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Journal of Analytical Research

Vol 3 Issue 2, Jul-Dec 2023
www.rsya.org/jar

ISSN: 2584-0037

Evaluating the Required Area and Performance of Solar Photovoltaic Panels at Various Locations

Gunjan Trivedi[1], Satish Gautam[1,2*] and Pankaj Kumar[1]

[1]Department of Electrical Engineering, Chandigarh University, Gharuan, Punjab -140413, India
[2]Department of Electrical Engineering, Indian Institute of Technology, Delhi, 110016, India

*Author for Correspondence E-mail: satishgautam86216@yahoo.com

Abstract: *Presently, photovoltaic (PV) systems, which harness solar energy, are among the most prevalent forms of renewable energy. This article conducts a comparative analysis of the efficiency of photovoltaic panels across three distinct locations in India—Mathura, Ladakh, and Bikaner—under identical environmental conditions at the same time and place. To generate the necessary voltage for the load side, the PV panel is outfitted with a boost converter. We test and monitor changes in panel and load parameters in response to varying solar irradiance and temperatures using simulation software. Using these data points, we can make adjustments to the efficiency of the existing panel. By employing the previously determined performance parameter values of the panel, this study illustrates the impact of elevated cell temperature and solar irradiation. In addition to determining the area and size of the PV panel necessary to generate 1 kilowatt, the performance parameter values will also dictate these factors.*

Keywords: *About Silicon carbide (SiC), Tensile strength, Alumina, Hardness, Stir casting process.*

INTRODUCTION

The With each passing day, our demand for energy to operate the machinery that facilitates technological progress increases. In order to fulfil our energy requirements, we currently employ a variety of conventional and unconventional methods of electricity production [1]. Traditional methods, however, depend on non-renewing natural resources, which are incapable of being replenished by nature or by themselves. It would, nevertheless, require millions of years to regenerate. Coal, diesel, petrol, and natural gas are all instances of fossil fuels, which define natural resources [2]. Power companies utilise these fossil fuels to generate electricity; nevertheless, their composition is abundant in carbon compounds, which contribute to environmental pollution. Because of these conventional methods of electricity production, the global climate changed. Emissions from power plants contribute significantly to pollution, which has deleterious effects on every living organism, including those inhabiting terrestrial and marine environments. Globally, thermal power plants are responsible for producing the majority of electricity. A substantial volume of water is heated in a sizable boiler at the thermal power plant using an assortment of fuels, such as diesel, petrol, and coal. The water undergoes a phase change from liquid to steam, which is exceedingly hot, as the boiler heats. This steam then flows through pipes to the turbine section, where it assists a generator in turning the turbine and generating electricity. However, the use of fossil fuels has an effect on the environment and these fuels are not renewable in nature. To maximise output, they must be either conserved or utilised efficiently. In an effort to address the issue of fossil fuel scarcity, scientists are increasingly considering unconventional energy sources [3]. This is due to the fact that these sources are abundant and environmentally friendly. Examples of renewable energy sources include solar, wind, geothermal, tidal, and wave power. However, this section will centre on solar energy as an unorthodox form of energy. It is widely acknowledged that sunlight is a source of free heat that permeates the Earth for approximately 360 days per year. However, the level of intensity differs based on geographical location. To harness solar energy, researchers have devised a system capable of converting the solar radiation's thermal energy into electrical energy. The aforementioned procedure, referred to as the photovoltaic effect, facilitates the conversion of thermal energy into electrical energy. However, a specialised device is necessary to execute this conversion [4]. This particular characteristic is utilised by the photovoltaic cell. The operational mechanisms of the cell are powered by solar radiation. It is universally recognised that light is composed of photons, each possessing a distinct quantity of energy. The electron acquires excitation and transitions from the valence band to the conduction band upon receiving this energy. The electric current in the circuit is generated by the movement of the electrons. Constantly, direct current is produced by the solar cell. It can be deduced that a solar cell inherently generates a direct current; however, due to the relatively low voltage output of a single cell, high voltage is necessary to supply power to machinery. To maximise voltages, it is necessary to arrange a substantial number of these solar cells in precise configurations. A photovoltaic (PV) array or panel is formed when a particular configuration of cells is aligned to generate elevated voltage levels [5]. Consequently, the aggregate power generated by each photovoltaic cell in the panel during operation on solar energy is equivalent to the sum of the power generated by each individual cell. However, certain characteristics and factors influence the performance of a solar cell. Efficiency, fill factor, open circuit voltage, and short circuit current are some examples. the subsequent equations, which delineate the interdependencies among different performance parameters:

a) Fill Factor $= \frac{V_{pm} * I_{pm}}{V_{oc} * I_{sc}}$ (1)

b) *Efficiency* (η) $= \frac{P_m}{P_{rad}}$ (2)

