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SOLAR MICRO ENERGY HARVESTING BASED ON THERMOELECTRIC AND LATENT HEAT EFFECTS

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ABSTRACT: The venture presents sun powered smaller scale vitality reaping in view of thermoelectric and inactive warmth impacts utilizing Thermoelectric generator(TEG) coordinated with the Phase evolving material(PCM). The fundamental idea driving the exploration-based work is it can collect night vitality alongside day reaping. The proposed framework has been designed to the point that it can gather sunlight based thermoelectric vitality. In the proposed inquire about work, the sun powered radiations on the thermoelectric generator, which lives on fundamental aluminium opening model occurrence through focal point, which is bolstered by a vertical customizable aluminium outline. Openings are totally filled till the best end of the balance with nano-pcm material, which is a blend of Nano particles and stage evolving material. In this manner because of these radiations temperature angle is setup crosswise over thermoelectric generator bringing about one side as hot side and opposite side as the cool side. Hot side shows the stage presented to the radiations, which where amplified through focal point then again cold side demonstrates the period of TEG which has been associated with the aluminium space display. Due temperature distinction crosswise over TEG little voltage is produced. At least 0.08V is created crosswise over TEG amid evening and a greatest of 0.508V in the day time contingent on the TEG limit. As the investigation incorporates PCM with Nano particles it will balance out properties of PCM in this way gives capable voltage crosswise over TEG to a more extended timeframe.

Index Terms: Thermoelectric Generator, Nano Particles, Heat Transfer, Coolant

INTRODUCTION

In recent times, environmental issues have been increased due to raise in emissions causing global warming leading to limitations of energy resources which result in wide range of research and innovative technologies for generating electrical power. Electric energy is one of the main accept in present day living but due to insufficient in production of electric energy frequent power cuts are being experienced. This is the case seen in urban areas but when coming to the remote areas they are still being powered using gasoline-based motor generators, which experience even worse power shortage due to improper management and lack of resources. At the same time those generators are too noisy and high maintenance is required. When the complete world is running behind the generation of clean and pure energy still those remote areas are being powered with those old gasoline motor generators. With The increasing advancement in science and technology thermoelectric generators have been emerged as a promising alternative for generation of clean and pure energy [1], [2].

1. BACKGROUND

A Thermoelectric Generato

Primary standard behind the working of thermoelectric generator is Seebeck effect. Seebeck effect states that when two disparate conductors are joined and the intersections are kept at various temperatures, potential is produced over the intersection. TEG is a solid-state gadget which straight forwardly changes over thermal vitality because of temperature inclination into electrical yield in view of the Seebeck impact. Connected thermocouples can be broadly utilized for temperature estimation as the yield voltage changes directly with the information temperature. These thermoelectric can likewise be utilized as electric power generators when both voltage and current yields are upgraded [3].

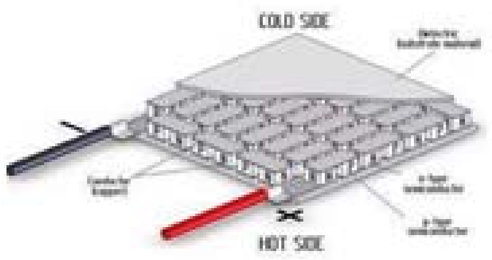

Figure 1 TEG

The above figure displays that the top and the bottom two dissimilar conducting materials are connected by a metal forming P-type and N-type on either side. The two sides of the thermocouple are maintained at two different temperatures due to this temperature difference a protentional drop is developed across the TEG. Charge carriers flow in bidirectional direction from p type to n type and vice-versa. The voltage output is given by

$V_{OC} = (\alpha_p - \alpha_n)\Delta T$ (Eq.1)

Where and are the Seebeck coefficient for the p and n type material in V/K respectively. The sign of Seebeck coefficient is positive for p type and negative for n type. The magnitude of the Seebeck coefficient for semiconductors can be up to hundreds of μV/K. ΔT is the temperature difference between the hot side and cold side in K Efficiency of thermoelectric material is given in terms of figure of merit(ZT)[3]. It is given by the formula:

$$ZT = \frac{\alpha^2 \sigma T}{k} \quad \text{(Eq.2)}$$

Where Z is the figure of merit in K^{-1}, αis the Seebeck coefficient, σ is the electrical conductivity, k is the thermal conductivity. The figure of merit describes how good is the thermoelectric material for the conversion. Each and every material has unique figure of merit. Figure of merit is dimensional less on the grounds that when it gets multiplied with the working temperature (T) it winds up dimensionless. Thermoelectric material with most extreme figure of merit at its working temperature conditions then it is said to be ideal thermoelectric material. Unit less figure of merit is utilized for correlation between different thermoelectric materials. Working temperature is found at its working time when diverse thermoelectric materials in view of their figure of merit are being analyzed [4].

