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DIODE MODEL OF PV ARRAY AND MAXIMUM POWER POINT TRACKER TECHNIQUE TO EXTRACT SOLAR ENERGY & ITS APPLICATION: A REVIEW

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ABSTRACT

In this paper, we give the main focus on the generation of energy. Here we developed a PV array for the voltage generation. We create a model with the help of diode for the single unit and technique used to extract the maximum solar energy by developing MATLAB –simulink model.

KEYWORDS: *PVC: PV Cell, PVA: PV Array, Il: Insulation Level (Sunlight Irradiance), Res: Renewable Energy Sources, Em: Energy Management, Load Forecasting, Mg: Micro-Grid, Mppt: Maximum Power Point Tracker, Aci: Atmospheric Clarity Index*

INTRODUCTION

Solar Energy

It is an important, clean, cheap and abundantly available renewable energy. It is received on Earth in cyclic, intermittent and dilute form with very low power density 0 to 1 kW/m^2 [1]. Solar energy received on the ground level is affected by atmospheric clarity, degree of latitude, etc. For design purpose, the variation of available solar power, the optimum tilt angle of solar flat plate collectors, the location and orientation of the heliostats should be calculated.

Units of Solar Power and Solar Energy

In SI units, energy is expressed in Joule. Other units are Langley and Calorie where:- 1 Langley = 1 calories / cm^2 / day, 1Calorie = 4.186 J For solar energy calculations, the energy is measured as an hourly or monthly or yearly average and is expressed in terms of kJ/m^2/day or kJ/m^2/hour. Solar power is expressed in terms of W/m^2 or kW/m^2.

SOLAR CONSTANT

Solar Constant (S)

Solar constant is the solar radiation received per unit area normal to the sun's rays in a space outside the earth's atmosphere. In SI units the value of S is 1353 W/m^2 [3]. As shown in fig.3.1.

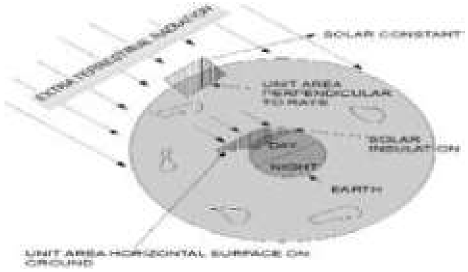


Figure 1

Clarity Index

While passing through the atmosphere, the beam radiation from the sun is partly absorbed and partly scattered by the atmospheric dust, gases, cloud, moisture etc. On a moderate cloudy day, reduction is 10-50%. During dark and cloudy day, radiation reduces to 1%. Flat plate collectors are better suited than focusing collectors for diffused sunlight (cloudy atmosphere). The effect of atmospheric conditions on the beam radiation is expressed by Atmospheric Clarity Index (ACI) given by: ACI = It is the ratio of solar radiation (W/m^2) to solar constant (W/m^2)

Solar Radiation Data for India

India is situated in the Northern hemisphere of earth within latitudes 7^ON and 37.5^ON. The average solar radiation values for India are between 12.5 and 22.7 MJ/m^2.day [3]. Peak radiation is received in some parts of Rajasthan and Gujarat. Radiation falls by 60% during monsoon.

Solar Radiation

Solar radiation is shown in fig.1 It is the solar radiation received on a flat, horizontal surface at a particular location on earth at a particular instant of time [4]. It depends on the following parameters:

- Seasonal variation and geographic location of the particular surface.
- Atmospheric clarity.
- Shadows of trees, tall structures, adjacent solar panels, etc.
- Area of exposed surface, m^2
- Angle of tilt of solar panel.

Modified Angstrom equation for Average Daily Global Radiation is used to determine the radiation at different places on earth.

WORKING OF SOLAR CELL

A solar cell (also called a photovoltaic cell as shown in fig.4.1 It is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage, or resistances vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source [15]. The term "photovoltaic" comes from the Greek word (*phōs*) meaning "light", and from "Volt", the unit of electro-motive force, the volt, which in turn comes from the last name of the Italian physicist Alessandro Volta, inventor of the battery (electrochemical cell). The term "photo-voltaic" has been in use in English since 1849. *Photovoltaics* is the field of technology and research related to the practical application of photovoltaic cells in producing electricity from light, though it is often used specifically to refer to the generation of electricity from sunlight. Cells can be described as *photovoltaic* even when the light source is not necessarily sunlight (lamplight, artificial light, etc.) [8].The operation of a photovoltaic (PV) cell requires 3 basic attributes:

- The absorption of light, generating either electron-hole pairs.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.
- In contrast, a solar thermal collector collects heat by absorbing sunlight, for the purpose of either direct heating or indirect electrical power generation.

