

Portable Solar Assisted Manual Controlled Thermoelectric Refrigeration Unit

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Abstract—This project presents a portable solar-powered thermoelectric refrigeration unit designed for off-grid applications. It uses the Peltier effect for cooling and is powered by a solar panel with battery backup. An ESP32 microcontroller monitors and controls temperature using sensors. The system is compact, eco-friendly, and suitable for preserving medicines, vaccines, and food in remote areas.

Index Terms—Thermoelectric Refrigeration, Peltier Effect, Solar Energy, ESP 32 Microcontroller, Portable Cooling System, Battery Storage, Temperature Monitoring, Renewable Energy, Off-grid Applications

I. INTRODUCTION

In recent years, the need for reliable and portable refrigeration systems has increased, especially in remote and off-grid areas where conventional power supply is not available. Preserving essential items such as medicines, vaccines, and perishable food remains a major challenge in such environments. Conventional refrigeration systems rely on compressors and refrigerants, which are bulky, consume more power, and may have harmful environmental effects.

To address these issues, this project proposes a portable solar-assisted thermoelectric refrigeration unit based on the Peltier effect. Thermoelectric cooling offers a solid-state solution with no moving parts, making it compact, lightweight, and environmentally friendly. The system is powered by solar energy with battery backup, ensuring continuous operation even in the absence of sunlight.

An ESP32 microcontroller is used to monitor and control the temperature of multiple cooling compartments using sensors and control circuits. This integration of renewable energy, thermoelectric technology, and intelligent control makes the system

suitable for emergency situations and rural applications.

Thus, the project aims to develop an efficient, sustainable, and portable cooling solution with potential for future advancements such as smart monitoring and improved energy management.

II. PROCEDURE FOR PAPER SUBMISSION

A. Review Stage

Submit your manuscript electronically for review. prepare it in two-column format, including figures and tables (until it doesn't fit properly and data is not visible).

B. Final Stage

After your paper has been accepted. The authors of the accepted manuscripts will be given a copyright form and the form should accompany your final submission.

C. Figures

As said, to insert images in Word, position the cursor at the insertion point and either use Insert | Picture | From File or copy the image to the Windows clipboard and then Edit | Paste Special | Picture (with —Float over text unchecked).

III. MATH

1. The Peltier Effect Equation

The core principle of this cooling system is the heat flux generated at the junction of two dissimilar semiconductors. The rate of cooling (Q_c) at the cold junction is calculated as:

$$Q_c = \pi I - \frac{1}{2} I^2 R - K \Delta T$$

Where:

πI : The Peltier cooling effect (where π is the Peltier coefficient and I is the DC current).

$\frac{1}{2}I^2R$: Joule heating loss, where R is the electrical resistance of the module.

$K\Delta T$: Thermal conduction (heat leaking back from the hot side to the cold side), where K is thermal conductance and ΔT is the temperature difference between sides.

2. Power Consumption Analysis

As noted in methodology for power monitoring, the instantaneous power (P) consumed by the three TEC1-12706 modules and the ESP32 controller is:

$$P=V \times I$$

V: Measured system voltage (typically 12V for the main bus).

I: Total current measured by the INA219 sensor.

3. Battery Runtime and Solar Charging

Mainly uses a 3.3V 2300 mAh Li-ion battery. The theoretical runtime (t) can be estimated by the ratio of battery capacity (Wh) to the average power load(W) Since the battery is 3.3V and 2.3Ah, its energy capacity is approximately 7.59\text {Wh}. If the cooling load exceeds this, the 50W solar panel must provide the surplus energy.

IV. UNITS

Cooling Capacity (Q_c):

Measured in Watts (W), this represents the rate at which heat is removed from the three cooling compartments.

Peltier Coefficient (π):

Measured in Volts (V), it defines the heat evolved or absorbed at the semiconductor junction per unit of current.

Electrical Current (I):

Measured in Amperes (A), this is the DC flow through the TEC1-12706 modules as monitored by the INA219 sensor.

Electrical Resistance(R):

Measured in Ohms, this refers to the internal resistance of the Peltier modules that causes Joule heating.

Thermal Conductance (K):

Measured in Watts per Kelvin (W/K), it represents the heat leakage from the hot side back to the cold side.

