IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 4, December 2025
Impact Factor: 7.67

Solar Refrigeration System using Peltier Modules

Dr. Shambhulingana Goud[1], B Shoiab[2], Inamul Hassain[3], Mohammed Muzamil[4], Vishal K[5]
Associate Professor, Electrical and Electronics Engineering[1]
Students, Electrical and Electronics Engineering [2-5]
Rao Bahadur Y. Mahabaleswarappa Engineering College, Ballari, India

Abstract: *The increasing demand for environmentally friendly and energy-efficient refrigeration systems has led to the exploration of alternative cooling technologies powered by renewable energy sources. This paper presents the design and development of a solar-powered refrigeration system using thermoelectric Peltier modules. The system operates based on the Peltier effect, where electrical energy is converted into a temperature difference across semiconductor junctions to produce cooling without the use of conventional compressors or refrigerants. Solar photovoltaic panels are used to generate electrical energy, which is stored in a battery and regulated through a digital temperature controller for precise temperature control. The proposed system is compact, portable, noiseless, and suitable for off-grid and remote areas. Experimental results demonstrate that the system can maintain temperatures in the range of 5 °C to 25 °C, making it suitable for food preservation and medical storage applications. Although the coefficient of performance of thermoelectric refrigeration is lower than conventional systems, the advantages of sustainability, low maintenance, and environmental safety make it a viable solution for small-scale cooling needs*

Keywords*:* Solar Energy, Peltier Module, Thermoelectric Refrigeration, Renewable Energy, Off-Grid Cooling

I. INTRODUCTION

Among the various renewable energy sources, solar energy has the greatest potential due to its abundance, sustainability, and wide availability. Even a small fraction of the solar energy incident on the earth is sufficient to meet global energy demands multiple times over. Solar energy plays a vital role in maintaining the earth's climate, supporting the water cycle, and enabling photosynthesis. Electrical energy can be generated from solar radiation using photovoltaic (PV) cells, which directly convert sunlight into electricity. In developing regions, particularly in Asia, PV systems are widely used for agricultural irrigation, drinking water supply, rural electrification, and street lighting.

Refrigeration is an essential process for preserving food, medicines, and temperature-sensitive materials. Conventional refrigeration systems rely on vapor-compression cycles and refrigerants that are harmful to the environment and require continuous electrical power. From a thermodynamic perspective, cooling is achieved by removing heat rather than adding cold, which requires external work as stated by the second law of thermodynamics.

Thermoelectric refrigeration based on the Peltier effect offers an alternative cooling technique. When a direct current passes through the junction of two dissimilar semiconductor materials, heat is absorbed on one side and rejected on the other. Peltier modules, also known as thermoelectric coolers (TECs), are compact, noiseless, and free from moving parts or refrigerants. Although their efficiency is lower compared to conventional systems, their advantages such as low maintenance, portability, and environmental safety make them suitable for small-scale and solar-powered refrigeration applications.

II. PROBLEM STATEMENT

Refrigeration is the process of maintaining a temperature lower than the surrounding environment in order to cool a product, space, or material to a required level. In thermoelectric systems, the Seebeck coefficient defines the relationship between the generated electric field and the applied temperature gradient across a material, or equivalently, the voltage produced per unit temperature difference. The Peltier coefficient characterizes the heating or cooling effect at the junction of two dissimilar materials and is defined as the ratio of heat absorbed or released to the electric current flowing through the junction. Additionally, the Thomson coefficient describes the heat absorbed or evolved within a single conductor when an electric current flows in the presence of a temperature gradient, depending on the direction of current flow relative to the gradient.

III. LITRATURE REVIEW

The increasing demand for eco-friendly and energy-efficient refrigeration has led researchers to explore thermoelectric cooling systems powered by renewable energy sources. Thermoelectric refrigeration based on the Peltier effect has attracted attention due to its compact size, silent operation, absence of moving parts, and elimination of harmful refrigerants.

