4 and the I_{01} and I_{02} is given by

$$I_{01} = I_{02} = I_0 = \frac{I_{sc,STC} + K_I \Delta T}{\exp\left[(V_{oc,STC} + K_V \Delta T)/\{(a_1 + a_2)/p\}V_T\right] - 1} \tag{7}$$

$$V_{T1} = V_{T2} = \frac{N_s KT}{q} \tag{8}$$

2.3 Photovoltaic arrays modeling using single and two diode models

For large arrays composed of $N_{ss}xN_{pp}$ modules the previous equations of one and two become

$$I = I_{Ph} N_{pp} + I_0 N_{pp}(\exp(\frac{V + IR_s(\frac{N_{ss}}{N_{pp}})}{aV_T N_{ss}}) - 1) - \frac{V + IR_s(\frac{N_{ss}}{N_{pp}})}{R_p(\frac{N_{ss}}{N_{pp}})} \tag{9}$$

$$I = I_{Ph} N_{pp} + I_{01} N_{pp}\left[\exp(\frac{V + IR_s(\frac{N_{ss}}{N_{pp}})}{a_1 V_{T1} N_{ss}}) - 1\right] - I_{02} N_{pp}\left[\exp(\frac{V + IR_s(\frac{N_{ss}}{N_{pp}})}{a_2 V_{T2} N_{ss}}) - 1\right] - \frac{V + IR_s(\frac{N_{ss}}{N_{pp}})}{R_p(\frac{N_{ss}}{N_{pp}})} \tag{10}$$

2.4 I-V and P-V characteristics of a typical panel

The I-V and P-V curves of a typical photovoltaic module are shown in following figures

