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# Design Modeling and Simulation of 150 KW Solar Photovoltaic Systems: A Review

**Zoya Fatma, Tarana Afrin Chandel, Mohd Yusuf Yasin**

***Abstract:*** ***Sun is the source of energy. Renewable energy is a clean eco-system free of harmful gasses such as carbon dioxide, and all the other harmful gases which are produced from the fossil. Many technologies have been used to design and manufacture the photovoltaic module. In this paper we have reviewed the design of solar photovoltaic system of using MatLab/Simulink. Characteristics of I-V and P-V are parameter of great importance in solar photovoltaic system. The effects of temperature and irradiation at the output of solar system that is current, voltage and output power have also been reviewed and studied.***

***Keywords: Irradiance, Solar cell, Fill factor, Maximum Power, MatLab/Simulink***

## I. INTRODUCTION

A photovoltaic (PV) system is formed when we connect the modules in series and parallel combination forming an array along with converters, inverters and load. The solar cells are basically used for the conversion of the light energy into electrical energy by means of photovoltaic process [1]. Photovoltaic systems can vary in size from mounted on a small rooftop having capacities of tens of KW or portable systems to massive utility-scale generation plants that generates hundreds of MW of electrical power. The radiations which are in form of electromagnetic are coming from the sun are used which are in the form of photons, containing packets of energy. The photon energy can be given by [2]

$$E_{ph} = hf = \frac{hc}{\lambda} \quad \text{.......................................} \quad (i)$$

Where,

f is as the frequency of radiations,

$\lambda$ is the Wavelengths;

h is the Plank's constant: value is 6.626176 x $10^{-34}$ joule-seconds.

c is the speed of light: value is 3x$10^8$ meter/second.

The sun light falls onto a solar panel, these radiations coming from sunlight are in form of photons which are incident on solar cell if the energy of photons are greater or equal to band gap energy of a semiconductor associated with the solar cell then generation of electron-hole pair will occur and creates a direct current through a process called the photovoltaic effect. The solar photovoltaic cell which is based on silicon is used to produce an open circuit voltage in the range of 0.5 to 0.6 Volts [3]. Cells and modules are connected in series and parallel to form a module and an array respectively as shown in figure 1[ 4]. Irradiance and temperature directly effects the output power of the SPV system.

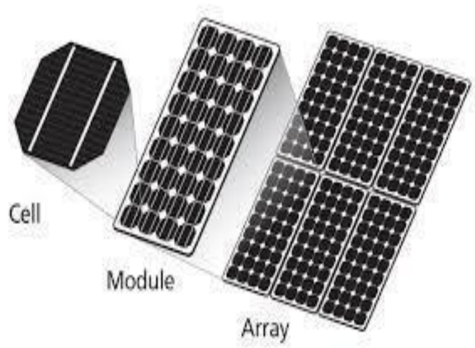


**Figure 1: Cell, Module and Array**

The creation of electron hole pair at same level of photonic energy will generate electric current. The released electron passes through the forbidden energy band gap and reached conduction band. The band gap which lies between 0.7 < $E_g$ > 0.4 [5]. The photovoltaic effect [6] is shown in figure 2

Solar cells are the basic building block of the module. Many cell combine to form a module and number of module combine to form an array. A SPV system is formed by connecting the output of an array to the battery for the storage. The battery may be directly connected to DC load but a charge controller is connected in between to prevent the battery from being over charging. On the other hand charge controller is used to prevent the loss and damage that caused due to the overcharging [7]. Another option to connect battery to load is via an inverter. AC load is connected at the inverter output shown in figure 3 [8].

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* Correspondence Author
**Zoya Fatma*,** Department of Electronic and Communication Engineering, Integral University, Lucknow, India . E-mail : zoyaf@iul.ac.in
**Tarana Afrin Chandel,** Department of Electronic and Communication Engineering, Integral University, Lucknow, India. E-mail : tarana@iul.ac.in
**Mohd Yusuf Yasin,** Department of Electronic and Communication Engineering, Integral University, Lucknow, India. E-mail : myyasin@iul.ac.in

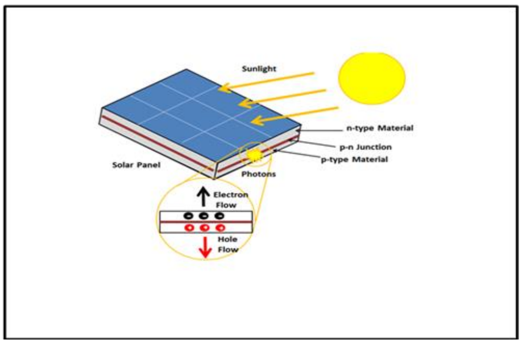


**Figure 2: A diagram showing photovoltaic effect**

High temperature [2,9,20], humidity, snow fall [9], environmental gases [9] (Oxygen, Hydrogen, sulphur e.t.c) and ultraviolet radiation [9] affects the performance of SPV system (i.e. output power) [9]

