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Impact of Liquid Immersion of Panels on Its Performance

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ABSTRACT

A semiconductor that is sensitive to the radiation falling on it is one of the materials utilised in the production of solar panels. After a certain temperature, semiconductor materials start to heat up and lose efficiency, and the power output drops too low to be useful. Various cooling solutions are used to solve the high temperature problem. By modelling the equations involved in the dissipation and absorption of heat from the panels, the goal of this work is to analyse the decrease in temperature of the panels that can be produced under various ambient circumstances when using liquid immersion of panels as a cooling approach. By switching the medium's refractive index from air to water, immersion of the panels lowers their direct contact with the heat absorbed from the irradiation.

Keywords: *Liquid Immersion, Semiconductor, Temperature.*

1.0 Introduction

With growing concerns over the cost and availability of fossil fuels, there has been a rapid increase in understanding of the relevance of solar energy for our future energy supply [1]. Thank you for providing insight into how incentives set up in various nations may make photovoltaic systems also beneficial financially. Over the past ten years, the sector has grown at an astounding rate of more than 40% annually [2]. The photovoltaic market exceeded 40 Gigawatts of power at the end of 2007. This is comparable to a market worth 20 billion euros, although the microelectronics market is still far larger [3]. By 2020, the photovoltaic market will surpass the micro market in size due to the current growth rate. Due to the fact that such a substantial sum of money is being invested in solar technology, it is projected that the introduction of new technologies will go more quickly and that price increases will follow [4]. Due to all of these potential developments in the photovoltaic industry, the human factor may ultimately be the limiting factor [5]. As a result, with adequate knowledge of the subject, as well as the financial sector, must get familiar with the fundamentals of photovoltaic energy [6]. The greatest solution is by collaborating on appropriate financial plans [7] with individuals and cooperating to make investments in energy around the world. Numerous governments have adopted accounting regulations to aid in the development of solar PV technologies. The National Solar Mission was launched by the Indian government in 2010 with the goal of [8] installing 20 Gigawatts of solar electricity by 2022. The goal has been changed by the current administration, who has set a 2019 deadline for achieving 100 Gigawatts of power. This has created a highly favourable environment for the development of PV technology [9].

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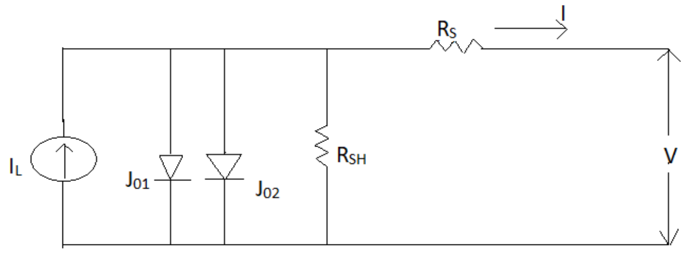
Figure 1: Solar Cell Circuitry in Its Most Basic Form



$$I_{sh} = \frac{V}{R_{sh}} \cdot \frac{N_p}{N_s} + \frac{I}{R_{sh}} . R_s \tag{1}$$

$$V_t = \frac{k.T}{q} \tag{2}$$

$$I_{sh} = \frac{V}{R_{sh}} \cdot \frac{N_p}{N_s} + \frac{I}{R_{sh}} . R_s \tag{3}$$

$$V_t = \frac{k.T}{q} \tag{4}$$

$$I_{ph} = [I_{sc} + k_i (T - 298)] \frac{I_r}{1000} \tag{5}$$

$$I_{rs} = \frac{I_{sc}}{e^{\frac{qV_{oc}}{N_s k_n T}} - 1} \tag{6}$$

$$I_o = I_{rs} \left(\frac{T}{T_r^3}^3\right) e^{\frac{q.E_{go}}{nK}\left[\frac{1}{T} - \frac{1}{T_r}\right]} \tag{7}$$

$$I = N_p . I_{ph} - N_p I_o \left[e^{\left(\frac{\frac{V}{N_S} + I\frac{R_S}{N_p}}{n.V_t} - 1 \right)} - 1 \right] - I_{sh} \tag{8}$$

$$\eta = \frac{I_{sc} V_{oc} F.F}{P_{in}} \tag{9}$$

Table 1: Solar Panel Specifications

Sr. No.	Factors	Value
1	Number of solar pv units	80
2	Maximum power	215.15 W
3	V_{Pmax}	26 V
4	I_{Pmax}	8.35 A
5	V_{OC}	37.3 V
6	I_{SC}	8.84 A
7	Temp. Coefficient for open circuit voltage	-0.46 % / ^{o}C
8	Temp. Coefficient for open circuit current	0.112 % / ^{o}C
9	Region occupied by panels	1 m^2

2.0 Boost Converter

An output voltage larger than the source voltage is provided by a boost converter, a DC-DC converter. It is called a step-up converter for this reason. The output current in this instance is smaller than the source current because power must be conserved [10]. Depending on the operating circumstances, this sort of converter can also be used in a continuous or discontinuous conduction

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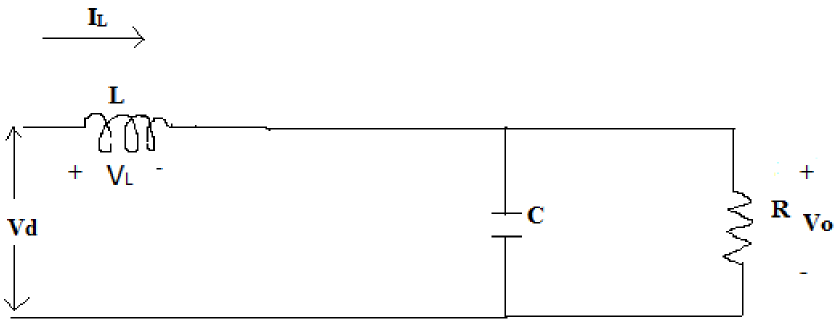
manner [11]. One can modify the duty cycle to alter the boost type converter's output voltage. The output voltage would range from the beginning voltage to infinity because the value of d can only fluctuate between 0 and 1, meaning that the output voltage would always be greater than or [12].

