PV ARRAY CONFIGURATION MODELING, SIMULATION, AND PERFORMANCE ANALYSIS (SERIES, SERIES-PARALLEL)

Irfan Ahmad Ansari, M.Tech Student, Department of Electrical and Electronics Engineering, Al Falah University, Faridabad, Haryana, India.
Mohd Shahid, Associate Professor, Department of Electrical and Electronics Engineering, Al Falah University, Faridabad, Haryana, India.

ABSTRACT

Making photovoltaic (PV) power generation systems more energy efficient is a fundamental obstacle to their advancement. One of the main causes of the output power reduction caused by the mismatched power losses between the PV modules is partial shading condition, or PSC. The PV system topologies, PV array designs, shading patterns, the actual location of the shaded modules, and the tilt angle all affect these losses. In this article, the performance of 3 ×3 Series, Series-Parallel PV array configurations is modeled, simulated, and compared. Solar photovoltaics, a clean and green energy technology, is essential for meeting any nation's power constraint when it comes to renewable power generation. Before installing a PV system anywhere, it is essential to model, simulate, and analyze solar photovoltaic (PV) generators. This helps to understand the behavior and features of the system in actual climatic conditions. A single diode equivalent circuit model is described here, along with a step-by-step thorough simulation of a solar PV module running under Matlab/Simulink environment. Researchers, manufacturers, and social communities can gain a comprehensive understanding from the I–V and P–V graphs of solar PV modules.

Keywords:
Maximum Power Point (MPP), Series–Parallel (S–P), Partial Shading Conditions (PSCs).

I. Introduction

The influence of renewable energy resources has increased as a result of the depletion of fossil fuel-based energy resources, concerns brought on by conventional power generation, growing environmental concern, and the need to satisfy the ongoing increase in load demand. Due to the declining cost of PV modules, deliberate government regulations, and creative business models in utility, commercial, and residential power systems, interest in solar photovoltaic (PV) power generation has increased. Over the previous 20 years, the amount of power generated by PV systems has increased steadily by 20–25% annually[1-3]. PV system structures, array configurations, shading patterns, solar irradiation, temperature, aging effects, potentially caused degradation effects, etc. all affect how well and efficiently PV systems work. The two most significant variables influencing the output power reduction are temperature and changes in sun irradiation. The design of solar-powered cells and the assessments of their performance depend critically on the precise learning of sun-based cell characteristics from exploratory data[4-5]. In the majority of reproduction investigations, the electrical proportional circuit provides a useful and consistent path. The photocurrent (IPV), series resistance (RS), diode immersion current (I0), shunt resistance (RSH), and idealism consider (A) are the five variables of enthusiasm for the proportional circuit. A scientific condition that is both definite and nonlinear is used to illustrate the current relation voltage of a solar-powered battery. An example of a photovoltaic cell is a current electrical current source (PN) connected to a diode in a shunt. A constant current is provided by the current source. The strength of the light striking the first cell is reflected in this current [6-7]. The environment and sun radiation in particular have an impact on photovoltaic frameworks. It is anticipated that the operation of a sun-oriented cell will grasp the connection between the cell's voltage and current [8]. Figure 1 depicts the optimal proportional circuit of a photovoltaic cell. In practice, there is no perfect solar cell, thus it includes a current source, a diode, a series arrangement resistance (Rs), and a shunt resistance (Rsh). These two resistances are added.

II- Work done:

Conditions provided in previous sections are shown to obtain IV and PV characteristics of a single diode solar cell module. The reproduction consists of multiple subsystems: the first determines the working and reference temperatures (T and Tref) of the PV cell; the second determines the photocell current (Iph); the third determines the diode turn around immersion current (Io); the fourth determines the current in shunt resistance (Ish); and the final one determines the aggregate yield voltage (I, V) and current in the PV cell [11]. Using source, sinks, and math's relation, all the blocks needed to represent the equations discussed in the preceding part were obtained using Matlab-Simulink. Table 1 below lists some of the parameters that were employed in this study and were presumed to be effective.