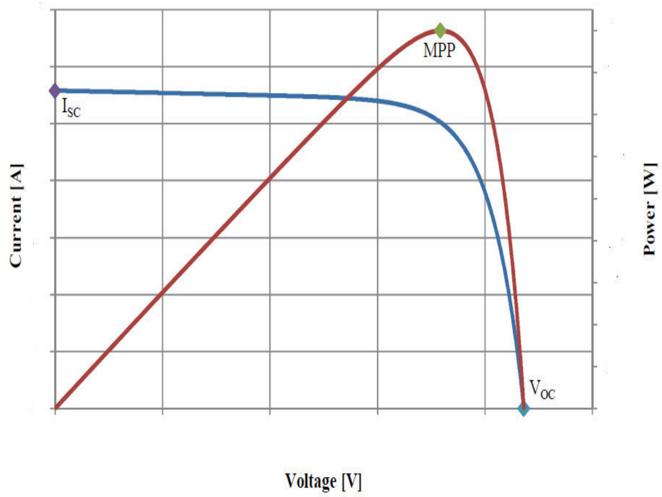

Fig. 1 I-V and P-V Characteristic of typical panel

3. Simulations and results

3.1 The experimental setup

Fig. 2 Hardware and software MP-160 of experimental Setup URERMS ADRAR

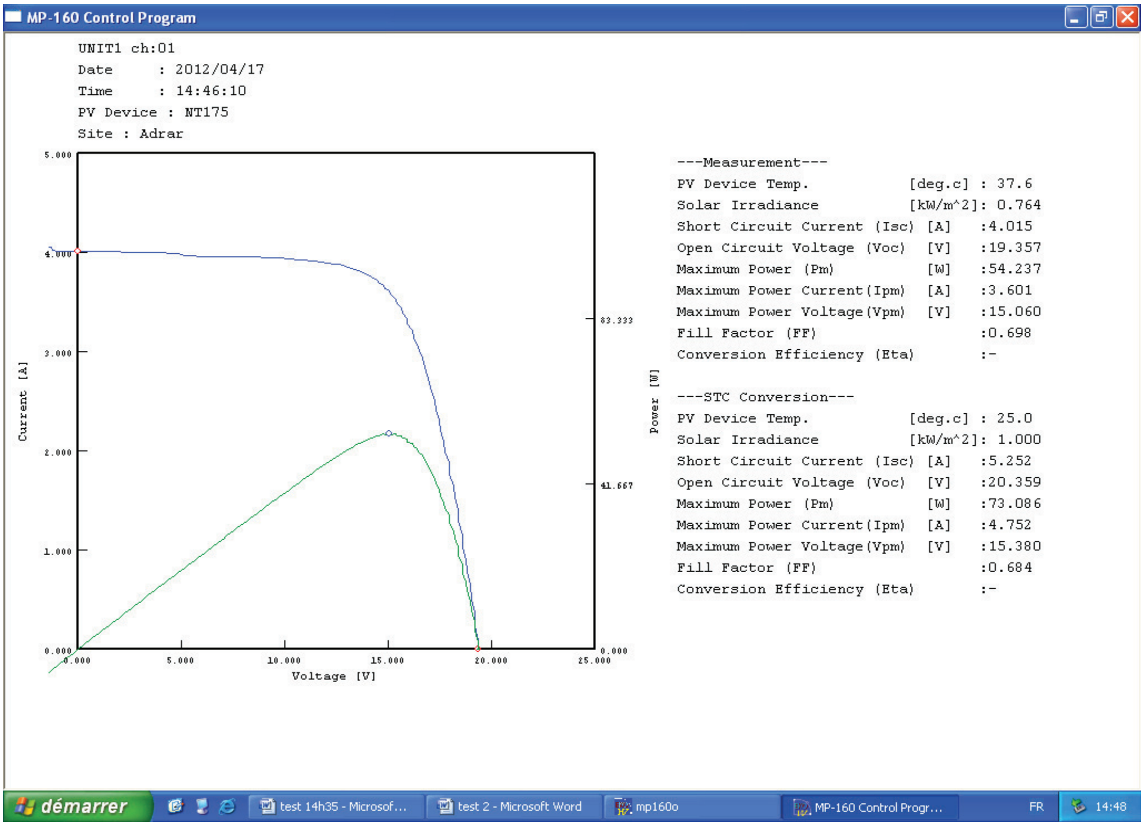

Fig. 3 I-V and P-V Tracer

3.2 The extraction of parameters of ISOFOTON 75 Panel based on One and two diode Model

In this work the extraction of module parameters is obtained using a accurate method proposed by [5,6]

Table 1. Parameters for One diode model

Parameters	Values
I_{sc}	5.252 A
V_{oc}	20.359 V
I_{mp}	4.752 A
V_{mp}	15.38 V
I_{pv}	5.265914 A
I_0	2.3278x10^{-7} A
a	1.3
R_s	0.39 Ω
R_p	149.36 Ω
N_s	36

Table 2. Parameters for two diode model

Parameters	Values
I_{sc}	5.252 A
V_{oc}	20.359 V
I_{mp}	4.752 A
V_{mp}	15.38 V
I_{pv}	5.252 A
a_1	1
a_2	1.2
$I_{01}= I_{02}$	$1.44856x10^{-9}$
R_s	0.5 Ω
R_p	103.05 Ω
N_s	36

3.3 Matlab/Simulink modeling for one and two diode model

For simulation the characteristics I-V and P-V of modules and arrays we use the models Matlab/Silmulink presented below

