Design And Performance Analysis Of Solar Refrigeration System Using Peltier Effect

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Abstract- *Solar energy can be converted into electric energy by means of solar panel. This energy can be stored in a rechargeable battery. The electric energy can be then created into any desired energy. In this project the electric energy is converted in to cool energy using peltier effect. The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa via a thermocouple. When a voltage is passed through a thermocouple one end of the thermocouple is heated, the other end gets cooled and. The heated air from the one end of the Pettier element is passed to the exhaust fan. The cool air from the other end of the Pettier element is passed to the blower fan. So as time increases, the cooling will be increased.*

Keywords- peltier effect,solar energy

I. INTRODUCTION

The refrigeration process means removing heat from a specific surrounded space to make its temperature lower than the surrounding temperature . The aim is to provide cooling by using thermoelectric effects rather than using vapour compression cycle or the vapour absorption cycle. The aim is to provide a device that can do the same function without polluting the environment and to reduce the production of the CO_2, SO_2 because it affects our environment. This study was a part of the advanced intelligence technology (AIT) that utilizes the solar energy. Also, it designs and develops a prototype unit that was illustrating the usefulness and economic sustainability of solar energy for the planned purposes

The main objective is to improve the COP of the system. Recent research provides three possible paths that may lead to significant progress in thermoelectric cooling

1. To improve thermoelectric cooling system's thermal design and optimization
2. To improve the intrinsic efficiencies of thermoelectric materials
3. To improve the intensity of the sunlight received through the panel

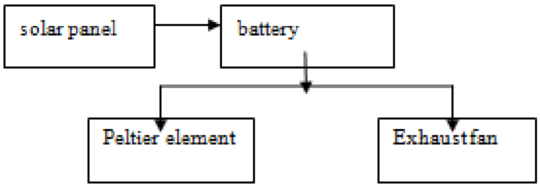
Already inthis paper the design and optimization technique is utilized to improve the COP now for future work the COP of the system can be improved through another two ways

II. METHODOLOGY

The main application of the Peltier effect is cooling. However, the Peltier effect can also be used for heating. In every case, a DC voltage is required. Thus, aim of the project is to utilize cooling effect of a peltier module efficiently. Peltier module can convert thermal energy into electricity. When dc voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface (cold side). The main energy resource that is being used in this prototype is solar energy. PV cells transform solar energy into electrical energy which is used to power the TE system. This system actively uses solar energy to maintain a temperature gradient across a material surface. The heating/cooling power is dependent on the input current direction to each element. Heating power increases with an increasing incoming current, whereas the cooling power has an optimum for a specific current. A regulator can make sure that the incoming current and voltage does not exceed the maximum for each module. The prototype has been designed to manage the maximum output from the solar panel. A battery could also be installed to collect the excess power produced by the PV panel and keep the system running as the sun sets, climate change etc. The electricity produced by the PV cells can be used to run a circulation fan. Air is filtered and blown into the chamber by the fan. The incoming air stream is cooled down by Peltier elements.

A. Block diagram

The Block Diagram Consists of following sub components they are as follows solar panel, battery, peltier module, exhaust fan.



B. Solar panel

Solar power is a renewable energy. A photovoltaic or PV module is a packaged; connect assembly of typically 6x10 photovoltaic solar cells. Photovoltaic modules use light energy called photons from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or back layer. Each module is rated by its DC output power under standard test conditions or STC. The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 W module will have twice the area of a 16% efficient 230 W module.

C. Battery

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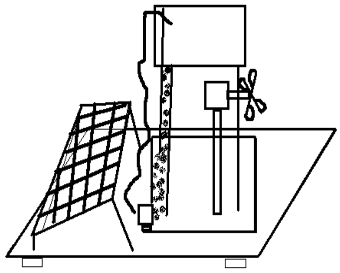
D. Peltier module

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates. By applying a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. At the hot junction, energy is expelled to a heat sink as electrons move from an n-type to a p-type.

E. Exhaust fan

It is an ordinary DC fan. When 12V DC is applied, the fan is operated. It sucks the air from the back side and delivers to the front side

F. line diagram



III. EXPERIMENTAL SET UP

Thermoelectric coolers operate by the Peltier effect (which also goes by the more general name thermoelectric effect). The device has two sides, and when a DC electric current flows through the device, it brings heat from one side to the other, so that one side gets cooler while the other gets hotter. The "hot" side is attached to a heat sink so that it remains at ambient temperature, while the cool side goes below room temperature. In some applications, multiple coolers can be cascaded together for lower temperature.