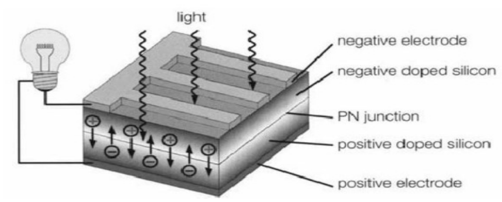


Figure 2: Solar Cell.

"Photo electrolytic cell" (photo electrochemical cell), on the other hand, refers either a type of photovoltaic cell (like that developed by A.E. Becquerel and modern dye-sensitized solar cells) or a device that splits water directly into hydrogen and oxygen using only solar illumination.

Solar Panel

The diagram of solar panel n is shown here in figures. Modern solar Cells make use of semiconductor materials usually based on single-crystal silicon. When doped with phosphorus, arsenic or antimony the silicon becomes an n-type semiconductor, and when doped with boron, Aluminum, Indium, or Gallium, it forms a p-type semiconductor [8]. If a p-type semiconductor is brought into intimate contact with one of the n-type, they form a p-n (or n-p) junction. if the two semiconductor materials are derived from the same element (or compound), such as silicon, the system is referred to as a homo-Jn. It is also possible for a p-n Jn. [9]. To be formed from two different semiconductor materials, such as CdS and Cu_2S. This is known as a hetero Jn.

The MIS (metal insulator semiconductor) Solar cell is similar to the Schottky type except that a very thin layer (about 0.1 to 0.3 micro meter) of an insulator is deposited between the semiconductors or and the metallic conductor a conversion efficiency of more than 17% has been reported for an MIS solar cell made with single crystal silicon. PV cell is a light sensitive two-terminal N-P junction made of semiconducting material such as silicon. P type and N-type semiconductor and a solar cell are shown in

Figure 3

Maximum Power Point Tracker (MPPT)

Fig. 4 Shows the I-V curve of the PV module simulated with the MATLAB model. A PV module can produce the power at a point, called an operating point, anywhere on the I-V curve. The coordinates of the operating point are the operating voltage and current [6]. There is a unique point near the knee of the I-V curve, called a maximum power point (MPP), at which the module operates with the maximum efficiency and produces the maximum output power [7]. It is possible to visualize the location of the by fitting the largest possible rectangle inside of the I-V curve, and its area equal to the output power which is a product of voltage and current.

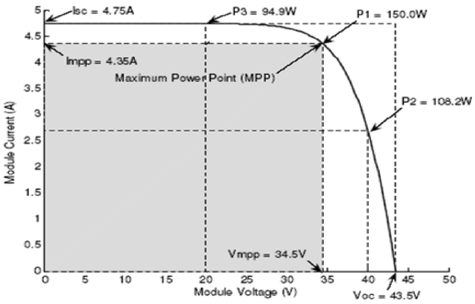


Figure 4: Simulated I-V Curve of PV Module.

It reveals that the amount of power produced by the PV module varies greatly depending on its operating condition.

It is important to operate the system at the MPP of PV module in order to exploit the maximum power from the module.

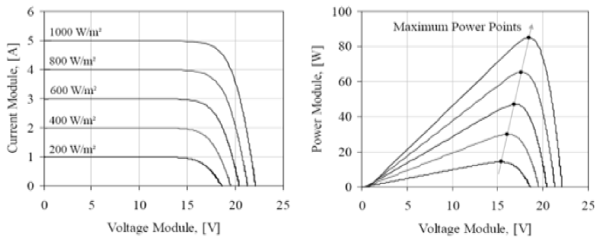
The position of the maximum power points on the PV generator characteristic depends strongly on the solar radiation and the cells temperature, as shown in Fig. 4.3. It is used to adjust the actual operating voltage and current of the PV generator so that the actual power approaches the optimum value as closely as possible [8]. Operation of the PV generator at its MPP involves matching the impedance of the load to that of the generator. For this purpose, an electronic device, normally a power conditioning unit, capable of performing the function of a MPPT has to be connected between PV generator and the load. Therefore, a tracking of the MPP is only meaningful, if components for processing are available and the tracking of the working point does not bring additional energy losses and at small additional costs [9]. Many different techniques have been developed to provide maximum power tracking of PV generators. These techniques can be classified as either direct or indirect methods. The direct methods are based on a searching algorithm to determine the maximum of the power curve without interruption of the normal operation of the PV generator [6]. For a certain working point, the corresponding voltage is changed around by a certain increment. Consequently, if the output power becomes larger than the last value calculated, then the search direction is maintained for the next step. Otherwise, it will be shifted in the opposite direction.

