Effect of Optical Liquid Filters on the Performance of PV panel

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Abstract

The aim of this work is to study the effect of using selective liquids as absorption filters to decrease the overheating of a PV panel by blocking the unwanted part of the solar radiation (long wavelength) and transmitting the useful part of the spectrum (visible light and near Infrared) into the panel. The liquids were tested on two separate panels and their performance was compared with the performance of a reference panel. Two liquids were used and tested in this work: copper sulfate solution ($CuSo_4.5H_2O$) and distilled water as absorption filters, each one was arranged to flow uniformly over the surface a PV panel through a cavity located over the PV panel. In addition a base PV panel was used for comparison purposes.

It was found that the performance of the panel was enhanced when distilled water was used as an absorption filter with an average increase of 31.33 % compared to the performance of the reference panel while using the copper sulfate solution has enhanced the performance of the panel with an average of 11.3% compared to the performance of the reference panel.

Introduction

One of the main obstacles encountered in the field of the photovoltaic technology is overheating due to excess solar radiation and high ambient temperatures. Overheating has a negative effect on the performance of the PV panels, as the temperature of the semiconductor material in the PV cell increases the cell becomes less efficient (Hamdy, et al., 1988).This is due to the fact that when the temperature of the semiconductor material in the PV cell increases, the liberation of the valence electrons becomes easier and requires low energy. When the electrons are liberated by incident rays, they partially reunite and therefore increase the current flow of the photovoltaic cells, which results in decreasing the output voltage of the PV cells and so decreases the output power of the PV panel. (Moharram, et al., 2013).

Interests in decreasing the overheating in PV panels have increased nowadays and various solutions were offered to suppress its effects, one of the suggested solutions was to control the range of wave lengths entering the PV panel in a way that long waves (infrared waves) that cause temperature rise in the PV panel are blocked and the remaining waves such as visible light and the near Infrared waves are allowed to pass towards the semiconductor material of the PV cell, certain liquids and dyes were recommended to be used for this purpose (Pushparaj et al, 2015) Studies have been conducted on using liquids as absorption filters in PV cells due to the lack of information about absorption filters and their spectral properties, though the concept of using absorption filters has been trending in the recent years.

Hamdy and El-Hefnawi, (1990) integrated three heat transfer fluids as liquid absorption filters into a solar system. These fluids were cobalt sulphate, Brayco 888 and Valvoline. These fluids optical properties was matched with the spectral response of the silicon solar cell. The filters were employed under different concentration levels; 1, 2 and 3 suns. Results showed that using all kinds of filters above reduced the temperature of the PV cell. Solar cells efficiencies under 2 suns using cobalt sulphate, Valvoline and Brayco were 10.8%, 10.2%, and 10.2% respectively. While the cell efficiency without filter was 9.2%. Highest cell efficiency was obtained using cobalt sulphate. Valvoline was the best in terms of thermal energy yield.

Fang, et al. (2009) immersed a solar module in six liquids which arethe polar ethanol and glycerin, the non-polar benzene and silicon oil, and the inorganic distilled water and tap water. Three thicknesses were chosen for each cover film of the liquids which are 3, 6, and 9 mm. For the solar module, the Voc is not changed whereas certain changes in Isc were observed. Lower Isc values was observed using thicker cover films using all liquid kinds.This was due only to the optical effect of the liquid filter layer.

The stability of a large number of organic and aqueous salts solutions of inorganic salts as optical filters was investigated by (Maiti et al., 2010). The best candidate liquid in terms of transmittance was found to be a mixture of ethelyne glycol, propylene glycol and glycerol with a fluorescent whitening agent. The latter mentioned was employed as an optical filter in a low concentrated photovoltaic system which comprises from a square parabolic reflector and a 0.13 m^2 silicon solar module. Results revealed that the liquid filter heat removal efficiency depends on the inlet temperature of the fluid. The I_{sc} was doubled for the parabolic set up compared to a conventional unconcentrated module. While the P_{max} was 2.5 times higher compared to the conventional unconcentrated module.

