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A Comparative Experimental Study Analysis of Solar Based Thermoelectric Refrigerator Using Different Hot Side Heat Sink

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HIGHLIGHTS

- Case (II) minimum cold temperature equal to -15oc, case (I) as -8 o c , hot temperature as 40oc ,45oc for two cases respectively for thermoelectric module (12076).
- The improvement in the average exergy efficiency of 19.4% in the case of the refrigerator with heat sink type (HWACHE) compared to the case of the refrigerator with the heat sink type (HWAC).

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ABSTRACT

The heat sink influences heat dissipation at the hot junction of the Peltier module and, hence, affects the performance of the thermoelectric refrigerator. The present work compares the performance of solar-powered thermoelectric refrigerator units with capacity (30 Liter) for two cases by employing two different heat sink types. In case (I) The Peltier module (12706) is connected with a heat sink type of Hot wall air-cooled (HWAC). In case (II) the Same Peltier is connected with a heat sink type of hot wall air-cooled with a heat exchanger (HWACHE). The exergy analysis method can help to determine the exergy losses and exergy efficiency of the thermoelectrical refrigerator unit. Despite the change of the (COP) of the thermoelectrical refrigerator throughout the day. The average value of it in two cases was approximately (0.3). Furthermore, the exergy efficiency varied from a minimum value of (0.3%) to a maximum value (0.8%)in case (I). While it varies from the minimum value of (0.4%)to a maximum value of (1%) in case(II). Whereas the average exergy efficiency was 0.5% and 0.62% in case (I) and case (II) respectively This means that there is a percentage improvement in the average exergy efficiency of 19.4% in case (II) compared to the case (I).

1. Introduction

The cooling system very important process for many applications in everyday life needed for keeping fresh Food and Drink, and cooling the drugs, and saving medical samples. Some refrigerators used compressor systems as the domestic refrigerators' compress system based on vapour have a high cop. The thermoelectric used in this test works directly from that sun the powered with (DC) electric current with a variable voltage. Thermoelectric cooling is based on the principle of the Peltier effect where the direction of heat flow depends on the direction of applied electric current and the relative Seebeck coefficient for two materials, which is made up of it, that the Heat sink devices that improve heat dissipation from the hot side of the thermoelectric device. While the inlet air temperature of the heat sink is higher, this will result in a Higher heat sink base temperature. The Peltier effect is created at different temperatures by applying a voltage between two electrodes connected to a sample of semiconductor. Peltier effect is one of three types of thermoelectric effect. The other type is the Seebeck effect when two ends of a conductor are held at different temperatures, the electrons at the hot junction at higher thermal velocities diffuse to the cold junction. See beck discovered that making one end of the metal bar hotter or colder than the other produced an EMF between two ends. Thomson Derived the relationship between the Effects from thermodynamic G.S. NOLAS and J. SHARP [1]. Solar technologies have played a limited role in the power sector in many countries, it is important to consider that the maximum amount of energy coming from the sun at the equator is in the range of 1000 w/m2 at peak hours of sunshine (solar irradiance). The best efficiency currently available for commercial solar panels is of the order of 16%-22%. The solar p-v system is a semiconductor converting sunlight directly into electricity. The main components of the solar system are (a photovoltaic panel, solar control charger, inverter, battery). This system considers maintenance and sustainable operation is less problem compared with traditional power plant Frank kreith [2]. The most important factor affecting the solar panel efficiency is the level of Irradiance with the low level of sunshine, the p-v efficiency will be low and increase with the increase of solar Irradiance.

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Abdulataf Ahmed, et al. [3]. The rising in the temperature led to drooping in the generated power for the same irradiance intensity Hussein, H et al. [4]. GaoMina, et al. [5] modeled the thermoelectric study and improved the coefficient of performance (COP) with heat pumping limit. It can be seen for giving contact characterizes, the cop increase with the increase in thermoelectric length and figurative the number of an ideal module. The effect of contact resistances on COP makes a difference when the thermoelectric length is short. The results also found increase the (COP) about 40% that may be obtained by reducing the thickness of ceramic plates from 0.7 to 0.1 mm for the module with thermoelectric length equal to 1mm the thickness of ceramic and the cop <o.5 for refrigerator operating at a different temperature equal to 20. S.B. Riffat et al. [6]. This investigation of improving the coefficient of performance of thermoelectric (Peltier) solid state by using a technique of heat exchanger to dissipate the heat reject in the hot junction into the atmosphere subsequently decrease the temperature of the hot side and decrease the temperature of the cold side to minimum value accepted, so then the efficiency of the heat exchanger system rise influences on the cop of Peltier so the Temperature change between hot and cold side reduced.