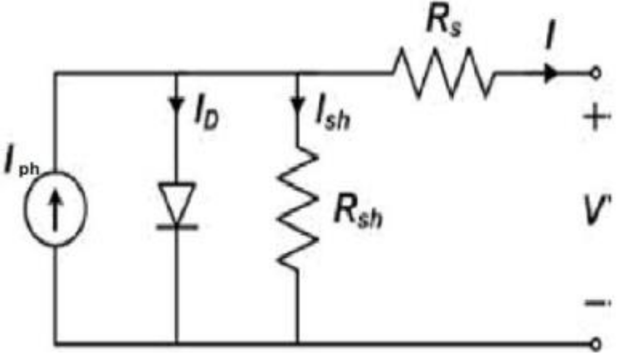


Figure 1 Diode model of the PV cell

Figure 1 depicts the optimal proportional circuit of a photovoltaic cell. In practice, there is no perfect solar cell, thus it includes a current source, a diode, a series arrangement resistance (Rs), and a shunt resistance (Rsh) [12]. These two resistances are added. Kirchhoff's law is applied to the same circuit Figure 1 to obtain the accompanying condition for the load current [13]:

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

I is output current in amp
I_{ph} is photo produced current in amp
I_d is Diode current in amp
I_{sh} is shunt resistance current in amp

The voltage applied crosswise across these components controls the current flowing through them:

$$V = V_J + IR \tag{2}$$

Where V = Voltage over the yield terminals (volt)
V_J= Voltage across both diode and resistor RSH (volt)
I = output current (ampere)
R_s= series resistance (Ω)

By the Shockley diode condition, the current occupied through the diode is:

$$I_d = I_o\left(e^{\frac{V_j}{n*V_T}} - 1\right) \tag{3}$$

I_o is diode reverse saturation current
V_T is thermal voltage at 25 degree celiac
n is diode ideality factor
q is electron charge
K is Boltzmann's constant
T is operating temperature

$$I_{sh} = \frac{V_j}{R_{sh}} = \frac{V+IR_s}{R_{sh}} \tag{4}$$

R_{sh} is shunt resistance

By entering these values into the first equation, the sun-oriented cell's distinctive state is created, which transmits the yield voltage and current to the sun-powered cell variables [14]:

$$I = I_{ph} - I_o\left(e^{\frac{V_j}{n*V_T}} - 1\right) - \frac{V+IR_S}{R_{sh}} \tag{5}$$

I_{sc} is short circuit current

K_i is solar cell short circuit current temperature coefficient = 0.0017

T stands for operating temperature in Kelvin. G is the irradiance (mW/m2). The irradiance in this equation is divided by 1000 to obtain (W/m2). The solar cell can exist in two different states: open circuit and short circuit. At this stage, the voltage across the yield terminals is known as the open-circuit voltage (VOC) if the cell is operated at an open circuit, with I = 0. The open-circuit voltage Voc, assuming that the parallel resistance is big enough to ignore the final term of the trademark condition, is: Since all of the current will cross the short out in a short circuit situation, Iph and Isc are equal.

$I = I_{ph} - I_d$

$$I = I_{ph} - I_o\left(e^{\frac{V_j}{n*V_T}} - 1\right)$$

$$I_o = \frac{I_{sh}}{e^{\frac{qV}{N_S*k*n*T}} - 1} \tag{6}$$

By setting I = zero (the condition when there is no yield current), we may get the invert immersion current I0, which is referred to as an open circuit. I = 0 and V = Voc at short circuit Where output voltage at open circuit state (Voc) is defined. Furthermore, as previously explained, this results in all current passing through the diode due to the high shunt resistance.

$$0 = I_{ph} - I_o\left(e^{\frac{V_j}{n*V_T}} - 1\right)$$

Moreover, the current in the shunt resistance that was obtained from the related situation

$$I_{sh} = I_0\left(\frac{T}{T_{ref}}\right)^3\left\{e^{\frac{qE_g\left(\frac{1}{T_{ref}}-\frac{1}{T}\right)}{kn}}\right\} \tag{7}$$

Here T_{ref} is reference temperature In Kelvin

T_g Band gap for silicon

In a solar array or cluster, Ns cells are arranged in series, and Np cells are arranged in parallel. It is expected that all of the cells will produce equal current and voltage and that they will all be indistinguishable under uniform and equivalent temperature and irradiance.

$$I_{module} = N_p * I_{cell} \quad \text{and} \quad V_{module} = N_p * V_{cell} \tag{8}$$

In accordance with equation 8, this block indicates photovoltaic output current. The temperature (T) in Kelvin, the voltage across the output terminals (V), the photovoltaic current, and the short circuit current (A) are the inputs and the photocell current (A) is the output. The Boltzmann constant, diode ideality factor, electron charge, number of series and parallel cells, and series and shunt resistance values are the parameters used in this block. Figure 2 displays this block's specifics.

