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Calculation of the electrical efficiency of a parabolic solar collector dish using TEG technology

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ABSTRACT

In this proposal study, the presentation of the thermoelectric generator, the power age by this framework is naturally companion. The objective of this task is to configure, fabricate, and test a limited-scale thermoelectric generator, as well as to explore a concentrator. Thermoelectric generator powered by solar energy, the objective of this review is to design, fabricate, and test a limited-scale sun-based concentrator. Solar Thermo Electric Generator (STEG) to add to the future improvement of STEGs as a practical sunlight-based nuclear power source in the purchaser market, is used in remote areas that are not equipped with electrical generation sources. The thermoelectric generator is built with a Peltier 12706 module, a heat sink made of aluminum, and copper with a fan, an antenna dish with a diameter of 85 cm that uses aluminum foil on a surface as a solar radiation reflector, and a programmed temperature difference monitor that includes: an LCD crystal screen 16*2, a microcontroller type pic16f676, a digital standard lm35 temperature sensor, and a small Vero Board. A solar power meter is used to calculate the intensity of solar radiation in W/m2. At 0 °C and 100 °C, all thermocouples are calibrated to within 1 °C. the result show the difference in solar radiation in different seasons greatly affects the temperature difference, which plays a key role in generating electric power through the TEC device. The value of temperatures in the summer seasons was up to 100° Celsius.

1. Introduction

Researchers at the University of Aberdeen in Scotland investigate the power correlated to concentrated quartz halogen using thermal-optical collection coupled with an acrylic Fresnel lens and heat sink. They also evaluated the effect of high temperature fluctuations on the open-circuit voltage generated in the electrical Peltier failure mode compared to the normal performance characteristics of TEG modules [1]. A proposed thermoelectric power generation system based on a solar parabolic mirror concentrator is evaluated theoretically and practically. The performance of the designed solar TEG was evaluated and validated using an analytical approach. Maximum power outputs of 16.43 W and 15.35 W were obtained from theoretical and practical studies [2].Test results showed that at a focal length of 57 cm, the conversion, PV and total efficiency of TE were 2.96, 16.69 and 19.65%. The device was powered by a 2.94W TE generator and a 1.93W PV module [3].The TEG model is intended to heat itself using solar energy. The focusing surface of the Solar Parabolic Dish is made of polished aluminum sheet. A thermoelectric module is placed between a support plate and a phase change material (PCM) cooled heat sink [4]. Parabolic trough mirrors and quartz-halogen lights are used to generate solar thermal energy. The heat concentration of the parabolic mirror increases as the intensity of heat utilizing natural sun radiations increase. The smaller parabolic trough mirror caught fewer sun rays than the larger dish form mirror, resulting in extremely little heat in the focus point [5]. Experiments were carried out to increase the performance of a small solar parabolic thermoelectric generator (SPD-TEG). Using affordable waste materials, the TEG module of the receiving unit is tailored to realistic outdoor settings. The temperature differential between the receiver plate and the heat sink has been found to have a significant impact on the output [6].Solar shell collectors have average collector efficiencies that range from 45% to 62% for a variety of designs and operating scenarios. Using a conical receiver design leads to higher thermal efficiency. The properties of heat transport and the thermal performance of the parabolic mirror collector were investigated [7]. In this work, we present an experimental study on a concentrator that converts thermal energy from concentrated solar energy using TEG. With no moving parts and virtually no maintenance, the TEG is reliable

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and robust. The generator was cooled using air, fan, and water cooling methods [8]. An experimental analysis of the power output from a thermoelectric generator (TEG) has been published. The TEG is made up of a flat receiver and a solar parabolic concentrator. The experiment was conducted at the National Institute of Technology in Puducheri, India [9]. A thermoelectric device of the type Module TE-12706 will be used to generate electrical power from sunlight by focusing and directing solar radiation towards the hot side of the electro-thermal device. The system will be constructed using an oval dish made of reflective aluminum for the purpose of concentrating solar radiation. The dish will be positioned at an angle to focus solar energy without the need of a fan (see Figs. 7–9, 15, 16 and 21).

