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A Review on Photo Voltaic Thermal Systems

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Abstract**—** The demand for Solar thermal and photo voltaic electricity generation is increasing day by day in market. Research and development work on Photo Voltaic Thermal (PVT) technology have been put forward since 1970s for a wide range of application including Agriculture, Processing plants and buildings. With PV Thermal panels, sunlight is converted into electricity and heat simultaneously. Per unit area the total efficiency of a PVT panel is higher than the sum of the efficiencies of separate PV panels and solar thermal collectors. During the last 20 years, research into PVT techniques and concepts has been widespread, but rather scattered. This reflects the number of possible PVT concepts and the accompanying research and development problems, for which it is the general goal to optimize both electrical and thermal efficiency of a device simultaneously. This study presents a review of different types of PV/thermal collector system i.e. flat plate and concentrator type, in which working medium is either liquid or air. After studying all available systems, it can be concluded that PV/Thermal are very promising devices and there is a wider scope to improve their performance on the basis of efficiency and cost, making them more competitive in the market.

Keywords**—** PVT; collector system.

I. Introduction

Today there is a need for clean and renewable energy sources. Fossil fuels are non-renewable and require finite resources which are dwindling because of high cost and environmentally damaging retrieval technique. So there is a need for cheap and renewable resources. A feasible and an efficient option is the 'Solar Energy'. It is the most practical form of energy because of its plentiful availability and it is derived directly from Sun [1-3] (Fig. 1).

A PVT system is a combination of photovoltaic (PV) and solar thermal components which produces both electricity and heat from one integrated system i.e. co-generation of thermal energy and electric energy. So PVT is also called Solar Co-generation. A solar cell has its threshold photon energy corresponding to the particular energy band gap below which electricity conversion does not take place. Photons of longer wavelength do not generate electron-hole pair but only dissipate their energy as heat in the cell.

PV panels absorb up to 80% of the solar radiation. However, only 5 – 20 % of the incident energy is converted into electricity, depending upon PV technologies used. The remaining energy is converted into heat. This led to extreme temperature in cell as high as 500C above ambient temperature. This result in-

- Drop in cell efficiency.
- Permanent structural damage of PV module if thermal stresses remains for longer period of time [4, 5].

In PVT, this heat is extracted from PV panels and made available for various uses like:

- In building, for tap water heating etc.
- Also by this extraction, Solar cells get cooled, this results in improvement in electricity yield [6].

So with an optimal design, PVT system can supply buildings with 100% renewable electricity and heat in a more cost effective manner than separate PV and solar thermal system and thus contribute to the long term international targets on implementation of renewable energy in the built environment [7].

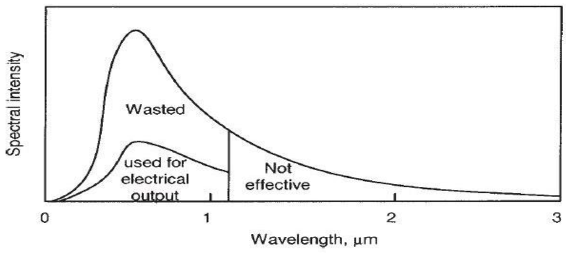

Fig. 1. Sketch of portion of incoming sunlight converted into electricity or heat [2]

II. Types of Photo Voltaic Thermal System (PVT)

A. *Flat-Plate PVT Collector System*

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (1). a dark flat-plate absorber, (2). a transparent cover that reduces heat losses, (3). A heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (4). a heat insulating backing [8-10]. The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminum, steel or copper, to which a matte black or selective coating is applied) often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover [11, 12] (Fig. 2).

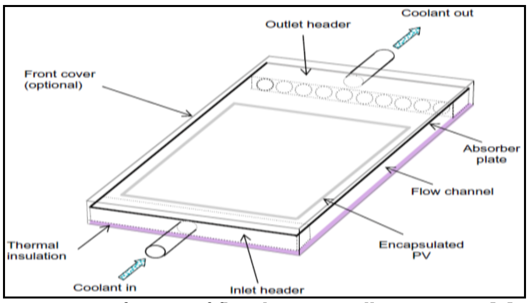

Fig. 2. Main features of flat-plate PVT collector system [3].