A. Construction

Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then joined with a thermally conducting plate on each side. When a voltage is applied to the free ends of the two semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. Thermoelectric Coolers, also abbreviated to TECs are typically connected side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

Some benefits of using a TEC are:

- No moving parts so maintenance is required less frequently
- No chlorofluorocarbons (CFC)
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration

- Long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Controllable via changing the input voltage/current

B. Experimental setup

The effect of Peltier is a crucial concept in this study. The thermoelectric effect is a direct exchange of temperature differences to electric voltage and vice-versa

Thermoelectric coolers operate by Peltier effect which also goes by general name thermoelectric effect. However, the device has two sides when a DC electric current passes over the Peltier; it generates heat from each side which one side gets cooler while the other hotter

The hot side is attached to the heat sink which remains at atmospheric temperature. On the other hand, the cold runs below the room temperature

Fig.1 photographic view of experimental set up

Fig.2 photographic view of peltier module

IV. DESIGN CALCULATION

A. product load calculation

Load in refrigeration means heat that is given as input by placing a product with in the system and now the process of refrigeration comes in to picture and this is referred to as product load

$$Q = m\,c_p\,(T_S - T_P)$$

M = mass of the product

c_p = specific heat of the product

T_S, T_P = temperature of surrounding and product

let as assume m=2 kg, c_p = 3.5 kJ/kgk, $T_S = 30°C$, T_P= 15°C

Q = 2*3.5*(30-15)

=105KJ

Since 1KWH = 3600KJ

Q = 105/3600

Q = 30.41 WH

similarly if the product vary the cooling load will be also vary and if the mass of the product vary this cooling load will vary

B. Battery capacity calculation

η = energy output/energy input

Let as assume our efficiency to be maximum as 90%

Energy output = CED

0.9 = 30.41/energy input

Energy input = 33.79 VAH

$$\text{Battery capacity} = \frac{\text{energy input}}{V * (\text{Depth of discharge})}$$

$$= \frac{33.796}{0.5 * 12V}$$

= 11AH

∴ 1 Battery of 15AH

C. Solar panel calculat ion

$$I_{PV} = \frac{\text{Energy input}}{V * H}$$

$$I_{PV} = \frac{33.796}{12 * 5}$$

= 0.563A

In order To compensate loss as 20 of I_{PV}

I_{PV} = 0.563+(0.563*0.2)

I_{PV} = 0.675A

Peak power = $I_{PV} * V_P$

Assume peak voltage V_P = 17.32V

Peak power = 0.675 *17.3

= 11.934W

D. Number of solar panel calculation

No of solar panel = $\frac{\text{peak power}}{\text{stand by mode power}}$

Standby mode power = 0.25VA/H(assume 24 hrs.)

= 6 VA

= $\frac{11.934}{6}$

= 1.37(or) 1

$\therefore 1$ Solar panel

E. Invertor rating

Invertor cannot load more than 75% of load

75% of I_R = product load

O.75 (I_R) = 33.79

$I_R = \frac{33.79}{0.75}$

$\therefore I_R$= 45.06 VA

F. Charge controller

To prevent overload of PV 20% OF I_{PV}

Charge Controller Rating = I_{PV} + (20% + I_{PV})

= 0.675+ (0.2*0.675)

= 0.81 A

$\therefore 1$ Charge controller of 5A is needed

G. Cable size calculation

A= $\frac{2D * I_{PV}}{\sigma * \Delta V}$

Assume

D = 10M

σ = Conductivity of the copper wire

ΔV = Drop in voltage

A = (2*10*0.563)/(0.36*56000000)

A = 0.585m^2

V. RESULTS

A. Heat rejection vs current

The variation of heat rejection with respect to current shows that the it is directly proportional when the current increases the heat rejection rate also increasing because when current flow increases the working of exhaust fan also increases and hence the heat rejection rate increases this can be obtain using the formula Q= m$c_p$dt

