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MODELING OF PHOTOVOLTAIC PANEL AND EFFECT OF VARIOUS PARAMETERS ON ITS PERFORMANCE

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ABSTRACT

As per the present scenario lot of power shortages are there all over the world especially country like India the grid transferring problem is also high. Almost the power from the fossil fuels is becoming so less. There is increasing demand for the use of power from renewable based energy sources such as solar, wind, biomass, tidal etc which does not cause any damage to the environment. Unlike conventional generation the solar energy is available at no cost and is pollution free. This paper shows a model for a photovoltaic system consisting solar source in order to estimate the I-V & P-V characteristics for various values of solar radiation keeping the cell temperature constant. The proposed model can also obtain the effect of variation of physical and environmental parameters and observe voltage profile with the proposed model and effects caused by randomness of solar radiation on the voltage profile. In addition, PV module model and PV array is also developed and their voltage profiles are observed. This model provides a tool to predict the behavior of any solar cell, module and array under the variation of several parameters.

KEYWORDS: Cost Benefit Analysis, Photovoltaic Cells, Photovoltaic Effects

INTRODUCTION

Renewable energy resources including wind power, hydro power etc., are gaining an increasing share of the global electricity generation in 2009 [1]. Among those energy sources, especially the photovoltaic power has been increasing its share and also it has been in the focus of many governments. Due to substantial subsidies, the installations of photovoltaic panels are increasing rapidly. For e.g. in Germany, the electricity generated through photovoltaic technology is about 50% of the total electricity generation in 2012 [2]. Due to, the ongoing trend of declining photovoltaic panel prices, the rate of growth of PV installations is expected to be at a higher level.

The PV module modeling involves the estimation of P-V and I-V curves. Among various mathematical models of PV model proposed in literature, simplest is the ideal single diode model, which involves short circuit current, open circuit voltage and diode ideality factor. This single diode model is further implemented with the effect of series resistance when subjected to large temperature variations.

The effect of temperature on the PV panel is reduced by including a shunt resistance for the above proposed model. This paper presents a comparison of different mathematical models of a PV array based on the Shockley diode equation. The different models include the single diode model and the double diode model which accepts temperature and solar irradiance as input parameters and gives the output as P-V and I-V characteristics respectively.

PHOTOVOLTAIC PANEL

A Photovoltaic cell is a component that converts solar energy into electrical energy by the photovoltaic effect. Photovoltaic effect occurs when the photons of sunlight strikes the semiconductor surface such as silicon, liberates electrons. Some chemicals added to the material composition helps to establish a path of free electrons which creates an electron current. In the production process of PV cell, very pure silicon is reduced to molten form and after processing it is made to solid crystal cylinder, which is cut into thin slices and is chemically treated to form photovoltaic cells. The series of these cells are called as PV array and when these arrays are connected in parallel forms a PV panel.

Working Principle

When one side of a semiconductor is doped with p type material and the other side of the same material is doped with n type material it forms a p-n junction. When the photons strike this junction the free electrons on the n-side will tend to flow to p-side and the holes of p-side tend to flow to the n-side. This diffusion creates electrical field from n-side to p-side.

When the two semiconductors are connected with electrical contacts through an external electrical conductor, due to the electric field created in the semiconductor junction the electric current flows through the electric conductor as long as the free electrons and holes are recombined with each other. The flow of electrons and holes to form a current field in a semiconductor material is as shown in the Figure 1.

