1) **Project Reference Number** - 46S_BE_4722

2) **Title of the Project:** Design and Implementation of Peltier based Mobile Solar Vaccine Refrigerator

3) **Name of the College and Department:** MVJ COLLEGE OF ENGINEERING, BENGALURU
ELECTRICAL AND ELECTRONICS ENGINEERING

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6) **Keywords:** Renewable energy, Peltier sensor, LM35 sensor, Refrigeration

7) **Introduction:** Nowadays we can see that there is more demand for electricity and renewable energy sources and the people are moving from conventional energy sources to non-conventional energy sources. In 2022 there was an 80% increase in electricity demand by wind and solar energy and it records 12% global electricity generation of wind and solar power. 2022 is marked as a turning point in fossil fuel decline. 40% of installed electricity capacity comes from non-fossil fuel sources. Low-carbon sources to cover 100% growth in electricity demand by 2023. India is world's third largest producer of renewable energy. India's vision is to achieve Net Zero Emission by 2070.
The safety of medical products and vaccines is the primary concern of pharmacy and health care centers, especially in rural and remote areas. Where there is electricity shortage, to power the refrigerator.
The basic idea is implementation of photovoltaic driven refrigerating system powered from direct current source or solar panel with a battery bank. Where vaccines and certain medicines must be maintained in low temperature ranging between 2 degree Celsius to 8 degree Celsius.
The thermoelectric refrigeration model aims at providing cooling effect by using prevalent conventional methods like those using the 'Vapor Compression Cycle' (or) the 'Gas Compression Cycle', we are using a cooling system an air-cooling system and liquid-cooling system to get an effective result/output. Where this model is Peltier based solar vaccine refrigerator which will run of a renewable energy as a source of energy, and it consists of battery. Hence it can be easily used to transport vaccines for remote areas and storing purpose. Peltier sensor used to provide the cooling effect in the refrigerator. Hence makes the model lightweight and easy for transportation.

8) **Objectives:** The objective of this project is to design and implement a Peltier based mobile solar vaccine refrigerator that can efficiently store and transport vaccines in areas with limited or no access to electricity. The main objectives of the project are as follows:
   - Utilize Peltier cooling technology to create a temperature difference for efficient refrigeration.
   - Integrate a solar power system to enable operation in off-grid locations.
   - Optimize temperature control within the required vaccine storage range of 2°C to 8°C.
   - Incorporate an LM35 temperature sensor for accurate internal temperature monitoring, displayed on a user-friendly interface for healthcare workers to ensure optimal storage conditions.

9) **Methodology:** The methodology for the design and implementation of a Peltier-based solar vaccine refrigerator involves several steps to ensure efficient cooling, reliable operation, and sustainable energy utilization. The following are the steps:

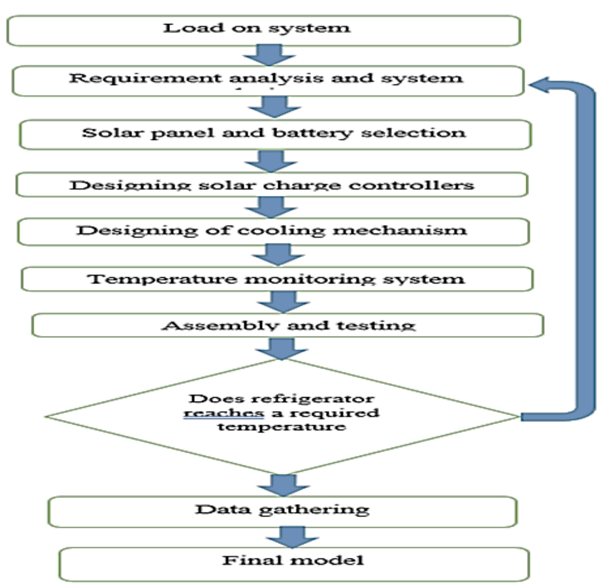


Figure 1. Flow chart of design and implementation of Peltier based mobile solar vaccine refrigerator

A. System design and fabrication:

A 3D model design of a vaccine refrigerator consists of an insulated cabinet, made of aluminium and lined with Styrofoam insulation, to maintain stable internal temperatures. The container, made of copper, is used to store vaccines and can be easily removed for cleaning or rearranging. The refrigerator door, also made of aluminium, features a seal lined with Styrofoam insulation to prevent air leakage.

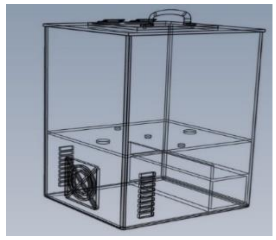
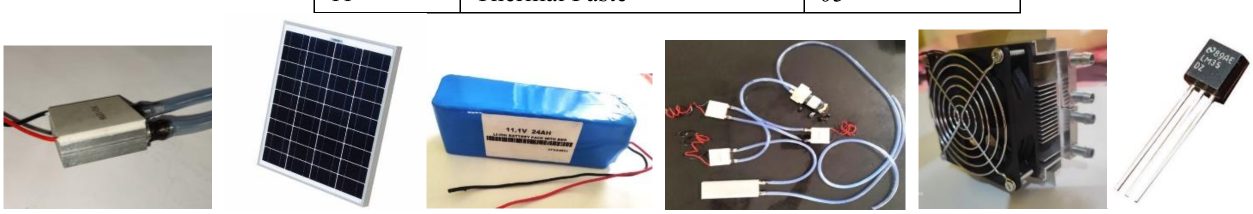


Figure 1. 3D design of a refrigerator

A. Components required:

The following are the components required for the portable solar vaccine refrigerator

