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Research Article

Analysis of Datasheet of Photovoltaic Modules and Calculation of Its Parameters

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ABSTRACT

The adoption of photovoltaic (PV) technology for electricity generation is gaining momentum worldwide, primarily due to its capability to mitigate carbon emissions. In India, the central cabinet has approved a scheme aimed at installing rooftop solar panels, further propelling the popularity of PV systems. Understanding the intricacies of photovoltaic modules and their associated parameters is crucial for gaining insights into their IV characteristics and making informed decisions when selecting PV panels. This paper provides a comprehensive overview of photovoltaic modules ranging from 210 Watts to 240 Watts, elucidating the calculation of cell efficiency and demonstrating mathematical analyses illustrating how temperature influences the characteristics of PV cells. Utilizing Matlab/Simulink, PV panel behavior is observed, providing valuable insights into real-world performance. Through practical parameter calculations and empirical results, the significance of these analyses in the context of PV panel selection is underscored, highlighting their importance for informed decision-making in renewable energy deployment.

Keywords: photovoltaic (PV) modules, renewable energy. sustainable development.

I.INTRODUCTION

The clamor for accessible, sustainable, and environmentally friendly energy generation is particularly pronounced, with a notable emphasis on the adoption of photovoltaic panels.in India, the central government approved a scheme PM Surya Ghar: Muft Bijli Yojana worth 75,021 crores. The initiative was inaugurated by the Prime Minister on February 15, 2024. This program entails furnishing households with a subsidy designed to facilitate the procurement and installation of solar panels on the rooftops of their residences. Due to this implementation, the government is planning to provide free electricity to up to 300 units across the country. Apart from the scheme the government has some goals namely reduction in using fossil fuels up to 50% by 2030 and achieving net zero emission of fossil fuels by 2070. The government has seven sustainable development goals (S.D.G) which S. D.G 7 is an affordable, accessible energy supply. Hence the details of the photovoltaic modules [1-5] and their parameters are important to acquiring knowledge in making decisions when selecting the PV panels [6-10]. This research provides a Datasheet of Photovoltaic Modules Polycrystalline 210 – 240W, the calculation of cell efficiency, and presents mathematical analyses showcasing the impact of temperature on PV cell characteristics. Section II consists of the Effect of Temperature on PV Cell Characteristics. Section III presents the Calculation of Short circuit current (I_{SC}) for 40 degrees Celsius, Section IV Calculation of Open circuit Voltage (V_{OC}) for 40 degrees Celsius, Section V Calculation of Peak power of the PV cell (P_{max}) for 40 degrees Celsius,

II. Datasheet of Photovoltaic Modules Polycrystalline 210 – 240W

Analyzing the datasheet and endeavoring to align its parameters with the IV characteristics can yield profound insights into the nuances of the IV curve and facilitate the discernment necessary for selecting optimal PV panels. By meticulously scrutinizing the datasheet, we aim to deepen our understanding of the intricate IV characteristics exhibited by the PV panel. Table 1 below displays the datasheet for the PV modules, specifying them as polycrystalline panels with a power range of 210 to 240 watts. Within the table, each column corresponds to a distinct panel variant, with parameters of particular interest to our analysis. Focusing on a specific wattage, namely the **240-wattage** peak output, we will meticulously examine each parameter and discern its correlation with the IV characteristics.

Table 1 datasheet of Photovoltaic Modules Polycrystalline 210 – 240W

Module type	**BLD240-60P**	**BLD230-60P**	**BLD225-60P**	**BLD220-60P**	**BLD215-60P**	**BLD210-60P**
Peak Power	240Wp	230Wp	225Wp	220Wp	215Wp	210Wp
Max-Power Voltage (Vmp)	30.18V	29.82V	29.52V	29.34V	29.70V	28.70V
Max-Power current (Imp)	7.96A	7.72A	7.63A	7.50A	7.48A	7.32A
Open Circuit Voltage (Voc)	36.72V	36.10V	36.30V	36.56V	36.50V	36.48V
Short circuit Current (Isc)	8.99A	8.73A	8.62A	8.48A	8.48A	8.28A
Cell Efficiency	16.50%	16.00%	15.75%	15.25%	15.00%	14.50%
Module Efficiency	14.66%	14.05%	13.74%	13.44%	13.13%	12.82%
Max system voltage	DC 1000V					
Temperature Coefficient of Isc	+0.045% / K					
Temperature Coefficient of Isc	-0.34% / K					
Temperature Coefficient of Isc	-0.47% / K					
Series fuse rating	15A					
Cells	6*10 Pieces Polycrystal Solar Cells series (156mm × 156 mm)					
Junction Box	With 3 bypass diodes					
Front Glass	Toughened safety glass 32mm					

