The appropriate technique for modeling of solar photovoltaic module

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Abstract: Photovoltaic system is a promising source of renewable energy which can lead to sustainable city growth and global warming reduction. It is generally anticipated that solar power going to be the cheapest source of power in the world within the next 20 years, as the cost of solar photovoltaic cells decreases. The photovoltaic cells need to have high efficiency to decrease the pay back time and ensure that solar photovoltaic plant have a long service life. The Solar PV modules typically consist of one or more diodes, modeled using identical circuits, this paper provides a study on different solar cell modeling techniques which A single-diode equivalent circuit is more commonly often used by researchers because the number of variable assessments is limited and thus convenient for performance evaluation. The single diode model is not properly used to model the solar cell and an additional diode is then applied to the single-diode model, several authors have been proposed The two-diode model because Variables of the equivalent circuit shall be used to improve the accuracy and reliability of the solar photovoltaic model.

Keywords: Solar cell modelling; Solar PV micro-grid; Three diode solar cell model; Maximum power generation.

I. INTRODUCTION

In the last ten years, the production of photovoltaic modules, supported by the large number of photovoltaic projects ordered daily, has increased significantly. Investment in RE(renewable energy) projects where PV and wind dominate and leading market shares was motivated by the global interest in changing the direction of energy supply[1]. Size and penetration expansion is a key objective in the major national energy policies around the globe, with the ever-growing implementation of renewable energy development projects anticipated in the energy sector[2].

Solar cell output power varies with the temperature of the cell. Cell temperature rises would minimize solar photovoltaic power production. The power output is due to an increase of the reversed diode saturation current as the cell temperature increases. [3]. This effect is caused by the decrease of bandwidth with rising temperature and by the addition of photons, which reach into and create load carriers, a slight increase in the short circuit current[4]. .Conversely, the increase in the temperature of the reverse saturation current contributes Linear decline in the open circuit voltage. The current source is directly related to the solar situation [5].

Some pyrometers Used to calculate incident solar radiation and the short-circuit current of the photovoltaic panel is used to calculate incident radiation. The energy provided by the solar photovoltaic module is more expensive than solar Thermal heating. Efficacy of the solar cell as solar output G = 1000 W/m2 and T = 25 degree Celsius can be determined under normal operating conditions. The working temperature of the cell in realistic conditions is more than 25 ° C. Ecological parameters such as temperature, solar radiation and wind direction, will alter the performance of solar Pv panels. Accurate awareness of these parameters is essential in assessing the efficiency and quality of solar Pv systems [6]. The manufacturer usually applies the specifications for the PV module to the Normal or standard Test Conditions (STCs). This isn't compatible with real or accurate time activity due to environmental and climate change. The assessment of these variables is more critical to the accurate modelling of the solar Photovoltaic module in the realistic conditions [7].

The Solar PV modules typically consist of one or more diodes, modeled using identical circuits. A single diode equivalent circuit is more commonly used by many scholars because the amount of variable assessments is limited and thus convenient for performance monitoring. This method is non-linear due to the current of the Pv system with voltage due to high operating conditions like irradiation and temperature [8]. Generally, the identical circuit of the solar PV cell is based on a diode with two resistors attached in series and in parallel, which would be responsible for the operational internal losses. Rs is the resistance of the series leading to the failure of the component. Rp refers to leakage of cell interaction current due to structural defects or particulates.[9]. The single crystalline silicon module diode model is commonly used, as many researchers do no consider recombination failure in the depletion layer for the modeling of photovoltaic cells. The single-diode modelling is commonly used because of its simplification[10].

The two main categories of single diode models are: 1) the model of four parameters which is the first model eliminates shunt resistance Rp. The value of Rp in this model is very high even sometimes It is assumed that it is infinity. 2) The next model is the five-parameter model, which involves an Rp(parallel resistance) with an identical or theoretical circuit. Shunt resistance Rp is commonly used to examine more complicated circumstances of solar photovoltaic modules, like unevenness and hot spot phenomena. The five-parameter modelling is most commonly used and studied by many writers in recent literature since the five-parameter modelling is more accurate and more practical to classify solar panels. nowadays, the simple and accurate processing of these parameters is getting more attention and it has been a hot topic of research in the field of solar PV cells [11]. The first diode corresponds to the diffusion current at the P-N junction in the two-diode model (Combined into a single crystal, two kinds of semiconducting materials, P-type and N-type),while the second diode correlates to the spatially charged recombination effects[12] which predominate At low irradiance and low voltage [13]. Methods for addressing these models using analytical methods[14];[15] and computational methods[16];[17] which In literature they are accessible.

