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Efficiency gains of photovoltaic system using latent heat thermal energy storage

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Abstract

This paper presents experimental assessments of the thermal and electrical performance of photovoltaic (PV) system by comparing the latent heat-cooled PV panel with the naturally-cooled equivalent. It is commonly known that the energy conversion efficiency of the PV cells declines with the increment of the PV cell temperature, at a typical value of 0.5 %/K. Instead of exploring new semi-conducting materials to reduce the temperature-dependent effect, passive cell cooling is an alternative way to improve the PV power outputs. In the experiment, latent heat thermal energy storage was coupled to the rear side of the PV panel to achieve cell cooling passively. The phase change material (PCM) filled in the thermal storage containment (PCMTS) was organic based paraffin wax which has low melting point of 27 ˚C and high latent heat capacity of 184 kJ/kg. To overcome the poor thermal conductivity of the PCM, metallic fins were incorporated in the LHTES to increase the melting rate of the PCM. In addition, studies of the heat transfer performance using different numbers of metallic fins in heat enhanced PCMTS are compared and analysed. The experimental results show that the finned latent heat-cooled PV panel was able to reduce the panel temperature by 15 ˚C compared to the naturally-cooled PV panel. The maximum electrical conversion efficiency improvement of 5.39 % was achieved by the proposed passive cooling approach.

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1. Introduction

Photovoltaic (PV) cells convert incoming solar radiation into useful electrical energy which is essential source of alternative energy for our daily use. For a typically polycrystalline PV panel, it has a solar-to-electrical conversion efficiency about 13-18 % [1] and the remaining solar energy will be converted into waste heat. The waste heat will then increase the temperature of the PV cells and lead to decline of cell efficiency (-0.5 % per $^{\circ}$C) [2]. Many studies on PV cells and panels cooling have been conducted to reduce the panel temperature and increase its conversion efficiency. Several kinds of cooling systems utilising different cooling methods such as air-cooled method (natural and forced convection) to remove the heat from the cells [3-5], water-cooled method [6-8] where heat is removed by water-circulating blocks, the use of heat pipes for cooling concentrated solar PV cells [9-12], using phase change materials (PCM) to cool the PV panel by storing the dissipated heat of the cells as latent heat during phase change [13-15] and other cooling methods [16-17]. This work will focus on the utilisation of latent heat thermal storage (LHTES) for cooling the PV panels passively.

There are two main kinds of energy storage which are the sensible heat storage and latent heat storage. This work will be centered on latent heat storage, which uses a phase change material (PCM) for storing thermal energy, with the great advantage of having a much higher heat capacity than the sensible heat methods, particularly due to latent heat of fusion during melting. This fact allows a more compact cooling system in terms of thermal mass and volumetric storage. This objective of this study is to assess the PV power output improvement by using the thermally enhanced PCMTS for cooling the PV panel passively and increase the energy conversion efficiency. Heat enhancement was implemented on the PCMTS through the utilisation of metallic fins to increase the heat spreading and melting rate of the PCM. In this paper, the thermal and electrical performance are compared between the PCM cooled PV panel and the naturally cooled equivalent and their experimental data are analysed.

2. Method and materials

In order to conduct a comparative assessment, two similar multi-crystalline PV panels (BP solar, SX 320 model) were used in this experimental study. One of the panels was naturally cooled by the surrounding air while the other was passively cooled by using PCMTS. In this experimental prototype, a simple thermal coupling of a PCMTS at the rear of the panel was implemented. This PCMTS- coupled panel is referred as a “PV-PCM” system” and the schematic diagram is shown in Fig.1 below.

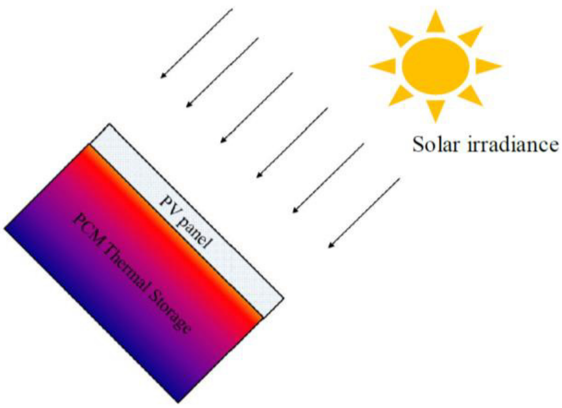

Fig. 1. Schematic PV coupled with PCMTS (PV-PCM System).