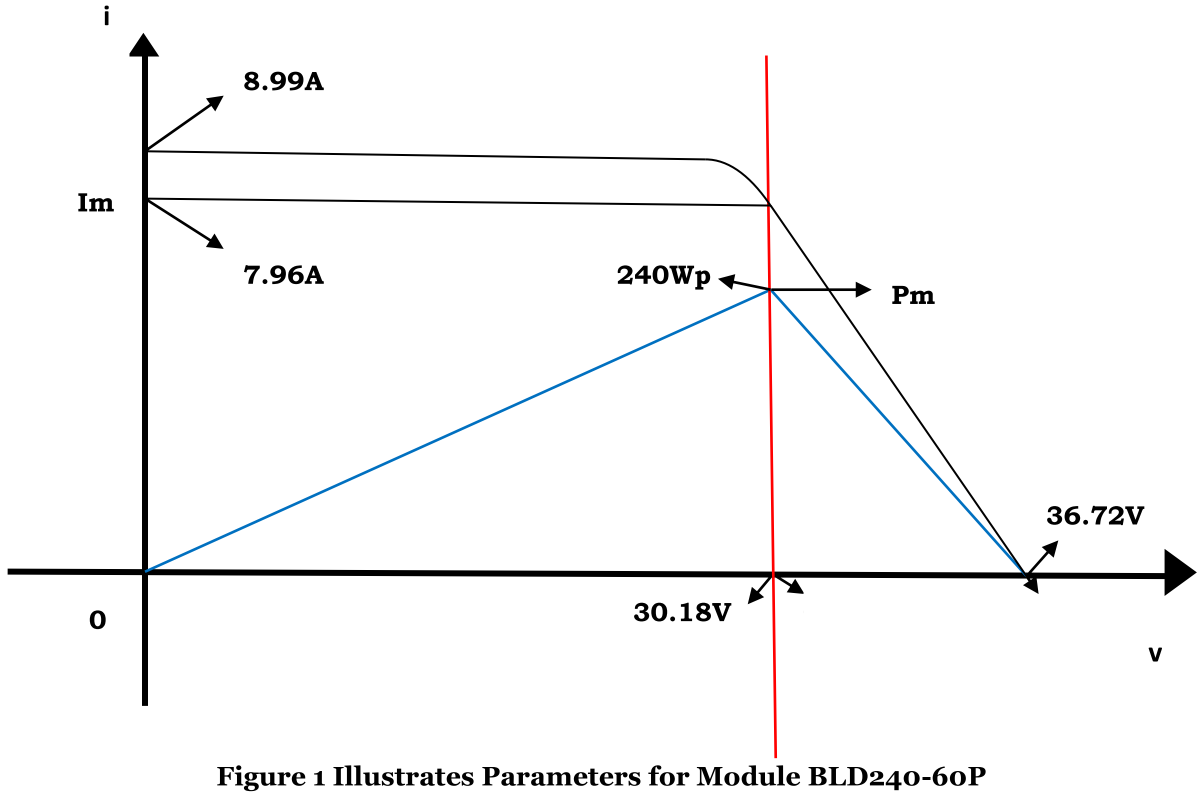

Figure 1 Illustrates Parameters for Module BLD240-60P

The Module type BLD240-60P serves as our exemplary case, In Figure 1 with graphs plotted to illustrate the parameters of the modules. These visual aids offer enhanced clarity and comprehension, facilitating a more profound understanding of the module's performance characteristics.
The question arises: at what incident solar power do all the aforementioned values apply for the 240Wp module? Typically, these values are standardized under specific incident solar power conditions as outlined below.

1 KW/m² at temperature 25° c

if not explicitly specified, the above values are generally provided for standard testing conditions, which include an incident solar power of 1 kW/m² and a temperature of 25 degrees Celsius. These standardized conditions ensure consistency and comparability across different PV modules.
To find the area of the panel in the datasheet look at the cell row (6 ×10 pieces of polycrystalline solar cells series 156mm ×156mm).
Area of the panel = 60 × 156mm×156mm