3.3.1 Global Simulator

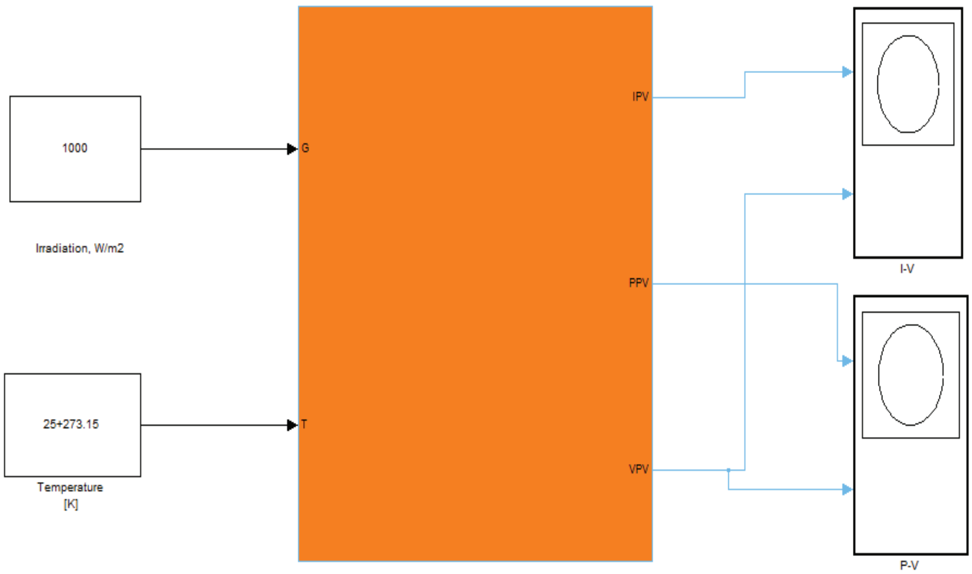

Fig. 4 Global Matlab/Simulink Simulator

3.3.2 One diode model

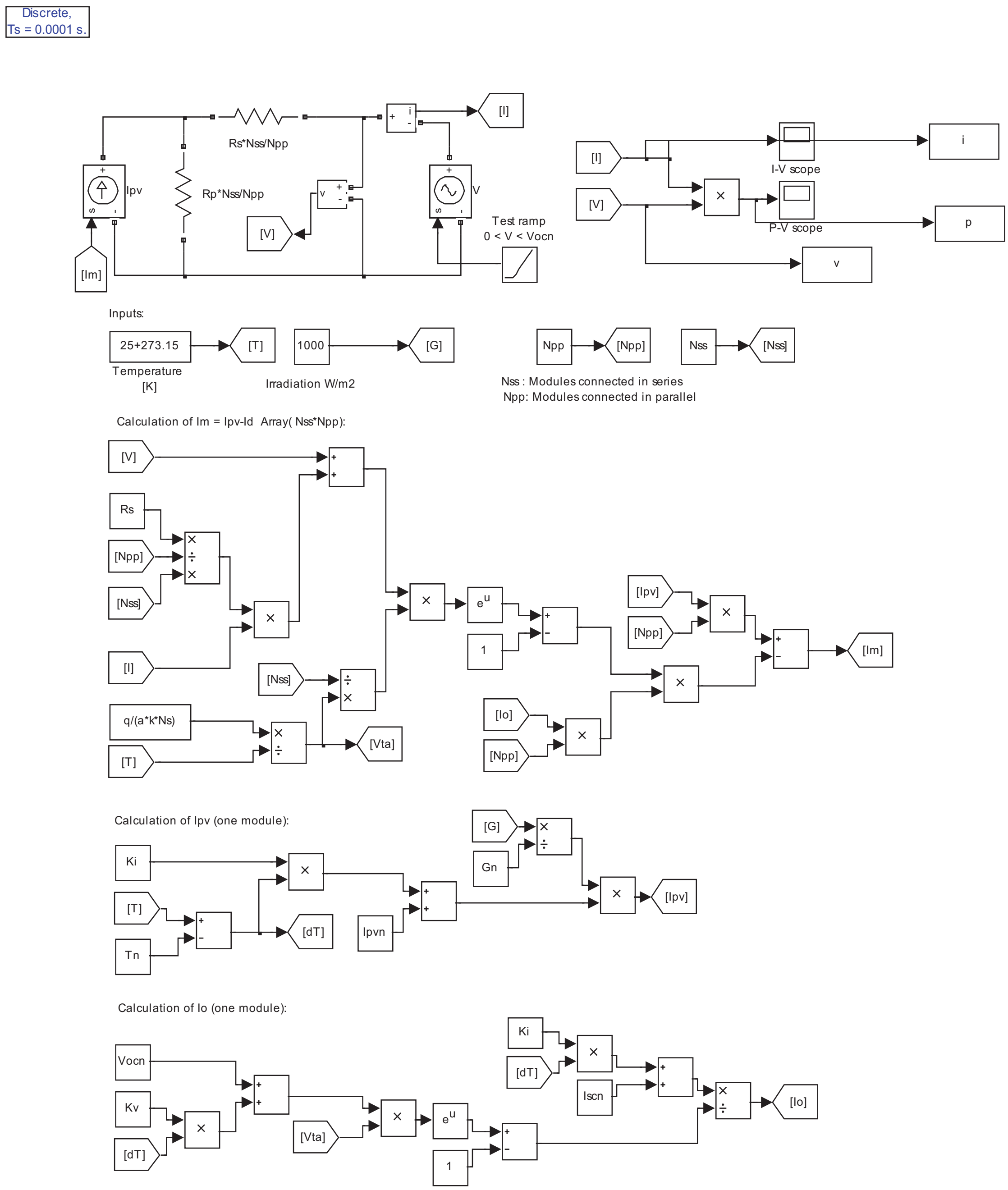

Fig 5 Matlab/Simulink of One diode model [6]

