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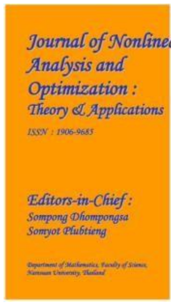

SMART TEMPERATURE DEPENDENT COOLING OF SOLAR PANEL USING ARDUINO

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Abstract:
This paper presents an innovative solution aimed at boosting the efficiency and performance of solar panels by harnessing the Arduino microcontroller platform alongside temperature sensors and CPU fans. Solar panels play a crucial role in our shift towards sustainable energy sources, yet their effectiveness can be hindered by temperature fluctuations. To tackle this issue, we've devised a smart cooling system sensitive to temperature changes, utilizing Arduino's capabilities to optimize solar panel functionality. By strategically placing temperature sensors on the panel's surface, we continuously monitor its temperature. When temperatures exceed the optimal range, the Arduino control unit activates CPU fans to effectively dissipate excess heat. Through real-time data analysis and decision-making algorithms, we ensure precise and efficient cooling control, maintaining the solar panel within its optimal operating temperature range. Through extensive experimentation and analysis, we illustrate the significant potential of this Arduino-driven system to enhance solar panel efficiency, leading to improved energy output and a more sustainable approach to solar energy generation. This paper paves the way for further advancements in the practicality and environmental impact of solar power, supporting its role in our renewable energy future.
Keywords: Arduino, Solar panel, Battery, Temperature and Sensors.

1.Introduction

The developments, difficulties, and uses of solar-powered cooling and air conditioning systems in buildings are covered in this paper [1], "A review on solar-powered cooling and air conditioning systems for building applications," which was published in Energy Reports, Volume 8, 2022, Pages 2888-2907. Qudama Al-Yasiri, Márta Szabó, and Müslüm Arıcı explore how solar energy can be used to power air conditioning and cooling systems, offering insights into environmentally friendly and energy-efficient construction solutions. A study by F.A. Mohamed Mallahi, M. Shaker, and Y.O. Mohamed titled "Integration of Solar Energy Supply on Smart Distribution Board Based on IoT System" [2] was published in Designs in 2022, Volume 6, Issue 6. It examines how IoT systems can be used to integrate solar energy supply into smart distribution boards. The writers talk about how this integration might improve sustainability and energy efficiency in different applications. Authors Mohammed M, Riad K, and Alqahtani N published "Design of a Smart IoT-Based Control System for Remotely Managing Cold Storage Facilities" in Sensors (Basel) in June 2022, Volume 22, Issue 13. The authors offer an intelligent Internet of Things (IoT) control system designed to remotely operate cold storage facilities. The report offers insightful information about IoT technology's use in cold storage management. The design and development of an IoT-based solar air cooler with the goal of promoting sustainable living practices is presented in this paper [4], "Design of IoT-based Solar Air Cooler for Sustainable Living," by K. R. Keshav and A. Ghosal, which was published in the IOP Conference Series: Materials Science and Engineering, Volume 1091, Issue 1. The writers most likely talk on how IoT technology can be used to improve the performance and efficiency of solar-powered air conditioning systems, which advances the development of environmentally friendly cooling options. Authors A. Singh, A. Singh, and B. Singh presented their paper "Solar Powered Internet of Things (IoT) Based Smart Energy Management System" [5] at the 2019 IEEE International Conference on Power, Intelligent Computing and Systems (ICPICS). The creation of a smart energy management system that integrates Internet of Things (IoT) technology and is fueled by solar energy is probably covered by the writers. With the use of clever monitoring and control methods, this system is intended to maximise energy consumption and boost effectiveness. The development of a smart air cooler that is integrated with Internet of Things (IoT) technology and powered by solar energy is the topic of this paper [6], "Development of Smart Solar-Powered Air Cooler Based on the Internet of Things," by S.P. Hadiwardoyo, M.M. Mustaqbal, and D. Alfani, which was published in 2020 in the Journal of Physics: Conference Series, Volume 1529. It is probable that the writers explore the blueprint, execution, and possible uses of this system, emphasising its sustainable and energy-efficient attributes. An Internet of Things (IoT)-enabled solar air cooler system's development and implementation are probably covered in this paper [7], "IoT-Based Solar Air Cooler," by R.M. Mhaske and A.B. Dhongade, which was presented at the 2019 6th International Conference on Computing for Sustainable Global Development (INDIACom). This system's integration of solar power with IoT technologies is probably intended to offer sustainable and energy-efficient cooling solutions. The development and application of a solar cooler system integrated with Internet of Things (IoT) technology—specifically, using the DHT11 sensor for temperature and humidity monitoring—are likely explored in this paper [8], "An IoT based Solar Cooler using DHT11 Sensor," by S. Singh and S. Jain, presented at the 2021 IEEE International Conference on Computing, Communication, and Security (ICCCS). The purpose of this integration is to make the solar cooling system more functional and efficient. The 2017 International Conference on Communication Technologies (ComTech) in Lahore featured a presentation by M. Mazhar Rathore, M. Rehan Raza, M. H. Ahmed, and I. Ahmed titled "Solar energy harvesting in Internet of Things (IoT)" [9]. The use of solar energy harvesting techniques in Internet of Things systems is probably covered by the writers, who also examine the advantages, difficulties, and possible uses of combining solar power with IoT networks and devices.

