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Efficient Harnessing Of Waste Heat And Solar Energy Using Peltier Module

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Abstract: **The electricity requirements of the world are increasing at an alarming rate and the power demand has been running ahead of supply .The recent energy crisis has forced the world to develop new and alternative energy generation techniques. Finding sufficient supplies of clean energy for the future is one of society's most daunting challenges. The accelerated consumption of fossil fuels now has been recognized to cause serious environmental and energy problems such as global warming, ozone depletion, atmospheric pollution, and worldwide shortage of energy. The utilization of solar energy and waste heat recovery must be enhanced, in order to mitigate the global energy crisis, as these energy sources are readily accessible and abundant in nature.**

Keywords— **Energy crisis, Thermoelectric effect, Peltier module, Hybrid solar-peltier system**

I. INTRODUCTION

Several researches have been carried on photovoltaic and thermoelectric devices to improve their cell conversion efficiencies. However, the conversion performance does not meet industrial requirements yet. One hopeful approach to improve the cell conversion efficiency is to combine these devices, which would let harvesting larger amount of solar energy along with the utilization of waste heat generated during the process. This paper elucidates the alternative power generation options for the manufacturing industry, focusing on the hybridization of photovoltaic and thermoelectric effects and waste heat recovery options.

II. THEORETICAL BACKGROUND

Photovoltaic effect: It is the effect observed when electromagnetic radiation (visible light) from sun, falls on thin film of one solid deposited on the surface of a dissimilar solid producing a difference in potential between the two materials.

Thermoelectric effect: It is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side.

The term "thermoelectric effect" encompasses three separately identified effects: the Seebeck effect, Peltier effect and Thomson effect.

Seebeck effect: It is the conversion of temperature differences directly into electricity. It is the reverse peltier effect.

Peltier effect: The Peltier effect is the presence of heating or cooling at an electrified junction of two different conductors.

A. Description of the preferred embodiments

Solar panel: A polycrystalline solar panel with performance specifications as follows is used for analysis.

Table I Panel Specifications

Dimensions (cms)	13*5*0.3
Maximum voltage(volts)	6 V
Maximum Power (Watts)	1.5 W

Peltier module: TEC1-12706, a heatsink thermoelectric cooler cooling peltier plate module is used. It is basically a thermoelectric cooling (TEC) module [2].

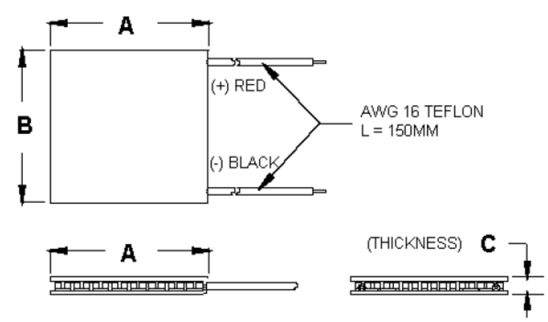

Fig. 1 Peltier dimensions

Table II Size table

A	B	C

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40	40	3.9

Table III Performance specifications

Hot side temperature (°C)	25 °C	50 °C
Qmax (Watts)	50	57
Delta Tmax (°C)	66	75
Imax (Amps)	6.4	6.4
Vmax (Volts)	14.4	16.4
Module Resistance (Ohms)	1.98	2.30

B. Setup of a hybrid Solar-Peltier system:

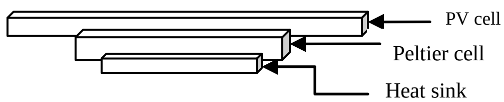

Fig. 2 Hybridised Solar-Peltier system

The hybrid Solar-Peltier system is fabricated by contacting the backside of a PV cell to a Peltier cell whose other side is connected to a heat sink. To improve heat conduction, a thermal conductive paste may be used as an adhesive for contact formation between PV and Peltier devices. PV and Peltier cells are connected electrically in series; hence a cathode and an anode of a hybrid circuit correspond to a cathode of a PV and an anode of a Peltier module, respectively.

III. Design Alternative 1

Peltier cells are used as heat pumps. When power is applied to a Peltier cell, it begins pumping heat, and one side becomes cold and the other, hot. However, the opposite can be done and power can be generated from temperature differential on the sides. To generate this differential, a Fresnel lens focuses light onto one side of the Peltier, and it becomes hot. The other side has a heat sink attached along with a fan that is powered by the Peltier. To generate this differential, a Fresnel lens focuses light on one side of the Peltier and it becomes warm enough. The other side is attached with heat sink which makes the side cool. Greater the temperature difference greater will be the output voltage. This effect can be utilized to recover waste heat in different industrial applications.

