

Fabrication of Solar Based Air Cooler and Refrigerator

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Abstract - The increasing global demand for cooling and refrigeration, coupled with rising energy costs and frequent power supply interruptions, has intensified the need for sustainable and energy-efficient alternatives. Conventional cooling systems rely heavily on grid electricity, contributing to high operational costs and environmental impact. In response to these challenges, this project presents the design and development of a solar-powered air conditioning and refrigeration system that utilizes renewable solar energy to provide reliable and efficient cooling solutions.

The proposed system is designed to operate flexibly in multiple modes, including air-cooling mode, refrigeration mode, or simultaneous operation of both, depending on user requirements. Solar energy is harnessed, regulated, and stored to ensure continuous operation even during periods of low sunlight or power unavailability. Simple manual control mechanisms are incorporated to allow easy switching between operating modes, making the system user-friendly and suitable for a wide range of applications. Temperature monitoring plays a crucial role in maintaining efficient performance, ensuring optimal cooling while minimizing energy wastage.

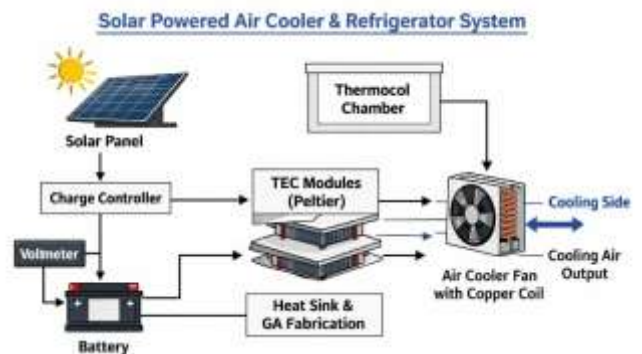
Key Words: □ Solar energy

- Air conditioning
- Refrigeration system
- Renewable energy
- Energy efficiency
- Sustainable cooling
- Power backup

1.INTRODUCTION

The rapid growth in population, urbanization, and industrialization has led to a significant increase in the demand for cooling and refrigeration systems. Cooling

appliances such as air conditioners and refrigerators have transitioned from luxury items to essential household and commercial necessities.



They play a crucial role in ensuring human comfort, food preservation, medical storage, and overall quality of life. However, the widespread use of conventional cooling systems has resulted in high electricity consumption, placing a substantial burden on power generation infrastructure and contributing to increased carbon emissions.

1.1 Aim of the Project

The primary aim of this project is to design and develop a solar-powered air cooling and refrigeration system that can operate efficiently with minimal dependence on conventional electrical power. The project seeks to utilize renewable solar energy to provide reliable cooling solutions suitable for small-scale domestic and rural applications, while promoting energy conservation and environmental sustainability.

1.2 Objectives of the Project

The objectives of the project are outlined as follows:

1. To study the limitations of conventional grid-powered cooling and refrigeration systems, particularly in regions with unreliable power supply.

2. To design a solar-powered system capable of delivering air cooling and refrigeration using renewable energy.
3. To implement an energy storage mechanism that ensures continuous system operation during periods of low or no sunlight.
4. To develop a simple and user-friendly control mechanism that allows selection between air-cooling mode, refrigeration mode, or combined operation.

1.3 Scope of the Project

The scope of this project is focused on the design, development, and testing of a compact solar-powered system capable of providing air cooling and refrigeration for small-scale applications. The system is intended to operate independently of continuous grid electricity, making it suitable for use in rural areas, remote locations, and regions experiencing frequent power interruptions. The project primarily addresses domestic cooling needs rather than large-scale industrial refrigeration.

Within its defined scope, the project includes the integration of solar energy harvesting, energy storage, regulated power management, cooling mechanisms, and temperature monitoring. The system allows user-controlled operation through manual switching, ensuring ease of use and adaptability to varying cooling requirements. Emphasis is placed on energy efficiency, system reliability, and environmental sustainability.

Although the current implementation is limited to basic air cooling and refrigeration functions, the system architecture is designed to be modular and expandable. This allows for future enhancements such as improved cooling capacity, automated control systems, advanced temperature regulation, and integration with smart monitoring technologies. The project also provides a foundation for further research into renewable-energy-based cooling solutions for healthcare storage, agricultural preservation, and disaster relief applications. Overall, the scope of this project is to present a practical, cost-effective, and eco-friendly cooling solution that demonstrates the effective utilization of solar energy for essential applications. It aims to contribute to the growing field of sustainable engineering by showcasing how renewable energy can be successfully integrated into everyday technologies to address real-world challenges.

2.1 Solar Energy Utilization in Cooling Applications

Solar energy has long been recognized as a viable alternative energy source for powering electrical and thermal systems. In cooling applications, solar energy can be utilized either through solar thermal conversion or photovoltaic conversion. Solar thermal systems rely on heat energy to drive absorption or adsorption cooling cycles, while photovoltaic systems convert sunlight directly into electricity to power cooling components.

Literature suggests that photovoltaic-based cooling systems are more suitable for small-scale and portable applications due to their simplicity and modularity. Researchers have demonstrated that photovoltaic panels coupled with energy storage systems can effectively power cooling loads such as fans, thermoelectric modules, and control circuits. These systems eliminate reliance on grid electricity and reduce vulnerability to power outages.

