Research Article

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Improving the Solar Cell Efficiency by Using Cooling Technique

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Abstract
The research investigates the usage of fins fastened to a solar panel's rear surface for passive cooling purposes. In the research, solar modules with air conditioning were compared to modules with connected fins acting as a heat sink to cool them. The former served as the benchmark for comparison. The research explores two approaches for cooling modules with fins: ventilation air and still air. The research looked at the heat transfer by photovoltaic panels with and without fins to examine the effects of the environment and solar radiation on the performance of solar cells. The inquiry was carried out ostensibly. According to the findings, the use of fins for cooling reduced cell temperature and improved electrical and thermal efficiency. The estimated performance values of PVT solar cells obtained by using the COMSOL software and the experimental tests carried out during the daytime were reasonably in accord. At midday, the cell temperature decreased by a maximum of 2.8 Co, while electrical and thermal efficiency increased by a maximum of 18.2% and 55.13%, respectively. Good agreement between experimental and numerical results.

Keywords: Thermal Efficiency, Electrical Efficiency, Photovoltaic, Temperature

1. Introduction

Resources from nature and the environment are used by renewable energy sources. sun energy is one such source, requiring 3.8 million watts of incoming sun radiation annually. Due to a few benefits, hybrid photovoltaic (PV/T) systems are preferred among the numerous uses of renewable energy. The procedure combines the concurrent creation of thermal energy and electricity, this paper suggests a method to improve electrical and thermal production in air-type PV systems by combining fins and surface zigzags. The study uses internal fins, back surface zigzags, and combinations of fins and surface zigzags. Surface zigzags are preferred for 0.06 kg/s airflow rates, while fins are preferred for higher rates. The fin-surface zigzag combination is the most effective, improving efficiency by 26% and 3%, respectively. Marrwa et al, [1]. The HRV system recycles heat from exhausting air by combining it with fresh air. A photovoltaic/thermal (PV/T) device produces electricity and heat, which can be used to warm water. Combining preheating air from an air-type PV/T collector improves airflow efficiency and reduces low temperature air caused by frost and dew condensation. Ahn et al, [2]. Study proposes air-type single-pass PV/T collector system with heat-dissipating fins, measuring temperature characteristics and comparing setups for efficient PV/T system efficiency. Mojumder et al,. [3]. The PV/T system without an absorber plate was studied computationally and experimentally using COMSOL Multiphysics. Outdoor experiments in Malaysian weather showed comparable thermal performance to 1000 W/m2 irradiation and 34 Co inlet and ambient temperatures, with 84.4% numerical efficiency and 80% experimental efficiency. The simulation model can be used for various thermal collector designs and materials. Nahar et al, [4]. The article explores solar photovoltaic devices and collectors' efficiency and durability, focusing on cooling techniques like air and water. It highlights the improvement in efficiency and their potential in various environments, highlighting the crucial role of solar energy in generating thermal energy. Saleh, et al, [5]. The study examined the air prejudiced PV/T trend in two cases: fully covered PV modules and partially covered glass. Results showed that the PV/T device should operate at a modest air flow rate of 0.013 kg/s. Case 1 had 34% thermal and 10% electrical efficiency, while case 2 had 48.9 and 9.1%. Jalil et al, [6]. The study developed a hybrid PVT double-pass counter-flow device with a mixed-mode solar dryer, reducing fuel usage and improving dried banana slices color, flavor, and taste. The system was tested using MATLAB 2015b, calculating PVT, room temperature distribution, heat gain, and thermal efficiency. Jadallah et al, [7]. The study examined the impact of cooling on PV panel performance. Two modules were used without a heat sink and with one. The heat sink increased solar conversion efficiency by 35% and power production by 55%, while decreasing temperatures by 9% in the front and 11% in the rear. Hussam et al, [8]. Experiments confirmed a 2D steadystate simulation system involving air flow rates and radiant and convection heat losses. Surface zigzags were preferred for 0.06 kg/s air flow rates, while fins were preferred for higher rates. The fin-surface zigzag combination was the most beneficial, improving electrical and thermal efficiency by 26% and 3%, respectively. Ghanim and Farhan, [9]. The experiment examined the efficiency of two passive cooling configurations: rectangular fins and circular fins on mono-crystalline PV modules. Results showed that larger modules wasted 155% more heat, produced 10.8% and 4% more power, reduced temperature by 10.6%, and increased efficiency by 14.5%. Round fins dissipated only 27% more heat than standard modules. Amber et al, [10]. The study compared the daily and yearly performance of a cooled air PVT collector with triangle-shaped obstacles to a standard collector. A computational model was built and verified using Ulsan, Korea weather data. The collector had higher daily thermal, electrical, and total energy and exergy efficiencies, while having higher yearly energy and exergy outputs. An, et al, [11]. The PVT air collector with a triangular barrier exhibited superior thermal performance compared to the collector without one, suggesting better solar energy utilization. Air mass flow rate impacts thermal, total energy, and electrical efficiency. Choi and Choi, et al, [12]. The study examined a photovoltaic/thermal air collector in Tetouan Morocco, which uses two movable mirrors to increase solar radiation. Simulations and experimental investigations showed good agreement on the mirrors' impact on the collector's thermal and electrical output. The technique estimates the collector's daily solar energy and searches for the ideal tilt angle, based on the sun's elevation and azimuth angle. Benkaddour, et al, [13]. The study analyzed the advantages of employing two distinct methods to cool solar cells: air cooling and incorporating fins on the underside of the cells. The dispersion of heat between the back sheet surface of the PV cell and the inflow air in the wind tunnel during the cooling process has been found to enhance both the electrical and thermal performance of each cell.

