



DESIGN AND FABRICATION OF SOLAR POWERED VAPOUR COMPRESSION REFRIGERATION SYSTEM

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Abstract: The paper will tell us about the working principle of the vapour compression cycle, explaining how conversion of sunlight into electricity powers the compressor, enabling the circulation of refrigerant and creation of cool temperatures within a designated space. Key components of the system, including solar panels, battery storage, inverter, and the vapour compression unit itself, will be discussed.

Index Terms - COP, Refrigerants, R-134a

I. INTRODUCTION

This world relies heavily on refrigeration systems, from the refrigerators in our kitchens to the air conditioners keeping us comfortable on hot days. But how exactly do these systems work? In essence, they act as heat pumps, moving heat from a cold space we want to maintain (like the inside of a fridge) to a warm space (usually the outside environment). This creates the illusion of "cold" being generated, even though it is simply the removal of heat.

Here is a deeper dive into the workings of a refrigeration system:

The Essential Components:

- Evaporator:** This component acts like a sponge, absorbing heat from the cold space. As a refrigerant, typically a liquid or gas, flows through the evaporator, it absorbs heat, causing it to evaporate (turn into a gas). This process lowers the temperature in the cold space.
- Compressor:** Once the refrigerant has absorbed heat and turned into a gas, it enters the compressor. Here, the gas is compressed, which increases the pressure and temperature.
- Condenser:** The hot, high-pressure gas then travels to the condenser. Here, it meets the ambient air (or sometimes water), which is typically cooler than the compressed refrigerant. This causes the refrigerant to condense (turn back into a liquid) and release the heat it absorbed earlier.
- Expansion device:** The now-cooled, high-pressure liquid refrigerant then passes through an expansion device, such as a capillary tube or expansion valve. This device reduces the pressure of the liquid, causing it to flash evaporate (partially turn back into a gas) and further decrease its temperature.

- 1. Reliable and sustainable refrigeration:** A solution for storing perishable food items and medicines without relying on an unreliable grid or expensive generators. (As shown in Fig – 1.4)
- 2. Reduced food spoilage:** Minimize losses due to spoilage, ensuring food security and economic benefits.
- 3. Improved healthcare:** Proper storage of vaccines and medications to enhance healthcare delivery in remote areas.
- 4. Cost-effective solution:** A system with long-term operational savings and minimal maintenance requirements.

PROPOSED ALGORITHM

Approach 1: Utilizing a Pre-built Refrigeration Unit

Concept: This approach involves acquiring a commercially available, small, DC-powered refrigerator unit.

Benefits:

Faster Development: Saves time and resources by using a pre-built, functional refrigeration unit.

Proven Performance: Leverages the existing design and performance characteristics of the commercial unit.

Drawbacks:

Limited Design Control:

Less flexibility in customizing components or optimizing the system for solar power use.

Potential Cost: Purchasing a pre-built unit might add to the prototyping cost compared to building individual components.

Approach 2: Focusing on Core Components

Concept: This approach emphasizes building the core components of the refrigeration system from scratch.

Benefits:

Maximum Design Flexibility: Allows for complete control over component selection, optimization for solar power, and potential innovations.

Educational Value: Provides a deeper understanding of the refrigeration cycle and the challenges of solar power integration.

Drawbacks: Increased Time and Complexity Requires more time and technical expertise to design, source, and assemble individual components.

Potential Performance Issues: Achieving optimal performance might require multiple iterations of design and testing.

Criterion to choose any of the two approaches:

Cost-Effectiveness: Considers a balance between component selection, efficiency, and affordability, which is crucial for a viable product.

Scalability: Consider modularity or future scaling for broader application, making it adaptable to different needs.

Focus on Constraints: Design constraints like manufacturability, safety, and environmental impact, leading to a well-rounded approach.

While the alternative approaches offer different advantages, both designs likely hold significant value due to its focus on real-world considerations and potential for future development. However, one can incorporate elements from these approaches strategically:

Focus on building core components (Structures and Wiring) from scratch if it is aimed for maximum design flexibility or educational purposes.

Paper can also be customized according to the need

Paper Team can impart their subject knowledge accordingly.

Cost can be minimized by wisely choosing components.