B Phase Changing Material

Phase changing material is a substance with high latent heat of fusion and undergoes liquefying and solidification at certain temperature conditions. Under phase change conditions it is capable of storing and releasing large amount of heat. Hence phase changing materials are called to be latent heat storage substances (LHS). Main difference between phase changing materials and the conventional heat storage devices like water is that the melting temperature of the phase changing material lies within the working range condition [5].Generally melting and solidification occurs at constant temperature. Below graph shows the variations in phase change under different temperature conditions.

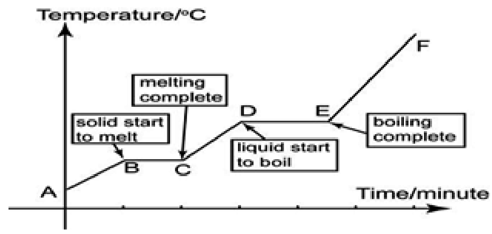

Fig. 2 variations in phase change of the material

The heat stored in a sensible (i.e. without phase change) heat store process is:

$$Q = \int_{T_i}^{T_f} mcpdT \quad \text{(Eq.3)}$$

where T_i and T_f are the initial and final temperatures. Where Q is the heat stored in the PCM.

Heat stored in a PCM heated from a temperature T_i below the melting point T_m to a temperature T_f above Tm is

$$Q = \int_{T_i}^{T_m} mCpdT + m\Delta h + \int_{T_m}^{T_f} mCpdT \quad \text{(Eq.4)}$$

Where the term mΔh is the latent heat. This additional term increases the energy stored when heating the material from considerably. Depending on the medium and the temperature range, in a latent heat storing process can be stored. There are different kinds of phase change. Solid- Solid phase have appreciably low latent heat of fusion and the volume changes will be low.

Solid- liquid phase have high latent heat of fusion but the volume changes are approximately 10 percent. Solid-gas and liquid-gas have the highest latent heat of fusion and have high volume changes. In technical applications liquid-gas PCM's are preferably used as their latent heat of increases the energy storage density considerably while the volume changes are handled easily [6].

In the proposed model OM35 is used as phase changing material. Reason behind the choice of OM35 is that it is economically available and can yield better results in the small-scale applications. Technical specifications and its properties are below mentioned [7]:

C Technicial Specifications

1. Series: OM 35
2. Description: Mixture of Organic materials
3. Appearance: White waxy flakes/Solid(below 35˚C).

Properties

1. Melting Temp (˚C) 37.0
2. Freezing Temp (˚C) 35.0
3. Latent Heat (kJ/kg) 197
4. Liquid Density (kg/m3) 870
5. Solid Density (kg/m3) 900
6. Solid Density (kg/m3) 900
7. Solid Specific Heat (kJ/kgK) 2.57
8. Liquid Thermal Conductivity (W/mK) 0.16
9. Solid Thermal Conductivity (W/mK) 0.20
10. Base Material -Organic
11. Congruent Melting -Yes
12. Flammability -No
13. Thermal Stability (Cycles) ~2000
14. Maximum Operating Temperature (°C) 120
15. Flash Point (°C) 200

2. NANO PARTICLES

A Nanoparticles As Coolant

Rapid development in infrastructure, industrial, transportation, defence, space sectors leaded to poor management in high thermal loads due to which several cooling techniques have been adopted recently. Conventional heat transfer techniques that rely on fluids like water, ethylene glycol, and mineral oils continue to be popular due to its simple nature similarly conventional heat transfer systems used in applications like petrochemical, refining, and power generation are rather large and involve significant amount of heat transfer fluids. In certain cooling applications, small heat transfer is required. These applications have a critical relationship between size of a mechanical system and the cost associated with the manufacturing and operation. Improvement could be made in the existing heat transfer system by enhancing the performance of heat transfer fluids resulting in lesser heat exchanger surface area, lower capital cost, and higher energy efficiencies [8].