2. Proposed Method

The method proposed for intelligent temperature-regulated cooling of solar panels integrates cuttingedge components and sensors, with a primary emphasis on an Arduino-based control system. By employing highly accurate temperature sensors such as digital thermistors or DS18B20 sensors strategically positioned across the solar panel surface, the system continuously monitors temperature fluctuations. An Arduino microcontroller acts as the central hub, processing real-time data and employing sophisticated algorithms to dynamically regulate cooling. When the monitored temperature exceeds predetermined thresholds, efficient CPU fans or heat exchangers are activated to dissipate surplus heat, thereby optimizing panel performance. This approach ensures precise and adaptable temperature management, leveraging real-time data analysis and responsiveness to environmental variables, ultimately enhancing solar panel efficiency and energy output, while promoting a sustainable and cleaner energy landscape.

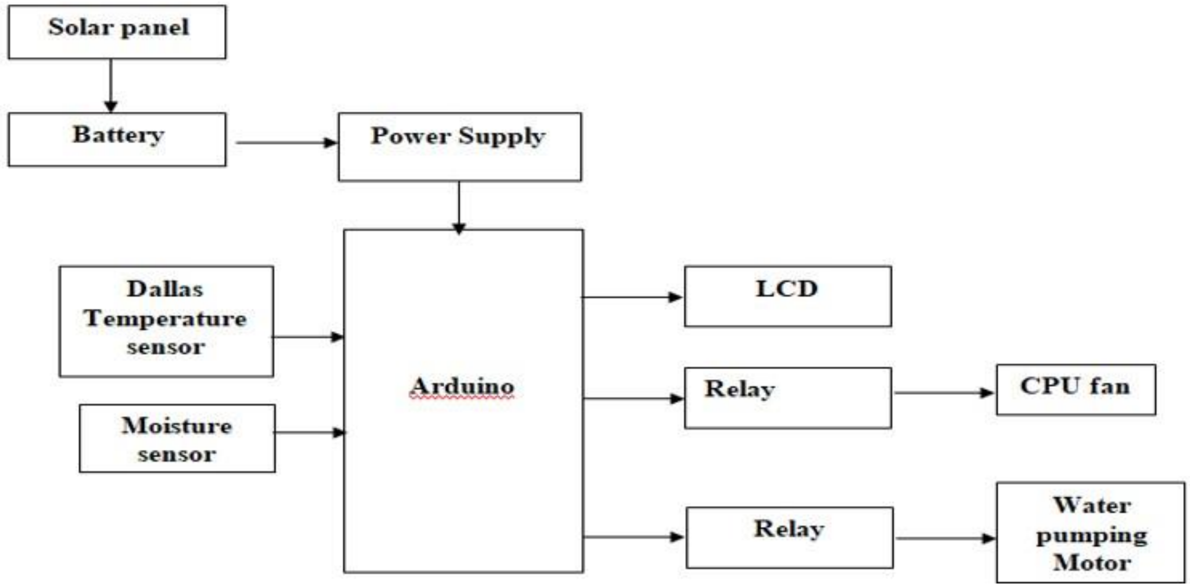

Figure: 1 Block diagram of the project

2.1 Hardware description

2.1.1 Introduction to Aurdino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It consists of a microcontroller that can be programmed to sense and control objects in the physical world. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. They are used for a variety of purposes, including creating interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino boards come in various shapes and sizes, each with its own set of features and capabilities. Some of the most popular Arduino boards include:

Arduino Uno: The Uno is one of the most popular Arduino boards. It features a microcontroller, digital and analog input/output pins, USB connection, and a power jack.