Several studies emphasize that the performance of solar-powered cooling systems depends heavily on effective energy management. Proper voltage regulation, current control, and protection mechanisms are essential to ensure system stability and longevity. Research also indicates that integrating solar systems with battery storage significantly enhances reliability, allowing continuous operation during nighttime or low solar irradiance conditions.

2.2 Photovoltaic Systems and Energy Storage

Photovoltaic systems form the backbone of solar-powered cooling solutions. A photovoltaic panel converts solar radiation into electrical energy, which can be directly utilized or stored for later use. Literature highlights that selecting appropriate panel capacity is crucial to match the energy demands of the cooling system.

Energy storage plays a vital role in maintaining uninterrupted operation. Rechargeable batteries are widely used to store excess solar energy generated during peak sunlight hours. Studies show that battery-based storage enables systems to function during cloudy conditions and after sunset, making solar-powered cooling viable for real-world applications.

Researchers also emphasize the importance of unidirectional power circuits and filtering mechanisms to prevent reverse current flow and electrical noise. These circuits improve system efficiency and protect

components from damage. Effective power management not only enhances performance but also extends system lifespan, a critical factor in sustainable design.

2.3 Thermoelectric Cooling Technology

Thermoelectric cooling has gained attention as a compact and environmentally friendly alternative to traditional refrigeration methods. Thermoelectric modules operate based on the Peltier effect, where an electric current causes heat to transfer from one side of the module to the other, creating a cooling effect.

Literature indicates that thermoelectric cooling systems offer several advantages, including compact size, silent operation, absence of refrigerants, and minimal maintenance. These characteristics make them particularly suitable for small-scale refrigeration and portable cooling applications. Researchers have successfully integrated thermoelectric modules with solar power systems, demonstrating their feasibility in off-grid environments.

Although thermoelectric cooling is generally less energy-efficient than compressor-based refrigeration, studies suggest that its simplicity and compatibility with DC power sources outweigh efficiency limitations for low-capacity applications. Proper heat dissipation mechanisms and temperature monitoring significantly improve performance and reliability.

2.4 Air Cooling Techniques

Air cooling remains one of the most energy-efficient and cost-effective methods for thermal comfort. Fan-based air cooling systems consume relatively low power and can be easily integrated with renewable energy sources. Literature indicates that solar-powered air cooling systems are particularly effective in hot and dry climates, where airflow provides significant cooling benefits.

Researchers have demonstrated that combining air cooling with energy storage systems allows continuous operation during peak temperature periods. Studies also highlight that air cooling systems are simpler to maintain and more affordable than conventional air conditioning units, making them suitable for domestic and rural applications.

Hybrid cooling systems that integrate air cooling with refrigeration technologies are increasingly explored in recent research. Such systems offer enhanced flexibility by allowing users to choose cooling modes based on immediate needs, thereby optimizing energy consumption.

2.5 Control Mechanisms and User Interaction

Control mechanisms play a crucial role in the usability and efficiency of cooling systems. Literature emphasizes that user-friendly control interfaces improve accessibility and reduce operational complexity. Manual control switches are widely used in small-scale systems due to their simplicity and reliability.

Temperature sensing and monitoring are essential components in cooling systems to ensure efficient operation and prevent overheating. Research highlights that continuous temperature monitoring allows dynamic adjustment of system performance, reducing energy wastage and enhancing safety. In solar-powered systems, temperature feedback is particularly important to manage limited energy resources effectively.

2.6 Structural Design and Enclosure Considerations

Mechanical design and enclosure selection significantly influence system durability and safety. Studies indicate that properly designed enclosures protect internal components from environmental factors such as dust, moisture, and physical damage. Metal-fabricated enclosures provide structural strength and improved heat dissipation, contributing to overall system reliability.

Portability is another important consideration discussed in literature. Compact and lightweight designs enhance system mobility, making solar-powered cooling systems suitable for temporary installations, rural households, and emergency applications.

2.7 Existing Cooling and Refrigeration Systems

Conventional cooling systems, including air conditioners and refrigerators, are primarily designed for continuous grid-powered operation. These systems offer high cooling capacity and efficiency but suffer from high energy consumption and environmental impact.

Industrial refrigeration systems, while effective, are expensive and unsuitable for small-scale applications.

Some solar-assisted cooling systems have been developed; however, literature indicates that many are limited to single-function operation and lack user flexibility. Additionally, high initial costs and complex control mechanisms restrict widespread adoption. Research consistently identifies a gap in compact, multi-functional, and affordable solar-powered cooling solutions.

2.8 Identified Research Gaps

A comprehensive review of existing literature reveals several gaps. Many systems focus either on air cooling or refrigeration, rather than integrating both functions into a single unit. Energy storage and power regulation are often underemphasized, leading to unreliable operation. User interaction is frequently overlooked, resulting in systems that are difficult to operate.

There is a clear need for a simple, cost-effective, and modular cooling system that operates entirely on renewable energy and supports multiple cooling modes. Such a system should be easy to deploy, maintain, and scale according to user requirements.

2.9 Problem Statement

Despite advancements in renewable energy and cooling technologies, access to reliable and affordable cooling remains limited in many regions. Conventional systems are energy-intensive and dependent on grid electricity, while existing solar-powered solutions often lack flexibility and practicality. This creates a demand for a compact, efficient, and user-friendly solar-powered cooling system capable of providing both air cooling and refrigeration.