Figure 2: Boost Converter Equivalent Circuit Diagram



$$L_{min} = \frac{D\,(1-D^2)\,R}{2f} \quad (10)$$

$$C_{min} = \frac{D}{R\left(\frac{\Delta V_O}{V_O}\right) f} \quad (11)$$

Table 3: Boost Converter Parameters

Sr. No.	Factors	Value
1	D	0.6
2	Frequency	25 KHz
3	R	110 Ω
4	$\frac{\Delta V_O}{V_O}$	0.002
5	Minimum value of capacitance	0.000100 F
6	Minimum value of inductance	0.0043 H
7	Used value of capacitance	0.004 F
8	Used value of inductance	0.4 H

3.0 Liquid Immersion Cooling Technique

One of the most effective cooling methods for panels is liquid immersion because there are many other methods available, including active cooling, passive cooling, thermoelectric cooling, nano fluid cooling, and employing phase-change materials [13]. In this cooling method, the solar panel is submerged in water to a specific depth; as a result, the medium's refractive index decreases and the panel absorbs less heat [14]. The heat that the panel absorbs also dissipates into the water because there is water above the panel surface, which lowers the panel's temperature.

$$C_{PV}\frac{dT_{PV}}{dt} = I_{reff} - Q_R - P_E - Q_{CV} - Q_H \quad (12)$$

$$I_{reff} = \varphi * \alpha \quad (13)$$

$$Q_R = \varepsilon_P\, \sigma\left[T_{PV}^{\,2} + T_S^{\,2}\right]\left[T_{PV} + T_S\right] \quad (14)$$

$$T_S = 0.037536\left[T_{amb}^{\,1.5}\right] + 0.32\left[T_{amb}\right] \quad (15)$$

$$P_E = C_{FF}\left\{\frac{\varphi \ln[K_1 \varphi]}{T_{PV}}\right\} \quad (16)$$

$$Q_{CV} = \left[h_{front,natural} + h_{front,forced} + h_{rear}\right][T_{PV} - T_{amb}] \quad (17)$$

$$h_{front,forced} = 2.84 + 3\, v_w \quad (18)$$

$$h_{front,natural} = 1.78\left[[T_{PV} - T_{amb}]^{\frac{1}{3}}\right] \quad (19)$$

$$h_{rear} = 1.31\left\{[T_{PV} - T_{amb}]^{\frac{1}{3}}\right\} \quad (20)$$

$$Conduction = 2\,K\,X\,[T_{PV} - T_{amb}] + K.X.H\,[T_{PV} - T_m] \quad (21)$$

$$C_{PV} = 0.1694e^{(2.375 * 10^{-4} * T_{PV})} \quad (22)$$

Table 4: Temperature and Power Variation of Cell

Sr. No.	I_R (w/m^2)	T_{PV} (Before Cooling)	T_{PV} (After Cooling)	P_{max} (Before Cooling)	P_{max} (After Cooling)
1	1200	24	24	210.68	207.78
2	840	75	42.7	145.2	158.6
3	840	67	44.4	149.0	160.88
4	820	57.25	35.2	154.3	164.81
5	888	62	38.25	162.3	170.98

The temperature change before and after the application of the cooling technique is shown in the above table, along with the increase in power output. The PV panel's operating temperature has decreased by about 26 oC, and the power output has increased by about 10 watts.

Table 5. Performance Parameters of Cell

Sr.No	I_R	T_P	V_{pmax}	I_{pmax}	P_{max}	V_{oc}	I_{sc}	F. F	η
1	1200	24	29.39	8.39	211.68W	38.14	7.87	0.85	0.222
2	840	58	25.76	6.9	155.66W	32.61	6.54	0.72	0.19
3	820	51.61	25.38	6.19	157.98W	34.28	6.42	0.72	0.189
4	810	42.35	32.4	6.11	161.71W	35.4 V	6.52A	0.72	0.195
5	878	48	32.05	6.61	172 W	34 V	7.4 A	0.75	0.154

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4.0 Conclusion

The simulation of the Simulink model of the heat mass transfer equations involved in the dissipation of heat absorbed by the panel produced the results shown above. When panels are submerged in liquid, their real-time temperature is reduced by about 26 degrees Celsius, giving the panel a high fill factor. The efficiency of the panel also rises since the fill factor is inversely correlated

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with the efficiency of the panel. Additionally, the power obtained exceeds the power gained prior to cooling the panel. However, the panels must be submerged in a lot of water for the temperature to be reduced. Although the investment is rather large, the maintenance is relatively low. The creation of insulation that can bear such pressure and resist insulation leakage, which would negatively impact panel performance, is what the future work entails.

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