Arduino Mega: The Mega is similar to the Uno but with more digital and analog input/output pins, making it suitable for larger projects that require more I/O.

Arduino Nano: The Nano is a compact board with similar features to the Uno but in a smaller form factor, making it ideal for projects with space constraints.

Arduino Due: The Due is based on a more powerful microcontroller than the Uno, making it suitable for projects that require more processing power.

Arduino Leonardo: The Leonardo is similar to the Uno but with built-in USB communication, making it easier to interface with computers.

In addition to the hardware, Arduino also provides a software development environment that allows users to write, compile, and upload code to their Arduino boards. The Arduino IDE (Integrated Development Environment) is a simple yet powerful tool that is used to write code in the Arduino programming language, which is based on Wiring, and upload it to the board.

Overall, Arduino is a versatile platform that is used by hobbyists, students, and professionals alike to create a wide range of projects, from simple blinking LED lights to complex robotics projects. Its ease of use, coupled with its affordability and flexibility, has made it one of the most popular platforms for electronics prototyping and experimentation.

2.1.2 Features of the Arduino

Arduino boards come with a variety of features that make them suitable for a wide range of projects. Some of the key features of Arduino boards include:

Microcontroller: Arduino boards are equipped with a microcontroller, which is the brain of the board. The microcontroller is responsible for executing the program and controlling the inputs and outputs of the board.
Digital Input/Output Pins: Arduino boards come with a number of digital input/output (I/O) pins that can be used to connect the board to external devices such as sensors, LEDs, and motors. These pins can be configured as either inputs or outputs, allowing the board to read data from sensors or control external devices.
Analog Input Pins: In addition to digital I/O pins, Arduino boards also feature analog input pins that can be used to read analog signals from sensors. These pins allow the board to measure variables such as light intensity, temperature, and sound level.
PWM (Pulse Width Modulation) Pins: Some Arduino boards come with PWM pins, which can be used to generate analog-like signals. PWM is often used to control the brightness of LEDs or the speed of motors.
USB Connection: Arduino boards feature a USB connection, which allows them to be connected to a computer for programming and serial communication. The USB connection also provides power to the board, eliminating the need for an external power source.
Power Jack: Arduino boards come with a power jack that can be used to connect an external power source, such as a battery or a wall adapter. This allows the board to be powered independently of the USB connection.
Reset Button: Arduino boards feature a reset button that can be used to restart the board and re-run the program.
Integrated Development Environment (IDE): Arduino boards are programmed using the Arduino IDE, which provides a simple and intuitive interface for writing, compiling, and uploading code to the board.
Open-Source: Arduino is an open-source platform, which means that the hardware designs and software libraries are freely available for anyone to use and modify. This has led to a large community of Arduino users who share their projects and collaborate on new ideas.
Overall, Arduino boards are versatile and easy-to-use platforms that are ideal for beginners and experienced makers alike. Their combination of features, affordability, and flexibility make them a popular choice for a wide range of projects, from simple blinking LED lights to complex robotics applications.

2.1.3 Arduino Pinout

• Arduino Uno is based on an AVR microcontroller called Atmega328. This controller comes with 2KB SRAM, 32KB of flash memory, and 1KB of EEPROM. The Arduino Board comes with 14 digital pins and 6 analog pins. ON-chip ADC is used to sample these pins. A 16 MHz frequency crystal oscillator is equipped on the board. The following figure shows the pinout of the Arduino Uno Board

