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A Simplified Modeling of Photovoltaic Modules Using MATLAB /Simulink

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Abstract: Due to the ever increasing demand for electric energy and problems due to the conventional thermal power plants, recently more attention is given to the solar photovoltaic (PV) based power generation. When designing photovoltaic (PV) systems an accurate model is essential. Photovoltaic models have added the model complexity due to a lay of transcendental nonlinear equations. In this paper proposed an easy-to-model and simple technique for carrying out photovoltaic (PV) system in simulations. The proposed photovoltaic model is constructed using a simple computational block and a controlled current source (CCS). This proposed technique neglects the use of a nonlinear equation solver and hence simple blocks of mathematical are required. A simplified modeling has advantage of ideal diode models and its deriving mathematical expression increases the accuracy. It is similar to the model parameter of extracting accurate estimation and directly correlated to the manufacturer datasheets. The work deal with the proposed technique has been proved by simulation data sheets.

Key words: Solar photovoltaic generation module, Photo current, Equivalent circuit, Solar energy.

1 Introduction

In recent developments there is an increased demand of renewable energy in the consumption of electric power. The primary sources of electric power of fossil fuels cause environmental pollution. So, a transition from conventional energy system to more clean and secure energy is the need of the new. For this point of view the renewable energies attract for more and more attention. The most common renewable energy sources in use are solar energy [1]. A wide range of atmospheric appearance photovoltaic (PV) modules operates, but electrical parameters at only Standard Test Condition (STC) provided by datasheets of manufacturing. A studies control technique of photovoltaic (PV) simulation model to succeed maximum power point tracking (MPPT) algorithms [2].

Power generation from solar source provide a realistic form has been carried out. Many studies on the use of renewable energy sources for power generation have been already presented.
Photovoltaic (PV) system designers need easy-to-implement and a reliable model to estimate photovoltaic (PV) energy generation under different insolation and temperature conditions [3]. Photovoltaic (PV) equivalent circuit can be categorized into three types.

(1) The ideal single diode model (ISDM) is the first and simplest model is shown in figure.1 [3]. Ideal single diode model (ISDM) does not assurance a perfect characteristic at the maximum power point (MPP) due to its simplicity [4].
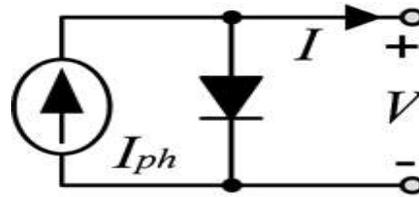
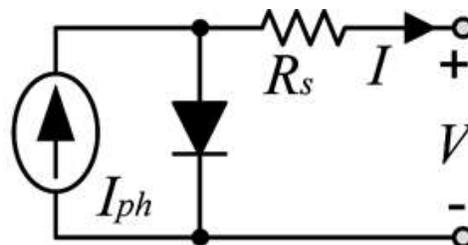**Figure. 1.** Equivalent circuit of ideal single diode model (ISDM)

(2) Due to accuracy single-diode model (SDM) is mostly used for studies of photovoltaic (PV) is shown in figure.2. For simulation model it has five parameters essentially to develop the photovoltaic (PV) system. The five parameters are obtained by solving nonlinear equations iteratively [6], otherwise it obtained characteristic conflict with the three operating points provided by the manufacturer datasheet by tuning the some parameters [2].
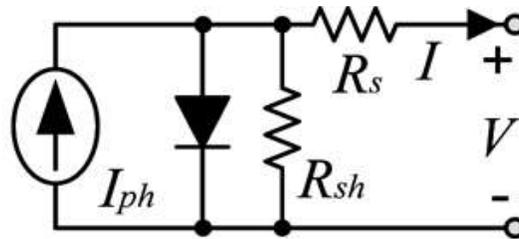
Figure. 2. Equivalent circuits of PV cell using single diode model (SDM)

Single diode model (SDM) requires a numerical solver because output current is the function of both voltage and current i.e. $I = f(V, I)$ and output voltage is the function of both current and voltage i.e. $V = f(I,V)$ for implementation of simulation [5].
For some studies of single diode model (SDM) to reduce the complexity by eliminating the shunt resistance, as shown in Figure.3 [7-8].