Sl.no	Components Required	Quantity
1	Peltier Sensors	03
2	Solar Panel	01
3	Battery	01
4	Cooling Blocks	05
5	Heat sink	01
6	LM35	01
7	Motor	01
8	Water Reservoir	01
9	Arduino uno	01
10	LCD Display	01
11	Thermal Paste	05



(a) (b) (c) (d) (e) (f)

Figure 2. (a) Peltier senor (b) solar panel (c) lithium ion battery (d) liquid cooling system (e) air cooling system (f) LM35 sensor

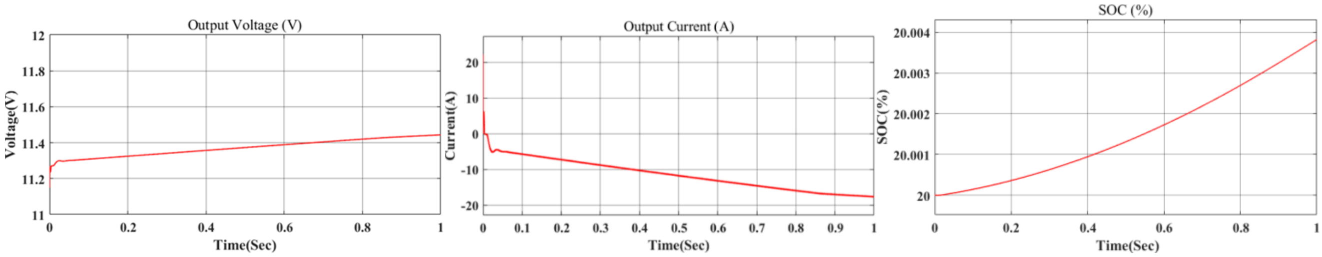
A. Work done:

The solar panel is mounted externally to the box and connected to a charge controller for battery charging. Peltier sensors are attached to the walls of a copper container using thermal paste to maintain the required temperature for vaccine storage. The cooling system is integrated into the refrigerator, including components like a fan, heatsink, and circulation system for heat dissipation and coolant circulation. An LM35 temperature sensor is installed inside the refrigerator and connected to an Arduino Uno and LCD display to monitor and display the internal temperature of the copper container. Power supply from solar panel is given to battery then it is supplied to motor, fan, Arduino and Peltier sensor.

10) Results

a. Software simulation of charge controller

This MATLAB SIMULINK simulation models the process of charging a battery using a photovoltaic panel. It employs the Perturb and Observe (P&O) algorithm to track the maximum power point by adjusting the reference voltage of the panel based on power variations. The system maintains the battery voltage at 12V while gradually charging it in response to changing radiation levels throughout the day. The simulation showcases an efficiency of approximately 90% in achieving the objective of charging the battery using solar power. The red signal represents the negative current flowing into the battery during charging.



(a) **(b)** **(c)**

Figure 3. Output waveforms of Charge controller (a) Output voltage (b) Output current (c) State of Charge Output

Figure 4. Internal compartments of the refrigerator

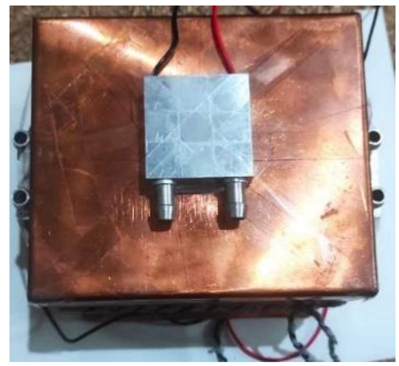


Figure 5. Copper container with Peltier sensor

11) Innovation: The innovation of this model lies in its combination of Peltier module technology and solar power integration for vaccine refrigeration in remote areas. It offers a compact, solid-state cooling solution without the need for traditional compressor-based systems. The integration of solar panels makes it self-sustaining and eliminates the reliance on grid electricity or fuel-powered generators. Its portability and mobility enable easy transportation to reach underserved communities. Precise temperature control systems ensure vaccines are stored within the optimal temperature range. This helps prevent vaccine spoilage and ensures maximum efficacy.

12) Scope for future work: The implementation of a temperature monitoring system with an audible alarm or buzzer to alert the users when the temperature exceeds or falls below the desired range. In the design of a vaccine refrigerator, a horizontal layout can be adopted to incorporate two to three cabins for storing vaccines. By arranging the cabins horizontally, the refrigerator provides distinct compartments, ensuring proper temperature control and minimizing temperature fluctuations between the storage areas. This design promotes effective storage management and facilitates easy access to vaccines. Incorporating fibre material for the outer body of the vaccine refrigerator instead of aluminium offers several advantages, including cost-effectiveness and lightweight construction.

13) Conclusion: The design and implementation of a Peltier-based portable solar vaccine refrigerator present a significant advancement in healthcare and immunization effort, particularly in remote and resource-constrained areas. This innovative solution addresses the critical challenge of vaccine storage and transportation, ensuring the integrity and efficacy of life-saving vaccines. The utilization of Peltier technology, which uses thermoelectric effect, offers numerous benefits for portable vaccine refrigeration. By harnessing solar energy, the refrigerator becomes independent of traditional power sources, making it ideal for areas with limited or unreliable electricity supply. This not only reduces operational costs but also minimizes the environment impact. The compact and lightweight design of portable solar vaccine refrigerator allows for easy transportation and deployment in remote areas. Health workers can easily access communities that were previously inaccessible due to logistical challenges, ensuring equitable access to vaccines and strengthening immunization coverage. It presents remarkable advancement in public health infrastructure.