On the market, some commercial software is available to help design solar photovoltaic systems, such as PV Sol and PV system[18], TRNSYS[19], Simulink and INSEL, and wxAMPS[20].

II. EQUIVALENT CIRCUITS OF SOLAR CELL

In studying solar photovoltaic cells, the complex existence of the energy supply from a solar panel is induced by evolving environmental and climatic conditions, thus equal circuit parameters are essential considerations. The exactness Of the simulation is impacted or influenced by equivalent circuit parameters for the modelling and simulation of a solar photovoltaic module. all equivalent circuit model of a solar cell is essentially represented by a parallel current source to a diode which is called ideal equivalent circuit of solar cell, which is shown in Figure 1. The basic or main equation can be taken from the semiconductor principle, which mathematically defines the IV (current-voltage) characteristics of the ideal solar cell[21];[22].

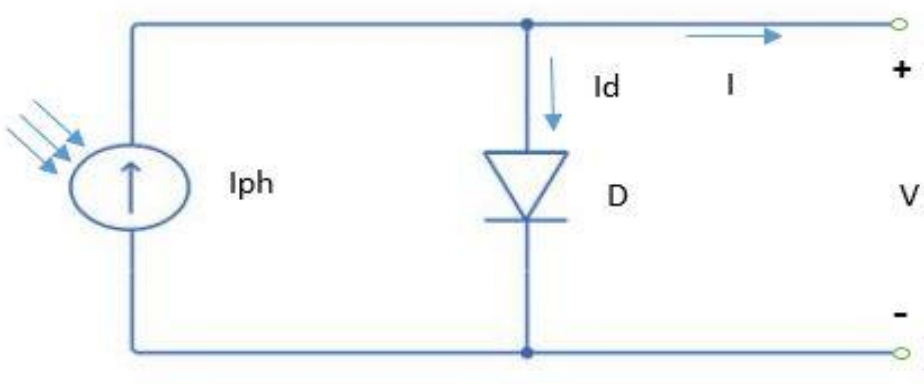

Figure 1. The Ideal equivalent circuit

From Figure 1. the PV cell current is given by

$$I = Iph - Id \quad (1)$$

$$Id = Io \times (exp\left(\frac{qv}{AKT}\right) - 1) \quad (2)$$

Substitute Equation 2. into Equation 1

$$I = Iph - Io \times (\exp\left(\frac{qv}{AKT}\right) - 1) \quad (3)$$

The I–V curve was derived from Equation 3. Figure 2 demonstrates this

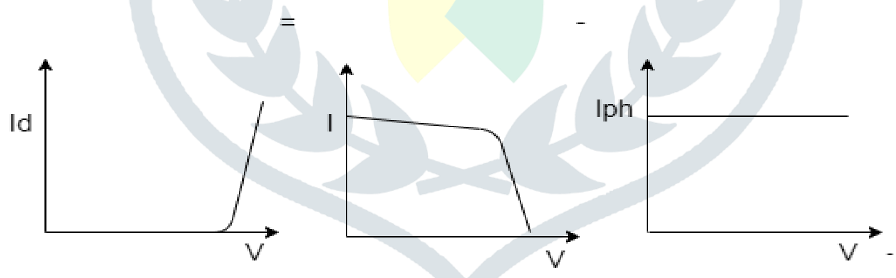

Figure 2. IV (Current-Voltage) Characteristic of the Ideal Model

III. SOLAR CELL MODELING

III.I. Single Diode Model

a)Model 1 with Rs

A single cell does not reflect the I – V characteristics of a functional PV array. A practical PV array consists of several connected solar PV cells in series or parallel, Therefore the simulation of the solar PV array includes applying Rs and Rp variables to the basic equation. Model 1 single-diode with Rs sequence resistance, often used by authors because of its simplicity, is represented in figure3.[23];[22];[7].