Figure. 3. Equivalent circuit of simplified single diode model (SSDM)

In this paper, a proposed technique for photovoltaic (PV) modeling is adds the advantages of ideal single diode model (ISDM) and single diode model (SDM) models which include easy of modeling, accuracy and simplicity. This technique relies to developed   two newly mathematical expressions,

developed to calculate photovoltaic (PV) parameters, for the ideal single diode model. The proposed technique is compared with previous methods using simulation results.

2 Calculations of the Parameters of Photovoltaic (PV) Model from Data Sheet

The generalize current voltage equation of a photovoltaic (PV) model is [11]:

$$i = I_{ph} - I_0 \ (e^{\frac{v+iRs}{Ns \ V_t}} - 1) - \frac{v+iRs}{Rsh} \tag{1}$$

Thermal voltage: $\qquad\qquad V_t = \frac{AkT_{STC}}{q}$

Where:

Photo generated current in standard temperature condition: I_{ph}

Dark saturation current in standard temperature condition: I_o

Series resistance: Rs

Shunt resistance: R_{sh}

Ideality diode factor: A

Boltzmann constant: k

Electron charge: q

Total number of cells in series: N_s

Temperature at STC: T_{STC}

2.1 Proposed PV Modeling Technique

The photovoltaic (PV) module characteristic equation I-V composed of series Ns cells connected is given as follows:

$$i = I_{ph} - I_0 \ (e^{\frac{v+iRs}{Ns \ V_t}} - 1) - \frac{v+iRs}{R_{sh}N_s} \tag{2}$$

Reducing the number of unknowns was assumed some parameters. Unfortunately, accuracy of the model overall affected. To eliminate the circuit complexity inflict by equation (2) the proposed technique will depend on the ideal single diode model expressed in (3)

$$i = I_{ph} - I_0 \ (e^{\frac{qV}{k \ A \ T \ N_s}} - 1) \tag{3}$$

Ideal single diode model has three I_{ph} , I_0 and A unknown parameters.

I_{ph} is calculated from datasheets of manufacturer, are as follows:

$$I_{ph} = \ G \ (I_{sc} + \alpha \ \Delta \ T) \tag{4}$$

Where;

Irradiance (kW/m^2): G,

Temperature difference between the module and the standard temperature condition temperature: Δ T

Temperature coefficient of current: α

By first setting expression is derived as follows:

$$V_{OC}(G,T) - V_{OC}(G,T_{STC}) = - |\beta| \, \Delta T \qquad (5)$$

Where;

At a certain temperature open circuit voltage: $V_{OC}(G,T)$

At the Standard temperature condition open circuit voltage: $V_{OC}(G,T_{STC})$

For specific irradiance level.

Absolute value of the coefficient of voltage temperature: β

In equation (3) putting $i = 0$, the voltages open circuit (V_{OC}) is calculated as follows:

$$V_{OC} = \frac{N_s kTA}{q} \, \ln\left(\frac{I_{ph}}{I_0} + 1\right) \qquad (6)$$

So

$$V_{OC}(G,T) = \frac{N_s kTA}{q} \, \ln\left(\frac{G\,(I_{sc} + \alpha \Delta T)}{I_0} + 1\right) \qquad (7)$$

And

$$V_{OC}(G,T_{STC}) = \frac{N_s kT_{STC}A}{q} \, \ln\left(\frac{G\,(I_{sc} + \alpha \Delta T)}{I_0} + 1\right) \qquad (8)$$

Equation (7) and (8) substituting in (5)

$$\frac{N_s kTA}{q} \, \ln\left(\frac{G\,(I_{sc} + \alpha \Delta T)}{I_0} + 1\right) - \frac{N_s kT_{STC}A}{q} \, \ln\left(\frac{G\,(I_{sc} + \alpha \Delta T)}{I_0} + 1\right) = - |\beta| \, \Delta T \qquad (9)$$

