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Smart Solar Air Cooler

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Abstract: The need for energy-efficient and eco-friendly cooling systems has led to the development of innovative smart air-cooling systems. The present study proposes a new Smart Solar Air Cooler with automation and energy-saving features for enhanced cooling performance with lower power consumption. Driven predominantly by solar power with a supportive power supply for uninterrupted operation, the cooler is suitable for application in urban and off-grid locations. The cooler features automatic temperature control, real-time water level monitoring, buzzer alert for low water level, and a dual-power operating system for high efficiency and reliability of operation. Through the use of advanced control methods, the system optimizes airflow and water distribution to provide substantially better cooling efficiency compared to conventional air coolers. Extensive experimentation and performance evaluation validate the system's prospects in delivering enhanced cooling, energy conservation, and greater operational sustainability. The study demonstrates the prospects of smart solar cooling technology in enabling eco-friendly and energy-efficient cooling systems, sustainable living, and harnessing renewable energy sources.

Key Words: Automation, Renewable Energy, Smart Cooling System, Solar Energy, Temperature Control

1. Introduction

Solar energy is among the most abundant forms of renewable energy and a key element in the reduction of the utilization of conventional energy systems that are environmentally unfriendly. [1] The increasing global need for cooling systems has raised the use of electricity, mainly from fossil fuel-fired generation stations, which release greenhouse gases and increase global climate change. [2]To surmount these challenges, Solar Air Coolers (SAC) have emerged as a sustainable and green alternative, utilizing photovoltaic panels to power cooling systems and reduce the consumption of grid electricity. [3] SAC systems rely on evaporative cooling principles, where the evaporation of water removes heat and lowers ambient temperatures, and are thus highly suitable for regions with high temperatures and frequent power outages. [4] Besides, SAC systems are equipped with automatic temperature control systems, offering optimal energy consumption through modulation of the amount of cooling based on ambient temperatures .[5] Through the reduction of electricity consumption and greenhouse gas emissions, solar-powered cooling technologies help achieve sustainable development and energy security [6]. Utilization of such renewable technologies not only reduces operating costs but also aligns with global efforts of climate change mitigation .[7]

2. Objectives

- As per the bylaw of the Constitution of India, the Election Commission of India (ECI) has been driven to conduct elections To improve the cooling performance of traditional air coolers with smart temperature regulation.
- Utilizing solar panels to reduce the consumption of electricity and promoting green energy.
- To come up with an energy-efficient cooling system with lower power consumption using optimized components and smart power management techniques.
- To integrate smart automation features through sensors that monitor temperature and humidity and water levels to allow real-time adjustments for peak performance.

- To provide convenience and safety to the user through features such as a buzzer alarm to notify users to maintenance requirements, such as low water levels.

3. Literature Survey

Nayak et al. (2020): This study reviews an automated solar-powered air cooler and heater using a microcontroller, temperature sensors, and a DC fan for efficient temperature control. The system optimizes power consumption, reduces mechanical load, and ensures uninterrupted operation using battery storage. It is a cost-effective, eco-friendly solution for rural areas with frequent power cuts.[1]

Mate et al. (2024): This paper discusses a solar-powered air cooler for residential and commercial use, incorporating photovoltaic panels, a fan unit, and evaporative cooling. It focuses on energy efficiency, cost-effectiveness, and reduced carbon emissions. Future improvements aim at better energy storage, automation, and hybrid cooling.[2]

Vijay Kumar Gupta et al. (2019): This research presents an automatic temperature-controlled air cooler that adjusts fan speed based on environmental conditions. The system utilizes sensors for real-time cooling modulation, contributing to energy-efficient cooling solutions powered by renewable sources.[3]

Rushiprasad Watpade: This article introduces a solar-powered air cooler designed for arid regions, featuring a cross-flow evaporative system, a honeycomb cooling pad, a 10W solar panel, a 12V battery, and a 15W water pump. It operates independently off-grid, offering sustainability and efficient humidity control.[4]

