Experimental evaluation of the efficiency of Photovoltaic / Thermal (PV/T) modules integrated in the built environment

Macedon Moldovan [a*], Ion Visa [a], Anca Duta [a]

[a] Transilvania University of Brasov, R&D Centre: Renewable Energy Systems and Recycling, 29 Eroilor Bd., 500036 Brasov, Romania

Abstract: In the built environment, solar energy is largely converted into thermal energy (mainly for domestic hot water) and, with lower efficiencies into electrical energy. However, the low density of the solar energy imposes large implementation surfaces which can be a main barrier when specific renewable energy systems are to be implemented. Thus, the available area has to be intensively used and one option is represented by Photovoltaic/Thermal (PV/T) modules which produce both electrical and thermal energy. The paper presents the results obtained during outdoor testing of two monocrystalline Si PV/T modules. The results (for a reference area of 1 m^2) are comparatively discussed with those obtained using a monocrystalline Si PV module.

1. Introduction

The energy demand in the built environment can be as high as 40% in developed countries. To diminish the fossil fuel consumption and related greenhouse gases emissions, renewable energy systems should be implemented at the building level as distributed sources of green energy. Solar energy is one of the most easy to convert source of renewable energy at the building level. Though, due to its low density, large surfaces are needed to install photovoltaic modules and/or solar thermal collectors when a high renewable energy share is targeted. During the last years, several investigations have been conducted, revealing that the output of both electricity and heat of PV/T based systems is recommended in the building sector, especially when the available area for installation is limited and a uniform architectural appearance is required (Yang, 2016) and also for their advantages from the environmental point of view (Lamnatou, 2017).

2. Theory

The PV/T module can be analysed as a photovoltaic module having a heat exchanger mounted at its rear surface. Thus, the overall specific output (q_u) of the PV/T module is obtained summing its electrical (q_{el}) and thermal (q_{th}) specific output

$$q_u = q_{el} + q_{th} = \frac{U_{PVT} I_{PVT}}{A_{PVT}} + \frac{\dot{m} c_p (T_o - T_i)}{A_{PVT}} \qquad \text{Eq. (1)}$$

where U_{PVT} and I_{PVT} are the voltage and the current measured at the PV/T module terminals, A_{PVT} is the active area of the PV/T module, $\dot{m}$ is the fluid mass flow through the heat exchanger, c_p is the specific heat of the fluid in the heat exchanger, and T_o and T_i are the PV/T module outlet and inlet temperatures.

* Corresponding author. Tel.: +40 740 300 804.
E-mail address: macedon.moldovan@unitbv.ro.

3. Results

The experimental PV/T system (Fig.1) is installed on the rooftop of the RESREC laboratory and consists of two identical PV/T modules, serially or parallely connected to a 140 liters storage tank. The inlet, outlet and absorber temperatures of the PV/T modules are measured, along with the mass flows to evaluate theirs thermal output. Electrical parameters (current and voltage) are separately monitored throughout Solar Edge power optimizers, to evaluate the power output of both PV/T and PV modules, all tilted at 40°. The direct, global horizontal and diffuse horizontal solar irradiance are measured with a Solys 2 Sun Tracker equipped with high accuracy instruments, needed to evaluate the global irradiance incident on the modules. The daily overall (thermal and electric) output of the PV/T modules is plotted against the PV module output in Fig.1 along with the incident global solar irradiance.

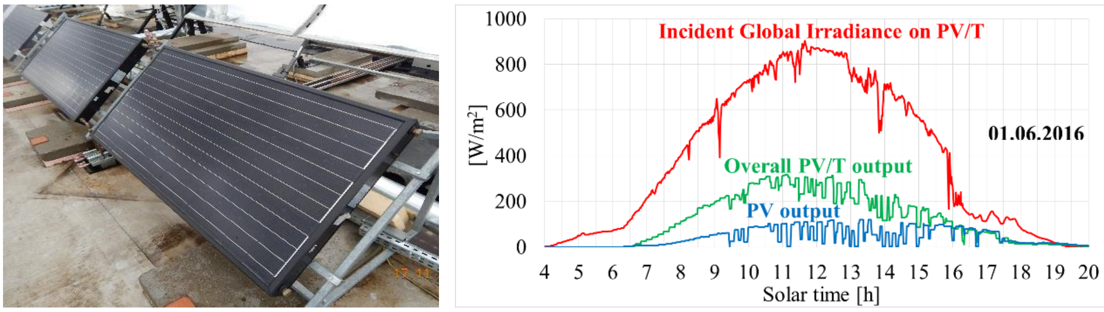

Fig. 1 Experimental PV/T system and infield results

4. Conclusions

The results show that the overall conversion efficiency (thus overall thermal and electric energy output) is higher than of the PV, and is significantly depending on the irradiance input and slightly influenced by the inlet temperature in the PV/T. Additionally, beyond the energy recuperating role of the "T" component in the PV/T, these systems are delivering a thermal output that can be directly used without any further conversion (e.g. for domestic hot water, DHW). Thus, for a given suitably oriented area of a building, PV/T can be installed correlated with the DHW demand and further available area (on the terraces, roofs or facades) can be filled with regular PVs allowing a high degree of coverage available for solar energy conversion.

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References
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