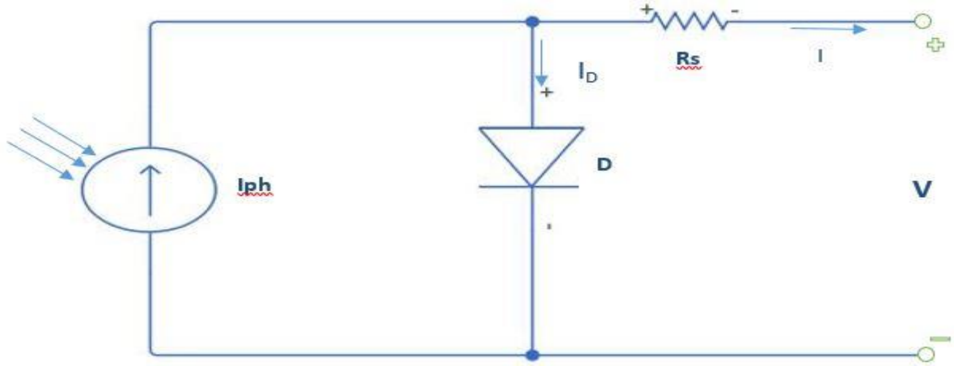

Figure 3. Model of single diode with Rs

$$I = Iph - Io \times \left(Exp\left(q \times \left(\frac{V+IRs}{AKT}\right)\right) - 1\right) \quad (4)$$

b) Second model with Rp and Rs

Figure 3.4 indicates the second single-diode model equivalent electrical circuit with Rp and Rs. A circuit similar to a solar cell consists of a diode, a source of current, a resistance series Rs and a resistance parallel Rp. Due to its accuracy, multiple authors have suggested the second single diode model, including Rp [24];[25];[26].

A feature of the Situation of solar radiation and temperature of the cell is the photo-current (Iph) produced by the current source. The P-N is defined by the diode of A solar PV cell junction. The saturation current of the diode depends on the temperature of the cell and also on the ideality factor of the diode (A), included the modelling of equivalent circuit In solar cells, which voltage drops occurs at the external contacts.

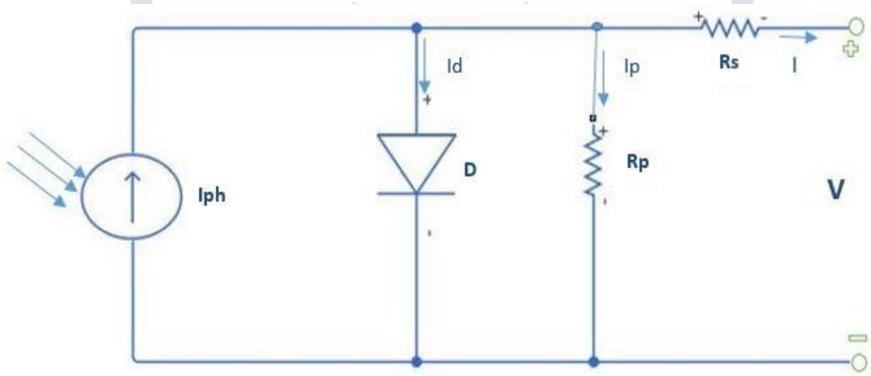

Figure 4. The second Single diode model with Rp and Rs

This decrease in voltage is reflected in the Rs and Rp series of resistances, which effects of which is greater in the current source region and the voltage source region [25]. Parallel resistance Rp reflects currents of leakage. In Equation 3.3, Using the first theorem of Kirchhoff, Equation 5. It is the extended version of the ideal model. The following equations shows the IV curve with Rp and Rs of the single diode in second model.[27]

$$\mathrm{I} = \mathrm{Iph} - \mathrm{Id} - \mathrm{Ip} \quad (5)$$

Where Ip is the current flow through *Rp*.

$$Iph = \frac{G}{Gref}(Iph, ref + \mu_{icc}(T - Tref)) \quad (6)$$

In which G and T are the incident of the solar irradiance as well as cell temperature, in both; reference temprature=25°C and Gref = 1000 W/m2 are the incident of solar irradiance.

At STCs commonly, cell temperature; Iph, and the Ref is the produced current by the incident light of the sun under STCs, and μIcc is (current temperature coefficient). The saturated current of the diode is shown

$$Id = I_0\left[\exp\left(q \times \left(\frac{V+R_S I}{AKTN_S}\right)\right) - 1\right] \quad (7)$$

And also the shunt-current is given by

$$Ip = \frac{V+R_S I}{R_p} \quad (8)$$

In equation 3.5, the cell current is the replacement equation from 3.6-to 3.8.

$$Iph = Iph - I_0\left[\exp\left(q \times \left(\frac{V+R_S I}{AKTN_S}\right)\right) - 1\right] - \frac{V+R_S I}{R_p} \qquad (9)$$

Where Ns is the number of PV modules connected is series.