B Enhancement In Heat Transfer Using Nano- Mixed Pcm

Thermal storage has been characterized as a kind of thermal battery; however, it is clear that if solar energy becomes important energy source efficient, economical and reliable solar thermal energy storage(TES) device methods will have to be developed. The storage of thermal energy in the form of sensible and latent heat has become an important aspect of energy management. In order to store the same amount of energy, significantly larger quantities of storage medium are required for sensible heat storage(SHS) in comparison to the latent heat storage(LHS) as the phase transition is at constant temperature. Of the two-latent heat storage(LHS) technique has proved to be a better engineering option as it has however as it has advantages like large energy storage for a givenvolume, uniform energy storage/supply, compactness, etc [9].

C Selection Of Nano-Particles And Pcm

Basically, the nanoparticles which have greater thermal conductivity materials are mixed with the phase changing material in order to increase the performance characteristics as well as stabilization of the material. When in proper proportions and of greater thermal conductivity than phase changing material then it absorbs greater amount of heat in compared to single phase changing material. In the proposed module considering economical aspect aluminium oxide (2,3) is used as Nano-particle to mix with phase changing material. Thermal conductivity of aluminium oxide is considerably large enough than phase changing material thereby providing better yield. Properties of aluminium oxide are below mentioned [10]:

Properties of aluminium Oxide nanoparticle

1. Thermal conductivity (W/mK) -25
2. Density(kg/m3) -3.72
3. Heat capacity at constant pressure(kJ/kgK)-880

There are many more better nanoparticles which provide better results than aluminium oxide such as carbon nanotubes. These carbon nanotubes are anisotropic materials which have exceptional thermal conductivity properties but are too costly to perform experimental study. But many experimental studies on carbon have already been performed and gave out remarkable results.

D Enhancement In Heat Conduction By The Use Of Carbon Nanotubes

Carbon nanotubes are allotropes of carbon with cylindrical hexagonal Nano structure. These exhibit exceptional properties which led towards their study in depth. In addition, these have extreme mechanical, physical and thermal properties and are used as additives in some structural designs. Generally, these are classified into three types: Single walled, Multi walled and Double walled carbon nanotubes, which are further categorised based on their alignment as chiral, arm chair and zigzag. Single walled carbon nanotubes are an important variety and have varied properties over the module. Multi walled nanotubes made of multiple rolled layers of graphene. On the other hand, double layered nanotubes are of special class of nanotubes which exhibit similar properties to that of the single layer carbon nanotubes [11].Carbon nanotubes are called to be anisotropic materials due to their varied properties along and across the axis. Its thermal conductivity along the axis is very high when compared to its axial thermal conductivity. Measurements show that its thermal conductivity along the axis is 3500 $W{\cdot}m^{-1}{\cdot}K^{-1}$ and 1.52 $W{\cdot}m^{-1}{\cdot}K^{-1}$ across the axis. Due their high standards in thermal conductivity they can be used in heat conduction methods. [12,13,14]. Due to their thermal conductivity properties these carbon nanotubes when mixed with any other phase changing material will yield extreme results, at the same time when mixed with phase changing materials it stabilizes the properties of phase changing material thereby allowing the mixture to absorb more heat and remain in its initial state for a long period of time without any phase change. Below figure.3 displays the heat transfer in carbon nanotubes:

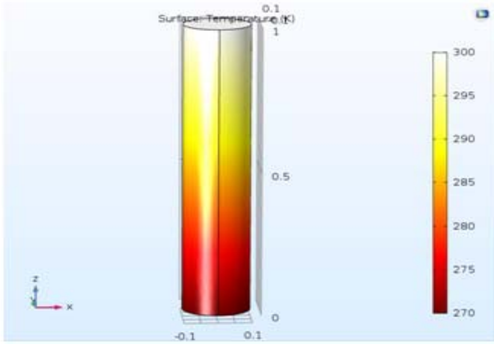

Figure 3 Heat transfer in CNT.