The last single diode condition for a module or exhibit gets to be:

$$\text{I} = (N_p * I_{ph}) - N_p * I_{ph}\left[e^{\left(\frac{q(V+IR_S)}{N_S*nkT}\right)} - 1\right] - \frac{V+IR_S}{R_{sh}} \tag{9}$$

The output equation will be:

Here I_{ph} is the solar induced current
The irradiance, or light intensity, falling on the cell is expressed in W/m2, or I_r.

R_r is the irradiance, or light intensity, that strikes the cell in W/m2.
I_{pho} is the measured solar-generated current for the irradiance I_{r0}.
I_s is the saturation current of the first diode.
I_{s2} is the saturation current of the second diode.
V_t is the thermal voltage, *kT/q*, where:
k is the Boltzmann constant.
T is the Device simulation temperature parameter value.
q is the elementary charge on an electron.
N is the quality factor (diode emission coefficient) of the first diode.
N_2 is the quality factor (diode emission coefficient) of the second diode.
V is the voltage across the solar cell electrical ports.
For amorphous cells, the quality factor varies, while for polycrystalline cells, it is usually 2.

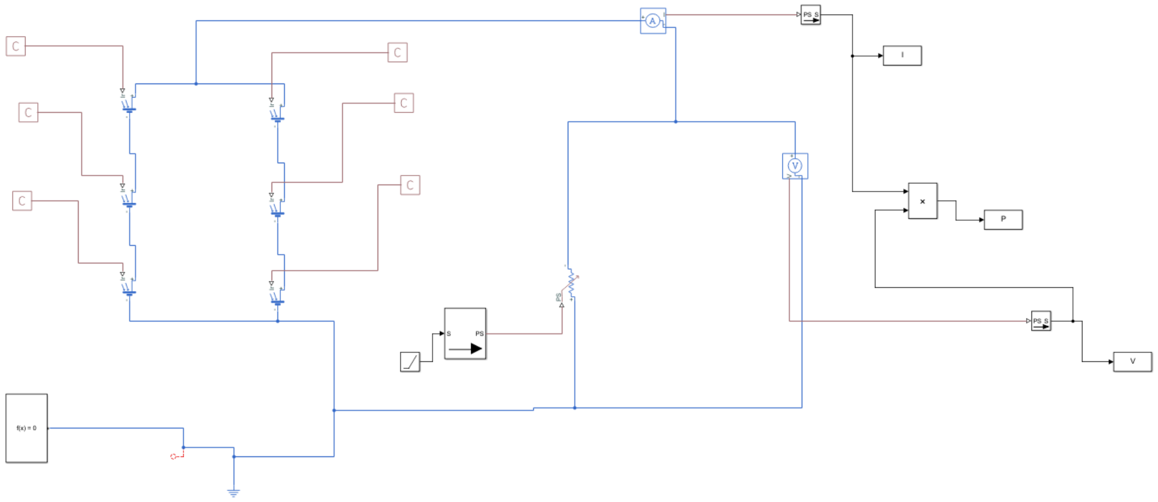


Fig -2 Matlab Simulink of solar cells

Table1 Photovoltaic Model Parameters[15]

Parameters	Value
R_s	0.002 ohm
R_{sh}	100000 ohm
K	0.0017
I_{sc}	3.8A
N_s	36
N_P	1
V	21.2 V
E_g	1.1
N	1.1
K_i	1.38*10^{-23} (J/K)
q	1.6*10^{-19} C
I_{sc}	3.8A
G	300-500-100 (W/$m^2$for test)

The previous segment's conditions are shown to obtain the IV and PV characteristics of a single diode solar cell module. The findings of the I-V and P-V simulations and the experiments indicate that the short circuit current, open circuit voltage, and maximum power are in good accord. In this work, the Matlab/SIMULINK model may be regarded as a clever tool to extract the internal parameters of any solar PV cell, such as the ideal factor, series resistance, and shunt resistance, in addition to helping to forecast the behavior of any PV cell under various physical and environmental situations. The manufacturers don't always supply all of these parameters.