Patil et al. (2020): This study reviews a solar-powered air cooler with a centrifugal fan and cooling pads, designed to minimize power usage and dependence on conventional cooling systems. It highlights the system's low maintenance, eco-friendliness, and affordability, making it suitable for rural areas.[5]

Kalyani et al. (2018): This research analyzes a solar air cooler equipped with solar panels, a charge controller, a battery, a DC fan, and cooling pads. The study focuses on optimizing power consumption, battery efficiency, and cooling performance. Results show that lowering cooling water temperature significantly enhances efficiency.[6]

Mekonen et al. (2023): This paper reviews a multi-stage solar evaporative cooler using cotton fiber pads and activated carbon for enhanced moisture adsorption. The system achieves a temperature drop of up to 12.19°C, with an efficiency of 94.25% and a COP of 52.2. Future improvements target industrial applications and hybrid cooling.[7]

Khobragade et al. (2018): This study presents a smart cooler integrating cooling and heating functions with automated temperature and humidity regulation. It reduces power consumption through optimized airflow and water usage, making it more economical than conventional air conditioning systems.[8]

Pusadkar et al. (2018): This paper explores the electronic aspects of a smart cooler, detailing the role of microcontrollers, relay switches, and PCB components in regulating temperature, humidity, and airflow. Automation enables precise temperature adjustments, improving energy efficiency and user comfort.[9]

4. System Design and Methodology

4.1 Hardware Components

I. **Cooler Motor :** A 12V 3A DC cooler motor is an electrical motor that operates on a 12-volt direct current supply, drawing up to 3 amperes of current. It is extensively utilized in air coolers, stand fans, and ventilators.

II. **Battery :** A 12V 16Ah battery is a rechargeable battery providing a stable 12-volt output with a 16 ampere hour capacity. That means it can provide 16A for one hour or 1A for 16 hours before it needs to be recharged. These batteries are used in a broad range of applications.

III. **Water Pump :** A 12V DC water pump (10 L/min) is a compact yet powerful pump designed to operate from a 12-volt direct current power source. It has a flow rate of 10 liters per minute (L/min).

IV. **Solar Panel :** A 12V 20W solar panel is a small photovoltaic (PV) module that generates 12-volt direct current (DC) electricity with a power rating of 20 watts from sunlight. It is utilized for charging 12V batteries, operating small DC devices, outdoor lighting, camping, and remote monitoring systems.

V. **Solar Charge Controller :** A solar charge controller is a crucial component in solar power installations that regulates voltage and current from the solar panel to the batteries to avoid overcharging, deep discharge, short circuit, and reverse current flow.

VI. **AI Thinker VC-02 Module :** AI Thinker VC02 module is a very compact and efficient Bluetooth 5.0 audio module for wireless audio transmission and voice communication.

VII. **Motor Driver :** The BTS7960 is a high-power H-Bridge motor driver module for the operation of DC motors with high voltage and current requirements.

VIII. **Temperature Sensor :** The DHT11 sensor is a low-cost and compact temperature and humidity sensor used in various environmental monitoring systems. It contains a capacitive humidity sensor and a thermistor to measure relative humidity (RH) and air temperature around it.

IX. **Water Level Sensor :** A water level sensor is a device that is used for water level detection and measurement in tanks, reservoirs, or any other liquid-containing systems.

X. **Microcontroller :** The Arduino Uno is a popular open-source, ATmega328P chip-based microcontroller board. It is used extensively in electronics projects, robotics, and IoT applications since it is simple to use, low in cost, and has strong community support.

XI. **Relay :** A relay is a solid-state or electromechanical switch used for controlling high-power electrical circuits with a low-power signal.

XII. **Voltage Sensor :** A DC voltage sensor is a device that is used to measure direct current (DC) voltage levels and provide an output signal for monitoring or control.

XIII. **SMPS Adapter :** A 12V 5A SMPS (Switched-Mode Power Supply) adapter is a compact and efficient power supply unit used for converting AC mains voltage (110V-240V) to a stabilized 12V DC output with a current rating of 5A.