3. HARDWARE DESIGN

The frame setup is made up of UPVC pipes which is used for supporting the lens, at the same times frame is vertically adjustable to focus the lens at different vertical positions. At the bottom end of the frame wooden plank is fixed with L type clamps so that it can provide base for the temperature monitor system and the PCM filled aluminium slot box. In the proposed model considering the economical constraints aluminium oxide is used as Nano particle to mix with the phase changing material. OM35 an organic phase changing material is mixed with nanoparticles in proper proportions. The mixture is prepared and filled completely in the slots of aluminium box without any air spaces left and sealed with 3mm transparent acrylic sheet so that there wouldn't be any leakages. Sealing is done by the use of superglue called anabond which binds the sealing tightly. For sealing transparent acrylic sheet is used so that phase change in the material can be evident properly. Three thermocouples are connected one to find out the cold side temperature, second one for the phase changing temperature and the last one is connected to find out hot side temperature. These connected thermocouples are connected to the temperature monitor system across three different channels to monitor the temperature at that position through display. Voltage is developed accordingly based on the temperature difference created across the TEG.

Figure 4 Hardware design

A Real Time Experimental Results

Experimentally analysis is performed day and night to find out the voltage developed when exposed to temperature gradient. Day time and night analysis are carried out separately subsequently nano-pcm mixture undergoes frequent phase changes during which it stores and releases the energy during phase change. During this process it will create a temperature difference between the top side and bottom side of the TEG resulting voltage across the TEG.

Table 1 Day time analysis

Time	Hot (°C)	Cold (°C)	Middle T (°C)	Temp gradient (°C)	Voltage (V)
10:00AM	41	39	34	7	4mV
10:30AM	53	42	41	8	84mV
11:00AM	58	49	50	9	92mV
11:30AM	62	50	51	11	100mV
12:00PM	50	46	47	3	39.5mV
1:00PM	38	36	36	2	5.2mV
1:30PM	140	44	45	96	0.615V
2:00PM	54	39	39	15	148.2mV
2:30PM	60	40	43	20	169.6mV
3:00PM	72	51	53	19	203.4mV
3:30PM	90	47	48	42	0.1V

Table 2 Night time analysis

Time	Voltage(V)
6:00PM	89 mV
6:30PM	68.2 mV
7:00PM	39.6 mV
7:30PM	28.7 mV
8:00PM	19.1 mV
8:30PM	11.3 mV
9:00PM	8.4 mV
9:30PM	6.2 mV
10:00PM	4.1 mV
10:30PM	1.5 mV

B Application Analysis

Considering a 76.5Watt LED street light bulb. To power that these TEG's can be connected in series and parallel to power a single unit LED street light bulb.Generally, for a 76.5 W LED street light bulb 9 LED's are connected in series like such 8 parallel paths are considered. Each LED has a voltage rating of 3 volt and a current rating of 700mA. When the LED's are connected in such series and parallel combination total current equals to (700mA x 8(parallel paths) = 5600mA) and the voltage is equal to (3volt x 9(series) = 27 volt). Hence the total voltage of the combination is 27V, from the above-mentioned table we can see that a single TEG can harvest a maximum voltage of 0.615 volt. So as to generate a voltage of 27 volt we require 44 TEG's in series. Similarly, total current through the combination is 5600mA and the maximum current developed by a single TEG is about 84.9mA hence 66 TEG parallel paths are required to produce 5600mA current. In the proposed module TEG of dimensions (4x4) is used considering 1cm spacing between each TEG. Like such when the TEG's are connected 44 in series and 66 in parallel then the total dimension of the series combination will be (330x220). Hence TEG's combination of dimensions (330x220) can power up to 76.5W. When considered normal LED street light of 70W rating and dimensions of (410x233) can be easily powered day and night efficiently by the TEG module of power rating 76.5W and dimensions of (330x220).

4. CONCLUSION

The thermoelectric system employing Thermoelectric generators integrated with phase changing material is able to harness voltage. The proposed system has been successfully designed, implemented and experimentally tested for the results. The proposed system is able to harness the voltage when it is exposed to temperature gradient across the TEG. It is able harvest both day and night energy by the use of Phase changing material along with aluminium oxide Nano powder, which helps in stabilization of properties of Phase changing material. The proposed system can harvest a maximum voltage of 0.615V when such TEG's are connected in series and parallel combination it can power a normal LED street light of 70W rating day and night efficiently. For such combination 44 TEG's in series and 66 TEG's in parallel combination can power up to 76.5W can be used to power a normal LED street light of 70W rating.

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