



Design And Development Of Solar Powered Evaporative Cooling Cart (Coolkart) For Rural Vendors And Healthcare Applications

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Abstract: The increasing temperature and lack of refrigeration facilities in rural and semi-urban areas cause rapid spoilage of fruits, vegetables, and medicines. Roadside vendors and primary healthcare centers such as Anganwadi and Primary Health Centres (PHC) face difficulty in preserving perishable items due to limited electricity access and high energy costs. This paper presents the design and development of a portable solar powered evaporative cooling cart called CoolKart. The system works based on the principle of evaporative cooling using a honeycomb cooling pad. Ambient air is drawn through the honeycomb pad using a DC fan, and moisture is supplied through a humidifier mechanism to enhance evaporation. A humidity sensor controls the moisture level to maintain effective cooling conditions. The entire system operates using solar energy supported by a battery and charge controller with an optional adapter backup. Experimental testing showed that the system can reduce internal temperature by approximately 10–12°C below ambient temperature. The CoolKart provides an eco-friendly, low-cost and sustainable cooling solution for preserving fruits, vegetables and basic medicines in rural environments.

Index Terms - Evaporative Cooling, Solar Energy, Portable Cooling Cart, Honeycomb Cooling Pad, Humidity Sensor, Sustainable Cooling System.

I. INTRODUCTION

India has a large population depending on small-scale businesses and informal sectors such as roadside vending and rural healthcare services. A significant number of fruit and vegetable vendors operate without access to proper refrigeration facilities. Similarly, Primary Health Centres (PHCs) and Anganwadi centres in rural and semi-urban areas often face challenges in storing essential medicines, tonics, and nutritional supplements due to irregular power supply and high electricity costs. This results in rapid spoilage of perishable goods and reduced effectiveness of temperature-sensitive medical supplies.

Conventional refrigeration systems are expensive, consume high electrical power, and rely on harmful refrigerants that impact the environment. In many rural regions, continuous electricity availability is also a major concern. Therefore, there is a strong need for an affordable, portable, and eco-friendly cooling solution that can function efficiently even in off-grid conditions.

Evaporative cooling is one of the most effective and natural cooling techniques suitable for hot climatic conditions. It works on the principle of heat absorption during water evaporation, which reduces surrounding air temperature. By integrating evaporative cooling technology with renewable energy sources, a sustainable cooling system can be developed for community-level applications.

The proposed system, “CoolKart,” is a solar-powered portable cooling cart designed specifically for roadside vendors and rural healthcare units. The system utilizes a honeycomb cooling pad structure through which ambient air is drawn using a DC fan. The air passes through moisture-saturated cooling media, reducing its temperature before circulating inside the storage chamber. A humidity sensor regulates airflow to maintain optimal cooling conditions. The system is powered by a solar panel integrated with a charge controller and rechargeable battery, with an additional adapter-based charging provision for hybrid operation.

The main objective of this project is to provide a low-cost, energy-efficient, and environmentally friendly alternative to conventional refrigeration systems. The developed prototype has been tested with local vendors, and practical feedback has been collected to evaluate its real-time performance. This approach not only enhances the shelf life of fruits and vegetables but also supports safe storage of medicines in rural healthcare settings.

METHODOLOGY

The basic aim of this paper is to develop a portable, low-cost, solar-powered cooling cart for roadside vendors and rural healthcare centers to preserve fruits, vegetables, tablets, and liquid medicines. The system is designed using the principle of evaporative cooling with minimum energy consumption and eco-friendly operation. The entire system operates using solar power supported by a rechargeable battery and optional adapter supply.