$= 60\times(0.156\times0.156)\ m^2$
$= 1.46m^2$

$$\mathrm{Pin} = 1\mathrm{KW}/\mathrm{m}^2 * 1.46\mathrm{m}^2$$
$$\mathrm{Pin} = 1.46\mathrm{KW}$$
$$\eta\mathrm{cell} = 16\cdot 5\%$$
$$\mathrm{Po} = \mathrm{Pm} = \mathrm{Pin} * \eta\mathrm{cell}$$
$$= \frac{16.5}{100} * 1.46\mathrm{KW}$$
$$\mathrm{Po} = \mathrm{Pm} \cong 240\mathrm{W}$$
$$\eta\mathrm{cell} = \frac{\mathrm{Po}}{\mathrm{Pin}}$$
$$\eta\mathrm{cell} = \frac{\mathrm{Pm}}{\mathrm{Pin}}$$
$$\mathrm{Pin} = (\mathrm{Insolation}) * (\text{area of the cell})$$

We shall use the symbol L for insolation

$$\mathrm{Pin} = \mathrm{L} * (\text{area of the cell})$$
$$\eta\mathrm{cell} = \frac{\mathrm{Pm}}{\mathrm{L} * \text{area of the cell}}$$
$$\eta\mathrm{cell} = \frac{\mathrm{Vmp} * \mathrm{Imp}}{\mathrm{L} * \text{area of the cell}}$$
$$\eta\mathrm{module} < \eta\mathrm{cell}$$

Module = Combination of cells or group of cells

III. Effect of Temperature on PV Cell Characteristics: -

There are three important parameters
1. Short circuit current (I_{SC})
2. Open circuit Voltage (V_{OC})
3. Peak power of the PV cell (P_{max})

Therefore, how do the three parameters vary with the temperature
Looking at the datasheet we can observe three parameters
1. Temperature coefficient of I_{sc} is +0.045% / K------(1)
2. Temperature coefficient of V_{oc} is -0.34%/k----------(2)
3. Temperature coefficient of P_{max} is -0.47%/K---------(3)

3.1. Effect of Temperature on I_{SC}:-

$I_{SC} = I_p$

I_p is the photocurrent, with the increase in the temperature the photocurrent will increase because the band gap energy (i.e.1.16ev) reduces and This will facilitate a greater number of valence electrons transitioning into the conduction band. Consequently, an augmented pool of free electrons will ensue, leading to an increase in photocurrent and a higher Isc value.

3.2. Effect of Temperature on V_{OC}:-

$$\mathrm{Voc} = \frac{\eta v_T \ln(\mathrm{Ip} + \mathrm{Io})}{\mathrm{Io}}$$

As Ip > Io

$$\mathrm{Voc} = \frac{\eta v_T \ln(\mathrm{Ip})}{\mathrm{Io}}$$

V_T and Io are the function of temperature
By considering V_T and Io

$$I_0 \propto T^m\, e\frac{-v_{GO}}{\eta v_T}$$

$$\frac{dv_{OC}}{dT} = \frac{V_{OC} - (V_{GO} + m\cdot n v_T)}{T}$$

3.2.1 Derivation of $\frac{dv_{OC}}{dT}$:-

The reverse saturation current

$$I_0 = KT^m \, e\frac{-v_{GO}}{\eta v_T}$$

$$\ln\{I_0\} = \ln(kT^m) + \ln(\ e\frac{-v_{GO}}{\eta v_T})$$

$$\ln\{I_0\} = m\ln(kT) + \left(\frac{-v_{GO}}{\eta v_T}\right)$$

$$\ln\{I_0\} = m\ln(k) + m\ln(T) - \left(\frac{v_{GO}}{\eta v_T}\right)$$

Differentiating for w.r.t T

$$\frac{d\ln(Io)}{dT} = \frac{m}{T} + \left(\frac{v_{GO}}{\eta v_T}\right) \text{--------(4)}$$

$$Voc = \frac{nV_T \ln(I_p + I_0)}{I_0}$$

As $I_P > I_O$

$$Voc = \frac{nV_T \ln(I_p)}{I_0}$$

$$\frac{Voc}{nV_T} = \frac{\ln(I_p)}{I_0}$$

$$\frac{Voc}{nV_T} = \ln(I_p) - \ln(I_0)$$

Differentiating for w.r.t T

$$\frac{d\frac{v_{GO}}{\eta v_T}}{dT} = (d\ln(I_p)/dT) - (d\ln(I_0)/dT)$$

$\frac{d\ln(Io)}{dT}$ is taken from equation (4)

$d/dT\{\ln(I_p)\}$ is negligible then

$$-\frac{Voc}{nTV_T} + \frac{1}{nV_T}\frac{d\,Voc}{dT} = -\left\{\frac{m}{T} + \left(\frac{v_{GO}}{\eta v_T}\right)\right\}$$

