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Efficiency Comparison of PV Panels Employing Diverse Cooling Strategies

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ABSTRACT

Effective heat storage materials have a higher specific heat capacity than others. Photovoltaic panels are unable to generate electricity from all of the radiation. Only a small portion is converted to electrical energy; the majority is converted to heat, which raises the operating temperature of the cell. The efficiency of the cell decreases with increased operating temperature. In this study, we examine the effects of different cooling strategies, such as phase change material cooling, thermoelectric cooling, nanotube cooling, etc., on operating temperature. The article's goal is to evaluate the panel's various cooling-related parameters and offer suggestions for the most effective cooling technique. Additionally, the panel temperature is adjusted for three distinct environmental conditions. According to the investigation, water spraying from the panel's front and back results in the biggest temperature change and boosts panel performance.

Keywords: *PV Panels; Photovoltaic Panels; Efficiency.*

1.0 Introduction

As we get closer to the second decade of the twenty-first century. Engineering technology is constantly developing. We're always looking for better services, equipment, and environments to meet our needs and streamline our daily activities [1]. People naturally seek out as much comfort as they can. People are always looking for new ways to make their daily tasks more comfortable and simpler. Males use commercial resources more frequently, which has improved their quality of life, but my issues have also become apparent. The adverse effects on the environment are arguably the worst. Prior to identifying the specific one, the entire word will be examined [16]. This figure will help in determining how long it will take for current energy sources to completely replace the need for sustainable energy, and this solution will be briefly discussed.

In recent years, we have seen both the rapid exhaustion of fossil fuels and the gradual end to their use. Generally speaking, it is advantageous to evaluate the rates of utilization of different renewable energy sources and provide some evidence of the remaining oil and natural gas stocks. [4]. It is not possible to use conventional energy sources indefinitely because they have a limited shelf life and were used to generate this electricity. We must select renewable energy sources, such as solar energy, as an alternative to conventional energy sources because they are naturally limitless [6]. There are three renewable energy options: tidal energy, wave energy, and wind energy.

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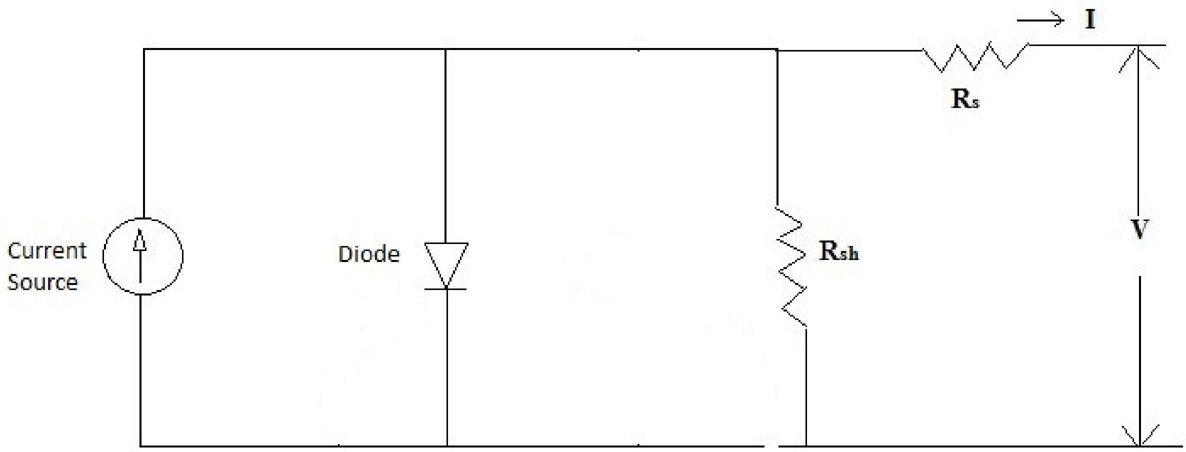
Solar energy [7] is a form of heat energy, and since light is a form of heat energy, it is challenging to transform light directly into electrical energy. We use photovoltaic cells to transform this solar energy, which is present as light, into electrical energy [8]. Although it is not distributed evenly around the world, solar energy is freely and infinitely available at the surface of our planet. The conversion of solar radiation into electrical energy is a phenomenon known as the photoelectric effect.

The efficiency of a solar thermal system is governed by a number of mechanisms, which in turn depend on how well heat transfer processes work [9]. Materials used in semiconductors have characteristics that straddle the line between those of non-metals and those of metals. It implies that they can display traits associated with both metals and non-metals depending on the situation [10]. The electrons in the valence band of these materials are excited to move into the conduction band after absorbing the energy of the photons present in sunlight.