3.3.3 Two diode model

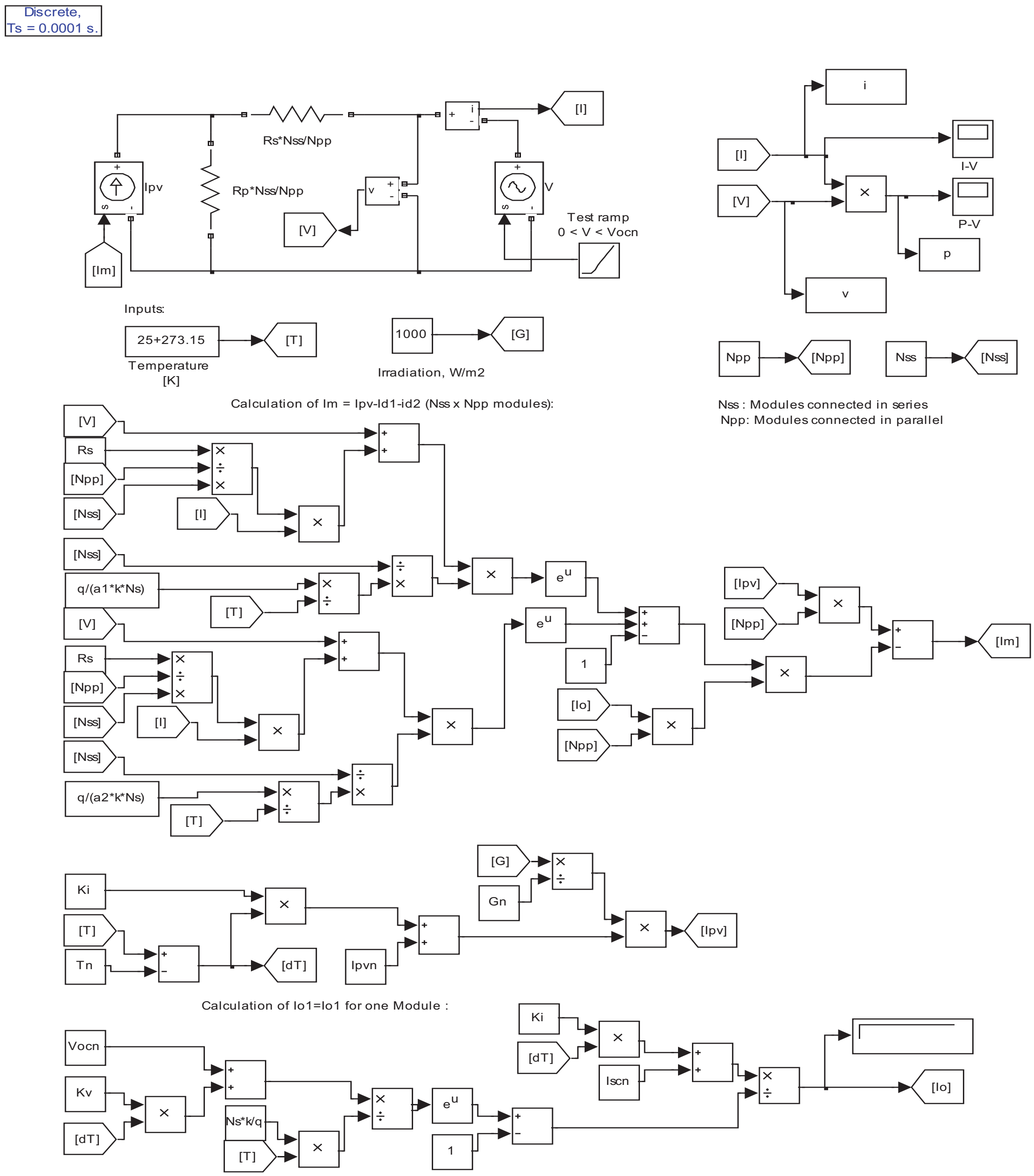

Fig 6 Matlab/Simulink of two diode model

3.3.4 Input parameters interface

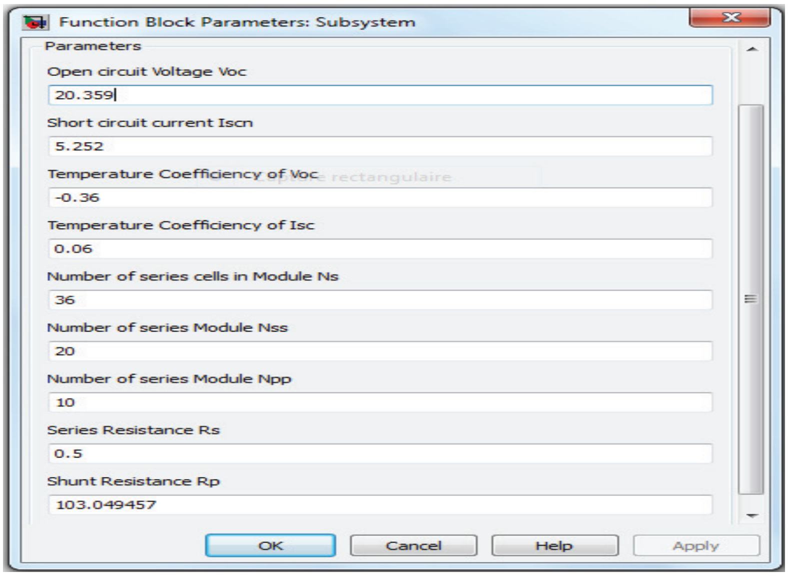

Fig. 7 Input parameters interface

3.5 The experimental validation of model based on one and two diode

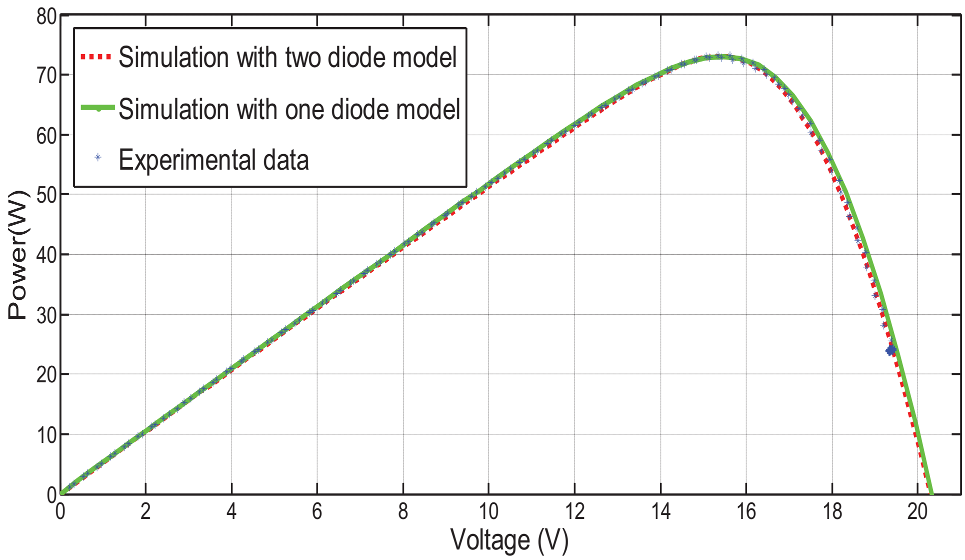

Fig. 8 P-V Curve under STC condition (1000W/m^2,25 °C)