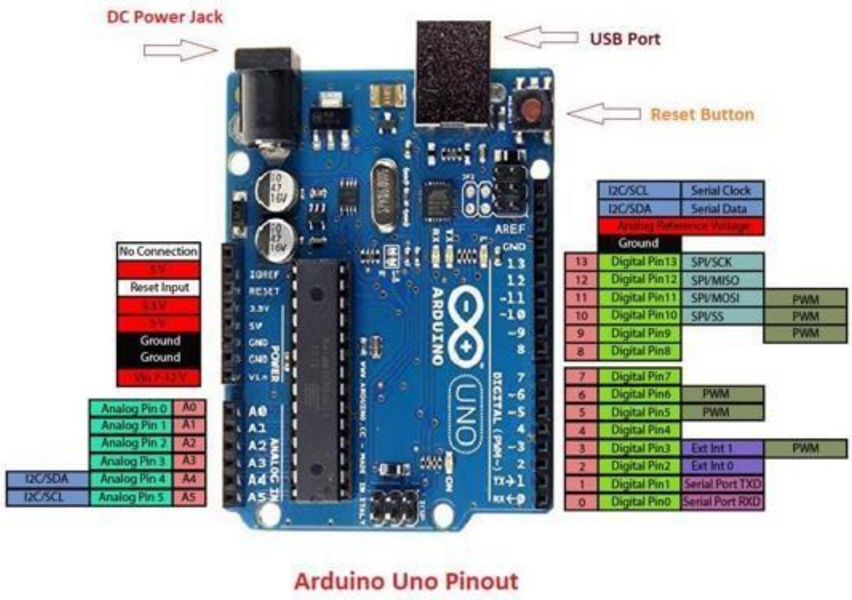

Figure.2. Arduino UNO Pinout diagram

3. Results and Discussion

The paper's implementation involved programming an Arduino UNO microcontroller using Embedded C language. The code was designed with four conditions based on a temperature threshold of 32°C. This code was then uploaded to the microcontroller and integrated with other hardware components.

3.1 Code for Arduino UNO

```
#include <OneWire.h>
#include <DallasTemperature.h>
#include<LiquidCrystal.h>
// Data wire is conntec to the Arduino digital pin 4
LiquidCrystal lcd(A5,A4,A3,A2,A1,A0);
#define ONE_WIRE_BUS 4
int temp; int
pump=2; int
fan=3; int
moist=5; int
moist_value;
// Setup a oneWire instance to communicate with any OneWire devices
OneWire oneWire(ONE_WIRE_BUS);
// Pass our oneWire reference to Dallas Temperature sensor
DallasTemperature sensors(&oneWire); void
setup(void)
{
  // Start serial communication for debugging purposes   Serial.begin(9600);
  lcd.begin(16,2);
  pinMode(pump,OUTPUT);
pinMode(fan,OUTPUT);
pinMode(moist,INPUT);
digitalWrite(pump,HIGH);
digitalWrite(fan,HIGH);   // Start up
the library   sensors.begin();
lcd.clear();   lcd.setCursor(0,0);
```

```
lcd.print("SOLAR PANEL TEMP.");
lcd.setCursor(0,1);
lcd.print("COOLING SYS.");
delay(3000);
}
void loop(void){
  // Call sensors.requestTemperatures() to issue a global temperature and Requests to all devices on the
bus          sensors.requestTemperatures();          Serial.print("Celsius    temperature:    ");
temp=sensors.getTempCByIndex(0);
  // Why "byIndex"? You can have more than one IC on the same bus. 0 refers to the first IC on the
wire
  Serial.println(temp);
delay(500);
  moist_value=digitalRead(moist);
  delay(500);   lcd.clear();
lcd.setCursor(0,0);
lcd.print("TEMPERATURE: ");
  lcd.setCursor(0,1);
  lcd.print(temp);
if(temp<32&&moist_value==0)
  {
    digitalWrite(fan,HIGH);
    digitalWrite(pump,HIGH);
lcd.clear();   lcd.setCursor(0,0);
lcd.print("FAN OFF");
lcd.setCursor(0,1);
  lcd.print("PUMP OFF");
  }
  else if(temp<32&&moist_value==1)
  {
    digitalWrite(fan,HIGH);
    digitalWrite(pump,HIGH);
lcd.clear();   lcd.setCursor(0,0);
lcd.print("FAN OFF");
lcd.setCursor(0,1);
  lcd.print("PUMP OFF");
  }
  else if(temp>=32&&moist_value==0)
  {
    digitalWrite(pump,HIGH);
    digitalWrite(fan,LOW);
lcd.clear();   lcd.setCursor(0,0);
lcd.print("FAN ON");
lcd.setCursor(0,1);
  lcd.print("PUMP OFF");
  }
  else if(temp>=32&&moist_value==1)
  {
```

```
   digitalWrite(pump,LOW);
   digitalWrite(fan,LOW);
lcd.clear();   lcd.setCursor(0,0);
lcd.print("FAN ON");
lcd.setCursor(0,1);
  lcd.print("PUMP ON");
  }
}
```

3.2 Implementation Results

IOT based solar panel cooling mechanism has been implemented and the working model is shown below.