2. Methodology

The simplified ideal equation for a thermoelectric generator is presented in this chapter. The thermoelectric equations, formulae, and structure are defined. The See beck, Peltier, and Thomson effects are discussed. The cooling system's performance is devoted. The Optimum Efficiency (OE) equation is extracted, and power generation is modelled. The parameters, temperature differential for hot and cold junctions, and voltage are all explained. The governing equations is presented for see beck effect, electric resistance, Peltier effect, thomon effect, thermal conductivity, joule effect, intensity of irradiance, the power output from solar panel and its efficiency, and efficiency for output electricity, The electrical parameters of the TEG power generation also described. Thermal efficiency of the dish system, heat sink, and offset parabolic mirror calculations are depicted.

2.1. Physical geometry and analyzing of thermoelectric generator

Thermoelectric materials [10,17–19] are semiconductors with strong coupling between heat flow and electric current flow. These parts are critical for two types of solid-state devices.

- A sturdy refrigerator that conducts electricity through the wall to remove heat from the interior. The Thermoelectric materials is operated below the temperature of room.
- Heat flow is used to generate power. The heat flow from the heat source is frequently greater than the temperature of the room. The Thermoelectric materials is operated above the temperature of room.

2.2. Seebeck effect

Thomas See beck was the one who discovered the See beck effect in 1821. The See beck effect occurs when the temperature difference between two different conductors or semiconductors leads to an electrical potential difference between the two substances. Electrons heated by heat move away from a cooler conductor or semiconductor when heat is applied to either a conductor or a semiconductor. Direct current (DC) flows through an electrical circuit if a power pair is connected to it. most Only a few microvolts are typically produced by the See beck effect for each kelvin of temperature change. Some See beck effect devices can generate millivolts if the temperature difference is significant. A thermocouple is a pair of metal wires used to create an electrical circuit. Thermocouples are used to roughly estimate temperature variations on a bigger scale because of the See beck effect. As illustrated in Fig. 3.3, the See beck effect affects the behaviors of thermocouples, which are employed to detect temperature variations or to activate electronic switches that turn off big systems (see Fig. 4).

See beck unable to pinpoint the source of the magnetic field. This magnetic field is created by equal but opposing currents running through the legs of the two metal strips. The potential difference across the connection generated by the temperature differential between the materials causes these currents. If the connection is open but the temperature difference remains constant, no current will flow in the branch, but the voltage across the open circuit can be monitored.

2.3. Cooling system

When oil in a mechanical gearbox overheats, it loses its capacity to lubricate, and hydraulic clutch or converter fluid leaks due to the pressure that builds up as overheating damages the insulation in electric motors. In order to generate a higher temperature difference across the thermoelectric generator (TEG), the system's efficiency needs be raised. The form and size of the heat sink in this case are crucial for cooling. Forced convection cooling uses an external force (pump or fan) to move the liquid and transfer heat [12] (see Fig. 1).

The cooling can be categorized into active and passive cooling as shown in Fig. 2. Although it is conceivable to think that passive cooling has no impact on net electrical output power, the high thermal resistance of this cooling affects yield. This is because temperature difference determines how much power is produced. The temperature differential may be considerably increased by using active cooling [13].

3. Governing equations

3.1. Seebeck effect

The generated voltage (V) is called the Seebeck voltage, and it is proportional to the temperature difference (T) between the hot and open junctions through a scaling factor (α) known as Seebeck [12],

$$V = \alpha \Delta T \tag{1}$$

were

α: Seebeck coefficient (depending on the material type).

$\Delta T := TH - TL$

If the EMF tends to carry current through wire A from the hot junction to the cold junction, the sign of AB is the positive pole.

A TEG is often made up of several thermopiles that are linked together to maximize output power. Each thermocouple is made up of many thermocouples (TCs) that are electrically coupled in series and parallel. Two distinct materials with opposing Seebeck coefficients are linked at their ends to form the thermocouple. An electric voltage is created when a temperature gradient, ΔT, an electric voltage is created when a temperature gradient, T, forms between the two TC ends.

