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Photovoltaic Thermal (PVT) Solar Panels

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***Abstract*— The turn towards alternative energy sources began quite a long time ago, depending on many factors such as the rapid depletion of fossil fuels, the desire to reduce external dependence on meeting energy needs, and a cleaner and greener energy supply. However, both the growing energy demand and population density necessitate the development of more compact systems that will produce more energy in less space, as well as the economic concerns of reducing energy unit costs, constitute a driving force for alternative energy systems to be more efficient in every respect. From the point of view of solar energy systems, it has made a rapid development in PV / T systems for increasing the total efficiency by combining solar cell and solar collector systems.**

In this study, it is aimed to give a general knowledge about solar energy systems and PV / T systems, working principles, advantages and disadvantages, recent developments and technologies.

***Index Terms*— Photovoltaic thermal collectors, PVT, solar cells, solar panels, hybrid solar systems.**

I. Introduction

It would not be wrong to argue that solar energy has even attracted attention of the early human. However, the use of this energy and the utilization rate have improved and improved in parallel with technology.

The global crises, which have been widespread in recent years, and the energy security issues that are affected by these crises are of interest to sustainable clean energy sources all over the world, as fossil fuel reserves are limited, each geography and / or country has its own resources and the negative effects on the environment have already aroused interest in renewable energy sources. Because clean energy is very important for a healthy future [1].

The total energy reaching the globe from the atmosphere is considerably higher than needed in the world, while the intensity of radiation at about 1370 W / m² outside the atmosphere varies from 0-1100 W / m2 due to reflections and reflections in the atmosphere. Solar energy, which is easily accessible on a clean and vast geographical area, is also prominent in terms of meeting a significant portion of the world's energy needs [2] and is at the top of the most studied topics.

Solar energy systems, compared to other energy installations, are advantageous for they;

- provide a noiseless working environment; create no unwanted wastes or harmful substances and cause no emission,
- offer high performance and reliability,
- are quiet credible for having and economic life span between 20 and 30 years.
- have low operating and maintenance costs

but they also;

- have non-uniform cooling and need an innovative absorber design,
- offer low yields and long payback time,
- have high production and installation costs,
- are not in proper shape and structure for integration with existing roof systems,
- require a large space for discrete installation which is not always possible

II. Solar Energy Systems and PVT

There are two basic systems for making use of solar energy; One is the solar cell (photovoltaic system) which generates electricity from the photon energy of the sun rays and the second, the solar panel (collector) systems which utilize the heat energy of solar rays [3] [4].

While the efficiency of PV modules have ascended to fairly good levels, there are some parameters that arise in real operating conditions and directly affect the payback time and initial investment cost of these systems. These parameters, which we generally refer to as sustainability parameters, such as surface temperature, dusting, radiation intensity and climatic conditions, becomes prominent in determination of the economy of this clean and infinite energy.

Among these parameters, the most effective and the most prominent is undoubtedly the temperature, due to the fact that excessively high temperature, as a result of continuous exposure to the solar radiation, either reduces open circuit voltage of the solar cells, or leads to accelerated degradation of solar cells incurred by thermal fatigue by overheating during exposure and cooling during the night or when there is no sun radiation.

As it is known, the sun light can be thought of as a stream of photons, each carrying a quantum of energy. It is also known that the solar spectrum has different photon energies at different wavelengths. The process of obtaining electric energy from solar energy takes place in accordance with the principles introduced by French physicist Edmond Becquerel in 1839. When electrons are removed from the valence band of the absorbing material upon collision of energy-bearing photon (Figure 1).

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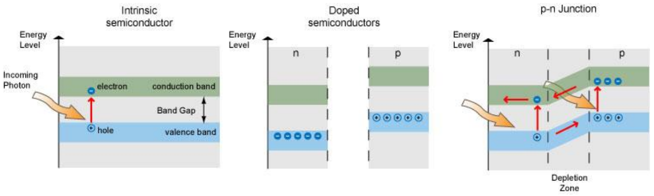

Figure 1 Electron excitation and the formation of electric current [5].