2.10 Proposed System Overview

The proposed system addresses these challenges by integrating solar energy harvesting, battery-based energy storage, air cooling, and thermoelectric refrigeration within a single compact unit. The system allows users to operate air cooling, refrigeration, or both simultaneously, depending on requirements. Manual control mechanisms and temperature monitoring ensure efficient and safe operation.

This integrated approach enhances energy utilization, reduces environmental impact, and improves accessibility to essential cooling services. The proposed system aligns with current research trends while addressing practical limitations identified in existing solutions.

Tale -1:
Comparison of Existing and Proposed Systems

Feature	Conventional Systems	Solar-Assisted Systems	Proposed System
Power Dependency	Grid Electricity	Partial Solar	Fully Solar
Cooling Modes	Single	Single	Dual
Energy Efficiency	Low	Medium	High
Portability	Low	Medium	High
Environmental Impact	High	Medium	Low
User Control	Complex	Moderate	Simple
Suitability for Rural Areas	Low	Medium	High

METHODOLOGY:

1. Solar panel generates DC electrical power.
2. Power is stored in a 12V, 7Ah battery.
3. Uni-directional circuit ensures safe current flow.
4. Filter reduces voltage fluctuations.
5. Air cooler operates using a DC fan.
6. Refrigeration is achieved using a TEC module.
7. Temperature sensor controls refrigeration automatically.
8. Three switches control system operation.

9. GA-fabricated enclosure protects components.

“Integration of air cooling and refrigeration using a single solar energy system”

“The project demonstrates an efficient solar-powered solution for both cooling comfort and refrigeration without grid dependency”

COMPONENTS

4.1 Peltier Module:



Fig. 4.1 Peltier Module

About Peltier Module:

The Peltier module, also known as a thermoelectric cooler (TEC), is a solid-state device that transfers heat using electricity based on the Peltier effect. It is widely used for cooling, heating, and power generation applications. The Peltier module is a versatile thermoelectric device used for cooling, heating, and power generation. In renewable energy applications, it plays a significant role in waste heat recovery and solar energy conversion, making it an important component in modern sustainable energy solutions.

Working:

The Peltier module operates on the Peltier effect, where an electrical current flows between two different semiconductor materials, creating a temperature difference:

- One side of the module absorbs heat (cold side), cooling the surface.
- The other side releases heat (hot side), warming up.
- If the heat is effectively dissipated from the hot side, the cold side becomes even cooler.

In power generation mode, a temperature difference across the module generates electricity due to the Seebeck effect (reverse Peltier effect).

Structure of a Peltier Module:

Two ceramic plates: Provide insulation and structural support.

Thermoelectric semiconductors (P-type and N-type materials): Create the temperature difference.

Copper conductors: Connect the semiconductor materials and allow current flow.

Advantages:

Highly Reliable: Since it has no mechanical components, it does not wear out easily.

Low Maintenance: Requires minimal upkeep compared to compressor-based cooling systems.

Cooling & Heating in One Device: By reversing the polarity, the module can switch between cooling and heating modes.

Precise Temperature Control: Used in applications like laser cooling and scientific instruments.

Fast Cooling or Heating: Responds quickly when power is applied, making it useful for real-time applications.

Operates in Harsh Environments: Functions effectively in conditions where traditional cooling systems might fail, such as vacuum, high altitude, or space.

Disadvantages:

Consumes More Power: Compared to compressor-based cooling, Peltier modules are less energy-efficient, leading to higher power consumption.

Cannot Cool Large Areas: Suitable only for small-scale cooling, as it cannot handle high heat loads efficiently.

Needs Proper Heat Sinking: If the hot side is not cooled effectively, the system's efficiency drops, leading to overheating.

Higher Cost Per Watt of Cooling: For large cooling systems, compressor-based or liquid cooling solutions are more cost-effective.

Requires Stable Power Supply: Voltage fluctuations can reduce performance or damage the module over time.

Condensation Risk: If operated below the dew point, it may cause moisture accumulation, which can affect electronics and sensitive components.

Specifications:

Operating Voltage (V): 12V DC

Current (Imax): 6A

Power Consumption: 72W

Max ΔT (Temp Diff): 67°C

Resistance (Ω): 1.98 Ω

Qmax (Heat Transfer): 60W

Applications:

1. Used in computer processors (CPUs), GPUs, and power electronics to prevent overheating.
2. Used in mini refrigerators, portable coolers, and thermoelectric wine chillers.
3. Functions efficiently in vacuum and extreme temperature conditions.
4. Converts waste heat into electrical energy (See-beck effect).
5. Ensures clear imaging and operational efficiency in extreme environments.
6. Used in electric vehicles (EVs) and industrial batteries to regulate temperature.
7. Used in smart clothing and medical wearables to regulate body temperature.

8. 4.2 Solar Panel:



Figure 4.2 Solar Panel

About Solar Panel:

A solar panel is a device that converts sunlight into electricity using photovoltaic (PV) cells. It is widely used for renewable energy generation, providing clean and sustainable power for homes, industries, and portable devices. A solar panel is made up of multiple solar cells connected together in series or parallel. These solar cells are typically made from silicon and generate electricity when exposed to sunlight through the photovoltaic effect.

