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Solar PV Panel Area Requirement and Performance - Specific Panel Sizing at Different Locations

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ABSTRACT

One of the most popular renewable power generation technologies in use today is solar photovoltaic (PV) technology. In this essay, the efficiency of PV panels at three separate Indian locations—Mathura, Ladakh, and Bikaner—is compared for some of the same environmental variables at the same time and place. To get the necessary voltage at the load side, a boost converter is integrated with the PV panel. To test and track changes in parameters of the panel and at the load, the simulation model is simulated using simulation software for various solar irradiation and temperature. The existing panel's efficiency will change after these numbers are obtained. The impact of high cell temperature and solar irradiation is shown based on the previously determined values of performance parameters for the panel. The values of the performance parameters will also be used to determine the size of the PV Panel and the area needed for it to generate 1 Kilo watt. Observations for various environmental circumstances will be recorded.

Keywords: *Performance; Cooling; Technique; Observations; Electricity.*

1.0 Introduction

As technology advances daily, so does our need for power to run the machinery that makes advancements possible. To meet our power needs, however, we today use both conventional and non-conventional means of electricity generation [1]. But as we all know, traditional methods rely on natural resources that aren't self-renewing, meaning that they can't be replenished by nature or on their own. However, it would take millions of years for them to renew themselves. Fossil fuels, such as coal, oil, diesel, and natural gas, are examples of natural resources [2]. These fossil fuels are used by the power companies to produce electricity; however, they are high in carbon compounds that pollute the environment. The world's climate changed as a result of these conventional techniques of producing electricity. The pollution that is produced by emissions from generating stations is quite detrimental for both people and all other living things, whether they are on land or in the sea. Thermal power plants generate the majority of the world's electricity. The thermal power plant heats a sizable boiler with a large amount of water using a variety of fuels, including coal, diesel, and gasoline. As the boiler heats, the water transforms

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from liquid to steam, which is extremely hot, and flows through pipes to the turbine section to rotate the turbine and produce electricity with the help of a generator. However, the ecology is impacted by the use of fossil fuels, and these fuels are not naturally renewable. In order to maximize output, we must save them or use them effectively. Scientists are turning to unconventional energy sources to solve the issue of the scarcity of fossil fuels because these sources are abundant and cost-free in nature [3For instance, the energy from the sun, wind, geothermal, tidal, and wave sources. However, we'll focus on solar energy in this section as an unconventional source of energy. As we all know, the sun's heat is freely available everywhere and is present for about 360 days out of the year. However, the intensity varies depending on where you are on earth. In order to use solar energy, scientists developed a system that can transform the heat energy from the sun into electrical energy. This process, known as the photovoltaic effect, allows the heat energy to be transformed into electrical energy. However, in order to perform this conversion, we require a special device [4]. The photovoltaic cell is the thing that makes use of this feature. The sun's rays are used by the cell to power its operations. As we are all aware, light exists in the form of photons, each of which has a certain amount of energy. This energy is transferred to the electron, which then gains excitation and moves from the valence band to the conduction band. The motion of the electrons in the circuit creates the electric current in the circuit. The type of current generated by the solar cell is always direct. It follows that a solar cell will always create a direct current, but since a single cell's voltage output is quite low in nature, we require high voltage to power our machinery. We need to organize numerous solar cells of this type in specific patterns in order to achieve larger voltages. A PV panel or a PV array is created when the cells are aligned in a specific arrangement to provide high voltage [5]. The total amount of electricity produced by all of the photovoltaic cells in the panel when it uses solar energy is therefore equal to the total amount of power produced by all of those cells. However, some factors and traits have an impact on how well a solar cell performs. These are efficiency, fill factor, open circuit voltage, and short circuit current. The following equations, which are provided below, show how various performance parameters are dependent on one another: -

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

$$\text{Efficiency } (\eta) = \frac{P_m}{P_{rad}} \quad (2)$$

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

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

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

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

Figure 1: Basic Circuit Diagram

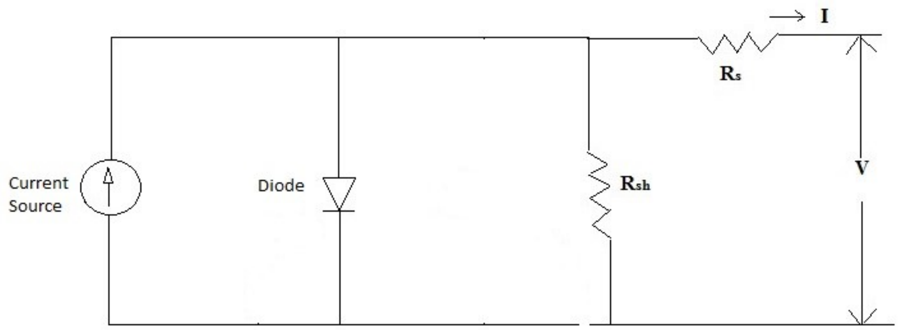


Figure 1 in the text below shows an analogous diagram of a solar cell with two types of resistance: shunt resistance and series resistance, both of which a perfect current supply feeds [6]. In contrast to shunt resistance, which should be as high as possible, series resistance should be as low as feasible.