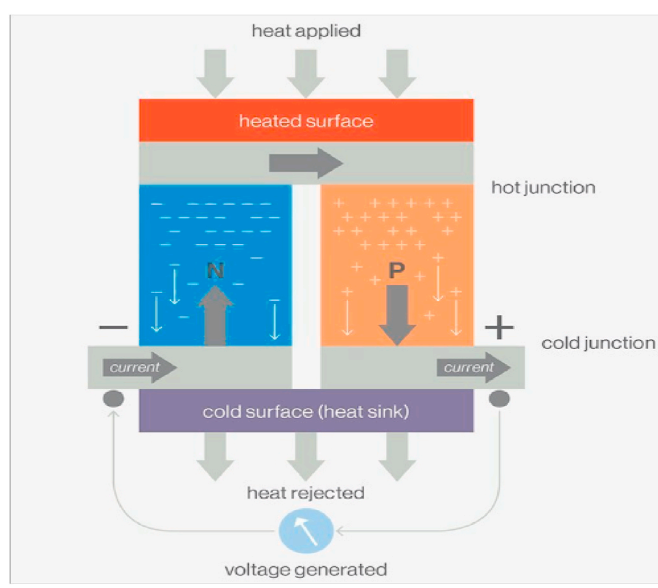

Fig. 1. The See beck effect description [11].

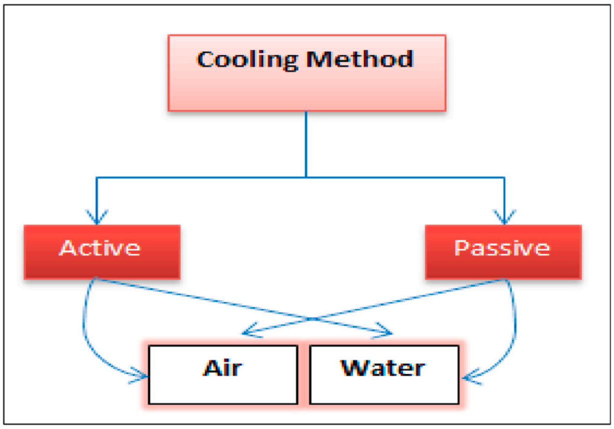

Fig. 2. TEG cooling system categorization.

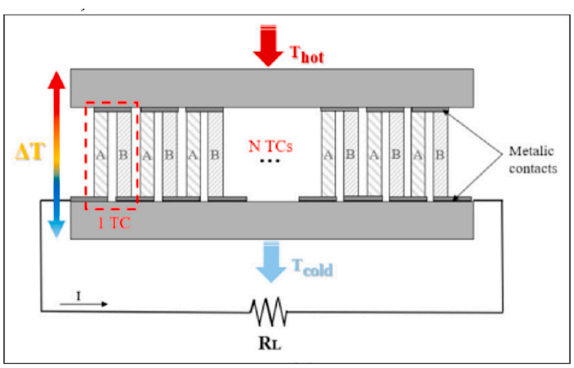

Fig. 3. The principle of thermoelectric generator [9].

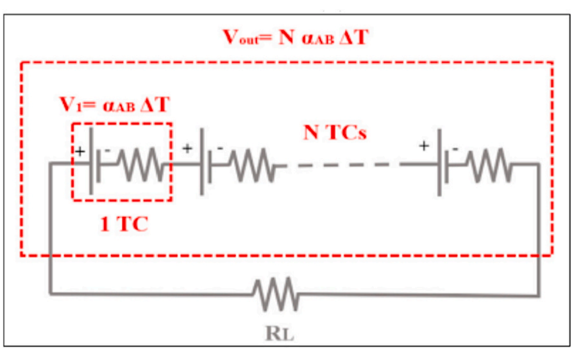

Fig. 4. The equivalent electrical circuit thermoelectric generator [9].

$$Vout = N\alpha AB\Delta T \tag{2}$$

were

N: number of thermocouples connected

αAB: The Seebeck coefficient of the two bonding materials A and B that make up the thermocouple (αAB = αA − αB).

3.2. Electric resistance

When TCs are connected in series, the total internal resistance is proportional to N (Fig. 3.8). Furthermore, a large number of TCs increases the voltage supplied by the TEG and lowers the internal resistance. In fact, increasing the number of TCs connected in series increases the internal resistance of the TEG, given by

$$RTEG = N(\rho ALA / SA + \rho BLB / SB + 2\,\rho CLC / SC) \tag{3}$$

were

ρ A, B, C: Resistivity of materials A and B, as well as metal contacts
L A, B, C: The lengths of the thermocouple arm through which the thermal current travels are LA and LB, respectively, while the contact length is LC.
S A, B, C: The A and B of the thermocouple and contact cross-section, respectively.

