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A Novel and Accurate Photovoltaic Simulator Based on Seven Parameter Model

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Abstract—the demand of electrical energy is increasing day by day and the world is more concern about the fossil fuel deficit, global warming and environmental damages. Among the renewable energy sources, solar energy is the most promising and photovoltaic (PV) system provides the most direct method to convert solar energy into electrical energy.The output characteristics of a photovoltaic (PV) array are highly non-linear. Therefore, an accurate and efficient PV model is required to study and analyze the operation of PV system in the changing environmental conditions.A precise PV simulator based on the seven-parameter electric circuit model. The robustness of the proposed simulator is demonstrated under the partial shaded conditions. Additionally, the performance of the developed simulator is verified by interfacing it with the actual power electronic converter and maximum power point tracking (MPPT) controller.

IndexTerms—Photovoltaic system, seven level parameter,MPPT Techniques

I.Introduction

Today, the world is seeing an increase in its energy usage at alarming speeds and conventional fossil-based fuel resources are being consumed at an ever faster rate. Moreover, the uncertainty in the supply of conventional fuels has resulted in a need form reliable and sustainable energy resources. The newer energy resources are expected to be sustainable, available in sufficient quantities, and have minimal environmental impact. Solar energy provides one such option and demonstrates all these desirable characteristics. Until the 1970s, the only application of the PV technology was in space crafts. But, in the last few decades, decrease in the price of commercially available PV modules as well incentives by governments around the world have resulted in very fast growth in the use of PV systems.

II. LITERATURE SURVEY

The output of PV is extremely non-linear and it is not suitable to represent it with a constant or controlled voltage/current source. Several PV electrical models have been proposed and developed [1]. In [2-3] a method of translation of I–V curve from one environmental condition to another was presented. The most efficient and practical model for PV is developed in Sandia Lab [4]. To overcome these shortcomings, an improved circuit based model is developed by adding shunt resistance and it is widely known as five-parameter model [5].Recently, seven-parameter model has been proposed in [6]in which efficiency of five-parameter is further improved by adding two additional parameters and without compromising its computational efficiency.

III. PV PANEL MODELING

The seven-parameter electric circuit model of PV is shown in Figure1. It consists of light depended current source, a p–n junction diode and two resistances one in series and another in shunt.

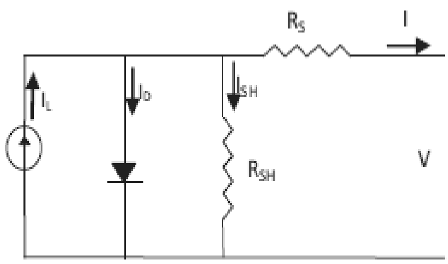

Figure1:Equivalent Model of PV Cell

Seven parameters are defined as:

I_L:Light generated current

$$I_L = \left(\frac{S}{S_{ref}}\right)^m [I_{L,ref} + \mu_{sc}(T_c - T_{c,ref})] \quad (1)$$

I_D:Diode saturation current

$$\frac{I_0}{I_{ref}} = \left(\frac{T_c}{T_{c,ref}}\right)^3 e^{\left(\left(\frac{N_s * T_{c,ref}}{a_{ref}}\right)*\left(\frac{E_{g,ref}}{T_{c,ref}} - \frac{E_g}{T_c}\right)\right)} \quad (2)$$

R_S:Series resistance

$$R_s = R_{s,ref} \quad (3)$$

Shunt resistances

$$R_{sh} = R_{sh,ref}\left(\left(\frac{S}{S_{ref}}\right)\right) \quad (4)$$

"a" Diode modified ideality factor

$$a = a_{ref}\left(\frac{T_c}{T_{c,ref}}\right) \quad (5)$$

m" Exponential constant for I_L "n" Exponential constant for "a"Where "m" and "n" are the two additional parameters and are exponential constants for "I_L" and "a", respectively and proposed [6]. Specification parameter taken from data sheet is tabulated in Table I.

