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Design of Solar Operated Portable Refrigerator Cum Oven

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ABSTRACT: The growing need for sustainable and energy-efficient refrigeration and heating solutions has led to the development of a solar-powered portable refrigerator-cum-oven based on the Peltier effect. This project aims to design a compact, eco-friendly system that can function as both a refrigerator and an oven, making it ideal for off-grid applications such as outdoor activities, medical storage, and food preservation in remote areas.

The core of the system is the thermoelectric module, which operates on the Peltier effect. When an electric current is supplied, one side of the module absorbs heat (cooling effect), while the other side releases heat (heating effect). By reversing the current, the system can switch between refrigeration and heating modes. A solar photovoltaic (PV) panel is used as the primary energy source, ensuring clean and renewable power supply. A battery storage unit is incorporated to store excess energy, allowing continuous operation even during non-sunny periods.

To enhance efficiency, the system includes thermal insulation materials that minimize heat loss and improve temperature regulation. A microcontroller-based control unit is integrated to monitor and adjust power distribution, ensuring optimal performance. The device is designed to be lightweight and portable, making it suitable for use in rural areas, emergency situations, and outdoor expeditions where conventional power sources are unavailable.

By utilizing solar energy and thermoelectric technology, this system eliminates the need for harmful refrigerants, reducing environmental impact. The combination of portability, dual functionality, and sustainable energy use makes it a versatile and eco-friendly alternative to conventional refrigeration and heating devices.

KEYWORDS: Solar energy, Peltier effect, thermoelectric cooling, portable refrigeration, thermoelectric oven, sustainable technology.

I. INTRODUCTION

The increasing global demand for sustainable and energy-efficient refrigeration and heating solutions has led to the exploration of alternative technologies. Traditional refrigerators and ovens rely on compressor-based cooling systems and resistive heating elements, both of which consume significant electrical power and often require non-renewable energy sources. In contrast, thermoelectric systems based on the Peltier effect provide a compact, lightweight, and eco-friendly alternative for temperature regulation. This project focuses on the design and development of a solar-powered portable refrigerator-cum-oven utilizing the Peltier effect. The Peltier effect is a thermoelectric phenomenon where an electrical current passing through a junction of two dissimilar materials creates a temperature difference. This allows for the simultaneous functioning of cooling and heating by simply reversing the current flow. Unlike traditional refrigeration systems, thermoelectric modules do not require refrigerants, making them environmentally friendly and maintenance-free. To enhance portability and sustainability, the system is powered by solar photovoltaic (PV) panels, eliminating the dependence on conventional electricity sources. A battery storage unit is included to ensure continuous operation during periods of low sunlight. The device integrates thermal insulation materials to enhance cooling and heating efficiency while minimizing energy losses. A microcontroller-based control system is used to regulate power flow, maintain optimal temperatures, and enable seamless switching between refrigeration and oven modes. The proposed system has a wide range of applications, including medical storage (for vaccines and medicines), food preservation, camping, and disaster relief. By utilizing solar energy and thermoelectric technology, this design provides a sustainable, portable, and energy-efficient solution for off-grid refrigeration and heating needs.

This research aims to explore the feasibility, efficiency, and practical applications of integrating solar energy with thermoelectric technology to develop an innovative dual-function portable appliance.

II. BLOCK DIAGRAM

When there is a temperature difference on both sides of a thermoelectric device, a voltage is produced. On the other hand, a temperature differential is produced when a voltage is supplied. The Peltier effect is another name for the temperature differential. Hence, the Peltier effect, which occurs when an electric current passes across the junction of two dissimilar materials, causes a temperature differential, is how TEC functions. A solid state electrically powered heat exchanger, or TEC, is used to develop an effective thermoelectric cooling design. The polarity of the applied voltage determines this. When TEC is used for cooling, heat is taken up from the surface that needs to be cooled and conducted to a finned or liquid heat exchanger, which convectively releases the waste heat into the surrounding ambient air. Here, we're using the Microcontroller (AT89S52), which enables quicker and more dynamic control. The system's LCD (liquid crystal display) makes it easy to operate. In this project, a lead acid battery (12 V, 1.2 Amp hours) is being charged by solar panels. A Peltier thermoelectric device is attached to the battery to produce either a hot or cold effect, depending on the user's selected mode. We just need the cool setting because we are using this as a fridge. To create a cooling effect, a peltier thermoelectric device is linked to the battery. We use the ADC0808 that is provided to the controller in order to display the voltage. In order for this ADC to function, we are providing clock pulses via a 555 timer. A regulated 5V, 500mA power supply is used in this project. Voltage regulation is accomplished with a 7805 three terminal voltage regulator. A bridge type full wave rectifier is utilized to rectify the ac output of the step down transformer secondary (230/12V).