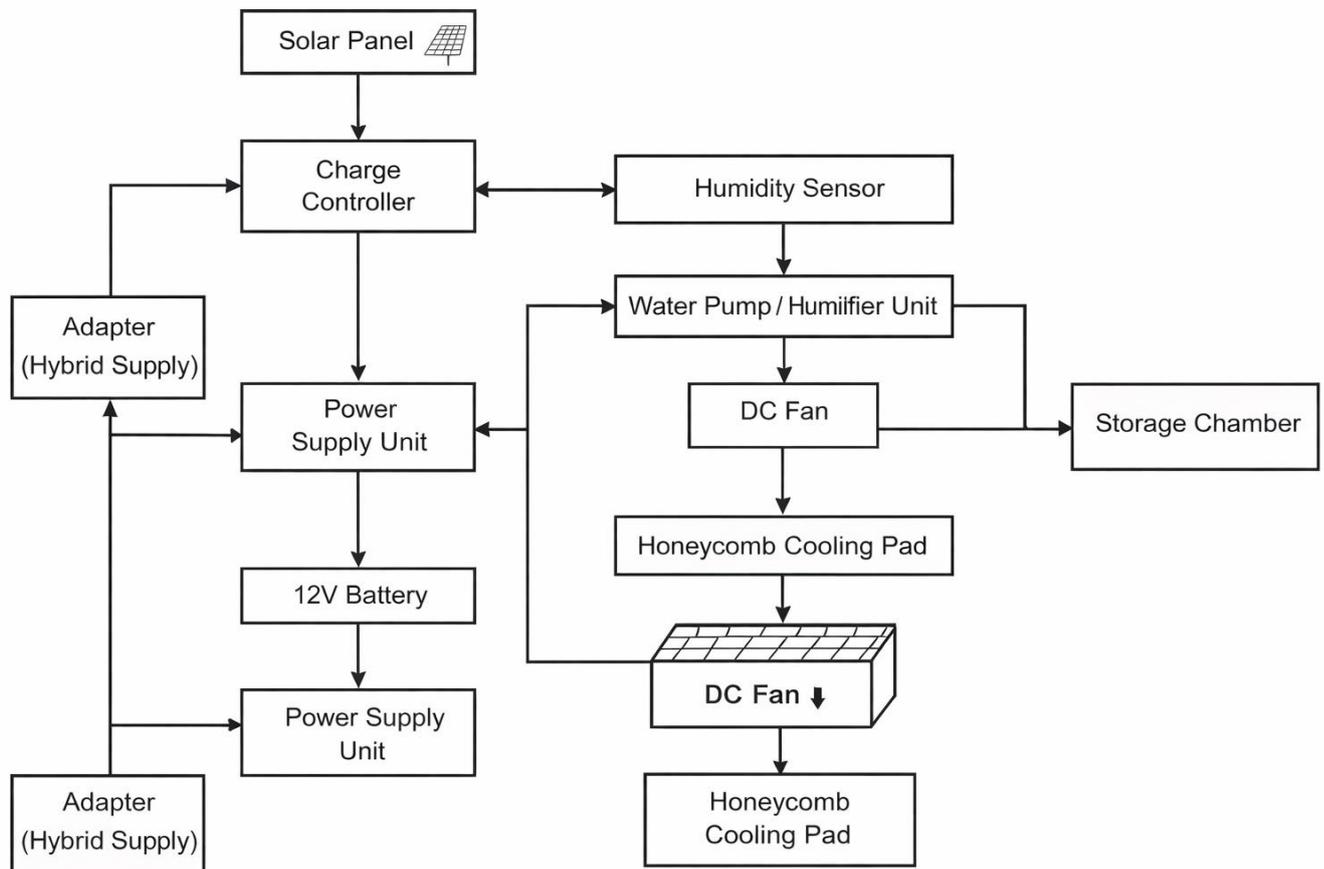


Fig: Block diagram of smart phone multipurpose agricultural robot

The methodology of the proposed CoolKart system is described below:

- The outer body of the cart is fabricated using a lightweight and insulated structure to reduce heat gain from the external environment.
- A honeycomb cooling pad (cooling media) is installed inside the side walls of the cart. This pad acts as the primary cooling element by absorbing water and facilitating evaporation.
- Ambient air enters through the outer air vents and passes through the moisture-saturated honeycomb pad.
- A DC fan is installed to draw outside air through the cooling pad and circulate the cooled air inside the storage chamber.
- A water distribution system with a humidifier mechanism maintains uniform moisture over the honeycomb pad to ensure continuous evaporative cooling.
- A humidity sensor is integrated into the system to monitor internal moisture levels and regulate airflow for optimized cooling performance.
- A solar panel is mounted on the top surface of the cart to generate electrical energy.
- The solar panel is connected to a charge controller, which regulates charging and protects the battery from overcharging and deep discharge.
- A 12V rechargeable battery is used to power the DC fan, humidifier system, and sensor unit.
- An adapter-based charging option is also provided as a hybrid backup system when solar power is insufficient.
- The prototype was tested with local roadside vendors to evaluate real-time performance and cooling efficiency under practical conditions.

The entire system is designed to operate independently of grid electricity, making it suitable for rural, semi-urban, and low-resource environments. The methodology ensures maximum utilization of renewable energy while maintaining cost-effectiveness and portability.

The block diagram of the proposed CoolKart system consists of the following major components:

- Solar Panel
- Charge Controller
- 12V Battery
- Power Supply Unit
- DC Fan
- Water Pump / Humidifier Unit
- Honeycomb Cooling Pad
- Humidity Sensor
- Adapter (Hybrid Supply)
- Storage Chamber

WORKING PRINCIPLE

The project aims at the design, development, and fabrication of a solar-powered portable evaporative cooling cart (CoolKart) for preserving fruits, vegetables, tablets, and liquid medicines in roadside and rural healthcare environments. The entire system operates using solar energy supported by a rechargeable battery and optional adapter supply. The cooling mechanism is based on the principle of evaporative cooling, where heat is absorbed during water evaporation, resulting in temperature reduction inside the storage chamber.

Keeping the above objective in mind, a unit with the following features is designed:

- The system is powered by a solar panel that converts sunlight into electrical energy.
- A charge controller regulates the voltage and charges the 12V battery safely.
- The stored battery power is used to operate the DC fan, water pump (humidifier unit), and sensor system.
- A humidity sensor continuously monitors the internal moisture condition inside the cooling chamber.
- When humidity drops below the set threshold, the water pump activates to supply water to the honeycomb cooling pad.
- The honeycomb pad absorbs water and maintains a wet surface for evaporative cooling.
- The DC fan draws hot ambient air from outside and forces it through the wet honeycomb pad.
- As air passes through the moist cooling media, evaporation occurs and heat from the air is absorbed, thereby reducing the air temperature.
- The cooled air is circulated inside the insulated storage chamber to preserve perishable items.
- In the absence of sufficient solar energy, an adapter supply provides backup power to ensure continuous cooling.

Step-by-Step Operational Working

Step 1 – Power ON the CoolKart system.

Step 2 – Solar panel generates electricity and charges the battery through the charge controller.

Step 3 – Battery supplies power to the fan, pump, and sensor system.

Step 4 – Humidity sensor monitors internal moisture level.

Step 5 – If humidity level is low, water pump turns ON.

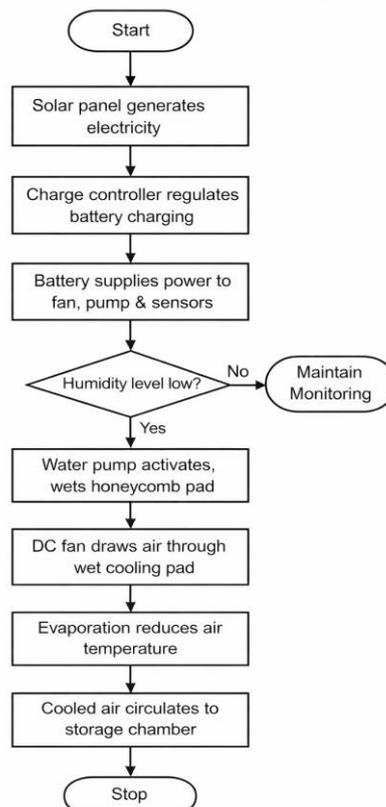
Step 6 – Water flows to the honeycomb cooling pad and keeps it moist.