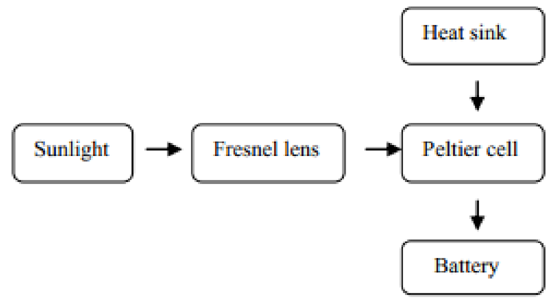

Fig. 3 Block diagram to model Peltier cell as a power generating device

IV. Design Alternative 2

The idea of hybridized Solar-Peltier system is a reasonable approach to provide a quiet and easy way to control the temperature of PV cells. PV cells convert some of the absorbed photon energy to electricity, but most of the energy is converted to heat. The generated heat is removed by thermal conduction to the back plane of the cell, to minimize the increase in cell temperature that would lead to reduction in the conversion efficiency of the cell [5]. Increasing the temperature can cause significant damages to the solar cells as well as losses in efficiency. Due to the varying nature of solar radiation, the allowable temperature range is a vital factor which needs to be considered before designing a PV system for a specific application. This is even more important on concentrating photovoltaic systems (CPV) when solar radiation could be much higher leading to higher cell temperature.

The electrical current crossing the cell structure produces the Peltier effect, a thermoelectric phenomenon where by some heat is transported as a thermoelectric interaction with the electrical current. This heat captured can be utilized either for domestic purposes or for power generation. Thermoelectric cooling modules are light, quiet and need least maintenance costs. They are also very small and it is possible to install them almost for any small application. These modules operate using electricity and provide a temperature gradient between the two faces. Therefore, it is easy to control them by varying the electrical current and get desired amount of cooling effect regarding the application. Therefore, it seems that it is possible to use Peltier modules to have some temperature control on solar cells. The power utilized by these modules can be provided by the PV cell itself which makes the whole system more compact. However, care needs to be given about how much power is required to provide enough cooling effect for the solar cell.

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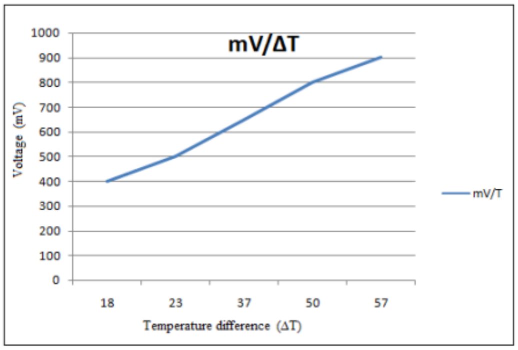

Fig. 4 Graphical representation of temperature gradient on voltage

V. Design Alternative 3

The Seebeck effect is the direct conversion of temperature differences to electric voltage. Applying temperature gradient causes charge carriers in the material to move from the hot side to the cold side. A thermoelectric device includes two dissimilar semiconductors, p- and n-type, connected electrically in series and thermally in parallel. The solar-peltier hybridized system is also capable of harvesting excess heat from the PV panel and then harnesses it into electricity. The idea of using thermoelectric generation modules for harvesting excess heat from the PV panel was first proposed and discussed by Sark [1]. He considered installing these modules underneath PV cells and carried out an analysis to explore the performance of the system. The result from his work shows that using Photovoltaic thermoelectric generator (PV-TEG) modules can potentially increase the annual energy yield by 11-14.7% for two annual irradiance and temperature profiles located in Malaga, Spain and Utrecht, Netherlands respectively.

Another way to enhance the solar output is to convert the DC output voltage of a solar cell to AC and then step it up through transformers. This idea may be used in solar farming so as to get higher solar output.

VI. Design Alternative 4

A valuable alternative approach to improve overall energy efficiency is to capture and reuse the lost or "waste heat" that is intrinsic to all industrial manufacturing. During these manufacturing processes, as much as 20 to 50% of the energy consumed is ultimately lost via waste heat convection, and contained in streams of hot exhaust gases and liquids, as well as through heat conduction, radiation from hot equipment surfaces and from heated product streams. Captured and reused waste heat is an emission-free substitute for costly purchased fuels or electricity.

