International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

# Construction and Performance Investigation of a Portable Solar Powered Thermoelectric Refrigerator

Umar Muhammad Kangiwa*[1], Gwani Mohammed[*2], Isaac Oseni Samuel[*3], Mudassir Na-Allah[*4]

*[1,2,4]. Department of Physics, Faculty of Physical Sciences, Kebbi State University of Science and Technology Aliero, Nigeria

3. Electrical Maintenance Department, Labana Rice Mill. Birnin Kebbi, Nigeria

Date of Submission: 01-01-2024 Date of Acceptance: 12-01-2024

**ABSTRACT**

Preservation and storage of perishable food, fruits and vegetables, vaccine and cooling of water face challenges of electrical power supply in isolated areas. The use of solar power with thermoelectric generator is prominent technology. This project present the solar powered thermoelectric refrigerator constructed by exploiting the solar energy and evaluated it's cooling performance with product load. The solar powered thermoelectric cooler comprised of a Peltier module of 60W capacity, large and small aluminum heat sink, photovoltaic panel 80W capacity connected with the device through storage battery of 62AH and solar charge controller of 20A as well as the cooling chamber of 5.2 liters capacity. The experimental investigation based on the performance parameters highlighted that, harnessing solar radiation at 673.91 W/m$^2$ enable enhancing 386.46 W input power and 24.31W PV output power at 6.25% efficiency. The thermoelectric refrigerator obtained 2.21 coefficient of performance as a result of 12.25$^0$C temperature difference by the thermoelectric module. The thermoelectric refrigerator has achieved a maximum temperature of 16$^0$C, which is a significance temperature for storing of vaccines, cooling of water and preservation of vegetables. Solar powered thermoelectric refrigerator is suitable, clean and environmentally friendly system for refrigeration in isolated areas. .

**Keywords:** Peltier Module, Thermoelectric Refrigerator, Solar energy, cooling effect

## I. INTRODUCTION

The current energy trends and irrational utilization of the world's resources pose a great threat to the globe. Exhaustible reserves of fossil fuels cannot take us to the promise land in terms of economic development, because they are not only improbable, but also harmful to the fragile systems on earth. Imbibing other means of sustainable energy resources to satisfy our increasing energy demand becomes paramount, as scientific researchers have been echoing on eminent environmental tragedy. Renewable energy sources are not only alternative to exhaustible fossil fuel reserves, but will go a long way to ameliorate the harm caused by fossil fuel utilization [1]. Presently, a lot of researches are ongoing on the cheapest, reliable and renewable energy sources. Most of the research works are channeled toward solar energy being common among the available renewable energy sources. Therefore, the ideal solution would be to use some type of renewable energy resource to provide houses with energy without an expensive electrical grid connection [1].

Thermoelectric systems are a solid-state heat device that either converts heat directly into electricity or transform electric power into thermal power.

For heating or cooling that takes the form of a heat flux which then induces a temperature difference across the thermoelectric cooling system. Such devices are based on thermoelectric effects involving interactions between the flow of heat and electricity through solid bodies.

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. Various refrigeration systems are being used commercially and for domestic use. They can be classified cyclic, non – cyclic, magnetic and thermoelectric refrigeration system [2].

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

Thermo-electric refrigeration based on the Peltier effect has important advantages compared to conventional vapor technology in spite of the fact that its coefficient of performance (COP) is not as high a vapour compression technology. Some of these can be listed: free of refrigerant, the using of electrons as refrigerant, more compact system state, lower noise and vibrations, high quality temperature control and less maintenance requirements [3]. Solar thermoelectric refrigeration systems capture the incoming sunlight and convert the solar thermal energy into electricity for powering the thermoelectric as a source of energy and its applications [1]. Thermocouple systems are electrical device consisting of two dissimilar electrical conductors forming electrical junctions (heating and cooling) at different temperatures. A thermocouple produces a temperature- independent voltage as a result thermoelectric effect, and this voltage can be interpreted to measure temperature. Thermocouples are a widely used type of temperature sensor [3].

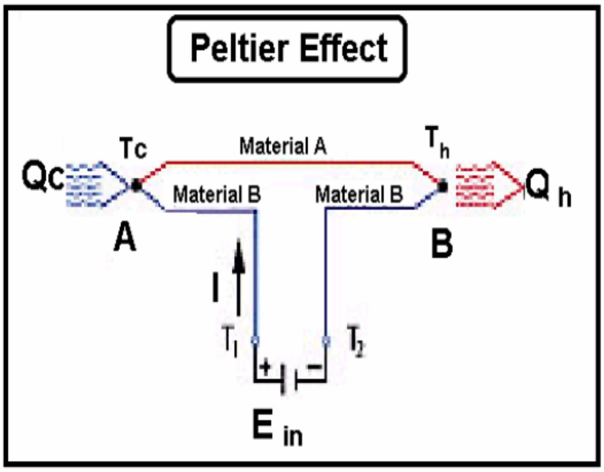


**Figure1: Experimental representation of Peltier effect [3]**

[1] Proposed a design and fabrication of thermoelectric solar refrigerator, using a cooling capacity of 60W for a single stage Peltier module of TEC1- 12706 (40mmx40mmx35mm) of temperature difference of $12^0$C, Seebeck coefficient of 0.05133V/K thermal conductivity of 0.0193W/K and module resistance of 0.367Ω. The experimental results of the developed prototype of thermoelectric shows a $10^0$C reduction at 250Ml water inside refrigeration space of developed thermoelectric refrigerator has be experimental found with respect to $31^0$C ambient temperature at 120 minutes (2hours). The refrigeration cabinet itself has been experimentally shown to have a $16^0$C reduction in temperature with respect to $31^0$C ambient temperature in 120 minutes and can work for 3 hours when battery is fully charged.

