



A Matlab-Simulink Model for Photovoltaic Cell with Single Cell Application

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ABSTRACT: The power generated by solar photovoltaic (PV) module it depends on the following factors firstly surrounding irradiance, temperature and shading conditions. Also the recent upsurge in the demand of Solar photovoltaic energy systems is due to the fact that they produce electric power without hampering the environment by directly converting the solar radiation into electric power. This paper presents a simple technique of simulation of photovoltaic cell in application of single cell and observe the I-V, P-V characteristics which is done in MATLAB-SIMULINK environment based on PV module model in which the basic circuit equations are used in the Photovoltaic (PV) cells including the effects of solar irradiation and temperature changes.

I. INTRODUCTION

With a spurt in the use of renewable energy sources, photovoltaic (PV) power generation is being employed in many applications. Also Photovoltaic (PV) technology has become attractive for its potential in reducing greenhouse gas emission, consuming less fossil fuel, and providing higher penetration of renewable energy source. Regardless of the intermittency of sunlight, solar energy is widely available and also is free in nature. Recently, photovoltaic system is recognized to be in the forefront in renewable electric power generation. It can generate direct current electricity without environmental impact and contamination when exposed to solar radiation. Being a semiconductor device, the PV system is static, quiet, free of moving parts, and has little operation and maintenance costs. PV module represents the fundamental power conversion unit of a PV generator system. The output characteristics of a PV module depend on the solar insolation, the cell temperature and the Output voltage of the PV module. Since PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of maximum power point tracking (MPPT) for PV system applications.

The knowledge of model parameters is important, for gaining insight into the physical process and for simulating PV systems conventionally PV power generator consists of solar photovoltaic arrays and electric converter. PV array is formed by series/parallel combination of PV solar modules. There is some operating conditions which result in non-uniform

insolation of PV array, such as shadow, clouds, dirt, debris, bird droppings, string-to-string imbalance, different orientations, tilts, panel aging, and so on. If several cells in a series PV module are mismatched, these cells will limit the output current of normal cells. This may lead to decreasing the output power, and can even present hot-spot which cause damage to the cells. To circumvent the destructive effects of hot-spot, bypass diode is connected in parallel with a module or a part of module. So bypass diode creates a path around the mismatched cells the output power of mismatched cells is cut off when bypass diode works. Mathematical modeling of PV module is being continuously updated to enable researcher to have.

II. MAJOR ADVANTAGES OF THE PHOTOVOLTAIC POWER

- Short lead time to design it, install, and start up a new plant.
- Highly modular, hence, the plant economy is not a strong function of size.
- Power output matches very well with peak load demands.
- Static structure, no moving parts, hence, no noise.
- High power capability per unit of weight.
- Longer life with little maintenance because of no moving parts.

Some of the best advantages indicated in the above section for photovoltaic power are as follows. So that it gives the knowledge for its application.

III. PHOTOVOLTAIC APPLICATIONS

Domestic Buildings Lighting and general power, Industrial Buildings Lighting, general power and process equipment, General Alarms for remote buildings, Area lighting CCTV Advertising, Leisure Boats, Electric boat, Battery charging (lighting & TV) Camping & Remote Homes, Battery charging (lighting & TV) Commercial Buildings Lighting and general power.

IV. GENERAL DESCRIPTION OF PHOTOVOLTAIC CELL

The solar cell is the basic unit of a photovoltaic module and it is the element in charge of transforming the sun rays or photons directly into electric power. The solar cell used is the P-N junction, whose electrical characteristics differ very little from a diode.

V. PHOTOVOLTAIC SYSTEM DESCRIPTION

Fig. 1 shows the block diagram of a photovoltaic system, which includes solar photovoltaic panel with DC to DC converter, single phase inverter and load. The solar photovoltaic panel produces electricity when the photons of the sun light strike on the photovoltaic cell array. The output of the photovoltaic panel is directly connected to the DC to DC boost converter to step up the DC output of photovoltaic panel. Then it is fed to an inverter which converts DC into AC power at the desired voltage and frequency. A current controller is normally preferred due to its advantages like flexibility and modify easily through of software, simplicity possible implementation in fixed point computation etc.

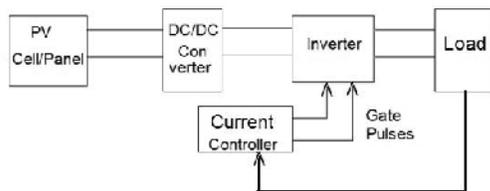


Fig.1. Block diagram of photovoltaic system.

So, the process of modeling this solar cell can be developed based on equations (1), and (2)

$$I_D = I_0 \left(\frac{V_{cq}}{akT_{CK}} - 1 \right) \dots\dots\dots(1)$$

Where

- ID is a dark current (A),
- I₀ is a saturation current of the diode (A),
- V_c is a cell voltage (V),
- q is the charge of an electron,
- a is the diode ideality constant,
- k is the Boltzmann’s constant, 1.38.10⁻²³ (j/K),
- T_{ck} is the cell temperature.

