Fins Integrated Phase Change Material for Solar Photovoltaic for South East United Kingdom

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Abstract. The temperature rise degrades the power of solar cells. The use of phase change material (PCM) is a self-regulatory process of upgrading the performance. Fins can additionally upgrade the performance. A photovoltaic (PV) equipped with fins embedded PCM is modelled in Fluent. Three arrangements: PV with no temperature management, PCM equipped PV and fins embedded PCM for PV are compared for South East UK. The outcomes convey that, for summers at Portsmouth (50.80ºN, 1.09ºW), the aggregated daily electrical output of a 4000Wp photovoltaic array can be elevated by 1200Wh and 1400Wh using phase change material and fins embedded phase change material respectively.

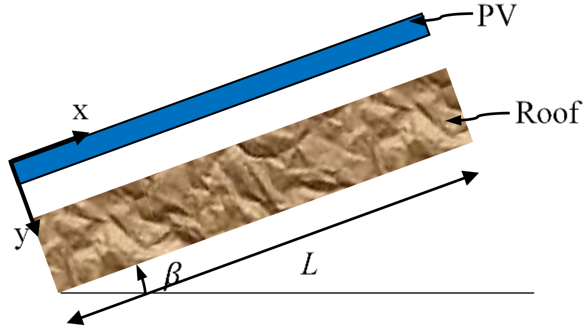
INTRODUCTION

The PV temperature rise degrades the power of solar cells [1]. Thus, thermal control of PV is necessary for better performance. Water-cooled PV is most commonly used method for PV temperature management. However, it requires additional pumping power. The use of PCM [2] is a self-regulatory process for thermal control [3]. Hasan et al. [4] have reported that PCM cost is around 1.9-2.5 euro per kg when purchased in tonnes and approximately 30 kg of PCM is required for 1m^2 PV. Atkin and Farid [5] have put the PV with no temperature management against PV with PCM. Salem et al. [6] have investigated PV with no temperature management against PV with water-cooling and PV with PCM. Karami and Kamkari et al. [7] have investigated the temperature stratification of PCM with inclination angle. Kibria et al. [8] have applied spatial discretization to model the latent heat storage of PCM. Asgharian and Baniasadi [9] have reported various different types of methods to model the phase change material. Navarro et al. [10] have examined the cyclic stability of the phase change material and reported the best one. Siyabi et al. [11-12] have used the concept of multiple PCMs and microchannel for the temperature management [13-14]. Manikandan et al. [15] have used PCM for low concentrating PV. Ma et al. [16-17] and Kazemian et al. [18] have done parametric study. Khanna et al. [19-20] have optimized the phase change material dimensions and studied the influence of operating conditions [21]. Yuan et al. [22] have examined the encapsulation of PCM. Yin et al. [23] have examined the influence of resistances on working of PV-thermoelectric equipped with PCM. Zhao et al. [24] have examined the viability of the PV equipped with PCM. Zarma et al. [25] have examined the working of nanoparticle-PCM for PV management. Choubineh et al. [26] have examined the air cooling system for the photovoltaic-phase change material arrangement. Different configurations [27-38] have been examined for PV temperature management [38-49]. Siahkamaria et al. [50] have used PCM-CuO nano particles for the temperature management of PV. Explicit equations [51-57] can make the PCM simulation easier.

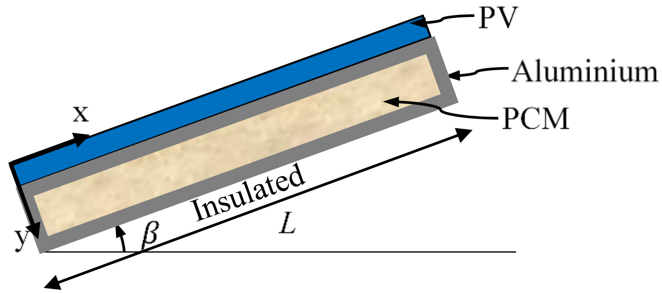
In previous paper, PCM was considered to improve the performance of photovoltaic array [58]. In this paper, fins embedded PCM is considered to improve the performance of photovoltaic array (4000Wp) at Portsmouth, UK (50.80ºN, 1.09ºW). Modelling is done for investigating three arrangements: PV with no temperature management, PCM equipped PV and fins embedded PCM for PV.