So, the output power provided by the generator is:

$$P = V^2\ out\ \left(RL / (RTEG + RL)^2\right) \tag{4}$$

were

RL: External load
RTEG: Internal resistances

The maximum output power is expressed as follows if the load resistance, RTEG, is equal to the internal TEG resistance:

$$P\ max = \left(V^2 out\right) / 4RTEG \tag{5}$$

where (5)

In the present experiment, a thermoelectric device of the type TE-12706 is used for the purpose of generating electrical power through sunlight, where the solar radiation was focused and directed towards the hot side of the electro-thermal device, the characteristics of the used device is shown in Fig. 5[14] (see Fig. 6).

3.3. Thermal efficiency of the dish system

The obtainable solar energy is described as follows:

$$Qs = Aa \times Gb \tag{6}$$

where
Aa: Effective dish aperture
Gb: Solar beam radiation
The energy balance in the fluid volume is used to compute the usable heat production as follows:

$$Qu = m.cp.(Tout - Tin) \tag{7}$$

The thermal efficiency (ηth) of the collector is calculated from the

Details	TEC1-12706	
Size	40 × 40 × 3.46	
Th (°C)	27	50
ΔT max(°C)	70	79
Vmax (Voltage)	16	17.2
Imax (amps)	6.1	6.1
Qc max (Watts)	61.4	66.7
AC resistance (ohms)	2	2.2

Fig. 5. The characteristics of the TECI-12706 device.

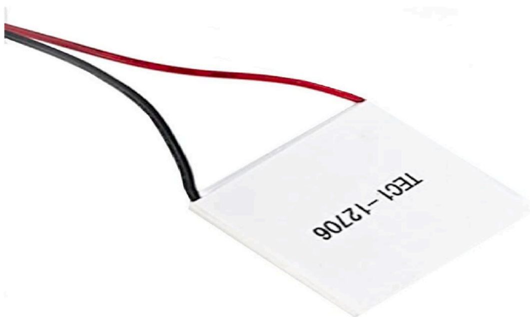

Fig. 6. Tec12706 device.

Fig. 7. Dish.

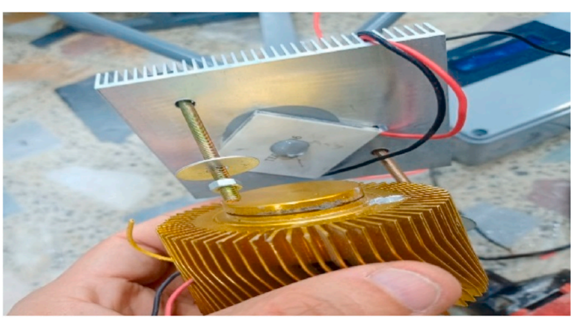

Fig. 8. Heatsink.

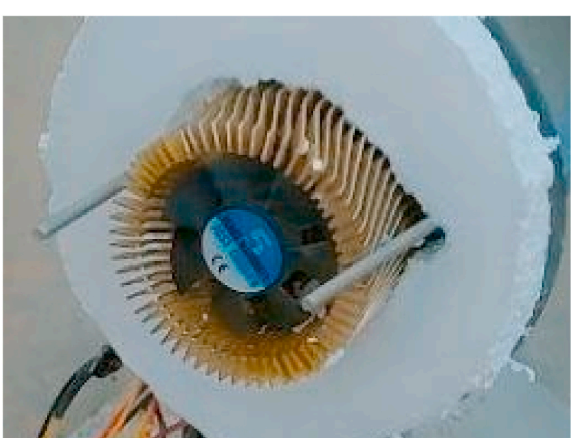

Fig. 9. Fan installation.

ratio of available energy yield and available solar energy as follows:

$$\eta th = Qu/Qs \quad (8)$$

The available exergy production is calculated as follows:

$$Eu = Qu - m.cp.Tam.\ln Tout / Tin - m.Tam\, \Delta p / (\rho fm.Tfm) \quad (9)$$

Solar radiation exergy is calculated using the Petela model [15]as follows:

$$Es = Qs.\left[1 - 4 \Big/ 3.(Tam / Tsun) + 1 \Big/ 3\ (Tam/Tsun)^4\right] \quad (10)$$