[2] Have worked on design and investigation of portable thermoelectric air chiller. They achieved a cooling power of 60W for a single stage Peltier module TEC1-12706L (40mm×40mm×35mm), within a temperature difference of $22^0$C, Seebeck coefficient of 53mV/K, thermal conductivity of 0.1815W/K, module resistance of 1.96Ω, cooling capacity of 53.265W and input power of 77.556W, they obtained a COP of 0.686. [3] Proposed and worked on design and analysis of solar powered thermoelectric refrigerator, using a single stage peltier module of 50W capacity TEC1-12706 of dimension 40mmx40mmx4mm, temperature difference of $15^0$C, Seebeck coefficient of 0.04832V/K, module resistance of 1.75Ω, thermal conductivity of 0.5435W/K, cooling capacity of 45.79W, input power of 76.3187W and COP of 0.6 was obtained, a temperature of $22.522^0$C was obtained from the cooling cabinet of dimension (250mmx250mmx265mm). [4] Worked on the solar powered thermoelectric refrigerator system, using a cooling capacity of 60W TEC1 – 12706, they used a 2L capacity cooler box. Having a cooling capacity of 6.17W, energy supplied 50W; a COP of 0.124 was obtained with cooler chamber temperature at $18^0$C. [5] Worked on the design and implementation of solar powered mini refrigerator using thermoelectric cooler module, using a single phase cooling capacity of 60W of Peltier module of TEC1 – 12706. The result shows that the temperature of the system reduces from $28^0$ C to $5^0$ C within one-hour operation. And the temperature

of the hot side of the TEC1 – 12706 module increases drastically within 15 minutes. The cooling chamber designed; having a 6 liters capacity of cooling space (20cmX15cmX20cm), from there experimental condition COP of 0.7 was obtained.

### 1.2 Solar Thermoelectric Refrigerator Performance Evaluation Parameters

The performance of the solar powered thermoelectric refrigerator is usually investigated by considering the solar power input, solar power output, solar module efficiency, energy supplied, and change in temperature, cooling capacity and coefficient of performance.

#### 1.2.1 Solar Power Input

A solar power meter (Phyranometer) has been used to measure the direct sun radiation in W/m$^2$. A solar module consists of several interconnected solar cells, these interconnected solar cell embedded between two glass plates to protect from the bad weather. The photons from solar radiation are being converted by the use of solar PV panels. The amount of sun radiation (W/m$^2$) directly striking the surface of the PV modules of given specifications (m$^2$) is refers as the useful power input and was evaluated using equation (1):

$$P_{input} = S \times A \quad (1)$$

Solar Power input = sun radiation in W/m$^2$ * Area of the PV module in m$^2$

Where A is the area of the PV module (m) and S is the Sun radiation striking the area of the module [11].

#### 1.2.2 Solar Power Output

The Solar PV module is a device that harnessed sun radiation and converts it into electricity through the principles of photovoltaic effect. The magnitude of the power output from the solar PV module duly depends on the intensity of solar radiation available at the location where it has been installed. The measured voltage and current output from the PV panel are usually used in equation (2) to determine the total power output generated by the PV module.

$$P = I_0 V_o \quad (2)$$

Where $I_0$ is current output and $V_o$ is the voltage outputof the solar PV panel directly connected from the module which is measured by voltmeters. However, the above equation is commonly associated with Ohms law [11].

#### 1.2.3 Efficiency of Solar Module

Efficiency (%) of the solar module is the ratio of the power output to the power input multiplied by 100 percent.

$$\text{Efficiency} = \frac{\text{power output}}{\text{power input}} \times 100\% \quad (3)$$

#### 1.2.4 Energy Supplied (P)

The solar thermoelectric refrigerator will be powered by solar panel via charge controller and storage battery. The energy supplied is the sum of the power delivered to the refrigerator and the cooling fans. The energy supplied to the system was evaluated by using equation (4) [7] [12].

$$W_{in} = VI + F_i \quad (4)$$

$W_{in}$ is the input power or energy supplied (W), V is the nominal voltage (V), I is the current supplied the modules and cooling fans (A) and $F_i$ is the fan input in Watt.