2. Theoretical Part

The experiment consisted of measuring the air velocity while entering a tunnel under two different conditions: with a back sheet without fins and with a back sheet with fins. The objective was to maintain a constant air velocity throughout both scenarios. The study involved the application of variable solar radiation for a duration of eight hours per day, specifically from 8 am to 4 pm. The impact of external wind velocity on the coefficient of heat transfer of the solar cell's external surface and its outer condition was considered. There was fluctuation in air temperatures throughout the day, with a total of eight hours observed. The experiment involved the utilization of the tunnel. The material used to construct the antenna is acrylic, which possesses favorable heat insulation properties. Numerical simulation was used to analyze the performance of a PV/T module. The user conducted an analysis with consistent parameters that were maintained throughout the entire process. The experiment aimed to compare the performance of a back sheet with fins and a back sheet without fins under identical conditions. The air velocity was kept constant while entering a tunnel to ensure consistency in the experiment. The study implemented variable solar radiation for a duration of eight hours daily, specifically from 8 am to 4 pm. The impact of external wind velocity on the coefficient of heat transfer of a solar cell's external surface and its overall condition was considered. The air temperatures exhibited fluctuations throughout the day, with a duration of eight hours. The experiment involved the use of the tunnel. The choice of acrylic material for constructing the antenna is likely due to its favorable heat insulation properties. The PV module is comprised of five distinct components: the front cover, which is constructed of glass; the encapsulation, which is made up of ethyl vinyl acetate (EVA); the photovoltaic (PV) cells; the back sheet, which is composed of Tedlar (as indicated in Fig 1); and the thermal paste, which functions as a heat conductor. The flow channel can be divided into two separate domains: a solid domain made of aluminum and a gas domain composed of air.