III- Results:

The simulation has yielded the I-V and P-V solar cell specification curves for varying operating temperatures and irradiance. Additionally, altering the constants block in this simulation makes it very simple to change the parameters in Table 1. These outcomes were attained through the use of Matlab-Simulink's workspace and output scope blocks. The I-V curves for varying temperatures and irradiance are displayed in Figures 3 and 7, respectively.

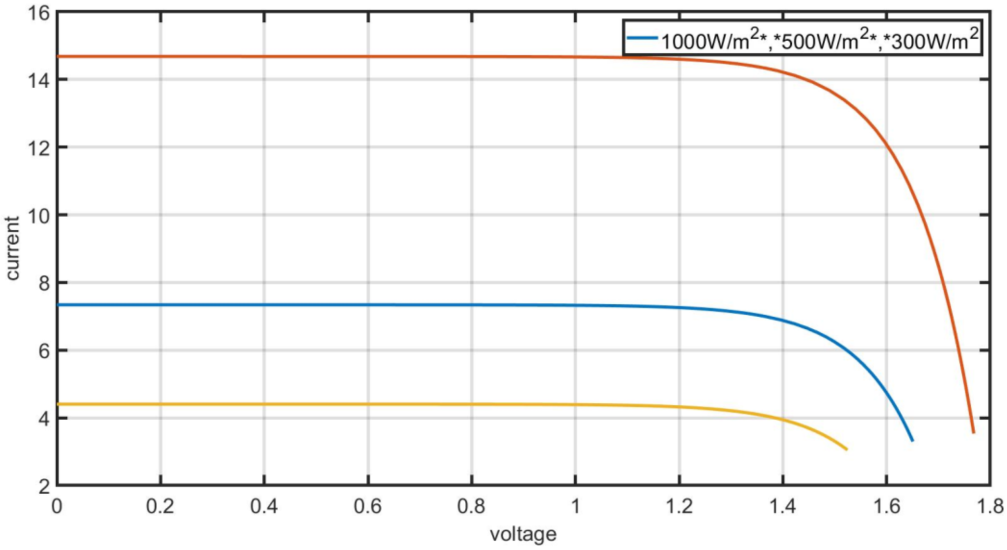


Fig-3 VI curves for the solar cell

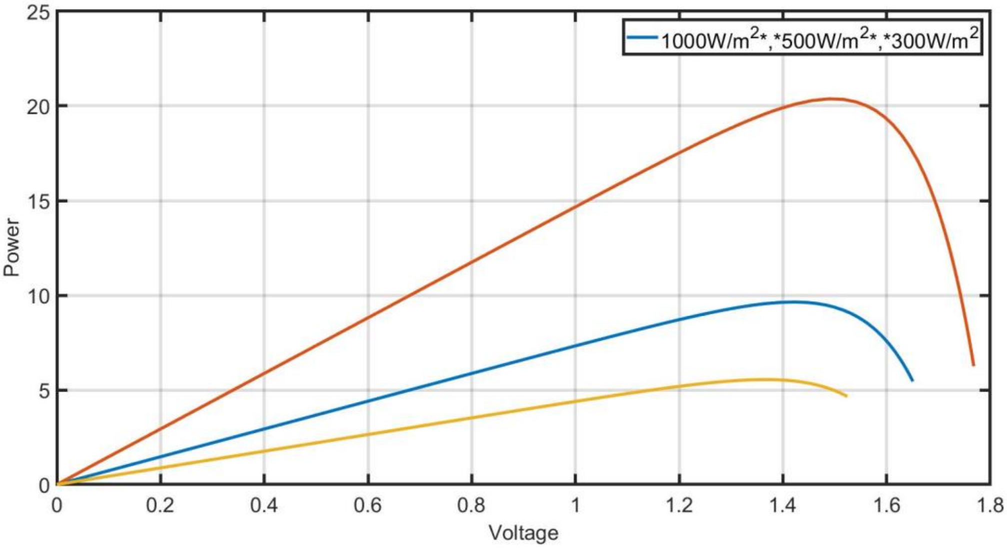


Fig-4 VI curves for the solar cell

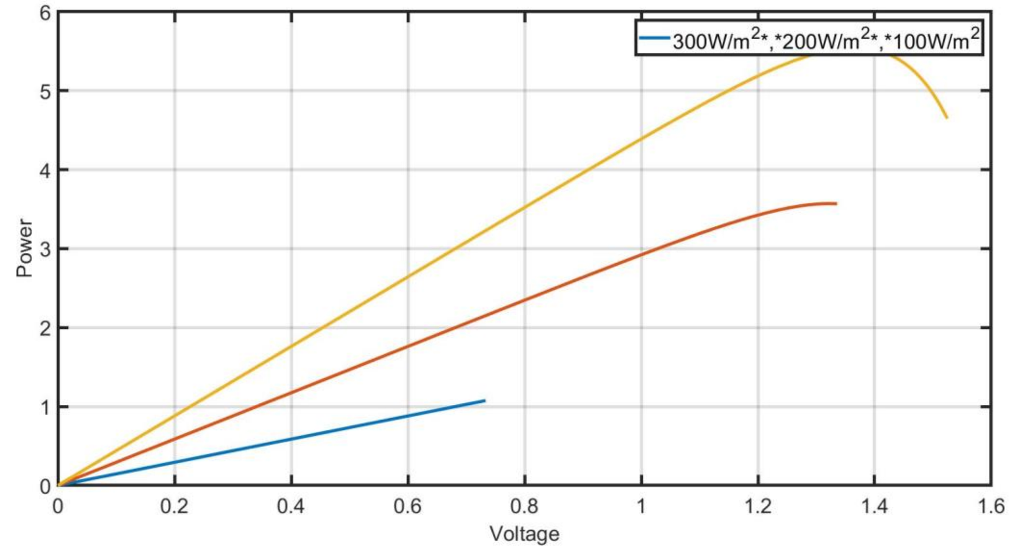
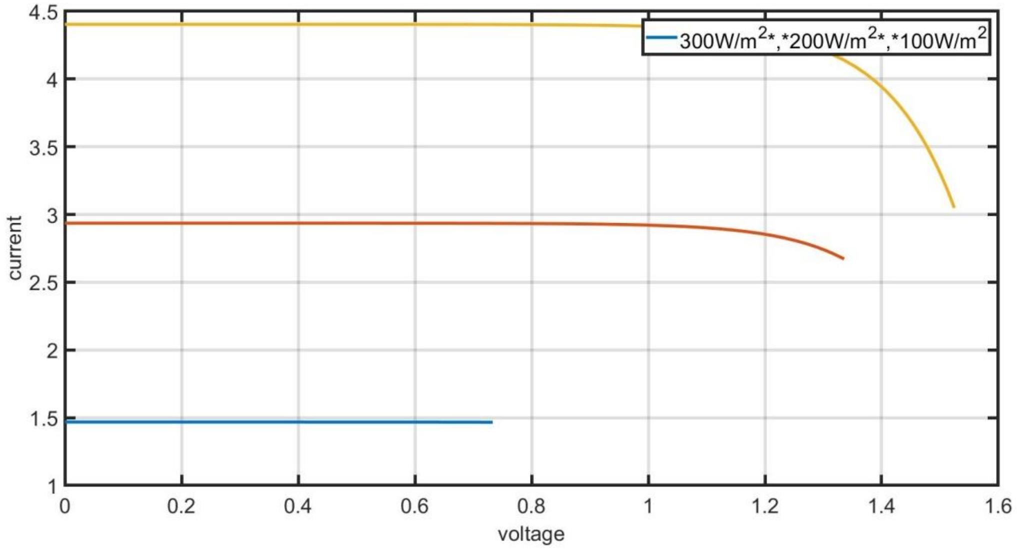