Temperature Difference (ΔT):

Measured in Degrees Celsius ($^{\circ}C$) or Kelvin (K), it is the real-time difference between the ambient temperature and the compartment temperature sensed by the DS18B20 sensors.

Voltage (V):

Measured in Volts (V), specifically the 12V DC bus for the cooling elements and the 5V regulated output for the ESP32.

Battery Capacity:

Measured in Milliampere-hours (mAh) or Watt-hours (Wh), indicating the energy stored in the 2300 mAh Li-ion battery.

Solar Power Output:

Measured in Watts (W), referring to the 50W peak power rating of the foldable solar panel.

Coefficient of Performance (COP):

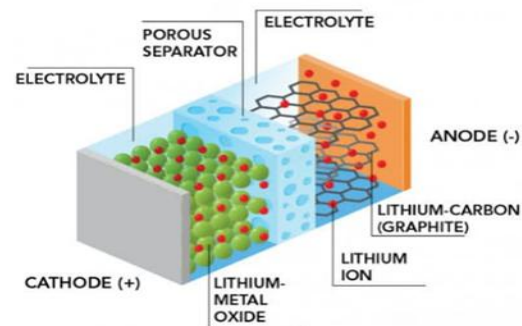
This is a Dimensionless unit, expressed as a simple ratio of cooling energy to electrical input.

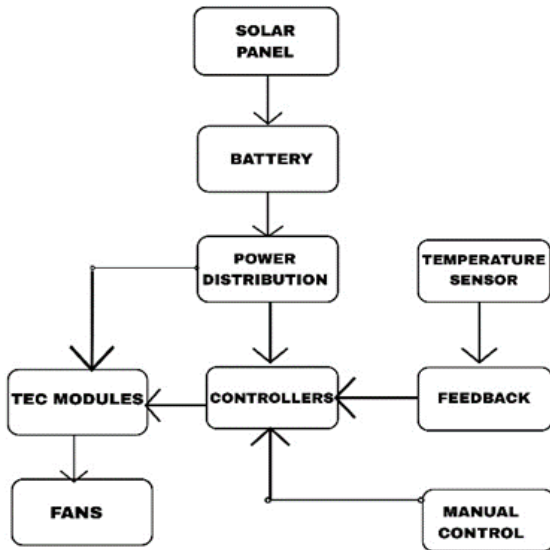
V. HELPFUL HINTS

A. Figures and Tables



PARTS OF A LITHIUM-ION BATTERY





B. References

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C. Abbreviations and Acronyms

- TEC – Thermoelectric Cooler
 ESP32 – Microcontroller with Wi-Fi capability
 PWM – Pulse Width Modulation
 MPPT – Maximum Power Point Tracking
 MOSFET – Electronic switching device
 IoT – Internet of Things
 COP – Coefficient of Performance

VI. PUBLICATION PRINCIPLES

1. Original Contribution

Submitted papers must present new ideas, innovations, or improvements and should clearly advance existing knowledge. Proper references to previous work must be included.

2. Appropriate Length and Clarity

The paper length should match the significance and complexity of the work. Unnecessary details should be avoided, while important concepts must be clearly explained.

3. Technical and Scientific Validity

Authors must provide strong evidence and justification for their results. Experimental data, analysis, and reasoning should be convincing to reviewers and editors.

4. Reproducibility of Work

Sufficient technical details, methods, and procedures must be provided so that other researchers can replicate the results. Transparency and clarity in methodology are essential.

VII. CONCLUSION

The developed portable solar-assisted thermoelectric refrigeration unit demonstrates an effective and eco-friendly solution for cooling applications in remote and off-grid areas. By utilizing the Peltier effect and renewable solar energy, the system eliminates the need for conventional refrigerants and bulky compressors, making it compact, lightweight, and environmentally sustainable. The integration of an ESP32 microcontroller enables efficient temperature monitoring and control, ensuring reliable performance across multiple cooling compartments. The inclusion of battery backup further enhances system reliability

by maintaining operation during low or no sunlight conditions. Overall, this project proves to be a practical solution for preserving medicines, vaccines, and perishable food items in rural and emergency scenarios. Future improvements may include enhanced energy management, IoT-based remote monitoring, and optimization of thermoelectric efficiency to further improve system performance

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