2.0 DC-DC Converter

A converter that is a tool that increases voltages or boosts voltages. The electric potential acquired at the output side is greater than the voltage at the input side in this device [7]. Despite this, there is some power loss that can be seen as a result of the converter's internal voltages being increased. The direct current to alternating current character and subsequent AC to DC conversion are not included in this device, though, as doing so would be a time-consuming and wasteful procedure. Because it has a semiconductor component called a MOSFET switch, which has the capacity to turn on and off quickly, this sort of converter is classified as a switch mode dc-dc converter [8]. Inductor, diode, capacitor, and a Such converters have a very high efficiency because, compared to the input side, around 99 percent of the energy is acquired on the output side, and only 1 percent is lost during the entire conversion [9]. This occurred as a result of the inductor's reverse polarity, which is also feeding the source and load. The fundamental boost converter model, which includes various electronic components, is depicted below.

Figure 2: Boost Converter Model

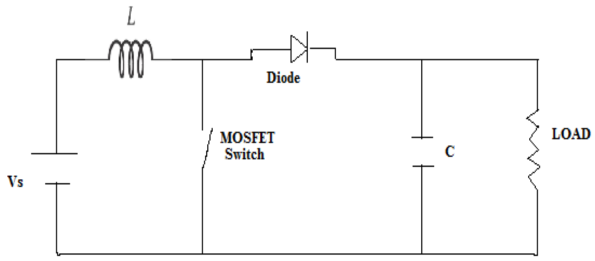


Table 1: DC-DC Converter Parameters

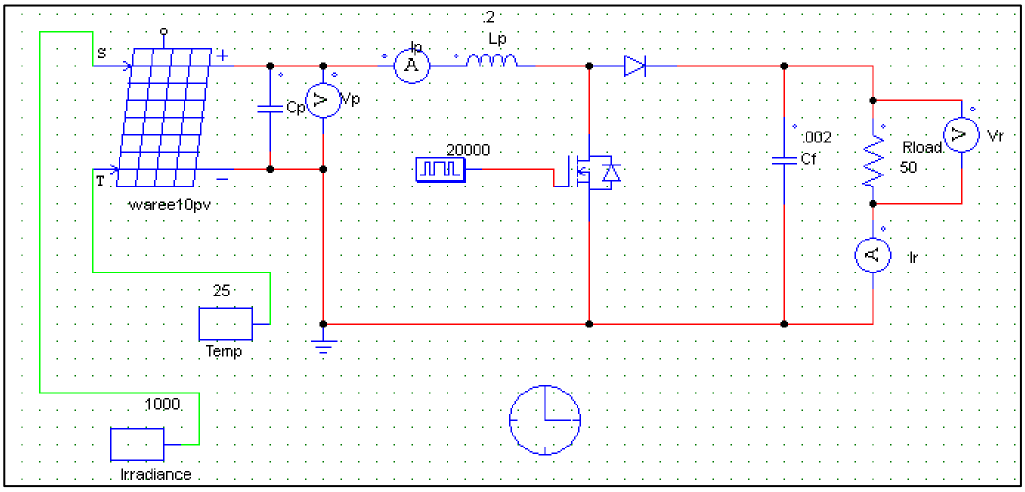
Sr.No.	Factors	Value
1	D	0.6
2	Frequency	25KHz
3	R	60 Ω
4	$\frac{\Delta V_O}{V_O}$	0.002
5	Minimum value of capacitance	0.0001 F
6	Minimum value of inductance	0.0026 H
7	Used value of capacitance	0.004 F
8	Used value of inductance	0.4 H

$$\text{Lmin} = \frac{D\{1-D^2\}R}{2f} \quad \ldots(7)$$

$$\text{Cmin} = \frac{D}{R\left\{\frac{\Delta Vo}{Vo}\right\}f} \quad \ldots(8)$$

3.0 PSIM Simulation Model

Figure 3: Simulation Model of PV Panel Integrated with a Boost Converter with a Resistive Load



A PV Panel with a maximum power of 60 W is utilized in the simulation model of a PV panel combined with a boost converter above, and its two nodes can be used to change the cell temperature and solar irradiance [10]. We will modify the temperature and irradiance [11] while keeping in mind the reference values of 25 oC and 1000 W/m2, respectively, to see how the PV Panel's efficiency changes [12].

