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Energy Procedia 74 (2015) 835 – 843

Energy Procedia

International Conference on Technologies and Materials for Renewable Energy, Environment and Sustainability, TMREES15

Analysis of a Hybrid Solar Collector Photovoltaic Thermal (PVT)

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Abstract

A solar hybrid photovoltaic thermal (PVT) is a set of combined solar collector, which consists of a photovoltaic module (PV) for the conversion of electrical energy and solar plan for the high efficiency thermal energy conversion, in the same frame.
An attempt made to analyze the hybrid solar collector using Computational Fluid Dynamics (CFD) to simulate the PVT solar collector to a better understanding of heat transfer capabilities in this type of systems. In the present work, the fluid flow and heat transfer in the module are studied using the ANSYS14 software. The heat transfer phenomenon conjugate between the photovoltaic cells and the coolant is modeled using the FLUENT software. The transfer of heat by the solar radiation is not modeled; however, the effects of radiation are taken for consideration when calculating the conditions for heat flux limit for the collector region. The geometric model and fluid domain for the CFD analysis is generated using ANSYS software DesingModeler, mesh geometry is carried out by ANSYS Meshing Software.

Peer-review under responsibility of the Euro-Mediterranean Institute for Sustainable Development (EUMISD)

*Keywords:*Solar Collector, Combined Heat Transfer, Simulation ANSYS, FLUENT

1. Introduction

A hybrid energy system is a system that uses two or more power sources in order to maximize the overall efficiency. A typical hybrid system in the building is the photovoltaic / thermal (PV/T). Conventional photovoltaic systems use only the photons from light to generate a current and heat from solar radiation tends to increase the temperature of photovoltaic modules and reduce its effectiveness. Against by the PV/T systems use not only light but also the thermal energy generated by solar radiation, the extraction of energy via a heat transfer fluid at the same time allows for space heating, cool the photovoltaic panels and increase yield.

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doi:10.1016/j.egypro.2015.07.819

More work is done on this type of hybrid systems Zondaget al. [1] numerically investigated the behavior of PV/T. To her, they compared the results obtained by a dynamic three-dimensional model and those obtained by the other three fixed models (1D, 2D, 3D). The numerical results were also confirmed experimentally, where a maximum error of 5% was observed.

Chow [2] proposed an explicit dynamic model. He has studied the effect of certain parameters, such as mass flow rate and the heat transfer coefficients by conduction between the absorber and the photovoltaic cell PV on the thermal and electrical efficiency.

Bhattarai et al. [3] compared a solar thermal system with a conventional solar system, numerically and experimentally. They found that the effectiveness of primary energy savings of PV/T collector is greater than that of a conventional solar system.

Dupeyratet al. [4] conducted an experimental study to improve PV/T collector thermal properties. The results showed an overall efficiency of the PV/T collector above 87% (as 79% thermal efficiency and electrical efficiency as 8.7%).

Touafek et al. [5] conducted an experimental study of a PV/T system and a conventional PV. They observed an improvement in the electrical efficiency of the PV collector due to the presence of the thermal system. They have also shown that the thermal efficiency of PV/T could be improved by adding glazing however, the electrical efficiency decreases in this case. Therefore, a compromise between the two yields should be found.

We will focus in this study to air PV/T systems; these systems use air as coolant.

