Solar Based Refrigeration with Respect to Peltier Effect

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ABSTRACT:

This study looks at using the Peltier effect to design and optimize a solar-powered refrigeration system. This study investigates a substitute for traditional compressor-based refrigerators, which use hazardous refrigerants and consume a lot of power, in response to the growing need for sustainable and eco-friendly cooling systems.

Thermoelectric modules, solid-state devices that facilitate heat transmission by applying an electric current, are the system's central component. These modules may produce a temperature differential by utilizing the Peltier effect, which allows for cooling on one side and heat generation on the other. The system is self-sufficient and less dependent on grid electricity thanks to the integration of solar panels, which capture solar energy and power the thermoelectric modules.

The study covers the selection and characterization of appropriate thermoelectric materials as well as the basic concepts of thermoelectricity. A prototype system is carefully planned and built, including the integration of solar panels, the design of a heat sink, and the application of a microcontroller-based control system for maximum efficiency. The purpose of this research is to show that solar-powered thermoelectric refrigeration systems are a practical and environmentally responsible substitute for a range of applications, especially in isolated locations with poor grid energy availability. This technology helps create a more sustainable and energy-independent future by reducing its negative effects on the environment and providing a sustainable cooling solution.

Keywords: Solar panel, Cooling fan, Peltier module, Battery

INTRODUCTION:

The search for novel and eco-friendly refrigeration systems has attracted a lot of attention in a time marked by rising energy demands, environmental concerns, and the pressing need for sustainable solutions. "Solar Refrigeration Using the Peltier Effect" is one such system that has shown itself to be a practical and promising solution. The Peltier effect-powered solar refrigeration concept represents the fusion of advanced thermoelectric technology and renewable energy sources to tackle the urgent problems of sustainability and energy efficiency. Peltier effect solar refrigeration, which combines thermoelectric technology and renewable energy, is a revolutionary approach to sustainable cooling solutions. Due to their reliance on chemical refrigerants and mechanical compression, conventional refrigeration systems present serious energy and environmental problems, such as high electricity consumption, greenhouse gas emissions, and restricted accessibility in off-grid locations.

Peltier effect solar refrigeration is a novel and environmentally friendly method of cooling and refrigeration that makes use of the special thermoelectric qualities of specific semiconductor materials, or Peltier modules.

The Peltier effect itself is important to solar refrigeration that makes use of it. Certain semiconductor materials, such bismuth telluride, exhibit this thermoelectric effect. A temperature gradient is created across these materials when an electric current is run through them. This indicates that the material cools on one side while heating on the other. Because the electric current's magnitude is directly proportional to the temperature differential, the cooling effect can be controlled by varying the current.

Peltier effect-based solar refrigeration systems use this temperature differential to move heat from the intended cooling area—such as a refrigerator—to the surrounding air. Heat transfer can be accomplished without the use of traditional refrigerants, compressors, or moving parts by joining Peltier modules so that one side is in contact with the cooling space and the other side is in contact with a heat sink. This method improves system reliability while reducing the negative effects on the environment.

Photovoltaic panels use solar energy to power the Peltier modules. Sunlight is converted into electricity via solar panels, which are usually composed of silicon-based photovoltaic cells. The Peltier modules are then powered by this electrical energy. The entire effectiveness of the solar refrigeration system is directly impacted by how well the solar panels convert sunlight into electrical power.

Using the Peltier effect to effectively use solar refrigeration requires proper thermal control. To dissipate the heat produced during the cooling process, heat sinks are usually positioned on the hot side of the Peltier modules and are composed of materials with high thermal conductivity. To improve heat dissipation, fans or other cooling systems may be added.

A control system is used to maximize the solar refrigeration system's performance. Sensors and microcontrollers keep an eye on things like the electrical current passing through the Peltier modules and the temperature inside the refrigeration area. The cooling process is made as efficient as possible by using this data to modify the current that is supplied to the modules.