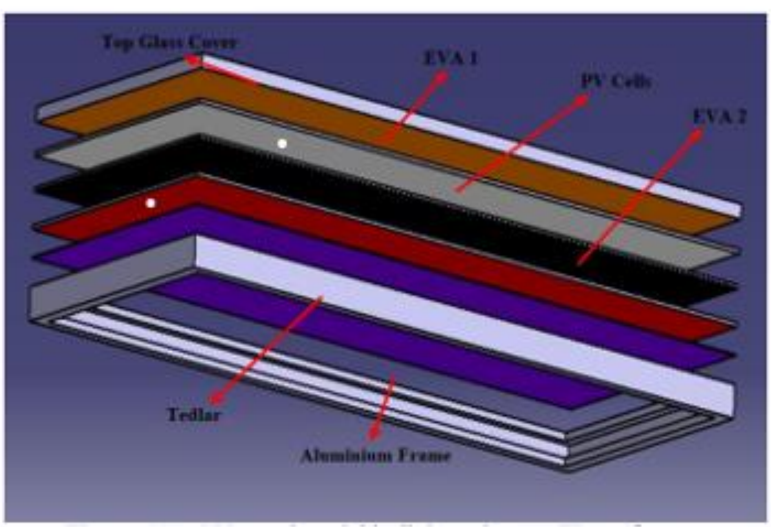
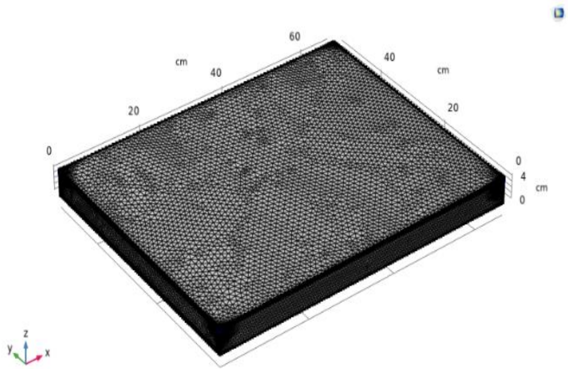
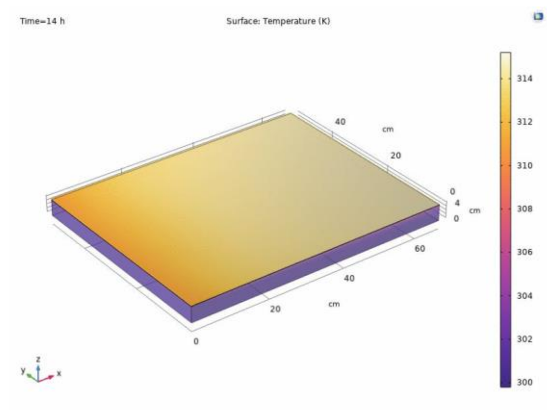


Fig 1. PV panel model built by using CATIA software [14].

The PV/T module panel consists of five layers, including solid and gas materials. COMSOL Multiphysics software solves governing equations using finite element method (FEM). The simulation achieves unsteady state conditions in 3D shown in fig.(2a-2d). Data on cell surface temperature and average air outlet temperature is extracted, which is then used to create graphs using Microsoft Excel™.



2a. Mesh process



2b. Surface temperature

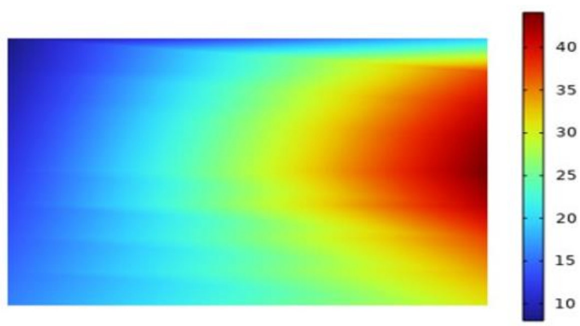


Fig. (2c) back sheet surface temperature without fins

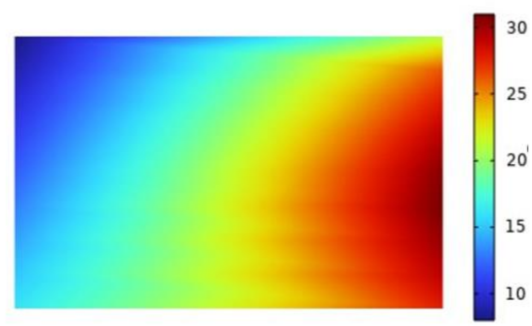


Fig. (2d) back sheet surface temperature with fins

2.1. Electrical and Thermal Efficiency Systems

Equation (1) calculates air's useful heat gain.

$$Q_u = \dot{m} c_p \, (T_o - T_i) \quad \ldots\ldots (1)$$

where To is the exit temperature, T_i is the input temperature, c_p is the specific heat capacity, and Q_u is the quantity of heat transferred. Evaluation is one way to figure the thermal efficiency. where to is the exit temperature, T_i is the input temperature, c_p is the specific heat capacity, and Q_u is the quantity of heat transferred. Evaluation is one way to figure the thermal efficiency.

$$\eta_{th} = \dot{m} \, c_p \, (T_o - T_i) / G * A_s \quad \ldots\ldots (2)$$

The mass flow rate (ṁ), specific heat capacity (cp), temperature differential between the outlet and intake (To), heat transfer area (As), mass flow rate (G), and the thermal efficiency (η_{th}) and the thermal efficiency Information on power production and photovoltaic efficiency is provided by equations (3) and (4). The circuit current (I) and voltage (V) are the two primary parameters used to characterize the power of a solar cell.

$$P_e = V * I \quad \ldots\ldots (3)$$

$$\eta e = P_e / G * A_{pv} \quad \ldots\ldots (4)$$

depicts a system's efficiency, with e standing for electrical efficiency, Pe for power output, G for solar radiation, and Apv for the area and pressure difference product. A formula that links electrical efficiency (e) to electrical power output (P_e) and PV module area (A_{pv}) has been submitted by the user.