I-V Characteristics of a Photovoltaic Module

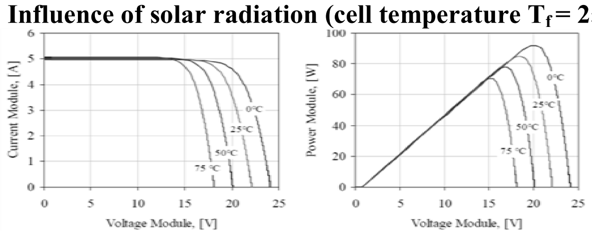
The performance characteristics of a photovoltaic module depend on its basic materials, manufacturing technology and operating conditions. Fig. 4.4 shows typical current-voltage I-V and power-voltage P-V curves of a *BP 585 High-Efficiency Mono crystalline Photovoltaic Module* according to the variation of solar radiation level and cell temperature. Three points in these curves are of particular interest:

- *Short circuit point*, where the voltage over the module is zero and the current is at its maximum (*short circuit current Isc*).
- *Maximum power point or MPP*, where the product of current and voltage has its maximum (defined by I_{mpp} x V_{mpp}).
- *Open circuit point*, where the current is zero and the voltage has its maximum (*open circuit voltage Voc*).

The measurements taken for obtaining an I-V curve depend on controlling the load current. At open circuit, when no load current is generated, a first characteristic value can be measured; the *open circuit voltage Voc*. Decreasing the load fed by the photovoltaic module leads to a decreasing voltage *V* with an increasing current *I*.



(a) Influence of solar radiation (cell temperature $T_f = 25^0$



(b) Influence of cell temperature (solar radiation $E_o = 1kW/m^2$)

Figure 5: (a) & (b) The I-V Curve and Maximum Power Point.

Advantages of the Photovoltaic Power

Major advantages of the photovoltaic power are as follows:

- Short lead time to design, 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.
- Highly mobile and portable because of light weight.

The *fill factor (FF)* of a photovoltaic generator is defined as the ratio of output power at MPP to the power computed by multiplying *Voc* by *Isc*. It determines the shape of the photovoltaic generator characteristics. The factors which affect the fill factor are the series and shunt resistances of the photovoltaic generator. A good fill factor is between 0.6-0.8. As the photovoltaic generator degrades with age, its series resistance tends to increase resulting in a lower fill factor.

5MODELING OF PHOTOVOLTAIC MODULE

Solar PV module and its equivalent are shown in figure. The specification of the PV module is shown in table 1.

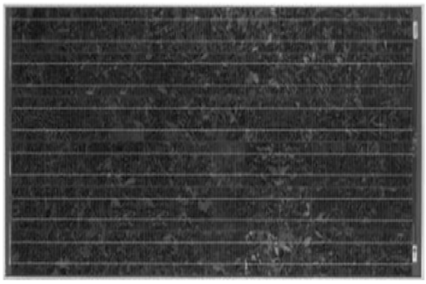


Figure 6: Picture of BPSX 50S PV Module.

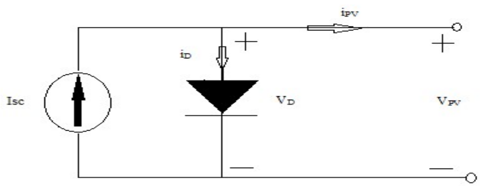


Figure 7: Equivalent Circuit Model of Solar Cell.