The results showed that if the efficiency of the heat exchanger is small, the different temperature of the hot and cold is high, it decreases Tc and decreases Th in the thermoelectric module and the improvement is too small with a different temperature equal to 30 and for the hot temperature of 60. The module operated at a cop of 0.670 compared to a cop 0.719 the improvement in COP was 7.3% and when the hot side temperature above 100 the cop is 0.151cmpared to o.232 for the cascade module. Yen-Iin Chen et al. [7]. This study investigates the performance of thermoelectric cooler chillers portable consist of the combined power fixed solar cell charger to control the voltage variation and data logger for measurement the cooled and hot point. The experiment was based on cooled the heat junction of the Peltier to improve the performance of the system. Then Cooling the solid-state by using a heat exchanger with water. The result shows the box cooled from 18.5 c˚ to 13 c˚ and the coefficient of performance is changed from 0.55 to 1.05 and the average of COP was 0.74. This result is useful through the acceptable minimum temperature.

Murat Gokcek, et.al [8] investigation of small channel water cooled the solid-state thermoelectric. This study found a way to cooler the Peltier type (TEC12709) thermoelectric the number of couples is equal to (127) the maximum current is 9A and the voltage was 15.2V. The method of cooling is by using a heat exchanger and pump, also a water tank and fan. The volume used to be equal to 0.063m3 with two piece of thermoelectric. The result showed that the cold side temperature was equal to - 0.1C˚ for 1.5 L/min flow rate of water and the coefficient of performance (cop) was 0.19. Also, the study showed that the inflow rate of 0.8L/min at the end of 25 min cooling time and when the voltage becomes 8V system's coefficients of performance is 0.41 with a flow rate of 1.5L/min. The condition of the experimental study in the lab room the temperature was from 24-26C˚at 120 min for state condition. Also the temperature of thermoelectric changes with variation in the flow rate of water. Dongare V.K et al. [9]. This paper deals with investigating and improving the operating of the thermoelectric refrigerator. The cooled volume cabin keeps the temperature from 33C˚ to 22C˚ during the time of cooling of 1 hour and calculate the coefficient of performance (COP) which was from 0.2 to 0.6. The cooler box volume is 2 liters insulated totally from the ambiance using puff in thickness about (3.8mm). The study analyzed the different temperatures, changing the thermocouple of measurements every 10 minutes and took the reading in different locations happen in the cabin and outside the table values plotted between the temperature and the time at several conditions for power operating and cut off. Mirmanto et al. [10] analyzed the different temperatures, changing the thermocouple of measurements every 10 Minutes, and took the reading in different locations happen in the cabin and outside. The table values are plotted between the temperature and the time at several conditions for power operating and cut off. The study analyzed the performance of the use of water, which is the load on thermoelectric cooler. The study discussed the effect of different changes of the full water inside the module of the application. The refrigerator dimensionality is equal to (390mm×320mm×530mm) and the limit value of water variation is from 0 to 4500 ml. The generated source DC used was 51. 27 W. The result shows that the temperature changes at the variation of volume of water when the water raises the temperature increase room temperature and cop decrease with the observation time and power. Also shown cooling load at an initial temperature equal to 30°C. The final water temperature was about 5°C for about 70 minutes. The bottle plastic gave restrictions to the heat transfer from the water to the surrounding air inside the cooler room so the water temperature is lower than the air temperature.

M.Mirmanto et al. [11] investigated the performance of thermoelectric cooler (module 12706), heatsink, fan with a dimension of (215mmx175mmx130mm) with many changes with different positions of thermoelectric. In the designed cooler box, the location of the thermoelectric TEC cooler test is put in several positions: on the top, on the deepest part at the same time, and on the wall of the cooler tank. The experiment showed that the coefficient of performance decreased with time, and the most excellent location of the display of the thermoelectric was on the wall.

L PI Midian et .al [12] presented a conception of the performance and Logistics of a temperature cooler box with a used fan and without a fan. The TEC- 25408 module with the dimension of (40x 40x 6) mm, heat sink physical was aluminum and cooper and fan dimension (92x92x25) mm, the copper block has used an extender to compare the hot side of the thermoelectric module and vapor device pad in the heat sink to the deep part of the cold sink which has the dimension of (80mmx80mm) with a small fan in the part cold with the dimension of (40× 40×15) mm. The thermocouples connected to measure the logistic temperature in the cooler box were put in six point on the cold side and the same number to measure on the hot side. The result shows that the temperature of the cold part decreased from 25.5c˚ to -5c˚ for 37 watts having fan and 25.5c˚ to -7.5c˚ for 37 watts with not have fan and also results show that with the power of 43watt the temperature decrease from 25c˚ to -5c˚ and the results shown that the maximum coefficient of performance was 0.103, and the coefficient performance (COP) change with difference in the load’s water.