3. Experimental Setup

The wind tunnel is installed below twice cells with the fins placed in the second cell. The wind tunnel is made of acrylic material, which has good thermal insulation. Its height is 4 cm and its length is 53 cm. In addition to installing DC fans with the wind tunnel, the practical side entails installing three photovoltaic cells that are identical in terms of size and quality. The fins below one of the solar cells are placed with an excellent heat-conducting epoxy, leaving the third cell without an air tunnel and without cooling fans. The fin has the following measurements: (2 cm) height, (53 cm) length, and (0.3 mm) to secure the fins firmly with the cell surface from below and eliminate air gaps, enhancing thermal conductivity and obtaining the greatest heat dissipation of the fins. In Najaf, Iraq (32.0107 N, 44.3265 E), this research was carried out starting in 18/5/2023. From 8:00 AM to 4:00 PM, eight hours total, are spent doing the studies. The temperature is measured on the back of each photovoltaic module, and the results are recorded for three panels at once for analysis and accurate comparison. The devices used in the experiment are a K-type temperature sensor for measuring temperatures installed in five different areas of the same panel that are identical to the three panels shown in Figs. (3) a and (3)b, and a solar radiation intensity meter for measuring the intensity of solar radiation with a unit (Lux).

Fig. (3) Experimentally state for PV panal

3.b (back sheet without fins)

3.b (back sheet with fins)

4. Results and Discussions

The experimental temperature for back sheet with fin and back sheet without fin of the photovoltaic cell was analyzed over the course of one day from 8:00 am to 4:00 pm. The results showed that the outlet experimental temperature for back sheet with fin and back sheet without fin in the soft plate was higher than that in the plate with fins, which indicates that the outlet experimental temperature in the soft plate was lower as shown in Figure (4) and the reason here is the presence of fins that will increase the area of heat dissipation for solar cells.

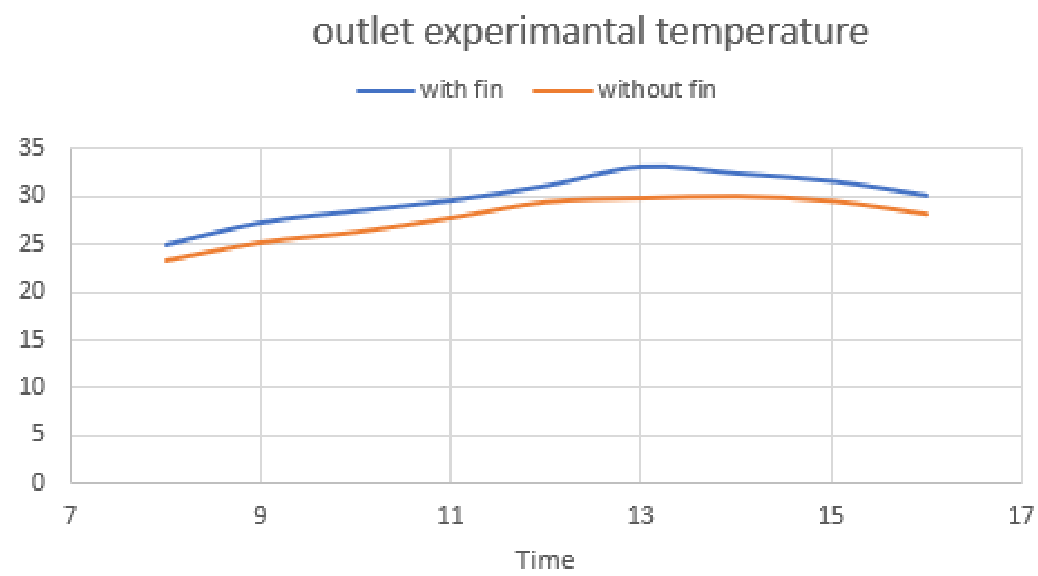


Fig.4 outlet temperature air for day.

