Temperature and ventilation effects on a PV panel

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ABSTRACT
The temperature of the photovoltaic panel influence its characteristic. The heat transfer in a photovoltaic panel will be explain as the effect of the temperature on the I-V (current-voltage) curve. An analysis will be made to find the best configuration for the PV panel between three cases: no gap between the PV panel and the roof, a gap of 5cm fill up with air, and a gap of 5cm fill up with water.

Key words: PV panels, heat transfer, ventilation gap,

INTRODUCTION
To react to the global warming, various green energy were developed these lasts years. One is the production of electricity by photovoltaic panel. Indeed, the PV systems converts sunlight and sun energy in electricity. Even if the fabrication of the PV panels is not really clean, the utilization of it is, because it only needs sun.

In this PV systems, the temperature has a major impact as we will explain later. We will, also, explain the heat transfer process in the PV panel. Then we will propose and analyse some solution to reduce the temperature of the PV.

PROBLEM STATEMENT
A PV panel is a semiconductor material: it is an insulator at low temperature and a conductor at higher temperature, in our case when there is some sun. But the increase of the temperature will reduce the band gap, because the electrons will have more energy and thus can pass the gap more easily. It will conduct in an increase of the current and a decrease of the voltage available as shown in Figure 1 below:

Fig. 1. I-V curve at different temperatures.

The problem will be to determine the best configuration to have the better efficiency of the PV panel.

The different layer of a photovoltaic panels are represented in Figure 3.

Fig. 3. Layers in a PV panel.

The EVA, stands for ethylene vinyl acetate, is a material to assure the shock protection of the solar cell and will not be
taken into account in our analysis. And the Tedlar composite is
assimilate to an aluminum.
The problematic will be to determine the temperature of the
solar cell in different conditions.

Three cases will be analyse, one where is no gap between the
roof and the PV panel, one with a gap of 5cm fill in with air,
and the third case where the gap is fill in with water. The
system is represented in the Figure 2 at the end of the
document.

PROJECT DESCRIPTION

Now that we have set down the problem, we can start the
resolution.
Before starting to develop the different equation, we will make
some assumptions. We assume that the outside temperature is
constant and that the wind is strong enough to renew the air in
the gap. The conductivity between the air and the PV is neglect
because the conductivity coefficient is pretty small.
We assume also that the solar radiation impact only the glass,
and doesn’t go throw the panel.
We neglect also the production of heat when the cell is used.
We take a PV panels of 1m², and we analyse only the heat
transfer in one direction.

By using the electric analogy we can show the three case

**Case 1:**

\[
\begin{align*}
    q_{\text{cond}} &= \alpha_{\text{glass}} \cdot q_s \\
    q_{\text{cond}} &= \frac{T_{\text{out}} - T_{\text{cell}}}{R_{\text{cond;glass}}} \\
    q_{\text{cond}} &= \frac{T_{\text{cell}} - T_1}{R_{\text{cond;si}}} \\
    q_{\text{cond}} &= \frac{T_1 - T_{\text{roof}}}{R_{\text{cond;alu}}} \\
    q_{\text{cond}} &= \frac{T_{\text{roof}} - T_{\text{in}}}{R_{\text{cond;roof}}} 
\end{align*}
\]

**Case 2&3:**

\[
\begin{align*}
    q_{\text{cond}} &= \alpha_{\text{glass}} \cdot q_s \\
    q_{\text{cond}} &= q_{\text{conv}} + q_{\text{ray}} \\
    q_{\text{conv}} &= \frac{T_2 - T_{\text{roof}}}{R_{\text{conv;air}}} \\
    q_{\text{ray}} &= FF \cdot \sigma \cdot \varepsilon_{12} \cdot (T_2^4 - T_{\text{roof}}^4) \\
    q_{\text{cond}} &= \frac{T_{\text{out}} - T_{\text{cell}}}{R_{\text{cond;glass}}} \\
    q_{\text{cond}} &= \frac{T_{\text{cell}} - T_1}{R_{\text{cond;si}}} \\
    q_{\text{cond}} &= \frac{T_1 - T_2}{R_{\text{cond;alu}}} \\
    q_{\text{cond}} &= \frac{T_{\text{roof}} - T_{\text{in}}}{R_{\text{cond;roof}}} 
\end{align*}
\]