Tsun: 5770K

The solar collector's exergetic performance is defined as the ratio of usable exergy output to solar exergy input as follows [16]:

$$\eta ex = Eu/Es \quad (11)$$

The optical efficiency parameter (ηopt) may be used to calculate the collector's rate of heat absorption as follows:

$$Qabs = \eta opt\ .Qs \quad (12)$$

The solar energy that is absorbed is split into useful heat and thermal loss as follows:

$$Qabs = Qu + Qloss \quad (13)$$

Heat loss consists of radiant heat loss and convective heat loss as follows [13]:

$$Qloss = Qrad + Qconv \quad (14)$$

4. Experimental work

It addresses the main parts through which the experimental side, the method of work of the existing devices and the method of their installation.

4.1. TCE12706

It is a thermal device that depends on the temperature difference between its surfaces. An increase in the difference generates a more external voltage and vice versa. This device used in the practical application of the thesis to take advantage of the heat coming from solar radiation and convert it into electrical energy.

Max's Working Tips Working temperature is 138 °C; Imax and Vmax should not be exceeded when using the module. Please advise HB of his options for moisture insurance (selling). Failure rate considering long-term testing is 0.2% in the future.

4.2. Dish

To collect the solar radiation and project it onto the tec12706 device, it was necessary to use an antenna dish with a diameter of 85 cm to collect and reflect the incident solar radiation and transform it into the thermal device to obtain the largest amount of radiation that can be used and converted into heat that generates an electric field. In order to obtain the best reflection, it was necessary to use aluminum tapes that are placed on the dish antenna to obtain a greater reflection of the rays falling from the sun.

4.3. Heat sink

To ensure getting the largest amount of heat by solar radiation to generate voltage, two types of heatsink had to be used. The first is in the form of longitudinal strips made of aluminum that increases the surface area for heat transfer from the solar collector to the tec12706 device, and the second is in a cylindrical shape made of copper that works to discharge heat from the other surface of the tec12706 device to ensure that the large difference in temperature is obtained to obtain the largest amount of generated voltage.

The heatsink is not without a fan to discharge heat from it. where an electric fan was used with a small size that fits the inner diameter of the heat sink that expels heat outside and cools. the cooling surface of the tec12706 device to obtain the largest amount of temperature difference that increases the amount of voltage generated.

4.4. Connect the control system

The electronic chip has been programmed to measure temperature, voltage and current by using a program (Flowcodev4 for picmicros) (see Fig. 13). Where some resistors, capacitors and electrical parts necessary to build the system were used, as the system was installed as in Fig. 14.

And then install the exits and entrances to the control system and put it in a box to protect it from external conditions

4.5. Measuring devices

- Voltage and current meter

Electronic voltmeter shortened as DVM is an instrument used to measure the electrical expected contrast between two concentrations in a circuit (see Fig. 10). The voltage could be a trading current (AC) or direct current (DC). It gauges the data voltage directly following changing the basic voltage over totally to modernized voltage and introductions it in number association using a convertor. The use of cutting-edge voltmeter has accelerated and precision with which the readings are noted. An ordinary DVM is shown under. Multi-reason electronic contraption used to evaluate voltage, current and obstacle, showed in Fig. 11.

- Solar radiation intensity meter

This device is used to measure the intensity in W/m2 of solar radiation. The solar power meter put in the same angular inclination for collector to accurately.as shown Fig. 12.

- Temperature difference measuring device

Temperature recorder 12 channels (Model: BTM- 4208SD) Extech TM500 12 Temperature channel data logger was used to record the temperature (see Fig. 17). Fig. 18 illustrates the device which has 12 channels. Such channels were attached to the thermocouple samples. The data logger will record and store the temperature on the side of the

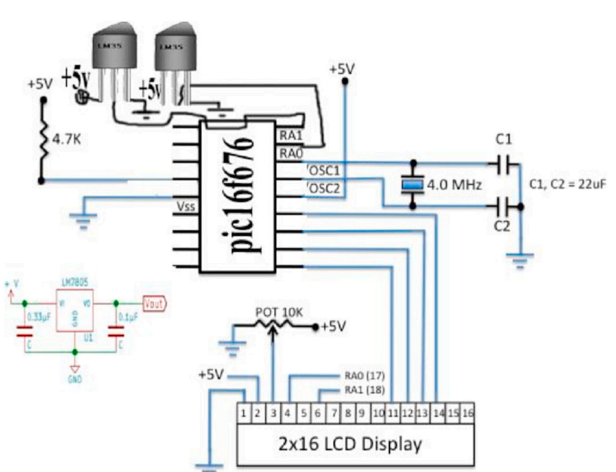

Fig. 10. Connect the control system.