METHODOLOGY

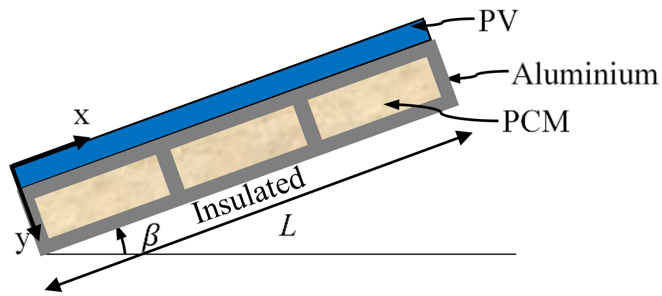
Three roof applied photovoltaic arrangements are investigated (Fig. 1). The arrangements are slanted at an angle β. First arrangement is the conventional photovoltaic with no temperature management (Fig. 1a). For second arrangement, phase change material is poured inside an aluminium box and integrated to the back of photovoltaic (Fig. 1b). For third arrangement, fins embedded PCM is considered (Fig. 1c). Fluent is used to model the arrangements. The temperature of the PV and the power output for each arrangement can be calculated using below equations [58-59]



(a) Photovoltaic with no temperature management



(b) Phase change material equipped photovoltaic



(c) Fins equipped phase change material for photovoltaic

FIGURE 1. Studied systems

$$\rho C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x} - \rho C_p u_x T\right) + \frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y} - \rho C_p u_y T\right) + G \tag{1}$$

$$\rho\left(\frac{\partial u_x}{\partial t} + u_x\frac{\partial u_x}{\partial x} + u_y\frac{\partial u_x}{\partial y}\right) = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u_x}{\partial x^2} + \frac{\partial^2 u_x}{\partial y^2}\right) + \rho g_x \tag{2}$$

$$\rho\left(\frac{\partial u_y}{\partial t} + u_x\frac{\partial u_y}{\partial x} + u_y\frac{\partial u_y}{\partial y}\right) = -\frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 u_y}{\partial x^2} + \frac{\partial^2 u_y}{\partial y^2}\right) + \rho g_y \tag{3}$$

$$\frac{\partial u_x}{\partial x} + \frac{\partial u_y}{\partial y} \tag{4}$$

$$P = \eta_{inv}\,\eta_{e,loss}\eta_{STC}[1 + \beta_c(T_{PV} - 25) + \gamma_c\ln(I_T/1000)]\,I_T A \tag{5}$$

RESULTS AND DISCUSSION

In this paper, three roof applied 4000Wp photovoltaic arrays are studied slanted at an angle of 45° at Portsmouth, UK (50.80ºN, 1.09ºW). Rubitherm 18 phase change material as coolant is used. A non-cloudy day of June is selected for the study. Irradiance and surrounding temperature are displayed in Fig. 2.

The temperature elevation during operation for the PV with no temperature management, PV with PCM and PV with fins embedded PCM are displayed in Fig. 3. The outcomes convey that the PV is cooled from 45 to 29°C and 27°C using PCM and fins embedded PCM respectively.