Where the different terms are defined like that:
- \( \alpha \) glass, is the absorptivity coefficient of the
glass.
- \( R_{\text{cond/conv}} \) are the conduction/convection
  resistance of the different layer.

\[
\begin{align*}
    R_{\text{cond}} &= \frac{\text{thik}}{k \cdot \text{A}} \\
    R_{\text{conv}} &= \frac{1}{h \cdot \text{A}} 
\end{align*}
\]

- FF is the form factor between aluminium and
  the roof. As we have a panel of 1m² and a
distance between the 2 matters of 5cm, we can
assume that the FF is equal to 1.
- \( \sigma \) is the Stefan-Boltzmann constant.
• $\varepsilon$ is the emissivity factor between the two matters.

$$\varepsilon_{12} = \frac{\varepsilon_{\text{alu}} \cdot \varepsilon_{\text{roof}}}{\varepsilon_{\text{alu}} + \varepsilon_{\text{roof}} - \varepsilon_{\text{alu}} \cdot \varepsilon_{\text{roof}}$$

The different parameters considered in our calculations are shown in the Table 1:

<table>
<thead>
<tr>
<th>Materials</th>
<th>Conductivity coefficient (k) [W/m²K]</th>
<th>Convective coefficient (h) [W/m²K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>0.93</td>
<td></td>
</tr>
<tr>
<td>Silicon</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>237</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parameters of the calculations

The convective coefficient of the water and the air depends on several parameter, but we take an average value.

And the temperature inside the house is fixed at 20°C.

To resolve the calculations we use the software EES (Engineer Equation Software, from the university of Liège, Belgium).

And we found in the Table 2 the different results for the temperature of the cell.

<table>
<thead>
<tr>
<th>Qs</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wh/m²</td>
<td>°C</td>
<td>°C</td>
<td>°C</td>
</tr>
<tr>
<td>100</td>
<td>26.44</td>
<td>25.91</td>
<td>25.58</td>
</tr>
<tr>
<td>200</td>
<td>31.87</td>
<td>31.81</td>
<td>31.15</td>
</tr>
<tr>
<td>300</td>
<td>37.31</td>
<td>37.71</td>
<td>36.73</td>
</tr>
<tr>
<td>400</td>
<td>42.74</td>
<td>43.61</td>
<td>42.3</td>
</tr>
<tr>
<td>500</td>
<td>48.18</td>
<td>49.5</td>
<td>47.88</td>
</tr>
<tr>
<td>600</td>
<td>53.61</td>
<td>55.4</td>
<td>53.45</td>
</tr>
<tr>
<td>700</td>
<td>59.05</td>
<td>61.28</td>
<td>59.02</td>
</tr>
</tbody>
</table>

Table 2: Cell temperature in each cases.

DISCUSSION

The model proposed as many limitations: simplification of the different layer of the PV, we don’t take into account the wind, we are in a permanent regime.

We can see that when the sun is not too much powerful, it is better to have a gap with air, and even better to have a gap fill up with water.

When the sun start to be powerful, the gap with air is not an advantage anymore.

CONCLUSIONS

In conclusion, in a warm weather the gap with air is not the best solution. Indeed, in a warm weather the temperature inside the building is still at 21°C, and so it will act as a cooling system for the PV panel. But this situation will increase the consumption of the energy of the house. A good choice can be the gap with water which will cool the PV and the hot water will be use inside the house.

In a cold weather, the PV panel will act as an insulator for the house.

At the end each installation of solar panel should be study separately, but the cooling system with air or water can be a good solution to improve both the efficiency of the panel and the energy demand of the building.

REFERENCES

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Where:
- $T_{\text{out}} =$ Ambient temperature
- $Q_S =$ Solar irradiation
- $T_{\text{cell}} =$ temperature of the silicium
- $T_1 =$ temperature of the aluminium
- $T_2 =$ temperature on the back side of the panel.
- $T_{\text{roof}} =$ temperature of the roof
- $T_{\text{in}} =$ Temperature inside the house.