Fig. 11. Voltmeter.

Fig. 12. Solar radiation intensity meter.

Fig. 13. Temperature recorder 12 channels (model: Btm- 4208SD).

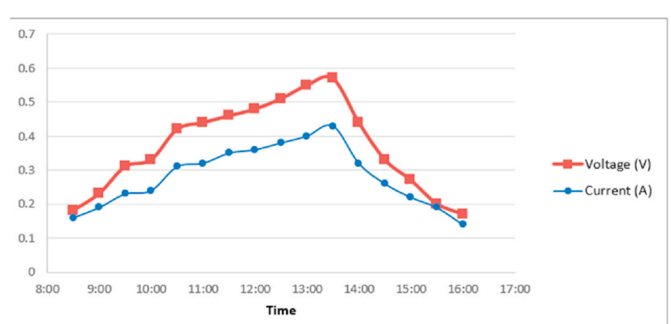

Fig. 14. Voltage and current distribution for the 7th month with heatsink.

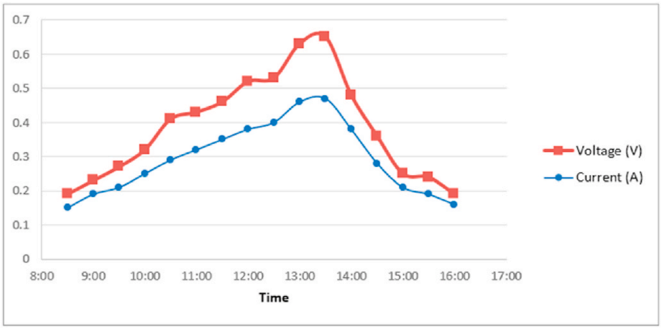

Fig. 15. Voltage and current distribution for the 8th month with heat sink.

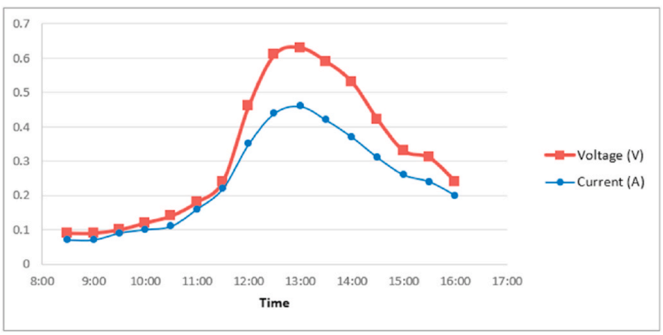

Fig. 16. Voltage and current distribution for the 12th month with heat sink.

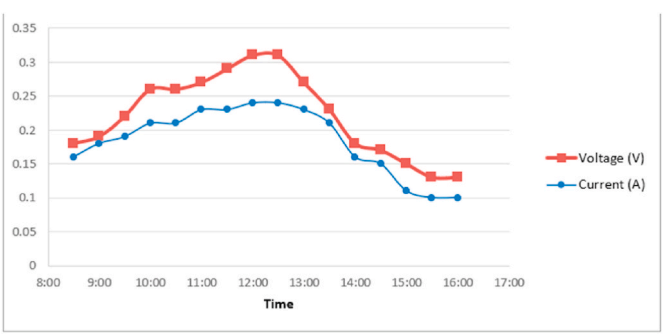

Fig. 17. Voltage and current distribution for the 1st month with heat sink.