Muhammad F. et al. [13] investigated a mini cooler with the dimension of (20x26x18) mm was developed using a thermoelectric cooler (12706). The Description for the module was maximum current was 6 amps, and the maximum voltage is

15.4 volts. The experimental study found the Peltier cooler was able to reach 0.5. In comparison to previous studies, the performance was very high by extracting 25 watts of heat from the cooler box, this cooler was able to reduce the temperature to 18.5 below the ambient before reaching a steady state at approximately 9.5 for more than 3 hours. As a result, also the coefficient of performance range (0.16-0.64) When the difference of temperature between Thot and Tcold equal 20). To design a mini Peltier cooler, it's crucial to understand the design requirements, such as the amount of heat extracted from The internal and external surfaces and the ability to transfer energy from low to high temperatures. Mirmanto M. et al. [14] investigated the development of a thermoelectric cooler, a plastic bottle containing 19 liters of water was put inside the cooler case, which dimension about (1000 mm x 500 mm x 400 mm). A water-filled mini channel was used to cool the thermoelectric hot side. Two Solar panel with a power of 200 watts (each with 100 watts) and 12 volts with the battery (100Ah), Solar charge monitor and a load of 19 liters of the plastic container. As well as to improve the effectiveness of the hot junction to the thermoelectric cooler by cooling with water in a small channel and a small pump to compress the water in a close circle with tank and flow meter. The results showed a lower temperature value in the cold side to 16.21°C, at the same time lower temperature value in the Hotter box was 24.25°C, while the coefficient of performance (cop) value obtained varied from 0.01 to 0.76. S.M.A. Rahman, et al. [15] This research study a novel concept of thermoelectric cooling effect was used To provide cooling to the refrigerator room with dimensions (6.5cmx6.5cmx15cm) and TEM ((12706 modules)) five piece Fixed on the room camper and the power supply used in this system with power about 5watt and current 0.58A, control charger, and battery to store the power. The heat rejected from the thermoelectric modules hot side is for low temperature heating cabin rendered aluminum sheet thickness 0.3 cabin and insulated to prove the system efficiency. The Experiments have shown that in the cold chamber, the device could achieve the target Temperature of about 10 C, while on the Hot side, the temperature reached was about 40 C. A higher coefficient of success (COP) is measured at about 0.61. The device consists of this system that is combined with an iron car on which solar panels are mounted, and the bottom part represents the position of the refrigerator, and it is used to provide remote cities with the required energy for their needs, particularly in the medical sector and in preserving medicines, and it relies on both thermoelectric technology and Renewable energy for one system. The use of a gas-charged copper heat sink to reduce the temperature of both the Tcold and the Thot and improve the system's performance coefficient is a novel feature of this. Hussam Jouhar, et al. [16] presented the deep study of the thermoelectric cooler (TEC). Thermoelectric systems have emerged in the last decade as a promising green power generation alternative to other technologies. The performance prediction of Thermoelectric devices is critical in this regard, both for determining the potential use of this new technology and for specifying the main design parameters of thermoelectric generators and systems. TEGs are therefore non-toxic to the Environment. The study details the Peltier effect, Seebeck effect, Thomason effect. The Peltier effect is very low in efficiency which is a setback. Another downside is that the circulating current it continues to produce a significant amount of heat which adds to the heat dissipation process. This results in an unnecessary amount of heat in large applications.

From the literature survey, it can see that there is scope for development and comparing of refrigerating systems by employing different types of heat sink at the hot side for the Peltier module in the thermoelectric refrigerator. This work study investigates the experimental performance system of a thermoelectrical refrigerator unit derived from a solar photovoltaic panel operating with two different types of heat sinks. In case (I) The Peltier module is connected with a heat sink type of Hot wall air cooled (HWAC). In case (II)the Peltier is connected with a heat sink type of hot wall air cooled with a heat exchanger (HWACHE). Each system with a different heat sink was operated under the same environmental conditions. Then the characteristics of performance such as cold side temperature, hot side temperature, power consumption, thermoelectric refrigerator capacity, the coefficient of performance, exergy out, and exergy efficiency of the two systems were compared with each other. The investigation has focused on energy saving with the help of an exergy analysis tool. The results showed that the use of Heat sink type (HWACHE) enhances the performance of the thermoelectrical refrigerator in terms of exergy efficiency and the temperature inside the refrigerator.

