Modelling & Analysis of PV-Array

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Abstract--- As per the flow of time the energy demand is increasing and thus the necessities for a renewable source that won't harm the environment are of prime importance. Some projections state that by 2050 the energy demand will triple. Now majority of the energy requirements is satisfied by fossil fuels but by the use of PV systems could help in fulfilling the energy needs. In this project we've deal with problem that persists with the modelling of photovoltaic devices. The problem that many different kinds of models of photovoltaic device face is the number of unknown parameters which aren't mentioned in the datasheet. Various methods have been proposed in order to determine these unknown parameters. Basically, in this paper, two of the proposed methods are being studied and then compared. This effort can give a brief idea to the developers & manufacturers who design power electronics products about the easy-to-use modelling methods that can be used in simulation of photovoltaic arrays.

Keywords: photovoltaic, converter/inverter, MPPT, Detailed full modelling, control strategies, PV design

I. INTRODUCTION

PVs are arrays (combination of cells) that contain a solar Photo voltaic material that converts solar energy into electrical energy. PV cell is a basic device for Photovoltaic Systems. Such systems let in multiple components like as mechanical & electrical connections and mountings & various means of regulating & (if required) modifying the electrical output. Applicant that are used for photovoltaic are mono-crystalline silicon, microcrystalline silicon, cadmium telluride, polycrystalline silicon, and copper indium selenide. The current & voltage available at the PV device terminals that can be directly used to feed small loads like small DC motors or lighting systems. With the objective of

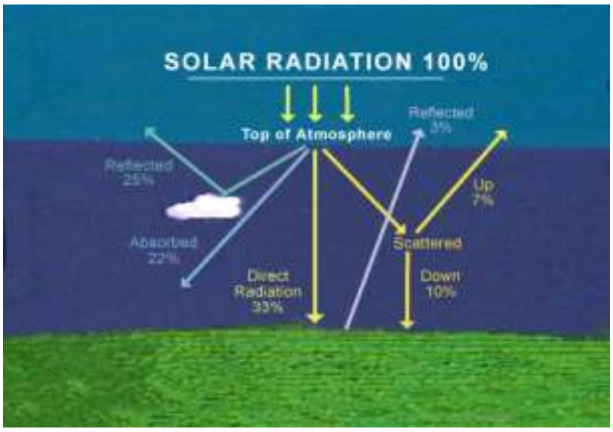


Fig. 1: The distribution of solar radiation. [Source: Modified figure of Houghton et al. 2001]

extract maximum amount of power from PV array we've to model converters so that it can track Maximum Power Point (MPP). At present, solar cell (PV) generation is assuming increased importance as a renewable energy sources application because of distinctive advantages such as simplicity of allocation, high dependability, absence of fuel cost, low maintenance and lack of noise and wear due to the absence of moving parts. So here we are trying to model a non-conventional energy generation system using wind and solar sources. No pollution is emitted here i.e. 100% environmental friendly.

II. PREPARATORY

Following are:

1. Sun as a Source
2. Solar energy reaching the earth's surface.
3. Spectrum of sun.
4. Nominal Test Conditions

A. *SUN AS A SOURCE:*

The energy from the sun is supplied in the form of radiation. The energy is generated in the sun's core through the fusion of hydrogen atoms into helium. Now due to the larger distance of sun from the earth only a small portion of sun's radiation reaches earth's surface. The intensity of solar radiation reaching earth's surface is around 1369W/m^2.

B. Solar Energy Reaching The Earth's Surface*:*

Till now the effect of earth's atmosphere isn't taken into consideration. The value calculated above is for the average solar radiation intensity at the outer regions of earth's atmosphere. So we are interested to know how much of this energy actually reaches the earth surface. The atmosphere absorbs about 68 W/m^2. & reflects 77 W/m^2(Wallace and Hobbs 1977). The radiation reaching the earth's surface is 198 W/m^2.The intensity of solar radiation also depends on the time of the year and the geographical positions. The energy reaching the earth surface is around 7000times the global energy consumptions.