4.2. Working Mechanism

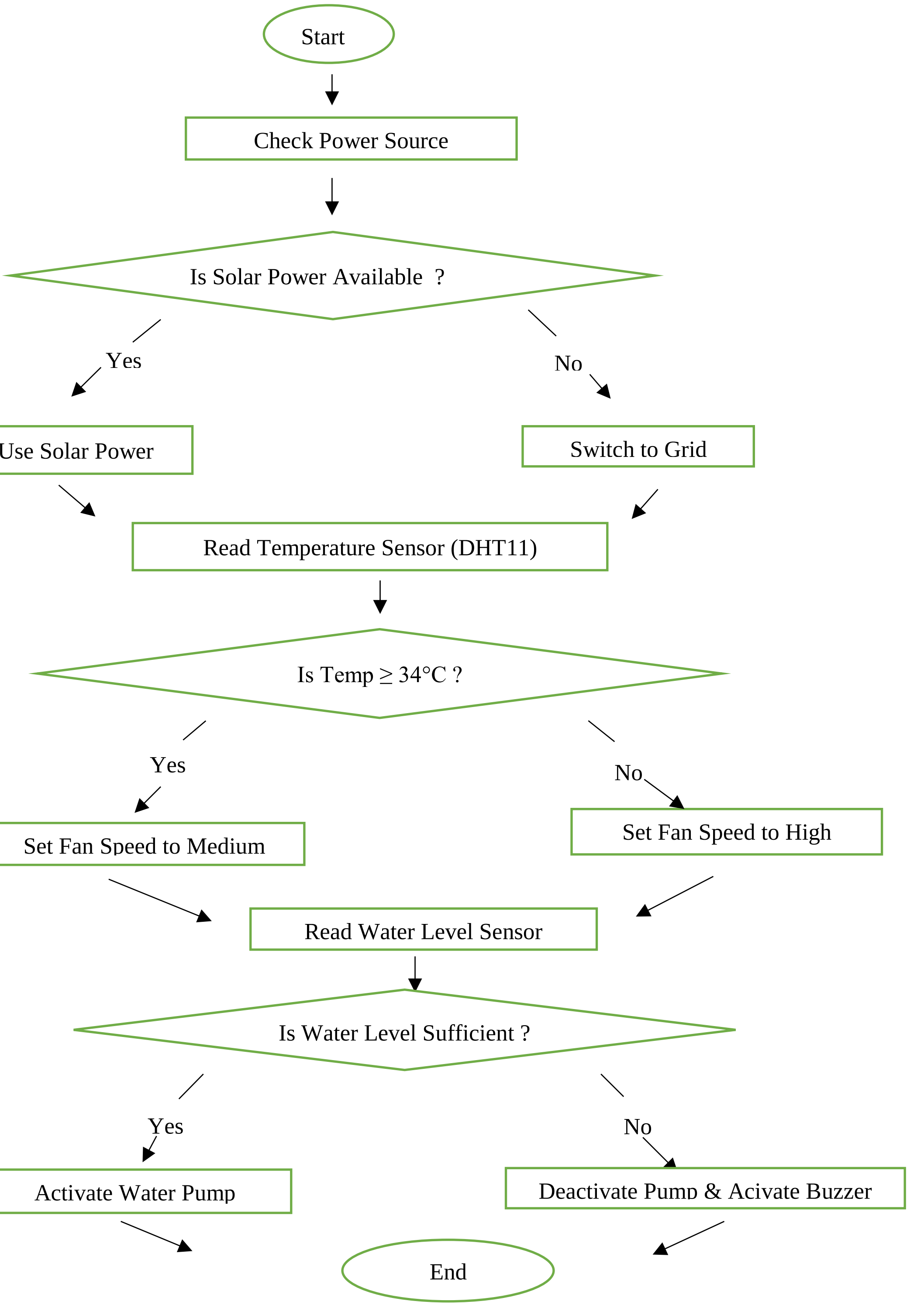

Fig.1 Flowchart of Smart Solar Air Cooler

4.2.1 Automatic Temperature Control : The system uses a DHT11 temperature sensor to monitor ambient temperature. Based on predetermined thresholds, the microcontroller controls fan speed via the BTS7960 motor driver. High temperatures trigger a higher fan speed, and low temperatures reduce fan speed, optimizing energy consumption.