Riffat and Ma presented a detailed review of thermoelectric cooling technologies and concluded that although the coefficient of performance (COP) is lower than conventional systems, thermoelectric refrigeration is suitable for small-scale and portable applications. Dai et al. experimentally demonstrated the feasibility of a solar-powered thermoelectric refrigerator and showed that photovoltaic-driven Peltier modules can maintain stable cooling under varying solar conditions.

Recent studies published in IJARSCT and related journals focus on improving system performance through efficient heat dissipation and digital temperature control. The use of aluminum heat sinks with DC cooling fans has been reported to enhance heat rejection and improve cooling efficiency. Researchers have also highlighted the role of digital thermostats, such as the W1209 temperature controller, in maintaining accurate temperature control for medical and food storage applications.

Overall, literature indicates that solar-powered thermoelectric refrigeration systems provide a sustainable and reliable solution for off-grid and remote areas. However, limitations such as low efficiency and limited cooling capacity remain key challenges. The present work aims to design a compact and solar-powered thermoelectric refrigeration system suitable for small-scale cooling applications.

IV. METHODOLOGY

The thermoelectric refrigerator operates based on the Peltier effect, a thermoelectric phenomenon in which electrical energy is converted into a temperature difference across a junction of two dissimilar semiconductor materials. A Peltier module, also known as a thermoelectric cooler (TEC), consists of alternating p-type and n-type semiconductor elements arranged electrically in series and thermally in parallel. These semiconductor elements are sandwiched between two ceramic plates, which provide electrical insulation and mechanical support while allowing heat transfer. When a DC voltage is applied across the terminals of the Peltier module, an electric current flows through the p-type and n-type semiconductors, creating junctions between them. Due to this current flow, heat is absorbed at one junction and released at the other, resulting in a temperature difference across the two sides of the module. One side of the TEC becomes cold by absorbing heat, while the opposite side becomes hot due to heat rejection.

The cold side of the Peltier module is placed inside the refrigeration chamber to absorb heat from the stored object or space. The hot side is attached to a heat sink, often assisted by a cooling fan, to effectively dissipate heat into the surrounding atmosphere and maintain efficient operation. In applications requiring higher cooling capacity, multiple Peltier modules can be connected together Solar energy is used as the primary power source for the system. A monocrystalline solar panel is employed due to its higher efficiency in converting sunlight into DC electrical energy. The generated electrical power is stored in a battery to ensure continuous operation during low or no sunlight conditions. The stored DC power is supplied to the Peltier module through conductive connections, enabling the thermoelectric cooling process. Thus, the integration of solar power with thermoelectric cooling provides an eco-friendly and off-grid refrigeration solution.

V. WORKING

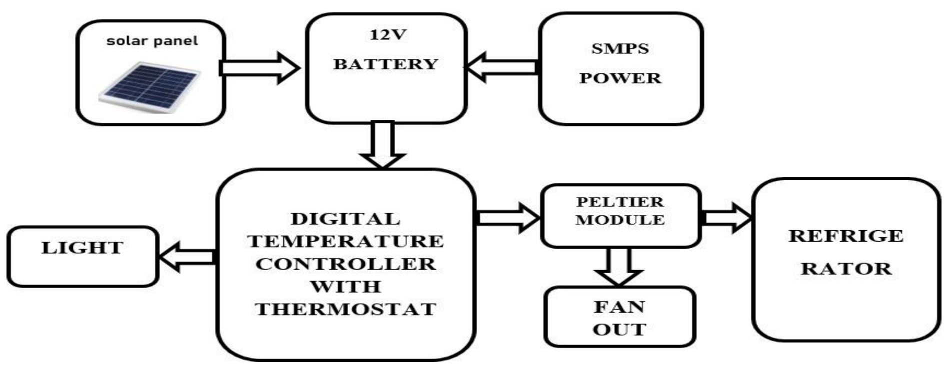
The solar-based thermoelectric refrigerator operates using the Peltier effect, where electrical energy is converted into thermal energy to create a temperature difference across a Peltier module. A solar panel is used to harness sunlight and

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 4, December 2025
Impact Factor: 7.67

generate DC electricity, which is stored in a battery for consistent energy supply. This DC power is then supplied to the Peltier module via a digital temperature controller thermostat, which regulates and maintains the desired temperature within a specified range (e.g., 5°C to 25°C).