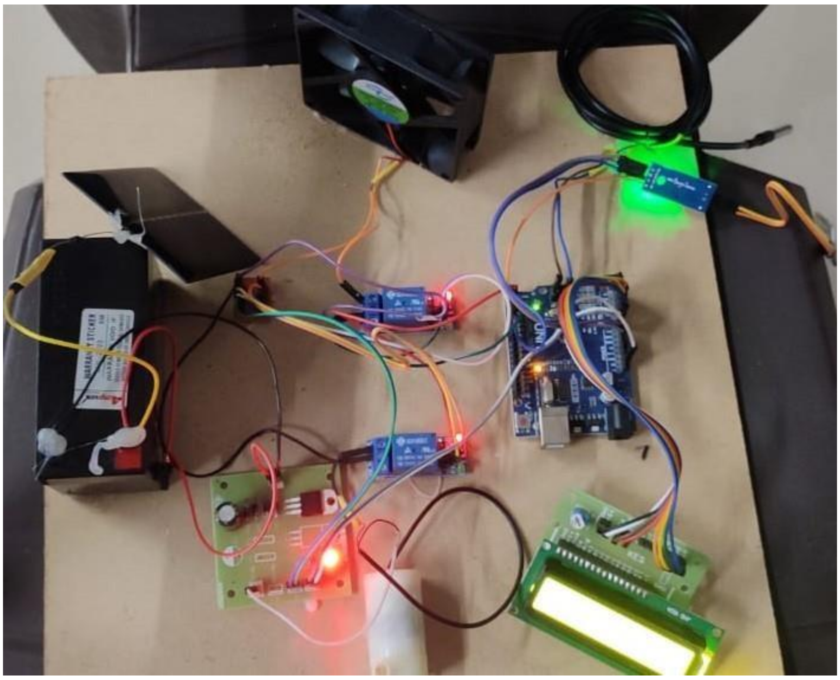

Figure.3.Working model of the project

The circuit is powered with a 12V battery. Arduino Uno microcontroller which is the main component of this work is programmed using embedded C language. Solar panel temperature is continuously measured with a temperature sensor and if it exceeds 32ºC, then Fan will be automatically ON. Similarly, if the moisture sensor indicates 1 which means the moisture level goes below the threshold, then automatically DC motor will turn ON and water pumping starts.

Water will be sprayed ON till the moisture sensor indicates 0, that means moisture level is again within the threshold, then automatically DC motor turns OFF, water pumping will stop. The following figures show the operating setup for different conditions.

