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PHOTOVOLTAIC THERMAL SYSTEMS – DESIGN AND BUILDING APPLICATION

Ivana Terzic[1], Danijela Nikolic[2], Vanja Sustersic[3], Jasmina Skerlic[4], Vladimir Vukasinovic[5]

Summary: *Within the solar energy technologies, the hybrid photovoltaic-thermal (PV-t) systems provide an appropriate option for the production of thermal and electrical energy, as the absorbed solar radiation is converted into the thermal energy and electricity.*
The aim of this paper is to review, present and evaluate the suitability of using hybrid PV-t solar systems for the supply of electricity and thermal energy in households (space heating is not considered). Special emphasis is placed on the design of the PV-t system as well as on their division. Great attention has been paid to PV-t systems based on water.
The review examined various articles with the proposed design of PV-t collectors and absorbers. The paper is presented the possibilities of using solar PV-t system in the buildings.
Key words: photovoltaic thermal (PV-t) collector, thermal energy, electricity, efficiency, building

1. INTRODUCTION

It is known that the use of solar energy requires converting it into different types of energy (electricity, heat). The conversion of solar energy into heat and electricity provides the opportunity to use more than 90% of the energy used in the power supply.

Solar energy can be classified into two areas of study: solar thermal systems, where solar radiation is converted into heat, and photovoltaic (PV) systems, where solar energy is converted into electricity.

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PV-t is a hybrid technology that combine PV and solar thermal components into a single module to enhance the solar conversion efficiency of the module and make economic use of the space. During the seventies of the last century, a first step was made to merge solar thermal and photovoltaic systems into one model, known as Photovoltaic Thermal Solar System (PV-t) or Hybrid Solar Systems. The general concept of the PV-t was originally developed by Kern and Russell in 1978 [1].

A PV-t module is basically constructed as a combined functions of a flat-plate solar (thermal) collector and photovoltaic panel and it simultaneously generate electricity and heat, and therefore takes advantages of both PV and solar thermal technologies. The dual functions of the PV-t result in a higher overall solar conversion rate than that of solely PV or solar collector, and thus enable a more effective use of solar energy [1].

In this paper, an overview of the possibility of using the PV-t system in the building industry was carried out.

2. PHOTOVOLTAIC THERMAL (PV-t) SOLAR SYSTEMS

The energy conversion in PV-t systems (electrical and thermal energy) is achieved when the PV panel (which converts solar radiation into electricity) functions as an absorber of the thermal collector [2]. When temperature increases, electrical efficiency decreases. However, in these systems, this is regulated by the removal of excess heat through solar cells, which establishes cooling in PV cells, and consequently increases the efficiency of the system [3]. Figure 1 shows the PV-t scheme for the production of electricity and heat. The electricity flows into an inverter for use in the building or export to the grid according to a standard PV configuration. The temperature is regulated through a control sensor and the coolant is transferred using a pump to a heat exchanger which heats water in a storage tank for use in DHW and heating systems.

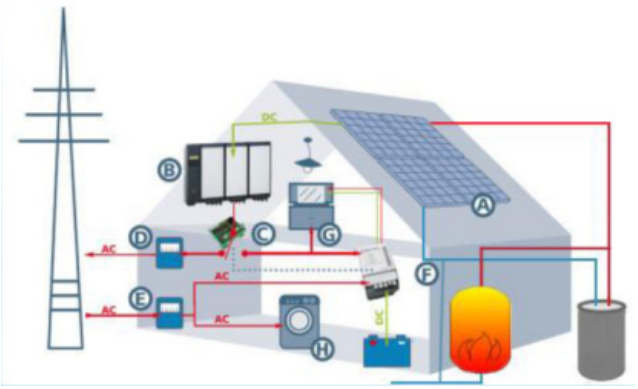

Fig. 1 *PV-t scheme for the production of electricity and heat energy* [2]

Figure 2 shows the cross-section of an glazed PV-t collector, with solar thermal and photovoltaic component. This type of hybrid solar system is used typical and it is covered with transparent glass. A typical PV-t module is a inserted structure consisting of several layers.