TABLE I. Specification parameter taken from Data sheet

parameter	**m-si (sun power)**	**CIS shell ST36**
Open circuit voltage (V_{OC})	48.7v	22.9 v
Short circuit current(I_{SC})	5.99	2.68 A

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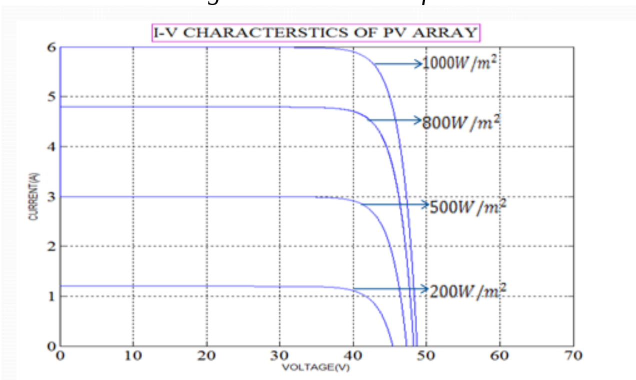
Max.power voltage(V_{MP})	41 v	15.8 V
Max.Power Current(I_{MP})	5.61 A	2.28A
Max.power(P_{MP})	230 W	36 W
No of cells in series(N_S)	72	42
I_{SC} temperature coefficient	3.5 m A/C	3.2ma /c
V_{OC} temperature coefficient	-132.5Mv/c	-100m v/c

TABLE II. SPECIFICATION OF SEVEN PARAMETER MODEL

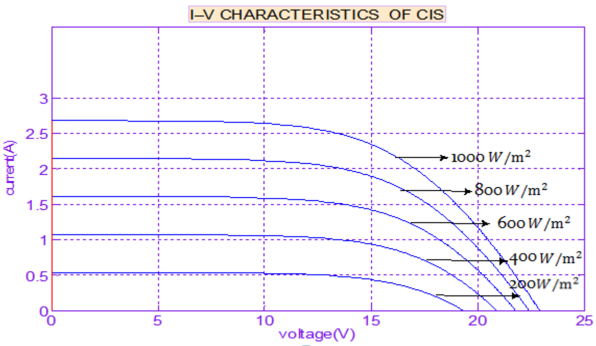
Parameter	m-si (sun power)	CIS shell ST36
Light current	5.97	2.6803
Saturation current	2.151e-7	4.11965e-05
Series resistance	0.00796	1.3901
Parallel resistance	89,546.41	38,544.6
Modified ideality factor "a"	2.6971	2.0662
Exponential constant of "m"	.9865	1.1213
Exponential constant of "n"	1.1056	0.9431

IV. RESULTS AND DISCUSSIONS

i. Current versus Voltage Characteristics of a PV Module



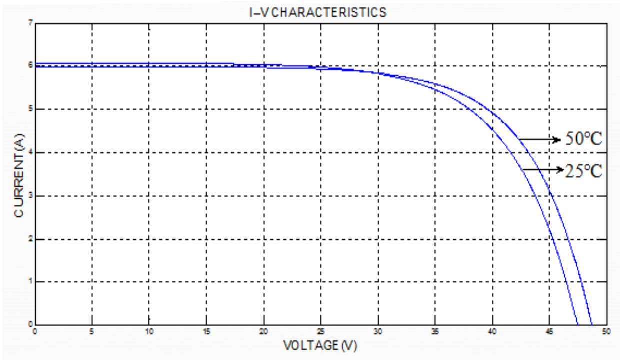
(a)



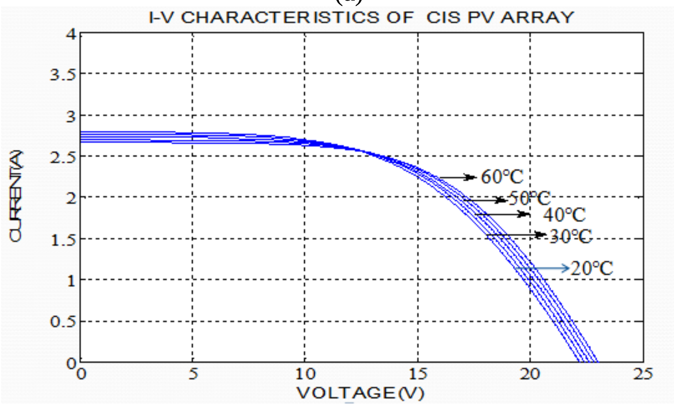
(b)