#### 1.2.5 Change in Temperature

This is the variation between the hot side of the peltier module and the cold side of the module.

$$\text{Change in Temperature} = T_h - T_c \quad (5)$$

Where $T_h$ is the temperature of the hot side while $T_c$ is the temperature of the cold side

#### 1.2.6 Cooling Capacity ($Q_c$)

Peltier effect gives the heating and cooling rate of a thermoelectric cooling. The cooling capacity $Q_c$ obtained from the energy balance at the cold side of the Thermoelectric cooler (TEC). The cooling capacity for the solar powered thermoelectric refrigerator was evaluated by using equation (6) [9] [12] to measure data.

$$Q_c = \frac{mc\Delta T}{\Delta t} \quad (6)$$

$$m = \rho \times V \quad (7)$$

$Q_c$ is the cooling capacity (W), m is the mass of the substance/water to be cooled (Kg), C is the specific heat capacity of water (KJ/Kg/K), ΔT is the temperature difference between the two sides (K), Δt is the change in time from the start to the end of operation, ρ is the density of the substance (kg/m$^3$), v is the volume of the inner chamber or the cooling box in metre cubic.

However, water has a density of 1Kg/L; that is one litre of water has a mass of exactly one kilogramme.

$$1\text{Kg of Water} = 1 \text{ litre of Water} \quad (8)$$

One litre of water has the same almost exactly one kilogram when measured at a maximal density when occurs at 4$^0$C [7].

### 1.2.7 Coefficient of Performance (COP)

The coefficient of performance is meant to determine the thermal efficiency of the system. The coefficient of performance (COP) is the ratio between the cooling capacity $Q_c$ and the electrical power input. The COP was evaluated by using equation (9) [7] [12].

$$COP = \frac{Q_c}{W_{in}} \quad (9)$$

$Q_c$ is the cooling capacity in watt, $W_{in}$ input power or energy supplied in Watt.

This research aimed at construction and investigation the performance of a portable solar powered thermoelectric refrigerator. This was achieved by constructing solar powered thermoelectric refrigerator using the available local components and experimentally investigating its performance by carrying out analysis of the operational parameters related to solar powered thermoelectric refrigerator. This project is a demonstration of an eco-friendly methodology for the implementation of solar powered thermoelectric refrigeration system. In the recent year, energy crisis and environmental degradation due to the increasing Carbon dioxide ($CO_2$) emission and ozone layer depletion has become the primarily concern to both developed and developing countries. Solar refrigeration using Peltier module does not need any kind of refrigerant and mechanical device like compressor, prime mover etc. for its operation, but however it utilizes solar energy. This system would be one of the most cost effective, clean and environment friendly for preservation of vegetables, storage of vaccines, cooling waters etc. If accurately constructed and developed towards utilization level, the inhabitant of the remote location would be provided with alternative, efficient solar powered thermoelectric refrigerator.

## II. METHODOLOGY

### 2.1 Materials

The equipment's and tools required for construction and performance investigation of a portable solar powered thermoelectric refrigerator are shown in Tables 2.1 and 2.2 respectively.

Table 1: Equipments used for construction

| S/NO | COMPONENT | SPECIFICATION | MODEL |
|---|---|---|---|
| 1. | Solar panel | 80W | Monocrystalline |
| 2. | Solar Charge Controller | 20A, 12V | PWM |
| 3. | Battery Bank | 62AH, 12V | Lithium – ion |
| 4. | Peltier Module | 60W, 12V | TEC1- 12706 |
| 5. | Heatsink | (166W/m.K - 299W/m.K) | T5 – 6063 (Alloy) |
| 6. | Cooling Fans | 3W, 12V | DC(GDT3007512B) |
| 7. | Aluminum Sheet | $1.00m^2$ | 3000 series (alloy) |
| 8. | Socket Outlet | 13A | Wall outlet |
| 9. | Plug | 13A | Wall outlet |
| 10. | Styrofoam | (28 x 20 x17) cm | Extruded Polystyrene |
| 11. | Connecting Wires | $1.5mm^2$ | Single and double core |
| 12. | Hard Board | (32 x 25 x 21) cm | |

Table 2: Measurement Equipment.

| S/N | COMPONENT | SPECIFICATION | MODEL |
|---|---|---|---|
| 1. | Phyranometer | Range (0.3 µm- 3.0 µm) | TES – 1333 |
| 2. | Thermocouple Thermometer | 16 Distinct Channel | AT - 4516 |
| 3. | Digital Multimeter | AC/DC Voltage (200mV–1000V)<br>AC/DC Current (200µA – 10A)<br>Frequency (1Hz – 1000Hz)<br>Resistance (200Ω - 20MΩ)<br>Capacitance (2000pF- 20µF) | ST - 3501 |

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

### 2.1.1 Peltier Module - (Tec1-12706)

A Peltier module (TEM) is a solid state current device, which, if power is applied, move heat from the cold side to the hot side, acting as a heat exchanger. This direction of heat travel will be reversed if the current is reversed. Combination of many pairs of p and n semiconductors allows creating cooling units, Peltier modules of relatively high power.