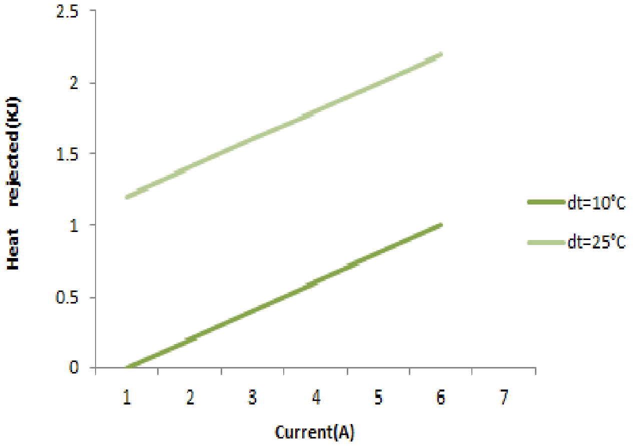


Fig.3 Heat rejected Vs current

B. *Coefficient of performance vs current*

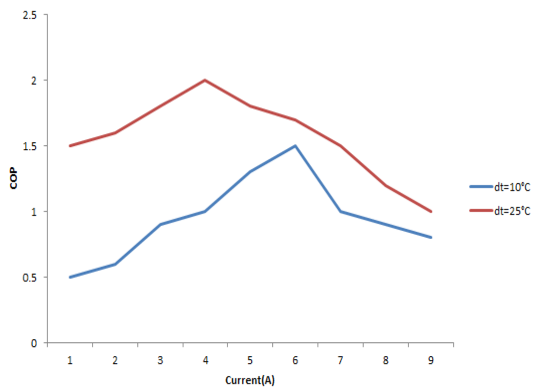


Fig.4 coefficient of performance vs current

The figure shows the variation of COP with respect to current and it shows that COP is increases up to a point when the current increases and it decreases due to heat produced in the peltier module it get overheated due to the increase in current flow and from the graph it is obtained that the maximum COP reached is 2 above this it decreases

C. Temperature vs current

The Figure shows that the variation of temperature with respect to current and it shows that current is increases when the temperature increases because when the temperature increases the rate of photon that hits the surface of the solar panel will increases and hence the rate of flow of current will increase

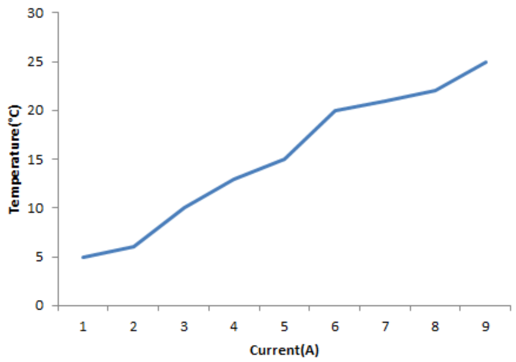


Fig.5 temperature VS current

D. Efficiency vs temperature

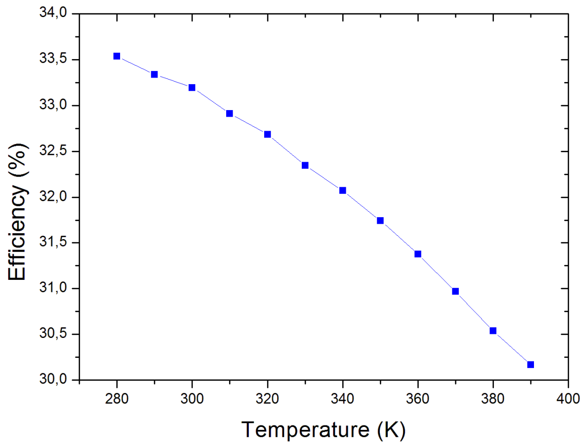


Fig.6 Efficiency vs temperature

The variation of temperature with respect efficiency shows in the figure 5.4 it is obtained that efficiency decreases as the temperature increases this what obtain in the P-V characteristics of the solar panel where we that the panel will reach the optimum point at 25°C at the same time from the above graph that it will produce maximum efficiency at 300K (i.e.27°C)

So from the above observation the panel will produce maximum power at atmospheric temperature (32°C) if the temperature rises above it the efficiency will decreases

E. Time vs temperature

The variation of time with respect to time in summer and winter shows that the voltage and temperature will maximum at noon time because of the position of the sun directly above the head so that it reach maximum intensity

So that by using tracking system can improve the solar irradiation and hence the intensity can be tracked by it so that maximum intensity which will utilized in the future work

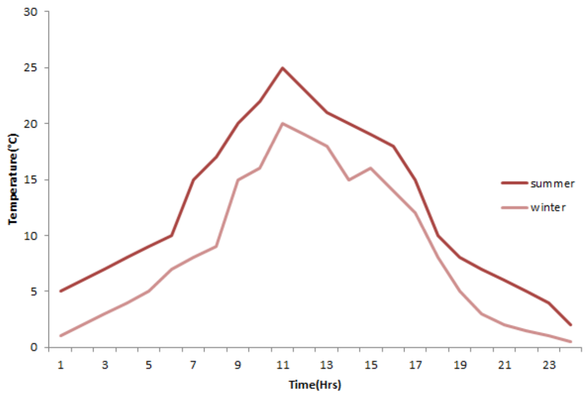


Fig.7 temperature Vs time

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REFERENCES

[1] Anliang Wang, Wei Zhu, Yuan Deng, Yao Wang, (2013), "Finite element analysis of miniature thermoelectric coolers with high cooling performance and short response time", Microelectron, Vol.44, pp.860-868.

[2] Chin Hsiang Cheng, Shu-Yu Huang, Tsung Chieh Cheng, (2010), "A three-dimensional theoretical model for predicting transient thermal behaviour of thermoelectric coolers", International Journal of. Heat and Mass Transfer, Vol.53, pp.2001-2011.