C. Spectrum of sun*:*

The efficiency of a PV device is dependent on the spectral distribution of solar radiation. The evaluation of PV devices is generally done with reference to a standard spectral distribution. There are two standard terrestrial distribution defined by the American Society

for Testing and Materials (ASTM), direct normal and global AM1.5. The direct normal standard corresponds to the solar radiation that is perpendicular to a plane directly facing the sun. The global corresponds to the spectrum of the diffuse radiations. Radiations which are reflected on earth's surface or influenced by atmospheric conditions are called diffuse radiations. To measure the global radiations an instrument named pyrometer is used.

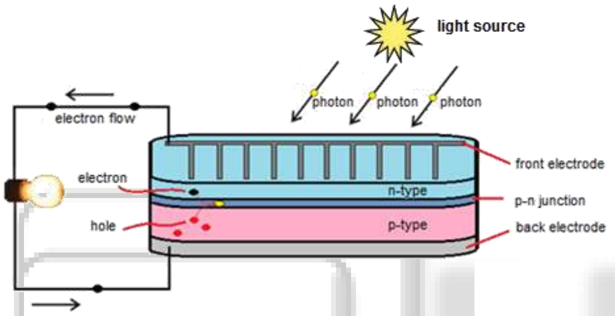
D. Nominal Test Conditions:

Test is done so that a comparison on the basis of performance between different PV cells can be done (Usually we specify standard conditions).The parameters are generally given in a datasheet. It provides remarkable parameters regarding the performance & characteristics of PV arrays with respect to these standard test conditions. The nominal (standard) test conditions are as follows:

- Irradiance = 1000 W/square of meter
- Temperature = 25 °*C*
- Spectrum of x = 1.5, i.e.AM1.5.

III. PHOTOVOLTAIC CELL:

PV cell are basically semiconductor diode. This semiconductor diode has got a p-n junction which is exposed to light. When illuminated by sunlight it generates electric power. PV cell are made up of various semiconductor materials. But mono-crystalline silicon and poly-crystalline silicon are mainly used for commercial use.



IV. PHOTOVOLTAIC MODULE

The power produced by a single PV cell is not enough for general use. So by connecting many single PV cell in series (for high voltage requirement) and in parallel (for high current requirement) can get us the desired power. Generally a series connection is chosen this set of arrangement is known as a module. Generally commercial modules consist of 36 or 72 cells. The modules consist of transparent front side, encapsulated PV cell and back side. The front side material is usually made up of low-iron and tempered glass. The efficiency of a PV module is less than a PV cell. This is due to the fact that some radiation is reflected by the glass cover and frame shadowing, etc.

V. PHOTOVOLTAIC ARRAY

A PV system is a interconnection of modules which in turn is made up of many PV cells in series or parallel. The power produced by a single module is seldom enough for commercial use, so modules are connected to form array to supply the load. The connection of the modules in an array

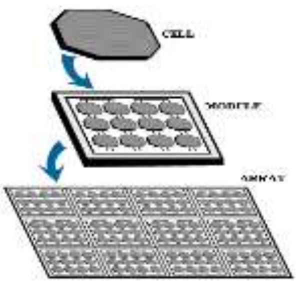


Fig. 3: Photovoltaic Hierarchy

is same as that of cells in a module. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current. In urban uses, generally the arrays are mounted on a rooftop. In agricultural use, the output of an array can directly feed a DC motor.

VI. WORKING OF PV CELL

Working of a PV cell is based on the basic principle of photoelectric effect. It can be defined as a process in which an electron gets ejected from the conduction band as a consequence of the absorption of sunlight of a certain wavelength by the matter (metallic or non-metallic solids, liquids or gases).So, for PV cell, when sunlight strikes its surface, some portion of the solar energy is absorbed in the semiconductor material. If absorbed energy is greater than the band gap energy of the semiconductor, the electron from valence band jumps to the conduction band. By this, pairs of hole-electrons are created in the illuminated region of the semiconductor. The electrons thus created in the conduction band are now free to move. These free electrons are forced to move in a particular