The photocurrent and saturation current can be expressed as Iph = Iph, cell*Np, I0 = I0,cell*Np if the PV array consists of Np parallel cell connections. Rs is the equivalent of the series resistance of the sequence in Equation 8 and Rp is the equivalent of the parallel resistance. vAs seen in Figure 5, equation 9 points out the I-V function curve of the solar photovoltaic module. Ideality factor A as seen in Table 1 is based on PV cell[28].

Table 1. Ideality factor A that used for various semiconducting materials in PV cells

A	1.2	1.3	1.8	3.3	5	1.5	1.5	1.3
Semiconducting Material	AsGa	CTS	CdTe	a-Si:H triple	a-Si:H tandem	a-Si:H	Si-poly	Si-mono

The The ideality factor related on the material of the semiconductor used in the photovoltaic technology. The semiconductor materials InGaN / GaN and AlGaN / GaN are used in and the P-N junction diodes[29]; [30]; [31]; [32]. Researchers use an ideality factor greater than 2 for these semiconducting materials.

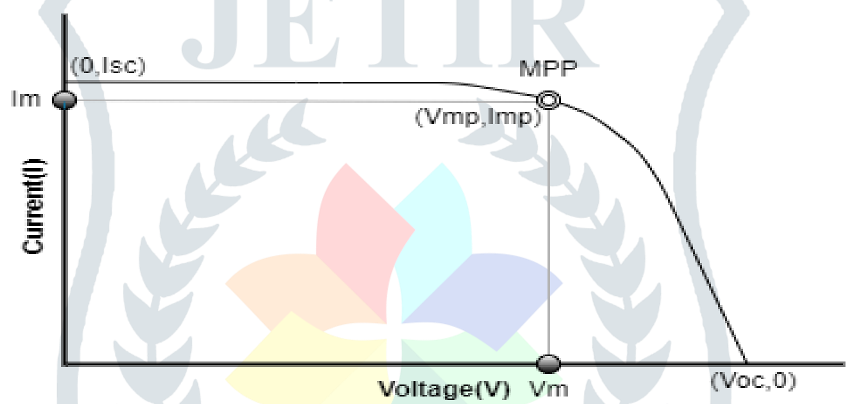

Figure 5. The current–voltage curve for a solar PV cell

Based on the Shockley diode model using Si, the PV cell equivalent circuit equations Do not have ideality considerations greater than 2 where AlGaN/GaN P-N junctions and AlGaInN ultraviolet (UV) light emitting diodes are larger than 2. Throughout this work, the Shockley diode model can be used for performance evaluation.[33].

III.2. Two Diode Model

Related to the lack of recombination failure, which leads to substantial losses, the single-diode model is not properly used for modelling of the solar cell and an additional diode is then applied to the single diode modelling. This model known as the model of two diodes or two diode model[28].

The second diode is used in a two-diode model reflecting the effect of the recombination of the carrier as seen in Figure 6. Several scholars have recommended the two-diode model because the variables of the equivalent circuit are being used to enhance the precision of the solar photovoltaic model.[17]; [34]; [35].