4.2.2 Automatic Water Monitoring System : The water level in the tank is detected by a water level sensor. As soon as the water level falls below a predetermined level, the system activates a buzzer alarm to alert the user for refilling. Moreover, the pump motor is also automatically switched off during low water to prevent dry running.

4.2.3 Buzzer Alarm for Low Water Level : The buzzer system alerts users when water levels reach critically low levels. This provides continuous operation of cooling and protects against pump damage.

4.2.4 Dual Power Operation : The system is run predominantly by solar power. In the absence of solar power, it automatically switches to grid power using a relay-based switching circuit. The dual power supply ensures uninterrupted operation without human involvement**.**

5. System Implementation

5.1 Circuit Diagram

The Circuit diagram of the Smart Solar Air Cooler represents the overall system architecture and its key components. It illustrates the interconnections between various hardware units and their functional roles in the system.

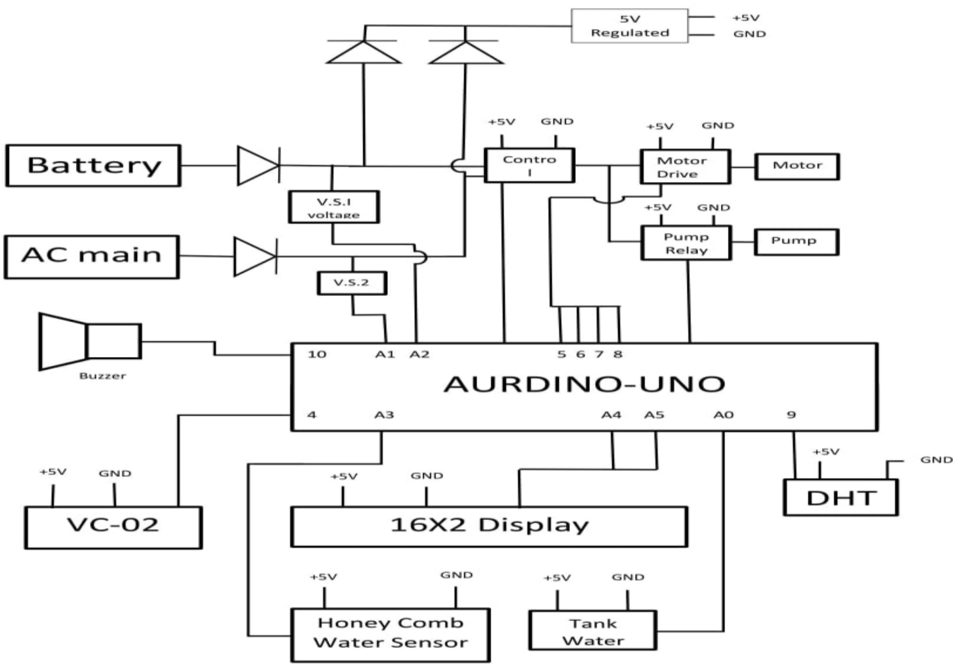

Fig.2 Circuit Diagram Of Smart Solar Air Cooler

5.1.2 Block Diagram

Overview of the System

The system primarily consists of the following major components:

- Power Supply System:
- The system operates on solar power using a 12V, 20W solar panel.
- A battery stores energy to provide backup power.
- If solar power is not available, then the system automatically switches to grid power via a relay-based switching mechanism.

1. Microcontroller Unit (MCU):

- The Arduino Uno microcontroller is the core of the system, which processes inputs from sensors and controls various components.
- It regulates motor speed, monitors water levels, and manages power switching.

