IJAREEIE

e-ISSN: 2278-8875
p-ISSN: 2320-3765

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

Volume 13, Issue 5, May 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.317

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 8.317|| A Monthly Peer Reviewed & Referred Journal |

||Volume 13, Issue 5, May 2024||

|DOI:10.15662/IJAREEIE.2024.1305037|

Design and Development of Peltier Based Solar Energy Powered Smart Refrigerator Unit

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ABSTRACT: The increasing demand for sustainable and energy-efficient solutions has spurred the development of innovative technologies that harness renewable energy sources for practical applications. This project presents the design and implementation of a portable solar-powered refrigerator system equipped with an auto-door closing mechanism, aiming to provide a sustainable and eco-friendly cooling solution for various off-grid environments. The core of the system is built around a Peltier cooling module, Arduino microcontroller, and a 12V 7Ah battery, powered by a 12V 10W solar panel. The system's efficiency is enhanced by integrating an auto-door closing feature using a servo motor controlled by the Arduino. The door automatically closes when the internal temperature surpasses a predetermined threshold (e.g., 32°C), ensuring consistent cooling and energy conservation. Additionally, a manual control option is available through a push button for user convenience. The design emphasizes portability, durability, and cost-effectiveness, making it ideal for applications such as camping, outdoor events, and emergency situations. The project serves as an educational platform, offering insights into renewable energy systems, electronics, and programming, encouraging hands-on learning and experimentation. Through this project, we demonstrate the feasibility of combining renewable energy sources with advanced technologies to create practical and sustainable solutions for everyday challenges, contributing to a greener and more sustainable future.

I. INTRODUCTION

In today's world, energy efficiency and sustainability are becoming increasingly important. With the rising concern for the environment and the need for sustainable living, there is a growing demand for innovative solutions that reduce energy consumption and utilize renewable energy sources. Our project aims to address this demand by creating a portable solar-powered refrigerator system equipped with an auto-door closing mechanism. The primary objective of this project is to design a compact and efficient refrigerator system that can be powered using solar energy, making it environmentally friendly and suitable for off-grid applications. The system incorporates advanced technologies, including a Peltier cooling module, Arduino microcontroller, and temperature sensor, to maintain a consistent and controlled temperature inside the refrigerator. The auto-door closing feature adds an extra layer of convenience and efficiency to the system. By utilizing a servo motor controlled by the Arduino, the refrigerator door can automatically close when the internal temperature rises above a predetermined threshold, ensuring that the contents remain fresh and cool. Additionally, users have the option to manually close the door using a push button if needed. This project combines elements of electronics, programming, and renewable energy

to create a practical and eco-friendly solution for cooling and preserving food and beverages in various settings, such as camping trips, outdoor events, or emergency situations where access to electricity may be limited. Join us as we delve into the design, construction, and testing phases of this innovative solar-powered refrigerator system, exploring the integration of different components and technologies to achieve a functional and sustainable cooling solution.

II. LITERATURE REVIEW

A literature review on Peltier-based solar refrigeration systems would examine existing research and studies on the use of Peltier devices in combination with solar energy for refrigeration applications. This would include an analysis of the performance and efficiency of Peltierbased solar refrigeration systems, as well as their potential advantages and disadvantages compared to traditional refrigeration systems. Some studies have found that Peltier-based solar refrigeration systems can be more energy-efficient and sustainable than traditional refrigeration systems, as they utilize

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renewable solar energy and do not rely on chemical refrigerants. These systems can also be cost-effective for remote or off-grid locations where access to power is limited. However, Peltier-based solar refrigeration systems also have some limitations. They are dependent on the availability of sunlight, and their performance may be affected by weather conditions such as cloud cover or shading. Additionally, Peltier-based solar refrigeration systems may not be able to achieve the same cooling capacity as traditional refrigeration systems, and they require the integration of solar panels, Peltier devices, and thermal storage systems which can be complex and challenging. For example, research has been conducted to increase the efficiency of Peltier-based solar cooling systems by developing advanced materials and designs to make Peltier devices efficient and effective thermal storage capacity. Other research has focused on integrating Peltier-based solar cooling systems with other renewable energy sources such as wind or geothermal energy to create more energy efficient and stable hybrid air conditioning systems. Overall, the literature review shows that Peltier-based solar cooling systems have the potential to be a promising alternative for cooling, especially in remote or indoor low-voltage grid. However, more research and development is needed to increase their efficiency and effectiveness and make them suitable for large-scale use.