There are a number of environmental advantages to solar refrigeration that uses the Peltier effect. It lowers greenhouse gas emissions linked to traditional refrigeration systems and does away with the use of ozone-depleting refrigerants. Additionally, it uses less energy, which makes it a green cooling option.

BLOCK DIAGRAM:

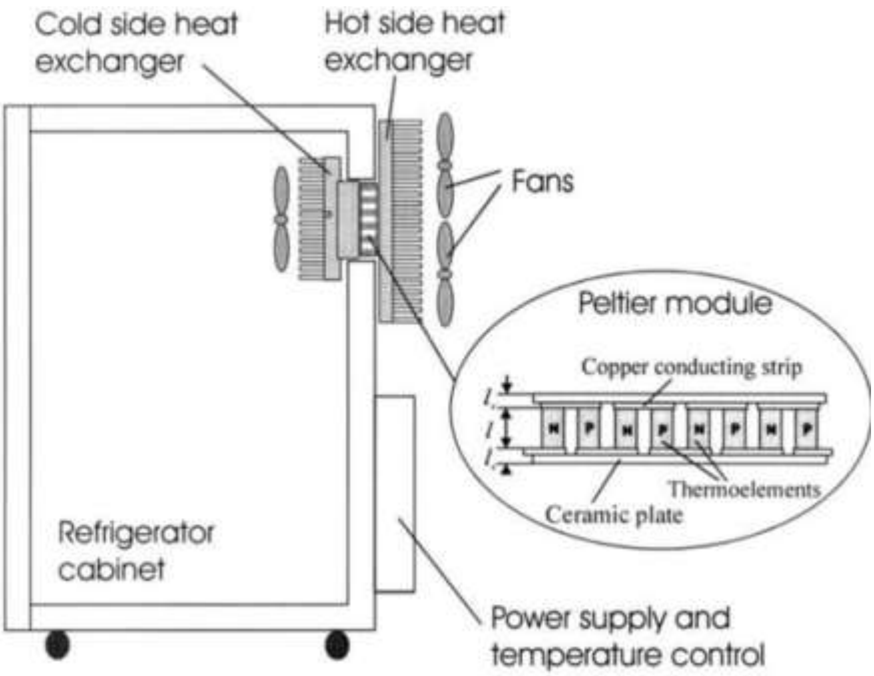

Fig: Block Diagram of Solar Refrigeration Using the Peltier Effect

COMPONENTS:

1. **Solar Panel (12V):**

Fig: 12-Volts Solar Panel

A solar panel converts sunlight into electrical energy using photovoltaic cells. In this setup, a 12V solar panel provides DC power to charge the battery and run the cooling system. The efficiency of the solar panel depends on factors like sunlight intensity, panel orientation, and weather conditions.
Specifications:
Wattage: 55W
Voltage Rating: 12V

2. Battery (12V, 9Ah):

Fig: Battery (12V, 9Ah)

A 12V, 9Ah battery stores electrical energy to power the system when sunlight is unavailable or insufficient. The Amp-hour (Ah) rating indicates how much charge the battery can hold. In this case, a 9Ah battery can theoretically provide 9A for 1 hour or 1A for 9 hours before needing a recharge.
Specifications
Voltage Rating: 12V
Capacity: 9AH (Ampere-Hours)

3. Peltier Plate (TECI-12706):

Fig: Peltier Plate (TECI-12706)

The TECI-12706 Peltier module is a thermoelectric cooling device that transfers heat from one side to the other when powered. It operates on the Peltier effect, creating a temperature difference across the module. The cold side is used for cooling, while the hot side must be efficiently dissipated using a heat sink or cooling fans.
Specifications:

Model: TEC1-12706
Voltage Rating: 12V
Current Rating: 6A
Maximum Cooling Capacity: Approximately 50-57 watts

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4. Cooling Fans (12V):

Fig: Cooling Fans (12V)

Cooling fans help in dissipating heat from the hot side of the Peltier plate. Without proper heat dissipation, the Peltier module becomes inefficient, and cooling performance decreases. 12V fans are commonly used in such applications to improve airflow and maintain thermal balance.