2. Temperature Monitoring and Fan Control:

- A temperature sensor continuously measures ambient temperature.
- Based on temperature readings, the motor driver controls the speed of the cooler fan to optimize cooling efficiency**.**
- The temperature range is set to be :

Case 1 : $T = \leq 34$ °C (Motor run with medium speed)

Case 2 : T = ≥ 34 °C (Motor run with full speed)

3. Water Level Monitoring System:

- A water level sensor detects the amount of water in the tank.
- If water is low, then a buzzer module creates audible alerts .
- The DC water pump operates only when sufficient water is available, preventing dry running.

4. Automation and Safety Features:

- Automatic switching between solar and grid power for uninterrupted operation.
- Buzzer alarm for low water level to notify the user.

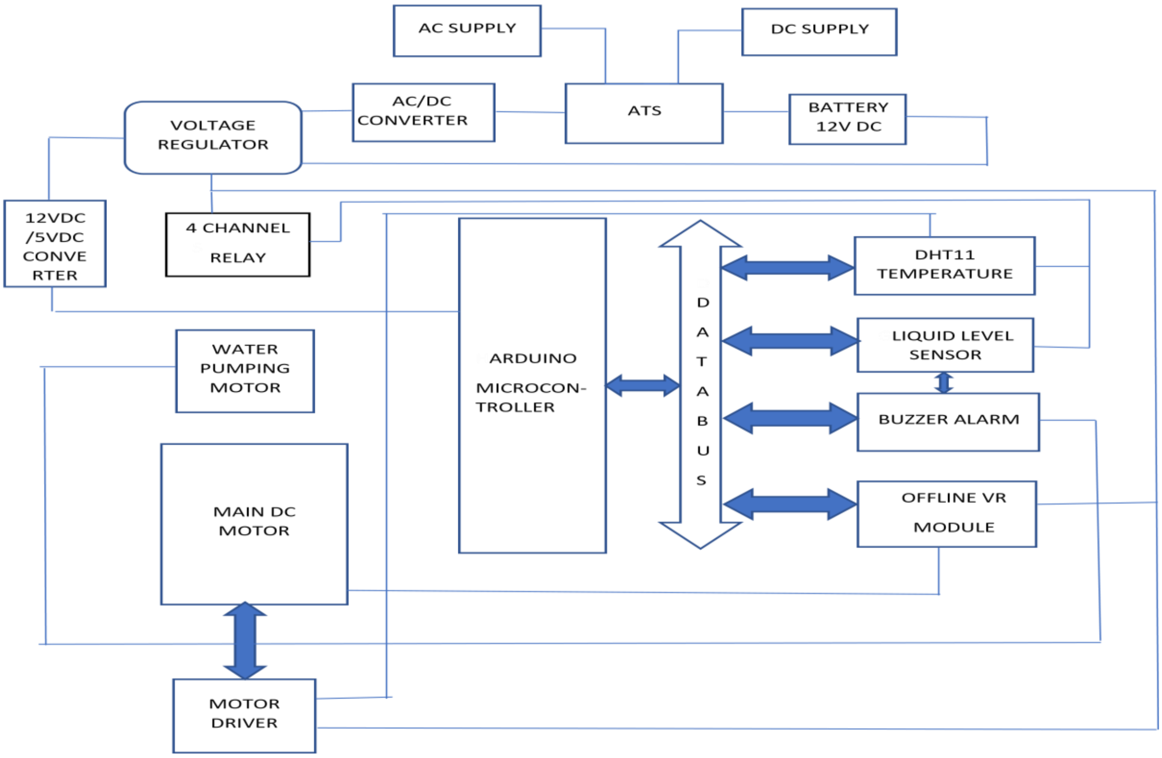

Fig.3 Block Diagram Of Smart Solar Air Cooler

5.2 Hardware Assembly

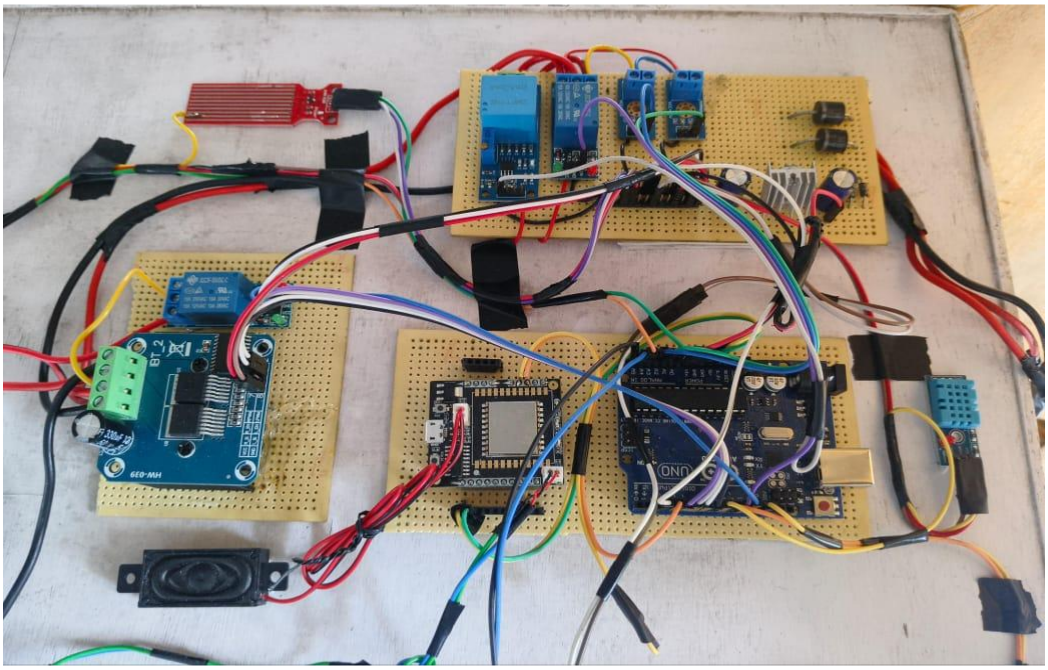

Fig.4 Physical Setup of Circuit Design

The hardware assembly of the Smart Solar Air Cooler involves by using various components to ensure efficient operation. The solar panel is connected to a battery, which serves as the primary power source. A relay-based switching circuit allows seamless transition between solar and grid power. The microcontroller such as Arduino Uno acts as the central control unit, receiving input from the temperature sensor to regulate the motor driver, which controls the cooler fan for automatic temperature adjustment. A water level sensor is installed in the tank to monitor water availability, and a buzzer module alerts users when the level drops below the threshold. The DC water pump is wired to operate only when sufficient water is detected, preventing dry running. The entire system is assembled on a sturdy frame, with proper insulation and wiring to ensure safety and reliability. This hardware integration enables an automated, energy-efficient cooling solution with minimal user intervention.

5.3 Final Assembly

The final assembly of the Smart Solar Air Cooler involves systematically connecting all the components to ensure proper functionality. The solar panel, battery, and power system are connected using appropriate wiring, ensuring smooth power flow. The microcontroller (Arduin Uno) is linked with the temperature sensor , motor driver, and water level sensor to enable automation. The cooler motor and water pump are wired to their respective control circuits, ensuring efficient cooling operation. A relay-based dual power switching system is integrated to alternate between solar and grid power. All components are arranged in a structured manner, ensuring ease of maintenance and minimizing wiring complexity. After completing the connections, the system undergoes multiple tests to verify stability, response time, and energy efficiency. This final step ensures that the smart cooler operates seamlessly with automated temperature and water level control.

