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Research Article

IOT BASED SMART COOLER WITH ADVANCED FEATURES

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Abstract

This paper presents a smart solar cooling system integrated with the Internet of Things (IoT) for enhanced control and efficiency. The system consists of a solar-powered absorption cooling unit connected to an IoT platform, allowing for remote monitoring and management. Sensors within the platform collect real-time data on temperature, humidity, and solar radiation, optimizing the system's performance. Designed for high-temperature regions with limited electricity access, such as rural and remote areas, the system offers an energy-efficient and cost-effective cooling solution. The study's findings indicate that the smart solar cooling system effectively provides cooling, while IoT integration enables real-time performance monitoring and optimization, enhancing overall efficiency.

Keywords: Smart, solar, cooling, internet of things,challenges, applications, energy efficiency, temperature control, renewable energy.

INTRODUCTION

Solar cooling systems have emerged as an environmentally friendly and efficient solution for cooling in hot climates. However, their high energy consumption raises concerns about sustainability. To overcome this challenge, integrating the Internet of Things (IoT) with solar cooling systems has been proposed to enhance energy management and efficiency. An IoT-enabled solar cooling system allows for remote monitoring and control, enabling real-time adjustments to optimize energy consumption. Additionally, these systems can incorporate sensors and intelligent algorithms to predict cooling demands and adjust operations accordingly.

This paper introduces a smart solar cooling system controlled by IoT. The proposed system consists of a solar cooling unit, a battery storage system, and an IoT-based control mechanism. The cooling unit is powered by photovoltaic panels, which generate electricity to drive the system. Excess energy is stored in the battery bank, ensuring continuous operation during periods of low sunlight. The IoT-based control system enables remote access, real-time monitoring, and the implementation of intelligent algorithms for performance optimization.

The structure of this paper is as follows:

1. Section II provides an overview of IoT and its applications in energy management.
2. Section III discusses the design and implementation of the proposed smart solar cooling system.
3. Section IV presents experimental results and performance evaluation.
4. Section V concludes the study and outlines future research directions.

Smart solar cooling systems represent a significant technological advancement in renewable energy, combining sustainable energy sources with cooling technology for efficient climate control. The integration of IoT enhances these systems by introducing intelligence, allowing for remote monitoring, control, and optimization.

This paper also presents a comprehensive review of IoT-controlled smart solar cooling systems. The review aims to provide insights into the latest advancements, existing challenges, and potential future research directions in this field. The key sections of this review include:

Introduction – The importance of smart solar cooling systems in sustainable energy solutions. IoT and Its Role in Smart Solar Cooling Systems – An overview of how IoT technology enhances solar cooling.

Key Components – A discussion of essential elements such as solar collectors, absorption chillers, and thermal energy storage systems.

Control Strategies – An analysis of optimization techniques, including rule-based control, model predictive control, and artificial intelligence-driven control.

Challenges – Addressing key barriers such as high initial costs, lack of standardization, and performance limitations under varying weather conditions.Future Research Directions – Exploring advancements like nanotechnology, hybrid energy integration, and the development of more sophisticated control algorithms.This review provides an in-depth analysis of the state-of-the-art in IoT-controlled smart solar cooling systems. By integrating renewable energy with IoT technology, these systems have the potential to transform cooling solutions and contribute to a more sustainable future. Through this discussion, we aim to inspire further research and innovation in this rapidly evolving field.

1. PROPOSED SOLUTION

To connect to the Internet of Things and manage WiFi-based controller and timer features, use a NodeMCU controller board. The DC fan is powered by a 12V battery and operates as a 12V DC pump and fan. The battery is charged by a solar panel. Fans and pumps can also be run using a 230V AC to 12V DC adapter when the battery voltage is low. The IoT accesses the device using its IP address, in this case nodemcu. The Nodemcu will connect to your home WiFi network as soon as the switch is flipped. And you can use your laptop or smartphone within this WiFi network to control the cooler's operation (Ganorkar R. A. et al., 2014). The NodeMCU is the main microcomputer that connects to the Internet of Things, and as can be seen in the figure, it controls the relay to turn the cooler on and off. The controller's built-in timer controls when the pump is turned on (Rahul Mishra et al., 2013). The system is powered by a 12V battery that is charged by a solar panel.

2. OBJECTIVES

The primary objectives of the system are as follows:

- **Energy-Efficient Air Cooler:** The first goal is to develop a low-power air cooler that operates efficiently while consuming minimal energy. This helps reduce electricity costs and enhances the system’s sustainability.
- **Wireless IoT-Based Control:** The second objective is to design an air cooler that supports wireless operation through IoT-based switching. By leveraging Internet of Things (IoT) technology, the system enables seamless data exchange and remote communication between devices, providing greater convenience and flexibility in control.
- **Solar-Powered Operation:** The third goal is to create an air cooler powered by solar energy. The system will utilize solar panels and a 12V power source to ensure eco-friendly and energy-efficient performance.