Being the net current of the cell, the difference of the photocurrent I,(the current generated by the incident light, directly proportional to the sun irradiation) and I_D (the normal diode current), as shown in equation (2).

$$I = I_0 - I_D \dots\dots\dots (2)$$

VI. A PHOTOVOLTAIC CELL WORKS AS IDEAL PHOTOVOLTAIC CELL.

The use of equivalent electric circuits makes it possible to model the characteristics of a PV cell. The mathematical model for a photovoltaic cell can be developed, using the MATLAB package. The basic equation from the theory of semiconductors that mathematically describes the I-V characteristics of the ideal photovoltaic cell is

$$I = I_{pv\ cell} - I_d \dots (3)$$

$$\text{Where, } I_d = I_0 \text{cell} [\exp (qV/akt) - 1] \dots (4)$$

$$I = I_{pv\ cell} - I_0 \text{cell} [\exp (qV/akt) - 1] \dots (5)$$

Where, I_{pvcell} is the current generated by the incident light (it is directly proportional to the sun irradiation), I_d is the diode equation, I_{0 cell} is the reverse saturation or leakage current of the diode, q is the electron charge and the value is [1.60217646*10⁻¹⁹C], k is the Boltzmann constant and T is the temperature of the p-n junction, and 'a' is the diode ideality constant.

A. Ideal Photovoltaic cell

For an ideal PV cell, there is no series loss and no leakage to ground, i.e. R_s = 0 and R_{sh} = ∞

$$I = I_{sc} - I_d \dots\dots\dots(6)$$

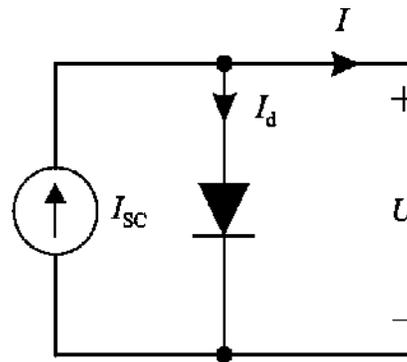


Fig. 2. Electrical circuit diagram representing the one-diode model of an ideal PV cell.

Therefore, the ideal solar cell can, theoretically, be modelled as a current source in anti-parallel with a diode as shown in (Fig. 2). Improving the PV cell model includes the effects of series and shunt resistance, as it presented here.

VII. MODELING OF PHOTOVOLTAIC ARRAY

The same technique is extended for developing the mathematical model of a PV module. Practical arrays are composed of several connected PV cells, and the observation of the characteristics at the terminals of the PV array, requires the inclusion of additional parameters (as shown in figure3) to the basic equation. Where = N_skT < I_q is the terminal voltage of the array with N_s cells connected in series.

And the Cells connected in parallel increase the current and cells connected in series provide greater output voltages V and I are the terminal voltage and current.

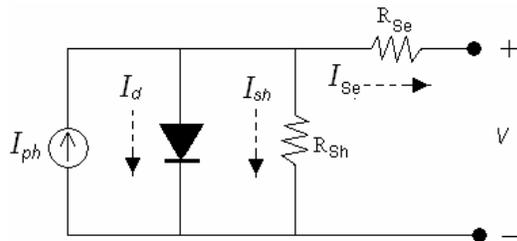


Fig. 3. Electrical Model of PV Cell.

VIII. PROPOSED TECHNIQUE OF MODELING FOR SINGLE CELL APPLICATION

In this proposed technique of Modeling for the single cell application from the above study about photovoltaics it is to be noted that the solar photovoltaic is modeled with a current source in anti-parallel to diode and a series combination of resistances.

The electrical output of a single cell is dependent on the design of the device and the semiconductor material(s) chosen but it is usually insufficient for most applications. In order to provide the appropriate quantity of electrical power a number of cells must be electrically connected. There are two basic connection methods.

(a) series connection, in which the top contact of each cell is connected to the back contact of next cell in the sequence

(b) parallel connection in which all the top contacts are connected together as are all the bottom contacts.

In both cases this results in just two electrical connection points for the group of cells.

The above discussion is used in the proposed technique of single cell photovoltaic is done in the MATLAB-SIMBULINK in simulation environment.

IX. PROPOSED SIMULATION DIAGRAM

Fig. 4 PV Module Model of single-cell photovoltaic in MATLAB-SIMULINK. Here the single cell of photovoltaic is designed in this model a irradiance block is used where direct sunlight is used and a inbuilt single photovoltaic cell is make to produce a voltage and current at required power.

This block models a solar cell as a parallel combination of a current source, two exponential diodes and a parallel resistor Rp that are connected in series with a resistance Rs. The output current I is given by

$$I = I_{ph} - I_s * (e^{((V+I*R_s)/(N*V_t))} - 1) - I_{s2} * (e^{((V+I*R_s)/(N_2*V_t))} - 1) / (V+I*R_s) / R_p \dots(7)$$

where I_s and I_{s2} are the diode saturation currents, V_t is the thermal voltage, N and N_2 are the quality factors (diode emission coefficients) and I_{ph} is the solar-generated current.