Three essential components are required for waste heat recovery: 1) an accessible source of waste heat, 2) a recovery technology, 3) a use for the recovered energy.

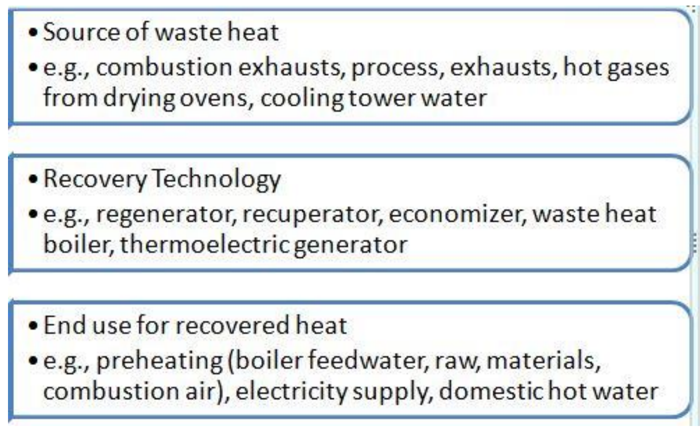

Fig. 5 Essentials for waste heat recovery

1. Sources of waste heat:

• Combustion air preheating like those from Glass melting furnace, Cement kiln, Fume incinerator, Aluminum reverberatory furnace Boiler.

• Process off-gases from Steel electric arc furnace, Aluminum reverberatory furnace.

• Cooling water from furnaces such as Air compressors, internal combustion engines

• Conductive, convective, and radiative losses from equipment: Hall-Heroult cells

• Conductive, convective, and radiative losses from heated products: Hot cokes, Blast furnace slags.

2. Recovery technology:

Methods for waste heat recovery include transferring heat between gases and/or liquids (e.g., combustion air preheating and boiler feedwater preheating), transferring heat to the load entering furnaces (e.g., batch/cullet preheating in glass furnaces), generating mechanical and/or electrical power, or using waste heat with a heat pump for heating or cooling facilities.

a) Heat Exchangers:

Heat exchangers are most commonly used to transfer heat from combustion exhaust gases to combustion air entering the furnace. Since preheated combustion air enters the furnace at a higher temperature, less energy must be supplied by the fuel. Typical technologies used for air preheating include recuperators, furnace regenerators, burner regenerators, rotary regenerators, and passive air preheater.

b) Recuperator:

Recuperators recover exhaust gas waste heat in medium to high-temperature applications such as soaking or annealing ovens, melting furnaces, afterburners, gas incinerators, radiant-tube burners, and reheat furnaces. Recuperators can be based on radiation, convection, or combinations.

c) Economizers:

Finned tube heat exchangers are used to recover heat from low to medium-temperature exhaust gases for heating liquids. Applications include boiler feedwater preheating, hot process liquids, hot water for space heating, or domestic hot water. The finned tube consists of a round tube with attached fins that maximize surface area and heat transfer rates. Liquid flows through the tubes and receive heat from hot gases flowing across the tubes.

d) Thermoelectric devices:

These are the devices that directly convert temperature gradient into electricity through Seebeck effect. These devices create voltage when there is a different temperature on each side. Therefore, by sufficiently passing the hot gases on one surface and by maintaining the other side cool, electricity can be generated.

VII. Conclusion

Thus, the overall cell efficiency could be improved by employing the Solar-Peltier hybridization technique. Therefore, additional energy harvesting from waste heat is useful not only for increasing the efficiency but also for removing unwanted heat that prevents efficient PV operation. The cooling of the solar cells due to Peltier effect lowers the cell temperature thus trapping more amount of sunlight and thereby producing higher power. The heat can either be harnessed into electricity or can be used for domestic purposes like heating water etc. In addition to replacing purchased fuels, the recovered industrial waste heat can potentially eliminate the need for additional space heating equipment, thereby reducing capital and overhead costs.

The recovery process will add to the efficiency of the process and thus decrease the costs of fuel and energy consumption needed for that process. It can also be used for power generation.

VIII. Future work

To test the hybridized solar-peltier system and to collaborate with the local PV manufacturers so as to bring in such a hybridized system into market. It's a great challenge for us to undertake the research on peltier based systems as there a few or no manufacturers of peltier modules in India.

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