Table 2: 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 % / ^{o}C
8	Temp. Coefficient for open circuit current	0.0751% / ^{o}C
9	Region occupied by panels	0.76 m^2

The PV Panel's short circuit current, open circuit voltage, and figures for its series and shunt resistance are all provided in the aforementioned datasheet [13]. Here, we will alter the temperature and solar irradiance in order to derive various Pmax, Vmax, and Imax values, which will then be used to compute the efficiency of the PV cell for each irradiance and temperature [14].

We'll also record the voltage and current at the input and output of the boost converter [15] and watch to see how they change as the voltage is increased from one value to another. After conversion, there won't be much of a change in power [16].

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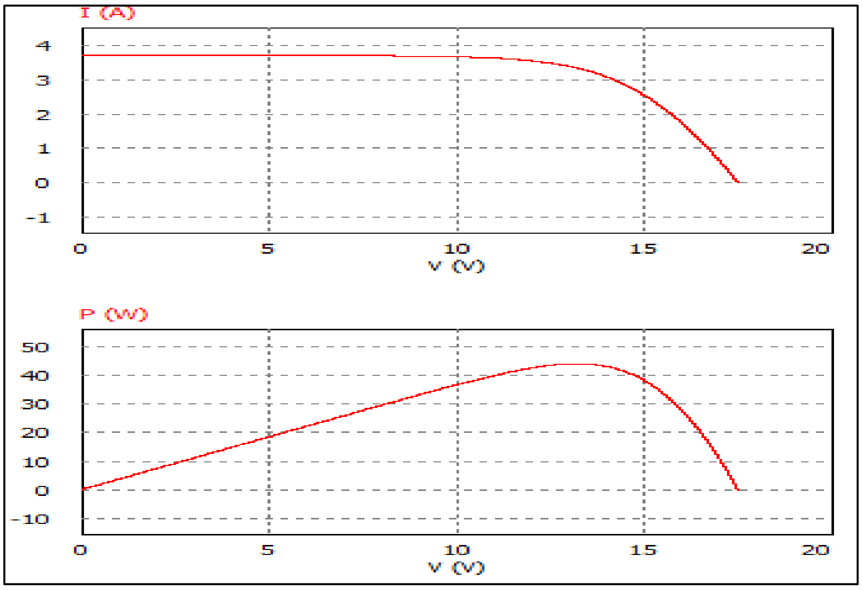
Now, we'll change the irradiance and temperature values for the PV panel and watch how they affect Pmax, Imax, Vmax, Vr, Ir, and Power [17] acquired at the load side or output side of the boost converter. Using those numbers, we'll figure out the efficiency in each situation.

We have information on the 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.

3.1 Kanpur, I_R = 957 W/m^2 and T $_c$ = 74 ^{o} C

Figure 4: Current Voltage Graph at Input and Output



3.2 Agra, I_R = 1208 W/ m^2 and T_c = 45.722^o C

Figure 5: Characteristics at Input and Output Side of Converter

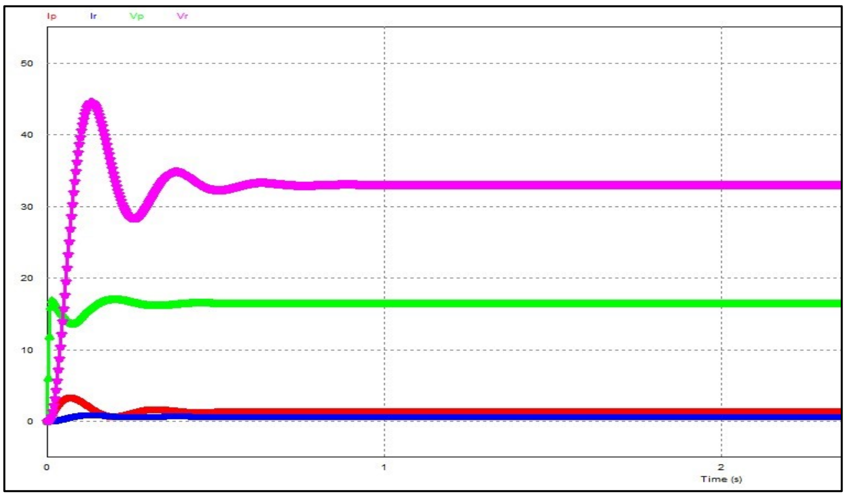
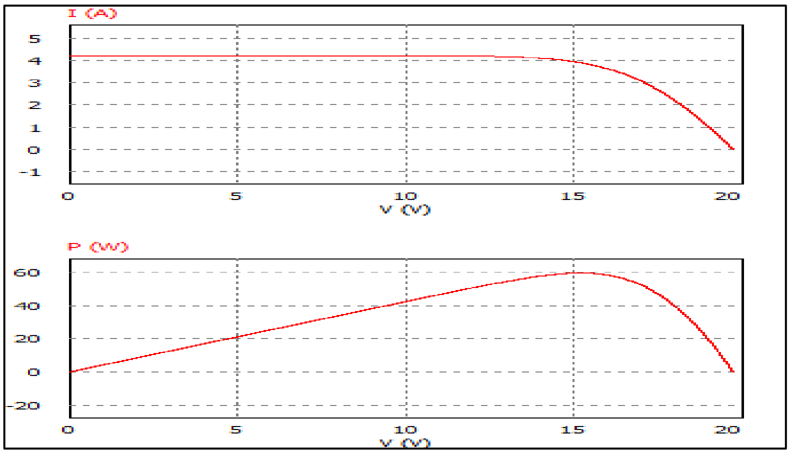