I_0 can be obtained by rearranging equation (9)

$$I_0 = \frac{e^{\frac{|\beta|\Delta Tq}{N_s kTA}}G\,(I_{sc} + \alpha \Delta T)}{(G\,I_{sc}\,/I_{ro} + 1)^{\frac{T_{STC}}{T}} - e^{\frac{|\beta|\Delta Tq}{N_s kTA}}} \qquad (10)$$

Where

Saturation current at Standard Test Condition: I_{r0}

I_{r0} can be calculated as follows (3);

$$I_{r0} = \frac{I_{sc}}{[e^{\left(\frac{qV_{oc}}{N_s kT_{STC}A}\right)} - 1]} \qquad (11)$$

Under Standard Test Condition (STC), (3) is expressed at maximum power point V_m and I_m as follows;

$$I_m = I_{sc} - I_{ro}[e^{\left(\frac{qV_m}{N_s kT_{STC}A}\right)} - 1] \qquad (12)$$

The unknown parameter "A" can be obtained by putting equation (11) into equation (12) and for the maximum power point solving the equation of V_m and I_m. The obtained equation (12) can be modified as;

$$\frac{I_m}{I_{sc}} = e^{\left(\frac{qV_m}{N_S kT_{STC}A}\right)} - \left(\frac{I_{sc} - I_m}{I_{sc}}\right) e^{\left(\frac{qV_{oc}}{N_S kT_{STC}A}\right)} \tag{13}$$

The photovoltaic datasheet parameters and the solution of equation (10) and equation (13) will be substituted in equation (3) to obtain the photovoltaic simulation model.

2.2 Block Model for Proposed Technique

The block model of proposed technique for photovoltaic (PV) model is presented in figure.4. The proposed photovoltaic model circuit is constructed using a simple computational block and a controlled current source (CCS).
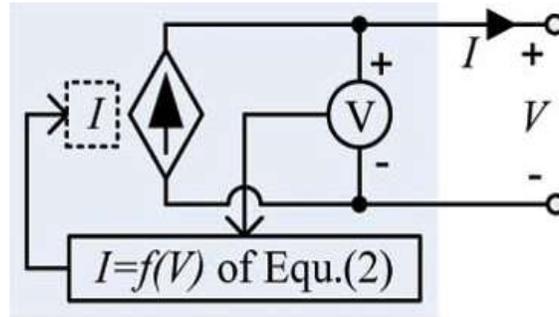

Figure. 4. Proposed model of Simplified single diode PV cell

So, proposed technique is using to constructing a simulation model is easy and simple because output current is a function of only voltage i.e. I = f(V). This proposed technique neglects the use of a nonlinear equation solver and hence simple blocks of mathematical are required.

3 Simulation and Results

This research paper has carried out the simulation of ideal single diode model (ISDM), single diode model (SDM) and simplified single diode model (SSDM). The simulink model is presented in figure.5.
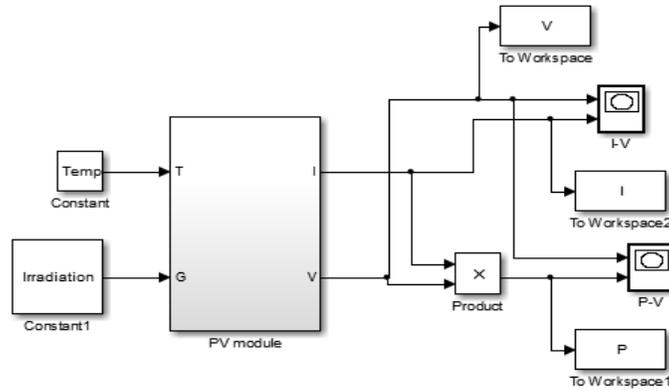
Figure. 5. Model of proposed technique

Figure.6 shows the comparison of curves above the three modeling technique. The proposed model parameter is shown in Table.1. The proposed model of simulation results in different temperature and different irradiance conditions are presented in figure.6 and figure.7 respectively. The simulink results have been compared to the characteristics and values provided by the data sheet. The results show that the proposed simple technique has comparable accuracy levels and Table.2 shows reduced simulation run time due to the simplified single diode simulation structure.