Dr. JIYA IMMANUEL NINMA [1]: The cooling and storage unit was designed to be compact, portable, well isolated and to make use of a PV solar energy system as a source of electricity. The cooling unit makes use of a Liquid to Air thermoelectric cooling module connected to some tubing and a liquid pump to cool the inside of the cooling unit. A monitoring system to monitor the temperature. It can vary temperature upto 2 to 8 degree celsius

Rahul Mutyala, Akashdeep Negi: In this study experimental investigation was performed on a solar powered refrigerator in which the 2 Peltier module was used to provide cooling to the system. The study was carried for the climatic condition of Dehradun at Graphic Era to be Deemed University. After operating the setup for 22min and 6sec the system temperature drops from 30.9˚C to 16.9˚C,

Sanjit S. Chavan, Satish P. Avhad [3]: There is no use of ozone-depleting chlorofluorocarbons, which have an inadequate effect on the environment. They occupy a very small room for operating, much less than the conventional systems. perform temperature control in the range of 5 °C to 25 °C, and provide refrigeration in the remote areas where the power supply is not possible.

Sunil Bharti Harishankar, Ritesh [4]: Solar refrigeration utilising thermoelectric module is likely to be one of the most cost effective, clean and environment friendly technology. This paper does not require any type of refrigerant and mechanical equipment like compressor, prime mover, etc for its functioning.

Vinayak Patil,Sandhya Jadhav,Sandip Kanase, [5]: .A Peltier device is a semiconductor device that can generate electricity from heat. By placing them on a solar panel that absorbs sunlight, a temperature difference is created in the device that creates an electric current that can be used to generate electricity

III. OBJECTIVE

- The objective of the project is to develop a thermoelectric cooling refrigerator by using solar energy.
- To develop a Eco friendly refrigerator
- Automatic door closing

VI. DESIGN AND DEVELOPMENT

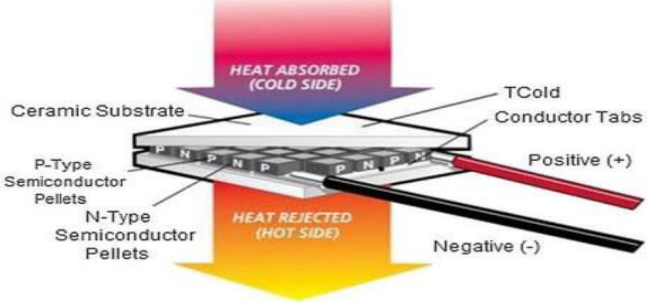

Fig 1: Structure of Peltier module

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Designing a solar-based Peltier module refrigerator unit involves a meticulous process. Initially, the system size is determined by assessing the cooling needs, considering factors like the volume of the refrigerator and desired temperature range. Peltier modules are then selected based on their cooling capacity, efficiency, and voltage compatibility with the solar power system. Solar panel sizing involves calculating the required power output based on the energy needs of the Peltier modules and other system components, factoring in variables such as location and available sunlight. Integration of a battery storage system is essential to store excess solar energy for use during periods of low sunlight or increased demand. Temperature control mechanisms, such as sensors and microcontrollers, regulate the power supplied to the Peltier modules to maintain the desired temperature inside the refrigerator. Efficient heat dissipation from the hot side of the Peltier modules is ensured through the use of heat sinks, fans, or other cooling methods. High-quality insulation materials are employed to minimize heat transfer and optimize energy efficiency. The integration of all system components is carefully executed to ensure seamless operation. Testing and optimization phases involve evaluating the system under various conditions to fine-tune performance and identify any potential issues. Establishing a maintenance schedule and implementing monitoring systems are crucial for detecting and addressing issues promptly, ensuring the long-term reliability and efficiency of the solar-based Peltier module refrigerator unit.

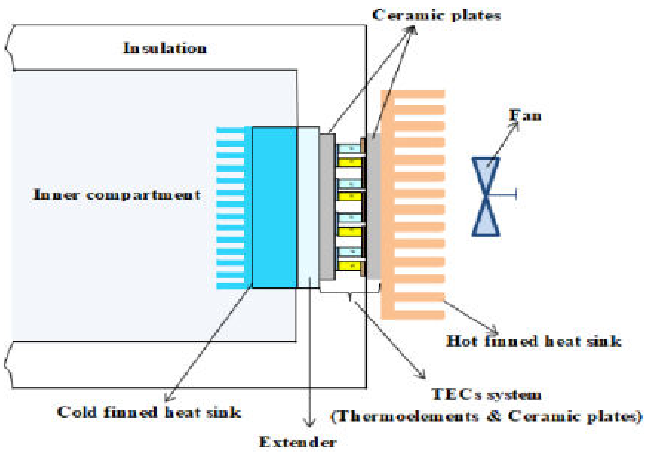
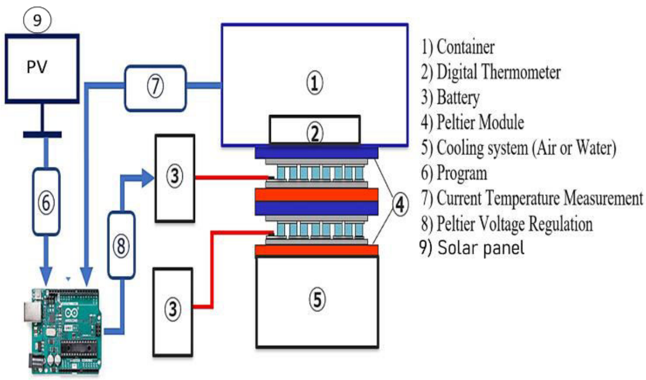