5. Temperature Sensor:

Fig: Temperature Sensor

A temperature sensor measures the internal temperature of the refrigeration chamber. It can be a thermistor, digital sensor (DS18B20), or a thermocouple. The data from the sensor can be used to control the Peltier module, ensuring efficient cooling and preventing overheating or excessive power consumption.
Specifications:
Digital temperature indicator with a suitable range.

6. Heat Sink:

Fig: Heat Sink

Heat sinks play a critical role in ensuring efficient heat transfer. They help dissipate heat generated by the Peltier modules and maintain the desired temperature within the cooling compartments.
Specifications:
Size: Appropriate to fit Peltier modules
Material: High thermal conductivity (e.g., aluminum)

7. Refrigeration Chamber:

The refrigeration chamber is an insulated enclosure where cooling is applied. It is designed to maintain a low temperature using the Peltier plate. Proper insulation minimizes heat loss and enhances the efficiency of the cooling system. Materials like polystyrene, polyurethane foam, or vacuum panels are commonly used for insulation.

WORKING:

1. **Solar Energy Conversion:**
   Solar panels capture sunlight and convert it into electrical energy using photovoltaic (PV) cells. The generated DC power is either directly supplied to the thermoelectric module or stored in a battery for continuous operation.

2. **Peltier Effect in Thermoelectric Module**:
   A thermoelectric module consists of P-type and N-type semiconductor materials arranged in pairs. When DC electricity flows through the module, one side absorbs heat (cooling side) while the other side releases heat (hot side). The cold side is placed inside the refrigeration chamber, while the hot side is attached to a heat sink or fan to dissipate heat.

3. **Heat Dissipation:**
   To maintain efficiency, the hot side of the Peltier module must be continuously cooled using heat sinks or cooling fans. Proper heat dissipation improves performance and prevents overheating.

4. **Refrigeration Effect:**
   The cold side lowers the temperature inside the chamber, providing refrigeration for perishable items, medicines, or other cooling applications. The temperature can be controlled by adjusting the input voltage to the Peltier module.

ADVANTAGES OF SYSTEM:

- Environmentally Friendly
- Energy Efficiency
- No Moving Parts
- Low Noise
- Scalability
- Remote Operation
- Simple Design

DISADVANTAGES OF SYSTEM:

- High Power Consumption
- Heat Management Issues
- Weather Dependency

APPLICATION:

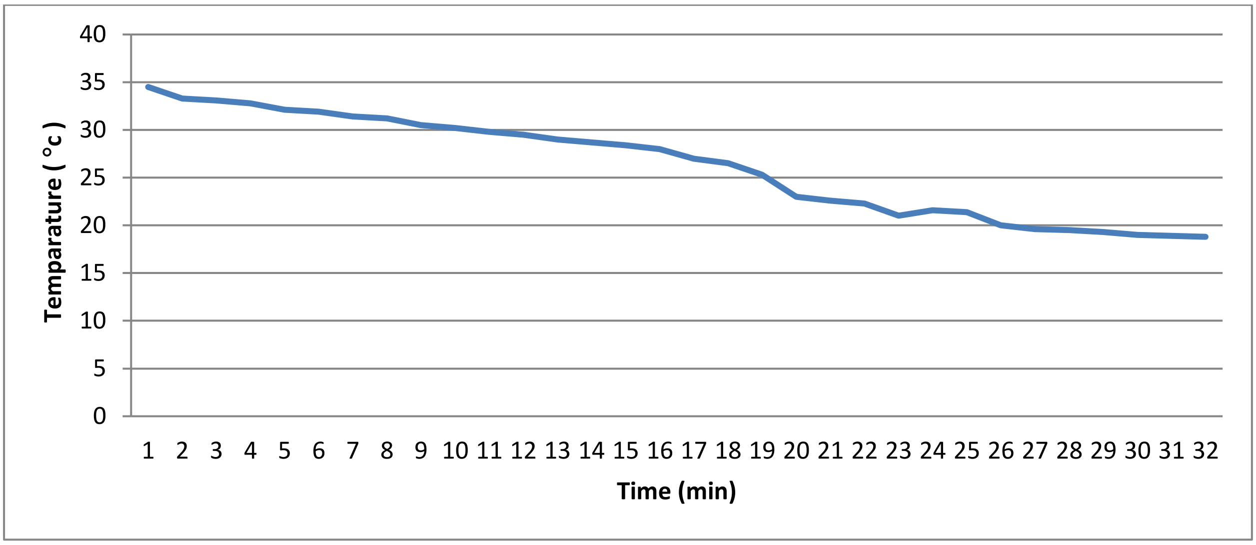
- Portable solar refrigerators for camping and outdoor activities.
- Medical storage in remote areas.
- Cooling systems for electronic devices.
- Food and beverage storage in off-grid locations.