Working:

Sunlight Hits the Solar Cells: The panel absorbs sunlight, which excites electrons in the semiconductor material (silicon).

Electric Field Generates Current: The movement of electrons creates a direct current (DC).

Power Collection: The electrical energy is collected via metal conductors.

Energy Conversion: A solar inverter converts DC electricity into alternating current (AC) for use in homes and industries.

Key Components:

1. **Photovoltaic (PV) Cells:** Convert sunlight into electricity.
2. **Glass Layer:** Protects the solar cells from environmental damage.
3. **Encapsulant:** Holds the layers together.
4. **Back-sheet:** Provides insulation and protection.
5. **Frame (Aluminium/Steel):** Supports the panel structure.
6. **Junction Box:** Houses electrical connections and bypass diodes.

Types of Solar Panel:

1. Monocrystalline Solar Panels.
2. Polycrystalline Solar Panels.
3. Thin-Film Solar Panels.
4. Bifacial Solar Panels.

Features:

- 1. Renewable & Sustainable Energy Source:** Uses sunlight, which is free and abundant.
- 2. Converts Sunlight into Electricity:** Photovoltaic (PV) cells absorb sunlight and generate direct current (DC) electricity.
- 3. High Durability & Long Lifespan:** Most solar panels last 25 to 30 years with minimal degradation.
- 4. Compatible with Energy Storage Systems:** Can be paired with solar batteries

Advantages:

- 1. Environmentally Friendly:** Zero greenhouse gas emissions (CO₂, SO₂, NO_x).
- 2. Reduces Electricity Bills:** Once installed, solar panels generate free electricity for decades.
- 3. Low Maintenance Costs:** No moving parts, so wear and tear is minimal.
- 4. Long Lifespan (25-30 Years):** Most solar panels retain 80-90% efficiency even after 25 years.
- 5. Works in Remote & Off-Grid Locations:** Ideal for rural areas, islands, and remote places without electricity.

Disadvantages:

- 1. High Initial Cost:** Buying and installing solar panels requires a large upfront investment.
- 2. Weather Dependent:** Efficiency drops on cloudy, rainy, or snowy days.
- 3. Energy Storage is Expensive:** Without a battery, nighttime power must come from the grid.
- 4. Requires Large Installation Space:** Solar panels need a lot of rooftop or open land for high power generation.
- 5. Efficiency Limitations (15-22%):** Solar panels do not convert 100% of sunlight into electricity.

Specifications:

Maximum Power Output (P_{max}): 50W, 100W, 200W, 300W, 400W, 500W, etc.

Open Circuit Voltage (V_{oc}): 18V to 50V for a single panel.

Short Circuit Current (I_{sc}): 5A to 15A.

Maximum Power Voltage (V_{mp}): 16V to 48V.

Maximum Power Current (I_{mp}): 8.8A

Temperature Coefficient: -0.3%/°C to -0.5%/°C.

Maximum System Voltage: 600V, 1000V, 1500V DC.

Efficiency (%): 18-20%

Nominal Operating Cell Temperature (NOCT): 45°C to 50°C.

Applications:

- 1. Residential Power Supply:** Reduces electricity bills by using solar energy instead of grid power.
- 2. Commercial & Industrial Use:** Businesses, offices, and factories use large solar power systems.
- 3. Solar Street Lighting & Traffic Systems:** Solar-powered streetlights, traffic signals, and road signs work in remote areas.
- 4. Agricultural Applications:** Solar-powered water pumps supply irrigation water to farmlands.
- 5. Solar-Powered Vehicles:** Some vehicles use solar panels for auxiliary power or direct propulsion.
- 6. Space Applications:** NASA and space agencies use solar panels to power satellites and space stations.
- 7. Solar Water Heating Systems:** Solar thermal collectors convert sunlight into heat instead of electricity.

4.3 12v 7ah Battery:

Figure 4.3 12v 7ah Battery

The 12V 7Ah battery is a sealed rechargeable power source widely used in embedded systems, backup power solutions, and mobility applications. It delivers stable DC power with sufficient current capacity to support medium-load devices over extended durations. Built on reliability and endurance, this battery is a cornerstone component in power-critical systems where consistency is non-negotiable.

In operational terms, this battery converts stored chemical energy into electrical energy, supplying a nominal voltage of 12 volts with a capacity of 7 ampere-hours. That translates to sustained performance, predictable discharge characteristics, and dependable uptime exactly what mission-oriented designs demand.

Working:

The 12V 7Ah battery operates on electrochemical principles. Inside the battery, chemical reactions between the electrodes and electrolyte generate electrons, which flow through the external circuit to power connected loads.

- When connected to a load, the battery discharges and supplies current.
- When connected to a compatible charger, the chemical reaction is reversed, restoring capacity.
- The sealed design ensures maintenance-free operation with minimal risk of leakage.

This battery is commonly available as Sealed Lead Acid (SLA) or VRLA (Valve Regulated Lead Acid), emphasizing safety, durability, and operational simplicity.