**Figure2: Peltier Module [10]**

The thermoelectric module chosen was Peltier module by Bismuth Telluride ($Bi_2Te_3$). Bismuth Telluride was used in this research because it has the highest thermoelectric figure of merit, of any material around room temperature; which can be traced to the high band degeneracy, low effective mass, high carrier mobility, readily available, cheap and relative low lattice thermal conductivity as adopted by [7]. In this study four (4) TEC1- 12706 Peltier module was utilized, whose specification is as follows [7]; The specification of common thermoelectric module of TEC1 – 12706 is shown in the Table (2.3)

Table 2.3: Specification of common thermoelectric Module (TEC1-12706)

| | | | |
|---|---|---|---|
| MODULE: Model TEC1-12706 | | | |
| $Q_{max}$ | 60watts | DIMENSION | |
| $I_{max}$ | 6Amp | Length | 40mm |
| $V_{max}$ | 15.4V | Width | 40mm |
| $T_{max}$ | $68^0$C | Thickness | 4mm |
| Number of couples | 127 | | |

### 2.1.2 Solar Panel

The direct conversion of solar energy is carried out into electrical energy by means of the Photovoltaic effect i.e. the conversion of light or Other electromagnetic radiation into electricity. Solar energy can be converted directly into electrical energy by solar cell, more generally a photovoltaic cell.

**Figure 3: Solar Panel**

### 2.1.3 Charge Controller

A charge controller is an essential part of solar refrigeration system that charge battery. Its purpose is battery properly fed and safe for the long term. The basic functions of a controller are quite simple. Whenever the sunrays fall on a solar panel then there is a fluctuation of solar rays on solar panel. To avoid the fluctuation of sunrays on solar panel, we use charge controller in solar refrigeration system. Also, charge controller prevents battery overcharge and electrical overload. We are using PWM (Pulse Width Modulation) base solar charger in our solar refrigeration system.


**Figure 4: Charge Controller**

### 2.1.4 Battery

The battery is an electrochemical device. It is used to convert the chemical energy into electrical energy. The operating of cranking motor and other electrical units depends on the battery, as the current is being supplied by the battery.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252


**Figure 5: Solar Battery**

**2.2 Methods**

**2.2 Construction of Solar Powered Thermoelectric Refrigerator**

In this research work, the method adopted for performance investigation of solar powered thermoelectric refrigerator was based on Peltier effect. The desired temperature ranges or cooling temperature for this proposed work was within the range of (0-16$^0$C), which can be used for food preservation; preserving vegetables, in medicine for storage of vaccines and cooling of drinking water as adopted [9].

The hardwoods were cut up into various sizes of (32cm × 25cm × 21cm) by using hand saw and screws were driving using a screw driving machine. An attachment of the small and large heat sinks and fans was made at the middle at each length and breadth of the cooling chamber, having a dimension of (10cm × 10cm × 2cm) and they were fixed using top bond gum. The thermoelectric modules were connected in parallel to the storage battery. The cooling fans were as well connected in parallel using connection cables from D.C source of the charge controller.The constructed casing of the solar refrigerator with installed thermoelectric generator and heats ink is shown in Figure (6)

