A Review on Fluid Based Beam Splitters for Solar Photovoltaic/Thermal System

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Abstract— Research and development work on photovoltaic/thermal (PV/T) technology has been done since 1970s. Innovative ideas have been put forward; most commonly Photovoltaic/Thermal systems put the working fluid directly in contact with PV system, thereby removing excess heat. Studies have shown that pure fluids such as water and organic fluids can be used in photovoltaic/thermal (PV/T) systems as beam splitters. Theoretical studies have been performed on fluid based beam splitters. In a beam splitting system, the heat load on the photovoltaic cell is reduced by the removal of the long-wavelength part of the solar spectrum, which otherwise would heat up the cell and reduce the efficiency. A beam splitter is a substance which filters the solar radiation specifically. This article gives a review of the trend of development of fluid based beam splitter technology in recent years and the future work required.

Keywords- *Photovoltaic/Thermal, Fluid beam splitter, Optical filter, Hybrid Solar Technology*

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I. INTRODUCTION

A hybrid solar energy conversion system refers to a combination of electrical, chemical or thermal conversion process which may increase the overall utilization of the solar spectrum. A trending solar hybrid system is the one which combine photovoltaic and thermal conversion, which produce electricity and thermal energy in combination.

The performance of solar cells is dependent on environmental conditions and their output parameters vary with temperature. Davud Mostafa et al[1]. performed experiments and the results showed that most significant change by temperature is voltage which decreases with increasing temperature while output current slightly increase by temperature.

Photovoltaic conversion is highly wavelength dependant and is most efficient when converting photons of energies close to PV cell band gap energy, the remaining wavelength part of the solar spectrum can be utilized for thermal applications. The optimal method of using solar cell is to direct on cell only the part of solar spectrum for which high conversion efficiency can be achieved, and to recover the radiation outside this range by diverting it to other receiver or absorber or filter. Thus the incident beam is separated into PV and thermal components as shown in Fig 1.

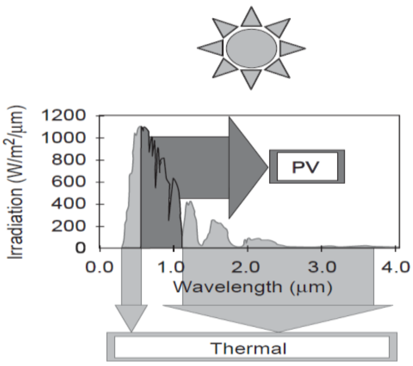

Fig 1: Solar spectrum components for PV and Thermal energy conversions [8]

In a fluid based beam splitting system (absorption filters), the heating part of the solar spectrum is substantially reduced and the wavelengths which are more efficiently converted by the PV cell are incident on the cell. Absorption filters consist of a liquid contained within a channeled thin glass plates. The long wavelength part of the solar spectrum is absorbed by the selective fluid filter used for thermal conversion as illustrated in Fig 2. which otherwise would heat up the cell and reduce the efficiency.

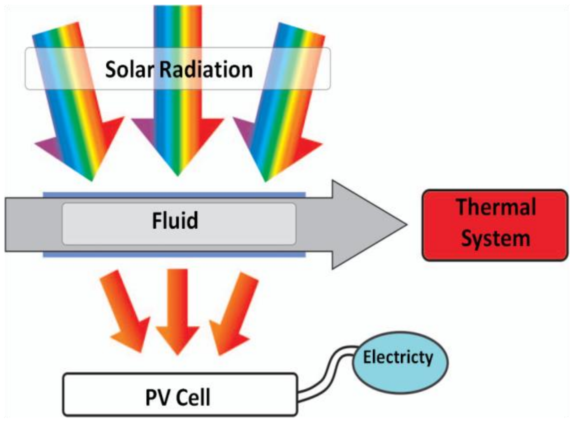

Fig 2: Sketch of a Fluid based beam splitter concept.

II. LITERATURE REVIEW

A very few research has been done on this concept of fluid based beam splitter or absorption filters. The concept is trending in the recent years i.e. from 2002. Researches done in recent years have been reviewed as follows.

Practical liquids suitable for use as absorption filters have been studied by Osborn et al.[2] and Chendo et al.[3]. The spectral response of more than 30 samples of optical liquid filters were tested across the solar spectrum between 300 and 1500 nm, either singly or combined, and the inorganic salts of cobalt, cupric, and nickel were found to have suitable spectral characteristics within the desired optical range. Cobalt sulphate showed a nearly ideal optical response match to Si cell, its thermal stability was verified in laboratory tests with temperatures ranging between 50°C and 200°C, and the filter did not lose its water of crystallization until 420°C. Brayco 888 HF was also tested and found to have sharp absorption character at 600nm and 1100nm, suitable for light transmission to a Si cell in PV/T system.

Kaluza J, et al.[4] studied the properties of fluids theoretically and compared the results with measured data. The conclusion says that pure fluids such as water or organic fluids can be applied to solar PV/T systems as absorptive filters.