Table 1: Electrical Characteristics PV Module

Electrical Characteristics	Rating
Maximum Power (P_{max})	150 W
Voltage at P_{max} (V_{mp})	34.5V
Current at P_{max} (I_{mp})	4.35A
Open-circuit Voltage (V_{oc})	43.5 V
Short-circuit Current (I_{sc})	4.75A
Temperature coefficient of I_{sc}	$0.065 \pm 0.015\% /^0C$
Temperature coefficient of V_{oc}	-160 ± 20 mV/^{0}C
Temperature coefficient of power	$-0.5 \pm 0.05\%/^0C$
NOCT	47 2^{0}C

Strategy of Modeling a PV Module

- The strategy of modeling a PV module is no different from modeling a PV cell. It uses the same PV cell model.

- The parameters are the all same, but only a voltage parameter (such as the open-circuit voltage) is different and must be divided by the number of cells. In the modeling of photovoltaic module, first of all we convert solar cell in to the equivalent circuit.

Equivalent circuit of solar cell contains short circuit current (Isc) parallel with diode as shown in fig.5.2 Equations for the above model is:

$i_D = I_o.(e^{VD/VT}-1)$

Input equation: $V_D = V_{PV}$

Output equation: $i_{PV} = I_{SC} - i_D$

A single PV cell produces an output voltage less than 1V, about 0.6V for crystalline silicon (Si) cells, thus a number of PV cells are connected in series to archive a desired output voltage. When series-connected cells are placed in a frame, it is called as a module. Most of commercially available PV modules with crystalline-Si cells have either 36 or 72 series-connected cells. A 36-cell module provides a voltage suitable for charging a 12V battery, and similarly a 72-cell module is appropriate for a 24V battery.

Which is V_{pv} and the o/p is the current which is $I_{pv.}$ Now modeling the circuit and we get the characteristics of solar cell. When the radiation is high, more current draw in the circuit. The radiation is change with the atmosphere. Condition at the early morning the radiation is about 600W/m^2, then nearer to noon its 800W/m^2 and at the noon it is max about 1000 W/m^2.

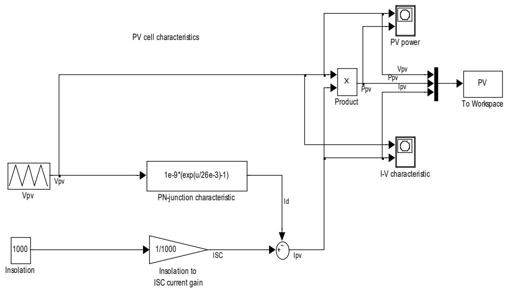


Figure 8: Modeling of PV Array.

Characteristics I-V and P-V at the radiation level at 000W/m^2
1000W/m^2:

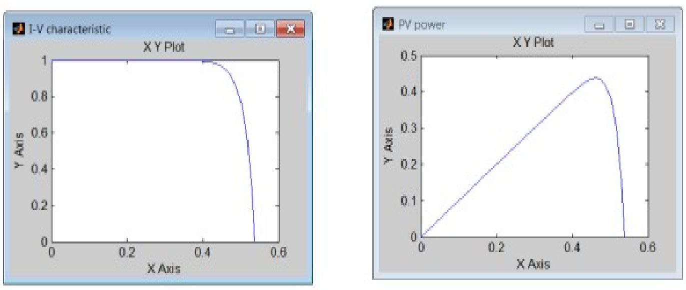


Figure 9: I-V and P-V Characteristics (1000 W/m^2).

Table 2: V, P, & I Output (1000 W/m^2)

Voltage	Power	Current
0.012	0.012	1
0.026	0.026	1
0.04	0.04	1
0.054	0.054	1
0.068	0.068	1
0.18	0.18	0.999999
0.194	0.194	0.999998
0.208	0.207999	0.999997
0.222	0.221999	0.999995
0.236	0.235998	0.999991
0.474	0.434799	0.917297
0.488	0.41885	0.858299
0.502	0.380121	0.757214
0.516	0.301353	0.584017
0.53	0.152252	0.287268

Table 3: Solar Radiation 1000W/m^2

MPP Power	MPP Voltage	MPP Current
0.2550	0.4460	0.5718

Application

- Small village electricity supply,
- Water pumping and systems,
- Lighting and small appliances,
- Emergency power systems and lighting systems,
- Stand-alone hybrid renewable energy systems.

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