A black-surface absorber is used in solar panels to absorb solar thermal energy and transmit it to a fluid that circulates inside [11] before being converted into the kinetic energy of the electrons. These moving electrons are what produce the current in the circuit. The term for the arrangement of multiple cells that are combined to produce more voltage than a single cell can. However, some performance factors associated with the PV module are important if you are taking solar panels in picture [12].

It includes short circuit voltage, open circuit current, efficiency, and fill factor. Direct sunlight causes PV panels to heat up and raise the temperature of the PV cell, which negatively impacts the solar cell's performance. efficiency.

Figure 1: Individual Solar Unit Used for Generation



$$V_{OC} = \frac{kT}{q} \ln\left\{\frac{I_L}{I_0} + 1\right\} \quad \ldots(1)$$

$$I_{Total} = I_0\left\{e^{\frac{qV}{kT}} - 1\right\} - I_L \quad \ldots(2)$$

$$F.F = \frac{V_M I_M}{V_{OC} I_{SC}} \quad \ldots(3)$$

$$\eta = \frac{V_{OC}\, I_{SC}\, F.F}{P_{Rad}} \quad \ldots(4)$$

$$L_{min} = \frac{D\,(1-D^2)\,R}{2f} \quad \ldots(5)$$

$$C_{min} = \frac{D}{R\left(\frac{\Delta V_O}{V_O}\right) f} \quad \ldots(6)$$

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Table I: Specifications of PV Panel

Sr. No.	Factors	Parameter	Value
1	Units	No. of cells	80
2	Maximum generation	Max. Power (Pmax)	215.15 W
3	V_{Pmax}	V_{Pmax}	28 V
4	I_{Pmax}	I_{Pmax}	8.45 A
5	V_{OC}	V_{OC}	39.3 V
6	I_{SC}	I_{SC}	8.84 A
7	Temp. coefficient for open circuit voltage	Temperature Coeff. Of Voc	-0.296 % / ^oC
8	Temp. Coefficient of short circuit current	Temperature Coeff. of Isc	0.204 % / ^oC
9	Sige for solar units	Area of panel	9 m^2

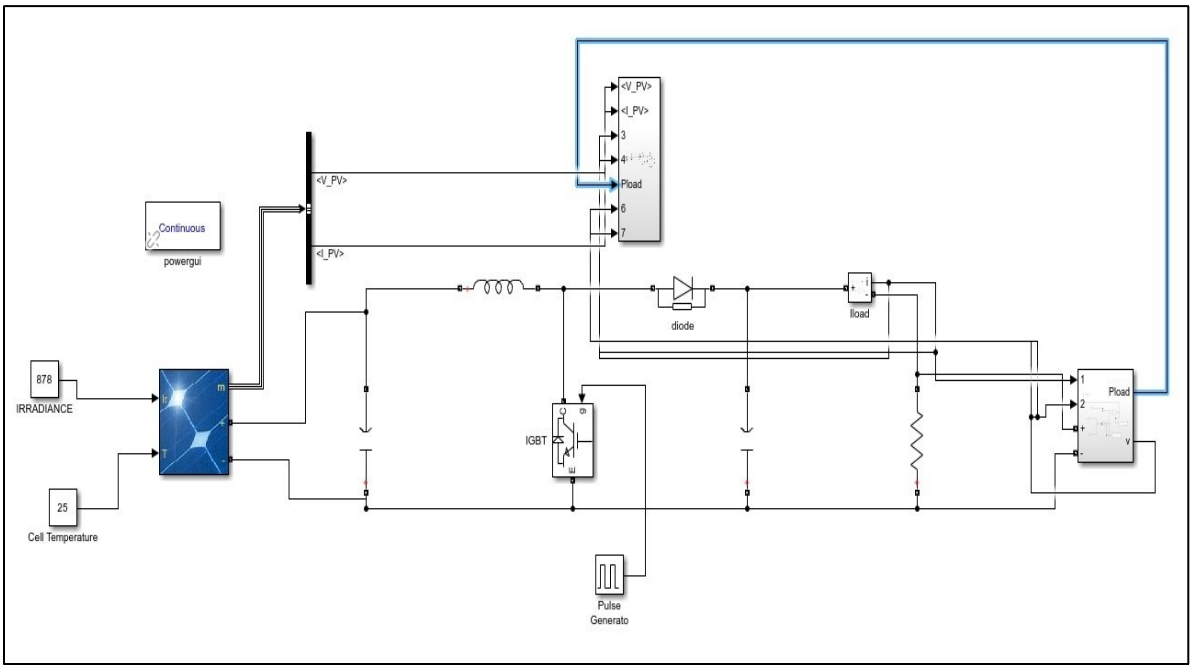
Table II: Comparison of Effect of Cooling on Temperature After Implementation