Figure2: Simulation result of I–V curves for different irradiations:
(a) mono-crystalline (m-si) and (b) thin-film (cis) under constant temperature

Figure 2 (a) & (b)and 3 (a) & (b) shows the current voltage (I-V) characteristics of PV panel. This curve is nonlinear. It can be noted that the maximum current output is 5.61A and the maximum voltage is 41 V. They are the same as the values given from the manufacturer datasheet. The current voltage (I-V) characteristics of PV panel which crucially relies on the temperature along with the solar irradiation. The current decreases significantly when the irradiance decreases. The plot matches the one provided in the manufactures data sheet.



(a)



(b)

Figure3: Simulation result of I–V curves for different temperatures:
(a) mono-crystalline (m-Si) and (b) thin film (CIS) under constant irradiation

ii. Solar PV Array under Partial Shading Condition

Partial Shading is one of the major causes of power reduction in Solar Photovoltaic (SPV) Systems when we observe the characteristics of a Photovoltaic system. Under partial shaded conditions the non-linear Power-Voltage characteristics of SPV system gets more complex with multiple maxima.

A. Occurrences

Few reasons for occurrences in the partial shading of a SPVA:

An obstruction or object covering a section of the array for a period (e.g.. The shade of neighbor building or nearby trees falling across the array). Loose debris, leaves, dirt covering a portion of the array. The sun moving behind cloud cover for a few minutes etc. From Figure 4 it can be noticed that when panel 2 started working PV array current trim down abruptly to a lower value of 4.8A.Reason for this drastic change is that the panel 2 is illuminated with lesser irradiation and it cannot produce more current than this value. Similarly, at high voltage level (greater than 98 V) all the three panels are functioning and the current is limited by panel3 because it has the lowest irradiation level. This test verifies the robustness of the designed simulator under the harsh condition of partial shading shown in Figure 5 and 6.