2. Steps of the Experimental System Set-Up

The actual setup of the experimental system is shown in Figure 1. The experimental system is a portable thermo-electrical refrigerator driven by photovoltaic solar panels. The whole system was fabricated and constructed locally to be tested under the outdoor condition of the city of Baghdad. The system consists of two main parts, which are the thermos-electrical refrigerator box unit and the photovoltaic (PV) array. The Refrigerator box unit has an internal capacity of 30L with dimensions of (40cm *29cm*27cm). The Refrigerator box is equipped with a thermoelectric cooling (Peltier) module type (supercool: PE-12706) and is shown in Figure 2. Table 1 shows the specifications of the Peltier Module. The photovoltaic (PV) array Consists of two solar panels connected in parallel. Table 2 shows the specifications of the photovoltaic module. The (1-5) curve obtained at the noon for the (PV) array is shown in Figure 3. The photovoltaic panels were examined at the Solar Energy Research Center (Baghdad). The thermoelectric cooler box consists of Peltier Module (12706), external heat sink, heat sink internal inside the cooler room and fan). The system was operated without load (water for example).

Table 1: Specification of Peltier Module type (Supercool: PE-12706)

Sample(Qmax ,V,I , ΔT)	parameter	Specification
	Peltier(module)	12706
	Q max	50 watt
	Maximum current	6.4A
	Maximum voltage	14.4v
	Different temperature (ΔT)	66 ℃

Table 2: Specification of photovoltaic module

Sample(W,V,I,A)	Parameter	Specification
	Module	Mono crystalline solar
	Maximum power / W (w)	50w
	Maximum power voltage /V_{MP} (V)	21.6
	Maximum power current /I_{mp}(A)	2.77A
	Short Circuit current/I_{Sc}(A)	2.99A
	Short Circuit Voltage /S_C(V)	21.6V
	Maximum power Tolerance	±5%
	Product Size	680*510*30mm

The measurement of two P-V connected in parallel with irradiator 898 W/m^2 at cell temperature of 41.1℃ .After Measurements , the following parameters were found Isc= 5.205volt ,Voc=21.2volt , Impp= 4.903A ,Vmpp= 16.78v ,P=82.3watt , FF=0.75.

Figure 1: Experimental system components picture

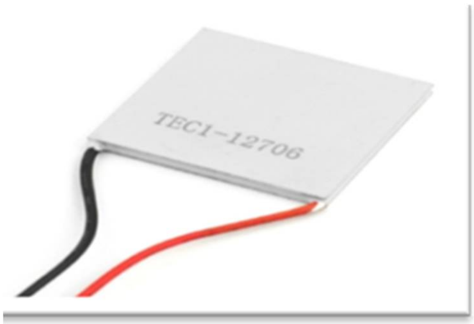

Figure 2: Peltier module type (supercool: PE-12706)

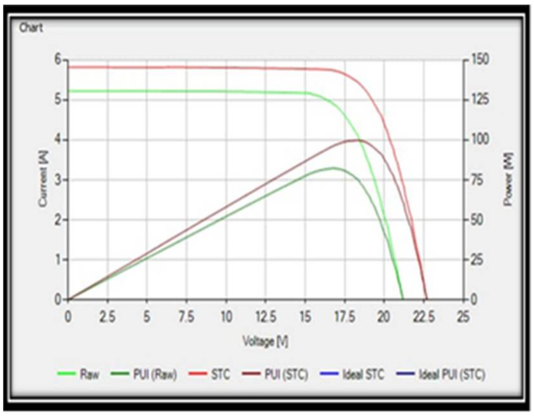

Figure 3: The (I-V) curve obtained of the (PV) array

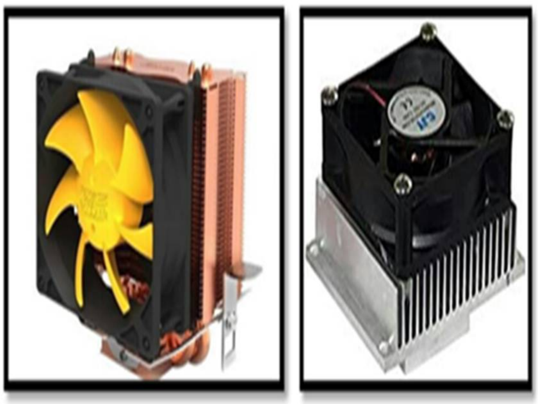

Figure 4: (A)(HWACHE)

Heat Sink

A heat sink device could be used to reduce thermally induced failures By enhancing heat dissipation from the device. The heat sink is a structural device that dissipates heat from a functional electronic device to the Environment to ensure the device operates Efficiently. The Heat sink is an important factor in microelectronics thermal management which influences heat dissipation. The heat sink to the environment, Mathias Ekpu et al. [17]. In the present experimental work, the hot side of the Peltier was cooled with two types of heat Sink directly connected with it. The first type is the hot wall air cooled (HWAC) and the second type is the air-cooled hot wall and the heat exchanger (HWACHE) shown in Figures 4- a and b. The heat exchanger consists of A finned radiator around a tube charged with refrigerant.