Sr. No.	Strategy	Variation	Advantages
1	Liquid spray	34	Costly
2	Passive Cooling	9^oC	Without power
3	Active Cooling	14 ^oC	High temperature variation
4	PCM Cooling	17 ^oC	Reliable
5	Nano Fluid	19 ^oC	Not heavy
6	Thermoelectric	29 ^oC	Power production
7	Liquid immersion	28 ^oC	Higher output

For the aforementioned PV panel, we will currently employ seven cooling techniques, each of which has a known effect on operating temperature, as we can see from the table above. These findings were attained following the execution of various authors' experiments.

2.0 Matlab Model

Figure 2: Simulink Model



3.0 Results

Table III: Variation in Temperature Following the Use of Cooling Techniques

Sr. No.	T_{Cell}	Liquid	Passive	Active	Pcm	Nanofluid	Thermoelectric	Submersion
1	74	42	67	62	58	55	49	49
2	68	37	59	56	56	49	45	44
3	58	28	49	47	46	39	36	36

Table IV: Solar Panel Characteristics after Respective Strategy

Sr. No.	T_{cell}	Technique	V_{pv} (V)	I_{pv} (A)	P_{pv} (W)	P_{max} (W)	F. F_{new}	η_{old}	η_{new}
1	44	Liquid	32.4	4.12	122.5	181	0.623	18.3 %	22 %
	65	Passive	29.80	4.42	97.45	164.56	0.645		18.9 %
	64	Active	27.12	4.51	98.57	166.81	0.65		19 %
	56	Pcm	25.45	4.65	102.65	169.79	0.66		19 %
	57	Nano	24.78	4.72	104.8	172.02	0.672		19.7 %
	49	Thermo	32.89	4.87	107	176.43	0.686		18.1 %
	48	Submersion	34.91	4.67	111	177.16	0.69		18.2 %
2	37	Liquid	34.12	4.72	12748	166.89	0.591	18.4 %	18.7 %
	59	Passive	27.46	4.56	98.7	151.45	0.567		18.2 %
	56	Active	28.78	4.57	102.9	156.67	0.574		18.4 %
	55	Pcm	32.81	4.58	107.2	158.24	0.553		19.7 %
	49	Nano	32.52	4.62	109.4	159.76	0.561		19.9 %
	44	Thermo	34.24	4.76	114.5	162.98	0.575		19.4 %
		Submersion	34.45	4.78	116.6	165.92	0.587		19.5 %
3	27	Liquid	32.12	4.97	146.4	178.67	0.695	19.07 %	19.56 %
	49	Passive	34.45	4.67	126.1	163.89	0.642		18.6 %
	48	Active	35.89	4.89	127.7	165.94	0.649		19.24 %
	47	Pcm	35.56	4.76	121.9	168.6	0.658		19.2 %
	39	Nano	36.87	5.74	124.45	166.45	0.665		19.4 %
	39	Thermo	37.45	7.89	129.78	174.78	0.679		19.9 %
	38 ^{o}C	Submersion	38.78	8.89	140.24	177.54	0.681		21 %

The metrics for solar panel performance that are obtained when a cooling technique is applied to the panel are shown in the table above. We obtained seven different cell temperature values and ran the model for those seven values to determine power, current, and voltage by panel. This was done because the operating temperature of the panel is affected differently by each cooling method. From 16 to 20%, the panel's efficiency has dramatically increased.

4.0 Conclusion

The aforementioned findings demonstrate a significant relationship between a solar cell's performance metrics and operating temperature. Solar cells experience lower performance parameters at higher operating temperatures because they are semiconductor devices whose open circuit voltage and short circuit current are temperature-dependent. According to the panel's characteristics, heat

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causes open circuit voltage to decrease while short circuit current to rise with temperature. The best performance is achieved when water cooling is applied to both sides of the panel, which results in a temperature drop of about 31°C and an efficiency boost of about 2.7%. Due to the greater temperature change when the panels were submerged in water at a specific depth, their efficiency increased by 1.9 percent (about 25oC). The panel will, however, be more effective the closer the operating temperature is kept to the ambient air temperature, according to an analysis of the aforementioned results. Nanofluid cooling technology is another option, but because it is non-toxic, it presents significant implementation difficulties. Phase change materials also show promising results when integrated with PV panels because they have a life cycle of about 2000 cycles and result in a temperature decrease of about 15 oC. In order to get the most power out of a particular system, this study concludes that using water cooling on both sides of the panel maximises its efficiency.

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