$= \frac{V_{pm} * I_{pm}}{P_{rad}}$ (3)

$= \frac{V_{oc} * I_{sc} * F.F}{P_{rad}}$ (4)

c) $I_{sc} = q * A * G\,(L_n + L_p + W)$ (5)

d) $V_{oc} = \frac{KT \ln\left\{\frac{I_L}{I_0} + 1\right\}}{q}$ (6)

An analogous diagram of a solar cell with two types of resistance—shunt resistance and series resistance—into which a perfect current supply feeds is depicted in Figure 1 of the text below [6]. Series resistance should be kept as low as possible, as opposed to shunt resistance, which ought to be maximised.

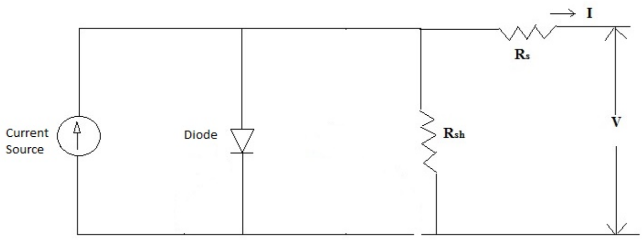

Fig 1. Basic circuit diagram

DC-DC Converter

A converter is an apparatus utilised to elevate or augment voltages. In this device, the electric potential obtained at the output terminal exceeds the voltage at the input terminal [7]. Notwithstanding this, a certain degree of power dissipation is evident due to the heightened internal voltages of the converter. Incorporating the direct current to alternating current conversion and subsequent AC to DC conversion into this device would be an impractical and time-consuming process. This type of converter is categorised as a switch mode dc-dc converter [8] due to the silicon component known as a MOSFET switch, which possesses the ability to rapidly toggle between on and off states. Such converters (inductor, diode, capacitor) have an exceptionally high efficiency [9] due to the fact that approximately 99 percent of the energy is transferred from the input to the output side, with only 1 percent being lost throughout the conversion process. This transpired due to the reverse polarity of the inductor, which is concurrently supplying power to the source and load. The boost converter model, comprising an assortment of electronic components, is illustrated in the following manner.

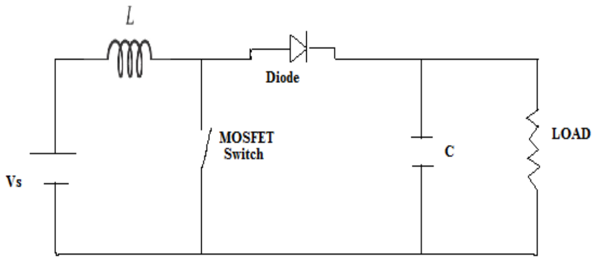

Fig 2. Boost Converter Model

PSIM SIMULATION MODEL

In the aforementioned simulation model of a PV panel integrated with a boost converter, a 60 W maximum power PV panel is employed; its two nodes are capable of regulating solar irradiance and cell temperature [10]. To determine how the efficiency of the PV Panel changes, we will alter the irradiance and temperature [11] while keeping in mind the reference values of 25 °C and 1000 W/m2, respectively[12].

TABLE I: DC-DC Converter Parameters

Sr.No.	Factors	Value
1	D	0.6
2	Frequency	25KHz
3	R	60 Ω
4	$\frac{\Delta V_O}{V_O}$	0.002
5	Minimum value of capacitance	0.0001 F
6	Minimum value of inductance	0.0026 H
7	Used value of capacitance	0.004 F
8	Used value of inductance	0.4 H