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3. BLOCK DIAGRAM

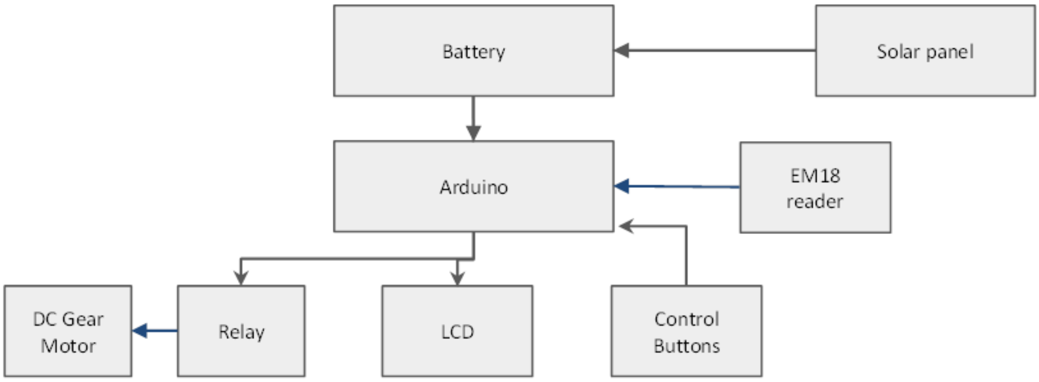

Fig. 1 :- Block Diagram

4. HARDWARE USE

- *Aurdino*
- *Relay*
- *Solar panel*
- *Battery*

A. ARDUINO

Fig. 2 :- Arduino

Arduino is an open-source electronics platform designed for ease of use, combining both hardware and software. It features a programmable microcontroller capable of sensing and controlling objects in the physical world.

Arduino boards can read various inputs—such as light detected by a sensor, the press of a button, or even a Twitter message—and convert them into outputs, like activating a motor, illuminating an LED, or publishing data online. They are widely used for building interactive projects, taking inputs from different sensors or switches, and controlling components such as lights and motors.

Arduino boards come in different sizes and configurations, each tailored for specific applications:

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- **Arduino Uno:** One of the most popular boards, featuring a microcontroller, digital and analog I/O pins, a USB connection, and a power jack.
- **Arduino Mega:** Similar to the Uno but with a higher number of digital and analog I/O pins, making it ideal for larger projects requiring more connections.
- **Arduino Nano:** A compact version of the Uno, designed for space-constrained projects while maintaining similar functionality.
- **Arduino Due:** Powered by a more advanced microcontroller than the Uno, suitable for projects that require greater processing power.
- **Arduino Leonardo:** Similar to the Uno but with built-in USB communication, simplifying interaction with computers.

Alongside its hardware, Arduino provides a software development environment that enables users to write, compile, and upload code to their boards. The **Arduino IDE (Integrated Development Environment)** is an intuitive yet powerful tool that supports programming in the Arduino language, which is based on Wiring.

Overall, Arduino is a highly versatile platform embraced by hobbyists, students, and professionals for a wide range of applications—from simple LED blinking projects to sophisticated robotics. Its affordability, flexibility, and ease of use make it one of the most popular choices for electronics prototyping and experimentation.

B. 12 VOLT DC SINGLE POLE DOUBLE THROW (SPDT) RELAY

Fig. 3:- Relay

A relay is an electrically operated switch that allows circuits to be controlled using a low-power signal. While many relays function through an electromagnet to mechanically toggle a switch, other types, such as solid-state relays, operate using different principles. Relays are particularly useful when electrical isolation between the control and controlled circuits is required or when a single signal needs to manage multiple circuits.

A **12V DC Single Pole Double Throw (SPDT) Relay** is an electromechanical switch commonly used in various electronic and electrical applications for circuit control.

C. LCD

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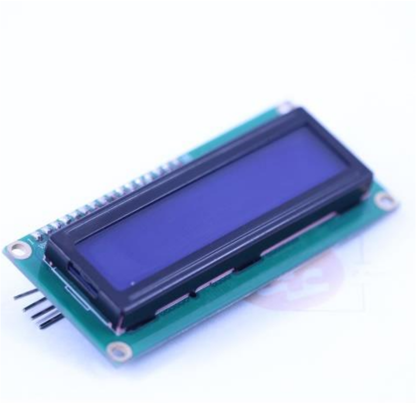

Fig.4 :- LCD

LCD stands for Liquid Crystal Display, a type of electronic display module widely used in various applications, including mobile phones, calculators, computers, and television screens. These displays are often preferred over multi-segment LEDs and seven-segment displays due to their versatility.
The key advantages of LCD modules include affordability, ease of programming, support for animations, and the ability to display custom characters and special symbols without limitations.
To optimize the use of I/O ports on an Arduino board, the IIC/I2C interface was introduced.

Specifications:

- Display: 16 characters wide, 2 rows
- Backlight: Single LED, easily dimmable with a resistor
- Supply Voltage: 5V

D. Solar Panel

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Fig. 5:- Solar Panel

Solar power is harnessed by converting sunlight into usable energy. The sun generates two types of energy for practical use: **electricity and heat**. Both forms are captured using solar panels, which vary in size from small residential rooftop installations to large-scale **solar farms** spanning vast areas of land.