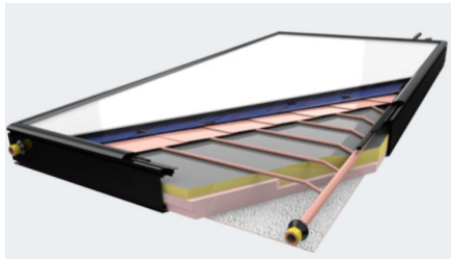

Fig. 2 *Photovoltaic thermal cross-section* [2]

Figure 3 shows the basic structure of the hybrid PV-t collector. The PV-t system consists mainly of: a transparent cover (glass), an air gap, a mono-crystalline (c-Si) PV module, an EVA encapsulating film, an absorber–exchanger which transforms the solar radiation to heat and transfers it to the collector fluid, and a layer of insulation material at the bottom [4].

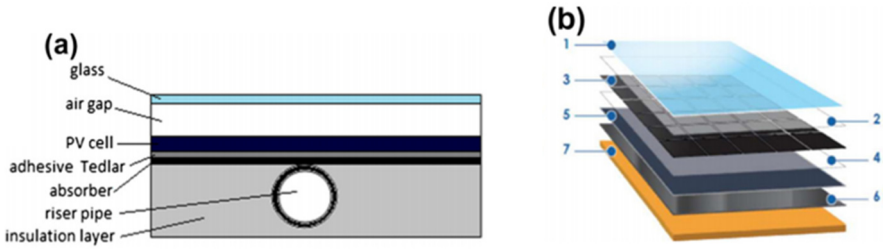

Fig. 3 *Construction of a PV-t: a) PV-t collector cross-section, b) PV-t layers* [4]

PV-t systems, based on the working fluid, can be categorized into:

- Water-based PV-t systems and
- Air-based PV-t systems.

2.1 WATER TYPE SOLAR PV-t SYSTEM

For these types of systems, the heat transfer fluid is water. Appropriate channels take the collected amount of heat from the absorber.The constructive solution of the channel performance in the absorber affects the efficiency of the system, so that they can be connected either in series or in parallel, while the circulation of heat transfer fluids can be achieved either by the pump system or by the difference in the specific gravity of the heat transfer fluid (gravity system). Figure 4 presents the flow-through channels of the PV-t collector on the water basis, and Figure 4 is a schematic representation of the PV-t system for the production of the electricity and thermal energy (heat).

The PV-t-water model is more efficient due to its better thermophysical characteristics compared to the air model, and further research in this paper is based on water PV-t systems [5].

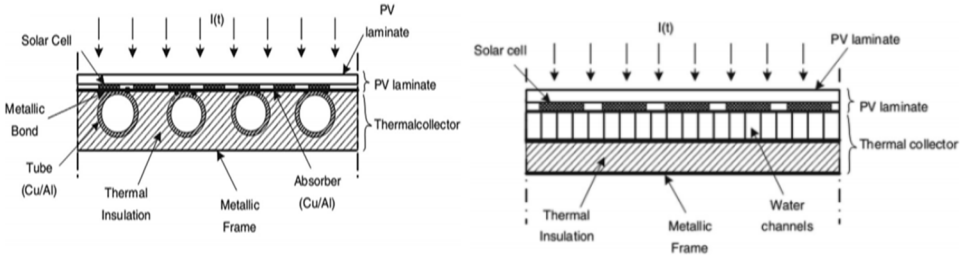

Fig. 4 *A typical water PV-t collector* [6]

2.2 APPLICATION OF PV-t SYSTEMS IN BUILDINGS

PV-t systems can greatly contribute to the reduction of fossil fuel energy consumption especially in buildings, where the available surfaces are often limited, on the other hand, with a great need for electrical and thermal energy.