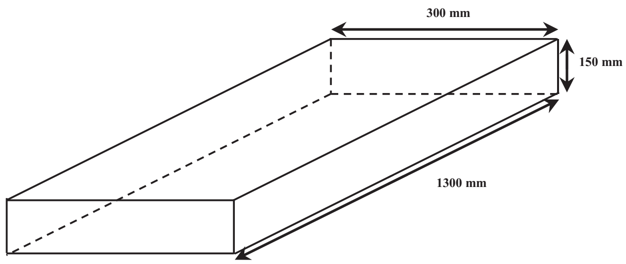

Fig .1 Dimensions of the PVT system

The hybrid collector PVT air consists primarily of single crystal silicon photovoltaic module and device for the discharge from the heat of the air stream produced by the conversion of solar radiation by the module.
The heated airflow also serves to cool the module and thus increase its electric performance. Several studies have been conducted by research teams around the world is recent years on the air hybrid collectors.
Ebrahim Ali alfegi et al [7]: presents an experimental study on the influence of mass flow (from 0.0316 to 0.09 kg/s) on the performance of the PVT system, Where the PV cell glued directly on the absorber with their fins attached to the rear. The effect of mass flow rate on yield (electrical, thermal, and overall) to solar radiation of 400 W/m^2 and an air inlet temperature of 30 °C, The electrical efficiency varies from 10.50 to 12.09%, the thermal efficiency varies from 17 to 26.433% and the overall efficiency ranges from 27.50 to 40.044 %. It was observed that the higher mass flow rates increase the efficiency of the PVT system. It is therefore important integrated fins on the rear surface of the absorber to significant savings for thermal and electrical output of the PVT. Goh Jin Li et al [8] presents an experimental study on PVT with one pass of the air tunnel with a rectangular geometry as a coolant. The PVT was tested with and without air rectangular tunnel PVT Solar System in a single pass. Solar radiation is set to (385.2 and 817.4 W / m^2) and the mass flow rate of air game (0.0110, 0.0287, 0.0409, 0.0552 and 0.0754 kg/sec) at room temperature of 25 ° C. the power efficiency, thermal, and throughout the PVT system was 10.02%, 54.70% and 64.72% in solar radiation 817.4 W / m^2, mass flow 0.0287 kg/sec was obtained. Adnan Ibrahim et al [9] presented a ranking of PV/T collector with a flat plate, the design and performance evaluation of these water systems, air and the combination of water and air on the base. The design of the tube sheet and is the simplest and easiest to make, even if the yield is 2% lower compared to other types of sensors such as the channel, free movement and two-absorber.
Ionuţ - Răzvan Caluianu et al [10] using the thermal model of a PV module developed and validated experimentally,

the temperature profile and the velocity of the air at the outlet section was studied. The simulation is performed with the application of the finite element method Galerkin to flow and of the energy equation, as the channel width increases (10, 20, 30 mm); the average temperature of the air to the outlet section varies from 30 ° C to 50 ° C.

2. Numerical Approach

ANSYS software (version 14.0) was used to perform all the simulations and used to develop the model geometry; that it is shown in Figure 1. In the region above the cell, the left side of the field was defined as the input speed with a determined flow speed and approaches the right side of the domain has been defined as the outlet pressure at zero relative pressure. The cells were fixed to a wall with thickness of 0.0003 m. The bottom of the cavity is defined as Air (were used thermos-physical parameters for an incompressible real gas) with a specified speed. The left and right side of the cavity was defined as adiabatic walls. A symmetry boundary condition was used for all the other sides, which means a zero velocity and temperature gradient. The thickness is 0.15 m, 0.3 wide and 1.3 lengths to give the real dimensions of existence hybrid solar collector.