Power Delivery Concept:

- Provides a constant 12V DC output during nominal operation
- Capable of supplying high surge current for motor startup
- Supports continuous and intermittent loads
- Can be recharged multiple times with proper charging control

Key Features:

1. **Stable Voltage Output:** Delivers consistent 12V DC for sensitive electronics.
2. **Rechargeable:** Designed for repeated charge-discharge cycles.
3. **Maintenance-Free:** Sealed construction eliminates electrolyte handling.
4. **Compact and Robust:** High energy density in a manageable form factor.
5. **Deep Discharge Capability:** Suitable for cyclic and standby use.

Advantages:

1. **Reliable Power Source:** Ensures uninterrupted operation in critical systems.
2. **High Current Availability:** Supports motors, inverters, and control circuits.
3. **Long Service Life:** Designed for durability under proper charging conditions.

Disadvantages:

1. **Weight:** Heavier compared to lithium-based alternatives.
2. **Limited Energy Density:** Larger size for equivalent capacity.
3. **Charging Sensitivity:** Requires regulated charging to avoid degradation.

Specifications:

1. **Nominal Voltage:** 12V
2. **Capacity:** 7Ah
3. **Battery Type:** Sealed Lead Acid (SLA / VRLA)
4. **Charging Voltage:** 13.5V – 14.4V
5. **Typical Backup Time:** Depends on load current
6. **Cycle Life:** 300–500 cycles (typical)
7. **Maintenance:** Maintenance-free
8. **Operating Orientation:** Any position

Terminal Configuration:

- **Positive Terminal (+):** Supplies 12V output
- **Negative Terminal (–):** Ground / return path

(Standard spade or bolt-type terminals depending on model)

Applications:

1. **UPS Systems:** Backup power for computers and servers.
2. **Robotics:** Powers controllers, sensors, and drive motors.

3. **Electric Vehicles:** Used in small EVs and mobility aids.
4. **Solar Power Systems:** Energy storage for off-grid solutions.
5. **Emergency Lighting:** Ensures illumination during power outages.
6. **Security Systems:** Supports alarms and surveillance units.
7. **Medical Equipment:** Provides reliable auxiliary power.
8. **Telecom Systems:** Backup power for communication equipment.
9. **Inverters:** Converts DC to AC for household use.
10. **Automation Systems:** Supplies control panels and actuators.

4.4 Rocker Switch:



Figure 4.4 Rocker Switch

A rocker switch is a type of electrical switch that is operated by a rocking or tilting motion. It is a two-position switch that can be used to control the flow of electrical current to a circuit or device.

A rocker switch typically consists of a rectangular or oval-shaped housing with a pivoting or rocking arm inside. The arm is connected to a set of electrical contacts that are used to control the flow of current.

When the rocker switch is in the "off" position, the contacts are open and no current flows. When the switch is rocked or tilted to the "on" position, the contacts close and current flows.

Types of Rocker Switches:

1. **SPST (Single Pole, Single Throw) Rocker Switch:** This type of switch has one set of contacts and can be used to control a single circuit.
2. **SPDT (Single Pole, Double Throw) Rocker Switch:** This type of switch has two sets of contacts and can be used to control two separate circuits.

3. **DPST (Double Pole, Single Throw) Rocker Switch:** This type of switch has two sets of contacts and can be used to control two separate circuits.

4. **DPDT (Double Pole, Double Throw) Rocker Switch:** This type of switch has four sets of contacts and can be used to control four separate circuits.

4.5 Uni-Directional Circuit with Filter:



Figure 4.5 Uni-Directional Circuit with Filter

1. Allows current flow in one direction only.
2. Prevents reverse current damage.
3. Filters noise and stabilizes voltage.

4.6 Cooler Fan:



Figure 4.6 Cooler Fan

1. Circulates air for cooling
2. Removes heat from hot side of TEC
3. Improves cooling efficiency

4.7 Temperature Sensing Module:

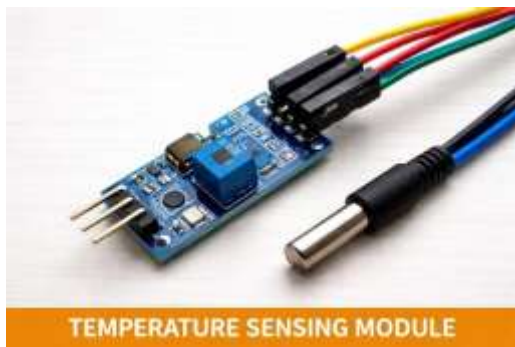


Figure 4.7 Temperature Sensing Module

1. Measures system temperature
2. Helps maintain required cooling level
3. Prevents overheating

4.8 Ga-Fabricated Enclosure:

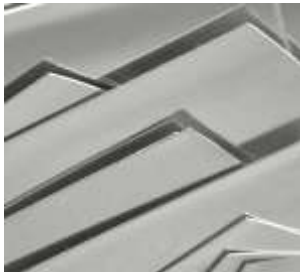


Figure 4.8 Ga-Fabricated Enclosure

1. Holds all components safely
2. Provides mechanical protection
3. Compact and neat appearance

5.1 FABRICATION OF SOLAR BASED AIR COOLER AND REFRIGERATOR:



5.1 Working Principle:

The working principle of the solar-powered refrigerator and cooler system is based on efficient utilization of renewable solar energy combined with controlled power distribution. When exposed to sunlight, the solar panel converts solar radiation into electrical energy. This energy is regulated through a charging circuit and stored in the rechargeable battery. In the absence of adequate sunlight, the AC charging unit supplies backup power to maintain continuous operation.