DESIGN SELECTION

Vertical door refrigerators, also commonly known as French door refrigerators or multi-door refrigerators, share many components with traditional top or bottom freezer models, but with a focus on improved space utilization and accessibility. Here is a breakdown of their construction:

Better Organization and Accessibility:

1. Easier access: A door allows you to easily see and reach all the items inside without having to dig around in a chest-style (cube) refrigerator. This can be a big advantage, especially for frequently used items.
2. Improved organization: Shelves and compartments in a door-type refrigerator help you organize your food and drinks more efficiently, reducing clutter and wasted space.

Potentially More Efficient Cooling:

1. Reduced cold air loss: Opening a chest-style refrigerator exposes a larger area to warm air, leading to more significant temperature fluctuations and potentially higher energy consumption. A door minimizes cold air loss when you access items.
2. Vertical stacking: Door-type refrigerators allow for vertical stacking of food and drinks, which can improve cold air circulation and potentially increased efficiency.

Ice cream storage refrigerators, also sometimes called ice cream freezers or hardening cabinets, share many components with regular refrigerators but have some key differences optimized for keeping ice cream at ideal temperatures. Here is a breakdown of their construction:

Core Components (Similar to Regular Refrigerators):

1. **Insulation:** Thick, high-quality insulation is essential to maintain the frigid temperatures (around -18°C or 0°F) required for ice cream storage. This minimizes heat transfer from the surrounding environment.
2. **Refrigerant System:** Like a regular refrigerator, a compressor, condenser coils, and evaporator coils work together to circulate refrigerant and remove heat from the interior.
3. **Evaporator Coils:** These coils, responsible for absorbing heat within the cabinet, might be strategically placed throughout for even temperature distribution. They are likely hidden behind panels to prevent frost build up directly on the ice cream.
4. **Condenser Coils:** As in a regular refrigerator, condenser coils release the heat extracted from the interior, typically located on the back or bottom of the unit.

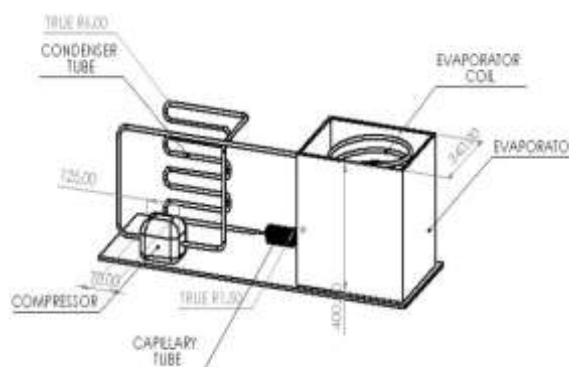


Fig 1.1 – CAD design of Model (all dimensions in mm)

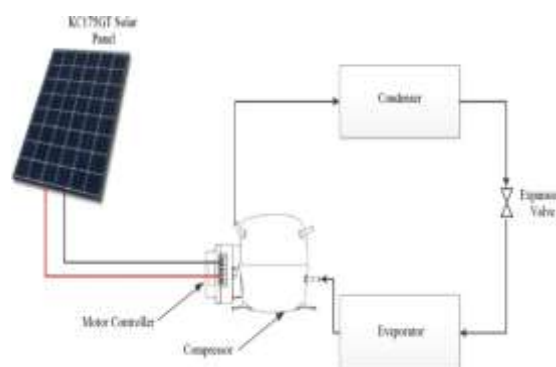


Fig 1.2 – Circuit diagram of Solar powered VCRS

The reason for selecting design flow 2 in explained below:

1. The design process of 2 is structured in a more direct and sequential manner, making it simpler to handle and implement. Each stage logically leads into the next, reducing the possibility of any confusion or duplication.
2. The primary focus of design process 2 is on creating a concept design and producing a prototype in the initial stages. This enables the system's functionality, reliability, safety to be tested early on, allowing for prompt adjustments if needed.
3. Design process 2 guarantees exceptional accuracy and validation in the fabrication and assembly stage by employing CAD software for the development of a comprehensive 3D model and conducting extensive prototype testing. This approach helps to align the final product with design specifications and industry standards for improved results.
4. The first step in the design process follows an iterative method, where the prototype is evaluated and the design is adjusted accordingly. This continuous cycle enables enhancements based on feedback and testing, ultimately leading to a stronger and more efficient product. Through prioritizing the design concept, prototyping, and perfecting stages at the beginning of the procedures.