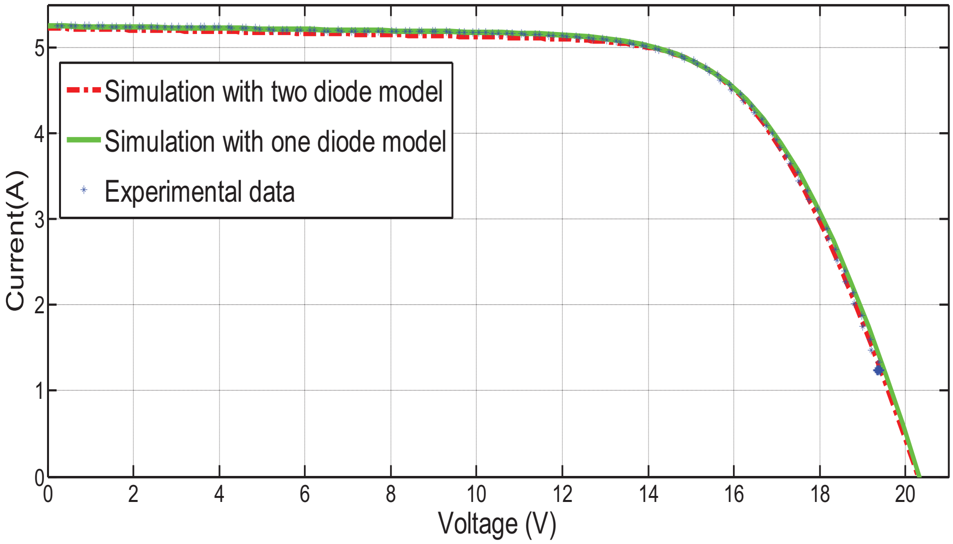

Fig. 9 I-V Curve under STC condition (1000W/m^2,25 °C)

3.6 Simulation of ISOFOTON 75 Panel with variation of temperature and irradiation

3.6.1 Simulation under variation of irradiation

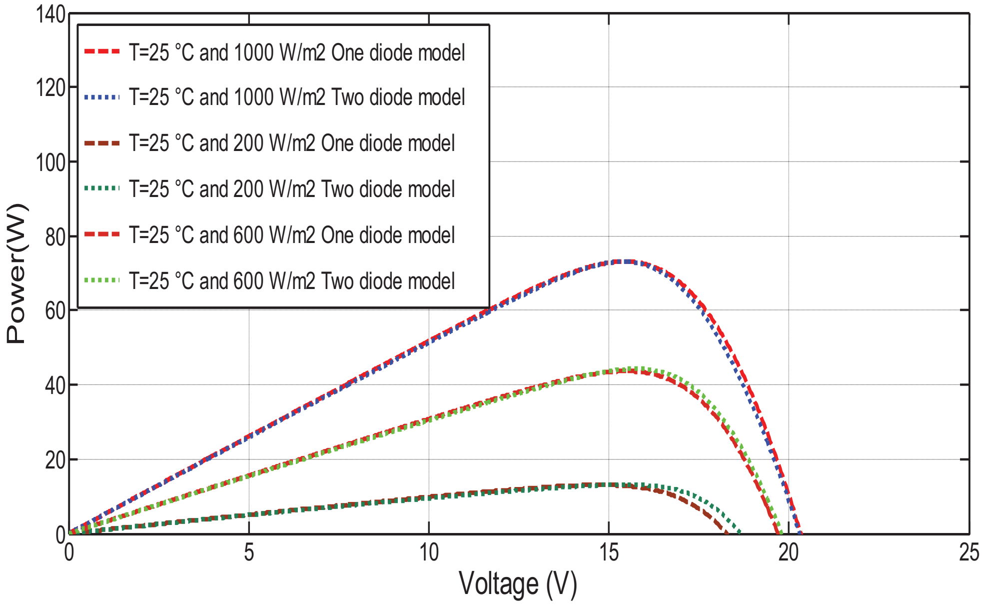

Fig. 10 P–V curves of the PV module at Irradiation levels (200, 600, 1000) with Constant temperature value 25 °C

