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Study of a Thermal Storage System Through Latent Heat With Phase Change: Application to the Cooling of a Photovoltaic Sensor

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ABSTRACT

Thermal storage holds immense importance across various domains due to its numerous advantages in managing industrial processes. One notable challenge in photovoltaic sensors lies in the elevated temperatures of their cells during intense sunlight, resulting in reduced efficiency. To address this issue, a passive system incorporating a Phase Change Material (PCM) has been implemented to capture and dissipate this heat. The study of the PV/PCM system was conducted using COMSOL Multiphysics software. However, a primary focus was on identifying and controlling diverse parameters, both physical and geometrical, to achieve a well-optimized model, with a specific emphasis on improving thermal efficiency. As a result, there is a pressing need to develop efficient systems for heat collection during periods of high irradiance.

Keywords: Photovoltaics; PCM; Solar energy; Passive cooling; Numerical modelling.

1. Introduction

Conduction and thermal convection are among the heat transfer modes that hold significance in both fundamental research and practical applications, such as heating and air conditioning in homes, cooling in thermosiphons, mechanical or electronic systems, fluid (air or water) heating systems involving solar panels, drying of agro-food products, heat exchangers, and agricultural greenhouses [1]. Given the depletion of conventional energy sources and their negative impact on humans and the environment, it becomes imperative to utilize clean, non-polluting, and renewable energy sources. Renewable energies can be classified into three major categories: mechanical energy (wave, wind), electrical energy (photovoltaic panels), or energy in the form of heat (geothermal, solar thermal, etc.). It is noteworthy that, at the root of all these energies, is the energy from the sun, subsequently transformed by the terrestrial environment, and solar radiation remains the most abundant energy resource on Earth [2] [3]. Solar energy has undergone significant developments day by day, leading to the use of solar collectors as solar energy converters, thereby emphasizing the need to study these systems for optimization and further development of clean and greenhouse gas-free renewable energy sources. The photovoltaic solar conversion process generates heat, which increases the temperature of the photovoltaic cell and causes a drop in its efficiency. This phenomenon results from the portion of solar radiation not absorbed by the cells, contributing to their heating [4]. When a pure material undergoes fusion, transitioning from the solid to the liquid state, regardless of the temperature of the heat source causing this phase change, the temperature of the melting front remains constant throughout the fusion process. This characteristic can be exploited for cooling solar panels by placing a container filled with a phase change material (PCM) behind the panel.

This study presents an investigation into the thermal transfers occurring during the fusion of a phase change material (PCM) and the dynamics of its fusion. The PCM is contained in an enclosure where one vertical wall is subjected to a heat flux (imposed temperature). The heat sink thus formed can act as a cooler for photovoltaic cells (heat sources) by storing, in the PCM, both sensible and latent heat dissipated by the solar panel. The proposed cooling system dissipates the power generated by the heat source by storing it in the PCM. This stored heat is then transferred within the PCM.

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2. Experimental

The COMSOL Multiphysics software is employed to model the thermal transfer within a container filled with PCM. Figure. 1 depicts the geometry of the investigated test cell, a modular structure representing a solar panel coupled with an PCM layer positioned inside a cavity. The PCM container is a box with dimensions of 58 cm in height, 61 cm in width, and 3 cm in thickness. Heat transfer in the PV/PCM system is assumed to involve both conduction and convection, treating the melted PCM as an incompressible fluid. The two-dimensional rectangular cavity containing the PCM is thermally insulated on all faces except the front, which is connected to the rear face of the panel, receiving heat from it. The PCM employed in this study is n-octadecane paraffin ($C_{18}H_{38}$), and its thermo-physical properties are 27-28 °C of solid_liquid temperatures and 241 KJ/Kg of latent heat enthalpy.

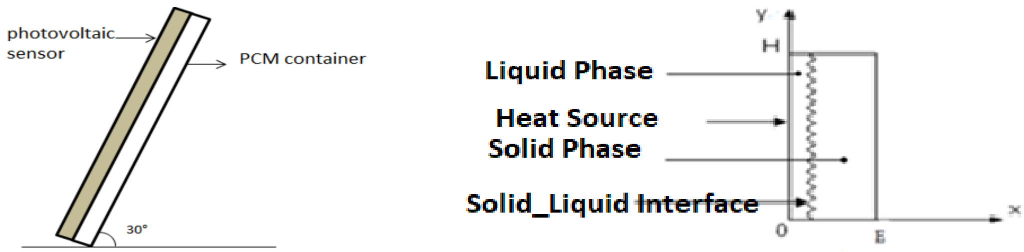

Figure 1: Physical model and representation of the beginning of the PCM melting process

3. Results and Discussion

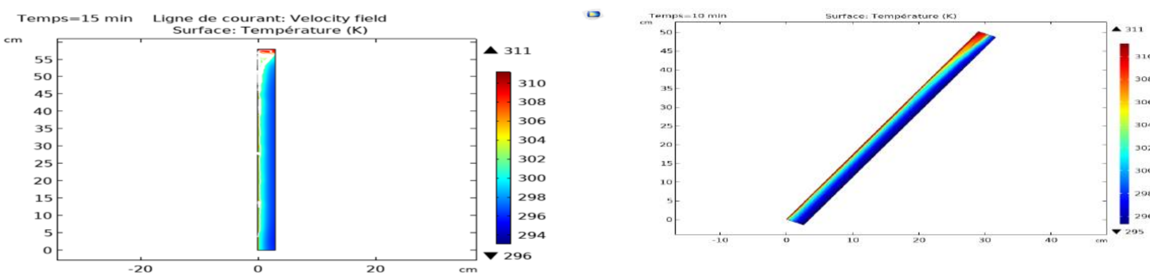

Figure 2: a) Contours of the solid-liquid interface for t=15 min b) Evolution of melting for the inclined case at t=10 min

4. Conclusions

These results have outlined the primary outcomes derived from the numerical approach, employing a two-dimensional model to depict the melting process within a storage unit filled with a phase change material intended for the cooling of photovoltaic sensors. The model effectively captured the overarching structure of the n-octadecane paraffin melting process.

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