The experimental and numerical outlet temperature for back sheet with fin and back sheet without fin of the photovoltaic cell was analyzed over the course of one day from 8:00 am to 4:00 pm. The results showed that the outlet temperature in the soft plate was higher than that in the plate with fins, which indicates that the outlet experimental and numerical temperature in the soft plate was lower , the cell temperature decreased by a maximum of 2.8 C° as shown in Figure (5-6) and the reason here is the presence of fins that will increase the area of heat dissipation for solar cells.

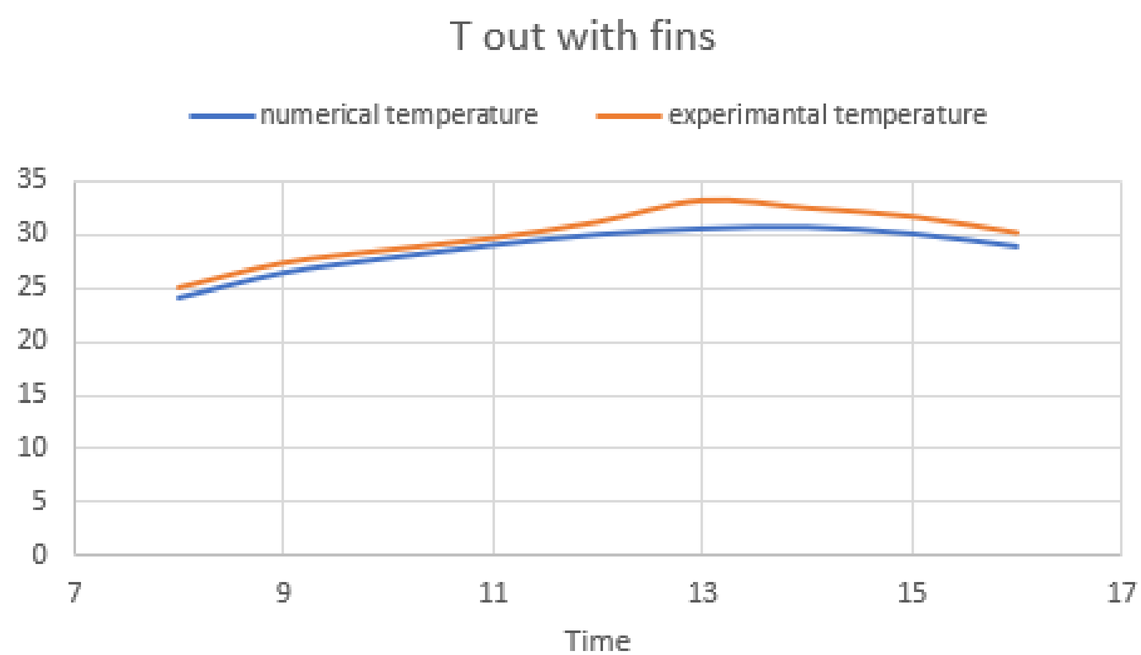


Fig. 5 experimental and numerical outlet temperature (PV without fins)