Simplifying

$$\frac{d\,Voc}{dT} = \frac{Voc}{T} - \left\{\frac{m}{T} + \left(\frac{v_{GO}}{\eta v_T}\right)\right\}$$

$$\frac{d\,Voc}{dT} = \frac{V_{OC} - (V_{GO} + m \cdot nv_T)}{T}$$

For Silicon m = 1.5, n = 2, V_{GO} = 1.16, V_{OC} = 0.6. substituting these values in the above equation

$$\frac{d\,Voc}{dT} = \frac{0.6 - (1.6 + 3v_T)}{T}$$

At T = 300 ^{o} K

$$\mathbf{\frac{dVoc}{dT} = -2.12\frac{mV}{K}}$$

4. Temperature Effect Calculation Example: -

By using the equation (1), (2), (3) Let us calculate short circuit current (I_{SC}), Open circuit Voltage (V_{OC}), and peak power of the PV cell (P_{max}) for another temperature namely 40 degrees Celsius knowing the values for standard temperature condition 25°c by using a data sheet.

Below Figure 2 plots the values of I_{SC}, V_{OC}, and P_{max} for another temperature namely 40 degrees Celsius knowing the values for standard temperature condition 25°c by using a datasheet

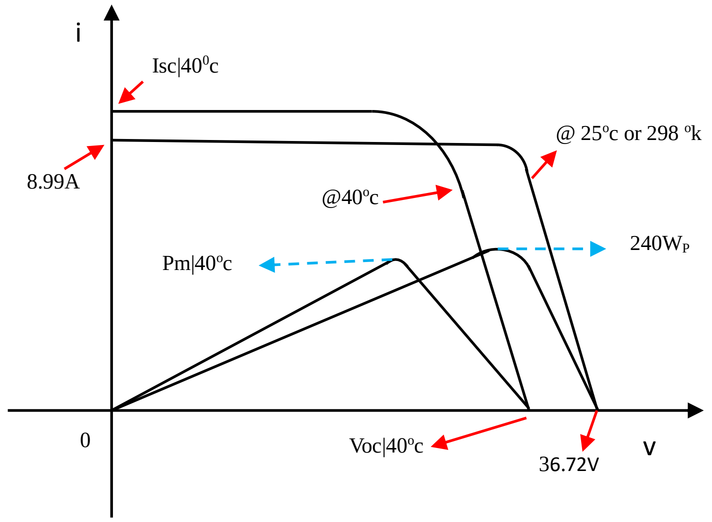

Figure 1 Illustrates Parameters for Module BLD240-60P for 40° Celsius temperature.

IV. Calculation of Short circuit current (I_{SC}) for 40 degrees Celsius: -

Isc|40°c = Isc|25°c + Δi

Voc|40°c = Voc|25°c + ΔV

Pm|40°c = Pm|25°c + ΔP

$$\propto \mathrm{I} = \frac{\frac{\text{change in Isc}}{\text{Isc@25}} \times 100}{\Delta \mathrm{T}}$$

$$\alpha \mathrm{I} = +0.045\%/\mathrm{K}$$

$$\text{Change in Isc}(\Delta \mathrm{i}) = \frac{\alpha \mathrm{I} \times \text{Isc@25} \times \Delta \mathrm{T}}{100}$$

Isc|40°c = Isc|25°c + Δi

Substitute ΔI in the above equation

Isc|40°c = = Isc|25°c + $\frac{\alpha I \times Isc@25 \times \Delta T}{100}$

Isc|40°c = Isc|25°c × $(1 + \frac{\alpha I \times \Delta T}{100})$

From Equation (1) and the datasheet we derive the value of Isc|25°c and αI

Isc|40°c = 8.99 × $(1 + \frac{0.045(40-25)}{100})$

Isc|40°c = 8.9968A

V. Calculation of Open circuit Voltage (V_{OC}) for 40 degrees Celsius: -

Voc|40°c = Voc|25°c + ΔV

Voc|40°c = Voc|25°c + $\frac{\alpha V \times Voc@25 \times \Delta T}{100}$

Voc|40°c = Voc|25°c ×$(1 + \frac{\alpha V \times \Delta T}{100})$

Voc|40°c = Voc|25°c ×$(1 + \frac{\alpha V \times \Delta T}{100})$

From Equation (2) and the datasheet we derive the value of Voc|25°c and αV

Voc|40°c = 36.72 ×$(1 + \frac{(-0.034)\times(40-25)}{100})$

Voc|40°c = 36.72 ×$(1 + (-0.051))$

Voc|40°c = 34.847V

VI. Calculation of Peak power of the PV cell (P_{max}) for 40 degrees Celsius: -

$Pm|40^oc = Pm|25^oc + \Delta P$

$Pm|40^oc = Pm|25^oc + \frac{\alpha P \times Pm@25 \times \Delta T}{100}$

$Pm|40^oc = Pm|25^oc \times (1 + \frac{\alpha P \times \Delta T}{100})$

From Equation (3) and the datasheet we derive the value of Pmax|25ºc and $\alpha Pmax$