RESULTS:

TIME (min)	TEMPERATURE (°C)
0	34.5
0.30	33.3
0.50	33.1
0.15	32.8
0.20	32.1
0.22	31.9
0.28	31.4
0.34	31.2
1.09	30.5
1.15	30.2
1.36	29.8
1.45	29.5
2.00	29.0
2.30	28.7
3.00	28.4
3.30	28.0
4.00	27.0
5.00	26.5
8.00	25.3
9.00	23.0
10.00	22.6
12.00	22.3
13.00	21.0
14.00	21.2
15.00	21.4

17.00	20.0
18.00	19.6
19.00	19.5
20.00	19.3
21.00	19.0
22.00	18.9
22.14	18.8

Table: Representing temperatures with time after installing the cooling system



Graph: Representing temperatures with time after installing the cooling system

The experimental findings demonstrate how the temperature has been steadily dropping over time. Based on the thermoelectric module, the model was created in precisely 22.14 minutes, with a temperature drop of around 18.8°C from 34.5°C. The battery's total power was approximately 12 volts, and the completely charged battery's total ampere was approximately 16.5 amps. It takes three hours in total to reach 0°C with all of the research and other experimental factors. About 40 amps of current are needed overall, with 12 volts of electricity.

Fig : Output of the Project

CONCLUSIONS:

The experimental findings demonstrate how the temperature has been steadily dropping over time. The model, which is based on the thermoelectric module, was created in precisely 22.14 minutes, with the temperature dropping by around 18.8°C from 34.5°C. The battery's total power was approximately 12 volts, and the fully charged battery's total ampere was approximately 16.5 amps. It takes three hours in total to reach 0°C with all of the research and other experimental factors. About 40 amps of current are needed overall, with 12 volts of electricity.

From the bottom up, the Peltier module solar refrigeration experiment has shown that harnessing renewable energy sources for cooling applications is both feasible and promising. The Peltier module's successful integration with solar energy demonstrates an environmentally responsible and sustainable refrigeration solution. Future developments in solar-powered refrigeration technology may result from ongoing research and development in this field, helping to create a more environmentally friendly and energy-efficient future.

FUTURE SCOPE:

The solar-based refrigeration system utilizing the Peltier effect holds significant potential for future advancements. One key area is improving the efficiency of thermoelectric modules by exploring advanced materials like bismuth telluride composites or nanostructured semiconductors, which could enhance cooling capacity while reducing power consumption. Integrating hybrid energy systems, such as combining solar panels with wind or piezoelectric energy harvesters, could ensure uninterrupted operation during low sunlight conditions. Further research could focus on optimizing heat dissipation using phase-change materials (PCMs) or liquid cooling systems to address thermal management challenges. Scalability for industrial applications, such as large-scale food storage or medical refrigeration in remote areas, is another promising direction. Additionally, incorporating IoT-based monitoring and adaptive control systems could improve real-time performance tracking and energy management. The project’s eco-friendly and modular design makes it adaptable for diverse climates and off-grid scenarios, aligning with global sustainability goals. Future work could also explore cost reduction strategies to make the technology more accessible.

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