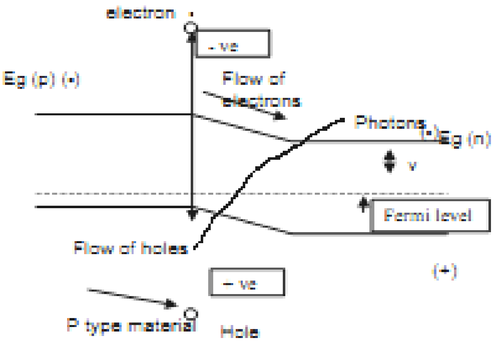

Figure 1: P-N Junction

MATHEMATICAL MODEL OF PHOTOVOLTAIC PANEL

Single Diode Model

The single diode model of a photovoltaic module is the ideal case which includes a diode and current source connected in parallel. In this model the amount of photo current generated is proportional to the solar irradiation. The equivalent representation of the single diode model is illustrated in Figure 2

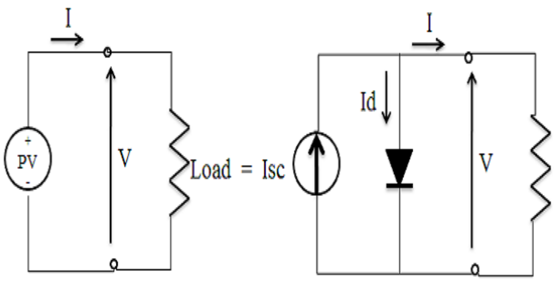

Figure 2: Equivalent Circuit of Single Diode Model

The mathematical model of current in function of voltage is given by non linear equations:

$$I = I_{ph} - I_0\left[e^{\frac{V+IR_s}{V_t}} - 1\right] \tag{1}$$

$$V_t = \frac{AKT}{q} \tag{2}$$

There are four parameters to define the shape of V-I curve described by the proposed model which are stated as: I_{ph}, I_o, V_t, R_s.

The Maximum Power Point (MPP) is an important point because the array produces maximum output power in it and it’s such to fulfill the condition:

$$\frac{dP}{dV} = 0 \tag{3}$$

In correspondent of current and voltage Imp and Vmp:

$$I_{mp} = I_{ph} - I_0\left[e^{\frac{V_{mp}+I_{mp}R_s}{V_t}} - 1\right] \tag{4}$$

As said above, the array, under uniform irradiance, exhibits a unique point, instead when a PV array is under partial shading conditions, its characteristic may exhibit multiple maximum power points.

Two Diode Model

The equivalent circuit for a two diode model for PV cell is illustrated in Figure 3.

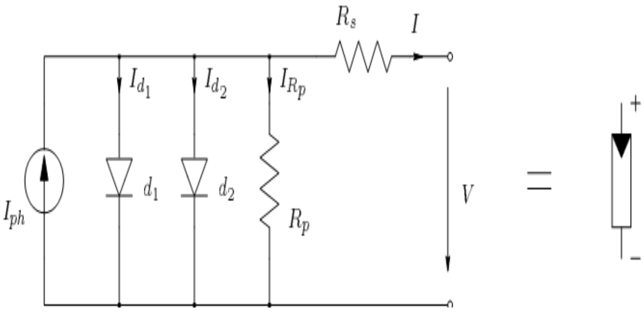

Figure 3: Equivalent Circuit of a Two Diode Model

From the characteristics of a p-n junction and the equivalent circuit, output current of PV arrays, IPV, can be described as: [4]

$$I_{pv} = n_p I_{ph} - n_p I_s\left[e^{\frac{q(V+IR_s)}{nKT}} - 1\right] - \frac{V+IR_s}{R_{sh}} \tag{5}$$

where VPV is output voltage of PV arrays, ns is the total number of cells in series, n_p stands for the total number of cells in parallel, q denotes the charges of an electron (1.6 × 10−19 coulomb), k is the Boltzmann constant (1.38 × 10−23 J/°K), T is temperature of the PV arrays (°K), and A represents ideality factor of the p-n junction (between 1 and 5) [4]. In addition, I_s is the reversed saturation current of the PV cell, which depends on temperature of PV arrays and it can be expressed by the following equation:[4]

$$I_s = I_{rs}\left[\frac{T}{T_{ref}}\right]^3 exp\left[\frac{qE_g}{nK}\left(\frac{1}{T_{ref}} - \frac{1}{T}\right)\right] \tag{6}$$

Where T_{ref} is the cell reference temperature, I_{rs} is the corresponding reversed saturation current at T_{ref}, and E_g stands for band-gap energy of the semiconductor in the PV cell. I_{ph} varies with irradiation Si and PV array temperature T, which can be represented as: [4]

$$I_{ph} = [I_s + k_i(T - T_{ref})]\frac{S_i}{100} \tag{7}$$

Where I_s is the short-circuit current while reference irradiation is 100 mW/cm2 and reference temperature is set at T_r, and K_i is the temperature coefficient.