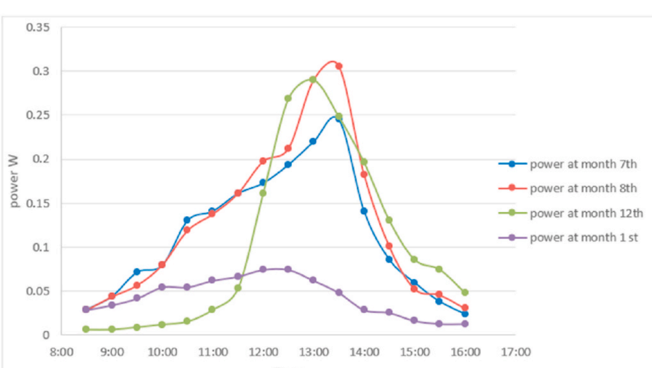

Fig. 18. Power distribution for all month with heat sink.

computer in an SD card. Model: BTM-4208SD.

4.6. Experimental setup

The experiment was carried out in the months 7 and 8 in summer and 1 and 12 in winter to see the differences in readings between winter and summer and the effect of solar radiation in summer on the cooling temperatures of the second face of tec12706, as in the summer the value of the temperature difference is small and therefore the value of the voltage generated by the device decreases.

The experimental aspect was applied in three stages:

In the first stage, the heat sink for the opposite face of the dish antenna was used from the tec12706 device to see the amount of radiation falling on the device and calculate the temperature differences that generate electrical energy. The tests were passed in two conditions. The first condition represents the operation of the measuring devices from 8:30 a.m. to 4:00 p.m., and the dish moves the air in the direction of solar radiation manually every half hour to obtain the largest amount of solar radiation capable of generating electrical potential difference. The second condition represents the operation of the measuring devices from 8:30 a.m. to 4:00 p.m. and installing the air dish without moving it to see the difference in the effect on the fall of solar radiation due to the different temperatures.

5. Results and discussion

5.1. The effect of the seasons on the voltage difference while using heat sink

Thermal electrical devices operate according to temperature differences, as the basic principle of power generation and electricity is the formation of a thermal difference between the two pages of the device. Through the concept that the value of the temperature difference was large in the 7th and 8th month, the value of the generated current and voltage is also large, as can be seen in the following Figures.

It is noticed from Fig. 14 that the value of the generated voltage at 1:30 is less compared to the 8th and 12th months. The reason for this is that the increase in the amount of radiation will not give the appropriate area to get rid of heat on the opposite side. Therefore, the value of the temperature difference between the two faces decreases and it is known the decrease in the temperature difference reduces the value of the generated voltage.

As for the remaining months, note that the value of the generated voltage has reached 0.65 V, which is the highest value reached in the heat sink cases at the 7th month, and it decreases at a rate of up to half in the winter season at the 1st month. The value of the current is affected by the effect of the internal resistance that is loaded on the device and therefore it follows the value of the generated voltage, through which the amount of electrical energy generated can be calculated as in the following figure.

As it was mentioned previously, the value of the generated voltage depends on the temperature difference of the device, and the increase in the value of the difference increases the amount of voltage generated. In Fig. 18, it is noticed that the energy value at the time when the radiation value is at the maximum point at the 8th month is better compared to the 7th month, and the reason is that the increase in the amount of radiation will not give the appropriate area to get rid of heat on the opposite side. Therefore, the value of the temperature difference between the two faces decreases and it is known the decrease in the temperature difference reduces the value of the generated voltage.

5.2. Peltier test

It is a test to narrate the accuracy and operation of the device, heat source was shed on the face of the TEC and on the other hand, an icy liquid to cause the largest difference in temperature to obtain high

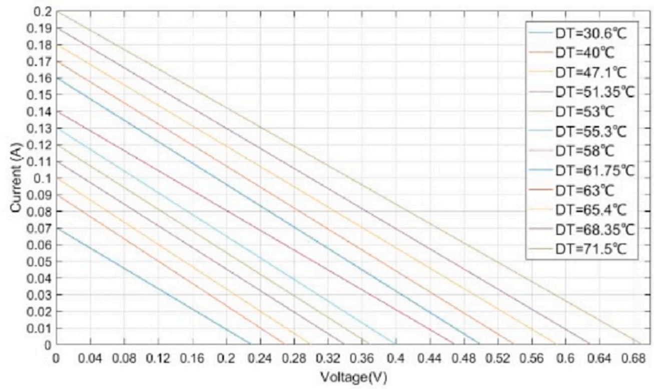

Fig. 19. Current with voltage in different delta T.