Implementation plan/methodology

The execution of design flow 2 for the design and fabrication of solar powered VCRS requires a systematic approach to every stage of the paper. The following is a comprehensive outline of the methodology:

1. Conducting a thorough investigation and determine applicable laws, guidelines, and safety protocols pertaining to solar powered VCRS.
2. Performing an in-depth evaluation of the planned operation of the Solar powered VCRS considering

element such as type of refrigerants, amount of energy required, amount of sunlight required and cooling required. Settle on the specific requirements for the system based on the establishment limitations and goals.

3. Using CAD software to convert the chosen concept design into a precise 3D model.
4. Creating a preliminary version of working Solar powered VCRS using appropriate materials and manufacturing methods, based on the 3D design.
5. Examine the prototype testing outcomes and collect feedback to pinpoint any design imperfection or inefficiencies.
6. Conducting thorough assessments and final evaluations of the produced Refrigerator prototype to ensure high quality standards are met.

EXPERIMENT AND RESULT

There are plenty of options available for each stage of process for implementing solution by using modern tools. Some of the tool used to complete the present paper is as follows:

For analyzing the problem: Referred to several research and review papers published by various authors in Google Scholar, Scopus, and Web of Sciences. Also referred to various videos posted on the internet

1. For analysing Cost, Online shopping sites like Amazon.com, Flipkart.com, etc. are referred. Local market was also referred.
2. For Material analysis, Research papers that included fabrication are referred to analyze the best material for fabrication
3. For designing purpose, Solid Works is used which is a 3D-computer aided design software for creating solid models, drawing and assemblies
4. For paper management, MS Excel for the preparation of the Gant Chart for task tracking.

This section analyzes the performance of solar-powered vapor compression refrigeration system and validates its effectiveness;

The detailed result analysis is given below:

Performance: System's cooling capacity (temperature achieved within the chamber is in the range of 0-5°C) under varying solar irradiance levels. Time taken to reach desired temperatures is about 10 minute and the duration the system can maintain them is about 15-20 min.

Coefficient of Performance (COP): The COP, which is the ratio of cooling output to electrical power input. A higher COP indicates better efficiency. COP is given by:

Working pressure range of refrigeration compressor is given below:

Calculating values from P-H graph of R-134a:

$$h_1 = 410 \text{ KJ/Kg}$$

$$h_2 = 465 \text{ KJ/Kg}$$

$$h_4 = 255 \text{ KJ/Kg}$$

$$\text{COP} = 2.81$$

Energy Consumption: The system's total energy consumption over a period of is 2 KWh. It does not vary with factors like solar irradiance and ambient temperature because of constant supply of power from battery.

Component Analysis:

Solar Panel Performance: The solar panel's efficiency in converting solar radiation to electricity is 99% since the Solar panel is new and in effective condition. Factors affecting its output, such as solar irradiance, tilt angle, and temperature.

Compressor Efficiency: The compressor's power consumption is high up to 2 KWh and it impact on overall system efficiency. Temperature Profile: Temperature profile is given by the temperature achieved with respect to time.

The test set for this evaluation experiment watermark image randomly selected from the internet. MAT LAB 7.0 software platform is use to perform the experiment. The PC for experiment is equipped with an Intel P4 2.4GHz Personal laptop and 2GB memory. The proposed scheme is tested using ordinarily image processing. From the simulation of the experiment results, we can draw to the conclusion that this method is robust to many kinds of watermark images.

CONCLUSION

This paper investigated the feasibility of a solar-powered vapour compression refrigeration system for the purpose of storing critical vaccines and vegetables/fruits. The findings demonstrate that this system has the potential to be a sustainable and effective solution in regions with good solar isolation and limited access to reliable grid electricity.

The key findings identified include:

1. Solar power: The system utilizes renewable solar energy, reducing dependence on fossil fuels and minimizing environmental impact.
2. Functionality: A single unit caters to the storage needs of both temperature-sensitive vaccines and perishable produce.
3. Reliable operation: Battery backup ensures uninterrupted cooling during periods of low sunlight.

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