The temperatures are measured at 4 points with by K-type thermocouple having an accuracy of (± 0.1oC). The thermocouples are installed at the hot-junction, cold-junction, inside box unit and outside box unit. A four channel digital thermocouple measuring device type (4-channel-HT-9815) was used to record the temperature at the fixation points of the thermocouple. A solar power meter type (Model- Sm 206-solar) and rating (0-1999 W/m2) was used to measure the solar radiation intensity. Before starting work and taking readings, the measuring devices are calibrated.

3. Methodology

The mentioned thermoelectrical refrigerator box unit is connected to the PV array, then it is mounted in the real outdoor conditions, powered by the PV array, the thermoelectrical is tested for (no load condition) during sunny days (from 22- 23 March .2021). All data of instantaneous voltage (V), current (A), the power P(W), and temperatures are recorded, then the obtained test data have been treated. The study analysis included different factors affecting the thermos-electrical refrigerator, the required electrical power, the cooling capacity provided by the refrigerator. The incident solar energy is received by the PV array, then the thermo-electrical refrigerator coefficient of performance (COP). Exergy in, Exergy out, and Exergy efficiency have been determined for each heat sink type.

Exergy analysis

The maximum work for a point in relation to the reference state can be determined using an exergy analysis (the second law of Thermodynamics). This study will assist in evaluating the best route to future changes. The mini-cooler refrigerator powered by a solar PV module has many sources of energy loss, causing the combined system's real output to deviate from the ideal.

Governing Equations

The see beck coefficient α of performance

$$\alpha = \frac{Vmax}{Th} \quad (1)$$

Vmax = maximum voltage of thermoelectric module (Peltier 12076).

Th= temperature of the hot junction of the thermoelectric cooler.

Electrical resistance

$$Rm = \frac{Th-\Delta T}{Th} x \frac{Vmax}{Imax} \quad (2)$$

Where ΔT = the difference of temperatures of the thermoelectric module (12076)

Thermal conductivity

$$Km = \frac{Vmax}{Imax} \quad \frac{Th-\Delta T}{2\Delta Tmax} \quad x \; x \; Imax \quad (3)$$

Where Imax = maximum current of the thermoelectric module.

To Determine the heat transfer cooling system

$$QC = (\alpha \ x\, I\, x\, Tc) - (I2 / 2)x\, Rm) - (Km\, x\, (Th - Tc)) \quad (4)$$

Where I = current of the module, Rm = thermal resistance, Km = Thermal conductivity, Tc= cold junction of the thermoelectric Where ΔT =Th- Tc

The work of the Peltier thermoelectric module can be obtained by.

$$W = \alpha * I * (Th-Tc) + (I^2 * Rm) \quad (5)$$

Where: Rm= Electric resistance.

Theoretical Cop equation

$$Cop_{exg} = Q/W \quad (6)$$

Q= cold heat transfer, where W=Work of Peltier.

$$E_{exg\ in} = s\,(1- 4/3\, (Tamb/ Tsun) + 1/3\, (Tamb\, /Tsun)^4) \quad (7)$$

Where Eexg in= input Exergy, Tsun = Temperature of the sun equal to 6000 k, and G is the solar radiation and Tamb temperature of the atmosphere.

$$E_{exg}\, out = QC(1-TC/Tamb) \quad (8)$$

Where the E exg out = Exergy output Qc= cold heat transfer, Tamb= atmosphere temperature
S=A*G
The exergy efficiency of the system

$$Q_{ex.f} = E_{exg} out / E_{exg\ in} \quad (9)$$

The output power of the solar panel

$$P_{solar} = V_{oc} I_{sc} FF \quad (10)$$

Where the Voc= open circuit voltage, and FF full factor
The efficiency of the solar panel is given as

$$\eta = (V_{oc} * I_{sc} * FF) / A \times G \quad (11)$$

Where A=Area of the solar panel.

4. Results and Discussion

Experimentally, the performance analysis of a solar powered thermos-electrical refrigerator system is carried out under the same operating conditions with two different types of heat sinks, namely, hot wall air cooled (HWAC) and hot wall air cooled and heat exchanger (HWACHE). The system was tested under local external conditions from eight in the morning until four in The afternoon, where readings were taken every quarter of an hour. The experimental tests are the test results used to show the behavior temperature of cold and hot sides of the two cases. The same results are processed to Analyze the variation of the parameters such as coefficient of performance (COP), exergy out and exergy efficiency for two cases.