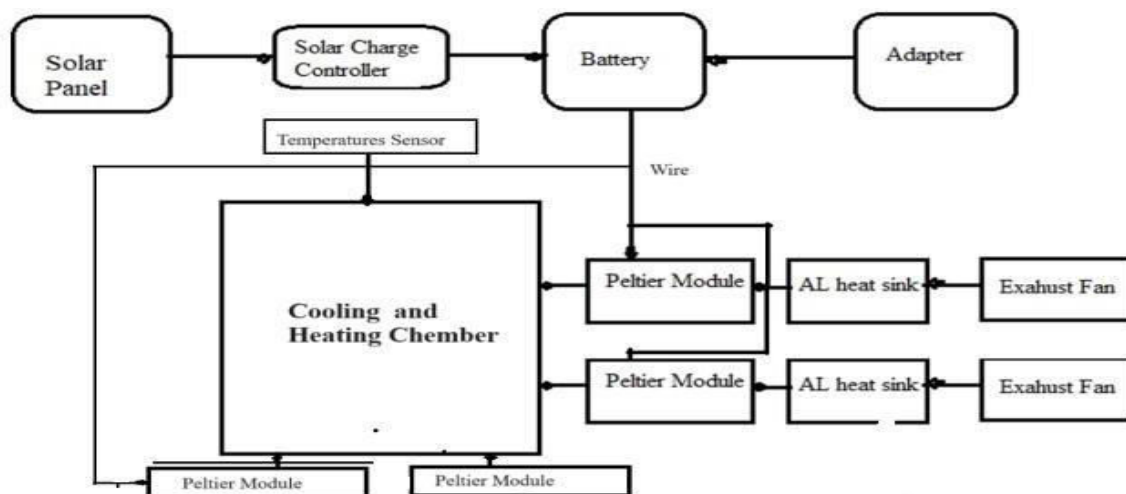


Figure 1: Block Diagram

III. METHODOLOGY

In this we first explain the definition of the problem then plan and conduct the market research and prepare the bill of materials with this make space for Peltier module and calculate the specification of the module then make the circuit connection and assemble the parts. Generally we see that the refrigeration process uses electric energy which is not available at most of the remote places in our country .We know that sun energy is available everywhere which is also green energy and renewable energy source. We also save electric energy here. From last century till now refrigeration has been one of the most important factors of our daily life. The current tendency of the world is to look at renewable energy resources as a source of energy. This is done for the following two reasons; firstly, the lower quality of life due to air pollution; and, secondly, due to the pressure the ever increasing world population puts on our natural energy

resources. From these two facts comes the realization that the natural energy resources available will not last indefinitely. The basic idea is implementation of a photovoltaic driven refrigerating system powered from direct current source or solar panel (when needed) with a battery bank. The Seebeck, Peltier and Thomson effects, together with several other phenomena, form the basis of functional thermoelectric modules. Thermoelectric module aims at providing cooling effect and heating by using thermoelectric effects rather than the more prevalent conventional methods like those using the vapour compression cycle or the gas compression cycle.

IV. WORKING

A thermoelectric device will create a voltage when there is temperature difference on each side of the device. On the other hand when a voltage is applied to it, a temperature difference is created. The temperature difference is also known as Peltier effect. Thus TEC operates by the Peltier effect, which stimulates a difference in temperature when an electric current flows through a junction of two dissimilar materials. A good thermoelectric cooling design is achieved using a TEC, which is solid state electrically driven heat exchanger. This depends on the polarity of the applied voltage. When TEC is used for cooling, it absorbs heat from the surface to be cooled and transfers the energy by conduction to the finned or liquid heat exchanger, which ultimately dissipates the waste heat to the surrounding ambient air by means of convection. Here we are using Micro controller (AT89S52) allows dynamic and faster control. Liquid crystal display (LCD) makes the system user- friendly. In this project we are using solar panels for charging a Lead Acid Battery (12V, 1.2 Amp hrs), a peltier thermoelectric device when connected to battery generates cool effect and hot effects depending on the mode required by the user. Since we are using this for fridge we need only cool mode. A peltier thermoelectric device is connected to the battery to generate cooling effect. We need to display the voltage for that we are using ADC0808 which is given to the controller. For this ADC we are giving a clock pulses through 555 timer to perform its operation. This project uses regulated 5V; 500mA power supply. A 7805 three terminal voltage regulator is used for voltage regulation. Bridge type full wave rectifier is used to rectify the ac output of secondary of 230/12V step down transformer.