$$\mathrm{Lmin} = \frac{D\{1-D^2\}R}{2f} \tag{7}$$

$$\mathrm{Cmin} = \frac{D}{R\{\frac{\Delta Vo}{Vo}\}f} \tag{8}$$

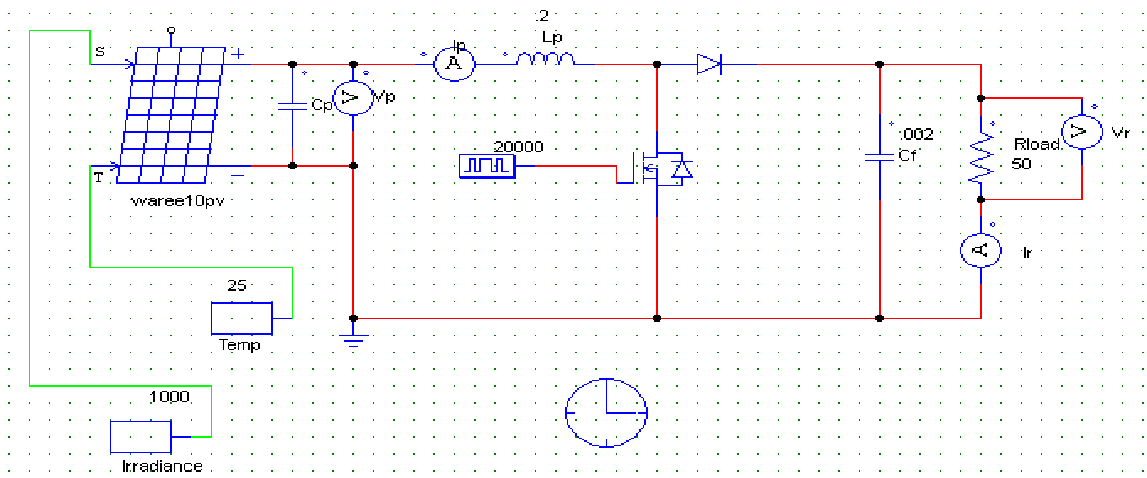

Fig 3. Simulation model of PV Panel Integrated with a boost converter with a resistive load

TABLE II. SPECIFICATIONS OF PV PANEL

Sr.No.	Factors	Value
1	Number of solar pv units	38
2	Maximum power	65 W
3	V_{Pmax}	17.6 V
4	I_{Pmax}	3.8 A
5	VOC	22.1 V
6	ISC	4.2 A
7	Temp. Coefficient for open circuit voltage	-0.42 % / ºC
8	Temp. Coefficient for open circuit current	0.0751% / ºC
9	Region occupied by panels	0.76 m^2

In the aforementioned datasheet [13], the short circuit current, open circuit voltage, and series and shunt resistance values of the PV Panel are detailed. In this experiment, we shall manipulate the temperature and solar irradiance to obtain different values of Pmax, Vmax, and Imax. These values will subsequently be utilised to calculate the PV cell's efficiency for every combination of irradiance and temperature [14]. The author additionally documents the current and voltage at the boost converter's input and output [15] and observes their variations as the voltage is raised from one value to the next. Following conversion, the power will not change significantly [16]. Now, we'll change the irradiance and temperature values for the PV panel and watch how they affect Pmax, Imax, Vmax, Vr, Ir, and Power [17] acquired at the load side or output side of the boost converter. Using those numbers, we'll figure out the efficiency in each situation. Author observed temperature and irradiance in three different India locations for the entire year and hour by hour. From those data, we will select a certain date and time, execute the model for that data [18], and acquire various performance characteristics for comparison with the reference temperature and irradiance.