Figure 6: Current Voltage Graph at Input and Output



3.3 Haridwar, I_R = 918 W/ m^2 and T_C = 56.82^o C

Figure 7: Characteristics at Input and Output Side of Converter

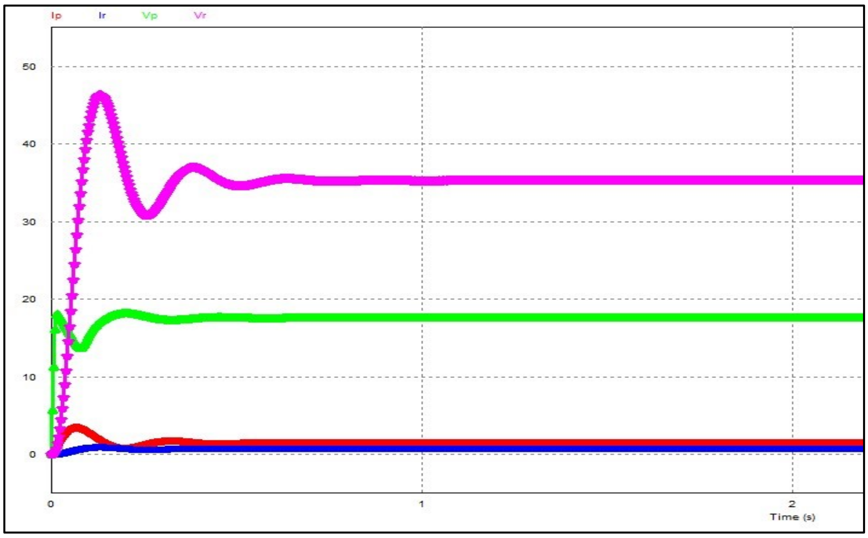


Table 3: Similarity of the Quality Characteristics of the PV Panel for Various Regions

Sr. No.	Location	Ppanel	Pload (Boosted)	Vpanel	Vload (Boosted)	Ipanel	Iload (Boosted)
1	Agra	27. W	27.2 W	19.7 V	36.50 V	1.4 A	0.77 A
2	Kanpur	24.1 W	22.8 W	17.5 V	35.02 V	1.4 A	0.76 A
3	Haridwar	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

The source characteristics, as shown in the aforementioned table, are those that are most conducive to the working of solar panels [19] because they result in the best conversion performance at an ample voltage.

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Table 4: Similarity of the Quality Characteristics of the PV Panel for Various Regions.

Sr. No.	Location	I_r (W/m^2)	T_{cell} (C)	Pmax (W)	Vpmax (V)	Ipmax (A)	F. F	η (%)
1	Agra	1200	454.6	58.62	16.22	3.82	0.87	10.02%
2	Kanpur	957	72.7	42.25	15.2	3.55	0.99	9.16%
3	Haridwar	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	11.5%

Table 5: Location-Specific Panel Requirements and Required Space for Generating 1 KW of Power

Sr. No.	Region	Single unit	Solar Plates	Area(m^2) (Min.)
1	Agra	29.61	29	40
2	Kanpur	24.24	51	41
3	Haridwar	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 needed by them.

4.0 Conclusion

According to the observations made above, the quantity of panels needed to provide a certain amount of power is inversely related to the power generated by the panels. However, the area they take up directly relates to the number of panels needed. Higher irradiation is therefore advantageous for the Ladakh region, but it increases temperature, which is unfavorable for us. However, if we are able to regulate the cell's temperature by the use of a cooling technology, we may obtain outcomes that make the cell even more effective than under the reference settings. High solar irradiation increases the material's temperature, that lessens the performance of the cell. This is supported by our estimates made for various cell temperatures and levels of irradiation at various sites. The reason for this is as solar cell is reacting very fast to temperature since high temperatures narrow the requiring less energy to release the electron from its bond. As a result, open circuit voltage drops as panel temperature rises. Temperature and irradiance, high irradiance causes an increase in the current at maximum power. But as cell temperature rises, there is a marked change in the magnitude of electric at maximum power. If the solar irradiation and solar stay as close to those values as possible, the total output achieved is also very similar to the optimum power retrieved at that benchmark solar irradiation and temperature.

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