Models of reduced complexity can be specified in the mask.

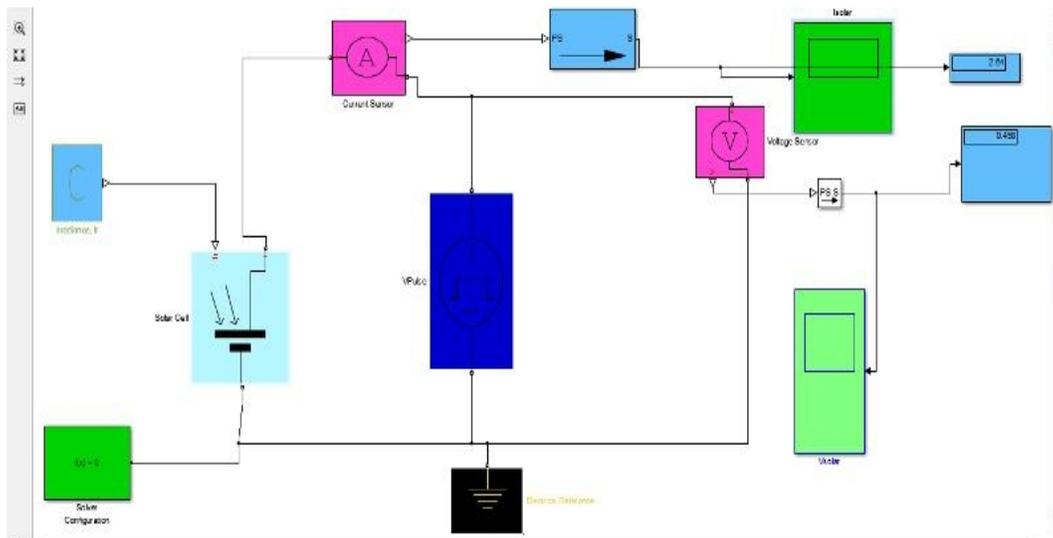


Fig. 4. Diagram of the MATLAB-Simulink based PV module model.

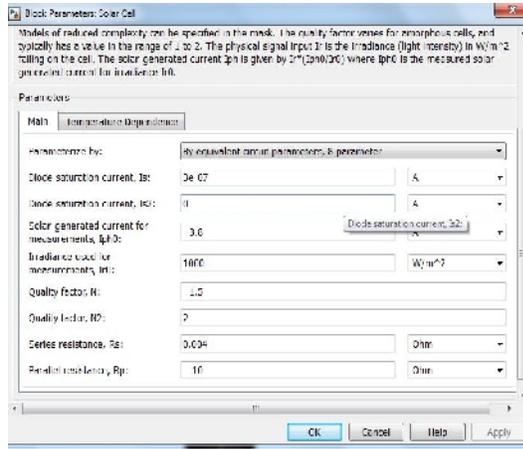


Fig. 5. Screen shot of Single cell.

The quality factor varies for amorphous cells, and typically has a value in the range of 1 to 2. The physical signal input I_r is the irradiance (light intensity) in W/m^2 falling on the cell. The solar-generated current I_{ph} is given by $I_r \cdot (I_{ph0}/I_{r0})$ where I_{ph0} is the measured solar-generated current for irradiance I_{r0} .

X. I-V CURVE

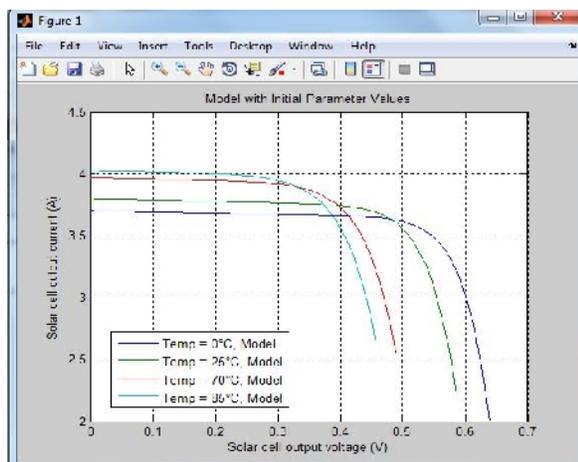


Fig. 6. Simulation model curve with initial parameters of PV cell I-V characteristic for different solar irradiation levels.

XI. CONCLUSION

This paper presents an improved Matlab/Simulink simulation model for a single cell. The model is compared to ideal pv cell which already exists. Here I have tried to design a model which is actually like ideal pv cell where minimum losses are found. It includes simplicity, accuracy, and elimination of some drawback of existing model.

Also it is to be concluded that the new model can be used in low voltage application accurately.

After simulation of this single cell PV results showed that real PV module I-V characteristics gained from this simulation are almost same as the characteristics of ideal PV. If we want to gain more voltage the same technique can be extended as per requirement. Future work could be presented on next paper.

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