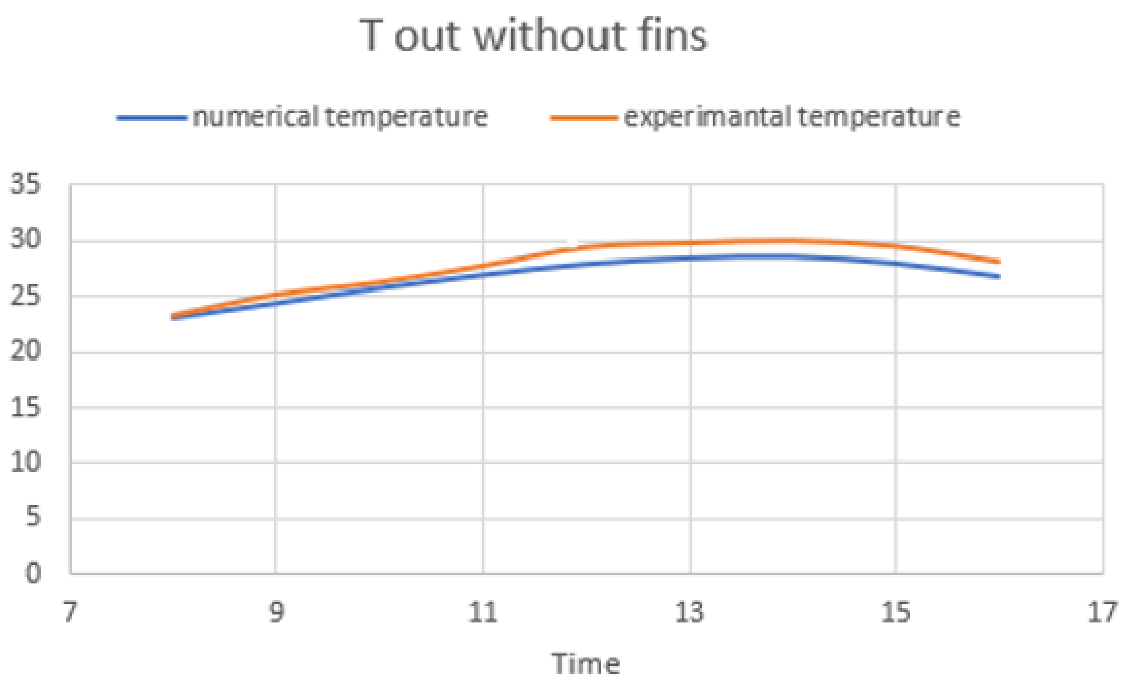


Fig.6 experimental and numerical outlet temperature (PV without fins)

Figure 7-8 shows the comparison between the experimental results for current and voltage of panal without fins and panal with fins, electrical efficiency increased by a maximum of 18.2%, thermal efficiency show the figure good agreement between with numerical and experimental with fins thermal efficiency increased by a maximum of (55.13%).