Figure 5 presents the possibilities of applying the PV-t system in the building, where the roof modules of the PV-t system are applied. A significant improvement in electrical and thermal effects is achieved by Zhao [7] using innovative PV-t system designs as the roof module. It is an electrical generator of the roof element and a heat pump heat exchanger which can achieve a significant increase in electrical and thermal efficiency. In the figure 5.a. is presented the intention for construction of a building energy system based on advanced new type of heat pump, while using a unique PV-t solar collector provides both - electricity and heat. This is the EU's largest research and innovation program and a receipt for maintaining high quality.

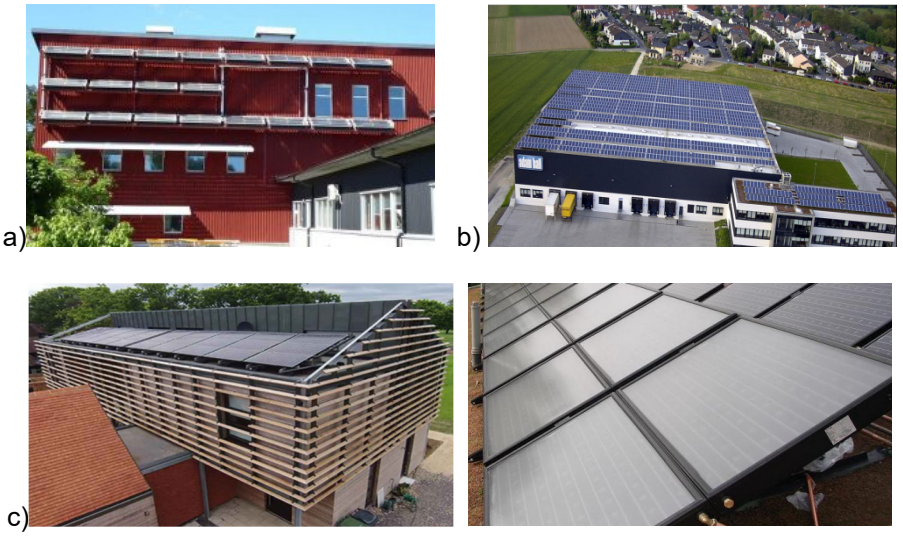

Fig. 5 *Examples of the application of the PV-t system in the buildings: a) An installation of 20 PV-t collectors from Solarus at Gävle University (HiG)* [8]*; b) Large commercial flattop system; c) Solar PV-t Project (Hawkes Architecture) with roof-mounted 6kW PVT system [9]*

This project (Fig. 5 c), designed by Hawkes Architecture, uses a roof-mounted 6kW PVT system to harness solar energy as electricity and heat [9].

The PV-t demonstration plant (fig. 6 a) was set up in the neighbourhood of Oberfeld, a sustainable and car-free housing area in the town of Ostermundigen, near the Swiss city of Bern. A reference PV system had been installed on the roof next to the PV-t one and had also been connected to an independent inverter. During the first year in operation, both PV installations produced the same number of kilowatt-hours, which means that there was no cooling effect from the thermal absorber in the back of the PV-t element. The PV-t system generated 163.3 kWh/m² and the reference system provided 162.4 kWh/m², resulting in a module efficiency of 13 % [10].

a)  b) 

Fig. 6 *PV-t System: a) Swiss multi-family housing area; b) Solimpeks PV-t system*

Solar panel manufacturer Solimpeks (fig. 6 b) is offering a hybrid solar panel that is capable of providing both electricity and water heating from the same panel. The panels are ideal for applications where there is limited roof space available, but both solar electricity and solar hot water are desired. Even better, the combination of the two functions actually improves the efficiency of the electrical generation of the photovoltaics [11].

3. CONCLUSION

The application of the PV-t system in the building allows the simultaneously production of electric and thermal energy by exploiting solar radiation.

The potential of solar radiation in the Republic of Serbia is around 0.64 million toe per year. With the assumption of a plan, about 10 600 000 m^2 of area could be used for the potential production of these two types of energy. That means that each household has PV-t system with area of 4 m^2, which is sufficient for partially energy needs of every individual residential building.

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