A REVIEW OF THE DESIGN AND FABRICATION OF A SOLAR PORTABLE REFRIGERATOR

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Abstract

The current tendency of the first 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. A thermoelectric module is a known type of heat pump in which the passage of an electric current through the module causes one side of the module to be cooled and the opposite side of the module to be heated. The thermoelectric module is also known as a Peltier Module or a thermoelectric heat pump. A practical thermoelectric module usually consists of several semiconductor modules that are connected electrically in series and thermally in parallel. There is no compressor and no fluid flow involved. The thermoelectric cooler has the advantages of being compact, simple, quiet, and reliable.

Keywords: *Solar Energy, Peltier Module, Thermoelectric Cooling, Portable Refrigerator, Renewable Energy, Energy Efficiency*

Introduction

A thermoelectric refrigerator is also called a thermoelectric cooler module. Heat will move through the module from one side to the other by applying low voltage Dc power source to the thermoelectric module.As a result, one face of the module gets heated, and the other face will be cooled.

When two junctions in a closed circuit of two dissimilar metal is formed and current flows between the junctions or the circuit, this phenomenon is known as seeback effect. The combination of semiconductors affects the flow of current. A French scientist, Jean C Peltier, discovered a reversed effect of the See-back. He discovered that, by joining dissimilar metals heat pump can be made. He also found that when two dissimilar metal if current passing through the junction; the temperature difference will be created between the two junctions. The basis of our project is that one junction becomes hot, and the other becomes cool

An intelligent system for the design and fabrication of a solar portable refrigerator and its parameters

The intelligent system for the design and fabrication of a solar portable refrigerator focuses on utilizing renewable solar energy to provide efficient and reliable cooling in remote and off-grid areas. The system integrates a photovoltaic (PV) panel, battery storage unit, charge controller, and a cooling mechanism such as a vapour compression or thermoelectric module. An embedded microcontroller-based intelligent control system is used to monitor and regulate key parameters like temperature, voltage, and energy consumption, ensuring optimal performance and energy efficiency. Sensors continuously collect data, enabling automatic control of the cooling unit to maintain the desired temperature range, typically between 5°C and 10°C, suitable for food and medical storage. The design also considers important parameters such as cooling load, coefficient of performance (COP), solar irradiance, insulation efficiency, and battery capacity. Fabrication involves constructing a well-insulated chamber, integrating the cooling system, and establishing proper electrical connections. Experimental analysis includes monitoring temperature variation, system efficiency, and power consumption under varying environmental conditions. This intelligent solar refrigeration system offers a sustainable, eco-friendly, and cost-effective solution, with potential applications in rural healthcare, food preservation, and disaster relief scenarios.

Fig. Thermoelectric Module

A **thermoelectric module** is a solid-state device used for cooling or heating based on the Peltier Effect. It operates by passing a direct current through a series of P-type and N-type semiconductor materials, which causes heat to be absorbed on one side of the module and released on the other side, thereby creating a temperature difference. This results in one surface becoming cold while the opposite surface becomes hot. Thermoelectric modules are compact, lightweight, and have no moving parts, making them highly reliable and silent in operation. They do not require refrigerants, which makes them environmentally friendly compared to conventional refrigeration systems. However, they are generally less efficient and require proper heat dissipation using heat sinks and fans. Due to their simplicity and portability, thermoelectric modules are widely used in applications such as portable refrigerators, electronic cooling systems, and medical storage devices.

Fig. Solar Panel

A solar panel is a device that converts sunlight into electrical energy using the Photovoltaic Effect. It is made up of multiple photovoltaic (PV) cells, typically composed of semiconductor materials such as silicon, which generate direct current (DC) electricity when exposed to sunlight. When solar radiation falls on the surface of the panel, electrons in the semiconductor material become energized and start flowing, producing electrical power. Solar panels are widely used as a clean and renewable energy source, especially in off-grid and portable applications. Key parameters of a solar panel include its power rating (in watts), efficiency, voltage output, and current generation capacity. In a solar-powered refrigeration system, the solar panel supplies energy to charge the battery and power the cooling unit, making the system energy-efficient and environmentally friendly.