$Pm|40^oc = 240 \times (1 + \frac{(-0.47) \times (40-25)}{100})$

$Pm|40^oc = 240 \times (1 + (-0.0705))$

$Pm|40^oc = 223W_P$

The above values comparing two temperatures namely 25 and 40 degrees Celsius we derive as follows
1) As temperature rises, there will be a corresponding increase in the short circuit current (Isc).
2) As temperature increases, there will be a decrease in the open circuit voltage (Voc).
3) With a temperature rise, there will be a decline in the peak power (Pm).

Based on the mathematical formulas, we draw our conclusion here. However, these are just necessary to conclude, to determine whether the following findings are justified, we need a workable approach. Thus, MATLAB Simulink software was used to create our PV panel.

VI. Simulation Results: -

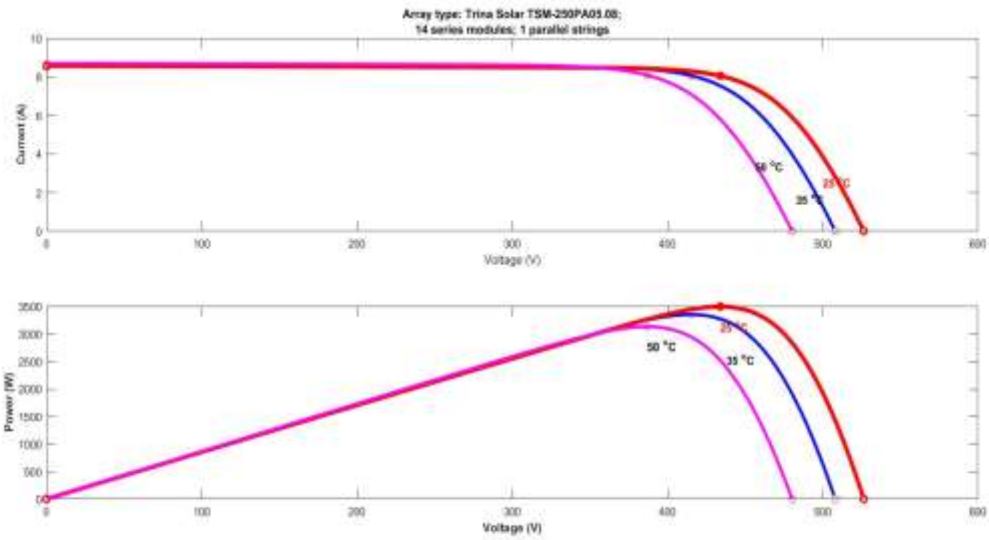

Figure 2 The Simulation Output of PV Panel For 3.5KW

Figure 3 gives the simulation results of the PV panel for 3.5KW using MATLAB Simulation software. The alternating current (Isc) exhibits a positive temperature coefficient, increasing with higher temperatures, while the voltage (Voc) shows a negative temperature coefficient, decreasing with rising temperatures. Additionally, the power, being the product of voltage and current, decreases with temperature, reflecting a negative temperature coefficient. The PV system plot corresponds to standard irradiance (1000 watts per square meter) and of three different temperatures namely 25, 35, and 50 degrees Celsius.

VII. Conclusion

In India, the central government approved a scheme PM Surya Ghar: Muft Bijli Yojana worth 75,021 crores. The initiative was inaugurated by the Prime Minister on February 15, 2024. This program entails furnishing households with a subsidy designed to facilitate the procurement and installation of solar panels on the rooftops of their residences. There are various parameters to take into account when photovoltaic modules are to be selected. This research provides a Datasheet of Photovoltaic Modules Polycrystalline 210 – 240W, the calculation of cell efficiency, and presents mathematical analyses showcasing the influence of temperature on PV cell characteristics. simulation results of the PV panel for 3.5KW using MATLAB Simulation software justifies the mathematical calculations and helps the reader select the appropriate photovoltaic polycrystalline modules and map with IV characteristics of the PV panel.

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