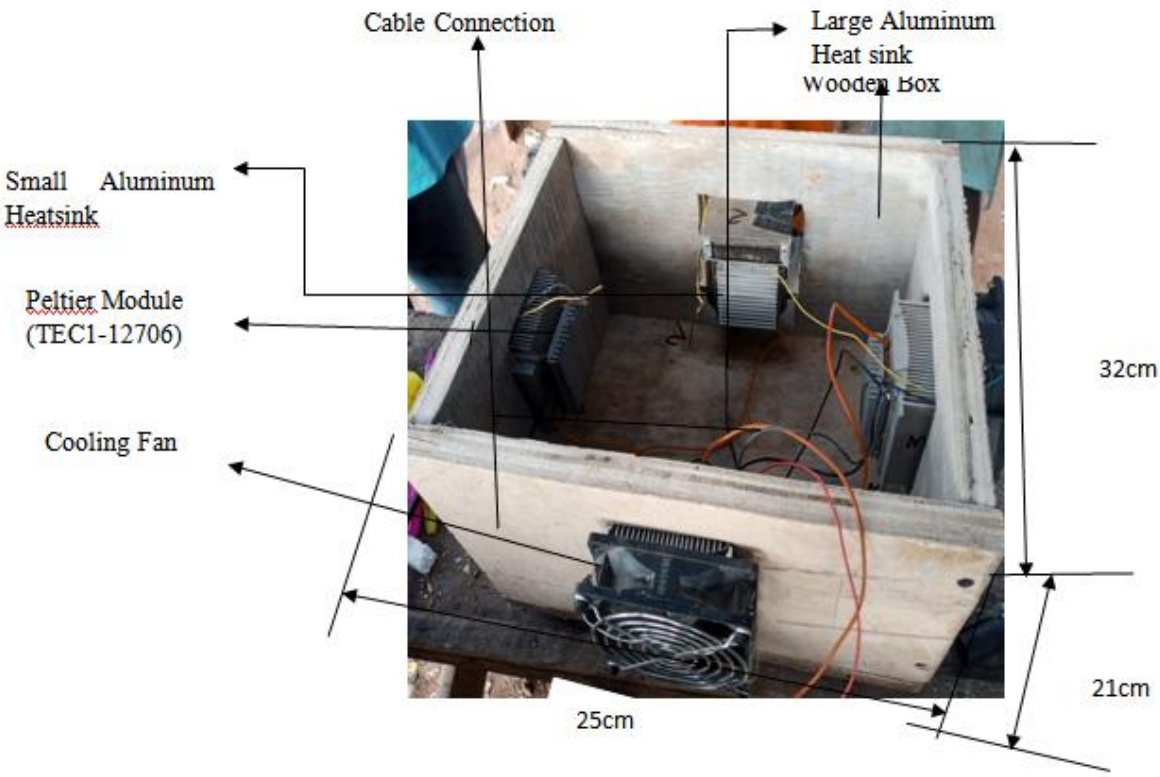


**Figure 6:. Constructed wooden cooling chamber and heat sinks**

The aluminum sheet was cut up and riveted into shaped box of (23cm × 15cm × 15cm); for cooling chamber by using measuring tape and scissor. The riveted aluminum sheet was fixed at the middle of the wooden box and lagging with foam was made between the wooden box and aluminum box. Insulation was made to prevent heat loss for a better cooling efficiency.

The constructed aluminum cooling box with insulation is shown in Figure (7).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

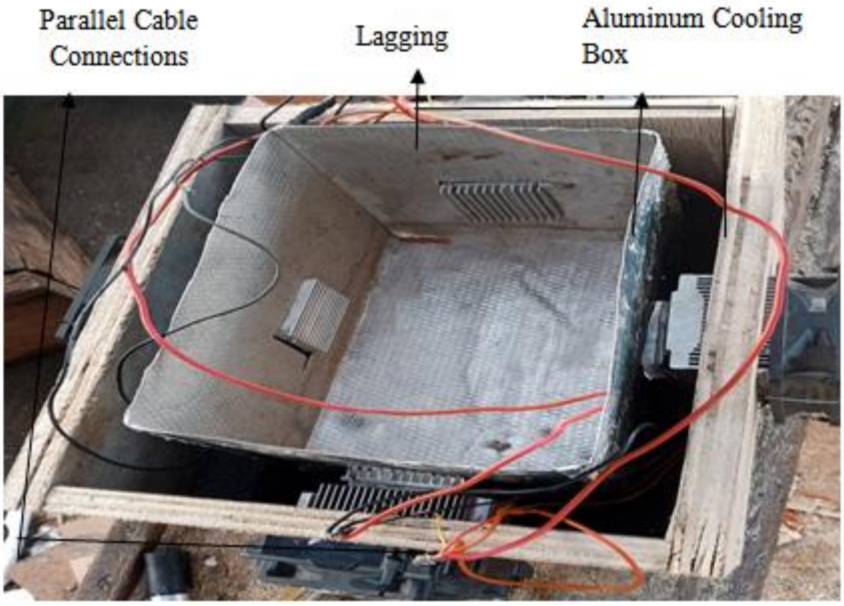


**Figure 7: Constructed aluminum box with insulation**

The complete assembly of the thermoelectric refrigeration was done, and all necessary materials were fixed. The cooling fans were connected directly from the D.C output of the charge controller. The Peltier modules were connected in parallel, the solar thermoelectric refrigerator was connected directly to the battery through a 13A socket, and the charge controller connected to the D.C battery. Figure (8) shows the complete assembly of the constructed solar thermoelectric refrigerator.


**Figure 8: Complete assembly of the constructed thermoelectric refrigerator.**

### 2.3 Experimental Setup and Procedure

The experiment was conducted at the Faculty of Physical Sciences Laboratory, Kebbi State University of Science and Technology Aliero. The testing site was situated at Latitude $12.5^0$N, and longitude $4.2^0$E. The system was served with power through the battery bank which was charged by the solar panel through the charge controller. The cooling fans were connected in parallel to the charge controller via the D.C supply. The multimeters were connected to the terminal of the outputs of the solar module and the input terminals of the refrigerator. The thermocouple thermometer probes were connected to the inner and outer sides of the cooling chamber as shown in Figure (9). The solar panel was installed under sun radiation, while battery, solar charge controller and cooling box or chamber of 5.2 Liters capacity refrigerator were installed in door. As the system was turn ON, the fans starts moving and the thermoelectric module starts operation, the temperature between the potential difference between the inner and the outer

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

parts of the refrigerator, this was due to the action of the Peltier effect. The cooling fans operations at the hot sides of the module reduces the temperature differences, thereby causes the temperature of the inner chamber to reduce to a lower value.