Zhu, et al. (2011) immersed solar cells in de-ionized (DI) water, isopropyl alcohol (IPA), ethyl acetate, and dimethyl silicon oil under concentration. The spectrophotometer test showed that all fluids matches the spectral profile of the solar cell. Also calculated values of photocurrent density of the solar cells based on the transmittance curves were the highest for DI water, IPA followed by ethyl acetate, and dimethyl silicon oil. Immersion of solar cells on both sides in 10 mm optical path of these liquids resulted in an improved electrical efficiency. The percentage change in electrical efficiency compared to the conventional case was 8.5%, 15.2%, 8.7% and 10.2% for DI water, IPA followed ,ethyl acetate, and dimethyl silicon oil respectively.

Vijayaraghavan, et al. (2013) tested a Fresnel lens based concentrator focusing light on a glass absorber containing copper sulphate. No PV cells were used during the test. Only the thermal performance of the spectrally selective liquid under concentration light was verified. Effect of several parameters was examined and reported. Results revealed that the collector thermal efficiency was not affected significantly by the flow rate or the concentration of the $CuSo_4$. While changing the optical concentration did not affect performance of the collector.

In this project the selected liquids (distilled water and copper sulfate solution) were selected due to their distinctive spectral properties, they were found to be able to partially block the infrared waves and transmit the whole visible part as well as a small portion of the short wave part of the solar spectrum due to their high absorbance in the long wave range and low absorbance in the visible and short wave part.

Experimental Setup and Procedure

As shown in figure 1, the experimental setup consists of two identical Mono-Crystalline PV panels, each one with an area of $0.184m^2$. The maximum output, current and voltage is 1.11A, 18V respectively, and each one with a maximum power output of 20W. These panels were mounted side by side and facing true south with an inclination angle of 28 degrees. The first PV was constructed such that the optical filter fluid flows uniformly through a 5 mm thickness cavity above the surface of the PV. The second one represents the base panel, which was not cooled. It is to be noted that the fluids after passing through the panels are cooled by chillers. Finally, the solar radiation was measured using a Pyranometer,

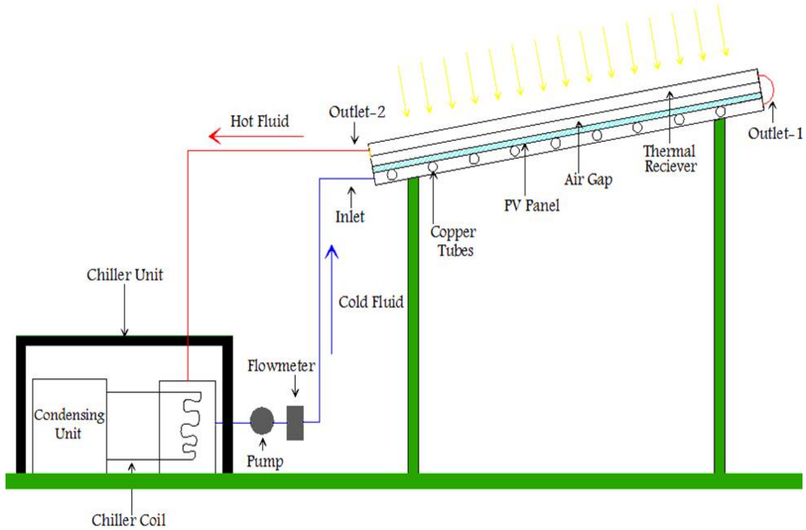

Figure 1. Experimental Setup

Distilled water and copper sulfate solution ($CuSO_4.5H_2O$) were selected to be used as absorption filters. This selection was based on their spectral properties which are indicated by their ability to transmit the right part of the solar spectrum (short wave part) into the photovoltaic panel and to block the unwanted part of the solar spectrum (long wave length portion).

The full system was initially tested to detect any malfunction or leakage in the pipes. Distilled water and copper sulfate solution ($CuSO_4.5H_2O$) were used as absorption filters in two separate panels in order to compare the performance of the filtered panels with the performance of the reference panel simultaneously. The chiller unit tanks of both panels were filled with both liquids in order to flow in the system's loop.

The parameters of each panel such as the open circuit voltage, the short circuit current and the surface temperature of the panel, the temperatures of the liquid absorption filter as it enters and leaves the glass filter of the panel were also recorded and stored in the data acquisition system for further analysis.

Results and Discussions

The average output power of the filtered panels was compared with the average output power of the reference panel for a typical day is shown in figures 2.