Solar panels are typically made from **silicon or other semiconductor materials** and are housed within a metal frame with a glass covering. When exposed to sunlight, these materials absorb **photons** (tiny energy packets), releasing electrons and generating an electric charge.

This **photovoltaic (PV) charge** produces **direct current (DC) electricity**, which is collected through wiring in the solar panels. An **inverter** then converts DC electricity into **alternating current (AC)**, the standard type of electricity used in household appliances and wall outlets.

How Solar Panels Work:

A **solar panel** is a device that transforms sunlight into electricity using **photovoltaic (PV) cells**, typically made of silicon. When sunlight strikes these cells, it creates an electric field that causes **electrons to move**, producing an electric current—a process known as the **photovoltaic effect**.

Advantages of Solar Panels:

- **Renewable & Clean Energy:** Solar power is a sustainable and environmentally friendly energy source.
- **Reduced Greenhouse Gas Emissions:** Solar panels help lower carbon footprints.
- **Lower Electricity Bills:** Generating electricity from solar panels reduces reliance on grid power.

Disadvantages of Solar Panels:

- **Sunlight Dependency:** Efficiency varies with sunlight availability and intensity.
- **Maintenance Needs:** Panels require periodic cleaning for optimal performance.
- **High Initial Cost:** Installation costs can be significant, though long-term savings often outweigh them.

Solar panels are widely used in **residential, commercial, and industrial** applications, as well as in space, often in combination with **batteries** for energy storage.

E. BATTERY

Fig.6:- Battery

Lithium-ion batteries store energy by transferring **lithium ions** between the **anode** and **cathode**. During **discharge**, the anode releases lithium ions to the cathode, generating a flow of electrons. When **charging**, the process reverses, with the cathode releasing lithium ions back to the anode.

Charging lithium-ion batteries requires a **voltage-limiting charger**, which operates similarly to a lead-acid charger but with some key differences. Lithium-ion batteries have a **higher voltage per cell**, **stricter voltage tolerances**, and do not support **trickle or float charging** when fully charged.

F. EM-18 RFID

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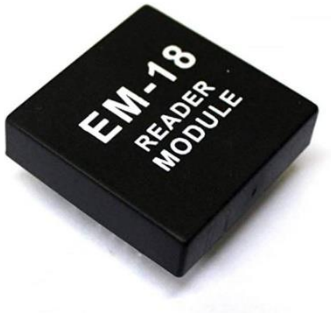

Fig. 7EM-18 RFID

The **EM-18 RFID reader module** operates using **radio waves** to detect and identify **RFID tags**.

How It Works:

- **Frequency Emission:** The EM-18 reader transmits a **125 kHz** frequency through its internal coils.
- **Tag Activation:** When a **125 kHz passive RFID tag** enters the reader's frequency field, it becomes energized.
- **Data Transmission:** The tag communicates its unique ID to the reader, which then sends this data to a **microcontroller or PC** via **UART communication** or **Wiegand format**.
- **Data Reception:** The microcontroller or PC processes and reads the transmitted data.

Specifications of the EM-18 RFID Reader Module:

- **Operating Voltage:** 4.5–5.5 V
- **Dimensions:** 32 mm × 32 mm × 8 mm
- **Reading Distance:** Up to 10 cm
- **Data Baud Rate:** 9600 bps
- **Data Bit:** 8 bits
- **Parity Check:** None

Applications:

The EM-18 RFID reader is widely used in **smart access control systems, card-based entry systems, and attendance tracking systems**.

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IMPLIMENTATION

In the proposed home automation system, various sensors will be strategically placed to continuously collect real-time data and transmit it to a central microprocessor. This system includes multiple sensing devices that detect, communicate, and gather data from household appliances. These sensors operate in real time, sending data to the microprocessor, which, using runtime function code, automatically controls devices such as fans, lamps, gas leak detectors, air conditioners, and other appliances. Additionally, it monitors distances, sends periodic notifications, and stores collected information in the cloud. The actual data processing occurs in the cloud, allowing end users to access and analyze results for informed decision-making. A Relay tool ensures the compliance of electrical devices connected to the home automation system's power supply. Sensor devices are integrated through various ports of the NodeMCU.

CONCLUSION

An inventive and environmentally responsible cooling solution that makes use of smart control technology and renewable energy sources is the Internet of Things (IoT)-controlled solar cooling system with smart features. The system is incredibly convenient and effective because it is made to run on solar power and can be remotely controlled online. The study's findings demonstrate that the system can keep an interior space at a comfortable temperature while using very little energy. The system is very flexible to various environments and user preferences thanks to its clever features, like the ability to remotely change the cooling settings.

Furthermore, the system's wireless power transfer technology does away with the necessity for wired connections, lowering the possibility of electrical hazards and simplifying installation and maintenance. As a result, the Internet of Things-controlled solar cooling system with intelligent features provides a practical and sustainable indoor cooling solution that can drastically lower energy use and its negative effects on the environment. A more sustainable and greener future may result from the widespread adoption of such systems brought about by additional research and development in this field.

AUTHOR(S) CONTRIBUTION

The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

CONFLICTS OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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