Fig 2: Schematic representation

V. WORKING PRICIPAL



Solar power generation and storage in the solar-powered Peltier-based refrigerator unit are orchestrated through a series of integrated mechanisms and control algorithms. The operation begins with the absorption of sunlight by a 12V 10W solar panel, which converts it into electrical energy, generating a DC voltage. This energy is then directed to charge a 12V 7Ah battery via an LM2566 buck converter, facilitating energy storage for subsequent use. Temperature monitoring and control are managed by a DHT11 temperature sensor, constantly surveilling the refrigerator's ambient temperature.

When the temperature surpasses a predefined threshold, typically 32°C, the Arduino triggers the Peltier module to initiate cooling. Operating on the Peltier effect, heat is transferred from the refrigerator's interior to the exterior,

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effectively cooling the space. An auto-door closing mechanism adds an additional layer of control, with a servo motor linked to the door's movement. The Arduino continually monitors the door's status, deciding whether closure is necessary based on temperature fluctuations or user input via a push button. When prompted, the Arduino signals the servo motor to close the door, stabilizing the internal temperature.

Energy management is efficiently handled by the Arduino, ensuring proper power distribution among components such as the Peltier module and servo motor. A LM2566 buck converter regulates voltage from the battery or solar panel, optimizing performance and efficiency. For user interaction, manual control is provided through a push button, allowing users to manually close the door if needed, activating the servo motor via the Arduino's signal. System monitoring and feedback mechanisms, potentially including LEDs or a graphical user interface (GUI), provide users with real-time information on temperature, battery status, and overall system performance, enabling informed decision-making and efficient operation.

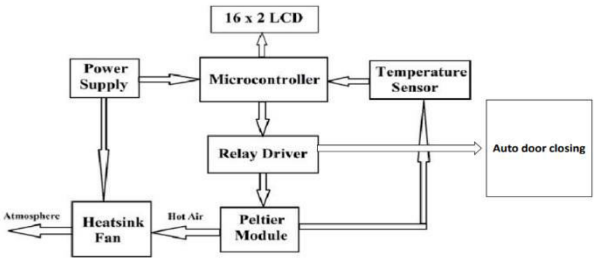
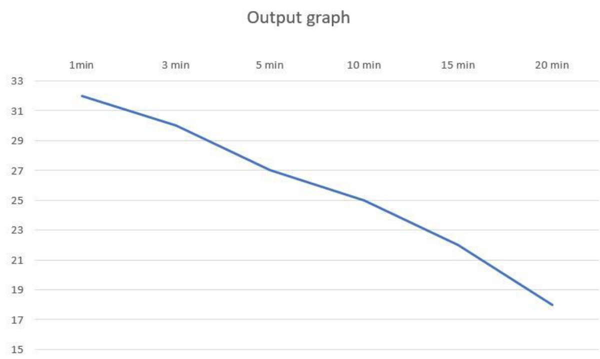


Fig 4: Block diagram

VI. RESULT



Sr. No.	Time (min)	Temperature
1.	00	33
2.	01	32
3.	05	27
4.	10	25.3
5.	20	22.6
6.	30	18.9

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VII. SCOPE OF IMPROVEMENT

proving a solar-based Peltier module refrigerator unit requires a multifaceted approach. Efficiency can be enhanced by refining design elements to optimize solar energy conversion and minimize energy losses. Advanced temperature control mechanisms ensure precise cooling, while increasing storage capacity involves innovative interior layouts and materials. Durability enhancements include using rugged materials and protective measures against environmental factors. Cost reduction strategies focus on sourcing affordable components and streamlining manufacturing processes. Portability improvements aim to make the unit lighter and more user-friendly. Integration with other renewable energy sources and energy storage systems ensures uninterrupted operation. Market accessibility can be expanded through partnerships and affordability initiatives. Feedback mechanisms enable continuous refinement based on user experiences. Environmental impact considerations guide the adoption of sustainable practices throughout the product lifecycle, from production to disposal.