As it may be noticed the filtered panels showed better performance than the reference panel. This is due to the fact that using liquid absorption filters leads to a control on the range of wave lengths entering the PV panels, unlike the reference panel which receives the full solar spectrum incident on it. Using distilled water as an absorption filter has improved the performance of the filtered panel with respect to the reference Panel by 30 %. Using copper sulfate solution as an absorption filter has improved the performance of the filtered panel with respect to the reference panel by 12 %.

Furthermore, it may be noticed that distilled water as a filter improves the PV performance more that copper sulfate solution. This might be related to the fact that distilled water does not absorb any solar radiation with a wavelength in the visible part of the solar spectrum, unlike the copper sulfate solution which absorbs a portion of the visible part of the solar spectrum in the red region. In addition, copper sulfate solution is also expected to transmit a small portion of the long wavelength part of the solar radiation which might be considered as another reason for the copper sulfate filtered panel to have lower performance than the water filtered panel.

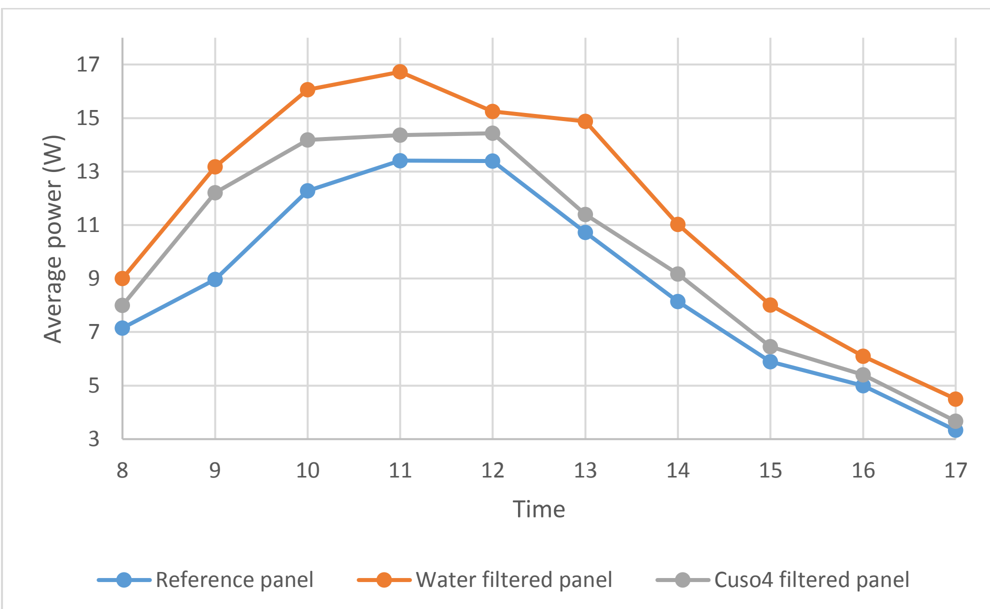

Figure 2: The average hourly output power.

The hourly average surface temperature of the three panels are presented in figure 3. As indicated, the surface temperature of the filtered PV panels are lower than that of the reference one. This is due to the fact that both distilled water and copper sulfate solution block portion of the spectrum that corresponds to high Infrared portion of the spectrum and hence decrease the heating effect of the solar radiation on the PV panels.

The average surface temperature of the distilled water filtered panel was lower than the average surface temperature of the copper sulfate filtered panel. This might be attributed to the fact that distilled water does not absorb any solar radiation with a wavelength in the visible part of the solar spectrum, unlike the copper sulfate solution which absorbs a portion of the visible part of the solar spectrum in the red region. In addition, copper sulfate solution is also expected to transmit a small portion of the long wavelength part of the solar radiation which might be considered as another reason for the copper sulfate filtered panel to have lower performance than the water filtered panel