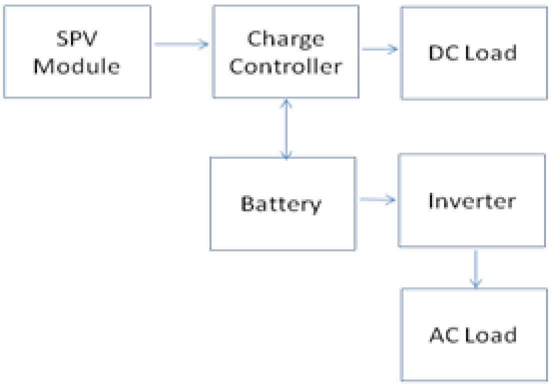


**Figure 3: Solar Photovoltaic System [8]**

## II. MODELING AND SIMULATION OF THE PV SYSTEM

The Solar cells are fabricated using p-type and n-type semiconductor on thin wafer. The solar cells can be mono-crystalline or polycrystalline depending on the fabricating materials and process. These solar cells basically use incident photon to generate electrons and holes. The generation and recombination of charge carriers are due to random motion of electrons and holes, causing band-gap. In carrier generation, electrons gain energy. It moves from the valence band to the conduction band, producing two mobile carriers; while in recombination, conduction band electron loses energy and re-occupies the energy state of an electron hole in the valence band [10]. Due to charge carriers current flows through solar cells. An ideal solar cell model [11] is shown in figure 4.

The basic model of solar cell is require for designing the SPV system which is further used for simulation on MATLAB/Simulink.

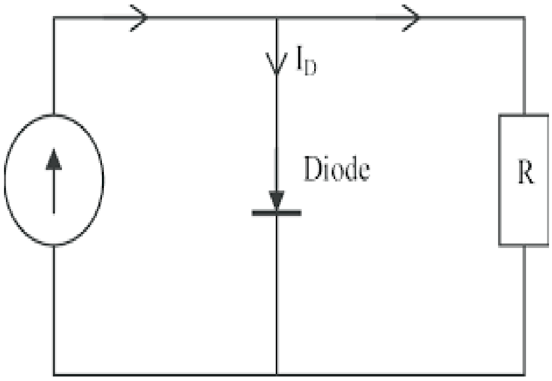


**Figure 4: Ideal solar cell model**

The output current at the load "R" of figure 4 is determined by the equation as shown below

$$I = I_p - I_d \qquad \text{(ii)}$$

$$I_d = I_o\left(e^{\frac{V_d}{\eta V_T}} - 1\right) \qquad \text{(iii)}$$

Substituting the value of $I_d$ in equation 1 we get

$$I = I_p - I_o\left(e^{\frac{V_d}{\eta V_T}} - 1\right) \qquad \text{(iv)}$$

Where,

$V_T = \frac{KT}{q}$ =26mV at room temperature,

V is the voltage across the output terminals,

$I_o$ is the reverse saturation current,

$\eta$ is a diode ideality factor, whose value is given as 1 for an ideal diode,

q is a charge whose value is 1.6 x $10^{-19}$ , Coulomb,

K is Boltzmann's constant having the value 1.3865 x $10^{-23}$,

T is the absolute temperature,

$V_T$ is the thermal voltage.

Solar cell is basically not active in the absence of sunlight as there are insufficient photonic energy to create electron-hole pair at p-n junction thereby unable to generate electric current. Modeling can be done by two diode model but single diode modeling is perfect model for the simulation [12,13,14,15,16].

## III. CHARACTERISTIC OF IDEAL PV CELL

A solar cell is modeled with one diode in which there is a shunt (parallel) and series resistors connected to it as shown in figure 5. The output current of single diode is shown in equation below

$$I_d = I_o\left(e^{\frac{V_d}{\eta V_T}} - 1\right) \qquad \text{(v)}$$

Where

$I_o$ is considered as the dark current or reverse saturation current,

$V_d$ is the forward bias voltage of solar cell.

The value of a diode voltage $V_d$, is approximately zero and hence reverse saturation $I_d$ current flows through it as shown in figure 5. In this figure dark dot (•) shows the dark current when voltage across diode voltage is almost zero and un dark dot (°) shows characteristic under illumination condition [17].