The Peltier module consists of alternating p-type and n-type semiconductors connected thermally in parallel and electrically in series. When a DC current flows through the module, heat is absorbed on one side (cool side) and transferred to the other side (hot side). The cool side of the module absorbs heat from the refrigerator compartment, lowering its temperature, while the hot side dissipates the heat with the help of a heat sink. The thermostat continuously monitors the temperature inside the refrigerator and adjusts the current flow through the Peltier module to maintain the set temperature. This system eliminates the need for conventional compressors and refrigerants, making it environmentally friendly and compact. It is especially suitable for off- grid and remote areas where solar energy can be efficiently utilized to power the refrigerator, offering a sustainable and portable solution for cooling needs

VI. BLOCK DIAGRAM



HARDWARE REQUIREMENT
SOLAR PANEL
12V BATTERY
DIGITAL TEMPERATURE MODULE WITH THERMOSTAT
PELTIAR MODULE
THERMO ELECTRIC PELTIER REFRIGERATION
SMPS
12V DC FAN

VII. COMPONENTS DESCRIPTION

Solar panel

The solar panel operates on the photovoltaic effect, in which incident solar radiation generates electron–hole pairs within a semiconductor material, producing direct current (DC) electricity. Monocrystalline solar panels are employed in this system due to their higher efficiency and better performance under varying sunlight conditions

Battery

A 12 V lead-acid battery is used to store the electrical energy generated by the solar panel. The battery provides a continuous power supply to the system and ensures uninterrupted operation during periods of low or no solar irradiance.

Digital Temperature Module with Thermostat

A W1209 digital temperature module is used to regulate the cooling process accurately. It is equipped with an NTC temperature sensor for real-time temperature monitoring and a relay output capable of switching loads up to 20 A, enabling precise control of the Peltier module

DOI: 10.48175/568

Peltier module

The Peltier module consists of multiple p-type and n-type semiconductor elements connected electrically in series and thermally in parallel, sandwiched between two ceramic plates. When a DC current flows through the module, one side absorbs heat and becomes cold, while the opposite side releases heat and becomes hot, facilitating thermoelectric cooling.

Heat sink and Fan

A heat sink is mounted on the hot side of the Peltier module to effectively dissipate heat into the surrounding environment. A DC cooling fan is used to enhance forced convection, thereby improving heat removal and overall system efficiency

SMPS

A switched-mode power supply (SMPS) is used to convert and regulate electrical power with high efficiency. It provides a stable and reliable voltage supply to the system components, ensuring safe and consistent operation.

VIII. ADVANTAGES

Eco-Friendly Technology

Eliminates the use of ozone-depleting refrigerants like chlorofluorocarbons (CFCs), reducing the environmental impact.

Compact and Portable

The system is lightweight and occupies less space, making it highly portable and suitable for remote and off-grid locations.

Renewable Energy Source

Powered by solar energy, it reduces dependence on conventional fossil fuels, promoting sustainable energy use.

No Moving Parts

The absence of moving components increases durability, reduces noise, and minimizes maintenance requirements compared to traditional refrigerators.

Temperature Control

Equipped with a digital temperature controller thermostat for precise and reliable temperature management within a specific range.

Versatile Applications

Can be used for cooling in remote areas, medical storage, and small-scale applications where traditional refrigeration systems are impractical.

Energy Efficient

Utilizes a Peltier module, which requires less power compared to compressor-based systems for small-scale cooling applications.

Long Lifespan

The solid-state design of Peltier modules ensures a longer operational life with reduced risks of leaks or mechanical failures.

IX. LIMITATIONS

Thermoelectric cooling systems have a low coefficient of performance (COP), resulting in higher energy consumption for the cooling produced.