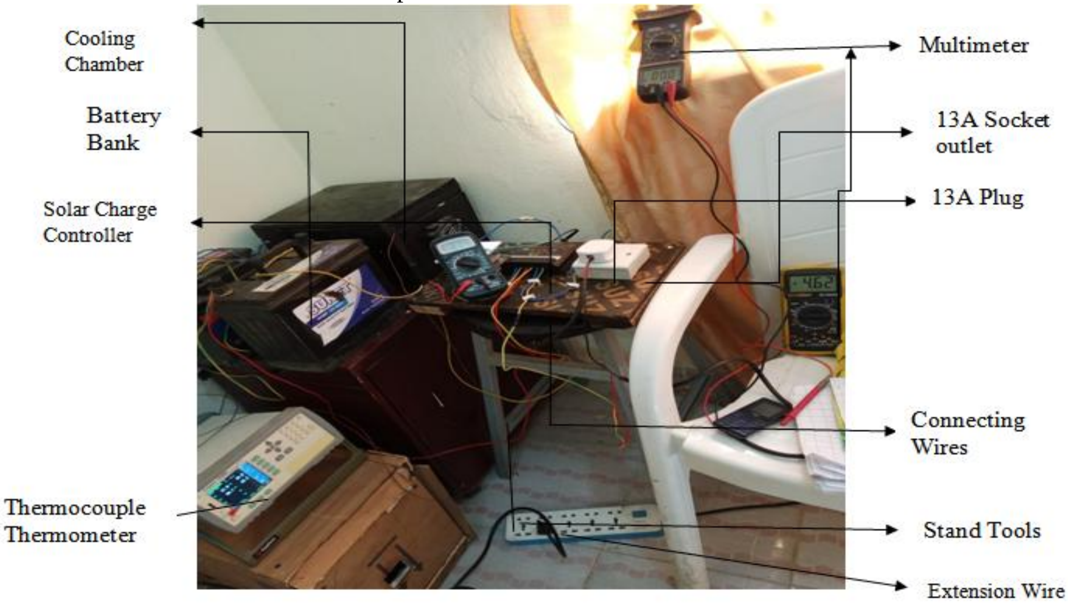


**Figure 9: Experimental Setup for Solar Powered Thermoelectric Refrigerator (SPTER)**

## III. RESULTS AND DISCUSSION

The results of the solar powered thermoelectric cooling system are showed below:

The graph of the PV Power output and TER Power input over local time is presented in Figure 10. The result shows that at 10:00 am, when the PV power output was 64.68 W, the thermoelectric module input power was observed to be 95.75 W. However, in the afternoon by 12.00 pm the PV power output slightly reduces to 50.54 W while the thermoelectric power inputs were 93.34 W. The PV power output drops to 24.31W while the thermoelectric power input has reduced to 41.6W at 5:00 pm. This indicates that the PV power output responds to the thermoelectric power input for optimum performance of the cooling system.

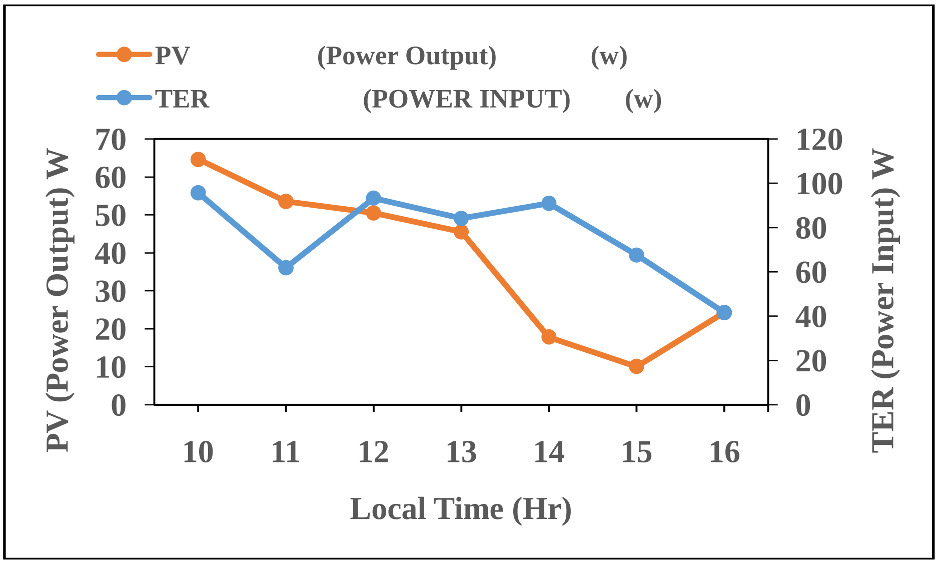


Figure 10: Graph of the correlation between PV Power output and TER Power input.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 01 Jan 2024, pp: 140-150 www.ijaem.net ISSN: 2395-5252

The graph of the PV input power and TER input current is presented in Figure 11. it has been shown that at 10:00 am, when PV input power was at the value 504.1W, the value of the TER input current has increases to 7.27A. By 12:00 pm the PV input power rises to 563.33 W while the TER input current was at a lower value of 7.18 A., at 5:00 pm the values of the PV input power and the TER input current reduces simultaneously to However 386.46 W and 5.26 A respectively. This shows that the TER current depends duly on the PV input power, this is due to the high thermal resistance of the thermoelectric module.