Fig. Battery

A 12-volt battery is one of the most commonly used power sources in everyday applications, providing 12 volts of electrical energy. It is typically made up of six internal cells, each producing about 2.1 volts, especially in lead-acid batteries. There are different types of 12V batteries, with lead-acid being the most common for cars, bikes, and inverters, while lithium-ion batteries are lighter, last longer, and are often used in solar systems and modern devices. The capacity of a battery is measured in ampere-hours (Ah), which indicates how much charge it can store and deliver over time. These batteries are widely used in vehicles, backup power systems like UPS and inverters, solar energy storage, and emergency lighting. Proper charging is important to maintain battery health, usually requiring a voltage between 13.7V and 14.7V, and overcharging or deep discharging should be avoided. The lifespan of a typical lead-acid 12V battery ranges from 2 to 5 years, while lithium batteries can last much longer. For safe operation, it is important to keep battery clean, avoid short circuits, and ensure proper ventilation during charging.

Methodology: solar portable refrigerator

A solar portable refrigerator uses several methods to generate, store, and efficiently use energy for cooling. First, it relies on **solar energy conversion**, where solar panels capture sunlight and convert it into electrical energy using photovoltaic cells. This electricity is then either used directly or stored in a **12-volt battery**, which allows the refrigerator to operate even when sunlight is not available, such as at night or during cloudy conditions.

The main cooling method used in most solar portable refrigerators is the **compressor-based refrigeration system**, which works similarly to a household fridge. It compresses a refrigerant gas, causing it to cool rapidly and absorb heat from inside the fridge. This method is highly efficient and provides strong cooling performance. Some smaller or low-cost models may use **thermoelectric cooling (Peltier effect)**, where electricity creates a temperature difference, but this method is less efficient and suitable only for mild cooling. In a few cases, **absorption refrigeration** may be used, which can run on heat energy, but it is less common in portable solar setups.

To improve efficiency, these refrigerators use **insulation techniques** such as thick foam walls to reduce heat transfer and maintain low internal temperatures. They also include **charge controllers** to regulate the flow of electricity from the solar panels to the battery, preventing overcharging and damage. Additionally, modern systems may use **energy management systems** that optimize power usage by adjusting compressor speed or switching modes based on available solar power.

Overall, a solar portable refrigerator combines solar power generation, battery storage, efficient cooling technology, and smart energy management to provide reliable refrigeration in off-grid or mobile situations.

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Gaps and recommendation

Solar portable refrigerators are very useful for off-grid cooling, but they have several gaps that affect their performance. One major issue is the dependence on sunlight, which makes them less effective during night time or cloudy weather, especially when battery capacity is limited. They also have a higher initial cost compared to conventional refrigerators and usually offer smaller storage space. In addition, their efficiency can be reduced due to high temperatures, poor insulation, and energy losses in the system. Compressor-based models may also face power surge problems that small solar setups cannot handle easily, and the overall system can be complex to maintain. To overcome these issues, it is recommended to use high-capacity batteries, efficient solar panels, and MPPT charge controllers to improve energy utilization. Better insulation and energy-efficient compressors can reduce power consumption, while adding hybrid power options like AC backup can ensure continuous operation. Proper system sizing and regular maintenance, such as cleaning panels and checking battery health, can further improve reliability and performance.

Conclusion

In conclusion, solar portable refrigerators are an effective and eco-friendly solution for cooling in remote and off-grid areas. They use renewable solar energy, making them sustainable and useful where electricity supply is limited. However, challenges such as dependence on sunlight, limited battery capacity, higher cost, and efficiency issues can affect their performance. By using better technology, proper system design, and regular maintenance, these limitations can be reduced. Overall, with the right improvements, solar portable refrigerators can provide reliable and efficient cooling for a wide range of applications.

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