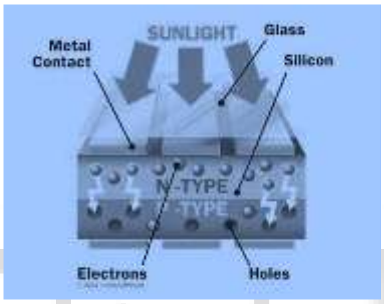


Fig. 4: Working of PV cell

VII. MODELLING & CHARACTERISTICS OF A PV CELL

In a PV characteristic there are basically three important points viz. open circuit voltage (V_0), short circuit current (I_s) & maximum power point ($I_{mpp,}V_{mpp}$). The maximum power

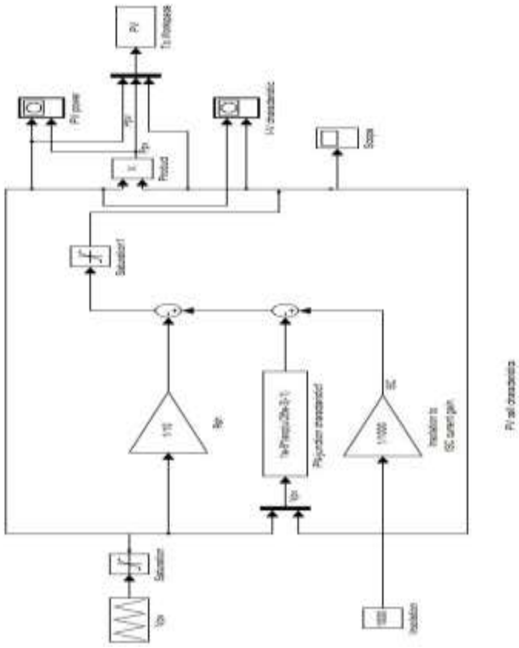


Fig 5:a PV cell MATLAB modelling

that can be extracted from a PV cell are at the maximum power points. Usually manufacturers provide these parameters in their datasheets for a particular PV cell or module. By using these parameters we can build a simple model but for more information is required for designing an accurate model. Its MATLAB modelling file is shown in Fig 5a & The I-V characteristic is shown in Fig 5b.

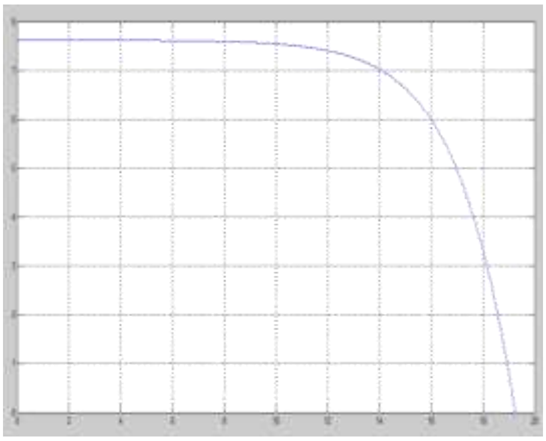


Fig.5 b. Solar Cell I-V characteristic curve

$$I_l = \frac{BKTN_s}{q} \times \exp\left(\frac{qE_{GO}}{BK}\left(\left(\frac{1}{T_v}\right) - \left(\frac{1}{T}\right)\right)\right)$$

$$I_{ph} = (I_d + I_{sh} + I_0)$$

Where,

I_{ph} = Light-generated Current or Photocurrent: It is generated directly by incident of sunlight on the PV cell

This current varies linearly with sun irradiation and depends on temperature given by,

$$I_{ph} = (I_{ph,n} + K_i \Delta T)\frac{G}{G_n}$$

Where,

$I_{ph,n}$ = Light-generated current at nominal condition.

K_i = Current temperature co-efficient.

G = Actual sun irradiation.

ΔT = Change in temperature (in Kelvin).

VIII. MODELLING OF PV ARRAY

Modelling of PV modules or arrays is required in order to design and monitor these systems. Usually, a grey model process is used to model PV arrays. In such models, physical parameters are determined using the measured data given in the datasheets (by manufacturers). In this section, basic models of PV array and their advantages and disadvantages over one another. Then, we will go through the two methods to determine the unknown parameters using known ones and their comparison.