Once the system is powered, the user selects the desired operating mode using the manual switches. Activating the air-cooling switch powers the fan unit to provide air circulation and cooling. Activating the refrigeration switch powers the thermoelectric module, initiating heat transfer and lowering the temperature inside the refrigeration chamber. Both switches can be turned ON simultaneously to enable combined cooling and refrigeration.

The temperature sensing module continuously monitors the refrigeration chamber and displays real-time temperature values. This allows the user to track system performance and ensures efficient operation without unnecessary energy consumption. The stored energy, regulated control, and compact mechanical design collectively ensure reliable, eco-friendly, and cost-effective cooling.

Through this integrated approach, the system provides a practical solution for basic cooling and refrigeration needs, especially in areas with limited or unreliable electricity supply, while promoting sustainable energy utilization.

5.2 Block Diagram:

The block diagram of the solar-powered refrigerator and cooler system illustrates the flow of energy from the solar source to the cooling and refrigeration units, along with control and monitoring mechanisms. The architecture is designed to ensure energy efficiency, reliability, and ease of operation. Solar energy is harvested, regulated, stored, and distributed to the cooling loads based on user selection, enabling flexible operation under varying environmental conditions.

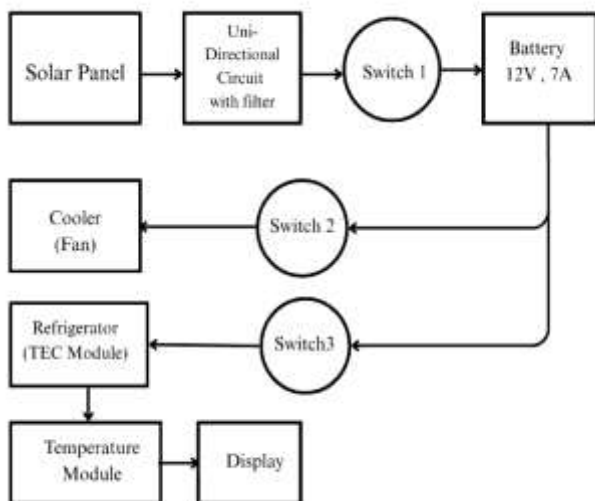


Figure 5.2 Block Diagram

5.3 System Architecture:



Figure 5.3 System Architecture

The system architecture is divided into five major functional subsystems:

1. Solar Energy Harvesting Unit
2. Power Regulation and Storage Unit
3. Control and Switching Unit
4. Cooling and Refrigeration Unit
5. Temperature Monitoring and Enclosure Unit

Each subsystem operates in coordination to deliver efficient cooling while minimizing dependency on grid electricity.

5.4 Solar Energy Harvesting Unit:

The solar energy harvesting unit forms the primary power source of the system. A photovoltaic solar panel converts incident sunlight into electrical energy. The output from the solar panel varies with sunlight intensity and is therefore routed through a unidirectional charging circuit with filtering to ensure controlled and safe power flow. This circuit prevents reverse current flow and protects the solar panel and battery from damage during low-light conditions.

The harvested solar energy is used to charge the storage battery and, when sufficient sunlight is available, can directly support system operation, enhancing overall energy efficiency.

5.5 Power Regulation and Storage Unit:

Energy storage is achieved using a 12 V, 7 Ah rechargeable battery, which ensures continuous system operation even during nighttime or low solar conditions. The charging circuit regulates the incoming voltage and current, maintaining battery health and extending operational lifespan.

An AC charging unit is provided as a backup power source to charge the battery when solar energy is unavailable for extended periods. This hybrid charging approach ensures uninterrupted cooling and refrigeration, making the system suitable for regions with inconsistent sunlight or power supply.

5.6 Control and Switching Unit:

The control and switching unit allows the user to select the desired mode of operation. Two manual switches are employed for this purpose. The left switch controls the air-cooling unit, while the right switch controls the refrigeration unit. Both switches can be activated independently or simultaneously, enabling three modes of operation: air cooling only, refrigeration only, or combined operation.

This manual control approach simplifies system usage, reduces electronic complexity, and improves reliability, making the system accessible for domestic and small-scale applications.

5.7 Cooling and Refrigeration Unit:

The cooling section consists of an air-cooling fan unit designed to circulate air and provide localized cooling. The refrigeration section utilizes a thermoelectric cooling (TEC) module to achieve temperature reduction within an insulated chamber. The TEC module operates based on the Peltier effect, creating a temperature difference when electrical current flows through it.

Heat generated on the hot side of the TEC module is dissipated using appropriate heat sinks and airflow, ensuring efficient refrigeration performance. The combination of fan-based cooling and thermoelectric refrigeration allows the system to serve dual purposes within a single compact setup.

5.8 Temperature Monitoring and Enclosure Unit:

A temperature sensing module continuously monitors the internal temperature of the refrigeration chamber. The real-time temperature readings are displayed, enabling users to observe system performance and maintain desired cooling levels. This feedback mechanism ensures efficient energy utilization and prevents excessive cooling or overheating.