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Flat Plate PVT Collector System are further classified as-

1) *Air Type PVT Collector System:* It is an Air based system in which heat transfer fluid is air (Fig. 3). The PV cells are either pasted to the interior of cover plate or to an absorber or the PV cells are acting as an absorber or cover plate itself [13]. The air can be circulated by either natural ventilation or by forced ventilation. Heat generated by PV module and metal absorber will be transferred to the air, hence the PV module, therefore electrical efficiency increases [14, 15].

In general the air collector is mostly applied if there is a demand for hot air, space heat, dry agricultural products or to condition the indoor air (air cooling). Using air as a heat transport medium compared to air, has significant advantages and disadvantages.

Advantages-

- No freezing and no boiling of collector fluid.
- No damage if leakage occurs.

Disadvantage-

- Low heat capacity and low conductivity, the result is low heat transfer.
- Low density due to which there is high volume transfer.
- High heat losses through air leakage.

2) *Liquid type PVT Collector System:* In this system, Glycol, mineral oil or water is used as a heat transfer fluid [1]. Heat transfer fluid runs inside the ducts on the absorber and collect heat from the absorber (Fig. 4). Useful thermal energy is extracted to one end of the duct where it can be utilized. The heat transfer fluid can be circulated by (a) Using Pumping System. (b) Difference in Specific gravity of heat transfer fluid [16-20].

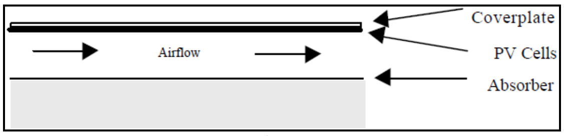

Fig. 3. Example of an Air-PVT collector

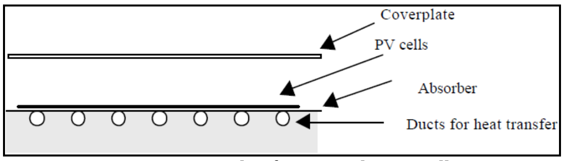

Fig. 4. Example of an Liquid-PVT collector

It is to presume that the operating temperature of the cell is at a higher temperature than a working fluid. In closed loop system, this heat is either exhausted or transferred at a heat exchanger. In open loop system this heat is used or exhausted before the fluid returns to PV cell [1]. Two types of advanced PVT liquid modules are-

- Uncovered PVT panels
- Covered PVT collectors

Fig. 5. Uncovered PV thermal panel seen at the front (left) and at the rear side

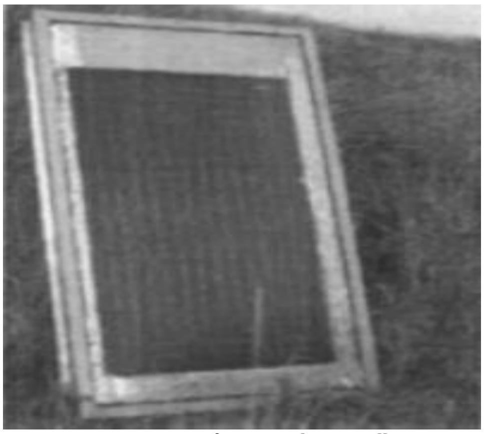

Fig. 6. Prototype of a covered PVT collector

3) *PVT integrated Heat Pump (PVT/Heat Pump):* This system is described as tap water heating system with the use of roof size PVT/w array combined with ground coupled heat pump. It was found that, the system is able to satisfy all the heating demand, while meeting nearly all of its electricity consumption and keeping the long-term average ground temperature constant [21-23].

The required investment is comparable to those of the conventional provisions but the PVT system requires less roof space and offers architectural uniformity. More recently, extensive analysis of the PVT/heat pump system with variable pump speed operation has been performed in China.

B. Concentrator Type PVT Collector System (c-PVT)

Combination of PV module with solar radiation concentration devices is the efficient method to reduce the system cost by replacing the expensive cell with a cheaper solar radiation concentration system [24]. Here a larger PV area is replaced by a cheap mirror area, and this will also reduce payback time. The use of concentrated type PVT is instead of flat plate type is able to increase in radiation intensity on the solar cell thus giving rise to higher efficiency, but this is possible only when PV module temperature is maintained as low as possible [25].

