Numerical Analysis of Liquid Immersion of Panels as a Cooling Technique

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Abstract- The materials used in the manufacturing of solar panels is a semiconductor which is sensitive to the irradiation falling on it. The semiconductor materials begin to heat and becomes inefficient after certain point of temperature and the power output becomes too low to utilize. To overcome this problem of high temperature certain cooling techniques are implemented. The aim of this paper is to analyse the reduction in the temperature of the panels which can be obtained for different ambient conditions by implementing liquid immersion of panels as a cooling technique by simulating the equations involved in the dissipation and absorption of heat from the panels. The immersion of panels reduces the direct contact of panels with the heat absorbed from the irradiation by changing the refractive index of the medium from air to water.

I.INTRODUCTION

The insight in the importance of solar energy for our future energy supply has been growing vigorously with the growing concerns about the price and availability of fossil fuels [1]. Thanks to the insight in the effect of incentives organised in many countries to make photovoltaic also effective from financial point of view. The sector has been growing at a breath-taking rate of more than 40% per year over the last 10 years[2]. At the end of 2007 the size of a photovoltaic market exceeds 40 Giga watt power. This is equivalent to the market of 20 billion euros all this is still substantially smaller than the microelectronics market[3]. The present growth rate will make the photovoltaic market grow larger than the micro by 2020. As a result of this large amount of money is going to the photovoltaic which in turn will lead to an acceleration for the introduction of new technologies and the come and price roses to be expected[4]. Due to all this prospects future for this going PV sector the limiting factor at the end might be the human factor in order to subscribe educational channel, where you can find by spell the searches [5] and experienced engineers to further improve the physical inside in all the components of the photovoltaic company to improved and novel devices to build the production equipment for the multipurpose production lines and will even be able to provide the installers [6] of new business systems with sufficient insight into the matter also the financial sector has to learn about the basics of photovoltaic energy. The best possible way by working of suitable financial schemes [7] with people and struggling to invest in
the form of energy worldwide. Many governments have been an accounting policy to support the growth of solar PV Technologies. Government of India started a mission known as national Solar Mission 2010 with the target of [8] setting up 20 Gigawatt power of solar power by 2022. The current government has revising the target and making it 100-Gigawatt power to be achieved 2019 only. This has really set up an enthusiastic circumstance for PV technology to grow [9].

\[ I_{sh} = \frac{V}{R_{sh}} \cdot \frac{N_p}{N_s} + \frac{1}{R_{sh}} \cdot R_s \]  

(1)

\[ V_t = \frac{kT}{q} \]  

(2)

\[ I_{sh} = \frac{V}{R_{sh}} \cdot \frac{N_p}{N_s} + \frac{1}{R_{sh}} \cdot R_s \]  

(3)

\[ V_t = \frac{kT}{q} \]  

(4)

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

(5)

\[ I_{RS} = \frac{I_{sc}}{e^{\frac{qV_{oc}}{nKT}} - 1} \]  

(6)

\[ I_o = I_{RS} \left( \frac{V}{I_r} \right)^3 e^{\frac{qE_s}{nKT}\left[\frac{1}{T} - \frac{1}{T_r}\right]} \]  

(7)

\[ I = N_p \cdot I_{ph} - N_p I_o \left[ e^{\frac{V}{nKT} + \frac{R_s}{nKT} - 1} \right] - I_{sh} \]  

(8)

\[ \eta = \frac{I_{sc}V_{oc}F_E}{P_{in}} \]  

(9)

| Sr.No. | Parameter       | Value |
|-------|-----------------|-------|
| 1     | No. of cells    | 60    |
Max. Power ($P_{\text{max}}$) & 213.15 W \\
\hline
Voltage at $P_{\text{max}}$ ($V_{\text{Pmax}}$) & 29 V \\
\hline
Current at $P_{\text{max}}$ ($I_{\text{Pmax}}$) & 7.35 A \\
\hline
Voltage at open circuit ($V_{\text{OC}}$) & 36.3 V \\
\hline
Current at short circuit ($I_{\text{SC}}$) & 7.84 A \\
\hline
Temperature Coefficient of $V_{\text{OC}}$ & -0.36 % / °C \\
\hline
Temperature Coefficient of $I_{\text{SC}}$ & 0.102 % / °C \\
\hline
Area of panel & 1 m$^2$ \\
\hline
\end{tabular}

**TABLE 2. PARAMETERS INVOLVED IN THE EQUATIONS**

| Sr.No. | Symbol | Description |
|--------|--------|-------------|
| 1      | $\phi$ | Irradiation |
| 2      | $H$    | Heat capacity |
| 3      | $\alpha$ | Absorptivity |
| 5      | $\varepsilon_p$ | Emissivity |
| 6      | $h$    | Heat loss coefficients |
| 7      | $\sigma$ | Boltzmann’s constant |
| 8      | $C_{\text{PV}}$ | Heat capacity of panel |
| 9      | $C_{\text{FF}}$ | Constant (1.22 km$^{-2}$) |
| 10     | $T_S$  | Sky temperature |
| 11     | $K_t$  | Constant (10$^7$ wm$^{-1}$) |
| 12     | $Q_{\text{CV}}$ | Loss due to convection |
| 14     | $P_E$  | Electrical power |
| 16     | $T_{\text{amb}}$ | Ambient temperature |
| 17     | $Q_H$  | Heat stored by water |
II. BOOST CONVERTER

A boost converter is a DC-DC converter that provides an output voltage greater than the source voltage. This is the reason why it is called step up converter. Since power must be conserved [10], in this case the output current is lower than the source current. This type of converter can also be operated in continuous or discontinuous conduction mode depending upon the operating conditions [11]. By changing the duty cycle one can control the output voltage of boost type converter. Since the value of \(d\) can only vary between 0 and 1, the output voltage would vary from initial voltage to infinity i.e. the output voltage would always be either equal to or higher than the input voltage [12].