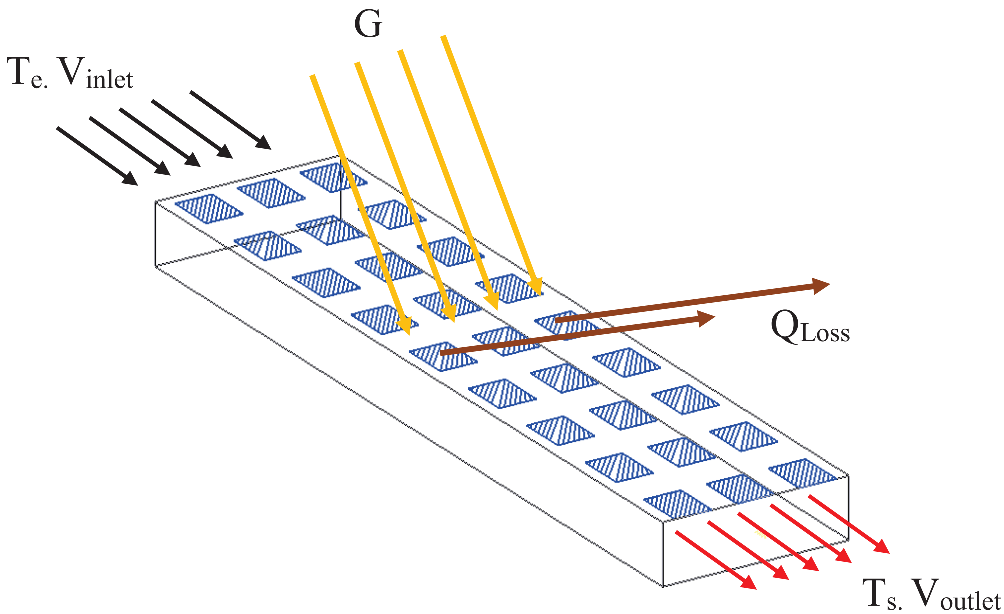

Fig .2 Presentation of the PVT system

3. Numerical Schema

The equations are solved for the conservation of the volume control to produce the velocity field and temperature of the airflow in the field and temperature PV photovoltaic cells. Convergence is performed when all the residues tend to below $1.0E^{-6}$ in the computational domain. The geometric model and the domain of the fluid is generated using a software ANSYS14 (Figure 2), the generation of gate is carried out by ANSYS Meshing Software, A three-dimensional computational domain, the mesh of this geometry with this software commonly depicted in Figure 4. The test of the independence of the grid is performed to check the validity of the mesh quality and refinement of the solution, which is taken here as a quality suitable mesh for the calculation.

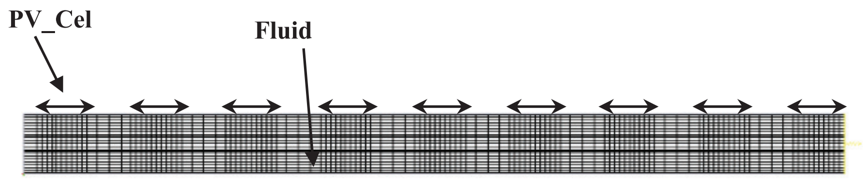

Fig .3 The Domain Mesh

4. Conditions and operating parameter

As the flow is turbulent, the k-ε turbulent model is chosen as a model for a thorough analysis of the problem. No slip condition is applied to all the "walls". The physical aspects of the flow of liquids are governed by the fundamental principles: continuity equation (mass conservation), energy conservation equation.
To solve these equations, the under-relaxation factors are used:

- A mass flow rate of flow corresponding to 0.025 kg/s
- The air temperature at the entrance Te = 298.15 K
- The output pressure: Ps = Patm

The material used for both the absorber plate and the tube is copper; The input parameters used in the analysis are shown in Table 1

Table 1. The values used during simulation.

	Air Proprieties	Cell Proprieties
Density	1.225 kg/m^3	2330
Thermal Conductivity	0.02 W/m K	131
Heat Capacity	1006.43	700
G W/m^2	500/1000	
V wind m/s	1	

5. Results and Discussion

The first simulation is performed on a rectangular area which is composed of photovoltaic cells on the outside and air as heat transfer fluid. In this case, the value of the temperature of solar cells is decreased due to heat transfer by convection between them and the heat transfer fluid.

Moreover, the distribution of the temperature and the flow are obtained by ANSYS simulation. The curves obtained for the temperature distribution are shown subsequently.

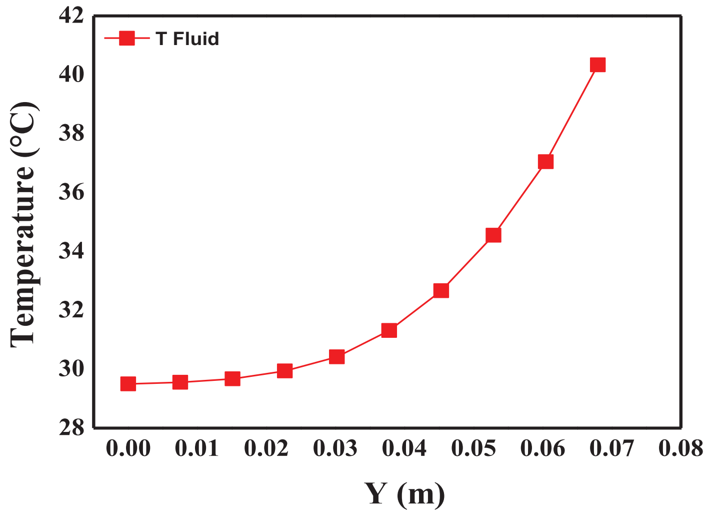

Fig .4 Evolution of the fluid temperature

With radiation and ambient temperature data used in this model PVT hybrid Collector, The results are shown in Figures 4, 5 and 6.