3. CONCLUSIONS

CALCULATIONS:

6.1 Battery Energy Storage Calculation

Battery capacity is calculated as:

$$Energy = Voltage \times Ampere - hour$$

Battery rating:

Voltage = 12 V

Capacity = 7 Ah

$$Energy = 12 \times 7$$

$$Energy = 84Wh$$

Battery Energy Storage = 84 Watt-hours

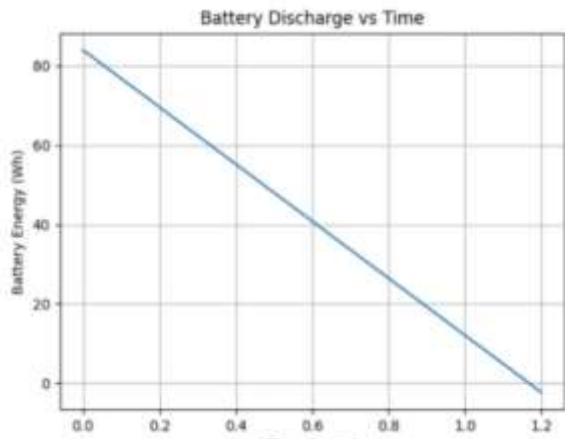
This means the battery can supply **84 W for 1 hour** or

Parameter	Value
Solar Panel Power	60 W
Battery Energy	84 Wh
Losses	20%
Effective Power	48 W
Charging Time	~1.75 Hours

42 W for 2 hours.

Table 6.1 Battery Energy Storage Calculation

Parameter	Value
Battery Voltage	12 V
Battery Capacity	7 Ah
Battery Energy Storage	84 Wh
Meaning	Battery can supply 84 W for 1 hour
Alternate Output	42 W for 2 hours



6.2 Solar Charging Time

Solar panel power = 60 W

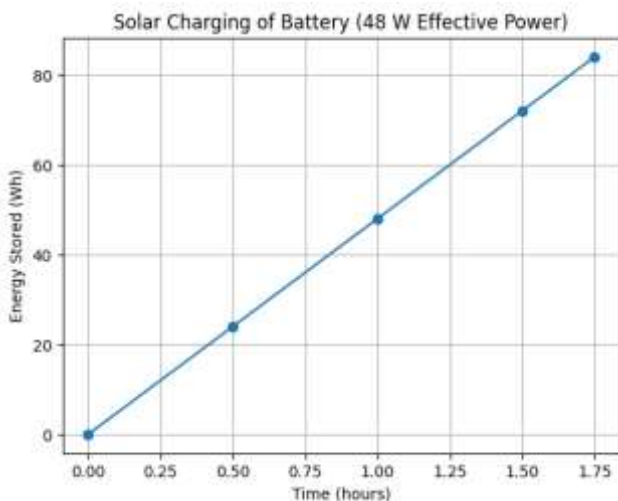
Battery energy = 84 Wh

$$\text{Charging Time} = \frac{\text{Battery Energy}}{\text{Solar Panel Power}}$$

$$\text{Charging Time} = \frac{84}{60}$$

Charging Time ≈ 1.7 hours

Table 6.2 Solar Charging Time



6.3 Solar Panel Output Calculations

Energy Generation Calculation Formula: Energy (Wh) = Power × Time

Assuming each interval = 2 hours

Summer Total Energy:

$$= (5 \times 2) + (50 \times 2) + (250 \times 2) + (320 \times 2) + (250 \times 2) + (80 \times 2) + (10 \times 2)$$

$$= 10 + 100 + 500 + 640 + 500 + 160 + 20$$

$$= 1930 \text{ Wh/day } (\sim 1.93 \text{ kWh})$$

Winter Total Energy:

$$= (0 \times 2) + (20 \times 2) + (170 \times 2) + (220 \times 2) + (170 \times 2) + (40 \times 2) + (5 \times 2)$$

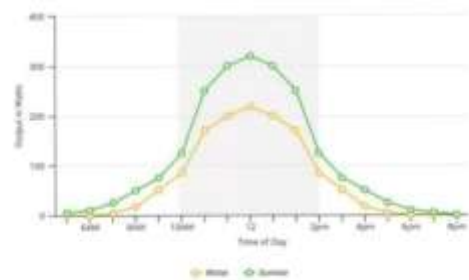
$$= 0 + 40 + 340 + 440 + 340 + 80 + 10$$

$$= 1250 \text{ Wh/day } (\sim 1.25 \text{ kWh})$$

Table 6.3 Solar Panel Output Calculations

Time	Summer Output (W)	Winter Output (W)
6AM	5	0
8AM	50	20
10AM	250	170
12PM	320	220
2PM	250	170

SOLAR PANEL OUTPUT - TIME OF DAY



6.4 Cost Analysis Calculations

1. Annual Cost Change

Solar System:

Decreasing cost = 30000 → 20000

Total reduction = ₹10000 in 5 years

Annual reduction = 10000 / 5 = ₹2000/year

Conventional System:

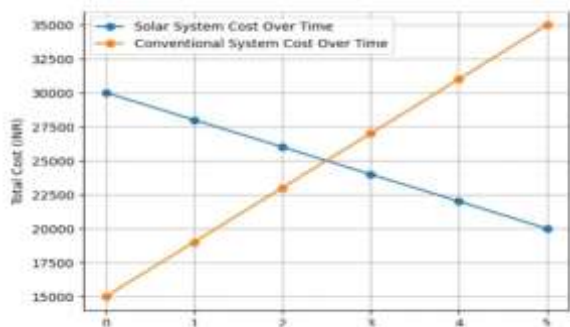
Increasing cost = 15000 → 35000

Total increase = ₹20000 in 5 years

Annual increase = 20000 / 5 = ₹4000/year

Table 6.4 Cost Analysis Calculations

Year	Solar Cost	Conventional Cost
0	38000	15000
1	28000	19000
2	26000	23000
3	24000	27000
4	22000	31000