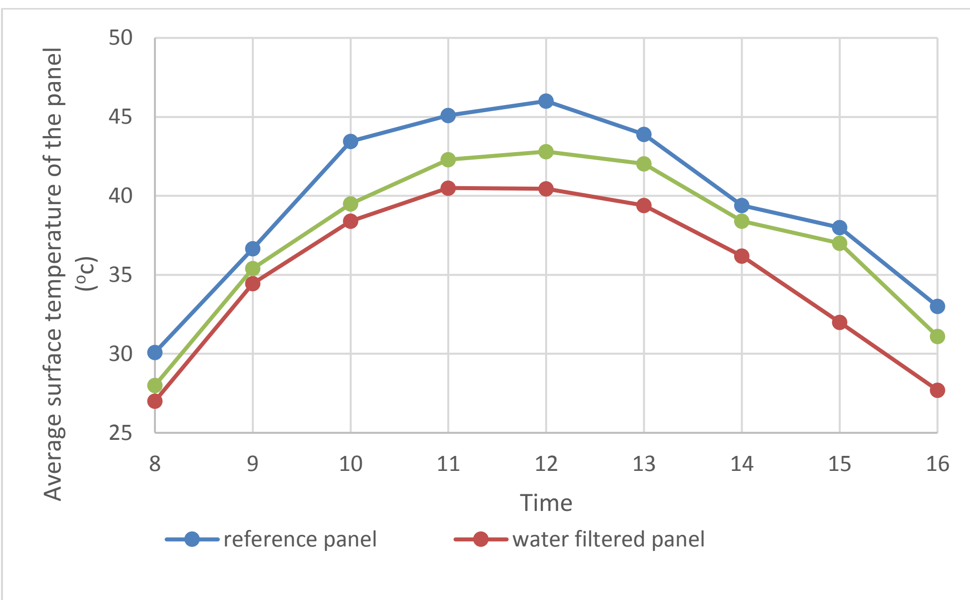

Figure 3. The average hourly surface temperature of the panel

The hourly average temperature of the liquid absorption filter as it exits the PV is shown in figure 4 for both liquid filters. As indicated, distilled water exit the PV at higher temperature that of copper sulfate and consequently water removes more heat from the PV compared with copper sulfate due its absorption band for solar radiation in the Infra-red region of the spectrum as discussed above. As a result it has more cooling effect on the PV leading to performance of the PV when water is sued as an optical filter.

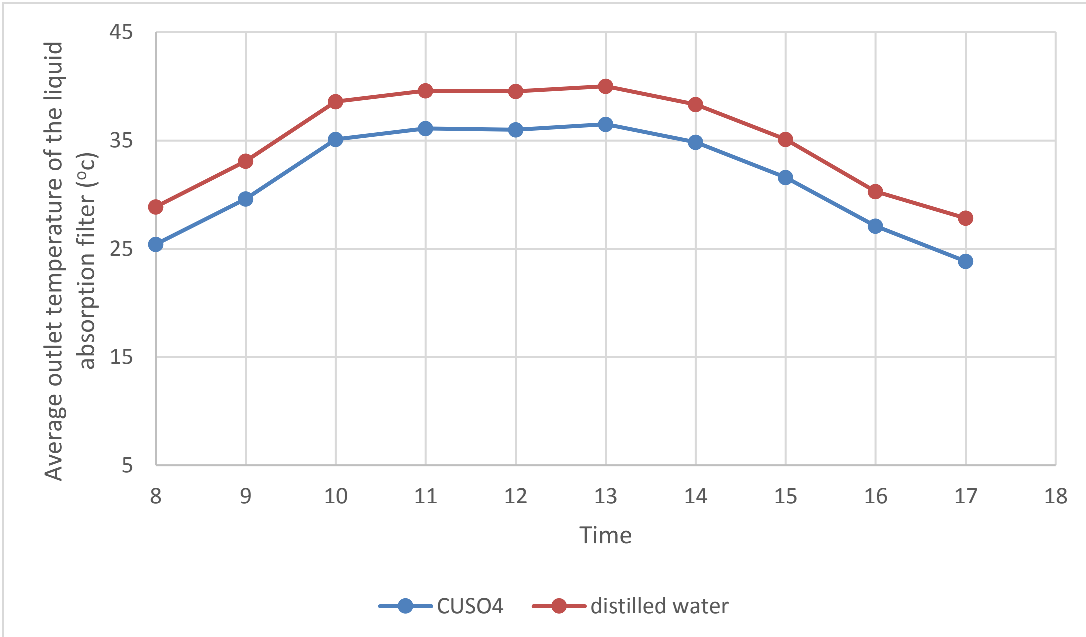

Figure 4: The hourly average outlet temperature of the liquid filter

Conclusion

In this project the performance of photovoltaic cells was investigated when using selective liquids as absorption filters. It may be concluded that both selected liquid optical filters (copper sulfate solution and distilled water) improve the performance of the PV panels. This improvement is more pronounced when distilled water is used compared with that when copper sulfate solution is used.

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