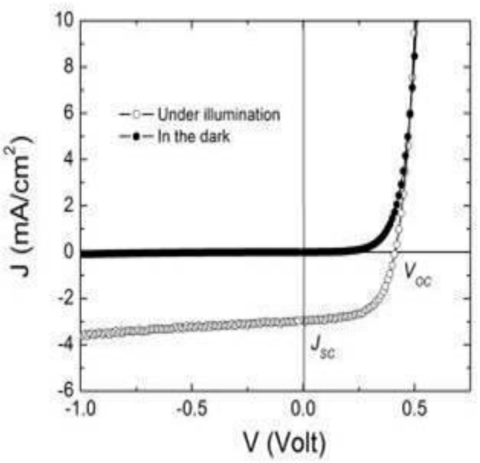


**Figure 5: I-V Charateristic of dark current**

## IV. I-V AND P-V CHARACTERISTICS OF SOLAR CELL

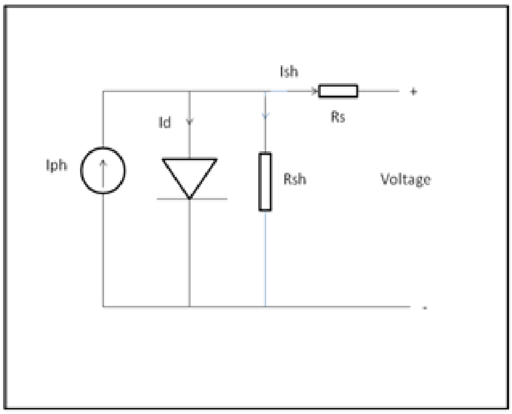


**Figure 6: circuit diagram of single diode solar cell**

The basic equation of the current from solar cell is described in equation which is mentioned below

$$I = I_L - I_O\left(e^{\frac{V+IR_S}{N_s V_t}} - 1\right) - \frac{V+IR_S}{R_{sh}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

Where $V_T$ is a Junction thermal voltage and it is expressed as

$$V_T = \frac{AkT}{q}$$

$I_L$ is the photo-generated current,

$I_O$ is the reverse saturation current,

$R_s$ is the series resistance of panel

$R_{sh}$ is the shunt (or parallel) resistance,

k is the Boltzmann's constant having the value of 1.3865 x $10^{-23}$

q is the charge, having the value of 1.6 x $10^{-16}$ Coulomb,

$N_S$ is the number of cells connected in series,

T is the temperature of the cell which is measured in degree Kelvin,

A is measured as the diode quality (or Ideality) factor

As compared to exponential terms which are given, the dark current which is available is very small, therefore the term ' -1' can be considered as negligible.[18]

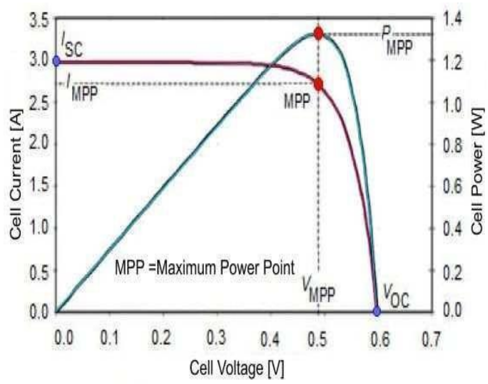


**Figure 7: Characteristic of solar cell**

Figure 7 shows the relationship of I-V and P-V characteristic merge on single scale [19,20]. Here $V_{OC}$ is the voltage which is open circuited and $I_{SC}$ is the current which is short circuited and MPP is maximum power point the above mentioned parameters are defined below [21, 22].

$V_{OC}$ is open circuit voltage which is defined as the maximum voltage when the current at solar cell is zero.

$I_{SC}$ is the short circuit current which is defined as the maximum current when terminal voltage is zero.

$M_{PP}$ is the maximum power point which is defined as the maximum power that occurs across the load.

## V. FILL FACTOR

t is an important parameter in evaluating the performance of SPV system. It may be defined as the ratio of maximum power obtained from the product of voltage which is open circuit ( $V_{OC}$ ) to the current which is short circuit ($I_{SC}$). Figure 8 showing fill factor (area in dark pink square) [23]. I-V curve squareness is used to measure the fill factor [21]. In most cases generally fill factor is usually in the range of 40% to 60% [24], but maximum possibility reaches up to 80% to 85% [22,23]. Fill factor also depend upon the material that is used for the fabrication of solar cell. Fill factor in case of Gallium Arsenide($G_a A_s$) approached up to 89% [23].