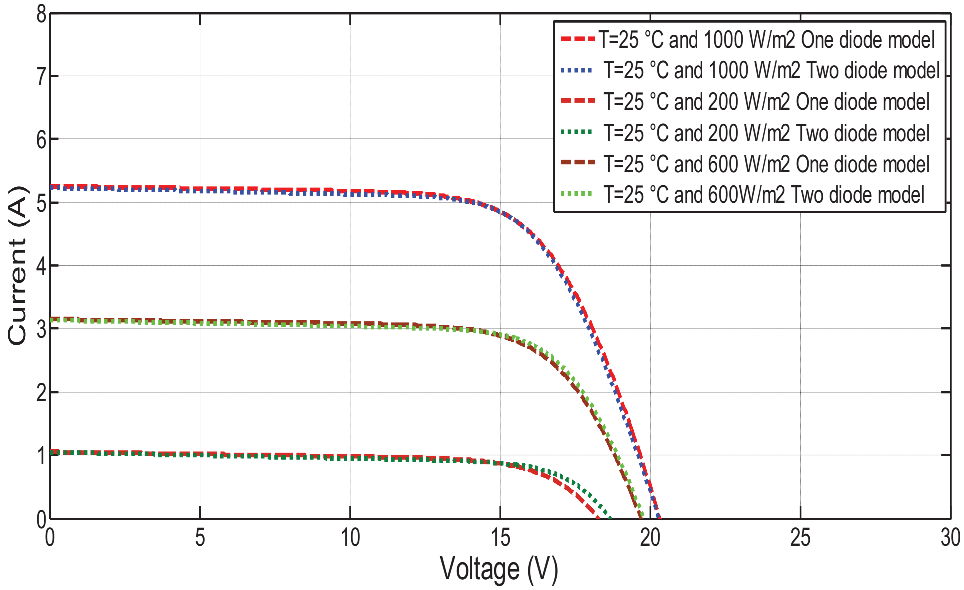

Fig. 11 I-V curves of the PV module at different Irradiation levels (200,600,1000) with Constant temperature value 25 °C

3.6.2 Simulation under variation of temperature

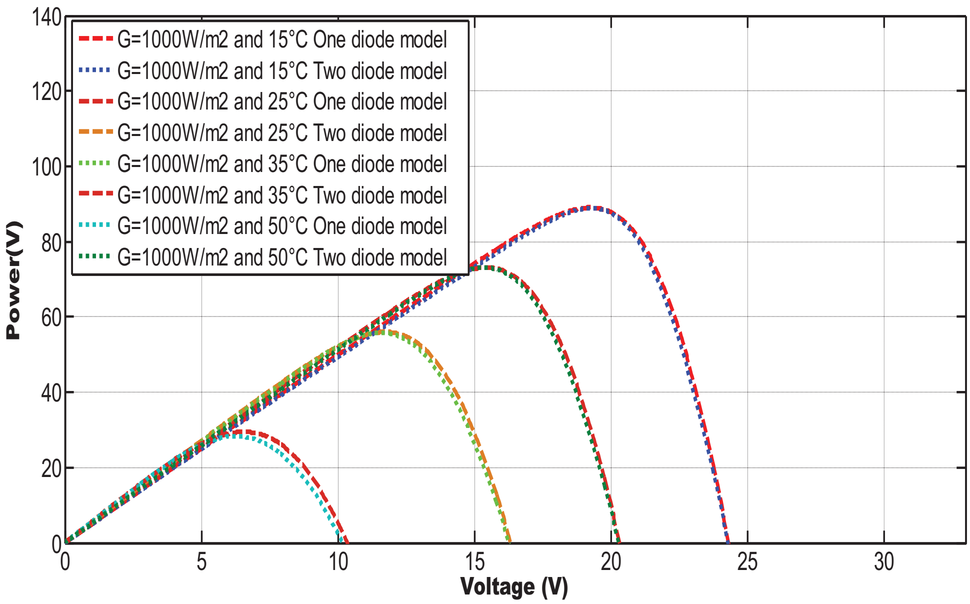

Fig. 12 P-V curves of the PV module at different temperatures levels (15,25,35,50) with Constant Irradiation value 1000 W/m^2