RESULTS

7.1 SOLAR BASED AIR COOLER AND REFRIGERATOR SYSTEM USING TEC MODULES:

S. N O	TIME (MINUTES)	SOLAR POWER (W)	AIR COOLER TEMPERATURE (°C)	REFRIGERATOR TEMPERATURE (°C)
1	0	120	34°C	30°C
2	5	118	31°C	25°C
3	10	115	28°C	20°C
4	15	112	26°C	15°C

5	20	110	25°C	10°C
6	25	108	24°C	7°C
7	30	105	24°C	5°C

- Initial temperature starts at room temperature (30–34°C).
- Air cooler reduces temperature quickly within 15 minutes.
- Refrigerator takes more time but reaches lower temperature (around 5°C).
- Solar power slightly decreases over time due to sunlight variation.
- TEC modules maintain cooling when proper heat sinks and fans are used.

Result:

Air cooler final temperature ≈ 24°C

Refrigerator final temperature ≈ 5°C

Total experiment time ≈ 30 minutes

DISCUSSIONS

The solar-powered refrigerator and air-cooling system was tested to evaluate its performance under different environmental and operating conditions. During experimentation, the solar panel efficiently converted sunlight into electrical energy, which was regulated through the charging circuit and stored in the 12 V battery for continuous operation. The stored energy successfully powered both the cooling fan and the thermoelectric refrigeration module, either independently or simultaneously, depending on the position of the control switches. The system demonstrated stable functionality during daytime conditions, while the battery backup ensured uninterrupted performance even when solar intensity decreased. This validated the system’s capability to operate reliably in regions with inconsistent grid electricity.

Temperature observations confirmed that the refrigeration chamber achieved a noticeable drop in temperature within a short duration, demonstrating effective heat transfer through the thermoelectric module. The air-cooling mode provided steady airflow suitable for localized cooling, showing that the dual-

function design can meet small-scale domestic requirements. The temperature sensing module continuously monitored and displayed real-time temperature values, allowing users to verify operational efficiency and maintain desired cooling levels. The GA-fabricated enclosure provided proper insulation and structural support, contributing to improved thermal retention and overall system durability.

The results indicate that the proposed system is energy-efficient, environmentally friendly, and capable of delivering reliable cooling without dependence on conventional electricity. The integration of solar power with compact cooling technology proves to be a practical solution for rural households, remote locations, and areas facing frequent power shortages. Overall, the experimental performance confirms that the system meets its design objectives of sustainability, portability, and cost-effectiveness while promoting the use of renewable energy for everyday cooling applications.

CONCLUSION

The solar-powered refrigerator and air-cooling system offers several significant advantages over conventional cooling technologies. First, it operates entirely on renewable solar energy, which reduces dependence on grid electricity and minimizes operational costs. This makes the system highly suitable for regions facing frequent power outages or lacking reliable electrical infrastructure. By utilizing clean energy, the system also contributes to environmental conservation by lowering carbon emissions and reducing the overall ecological footprint associated with traditional refrigeration and air-conditioning units.

Another key advantage is the dual-function capability, as the system can provide both refrigeration and air cooling within a single compact unit. This multifunctional design enhances usability while maintaining simplicity and portability. The system requires minimal maintenance because it contains fewer mechanical parts compared to compressor-based refrigeration systems, resulting in reduced wear and longer service life. The inclusion of battery storage ensures continuous operation even during low sunlight conditions, thereby improving reliability. Additionally, the manually controlled switches allow users to operate the system easily without requiring technical expertise, making it practical for domestic and small-scale applications.

The lightweight construction and GA-fabricated enclosure make the setup portable and adaptable for rural

households, temporary installations, and outdoor usage. Overall, the system is cost-effective, energy-efficient, environmentally friendly, and well-suited for sustainable cooling needs.

FUTURE SCOPE

Although the present design successfully demonstrates solar-powered cooling and refrigeration, there is considerable potential for further enhancement. Future developments may include integrating automatic temperature control systems to regulate cooling based on real-time conditions, thereby improving efficiency and reducing unnecessary energy consumption. The addition of advanced thermal insulation materials could enhance cooling retention and further increase system performance.

The system can also be upgraded by incorporating larger-capacity solar panels and higher-efficiency energy storage solutions to support extended operation and increased cooling loads. Smart monitoring features such as wireless data logging and mobile-based control could be introduced to allow users to track temperature and system status remotely. Furthermore, integrating hybrid energy options, such as auxiliary grid or alternative renewable sources, could ensure uninterrupted functionality under all environmental conditions.

With continued improvements, the system can evolve into a fully autonomous, smart, and scalable cooling solution suitable for commercial use, disaster-relief applications, and sustainable infrastructure projects. Thus, this project establishes a strong foundation for future innovation in renewable-energy-based refrigeration and climate control technologies.

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