The above graph shows I-V and P-V characteristic on same scale. I-V characteristic is shown by red line and P-V characteristic is shown by blue line. From the above graph, fill factor is shown as the ratio of area A to area B. Area A shows product of maximum voltage and maximum current ($V_{mp} \times I_{mp}$).

$$\text{FF} = \frac{V_{mp} \times I_{mp}}{V_{OC} \times I_{SC}}$$

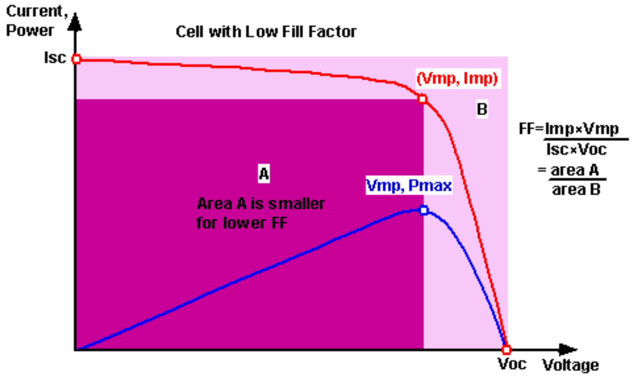


**Figure 8: Pink square area showing of fill factor**

## VI. CONCLUSION

In this paper, we study the designing and modeling of solar photovoltaic system. Various methodologies have been used for designing and modeling of SPV system but emphasis was done by mathematical modeling with MATLAB/simulink. We also observed that the fill factor is an important parameter for evaluating the performance of SPV system.


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## AUTHORS PROFILE

**Zoya Fatma** received the degree of Bachelor of Technology in Electronics and Communication Engineering from Integral University, Lucknow in 2018. Currently she is perusing her Masters of Technology in Electronic Circuit and Systems from Integral University, Lucknow. Her area of interest is in Renewable Energy and Resources. She was also a participant of international symposium on "Computational and Characterization Techniques in Engineering and Sciences" held at Integral University, Lucknow.

**Tarana Afrin Chandel** has received her M .Tech degree from UP Technical University, U.P and B. Tech degree from Magadha University, Bihar in the year 2002 and 2009 respectively and pursuing PhD from Integral University. Presently she is working as Associate Professor in Integral University, Lucknow, U.P. She is a Principal Investigator of the project title "**Performance Analysis of 1MW Grid Connected Solar Photovoltaic System using Image Analysis,** sanctioned by Institute of Engineer, Kolkata-700020, West Bengal, India. She is honored as **Pride of India** by International House on 12 September 2018. She is awarded **Excellent Teaching Award** in Higher Education for AIRF-International Women Research and Connect Award 2018 on 8 March 2018, **Best Faculty Award** in Rural Institution, AIRFA- National Conference on Exploring Science and Technology for the Future Developments held on 25 November 2017, She is awarded **Best Paper Award**: Paper title "**Efficient Address Generator for WiMAX Deinterleaver"** in 4 National Conference on Challenges & opportunities for Technical Innovation on 19th & 20th February 2016 held at Ambalika Institute of Management and Technology, Lucknow, U.P. She is honored as

**"Rashtriya Gaurav Award" And Certificate of Excellence for Meritorious Services, Outstanding Performance** and Remarkable Role by Dr Bhishma Naraian Singh (Former Governor of Assam and Tamil Nadu) at the Seminar on Global Participation of India's Economic Development at New Delhi on 24 May 2010. She has published 24 research articles in International Journals and has published 22 papers in International and National conference and also had poster presentation in IEEE conference. She is **"Life member** of **Indian Society for Technical Education"** and "**The Institution of Engineers (India).** She is **President and Life member of Robotic Society**, Integral University, Lucknow, U.P. She is also serving as **Reviewer** in National and International Journals indexed **Web of Science and Scopus**. She has served as Jr. Engineer in M/s Bharti Telecom Pvt Ltd from August 1995 to 28 October 1998 and M/s Pramod Telecom Pvt Ltd as Manager (QC) and Manage Representative for ISO 9000 from June 2003 to July 2004.

**Dr. Mohd Yusuf Yasin** is associated with ECE Department of Integral University, Lucknow, India. He did his Ph. D in Low Power VLSI IN 2014. He obtained M.Sc. Engineering in Electronics Circuits and Simulation in 1996 and B. Sc Engineering in Electrical Engineering in 1988, both from AMU, Aligarh, India. His research interest includes Low Power VLSI, Digital Signal Processing, Circuit and Systems, Non-Conventional Energy sources etc. He is working on government project