IX. REPRESENTATION OF PV DEVICES

The PV devices are basically represented in two different models,

- ❖ Single diode model
- ❖ Double diode model

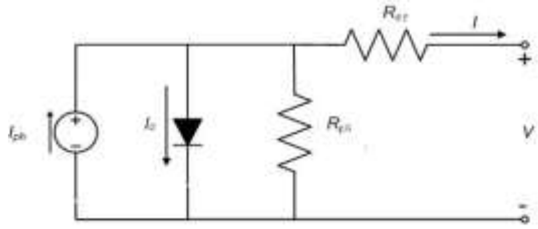


Fig.6:a.Single diode Model.

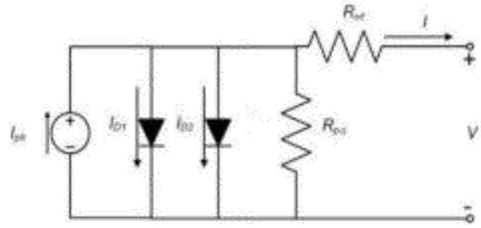


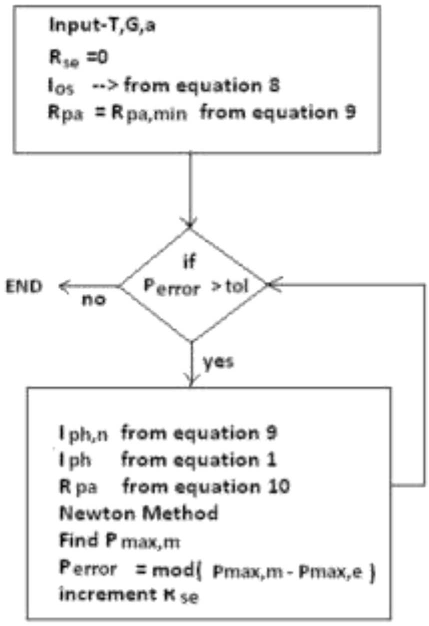
Fig. 6:b.double diode Model

In fig 6a.The current source represents light-generated current, which varies linearly with solar irradiation. This is the simplest and most widely used model as it offers a good compromise between simplicity and accuracy.

In fig 6b. An extra diode attached in parallel to the circuit of single diode model. This diode is included to provide an even more accurate I-V characteristic curve that considers for the difference in flow of current at low current values due to charge recombination in the semiconductor's depletion region.

X. METHODS TO DETERMINE THE UNKNOWN PARAMETERS:

As mentioned earlier, we have considered two methods for determining the unknown parameters using the known ones (from the datasheet).



- Newton's Method.
- Newton-Raphson method to solve system of non-linear equations

A. For Newton's Method,

Following figure shows the algorithm that can be followed using MATLAB in order to unknown parameters;

By Using Newton-Raphson method or other algorithm to solve system of non-linear equations and above initial values, a numerical solution can be obtained

By Using Newton-Raphson method or other algorithm to solve system of non-linear equations and above initial values, a numerical solution can be obtained

XI. CONCLUSIONS

After going through both the methods for determining unknown parameters, we can conclude the advantages and disadvantages of both over one another.

A. For 1st method

1) Advantages:
Since, we assume the value of diode ideality factor beforehand, only two parameters remain unknown. These can be easily determined using Newton method to solve a non-linear equation. No experimental data is required.

2) Disadvantages:
A big compromise is done by assuming diode ideality factor beforehand. The parameters obtained can be less accurate. Though the computational time is less w.r.t. to other method the number of iterations is large.

B. For 2nd method

1) Advantages:
No compromise with any parameter is done. Accuracy is more than the previous method. Though computational time is more, the equations converge in 4 to 10 iterations.

2) Disadvantages***:***
Initial values should be properly determined otherwise there is greater number of chances for divergence to take place. Therefore, proper experimental values are required

ACKNOWLEDGMENT

Success of any work depends upon the dedication, sincerity and hard work. It also requires some ingredients such as motivation, guidance, encouragement and time. For that, I would like to say thanks, work related to "Modelling & Analysis of PV-array**"** Asst. Prof. Ashish Shah, Asst. Prof, Electrical Engineering Department, PIET, Who helped me for the successful completion of this work and for providing valuable guidance throughout the work.

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