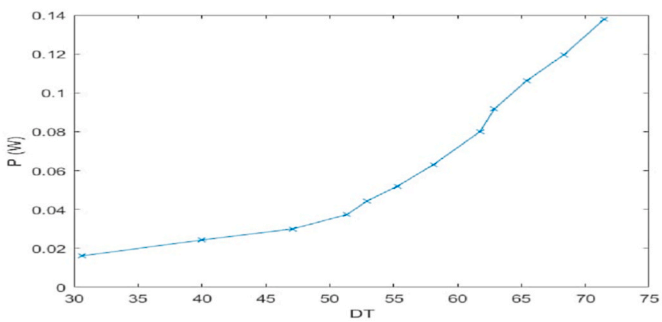

Fig. 20. Power with different delta T.

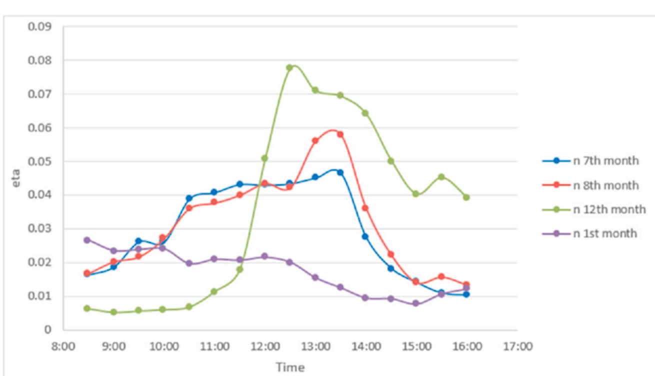

Fig. 21. Efficiency with time at all month by using heatsink.

voltage and current.

The results showed the effectiveness of the device that increasing the temperature difference between the two faces increases the voltage significantly, which leads to obtaining high power, Fig. 19shows the temperature difference between the two faces with the formation of voltage and current at different points (see Fig. 20).

It is noted that the results of the test are similar to the real experiments that were carried out. The temperature difference is at 70° Celsius, it notes that the value of the voltage reached 0.7 V as a maximum for the manufacture of the device. As for the current, at the same temperature difference, it has reached 0.2 A. The value of the output power, which must be at high efficiency due to the large difference in temperature, was also calculated. The value of the power was 0.14W.

5.3. The efficiency of the thermoelectric system

The main principle for knowing the effectiveness of any device, whether it is thermal, mechanical or electrical, is the efficiency factor between the incoming and outgoing capacity and knowing the best state that has been reached to judge it. The results of the experiment were taken and the amount of energy coming out of the current and voltage was calculated, as well as the calculation of the incoming energy represented by the solar radiation falling into the air dish space in order to complete the process of calculating the efficiency.

The value of the efficiency increased at 12:00 to 13:00 to receive the largest amount of heat sink thermal energy. As the 12 month was superior in terms of efficacy, which reached 0.08%. The reason is that the increase in the value of solar radiation does not mean that it leads to better efficiency, as it notices the opposite in winter, due to the great heat on the cold side of the tec device that works on reducing the thermal difference between the two sides and thus reducing the value of the resulting energy.

6. Conclusion

1. The generated voltage depends on the temperature difference of the device, and the increase in the value of the difference increases the amount of voltage generated. It is noticed that the energy value at the time when the radiation value is at the maximum point at the 8th month is better compared to the 7th month. Increase in radiation will not give the appropriate area to get rid of heat on the opposite side.
2. The results of the test are similar to the real experiments that were carried out. The value of the output power, which must be at high efficiency due to the large difference in temperature, was also calculated. The results showed the effectiveness of the device that increasing the temperature difference between the two faces increases the voltage significantly, which leads to high power. It is noted that the values of the voltage and current reached 0.7 V and 0.2 A.
3. The main principle for knowing the effectiveness of any device, whether it is thermal, mechanical or electrical, is the efficiency factor. The results of an experiment were taken and the amount of energy coming out of the current and voltage was calculated, as well as the calculation of the incoming energy represented by the solar radiation falling into the air dish space. The value of the efficiency increased at 12:00–13:00 to receive the largest amount of heat sink thermal energy. As a result, the 12-month period was superior in terms of efficacy, which reached 0.08%.

Credit author statement

W.B. Hantosh: Paper written, simultion, out put figures, S.R. Farag: related work, English editing, S.S. Jumaah: referencess arangement.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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