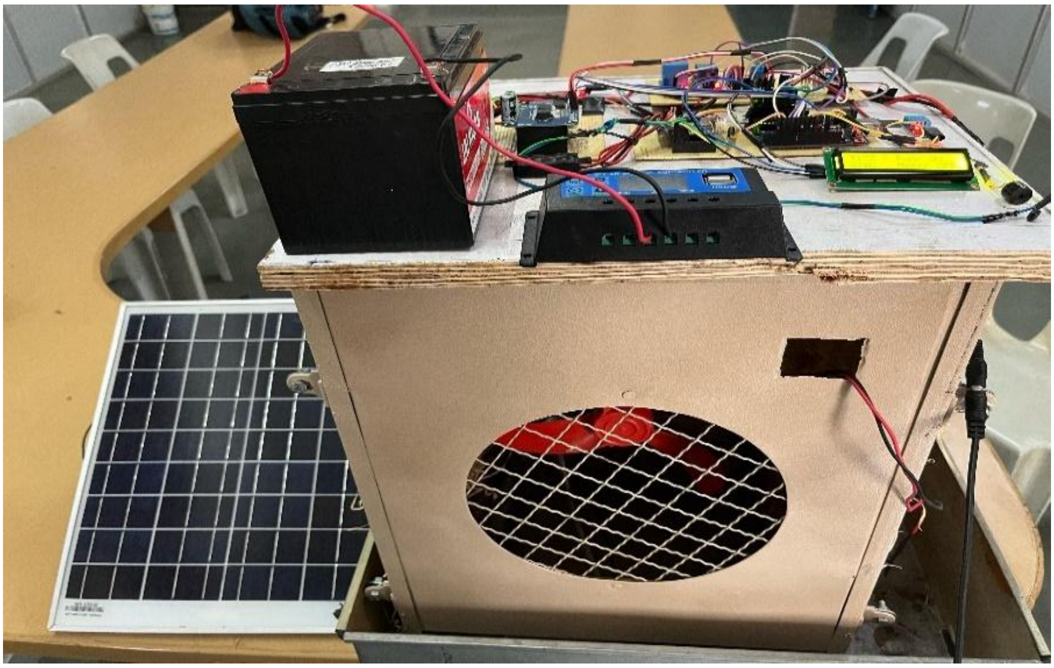

Fig. 5 Final Assembly of the system

6. Result And Performance Analysis

6.1 Power Consumption Analysis

The Smart Solar Air Cooler is designed to achieve optimum energy efficiency by regulating power based on ambient conditions. The power consumption of each component varies based on its operating state. The fan motor consumes more power at higher speeds, whereas the pump motor runs intermittently to maintain the water circulation at the desired level. Additionally, the use of a dual power supply system ensures the utilization of solar power as the primary power source, significantly reducing the consumption of grid power.

Table 1: Power Consumption Analysis

Component	Power Consumption
Cooler Motor	36 W
Water Pump Motor	12 W
Total Peak Load	48 W

For additional energy efficiency, the system also dynamically controls the motor speed and pump operation based on real-time humidity and temperature. The test results show that solar power alone can operate the cooler for extended periods of time at peak sunlight hours, and hence it is a viable alternative to conventional coolers that are solely dependent on electricity.

6.2 Response Time and Automation Performance

The effectiveness of an automatic cooling system is largely a factor of how it responds to changes in the environment. The Smart Solar Air Cooler is equipped with a temperature sensor that continuously monitors ambient conditions and modulates the cooling mechanism accordingly. The system's response time to the different temperature changes is negligible, and it ensures a stable and comfortable indoor climate.

Table 2: Response Time Analysis

Function	Response
Temperature adjustment	2-3 Second
Water level detection &Buzzer Activation	1 second
Power source Switching Delay	1-2 second

Similarly, the water level monitoring system also operates in real-time, triggering the buzzer alarm right away as soon as the water level drops below a critical level. The dual power operation mechanism also switches between solar and grid power seamlessly, without interrupting the cooling. The speedy response of the system minimizes manual intervention to the bare minimum, providing users with a hassle-free cooling experience.

6.3 Efficiency Comparison with Traditional Coolers

The Smart Solar Air Cooler was pitted against conventional air coolers to test its efficiency in terms of energy consumption, cooling efficiency, and sustainability. The smart cooler, in contrast to conventional air coolers that operate continuously at fixed power levels, responds dynamically to variations in temperature by modulating its operation, thereby reducing the overall energy consumption.