A. Chandigarh, $I_R = 957\ W/m^2$ and $T_c = 74^o\ C$

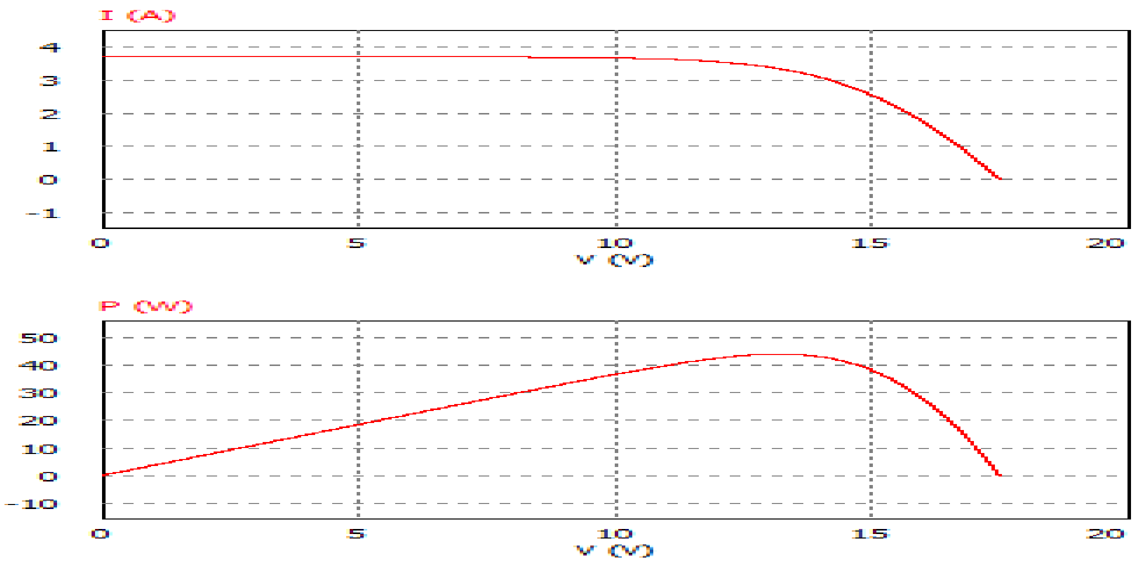

Fig.4. Current voltage graph at input and output

B. New Delhi, I_R = 1208 W/ m^2 and T_c = 45.722° C

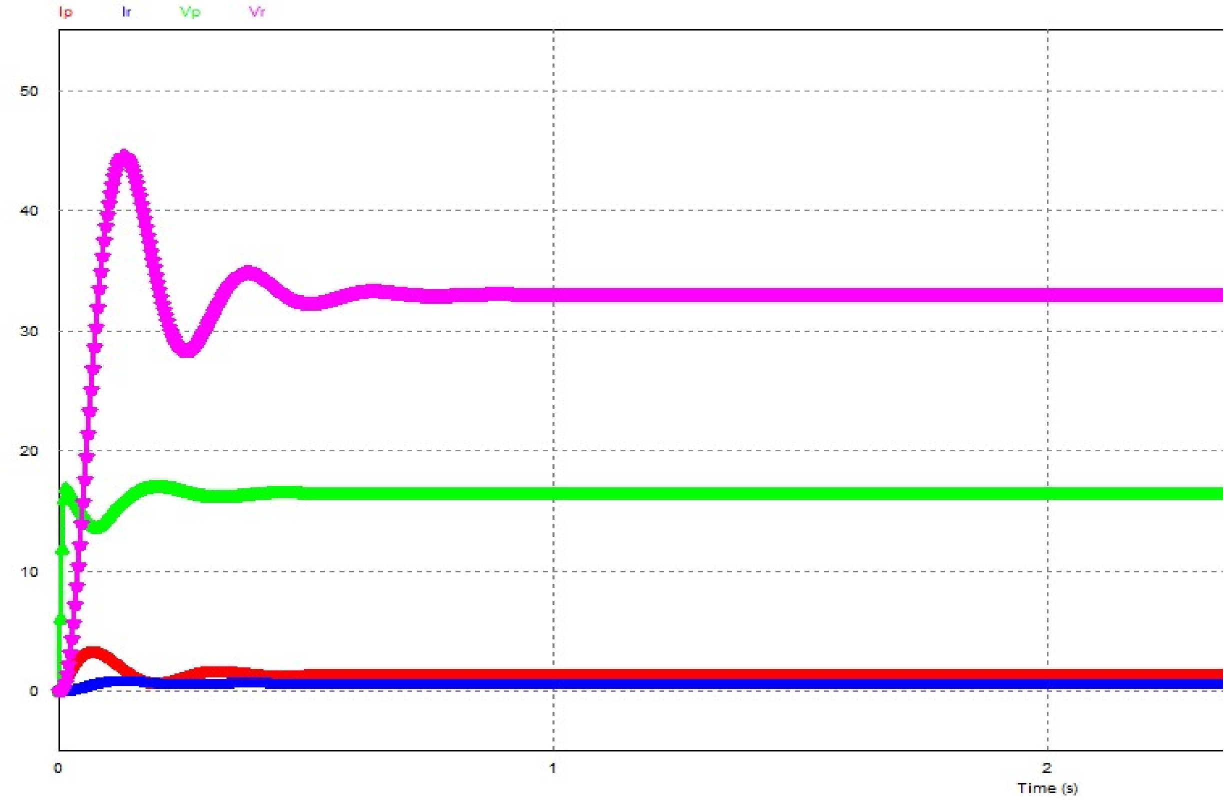

Fig 5. Characteristics at input and output side of converter

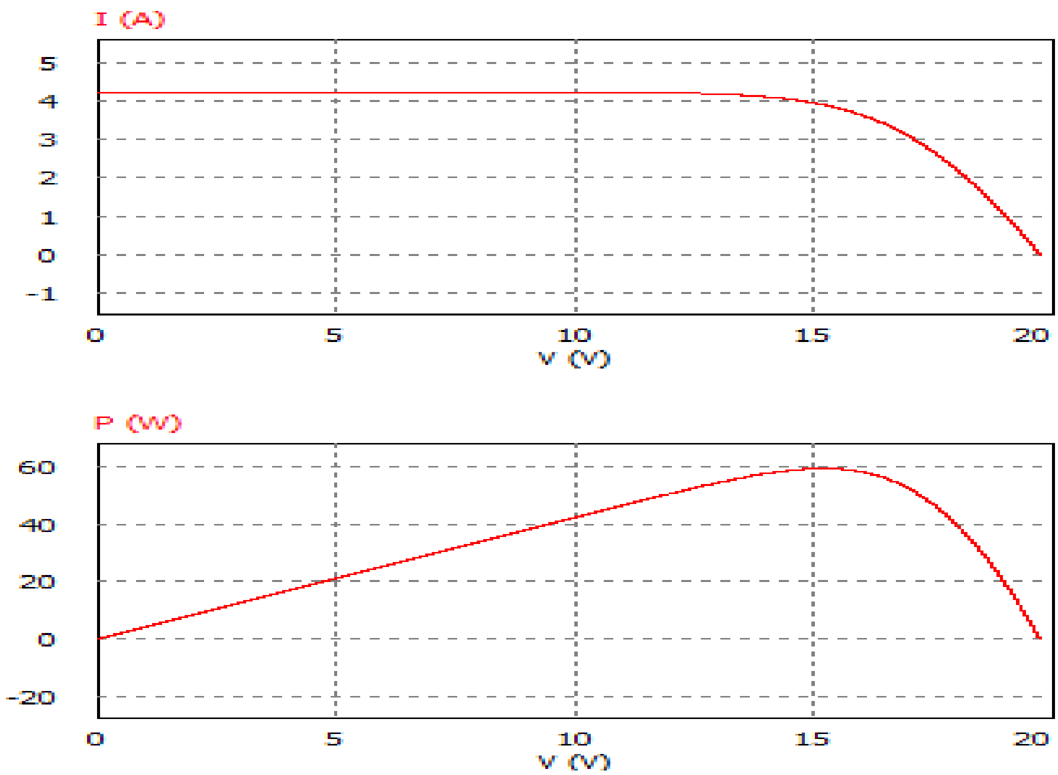

Fig 6. Current voltage graph at input and output

C. Mumbai, I_R = 918 W/ m² and T_C = 56.82° C

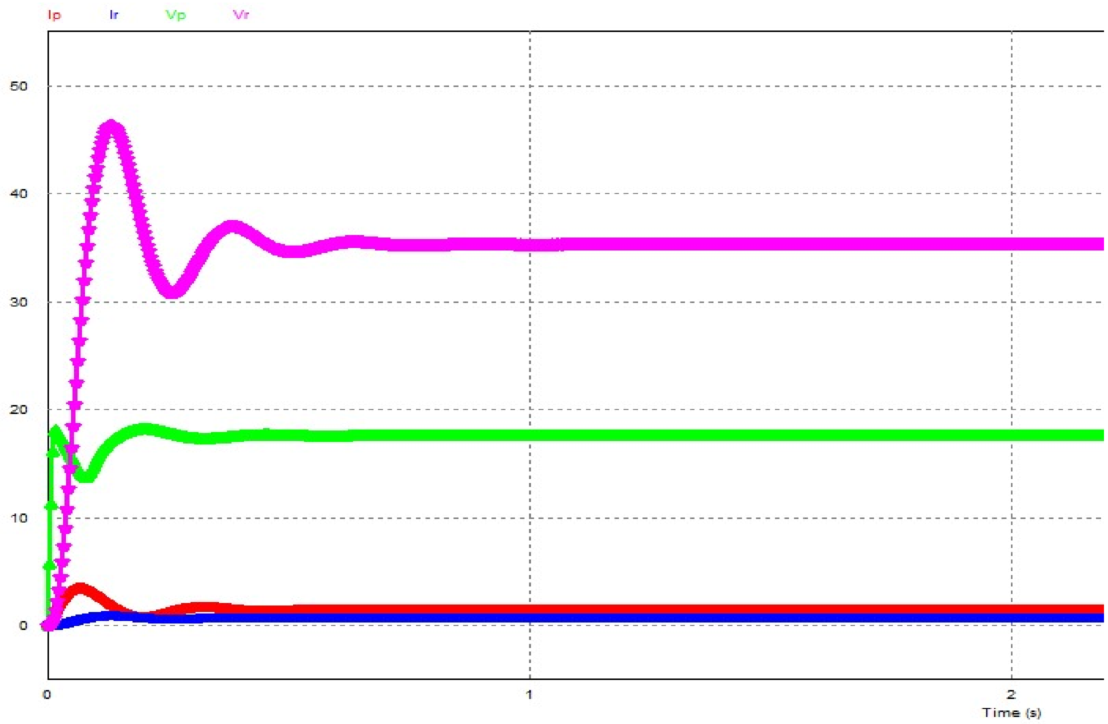

Fig 7. Characteristics at input and output side of converter

Table III. Similarity of the quality characteristics of the PV panel for various regions

Sr. No.	Location	Ppanel	Pload (Boosted)	Vpanel	Vload (Boosted)	Ipanel	Iload (Boosted)
1	New Delhi	27. W	27.2 W	19.7 V	36.50 V	1.4 A	0.77 A
2	Chandigarh	24.1 W	22.8 W	17.5 V	35.02 V	1.4 A	0.76 A
3	Mumbai	25.9 W	25.5 W	18.5 V	36.07 V	1.5 A	0.75 A
4	Initial	34.8 W	32.4 W	20.8 V	38.49 V	1.7 A	0.88 A

TABLE IV. Similarity of the quality characteristics of the PV panel for various regions.

Sr. No.	Location	I_r	T_{cell}	Pmax	Vpmax	Ipmax	F. F	efficency
		(W/ m²)	(C)	(W)	(V)	(A)		(%)
1	New Delhi	1200	454.6	58.62	16.22	3.82	0.87	10.02%
