TEAM: 062

Cooling System for Photovoltaic Panels

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Introduction

❖ ELEVATOR PITCH

Did you know that a solar panel can lose up to 30% of its efficiency when temperatures exceed 40°C?

Our project offers a sustainable and efficient solution by implementing a closed-loop water circulation system to dissipate excess heat, maintaining optimal energy efficiency and enhancing the long-term performance of photovoltaic panels.

❖ Background

In the field of solar energy, particularly in enhancing photovoltaic (PV) panel performance, cooling technologies address critical challenges:

V. **Overheating Issues**: PV panels experience significant efficiency loss as temperatures rise, limiting their electricity output.

VI. **Energy Consumption**: Active cooling methods must minimize power usage to avoid reducing net energy output.

VII. **Automation Needs:** Effective systems require integration with sensors and microcontrollers for real-time response.

VIII. **Sustainability Goals:** Cooling solutions support initiatives like Saudi Arabia's Vision 2030 by enhancing renewable energy usage.

❖ Constrain

Criteria	Required	Status
Water usage	Limited to 2-6 liters per day	Achieved
Wind resistance	Withstand wind loads up to 120 km/h	Achieved
Cooling system performance	Increase energy output by 15% – 25%	Achieved (Expected, 1/5/2025)
Power source	Work on DC	Achieved
Maintenance cycle	Operate for 12 months without major maintenance	Achieved

❖ Specification

Criteria	Required	Status
Temperature reduction	At least 10°C	Achieved
Response time to temperature changes	Within 5-15 seconds	Achieved
Structural load	Add no more than 300 kg/m² to the building structure	Achieved
Power consumption	Not more than 10% of total PV panel power	Achieved
Operation duration	Must work during full daytime	Achieved

Design & Prototype

Passive Cooling: Aluminum heat sink to dissipate heat through conduction and convection.

Active Cooling: Water circulates through pipes from the top of PV panel, controlled by Arduino and temperature sensors.

Closed-Loop System: Conserves water and prevents mineral deposits on panels.

Prototype Achievements:

- Panel mounting structure designed for structural safety against wind loads (up to 120 km/h).
- Full automation using Arduino, temperature sensors, water pumps, and relays.

Multidisciplinary Control and Monitoring System

- COE and EE students implemented real-time sensing and automation using Arduino, temperature sensors, and water level detection.
- ME student optimized the cooling flow design to ensure effective heat dissipation.
- ISE students applied forecasting and modeling techniques to predict performance, with plans to use hypothesis testing after obtaining real-world data.
- CE student designed the structural mounting to safely support the cooling system under environmental loads.

```
void loop() {
  // --------------- Water Measurement ---------------
  Serial.print("one reading:\t");
  Serial.print(scale.get_units(), 1);
  Serial.print("\t| average:\t");
  volume = (scale.get_units(10) - 2200);
  Serial.print(" Water Amount in Liters: ");
  Serial.println(volume, 5);

  if (volume < 2000) {
    tone(buzzerPin, 1000); // Play 1000 Hz tone
    delay(1500);           // for 1.5 second
    noTone(buzzerPin);
  }
```

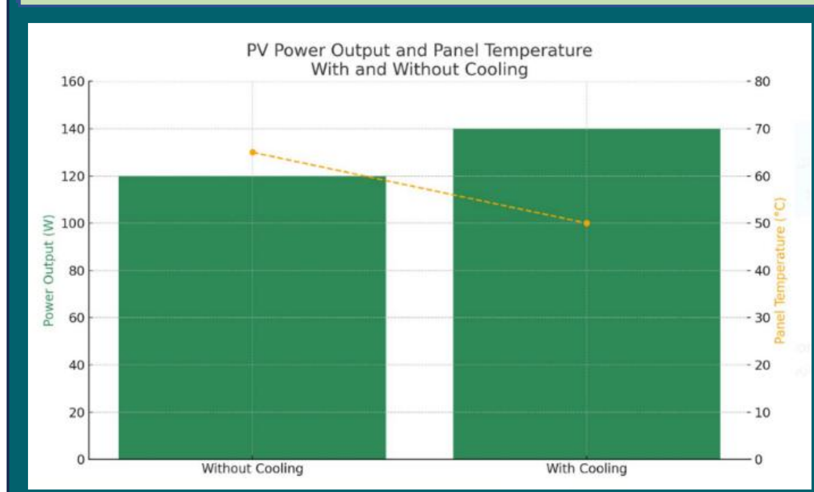
```
// --------------- Temperature and Pump Control ---------------
float temperature = mlx.readObjectTempC();
if (temperature > 40.0 && !pumpState) {
  digitalWrite(relayPin, LOW); // Turn ON pump
  pumpState = true;
  Serial.println("Pump ON");
} else if (temperature < 30.0 && pumpState) {
  digitalWrite(relayPin, HIGH); // Turn OFF pump
  pumpState = false;
  Serial.println("Pump OFF");
}
```

```
// --------------- LCD Display ---------------
lcd.clear();
lcd.setCursor(0, 0);
lcd.print("L:");
lcd.print(volume, 2);

if (volume < 2000) {
  lcd.print(" -->LOW"); // Show LOW message beside the water amount
}

lcd.setCursor(0, 1);
lcd.print("Temp: ");
lcd.print(temperature, 1);
lcd.print(" C");

delay(5000);
}
```

Power (Energy Analysis)

- Energy Consumption: ~14.4W for entire cooling system
- Net Power Output: 185.6W (Expected, 1/5/2025)
- Overall Efficiency Gain: +23.7% (Expected, 1/5/2025)
- Power Source: Two DC USB power banks (enabling 16+ hours of operation)

Validation



$$\text{Power Increase (\%)} = \frac{140 - 120}{120} \times 100 = \frac{20}{120} \times 100 = 16.7\%$$

$$\Delta T = 65^{\circ}C - 50^{\circ}C = 15^{\circ}C$$

Cooling System Selection

- Efficient cooling: Reduces PV panel temperature by 10–20°C, improving output by 15%-25%. (Expected, 1/5/2025)
- Low water usage: Closed-loop system limits usage to ≤6 liters/day.
- Durable materials: Uses PVC pipes and aluminum heatsink for corrosion resistance and high thermal conductivity.
- Automated operation: Controlled by Arduino and sensors for real-time temperature-based cooling.