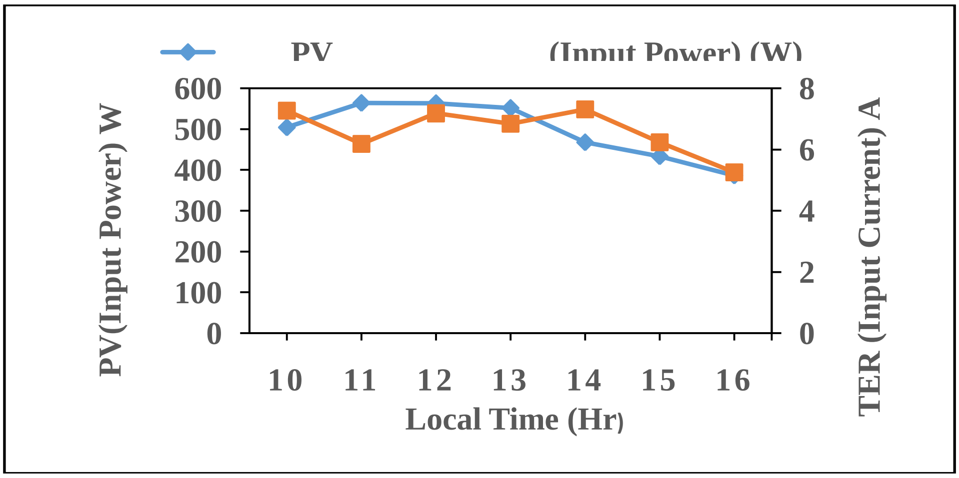


**Figure 11: A graph of PV input power against TER input current over local time.**

Graph of input power of thermoelectric module over change in temperature in Figure 12. This result shows that at 11:00 am, when the input power of thermoelectric module was 61.9 W, the change in temperature between the hot and cold junction of the thermoelectric refrigerator was 14.53$^0$C. During the afternoon at about 1:00 pm, it was observed that the input power of the thermoelectric module increases to 84.2W, the change in temperature has also increases to 16.1$^0$C. Moreover, at 5:00 pm, towards the evening, when the input power of the thermoelectric module has further reduced to 41.6 W, the change in temperature has also reduced to 12.25$^0$C. These indicate that with any given instant, the change in temperature in the enclose of the thermoelectric refrigerator responds to the thermoelectric module input power, this occur as a result of sudden decrease to the TER Current and increase of TER voltage which 16.11$^0$C was obtained at 4:00 pm.

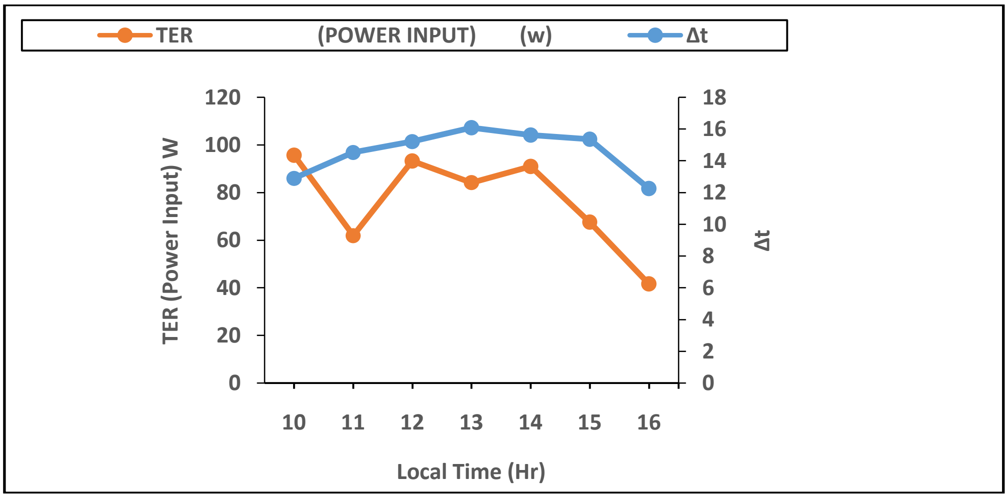


**Figure 12: A graph of TER (power input) against change in temperature over local time.**

The graph of the cooling capacity and the coefficient of performance is given in Figure 13 over local time. It has been shown that at 11:00 am, the cooling capacity rises to a value of 216.7W while the coefficient of performance also rises to 3.50. Moreover, by 1.00 pm the cooling capacity was 115.43 W while the coefficient of performance was 0.91. However, in the evening at about 5.00 pm the cooling capacity reduces to 91.94 W and the coefficient of performance also reduces to 2.20. This shows that the cooling capacity responds to the coefficient of performance. The coefficient of performance varies directly to the cooling capacity, the follows the same trends.