The output power (PPV) of PV arrays then can be determined as follows:

$$P_{pv} = I_{pv}V_{pv} \tag{8}$$

Which reveals that the amount of generated power PPV varies with irradiationS_i and PV-array temperature T.

COST ANALYSIS

The cost benefit analysis for the proposed model in this paper is calculated on a given price of EMMVEE Black pearl photovoltaic module. The break even for the proposed model of PV panel is calculated for a panel of 1KW generating power for an average of 7hours of sun per day. The price of residential consumption for three levels is calculated based on the tariffs of APCPDCL. The overall cost for the generation and maintenance of PV panel for a lifetime of 20 years is calculated and compensated with the normal electrical usage.

RESULTS AND DISCUSSIONS

As per the given parameters in table 1 of a photovoltaic module the various parametric effects are observed in two cases. First is the variation in temperature with constant insolation for which I-V and P-V characteristic curves are observed in figure 4 and 5. Another case is the variation in insolation with constant temperature for which I-V and P-V characteristic curves are observed in figure 6 and 7 respectively. In addition to the performance of the module the cost analysis is also calculated for the proposed model for a lifetime of 20 years. The break even is calculated with three levels of residential consumption based on normal electricity tariffs which occurs at 9 years for higher level of consumption which is 200kWH.

Table 1: Input Parameters

Parameter	Variable	Value
Maximum Power	P_m	60W
Voltage at P_m	V_m	17.1V
Current at P_m	I_m	3.5A
Short circuit current	I_{sc}	3.8A
Open Circuit Voltage	V_{oc}	21.1V
Temperature Coefficient of Open Circuit Voltage	B	(80±10)mV/ºC
Temperature Coefficient of Short Circuit Current	A	(0.0065±0.015)%/ºC

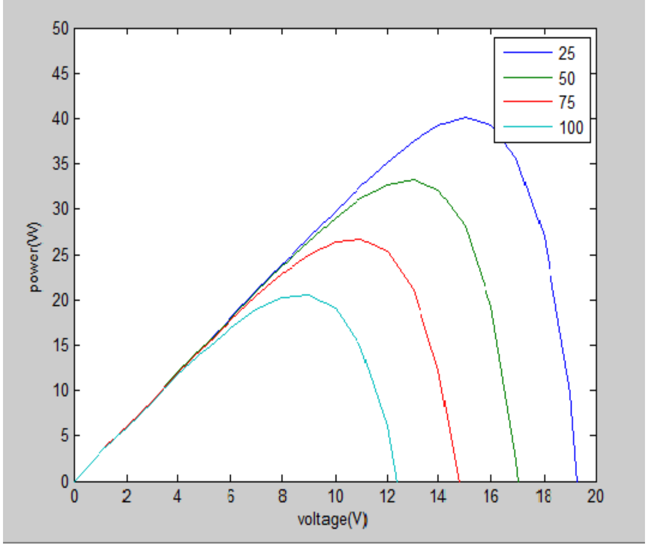

Figure 4: P-V Characteristics with Constant Insolation and Variation in Temperature