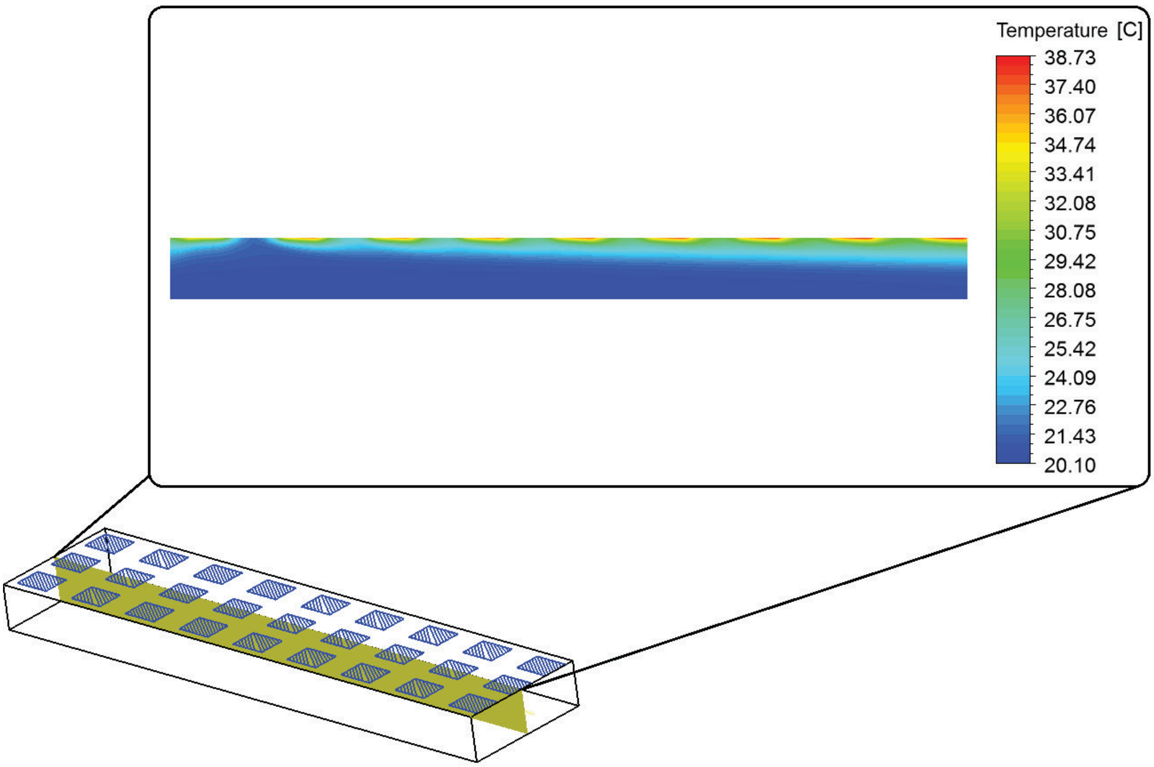

Fig.5 Vertical section of the temperature field in the center of PVT collector

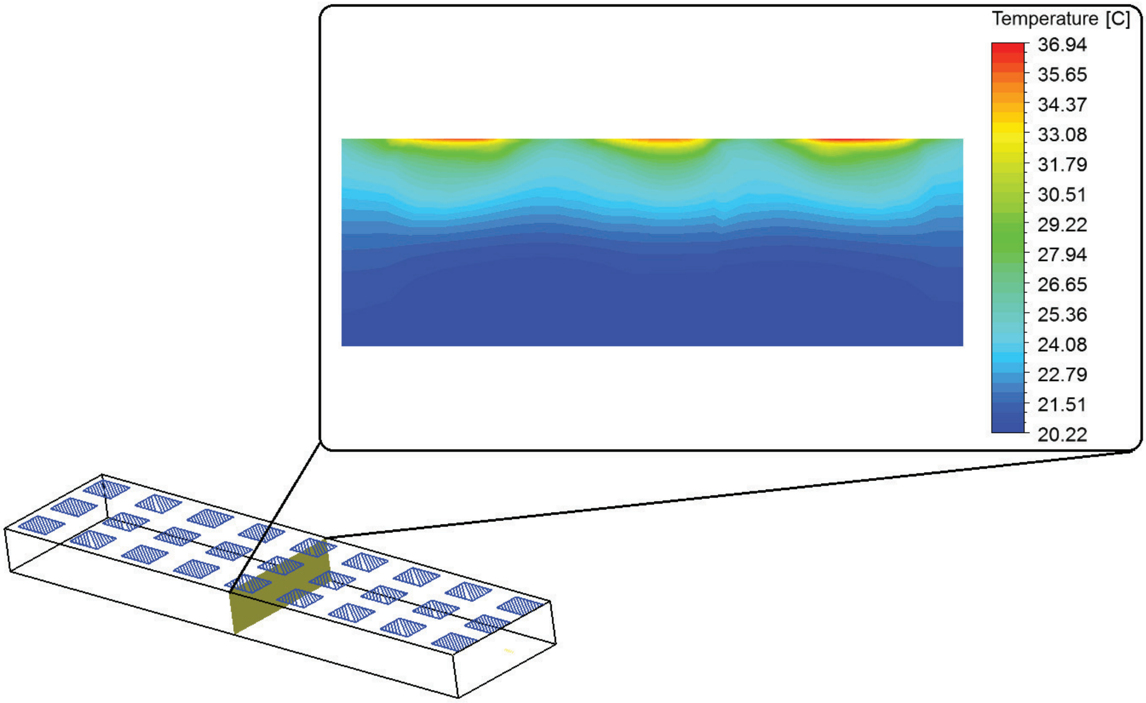

Fig .6 Temperature distribution along the width of the PVT

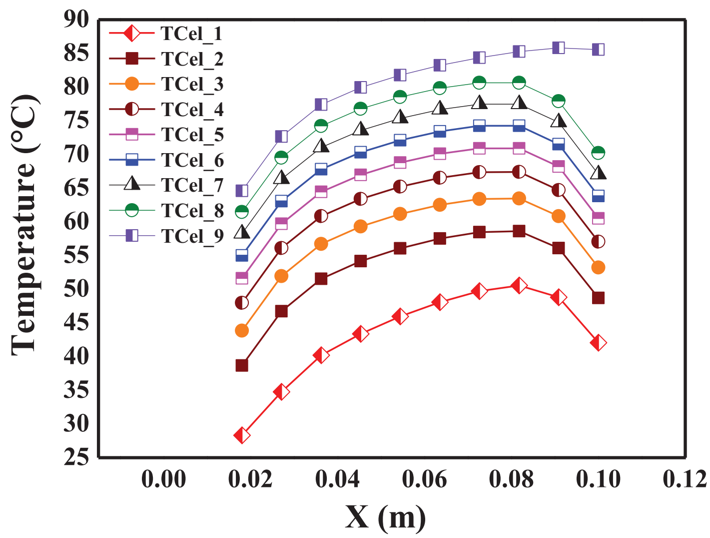

Fig .7 Evolution of the temperature in the cells of PVT

The fluid temperature shows a variation of 20 to 40 ° C (Figures 6. 7) between the inlet and the fluid outlet, which obtain a higher temperature to the lower layers of the PV cells, which led to a cooling of the photovoltaic module in general by thermal effects.

Figures 8, 9 and 10 respectively show the fluid temperature profiles simulated volume of the hybrid solar collector for solar radiation incident given value of 500 W / m^2 to 1000 W / m^2. It is clear that the difference of the maximum temperature value at 35 ° C, which shows a highly significant effect of radiation on the cell of the heating by the Joule effect.