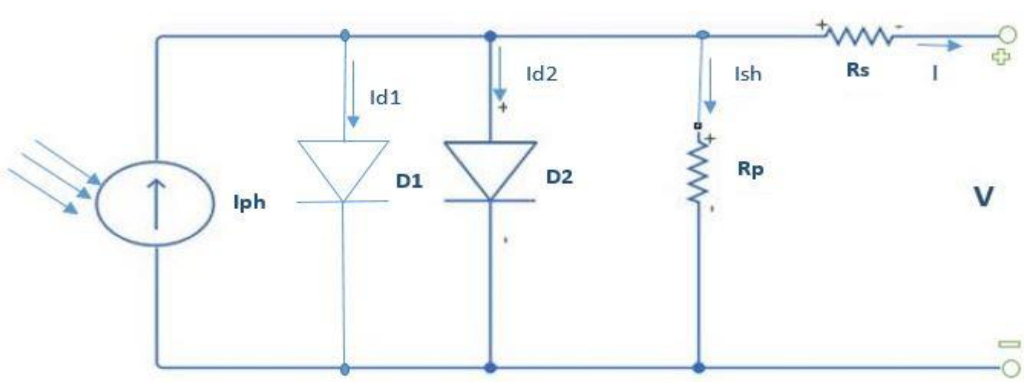

Figure 6. The two diode model of a solar photovoltaic cell

The performance current I of the PV module can be described

$$I = I_{ph} - I_{d1} - I_{d2} - I_{sh} \quad (10)$$

$$I = I_{ph} - I_{d1}\left[\exp\left(\left(\frac{V+IR_S}{A_1 V_{T1}}\right) - 1\right)\right] - \left[\left(\left(\frac{V+IR_S}{A_2 V_{T2}}\right) - 1\right)\right] - \left(\frac{V+IR_S}{R_p}\right) \quad (11)$$

In which the inverted saturation currents I01 and I02 relate, respectively, to diodes one and two. In the depletion field, Current I02 is the recombination failure [30]; [28].

$V_{T1,2} = \frac{N_S KT}{q}$ is the thermal or thermic voltage of the solar photovoltaic panel; in this formula Ns represent the number of cells connected together in PV array. Diode ideality factors for diodes one and two approximately, correspond to A one and A two, and absorption and replication current are expressed by I_{d1} and I_{d2} respectively. For convenience, most of scholars presume A1 as 1 and A2 as 2. Usually, the manufacturer supplies 3 points, such as the short-circuit current, the maximum power point(MPPT) and the open-circuit voltage of the standard test conditions or STCs, These 3 points can be taken from current-voltage curve by using the exact PV models[36].

III.3. Three Diode Model

To better illustrate the experimental data, a model with three-diodes has been suggested. We considered the series resistance, Rs, of the solar cell in the suggested model to differ with the current flowing through the solar cell system[27]. Figure 7. shows the modified three-diode modelling. Characterization of the solar cells of Mc-Si can be obtained by using this model, taking into account the effect of Grain boundary and strong leakage current across the periphery, and extracted or removes electrical properties [37].

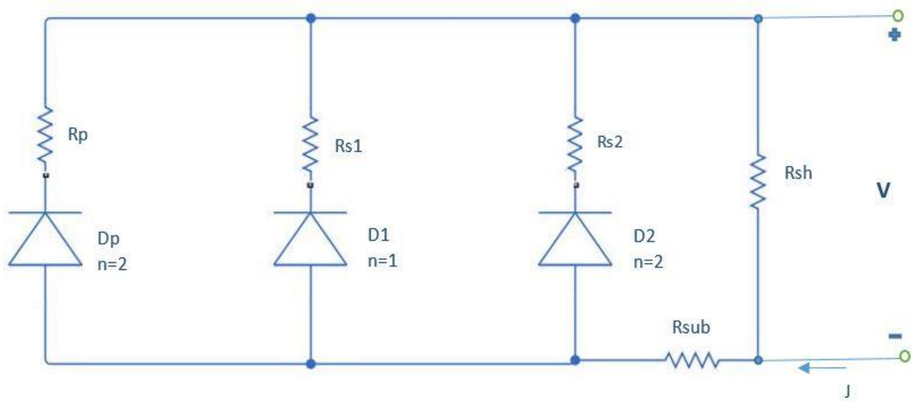

Figure 7. The corresponding circuit of the modified 3-diode model

IV. CONCLUSION

An accurate model for the PV module and an MPPT controller is required to obtain full power from the solar PV system under varying climatic conditions. Ecological factors like temperature, solar radiation and wind direction, will change the performance of solar PV panels . Accurate awareness of these parameters is essential in assessing the efficiency and quality of solar PV arrays or modules. The Solar PV modules typically consist of one or more diodes, modeled using identical circuits. A single-diode equivalent model of the circuit of the PV module is commonly used by most of researchers, Since the number of parameter tests is limited and thus convenient for performance evaluation. Due to the lack of recombination failure, that leads to large losses, the single diode model is often not properly often used model the photovoltaic cell and an extra diode is then added to the single diode model. This model is known as two diode model, The two-diode model has been suggested by several authors Since the equivalent circuit parameters are being used to boost the accuracy of the solar Photovoltaic model. To better illustrate the experimental data, a model with three-diodes has been proposed. We considered the series resistance, Rs, of the solar cell to differ with the current flowing through the solar cell system.

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