2	Chandigarh	957	72.7	42.25	15.2	3.55	0.99	9.16%
3	Mumbai	926	55.6	45.6	16.48	3.12	0.87	9.62%
4	Initial	1100	27	58.27	17.73	3.64	0.99	11.50%

TABLE V. Location-specific panel requirements and required space for generating 1 KW of power

Sr. No.	Region	Single unit	Solar Plates	Area(m^2)
1	New Delhi	29.61	29	40
2	Chandigarh	24.24	51	41
3	Mumbai	25.87	50	42
4	Initial	34.77	40	45

The table above can be used to draw several conclusions, such as the fact that as the power produced by a panel decrease, more panels are needed to generate 1000 W, and that as the number of panels needed increases, so does the area need.

CONCLUSION

The inverse relationship between the power generated by the panels and the quantity of panels required to supply a specific amount of power has been established based on the aforementioned observations. However, the quantity of panels required is directly proportional to the area they occupy. Therefore, increased irradiation benefits the Ladakh region; however, it causes a rise in temperature, which is detrimental to our well-being. However, by controlling the temperature of the cell through the implementation of a cooling technology, it is possible to achieve results that enhance the cell's performance beyond what it was under the reference conditions. Elevated levels of solar irradiation elevate the temperature of the material, thereby diminishing the cell's performance. Our estimations for various cell temperatures and levels of irradiation at various sites provide support for this. This is due to the fact that solar cells exhibit a rapid temperature response, as elevated temperatures reduce the energy needed to liberate an electron from its bond. Open circuit voltage consequently decreases as panel temperature increases. Irradiance and temperature are correlated; at maximum power, an increase in irradiance causes an increase in current. With increasing cell temperature, however, the magnitude of the electric current at maximum power changes significantly. When the solar irradiance and temperature remain as constant as possible around those benchmark values, the overall output is also quite comparable to the maximum power obtained at those specific conditions.

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