Operating Principle OfThe Thermo-Electric Module

The TEM operating principle is based on the Peltier effect. The Peltier effect is a temperature difference created by applying a voltage between two electrodes connected to a sample of semiconductor material to create a hot side and a cold side. The cold side of the thermoelectric module is utilized for refrigeration purposes; it provides cooling to the refrigerator space. On the other hand, the heat from the hot side is utilized for heating purposes. In a thermo-electric heat exchanger the electrons act as the heat carrier. The heat pumping action is therefore a function of the quantity of electrons crossing over the p-n junction.

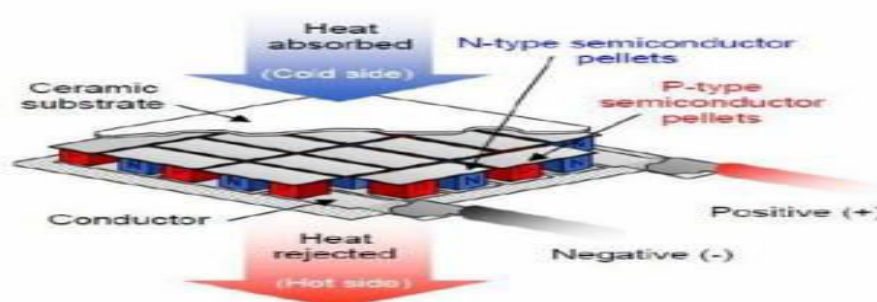


Figure : Peltier Effect

V. CALCULATION

Thermoelectric plate heating and cooling efficiency

Heating up to :- 70 to 80 Degree Celsius. Cooling up to:- 5 to 8 Degree Celsius.

Energy produced by 20 W solar plate

The 20 W of 1 solar panels can produce 20 W of output of DC power during peak solar hours.(on 2 to 3 hours in sunlight).

Load Calculation of Battery

Load calculation = $12\text{ V} * 14\text{ A} = 168\text{ W}$. (max capacity)

Load consumption

When plate is heating :- $12\text{ V} * 6\text{ A} = 72\text{ W/H}$ (Which is 259200 joules). When plate is cooling

:- $12\text{ V} * 2\text{ A} = 24\text{ W/H}$ (Which is 86400 joules). Overall load consumption of the system :

Maximum on heating= 72 W/H. Minimum on cooling=24 W/H.

Battery backup It can operate up to 4-5 hours.

OBSERVATION This thermoelectric type combines the functions of an oven and refrigerator onto a single plate, allowing for temperature control. This means that we can heat and cool the material with a single Peltier plate (a thermoelectric module). The primary distinction with the current system is that our project operates without the need for freezing systems.

VI. CONCLUSION

Using an electric control unit and thermoelectric module, a portable heating and cooling system was constructed and tested for both heating and cooling purposes. The system is self-sufficient and suitable for usage in isolated and remote areas of the nation where load-shedding is a significant issue. The fact that it requires no maintenance and is an upfront expenditure is a crucial point to remember. Improving the module's contact-resistance and thermal interfaces may allow for even more system efficiency gains. This could be accomplished by expanding the system's surface area by inserting extra modules.

VII. FUTURE SCOPE

1. In addition to the detrimental effects of pollution, civilization is currently facing an energy crisis. A "Green Technology" that produces power without causing any harm is thermoelectricity.
2. Sites like universities, industrial areas, furnace districts, metropolises, and educational institutions can be chosen for the construction of these energy centers since they provide readily available waste heat that can be recycled using the same technique.
3. The car's air ventilation system would make use of this system.
4. This system serves as a catalyst for the implementation of government plans such as solar cities.

1. Advantages

We believe that thermoelectric cooling offers a number of advantages over traditional refrigeration methods, as:

1. No moving parts, eliminating vibration, noise, and problems of wear.
2. No Freon's or other liquid or gaseous refrigerants required,
3. High reliability and durability.
4. Compact size and light weighted,
5. Relatively low cost and high effectiveness,
6. Eco-friendly C-pentane, CFC free insulation
7. Reversing the direction of current transforms the cooling unit into a heater.

2. Disadvantages:

1. C.O.P. is less as compared to conventional refrigeration system.
2. Suitable only for low cooling capacity.

3. Applications:

1. Can be used for remote places where electric supply is not available.
2. Medical and pharmaceutical equipment.
3. Military applications.

4. Laboratory, scientific instruments, computers and video cameras.

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