4.1 Effect of heat sink type on cold and hot temperatures

Figures 5and 6 show the change in the temperature of the cold side and the temperature of the hot side, as well as the temperature of the outside air throughout the day for each of the two types of heat sink respectively. Figure 5 shows the temperature change of the cold side of the thermoelectric refrigerator, which works with the help of the first type of heat dissipators, which ranges between - 8 degrees celsius as a minimum and 12 degrees celsius as a maximum with an average temperature of (0.39o C) along the day, while the temperature of the cold side of the refrigerator changes with the help of the second type of heat sink, Where ranges between -15 degrees Celsius as a minimum and 5 degrees Celsius as a maximum, with an average temperature of (-7oC) along the day. Whereas, the temperature of the hot side of the refrigerator, which works with the help of a heat sink of the type (HWAC), ranges between 25 degrees Celsius as a Minimum and 44 degrees Celsius as a maximum, with an average temperature of (32.4) degrees Celsius throughout the day. Figure 5 shows that the temperature difference between the cold side and the hot side is roughly the same throughout the day.

While the temperature of the hot side of the refrigerator that works with the help of a heat sink of the type (HWACHE) Changed between 18 degrees Celsius as a minimum and 40 degrees Celsius as a maximum and with an average temperature of 29 degrees Celsius throughout the day. Also, through Figure 6, it can be seen that the difference in temperature between the cold side and the hot side starts to increase since the beginning of the day and is at the highest level in the middle of the day, after which this difference starts to decrease. This means that the heat sink of type (HWACHE) improves the performance of The refrigerator, considering the temperature of the cold side and the hot side of it.

4.2 Effect of heat sink type on COP

Figure 7 shows the change of the coefficient of performance (COP) of the thermoelectric refrigerator for the two types of Heat sinks throughout the day. The results showed through this figure that the COP of the refrigerator that works with The Help of the heat sink of the type (HWAC) ranges between 0.29 and 0.45 along the day with an average value of approximately equal to (0.3), while the COP for the refrigerator that works with the help of the heat sink of the type (HWACHE) Ranges between 0.15 and 0.6 along the day, with an average value of approximately equal to (0.31). This means that the amount of average performance factor of the refrigerator is approximately the same in the two cases. In other words, despite the improvement in the temperature of the cold side of the refrigerator for the second case, the COP did not change much. This behavior can be justified as the heat sink of the type (HWACHE) affected more than the heat sink type (HWAC) with the ambient temperature. Also, the difference between the temperature of the cold side and the hot side of the refrigerator that works with the Help of a heat sink of the type (HWACHE) is greater than in the case of the refrigerator that works with the help of a heat Sink of the type (HWAC), which affected the performance coefficient, especially after midday when the difference was large. Also, because, as it is known, the temperature difference between the cold side and the hot side is one of the direct influences on the performance parameter of the thermoelectric refrigerator, the cop decrease with the increase in the temperature difference between the Thot and Tcold junction of Peltier. The coefficient of performance (COP) is a high value when increasing the difference in temperatures (ΔT).

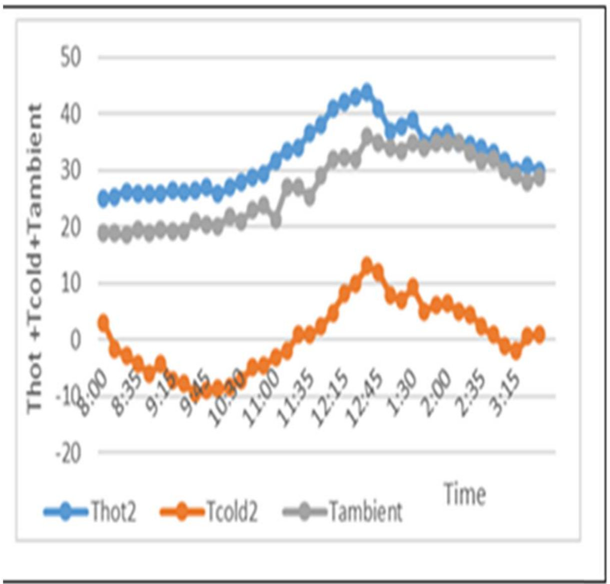

Figure 5: Variation of hot wall air cooler heat sink (HWAC)