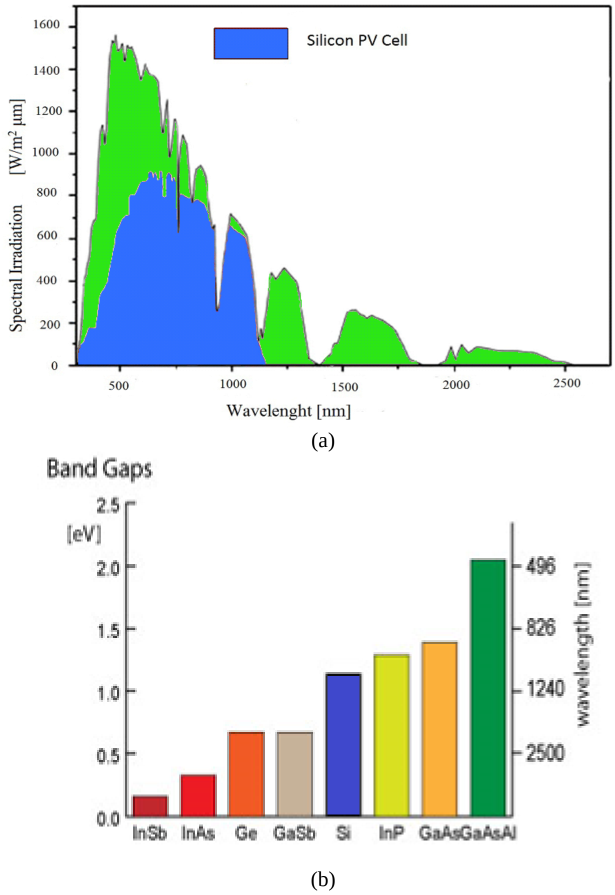

Figure 2 a) Band gap energies of solar cell materials and b) utilizable level of sunlight spectrum fort he Si sample [6].

As can be seen in Figure 2 (b), the band gaps of materials used in solar cells are of different values, and it is not possible for the valence band threshold energy to exactly coincide with the photon energies in the solar spectrum (Figure 2a). The portion of the photon energies that is higher than the band gap energy is wasted and converted into heat energy. This waste heat causes the solar cells to heat up and negatively affect electrical efficiency of the cells and reduce their lifetime due to thermal fatigue.

Although solar cells and solar collectors, with a wide application area, are used for different purposes, they are not inconsistent when compared in terms of installation and usage areas, market and end-user needs. Thus, the idea of obtaining both heat and electricity (PV / T) [7] from the same system by combining these two systems can’t be said to be new, but it is also true that it has generated limited interest for a long time so far.

Researches, especially focused on solar cells as a result of increasing interest in new and renewable energy sources and after the rapid growth of the solar energy market with a rate of 30% per year [8], have shown thermal fatigue and excessive cell temperature cause accelerated degradation of solar cells. The findings that suggest, by combining the solar cell and collector systems, both the collector efficiency can be directly increased and degradation of solar cells can be decelerated while their electrical yield is increased, have boosted the interest on hybrid systems which combines these two systems.

The fact that solar cells can convert only a small portion of the solar energy coming to the unit to electricity and the remaining accumulates as waste heat in the unit, hence decrease the efficiency of the system lie behind the idea of PV/T systems. With PV/T solar collectors, solar radiation is converted directly into both electricity and heat energy and thus combines the functions of a solar cell with flat plate solar collector [9].

III. PV/T Systems

Studies on PVT began in the mid-70s in the second half of the 20th century, and the primary goal was to increase PV yield [10]. The warming of the system increases the resistance in the electrical system and reduces the PV efficiency [11]. PV/T technology takes part of this waste heat to provide hot water or hot air for use in utility applications and cooling the photovoltaic system, leading to a reduction in the efficiency of the system [12]. Simultaneous cooling of the PV module maintains the electrical yield at a reasonable level, thus PV / T hybrid systems provide a greater advantage over total efficiency [13].