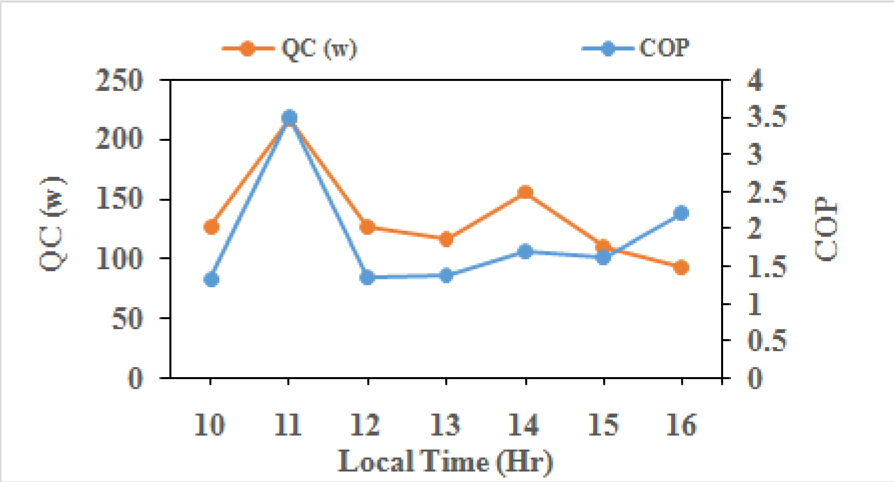


**Figure 13: A graph of cooling capacity against coefficient of performance over local**

This results are in consistent with the result obtained by [5] who reputed a value of 0.686 COP; the value of 0.6 COP reputed by [6]; the value obtained by [7] who obtained the COP of 1.66 and the result obtained by [13] who reputed a COP of 0.51. This result has agreed with the findings of [14] who reputed the value of (0.0 – 0.76) COP. However, four thermoelectric modules of a single phase of 60W was used, this is to enhance an optimum performance of the COP.

## IV. CONCLUSIONS

Solar thermoelectric refrigerator using Peltier module has been constructed and investigated.
The following findings were drawn:

- The thermoelectric refrigerator obtained 2.21 coefficient of performance as a result of 12.25$^0$C change in temperature by the thermoelectric module.
- However, a maximum temperature of 16$^0$C was achieved by the thermoelectric refrigerator which is suitable for storing of vaccines, cooling of water and preservation of vegetables especially in remote areas where people are isolated from National grid (Electricity).
- Using solar based thermoelectric refrigerator as an alternative of using compressor operated refrigerator has many benefits such as saving the environment, cost and portable, noiseless.

## REFERENCE

[1]. Pradeep, G., & Jibhakate, Y.M. (2016). Design Construction and Performance of solar operated dual purpose refrigerator using thermoelectric module. International Journal for Research in Applied Science and Engineering Technology 4, 2391-9653

[2]. Sanket, P., Harshit, J., Desai, Gaurav, L. Gadhesana. (2018). "Experimental Peerformance Analysis of Solar Thermoelectric Refrigerator". International Journal of Advanced Engineering and Research Development. 5, 2348-6406

[3]. Manoj, B.D., Ekta, M., Anurag, Y., David, S., Suprabhat, A. M., Vaibhav, N. D. (2016). Review on portable solar thermoelectric refrigerator cum air cooler. International Journal Advance Research in science and Engineering 1, 67-85

[4]. Vijayarengan, S., Sooriyaraj, R., Vinithraj, G.J., Venkatesan, C.J., Vinoth, A. (2018). Design and Fabrication of Thermoelctric Solar Refrigerator. International Journal of

Emerging Technologies in Engineering Research (IJETER)

[5]. Shaik, A., Parankusum, C. S., Ommi, S. R., Mulampaka, B., Sirugudi, K. Kumar. (2019). Design and Investigation on Portable Thermoelectric Air Chiller. International Journal of Engineering Trends and Technology 67.3,

[6]. Bhushan, Y., Birla., Shubham, A., Pritam, A.C. (2020). Design and Analysis of Solar Powered Thermoelectric Refrigerator.Iconic Research and Engineering Journal (IREJ). 1, 2456 – 8880

[7]. Sayali, P., Aparna, G., Ashish, P., Sanket, R., Harshal, J., Rani, S., Katole, D.N. (2021). Solar Powered Thermoelectric Refrigerator System. Journal of Optoelectronics and Communication.

[8]. Divine, N., Claude, V.A, and Armand, P.N. (2022). Design and implementation of solar powered mini refrigerator using thermoelectric cooler module. Department of Renewable Energy, HTTTC – Kumba, P.O.BOX. 249 Buea, University of Buea

[9]. Abhijith, R., & Ajeesh, J. (2016). Development of Portable Solar Thermoelectric Refrigerator. International Journal of Scientific and Engineering Research 7, 2229-5518

[10]. Rakesh, B.K., Anuj, S., Mithun, S. M.N., Mohan, M., Vinay, K. (2016). Study, Analysis and Fabrication of Thermoelectric Cooling System. International Journal for Science development and Research 1,5:2455-2631:

[11]. S. Yasaswini Shirisha, V.Uttej , Y. Lakshmi Pravallika (2016). Design And Implementation Of Efficient Solar Powered Dc-Dc Boost Converter for loads,International Research Journal of Engineering and Technology (IRJET)ISSN: 2395 -0056 Volume: 03 Issue: 09 | Sep-2016 www.irjet.net p-ISSN: 2395-0072

[12]. Sujith, G., & Anthony, V. (2016). Design and Fabrication of Thermoelectric Refrigerator with Thermosiphon System. International Journal of Scientific Engineering and Applied Science 2, 2395-3470.

[13]. Mirmanto, M., Syahrul, S., Made, A.S., Agung, T.W., Ilham, M. (2020). Performance of a Thermoelectric by Solar Panel for a Large Cooler Box. Advances in Science, Technology and Engineering Systems Journal. Volume5:NO.1, 325 – 333

[14]. Mirmanto, M., Syahrul, S., Made, A.S., Agung, T.W., Ilham, M. (2021). Performance of a Thermoelectric by Solar Panel with a Mini pin fin heat removal unit. Advances in Science, Technology and Engineering Systems Journal. Volume 6: NO.3, 355 – 360: ISSN:2415- 6698.