[3] Daniel Mitrani, Jordi Salazar., Antoni Turo, Miguel J. Garcia, Juan A. ChaveDz,(2018), "One-dimensional modeling of TE devices considering temperature dependent parameters using SPICE", Microelectron,Vol.40,pp.1398-1405.

[4] Diago et al, (2013), "Cooling, heating, generating power, and recovering waste heat with thermoelectric systems", Science, Vol.321, pp.1457-1461.

[5] Han Li, (2009), "High performance $In_xCe_yCo_4Sb_{12}$ thermoelectric materials with in situ forming nanostructured InSb phase", Applied Physics Letters, Vol.94, pp.102-114.

[6] Hilaal Alam, Seeram Ramakrishna, (2013), "A review on the enhancement of figure of merit from bulk to nano-thermoelectric materials", Nano Energy, Vol.2, pp.190-212.

[7] Hongxia Xi, Lingai Luo, Gilles Fraisse, (2017) "Development and applications of solar based thermoelectric technologies", Renewable and Sustainable energy, Vol.11, pp.923-936.

[8] Hosung Lee, (2013), "The Thomson effect and the ideal equation on thermoelectric coolers", Energy, Vol.56, pp.61-69.

[9] Huili Liu, (2012), "Copper ion liquid like thermoelectrics", Nature Materials, Vol.11, pp.422-425.

[10] Jeffrey Snyder .G, Toberer.S,(2018),"Complex thermoelectric materials", Natural Material, Vol.7,pp.105-114.

[11] Jing-Hui Meng, Xiao-Dong Wang, Xi Xin Zhang, (2013), "Transient modeling and dynamic characteristics of thermoelectric cooler", Applied Energy,Vol.108 ,pp.340-348.

[12] Jong Soo Rhyee, et al., (2009) ,"Peierls distortion as a route to high thermoelectric performance in In_4Se_{3-}d crystals", Nature of materials459Vol.5,pp.965-968.

[13] Kanishka Biswas, et al., (2011), "Strained endotaxial nanostructures with high thermoelectric figure of merit", Nature of Chemistry, vol.2, pp.160-166.

[14] Kuei Fang Hsueal.,(2018), "Cubic $AgPb_mSbTe_{2\ m}$: bulk thermoelectric materials with high figure of merit", Science, vol.3,pp.303-818

[15] Mei Jiau Huang, Ruey-Hor Yen, An-Bang Wang,(2015),"The influence of the Thomson effect on the performance of a thermoelectric cooler", International Journal of Heat and Mass Transfer",vol.48,pp.413-418

[16] Pierre F.P., Poudeu, et al., (2010), "High figure of merit in nanostructured n-type $KPb_mSbTe_{mþ2}$ thermoelectric materials", Chemistry of Materials. Vol.22, pp.1046-1053.

[17] Riffat S.B, Xiaoli Ma, (2019), "Thermoelectric: a review of present and potential applications", Applied Thermal Engineering, Vol.23, pp.913-935.

[18] Simon Lineykin, Shmuel Ben-Yaakov, (2007), "Modelling and analysis of thermoelectric modules" IEEE Trans, Vol.43.

[19] Sootsman.J.R, (2015), "New and old concepts in thermoelectric materials, Angew", Chemical International Editions, Vol.48, pp.8616-8639.

[20] Terry M. Tritt, "Thermoelectric phenomena, materials, and applications", Annual Reviews of Material Research. Vol.41, pp.433-448.

[21] Weishu Liu, Xiao Yan, Gang Chen, Zhifeng Ren, (2016), "Recent advances in thermoelectric Nano composites", Nano Energy, Vol.1, pp.42-56.

[22] Wei-Shin Chen, Chen-Yen Liao, Chen-I. Hung, (2012), "A numerical study on the performance of miniature thermoelectric cooler affected by Thomson effect", Applied Energy, Vol.89, pp.2464-473.

[23] Wei Zhu, Yuan Deng, Yao Wang, Anliang Wang,(2013), "Finite element analysis of miniature thermoelectric coolers with high cooling performance and short response time", Micro electron, Vol.44, pp.860-868

[24] Xiao-Dong Wang, et al.,(2012), "A three numerical modelling of thermoelectric device with consideration of coupling of temperature field and electric potential field", Energy,Vol.47, pp.488-497.

[25] Yuanyuan Zhou, Jianlin Yu, (2012),"Design optimization of thermoelectric cooling systems for applications in electronic devices", international Journal of Refrigeration.Vol.35,pp.1139-1141.

[26] Zhi-Gang Chen, Guang Han, Lei Yang, Lina Cheng, Jin Zou, (2012), "Nanostructured thermoelectric materials: current research and future challenge", Progress in Natural Science: Materials International, Vol.22, pp.535-549.

[27] Zhang Y.C., Mui, Tarin.m, (2010), "Analysis of thermoelectric cooler performance for high power electronic packages", Applied Thermal Engineering.Vol.30, pp.561-568