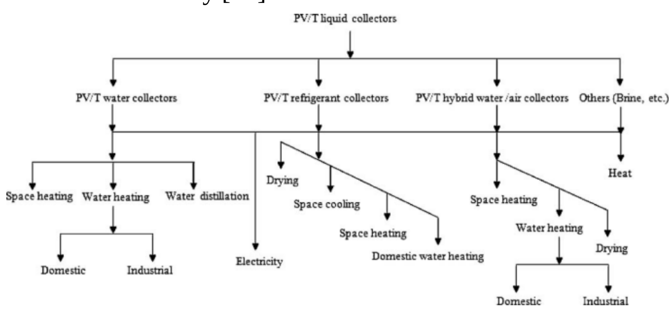

Figure 3 Classification and Implementation of PV/T systems [14].

Air, water and air-water hybrid systems have been used to cool the system or in other words to transfer out the heat energy away from the PV module.

While PVT-air systems are more developed, a rapid development in PVT-water systems has recently been recorded. Concentration on the water systems and the rapid progression in these systems can be attributed to the fact that the specific heat capacity of water is higher than that of air and the need to and usage areas of hot water are higher than air.

There are many alternatives for photovoltaic-thermal integration. Whether the cells are mono-crystal, polycrystalline, amorphous silicon (c-Si / pc-Si / a-Si) or thin-film, the cell being glazed or unglazed, circulation being natural or forced, the system being discrete or integrated are among options. Much of the research and development work on PVT technology has been carried out in the past few years, and gradual increase in practice has been observed.

Attractive features of PV/T systems [15] include but not limited to:

• Multi-purpose: Both the electricity and heat energy can be obtained from the same system;

• Flexible and efficient: Efficiency is higher than those of two systems when used separately. Also, when the roof area is unfavorable or limited, the integrated systems of the building are quite attractive;

• Has wide application area: The heat energy obtained can be used for heating and cooling depending on the season and is suitable for domestic applications;

• Inexpensive and convenient: Buildings can be added or integrated without the need to make major changes. Also, replacing roofing materials with PV / T systems can significantly shorten the cost-recovery period of the system.

The PV / T application of both cell types, which is more common in polycrystalline cell solar cells than in the polycrystalline solar cells, shows that PV / T application improves significantly in the case of the amorphous and polycrystalline silicon solar cells in the detection light [16].

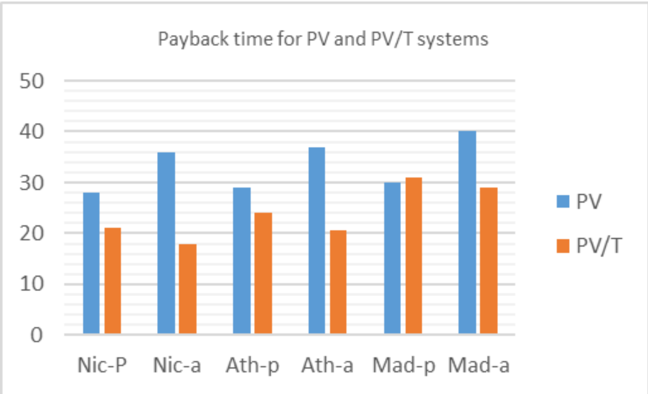

Figure 4 The payback times of amorphous (a) and polycrystalline (p) silicon solar batteries for flat PV systems and aqueous PV / T systems

When considered as a whole, PV / T panels are a good alternative for housing market with low energy consumption and promise the future [17]. Considering from a technological point of view, these systems are designed and developed for low-temperature applications because, considering that both systems are affected differently by the same parameter (temperature), it is seen that this is the only ideal working point for the systems and that this can be achieved for low temperatures [18].