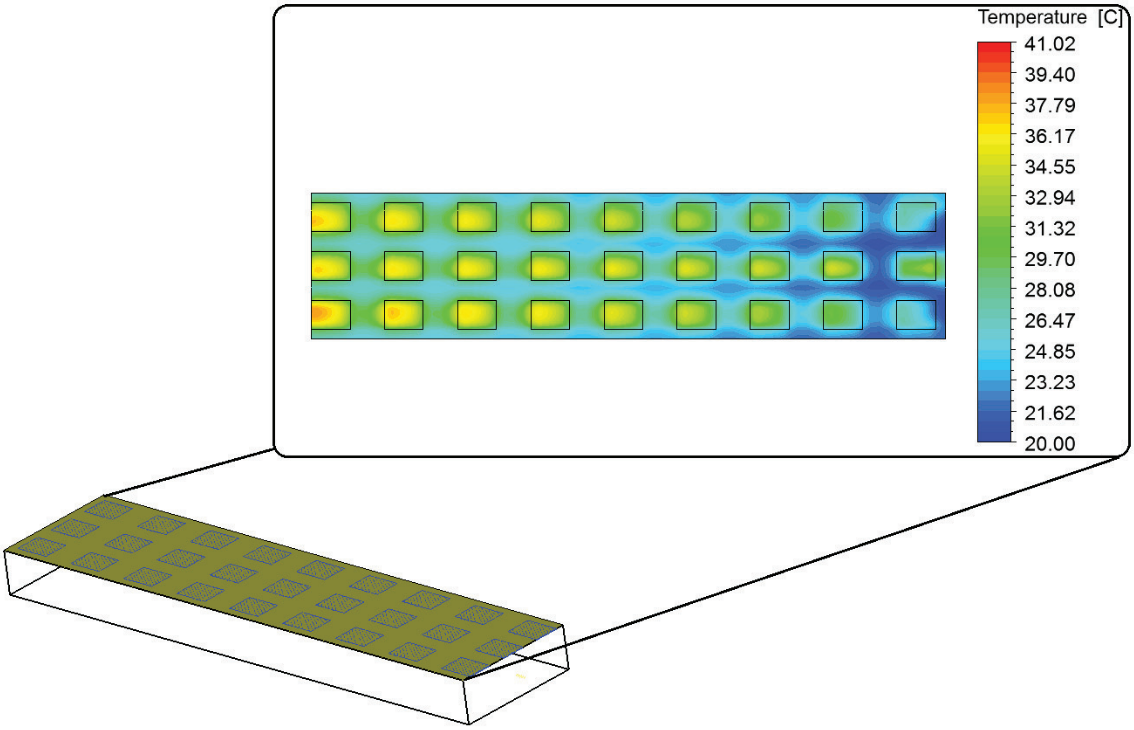

Fig .8 Top section temperature distributions

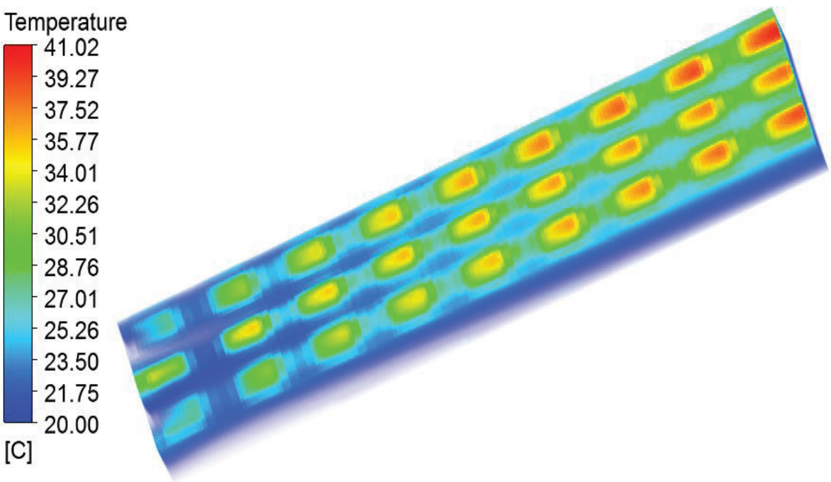

Fig .9 Temperature distributions in the PVT 3D

There is also an increase in the cell temperature that advance along the PVT collector, that is to say the input to the output of the heat transfer fluid. This is mainly due to the fluid inlet with a low temperature and extract heat energy from the cells, the average temperature from 20 ° C upstream (input) at 40 ° C downstream (outlet) of collector.