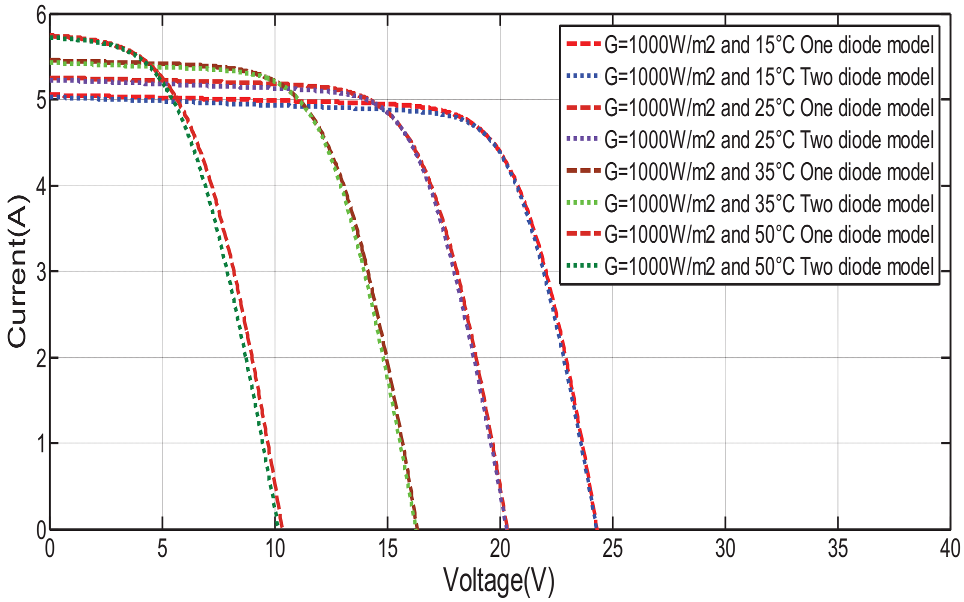

Fig. 13 I-V curves of the PV module at different temperatures levels (15, 25, 35, 50) with Constant Irradiation value 1000 W/m^2

3.7 Simulation of large array (N_{ss}=20, N_{pp}=10) with variation of temperature and irradiation

3.7.1 Simulation under variation of irradiation

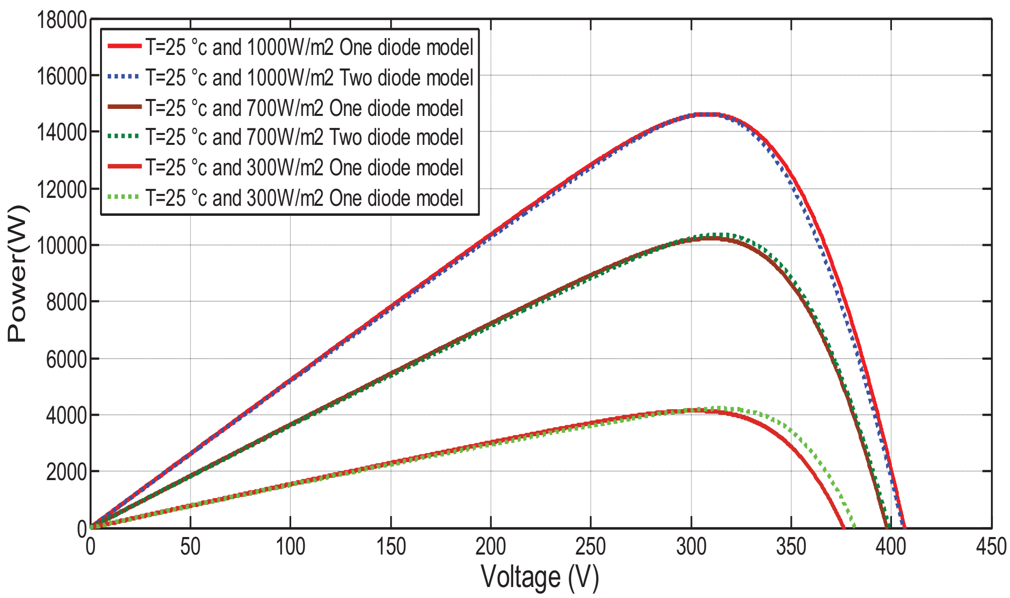

Fig. 14 P-V curves of the PV array at different Irradiation levels (300, 700, 1000) with Constant temperature value 25 °C

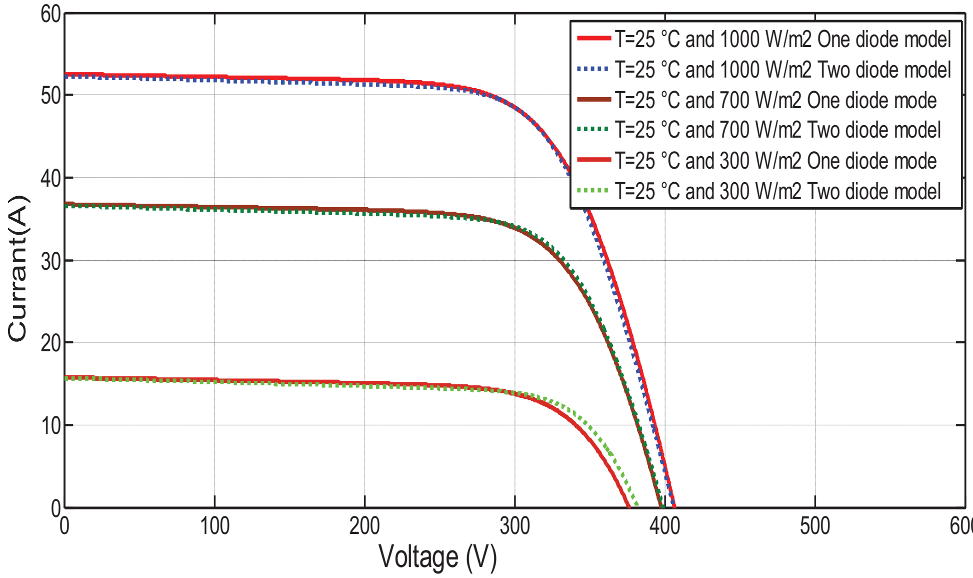

Fig. 15 I-V curves of the PV array at different Irradiation levels (300,700,1000) with Constant temperature value 25 °C