IV. Types of PV/T Collectors

PV / T devices can show design changes for various applications. If you need solar collectors, the solar pacific market is growing very fast all over the world and it is quite a big moment at the moment. It is therefore not unreasonable to expect a similar growth for PV / T systems with proven feasibility and built-in application integration.

It is also very suitable for providing hot water for residences with glass covered PV / T collectors and is also suitable for preheating ambient air in winter months of other institutional buildings or business and shopping centers. At the same time, a natural ventilation force is created in these applications to provide air circulation and also a need for an air ventilation system.

Depending on the type and design of the PV unit, the type of fluid used to extract the heat energy, and whether solar radiation is collected or not, PV / T systems are available in a variety of configurations. Accordingly, PV / T products; Liquid flow PV / T collectors, air circulated PV / T collectors, and collective PV / T collectors.

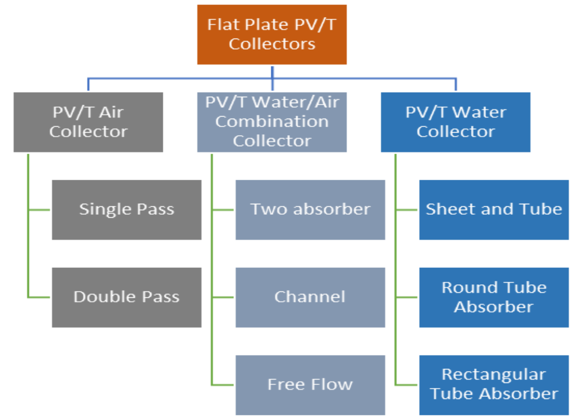

Figure 5 Classification of PV/T collectors [19].

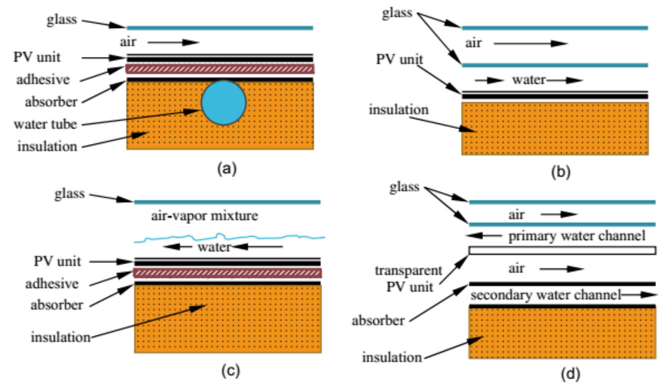

Figure 6 Structure of different types of PV/T collectors (a) sheet-and-tube PV/T, (b) channel PV/T, (c) free-flow PV/T and (d) two-absorber PV/T [20].

PV/T collectors are also more efficient than standard BIPV modules for being used in building envelope as integrated systems, and three pros that a PV/T system offers, listed below, are quite satisfying.

(i) protecting PV cells from overheating and reducing and/or eliminating excessive thermal load on PV cells lamination (EVA foil), hence decelerate degradation;

(ii) increasing electricity generation by maintaining a notably lower operation temperatures at all times;

(iii) providing higher specific energy gain compared to separate installation of PV and PT collectors, where low potential heat is usable in technical system of the building [21].

V. Conclusion

PV/T systems may be utilized in many applications in various fields such as space heating, domestic and industrial water heating, distillation of water and drying as well as electricity generation. As the thermal collector integration also provides simultaneous cooling of the PV system during electricity generation, it enables the efficiency of the system to be increased as compared to conventional methods. This study provides information on PV panels and thermal collectors, which are the main components of PV/T systems, and discusses the advantages of the system.

Researches have shown that any type of photovoltaic-thermal combination, regardless of whether single fluid or a combination of fluids are used, have increased both the overall efficiency of the system and electrical yield from the PV module by reducing electrical resistance thanks to the cooling the thermal unit provides.

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