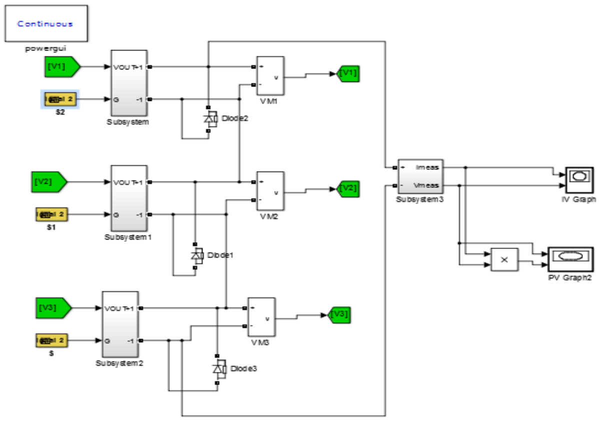


Figure4: Simulation Circuit of Shaded PV Modules

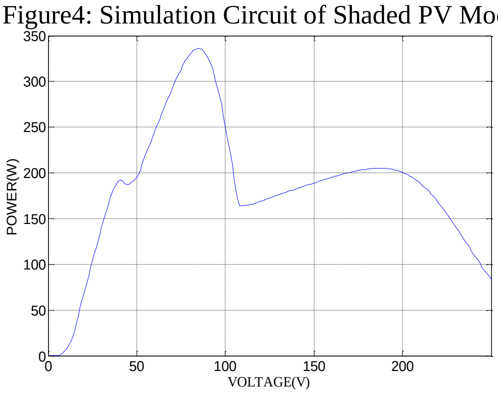


Figure5: Partial Shaded P-V Characteristics

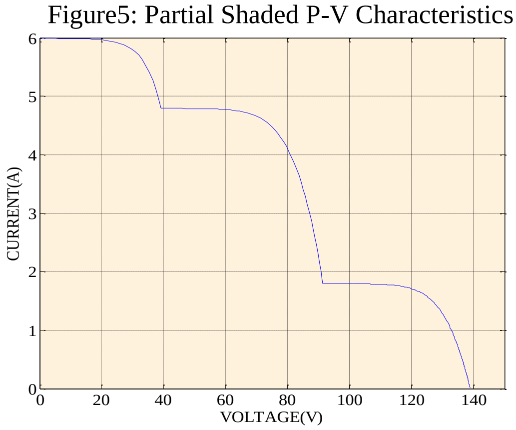


Figure6: Partial Shaded I-V Characteristics of PV Array

iii. Maximum Power Point Tracking

The power output of the PV module changes with the amount of solar irradiance and with the variation of temperature. Then nonlinear response characteristic of the PV module could be observed. There exists a single maxima point of the power that corresponds to a specific voltage and current. Since we know the efficiency of a solar cell is around 8-15% [6].

A. Incremental Conductance Method

The Incremental conductance method eliminates the drawbacks of the Perturb and Observe method. It uses the advantage that the derivate of the power with respect to the voltage at the maximum power point is zero shown in Figure 7.

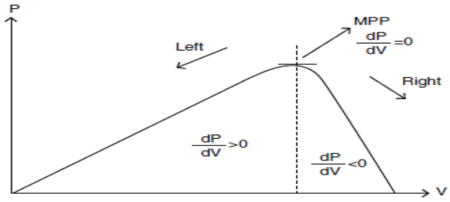


Figure7:Basic Idea of Incremental Conductance Method On P-V Curve

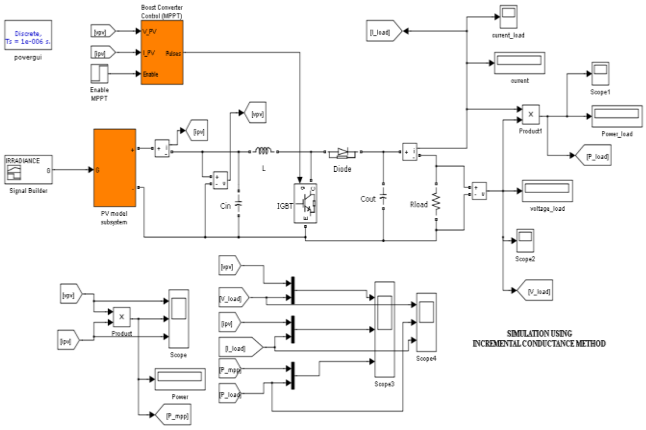


Figure8:Simulink model of Incremental Conductance Method

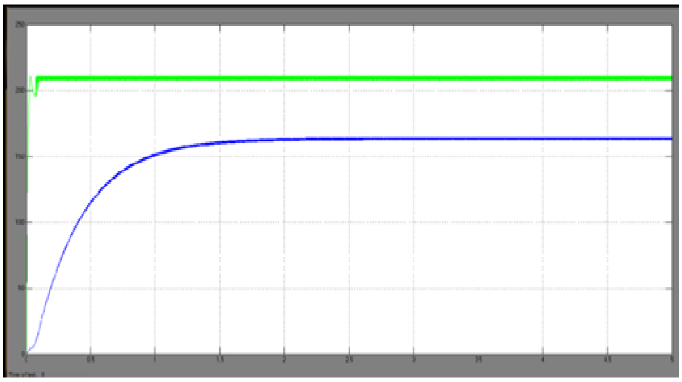


Figure9: Simulation result of PV with MPPT Controller at STC condition

Figure 8 shows the Simulink model of incremental conductance method and figure.9 shows the PV output without MPPT and with MPPT. The greenshow with MPPT and the output power is improved when compared to without MPPT shows bluecolour.

V CONCLUSION

In this paper, a generalized PV simulator has been proposed and designed in MATLAB/ Simulink software package. The proposed simulator has been developed as a masked block. It has shown that the developed simulator can generate the real I–V and P–V curve of PV under different operating conditions including the harsh condition of partial shading. Further, the designed simulator can also be utilized in a complete PV system interfaced with different power electronic devices and MPPT controllers. The developed PV simulator will facilitate the design aspects of PV systems and help in behavior assessment of newly developed controllers prior to practical implementation.

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