![Boost converter equivalent circuit diagram](image)

\[
L_{\text{min}} = \frac{D (1-D^2) R}{2f}
\]
\[
C_{\text{min}} = \frac{D}{R \left(\frac{V_D}{V_0}\right)} f
\]

TABLE 3. BOOST CONVERTER PARAMETERS

| Sr. No. | Parameter             | Value     |
|---------|-----------------------|-----------|
| 1       | Duty cycle            | 0.5       |
| 2       | Switching Frequency   | 20 KHz    |
| 3       | Resistance            | 100 \(\Omega\) |
III. LIQUID IMMERSION COOLING TECHNIQUE

Liquid immersion of panel is one of the most reliable cooling techniques which can be used for panels because there are various cooling techniques which can be used for panels like active cooling, passive cooling, thermoelectric, nano fluid cooling and by using phase change material [13]. In this cooling technique the solar panel is immersed in water at a certain depth and due to this the refractive index of the medium changes and results in less heat absorption by the panel [14]. Due to the presence of water above the panel surface the heat absorbed by the panel also get dissipated into the water and the temperature of the panel gets reduced.

\[
C_{PV} \frac{dT_{PV}}{dt} = \text{Effective Irradiance (I}_{\text{reff}}\text{) – Radiation (Q}_R\text{) – Power (P}_E\text{) – Convection (Q}\text{CV}\text{) – Heat stored by water (Q}_H\text{)}
\]  

(12)

\[
I_{\text{reff}} = \varphi \times \alpha
\]  

(13)

\[
Q_R = \varepsilon_P \sigma [T_{PV}^2 + T_s^2][T_{PV} + T_s]
\]  

(14)

\[
T_s = 0.037536 \left[T_{\text{amb}}^{1.5}\right] + 0.32 \left[T_{\text{amb}}\right]
\]  

(15)

\[
P_E = C_{FF} \left\{ \frac{\varphi \ln[K_i \varphi]}{T_{PV}} \right\}
\]  

(16)

\[
Q_{CV} = [h_{\text{front,natural}} + h_{\text{front,forced}} + h_{\text{rear}}][T_{PV} - T_{\text{amb}}]
\]  

(17)
\[ h_{\text{front,forced}} = 2.84 + 3 v_w \]

(18)

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

(19)

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

(20)

Conduction = \( 2 \times K \times (T_{\text{PV}} - T_{\text{amb}}) + K \times X \times H \times (T_{\text{PV}} - T_m) \)

(21)

\[ C_{\text{PV}} = 0.1694e^{(2.375 \times 10^{-4} \times T_{\text{PV}})} \]

(22)

| Sr. No. | \( I_R \) (w/m²) | \( T_{\text{PV}} \) (Before Cooling) | \( T_{\text{PV}} \) (After Cooling) | \( P_{\text{max}} \) (Before Cooling) | \( P_{\text{max}} \) (After Cooling) |
|---------|------------------|------------------------------------|-----------------------------------|----------------------------------|----------------------------------|
| 1       | 1000             | 25                                 | 25                                | 209.68                           | 209.68                           |
| 2       | 820              | 70                                 | 44.7                              | 144.2                            | 156.6                            |
| 3       | 820              | 65                                 | 41.4                              | 148.0                            | 159.98                           |
| 4       | 810              | 56.35                              | 34.2                              | 152.3                            | 162.71                           |
| 5       | 878              | 60                                 | 37.25                             | 161.3                            | 172.88                           |

The above table represents the variation of temperature before and after implementation of cooling technique and depicts the increase in power output. There is a reduction of about 26 °C in operating temperature of the PV panel and increment of around 10 watts can be observed in the power output.

| Sr. No | \( I_R \) | \( T_P \) | \( V_{\text{max}} \) | \( I_{\text{max}} \) | \( P_{\text{max}} \) | \( V_{oc} \) | \( I_{sc} \) | F. F | \( \eta \) |
|--------|-----------|----------|-----------------|-----------------|----------------|-----------|----------|------|-------|

6
The above table shows the variation of various performance parameters of the panel before and after implementation of the cooling technique because open circuit voltage and short circuit current both varies with change in operating temperature of the cell and all these factors contribute towards change in efficiency of the panel which is higher than initial efficiency of the panel.

IV. CONCLUSION

The above obtained results from the simulation of the Simulink model of the heat mass transfer equations involved in the dissipation of heat absorbed by the panel. The liquid immersion of panels results in a reduction of around 26°C from the real time temperature of panel which results in a high fill factor for the panel. As the fill factor of the panel is directly proportional to the efficiency of the panel, the efficiency of the panel also increases. The power obtained is also more than the power obtained before cooling of the panel. The liquid immersion of the panel has a positive impact on efficiency of the panel but there is always a possibility of short circuit of the wires inside the water if the insulation of the circuit leaks. But the liquid immersion of panels requires a lot of water to decrease the temperature of the panels. The investment is quite high but the maintenance is quite low in comparison to it. The future work involves the manufacturing of such insulation which can withstand such pressure and resist the leakage of insulation which will adversely affect the performance of panel.

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