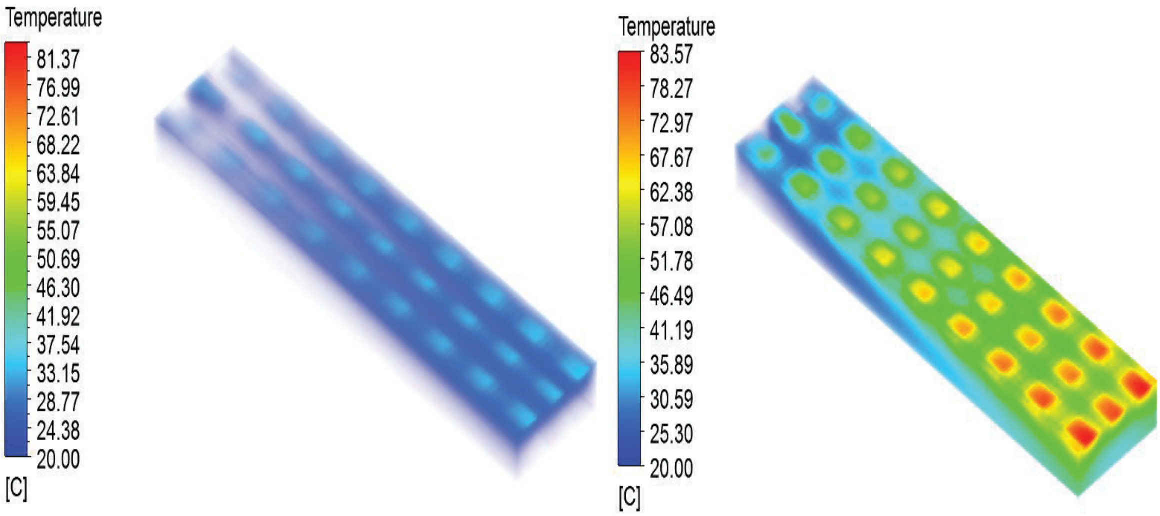

Fig 10. Distribution of PVT module C according to the G

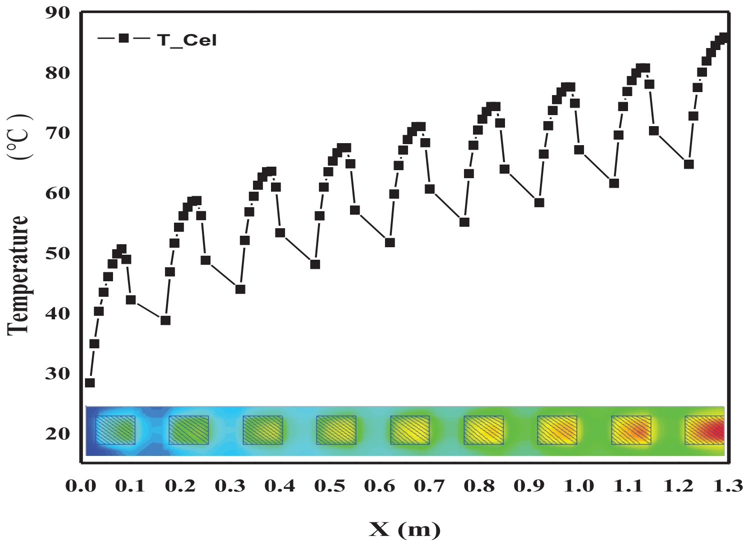

Fig 11. Evolution of temperature in each cell of the PVT modulus versus X

6. Conclusion

The installation of thermal equipment and photovoltaic solar systems are increasingly rapidly due to the growing demand for electricity and heat. In the last decade, the performance of the PVT system was studied theoretically, numerically.

The study used to provide design and simulation data for this type of hybrid solar collector Photovoltaic thermal air. Several climatic parameter such as global radiation and wind speed also affects the performance of its types of systems.

This study presents the heat transfer performance in a hybrid photovoltaic thermal solar collector from experimental data. The calculated coolant temperature are similar to the experimental results that are preceded already made.

It is observed that cell temperature is lower resulting in a significant increase in the electrical performance of the system such as electrical and thermal efficiency.

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