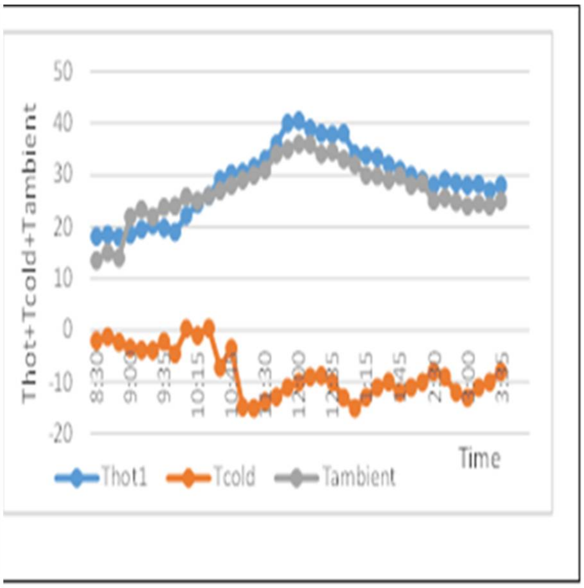

Figure 6: Variation of hot wall air cooler heat exchanger (HWACHE)

4.3 The effect of the type of heat sink on the temperature of the hot side

Figure 8 shows the effect of the type of heat sink on the temperature of the hot side of the refrigerator for two types of the heat sink. Where we notice through this chart that the highest temperature reached by the hot side of the refrigerator that works with the help of a heat sink of the type (HWAC) is about 45oC, while the highest temperature for the hot side of the Refrigerator that works with the help of a heat sink of the type (HWACHE) is approximately 40 C. This is because the heat sink of the type (HWACHE) has a lower thermal resistance than the type (HWAC) and at the same time, it has a higher thermal conductivity than its. Thus, the temperature difference between the hot side and the Ambient temperature is Reduced, as we noticed in Figures 5 and 6, especially in the early to midday. Figure 8 also shows that the increase with time means an increase in the temperature of ambient. This indicates that the heat sink type (HWACHE) is useful for heat transfer as compared with the second type.

4.4 The effect of the type of heat sink on the output exergy

Figure 9 shows the change in the exergy-out amount of the thermoelectric refrigerator for two types of heat sink Throughout the day. It is noticed through the figure that the amount of exergy-out ranges between (1.79) as a minimum and (2.8) as a maximum with an average value of (2.13) for the refrigerator that works with the help of the heat sink of The type (HWAC), while the output energy of the refrigerator that works with the help of the heat sink of the type (HWACHE) ranges between (2.23) as a minimum and (3.49) As a maximum with an average value of (3.1). Clearly, it can be said that the average exergy output from a refrigerator that works with a heat sink of the type (HWACHE) is higher Than that of a refrigerator that works with the help of a heat sink of the type (HWAC). This indicates that the energy losses of the refrigerator operating with the help of the heat sink (HWACHE) type are less than the energy losses of the Refrigerator operating with the heat sink (HWAC) type. This will also affect the exergy efficiency later on.

4.5 The effect of heat sink type on exergy efficiency

Figure 10 shows the effect of the type of heat sink on exergy efficiency. In this figure, it can be seen that the amount of change in the exergy efficiency of the refrigerator that works with the help of a heat sink of the type (HWAC) varies from a minimum value of (0.3%) to a maximum value (0.8%) with an average value of (0.5%). While it varies from a minimum value of (0.4%)to a maximum value of (1%) in the case of the refrigerator works with the help of a heat sink type (HWACHE) with an average value of (0.62%). This is due to the fact that the refrigerator that works with the heat sink type (HWACHE) has less exergy loss than the refrigerator that works with the heat sink (HWAC). Thus, we can conclude that there is a percentage improvement in the average exergy efficiency of 19.4% in the case of the refrigerator with a heat sink type (HWACHE) compared to the case of the refrigerator with the heat sink type (HWAC).

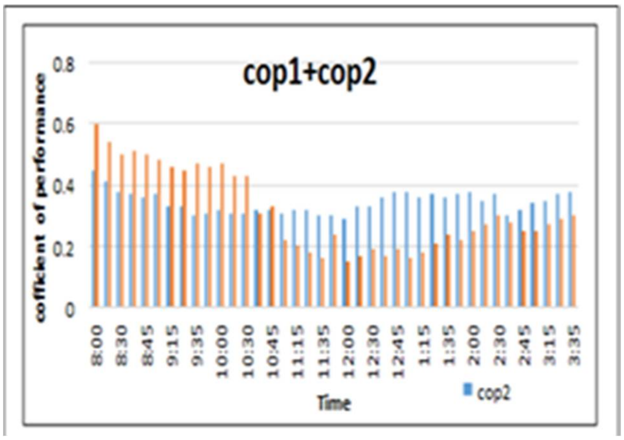

Figure 7: Variation of cofficient of performance (cop) for two different heat sink