**Table 1.** Proposed model parameters

Parameter	Data
I_{pv}	8.23 A
V_{oc}	32.9 V
I_{mp}	7.62 A
V_{mp}	26.26 V
I_{sc}	8.21 A
I_o	4.22×10^{-10} A
R_s	0.32 Ω

Table 2. Performance of proposed technique

Technique	Equivalent circuit	Parameterization	Simulation Time (Second)
A	ISDM	Proposed in [1]	4.04
B	SSDM	Proposed in this paper	4.23
C	SDM	Proposed in [2]	6.70
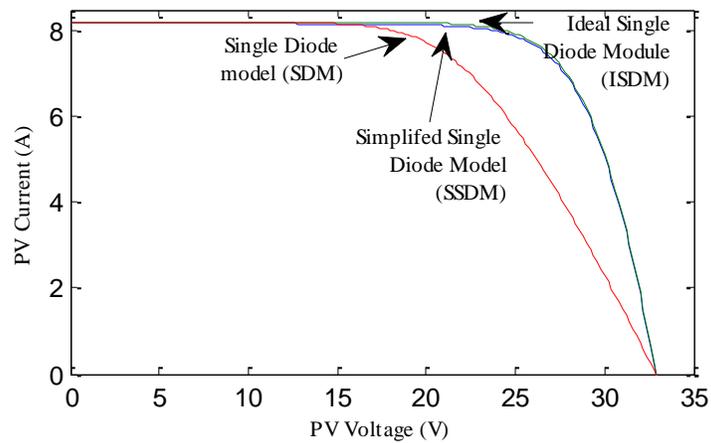
Figure. 6. Comparison of curves above the three modeling technique
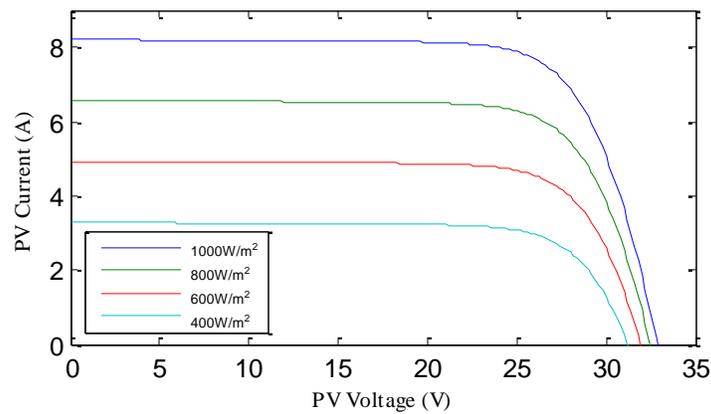
Figure. 7. Characteristics of current-voltage (I-V) of the photovoltaic model at different irradiation
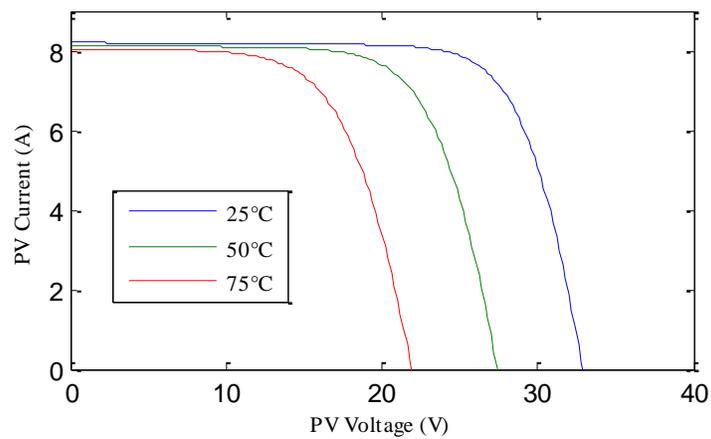
Figure. 8. Characteristics of current-voltage (I-V) of the photovoltaic model at different temperature

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4 Conclusion

In this research paper proposes an intended technique to modeling of photovoltaic modules. The proposed modeling technique avoids complexities involved in photovoltaic identification of parameter. It is also attaining comparable accuracy. The technique is simple and easy to implement in different simulation platforms for photovoltaic power systems verified and studied. The simulation results has been verified and proved the efficacy of the proposed modeling technique.

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