Fig-5 PV curves for the solar cell



Fog-6 VI curves for the solar cell

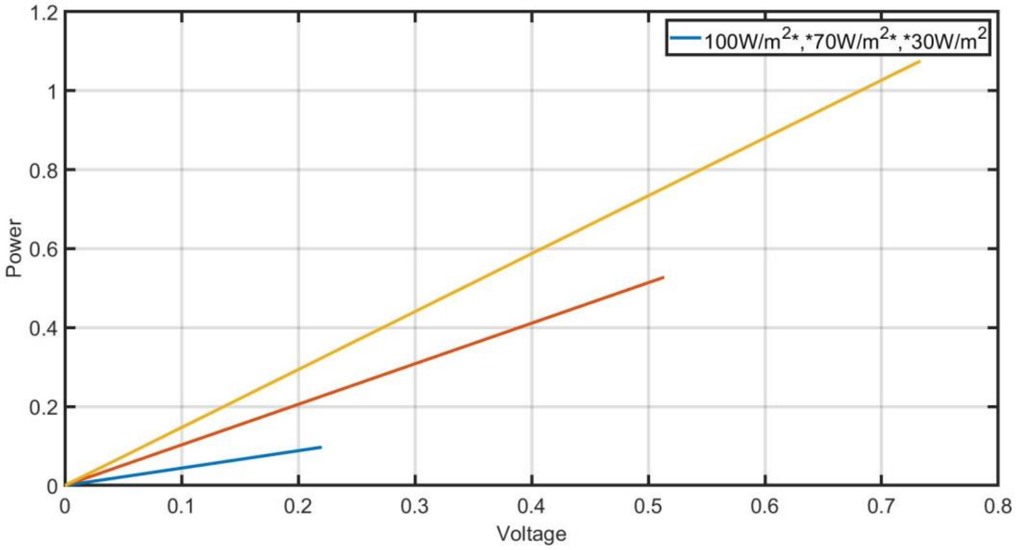


Fig-7 PV curves for the solar cell

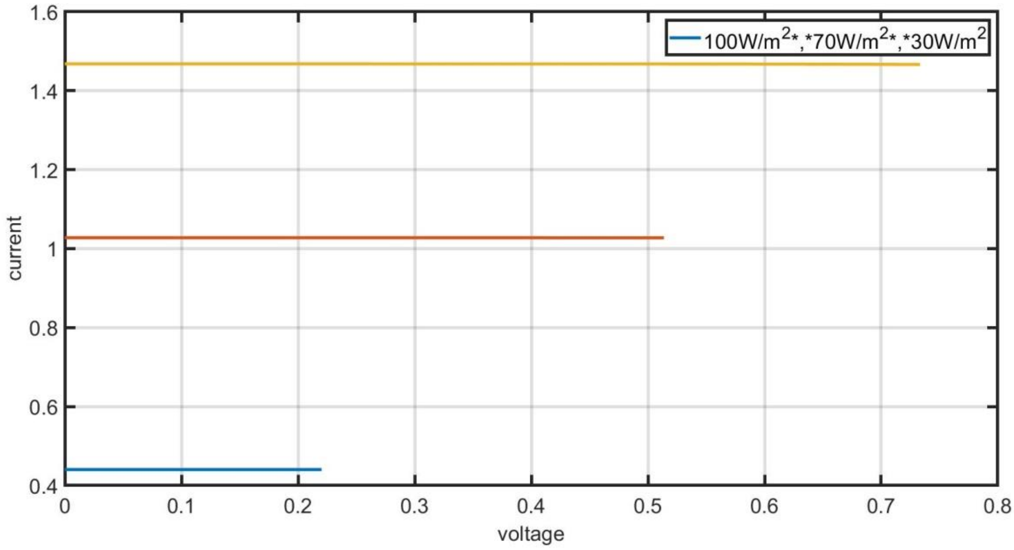


Fig-8 VI curves for the solar cell

While the temperature remained at 30 degrees Celsius, raising the irradiance had the effect of increasing the output and short circuit current while having essentially little influence on the output voltage. In the second test, the irradiance (1000 mW/m2) remained constant while the working temperature increased, causing the output voltage to decrease. P-V curves for varying operating temperatures and irradiance, as illustrated in figures 6 and 7. Increasing temperature causes a decrease in maximum power and maximum peak voltage, whereas increasing irradiance causes an increase in maximum power and peak current.

IV- Conclusion:

This paper describes an accurate single-diode equivalent circuit model of a photovoltaic solar module. A methodical approach to simulate a photovoltaic solar module within the Matlab/Simulink environment is described. Researchers, producers, and the general public may all easily grasp the operating performance curves of PV solar modules thanks to this modeling technique. The greatest relative error percentage of 1.65% indicates that the simulated values and manufacturer values coincide rather well. This demonstrates that the simulation agrees with the PV solar module's performance and characteristic curve. The PV solar module's performance for temperature and irradiance measurements from February to October yields positive findings. Furthermore, it is thought to be a reliable package for assessing how well solar cells and modules operate under various metrological situations. This will therefore support the "Made in India" initiative in the photovoltaic manufacturing industry.

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