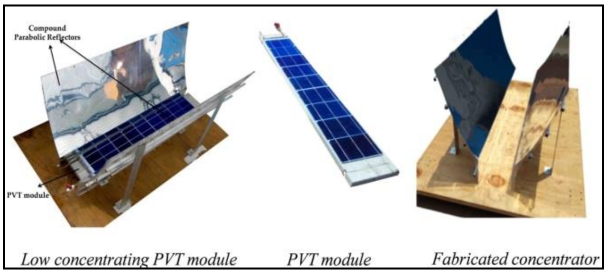

Fig. 7. Some Concentrator type PVT collector.

Reflective and refractive optical devices are used in concentrating solar system and are characterized by their concentration ratio (CR). Concentrating System with CR > 2.5, must use a system to track the sun, while for system with CR < 2.5, stationery devices are used [1]. The electrical output is affected by mainly two problems:

- Distribution of solar radiation on the absorber surface (PV module).
- Temperature rise of PV module.

The uniform distribution of the concentration solar radiation on PV surface and suitable cooling adds to an effective system operation and achievement of high electric output. Using “Liquid” as the coolant is more effective than using “Air” to obtain better electrical output [26, 27]. For these reasons, reflector type c/PVT system are common for medium/ to high temperature hot water system applicable for cooling, desalination, or other industrial processes [28].

III. PVT Research And Development So Far

The first systematic research into the possibilities of combining photovoltaic and solar thermal techniques was performed in the early 1980s by a group at MIT [29]. In this comprehensive study, several PVT designs were made and tested both air-type and water-type. The work was discontinued because of a change in government funding.

The PVT research regained attention in the mid 1990s with, amongst others, the PhD work of De Vries at the Eindhoven University of Technology [30]. He designed several PVT module concepts, of which one was realized and tested. A numerical model was developed calculating both electrical and thermal performance. The model predictions were found to agree with the experimental results [31].The work was continued with a development programme at the Energy research Centre of the Netherlands ECN [32]. In collaboration with industry and the EUT the thermal performance was further optimized and a production technology was developed [33]. Bakker investigated another PVT concept, a two-absorber module, at ECN [34].

In recent years, several other research groups worked on the topic of PVT. At the University of Patras in Greece, a broad range of PVT geometries for PVT panels were designed, built and tested [35]. PhD research on a PVT design with a concentrating reflector is being performed in Sweden [36]. In Norway, a concept is developed in which a plastic thermal absorber is used [37].

Generally speaking, the R&D efforts on the PVT collector systems in the first 25 years or so had been on improving the cost-performance ratio as compared to the solar thermal and PV systems working side by side. For real-building project applications, the PVT systems were more readily adopted in the European and North American markets though the higher efficiency of the PVT/w system has been confirmed. The contemporary issues related to the PVT technology, including the marketing potentials, were summarized in the expert reports of the working teams commissioned by the Swiss Federal Office [38, 39] and the IEA (International Energy Agency) [40]. An overview of the applications and development directions was also presented in Bazilian et al. [41].

IV. Conclusion

The performance of various PVT collector types had been studied theoretically, numerically and experimentally for more than three decades. Various researchers and professionals showed their work done on the possibility of generating electricity and heat energy from PVT system. In this article, we have reviewed various PVT systems. These collectors may be applied as building integrated elements. In further research, it is necessary to identify typical design for building integrated for different architectural requirement. PVT modules convert sunlight into electricity and heat simultaneously. There total efficiency is higher than sum of the efficiencies of solar PV and solar thermal system. In case of limited available roof area PVT offers a more cost-effective alternative. Moreover, through the higher combined yield PVT can contribute to the reduction in consumption of fossil fuel in the built environment in a more cost-effective way.

At the present level of activities globally, the number of commercially available character and systems are still very limited. Measure barriers like product reliability and cost remain to break-through. Collaborations have been underway among institution or countries, helping to identify suitable product material, manufacturing techniques, testing and training requirement etc. since PVT system has a much shorter economic payback period than the PV counterpart, PVT as a renewable energy technology is expected to first become competitive with the conventional power generation. Thus, the large scale introduction of PVT could help to achieve the international goals for PV and solar thermal installation in the future, at lower costs.

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