Table 3: Comparison of Traditional Air Cooler with Smart Air Solar

Parameter	Traditional Air Cooler	Smart Solar Air Cooler
Power Source	Grid Electricity	Solar & Grid
Temperature Regulation	Manual	Automatic
Water Monitoring	Manual	Automatic with Alarm
Power Consumption	High	Optimized
Sustainability	Low	High

In addition, the utilization of solar energy lowers operational costs significantly, making it a more sustainable option. Traditional coolers lack the automatic water monitoring system as well, which typically leads to dry pump operation and reduced efficiency. The proposed system removes these drawbacks by offering optimal water use and timely alert for refilling, which also increases its reliability and lifespan.

7. Conclusion

It is concluded that the Smart Solar Air Cooler is a more efficient and sustainable alternative to traditional air coolers. Unlike conventional coolers, it automates temperature control, reduces energy consumption, and operates on solar power, making it cost-effective and eco-friendly. The dual power operation ensures uninterrupted functionality, while the automatic water monitoring system prevents pump damage. This system is particularly beneficial for regions with high temperatures and unreliable electricity, offering a practical and smart cooling solution.

8. Future Scope

There is ample scope for the Smart Solar Air Cooler to be developed further in energy efficiency and automation. The addition of IoT-based remote monitoring can enable mobile app control of the system.

AI-driven cooling optimization can increase efficiency by learning temperature patterns and adjusting the fan speed. Solar panel capacity expansion and battery storage enhancements can enhance reliability, enabling off-grid applications.

Addition of new cooling materials and integration into smart home networks can also optimize performance. These future developments can expand the application range of the cooler in the residential, industrial, and commercial segments, enabling sustainable cooling systems.

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References

1. *Manish Nayak, Manjunath H N, Madhusudhan M ,"Performance Studies On Automated Solar Powered Air Cooler/ Air Heater" ,INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 9, ISSUE 01, JANUARY 2020.*
2. *Prof. S. V. Mate , Akshay H. Budhe , Harshal S. Nanaware 3, Sudarshan B. Khandare , Kulwantsingh S. Sharnagat , Dipak G. Shahare,"SOLAR OPERATED AIR COOLER",IJARIIE-ISSN(O)-2395-4396,Vol-10 Issue-3 2024.*
3. *Vijay Kumar Gupta, Himanshu Singh, Kunwar Utkarsh, Ankit Kumar, Abhinav Kumar Vishwakarma, Mohak Gupta, "Automatic Temperature Controlled Air Cooler: Design, Assembly and Testing", International Journal of Trend in Scientific Research and Development (IJTSRD) Volume: 3 | Issue: 3 | Mar-Apr 2019*
4. *Rushiprasad Watpade, "SOLAR POWERED AIR COOLER", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 09 Issue: 03 | Mar 2022.*
5. *Patil, Amit A., Bongarde, Uttam S., Dhavale, Atul J., and Joshi, Rahul R. "Study on Solar Powered Air Cooler." International Advanced Research Journal in Science, Engineering and Technology (IARJSET), Vol. 7, Issue 11, November 2020.*
6. *Kalyani, T., Arokya Anicia, S. A., and Ramakrishna, G. "Fabrication and Analysis of Solar Air Cooler." International Journal of Management, Technology and Engineering, Vol. 8, Issue 10, October 2018.*
7. *Mekonen, Tadelle N., Delele, Mulugeta A., and Molla, Sissay W. "Development and Testing of Solar Powered Evaporative Air-Cooling System with an Improved Performance." Cogent Engineering, Vol. 10, Issue 1, 2023.*
8. *Khobragade, Suhas, Sonwane, Sweeti, Ate, Aditya, and Parikh, R. H. "Design and Fabrication of Smart Cooler." International Journal for Scientific Research & Development, Vol. 4, Issue 3, March 2018.*
9. *Pusadkar, Nakul, Duragkar, Swarup, Sakharkar, Kajal, and Kawadkar, D. B. "The Electronic Aspects of Smart Cooler." International Journal for Scientific Research & Development, Vol. 4, Issue 3, March 2018.*