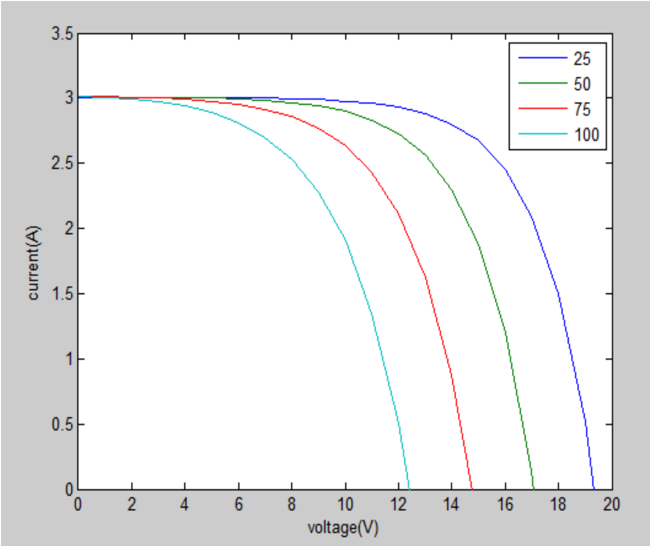

Figure 5: I-V Characteristics with Constant Insolation and Variation in Temperature

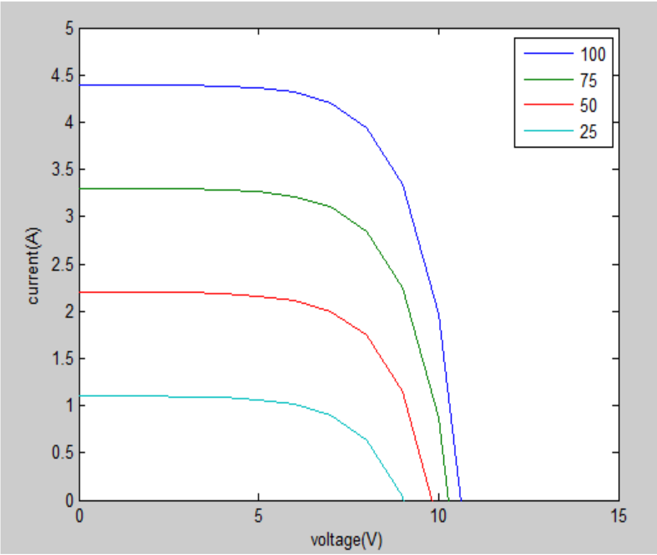

Figure 6: V-I Characteristics with Constant Temperature and Variation in Insolation

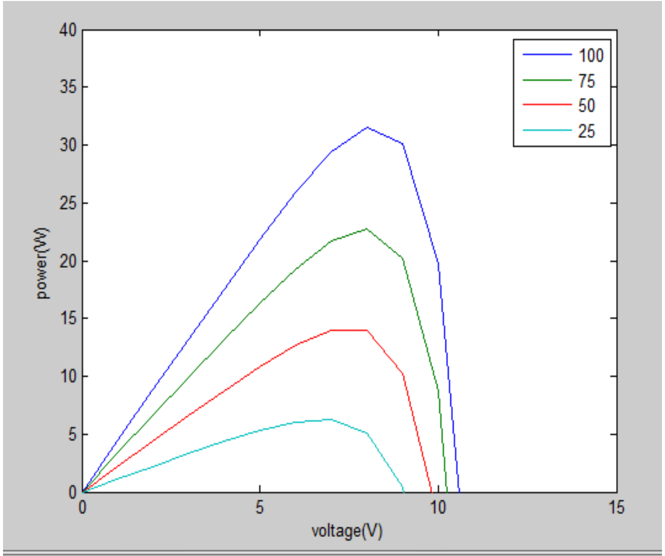

Figure 7: V-I Characteristics with Constant Temperature and Variation in Insolation

Table 2: Break Even Occurrence for the Proposed Panel

Monthly Consumption (Units)	Cost per Month (Rs)	Cost per Year (Rs)	Break Even (Years)
100	325	3900	22
150	732	8784	15
200	1126	13512	9

CONCLUSIONS

In this paper, the analysis and modeling of photovoltaic panel in the application of solar power generation is carried out and the results are obtained. The various parametric effects involving temperature and solar irradiation are observed the cost benefit analysis for three levels of energy consumption for the proposed PV panel is obtained for 20 years of lifetime.

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