Peltier modules offer limited cooling capacity and are unsuitable for large-scale or high heat-load applications.

The initial cost of Peltier modules, monocrystalline solar panels, and high-capacity batteries is relatively high.

System performance is dependent on solar energy availability, with reduced efficiency during cloudy or rainy conditions.

Effective heat dissipation is required on the hot side of the Peltier module, increasing system complexity and power consumption.

Thermoelectric modules provide a narrower and less precise temperature control range compared to compressor-based systems.

Repeated electrical and thermal cycling can reduce the operational lifespan of Peltier modules.

The low energy density of thermoelectric coolers necessitates the use of multiple modules, increasing cost and space requirements.

X. CONCLUSION

The solar-powered refrigeration system using Peltier modules demonstrates a sustainable and eco-friendly alternative to conventional refrigeration systems. The integration of solar energy with thermoelectric cooling eliminates the need for harmful refrigerants and grid electricity. Although the efficiency is lower than compressor-based systems, the advantages of portability, low maintenance, and environmental safety make it suitable for small-scale and off-grid applications. The project successfully proves the feasibility of solar-powered thermoelectric refrigeration.

XI. FUTURE SCOPE

Future improvements may include the use of advanced thermoelectric materials with higher efficiency, improved heat dissipation techniques, hybrid renewable energy sources, IoT-based temperature monitoring, and enhanced energy storage systems to improve overall performance and scalability.

REFERENCES

[1] M. Cosnier et al., “Thermoelectric Cooling and Heating System,” 2008.

[2] G. Gupta, A. K. Yadav, and S. Singh, “Solar Air-Conditioning Using Peltier Effect,” *International Journal of Engineering Research*, 2014.

[3] G. S. Dhumal et al., “Experimental Investigation of Thermoelectric Refrigeration System,” *IERJ*, 2015.

[4] Prof. Pushkarny B. H. et al., “Solar Refrigeration Using Peltier Effect,” *IJRAME*, 2016.

[5] P. Nakhate et al., “Eco-Friendly Refrigerator Using Peltier Device,” *IJRSE*, 2017.

[6] N. N. Chaudhari, P. A. Patil, and S. P. Shinde, “Design and development of solar based thermoelectric refrigeration system,” *International Journal of Engineering Research & Technology*, vol. 6, no. 4, pp. 227–231, 2017.

[7] A. Kumar and R. Saini, “Solar powered thermoelectric cooling system,” *International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)*, vol. 2, no. 1, pp. 112–118, 2022.

[8] S. R. Patil and V. B. Jadhav, “Performance analysis of Peltier module based refrigeration system,” *IJARSCT*, vol. 3, no. 2, pp. 45–51, 2023.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 4, December 2025
Impact Factor: 7.67

AUTHOR DETAILS

Dr. SHAMBHULINGANA GOUD
Associate Professor, Ph.D.
Department: **Electrical & Electronics Engineering**
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari,
Visveswaraya Technological University, Belagavi
Email: shambu1401@gmail.com

Mr. B SHOIAB
3VC23EE408
B.E (Electrical and Electronics)
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari,
Visveswaraya Technological University, Belagavi
Email: shoiab.eee.rymec@gmail.com
Mobile number : 7483160285

Mr. INAMUL HASSAIN
3VC23EE419
B.E (Electrical and Electronics)
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari,
Visveswaraya Technological University, Belagavi
Email: inamulhassain.eee.rymec@gmail.com
Mobile number : 8618684302

Mr. MOHAMMED MUZAMIL
3VC23EE433
B.E (Electrical and Electronics)
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari,
Visveswaraya Technological University, Belagavi
Email: mohammedmuzamil.eee.rymec@gmail.com
Mobile number : 8660024927

Mr. VISHAL K
3VC23EE460
B.E (Electrical and Electronics)
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari,
Visveswaraya Technological University, Belagavi
Email: vishalk99.eee.rymec@gmail.com
Mobile number : 9342808008