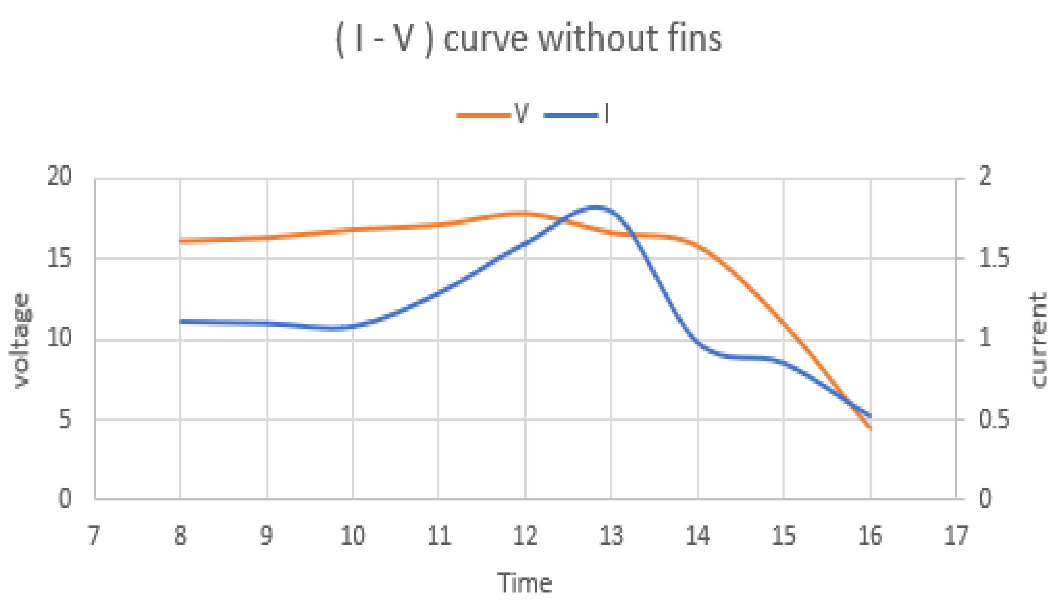


Fig.7 experimental results for current and volt without fins

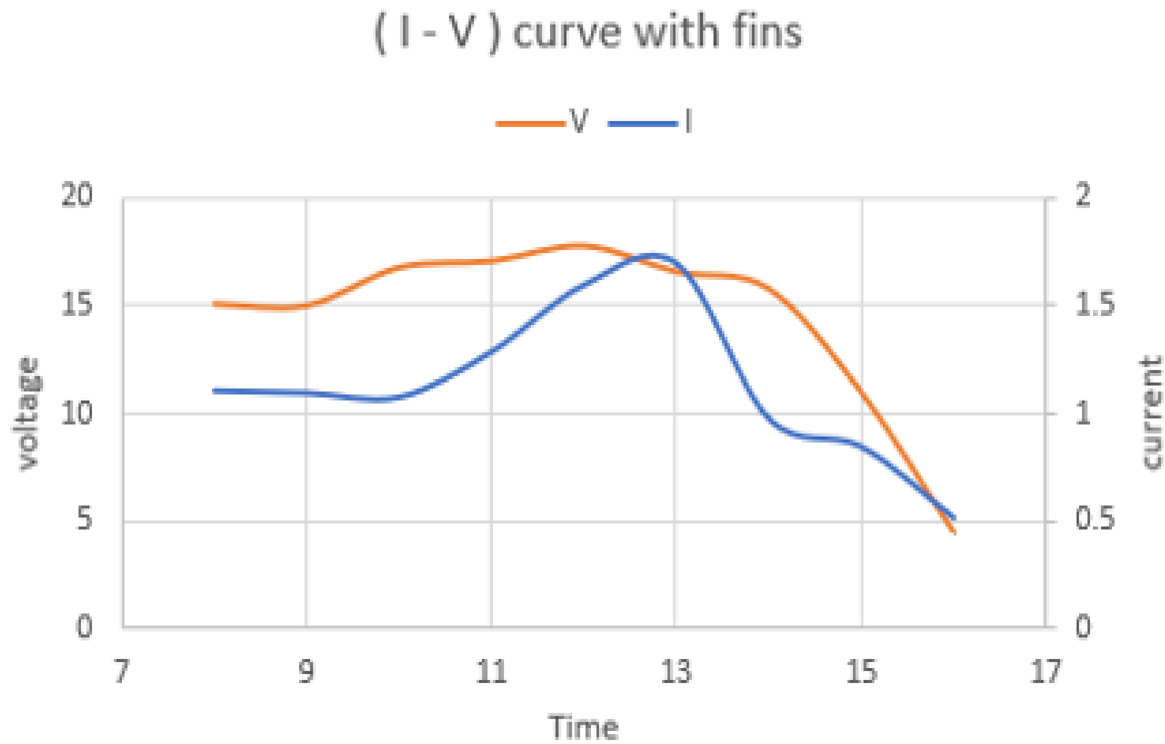


Fig.8 experimental results for current and volt with fins

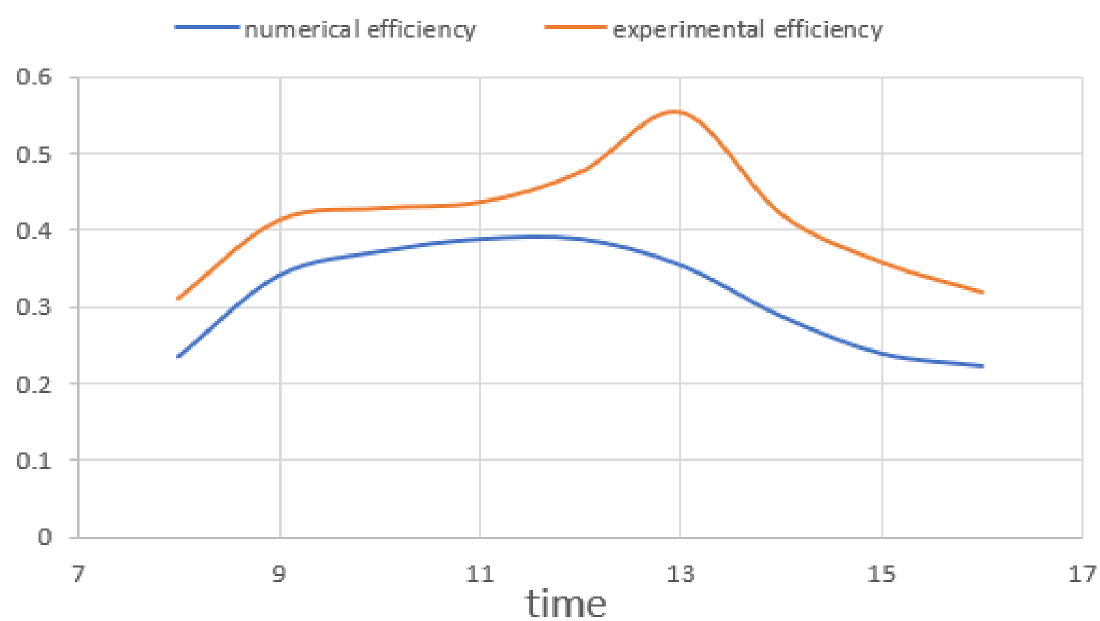


Fig. 9 numerical and experimental thermal efficiency with fins

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