3.7.1 Simulation under variation of temperature

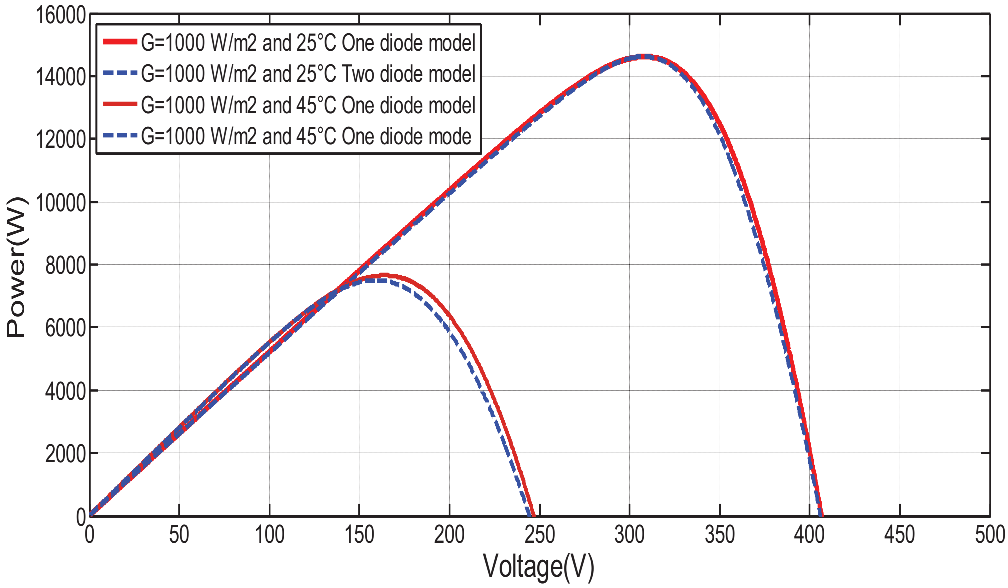

Fig. 16 P-V curves of the PV array at different temperatures levels (25,45) with Constant Irradiation value 1000 W/m^2

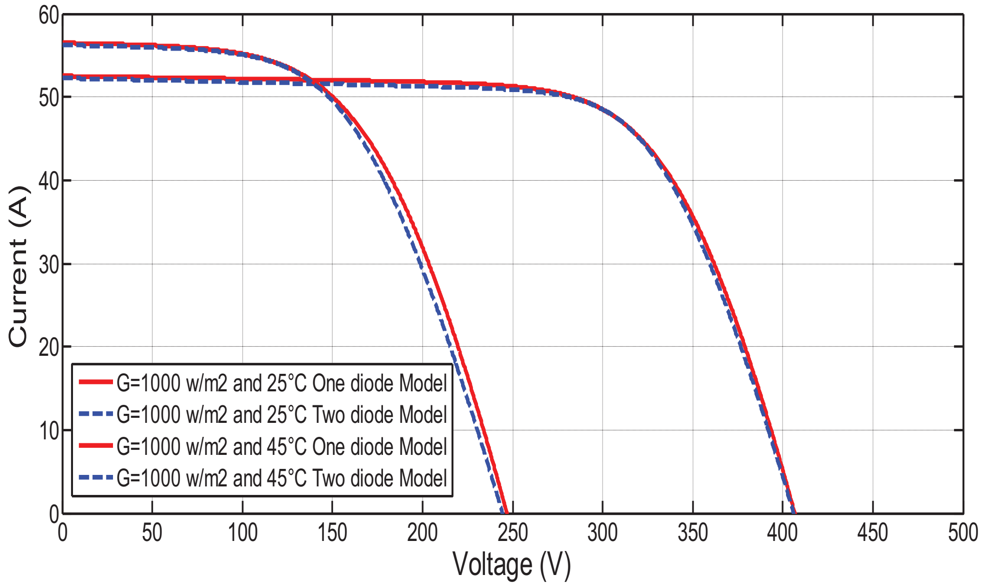

Fig. 17 I-V curves of the PV array at different temperatures levels (25,45) with Constant Irradiation value 1000 W/m^2

4. Conclusion

In this paper, the equivalent schema of photovoltaic cell based on one and two diode models are presented. The simulations are obtained using the software Matlab/Simulink. The both models two diodes and one diode are respectively developed and presented using the design of photovoltaic panels and arrays. The previously models show the temperature and solar irradiation effect on P-V and I-V modules array characteristics. Also, for all PV modules array connection with the systems and loads electrics.

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