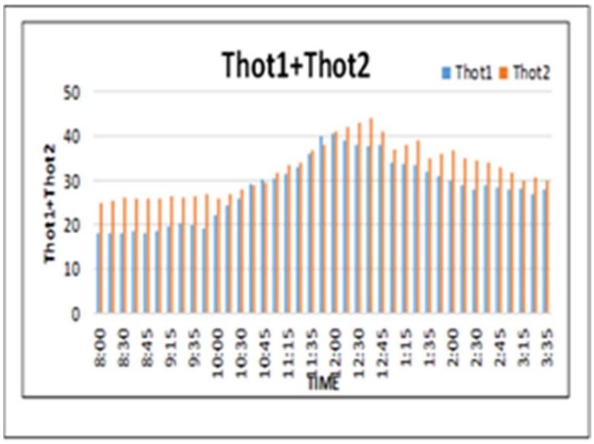

Figure 8: Different temperature hot junction for two heat sinks (HWACHE) and (HWAC)

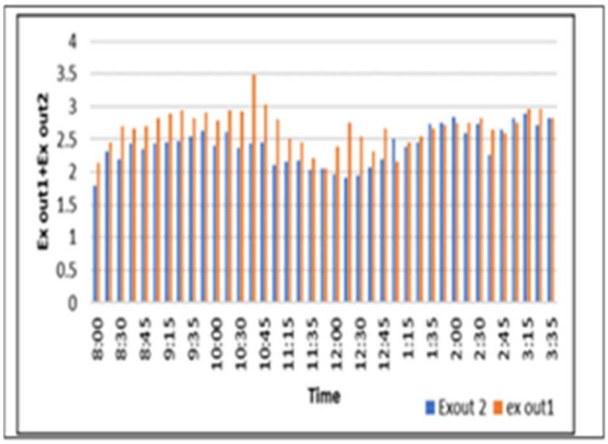

Figure 9: Variation of exergy out along the day for two different heat sink

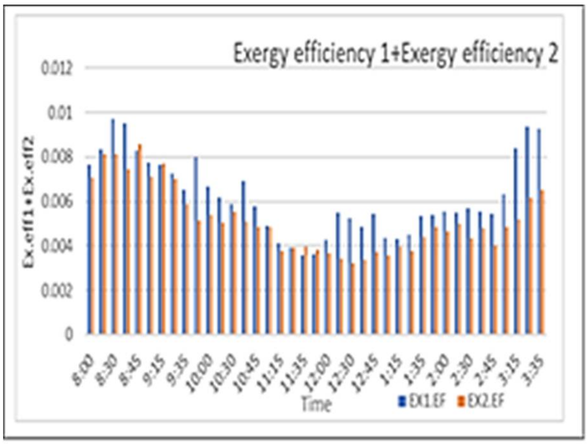

Figure 10: Variation of exergy efficiency through the day for two different types of the heat sink

5. Conclusions

The experimental exergy analysis of a thermo-electrical refrigerator driven by a solar (pv) panel with two different types of the heat sink (HWAC) and (HWACHE) is studied to check the possibility of exergy efficiency. An improvement in the system performance and a reduction of exergy destruction of the thermo electrical refrigerator unit are observed. With the help of heat sink (HWACH) type. Based on the results obtained, the following conclusions can be drawn.

1) The thermoelectric refrigerator that works with the help of a heat sink of the type (HWACHE) can lower the temperature of the cold side to (-7oC) as an average value throughout the day while the thermoelectric refrigerator that works with the help of the heat sink of the type (HWAC) can reduce the temperature of the cold side of the refrigerator to (0.39oC) as an average value during the day.
2) Despite the change of the performance factor during the day for the two types, its average value is almost equal, which amounted to approximately equal to (0.3).
3) The highest value reached by the temperature of the hot side of the refrigerator is (45oC) and (40oC) for both the thermoelectric refrigerator that works with the heat sink of the type (HWAC) and (HWACHE) respectively.
4) The exergy losses of the refrigerator operating with the help of the heat sink (HWACHE) type are less than the heat losses of the refrigerator operating with the heat sink (HWAC) type.
5) The thermoelectric refrigerator that works with the help of the heat sink of the type (HWACHE) can be adopted and utilized with an average exergy efficiency of (0.62%) and an improvement of (19.4%) compared to the thermoelectric refrigerator that works with the help of the heat sink of the type (HWAC).
6) A copper heat sink that is charged with gas As compared to the aluminum heat sink, The cold temperature was constant at a minimum value and the hot temperature of aluminum more than the copper heat sink.
7) The effect of humidity and wind on air temperature and, as a result, on the hot junction of a thermoelectric cooler.
8) The results of this study were compared with other studies, in particular Study No. [14]. It was found that the value of the performance factor was an equal approximation for the two studies when they used the same type of heat sink

(HWAC), which applies to all the previous studies that the research dealt with, but the difference was when we used the second type of heat sink (HWAC), which is represented the point of novelty in this type of studies where better results were obtained through the use of this type, especially in terms of performance factor and temperature of the hot and cold side.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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