Step 7 – DC fan draws hot air through the wet honeycomb pad.

Step 8 – Evaporative cooling occurs and air temperature reduces.

Step 9 – Cooled air circulates inside the storage chamber.

Step 10 – System continuously monitors humidity and repeats the process to maintain cooling.



EXPERIMENTAL RESULT

The developed CoolKart prototype was tested under real-time outdoor conditions to evaluate its cooling performance and practical usability. The system was operated during daytime with an average ambient temperature ranging between 36°C and 38°C. Initially, the internal temperature of the storage chamber was equal to the surrounding temperature (36°C). After 15 minutes of operation, the internal temperature reduced to 30°C. Within 30 minutes, it further dropped to 27°C, and after 45 to 60 minutes of continuous operation, the temperature stabilized between 25°C and 26°C. The system achieved a maximum temperature reduction of approximately 10–12°C below ambient conditions.

Time (Minutes)	Ambient Temp (°C)	Internal Temp (°C)
0	36	36
15	37	30
30	37	27
45	38	26
60	38	25

The humidity sensor effectively monitored the internal moisture level and automatically controlled the water pump to maintain adequate wetness in the honeycomb cooling pad. The DC fan continuously circulated air through the moist cooling media, ensuring consistent evaporative cooling. The solar panel successfully powered the system during sunlight hours, while the battery provided backup support for uninterrupted operation. Field testing with local roadside vendors indicated improved freshness of fruits and vegetables and reduced spoilage during peak afternoon heat. The experimental results confirm that the CoolKart system provides an efficient, low-cost, and eco-friendly cooling solution suitable for rural and semi-urban applications.



V. ADVANTAGES

- i. Provides eco-friendly cooling without using harmful refrigerants.
- ii. Operates using solar energy, reducing electricity dependency and operational cost.
- iii. Portable and suitable for roadside vendors and rural healthcare centers.
- iv. Low maintenance and simple working mechanism based on evaporative cooling.
- v. Improves shelf life of fruits, vegetables, and basic medicines by reducing temperature up to 10–12°C below ambient.

VI. APPLICATIONS

- Roadside fruit and vegetable vendors for preserving freshness during hot weather.
- Primary Health Centres (PHC) and Anganwadi centers for storing tablets, tonics, and nutritional supplements.
- Rural and semi-urban areas where continuous electricity supply is not available.
- Temporary markets, exhibitions, and outdoor medical camps.
- Small-scale farmers for short-term storage of harvested produce.

VII. FUTURE WORK

Renewable energy-based cooling systems are gaining importance due to rising temperatures and increasing electricity costs. The proposed CoolKart system can be further enhanced by integrating temperature sensors and digital display units for real-time monitoring. IoT-based monitoring can be implemented to track internal temperature and humidity remotely. Future developments may include improved insulation materials, larger storage capacity, and automatic water level control systems. Integration of phase change materials (PCM) can further enhance cooling efficiency and maintain temperature for longer durations. With technological advancements, the system can be optimized for vaccine storage and expanded into larger community-level cooling units.

VIII. CONCLUSION

The CoolKart system presents a sustainable, low-cost, and portable cooling solution for roadside vendors and rural healthcare applications. By utilizing the principle of evaporative cooling combined with solar energy, the system reduces internal temperature effectively without relying on conventional refrigeration methods. Experimental results demonstrate a temperature reduction of up to 10–12°C below ambient conditions, improving freshness and reducing spoilage. The system is environmentally friendly, energy-efficient, and suitable for regions with limited electricity access. CoolKart offers a practical approach toward sustainable cooling technology and supports rural economic and healthcare development.

IX. REFERENCES

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