VIII. CONCLUSION

From this project we can conclude that without the use of Compressor and the Refrigerant It is possible to cool the system. There are several different types of cooling devices available to remove the heat from industrial enclosures as well as medical enclosures, but as the technology advances, thermoelectric cooling is emerging as a truly viable method that can be advantageous in the handling of certain small to medium applications. As the efficiency and effectiveness of thermoelectric cooling steadily increases, the benefits that it provides including self contained, solid-state construction that eliminates the need for refrigerants or connections to chilled water supplies, superior flexibility and reduced maintenance costs through higher reliability will increase as well. it can use in ambulance for storing medical equipment can use in remote area for storing medicines, etc. Blood plasma and antibiotics are manufactured using a method called freeze drying.

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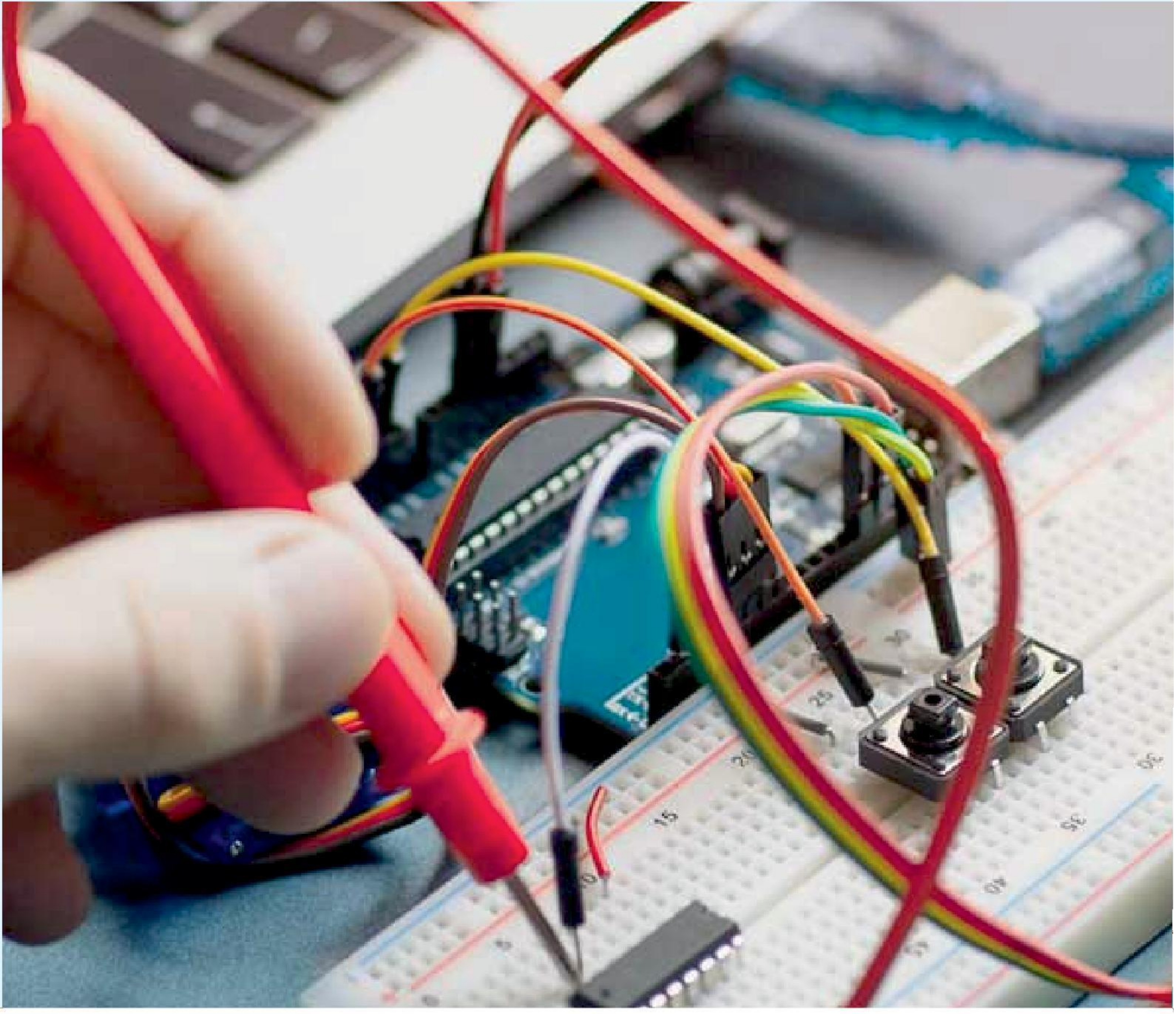

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