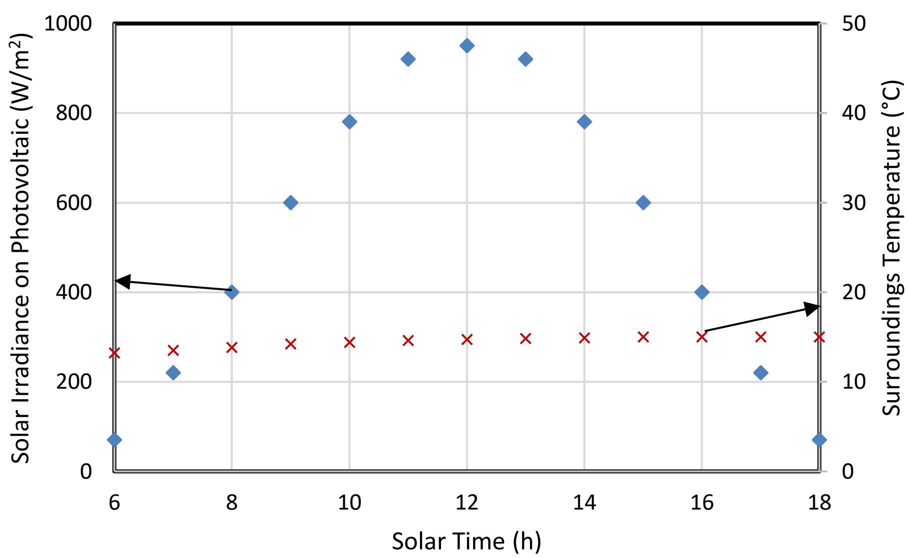


FIGURE 2. Radiation on photovoltaic array and surroundings temperature

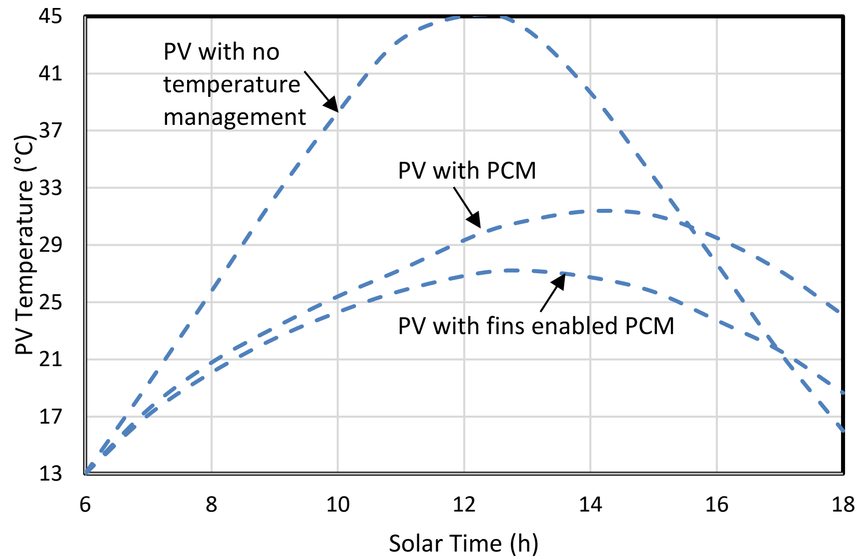


FIGURE 3. Photovoltaic temperature

Power output of the studied arrangements are presented in Fig. 4. The outcomes convey that the electrical improvements are 220W and 260W using phase change material and fins equipped phase change material respectively around solar noon. The aggregated electrical improvements over the day are also presented (Fig. 5). The outcomes convey that the aggregated daily electrical improvements are 1200Wh and 1400Wh using PCM and fins equipped PCM respectively.

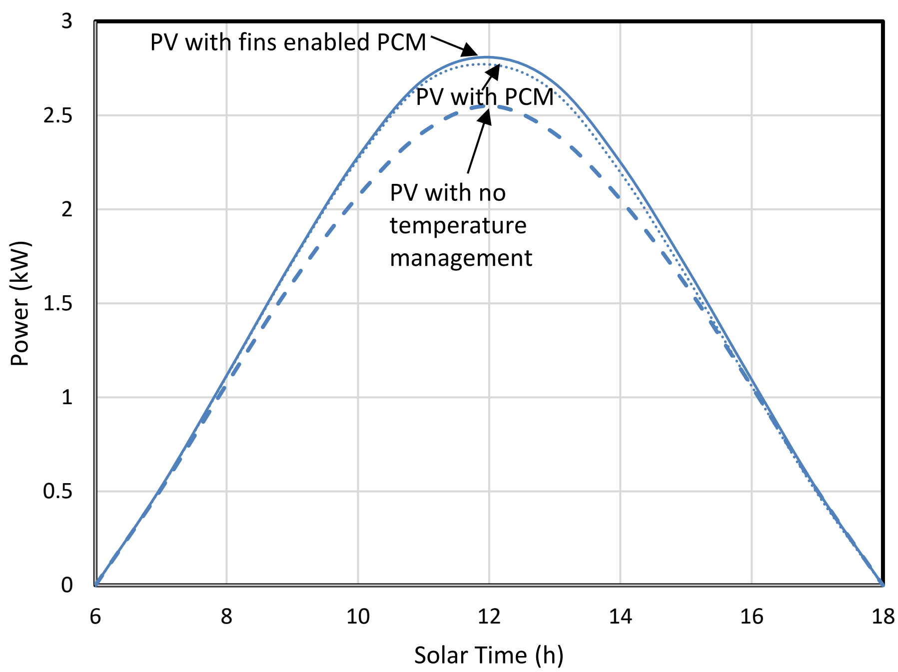


FIGURE 4. Power output for the studied 4000Wp photovoltaic arrays

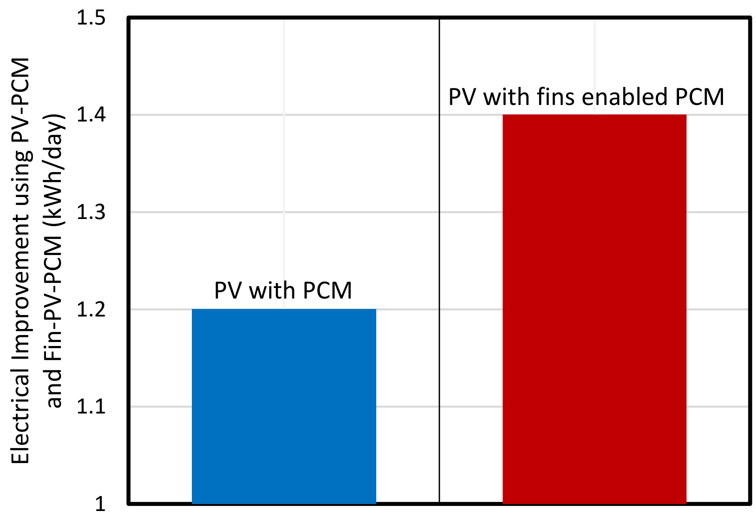


FIGURE 5. Electrical improvement for the studied 4000Wp photovoltaic arrays

CONCLUSIONS

In this paper, phase change material (PCM) and fins embedded PCM are considered to improve the performance of 4000Wp photovoltaic (PV) array at Portsmouth, UK (50.80ºN, 1.09ºW). Modelling is done for investigating three arrangements: PV with no temperature management, PCM equipped PV and fins embedded PCM for PV. The outcomes convey that

i. Electrical improvements are 220W and 260W using PCM and fins equipped PCM respectively around solar noon.
ii. Aggregated daily electrical improvements are 1200Wh and 1400Wh using PCM and fins equipped PCM respectively.

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