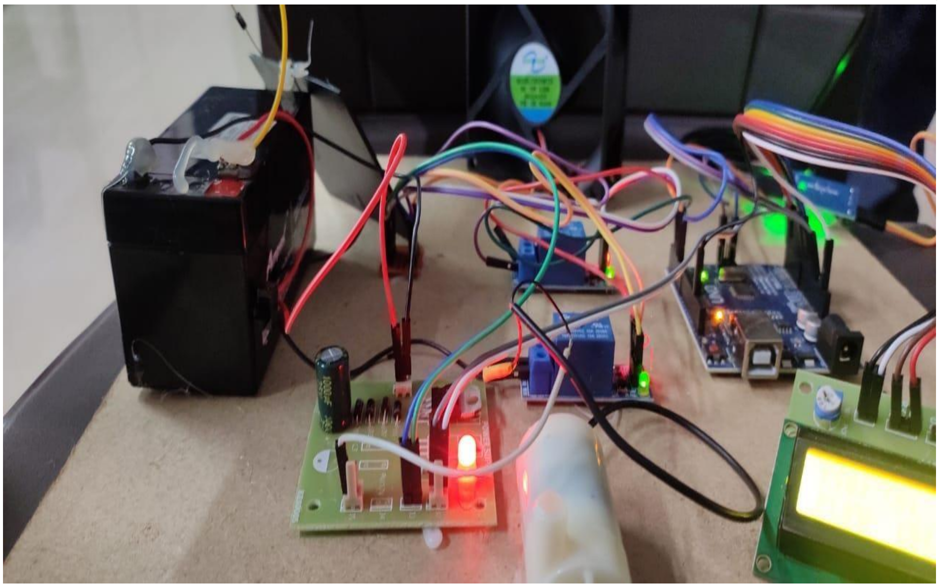

Figure.4. Working condition of temperature exceeds threshold case

Figure.5. Display of temperature exceeds threshold case

Figure.6. Display of Fan and Pump ON condition.

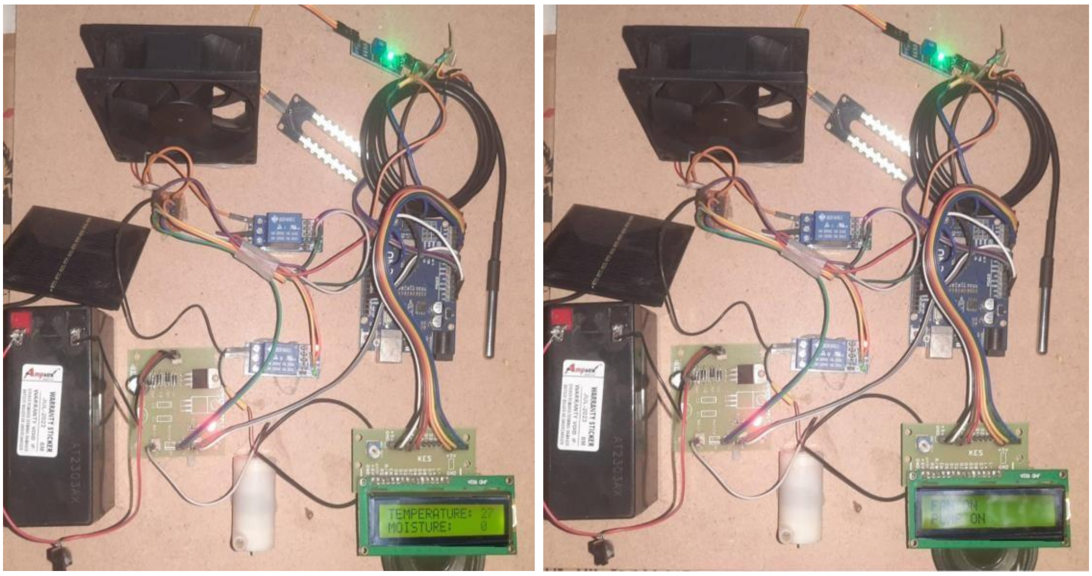

Figure.7. Display of temperature and moisture

4. Conclusion

The implementation of a smart temperature-dependent cooling system for solar panels using Arduino presents a promising solution to enhance the efficiency and performance of solar energy systems. By actively monitoring and regulating panel temperatures, this project effectively tackles challenges associated with excessive heat buildup, which can diminish energy output and shorten the lifespan of photovoltaic modules. Through the integration of sensors, actuators, and microcontroller technology, the system can dynamically adjust cooling mechanisms in response to environmental conditions, ensuring optimal operating temperatures for maximizing energy harvest.

Moreover, the adaptability of Arduino-based systems allows for scalability and customization across various applications and settings. Whether deployed in residential, commercial, industrial, or off-grid contexts, the smart cooling system can be tailored to meet specific energy requirements and environmental conditions. This versatility extends its potential impact to diverse sectors, including agriculture, telecommunications, disaster response, and research, thereby contributing to the advancement of sustainable energy solutions and resilience in various scenarios.

Overall, the successful development and deployment of the smart temperature-dependent cooling system represent a significant stride towards enhancing the reliability, efficiency, and affordability of solar power generation. By leveraging technology to address thermal management challenges, this project underscores the importance of innovation in driving forward renewable energy technologies and facilitating the transition to a greener and more sustainable future. Through ongoing research, innovation, and collaboration, initiatives like this have the potential to drive meaningful change and support global efforts to mitigate climate change while promoting the adoption of clean energy solutions.

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