Bakker et al.[5] studied a design in which water used for cooling the PV was studied as shown in Fig 3. The water was passed through channels above the PV panels, water and air were separated by glass layer. This configuration was studied in context of cooling the PV panel and not for optical filtering. The author concluded that this design imposed constraints on the choice of the collector fluid; for a PV/T collector design the absorption spectrum of the fluid should be sufficiently different from the absorption spectrum of the PV in order to allow the PV to receive the incoming radiation.

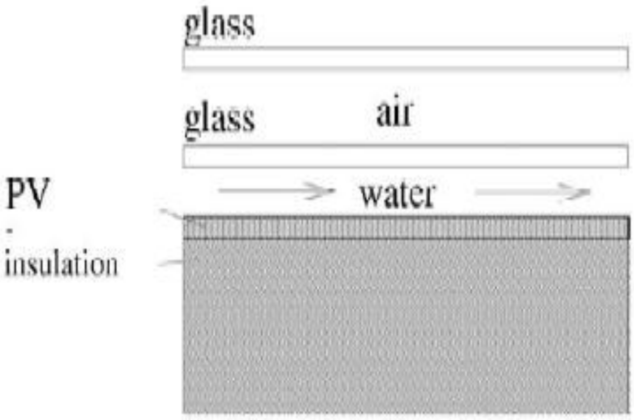

Fig 3: Water above PV for cooling the panel.

Zondag H.A et al.[6] studied a design in which water and air was used for cooling the PV. This design was called a **Free Flow Panel** in which unrestrained fluid flows over the absorber, as shown in the Fig 4. In comparison to the channel case, this design eliminates one glass layer. A disadvantage is the increased heat loss due to evaporation. Water seems a natural choice, but since its evaporation pressure is not very low, evaporation will create problems at higher temperatures.

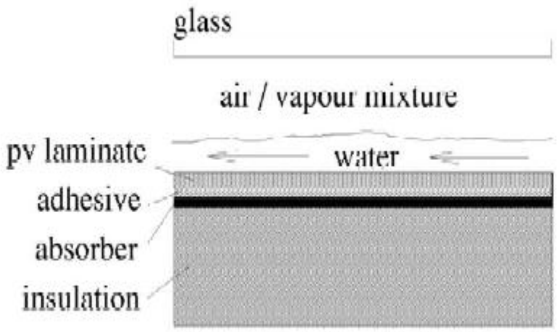

Fig 4: Water + air/vapour for cooling the PV panel

M. Sabry et al.[7] performed systems simulations to identify the ideal fluid absorption filter characteristics for operation with a Si concentration cell. The optimum filter was found to have a transmission range of 450-920 nm, equivalent to 59% of the incident energy at AM 1.5 spectrum. The ideal filter resulted in a 30% predicted increase in cell efficiency compared to unfiltered under 7 suns concentration, accompanied by a potential thermal gain of up to 40% from the liquid absorption filter. The temperature of the thermal component was not discussed by the authors, and for complete analysis it would be necessary to take into account the thermal losses and auxiliaries.

Robert A Taylor et al.[9] suggested that nanofluids (nanoparticles suspended in conventional base fluids) provide one possible solution for a perfect absorption filter. Several studies have investigated the capacity for nanofluids to achieve tunable optical properties. The study demonstrated that alternative liquid nanofluid optical filters can achieve the same level of control as conventional optical filters. The advantages of nanofluids are that they can easily be controlled by magnetic/electric fields, making them ideal for applications where dynamic optical switching is desired. Nanofluid based filters provide superior solar weighted efficiency to pure fluids and a comparable efficiency to conventional optical filters over the solar wavelengths (ultraviolent to near infra red). The optimization results of the study revealed that, at the most, a volume fraction of 0.0011% is required to achieve optimum filters for PV/T applications. This indicates a potential for low cost liquid filters with comparable performance to conventional filters.

Sanjay Vijayaraghavan et al.[10] tested a prototype of a concentrating type spectrally selective direct absorption collector with $CuSO_4$ solution as absorbing fluid for AM 1.5. The performance of the collector was characterized by changing various parameters. The collector performance was not found to significantly vary with flow rate of the working fluid through the absorber. Changing the optical concentration itself without changing any geometrical parameter did not appear to impact the performance of collector either. Higher concentration also did not result in measurable improvement in efficiency.

III. CONCLUSION

A very less study has been done on the fluid based beam splitters concept. The absorption filters and their properties are not explored much. There is a lack of data for fluids and their properties in regard to use as optical filters. One of the main advantage of fluid based absorption filters is that it can be controlled with help of pumps and the thermal energy can be utilized directly with suitable applications. This review gives the trend of development and studies performed on the concept. The use of nanofluids has potential for the future because nanofluids can be made tunable and the optical properties can be varied by selecting suitable nanoparticles. The use of pure and organic fluids which are commercially available can also prove its potential for use of absorption filters.

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IV. FUTURE WORK

Experimental studies are necessary to check the feasibility for practical use of fluid based beam splitters or absorption filters for commercial use. Many other commercially available heat transfer fluids remain to be characterized, and further studies of matching specific filters to specific quantum converters would be needed to establish cost effectiveness. Experimental studies are needed to measure filter performance. For real practical applications, economic optimization based on the fabrication and the relative value of electricity *v/s* heat is needed.

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