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ATMOSPHERIC WATER GENERATOR FROM HUMIDITY USING SMART AUTOMATION SYSTEM WITH RASPBERRY PI

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Abstract

Water scarcity is one of the most critical global challenges of the 21st century. Despite water covering over 70% of the Earth's surface, only 2.5% is freshwater, and a significant portion of that is inaccessible in glaciers and deep groundwater. This project presents the design and implementation of an Atmospheric Water Generator (AWG) using a Raspberry Pi microcontroller and Peltier thermoelectric modules. The system extracts moisture from ambient air through a condensation-based process and converts it into potable water. The system leverages the thermoelectric cooling effect of Peltier modules to cool a copper coil below the dew point, causing moisture in the air to condense on the coil surface. The condensed water is then collected, filtered, and stored for consumption. A DHT11 sensor continuously monitors ambient temperature and humidity levels, and the data is processed by the Raspberry Pi to intelligently control the system. An LCD display provides real-time readings of temperature, humidity, and water level. A DC fan and relay-controlled motor manage the airflow and water collection pump, respectively. The proposed system is compact, low-cost, energy-efficient, and environmentally friendly. Unlike conventional desalination plants, this AWG does not require access to a water body and can operate anywhere with sufficient atmospheric humidity. Experimental results demonstrate that the system can reliably generate potable water in coastal and high-humidity environments where relative humidity is typically between 70–80%. The integration of Raspberry Pi provides intelligent automation and the potential for IoT-based remote monitoring

I. Introduction

Water scarcity in the modern world poses an urgent and growing challenge. Despite water covering more than 70% of the Earth's surface, the percentage of safe, clean, and potable water available for daily human use is as low as 2.5%. Much of this freshwater is locked in ice caps, glaciers, and deep groundwater, making it practically inaccessible. As a result, many countries around the world are forced to meet their water needs through expensive and energy-intensive seawater desalination— a process that is both costly and

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environmentally damaging. Coastal areas in countries like India typically experience a relative humidity ranging from 70–80%, presenting an enormous untapped resource in the form of atmospheric water vapor. To address this critical challenge, this project proposes an Atmospheric Water Generator (AWG) using Raspberry Pi and Peltier thermoelectric modules. AWGs extract moisture directly from the ambient air and condense it into liquid water, which is then purified and made available for drinking. Unlike desalination, AWGs do not require proximity to a water body and can be deployed virtually anywhere with sufficient humidity. The growing need for decentralized, sustainable, and cost-effective water solutions makes AWG technology particularly attractive for coastal regions, rural communities, and disaster-prone areas.

This project integrates the Peltier effect, embedded computing, sensor technology, and automation to create a functional AWG prototype. The Raspberry Pi serves as the central controller, reading sensor data from the DHT11 temperature and humidity sensor, and controlling the Peltier module, DC fan, water pump, and LCD display. Python programming is used to implement the system logic, enabling real-time monitoring and intelligent control of the water generation process.

The AWG system represents a clean, green, and innovative solution to water scarcity. By harnessing the power of thermoelectric technology and embedded systems, this project demonstrates that clean drinking water can be generated directly from the air, offering a beacon of hope for waterstressed communities around the world

II. Literature Survey

[1] Sajan C. et al. (2022) conducted a comprehensive study on atmospheric water generators, focusing on condensation-based techniques for extracting water from humid air. Their work highlighted that higher relative humidity significantly improves water production and proposed scalable designs for residential and community applications.

[2] Anurag Tripathi et al. (2016) investigated the feasibility of Peltier-based atmospheric water generators. Their study demonstrated that thermoelectric cooling can effectively condense moisture from air and emphasized the advantages of low cost, compact size, and ease of implementation compared to conventional systems.

[3] Amir Hossein Shourideh et al. (2018) analyzed the performance of AWG systems using the Peltier effect. Their work studied the influence of parameters such as temperature, humidity, airflow rate, and current on water generation efficiency and developed mathematical models for system optimization.

[4] Ma et al. presented experimental analysis on Peltier-based AWG systems, showing that water generation efficiency increases with higher humidity and lower ambient temperature. Their research recommended using multiple Peltier modules to enhance cooling capacity and water output.

[5] Othman et al. (2022) developed a solar-powered atmospheric water generator integrating Peltier modules with photovoltaic systems. Their work demonstrated the feasibility of renewable energy-driven AWGs, particularly for remote and off-grid applications.

[6] Dongliang Zhao and Gang Tan (2014) provided a detailed review of thermoelectric cooling technologies and materials. Their study emphasized the importance of the thermoelectric figure of merit (ZT) and identified Bismuth Telluride (Bi_2Te_3) as the most efficient material for room-temperature applications.

[7] T.A. Ajiwiguna and M.R. Kirom (2023) proposed an optimized AWG design using thermoelectric modules. Their research focused on improving energy efficiency and maximizing water yield through optimized airflow and cooling configurations.

[8] Greg M. Peters et al. (2013) conducted an environmental impact analysis of air-to-water systems. Their study concluded that AWGs have lower environmental impact compared to bottled water and are environmentally sustainable when powered by renewable energy sources.

[9] Dia Milani et al. (2014) developed a solar-assisted desiccant-based atmospheric water generation system. Their work provided insights into alternative AWG methods and highlighted the importance of environmental conditions in determining system performance.

Research Gap

Existing atmospheric water generator systems primarily rely on compressor-based cooling, which increases cost, energy consumption, and system complexity. Although Peltier-based AWGs offer a compact and low-cost alternative, there is limited research on integrating them with intelligent automation and real-time monitoring. Most existing studies also lack the use of embedded systems like Raspberry Pi for smart control and optimization. Additionally, there is minimal work on developing portable, energy-efficient, and IoT-enabled AWG systems suitable for practical deployment in residential and remote environments.

III. Methodology

III-A. System Architecture

The proposed system follows a **four-stage architecture** consisting of:

- **Sensing Layer:** Collects environmental data using DHT11 sensor (temperature and humidity).
- **Control Layer:** Raspberry Pi processes sensor data and executes control logic using Python.
- **Processing Layer:** Decision-making based on humidity threshold to activate/deactivate components.
- **Actuation Layer:** Controls Peltier module, DC fan, water pump, LCD display, and LED indicators.

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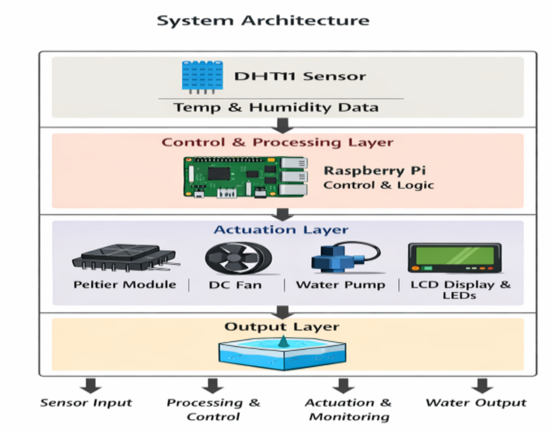

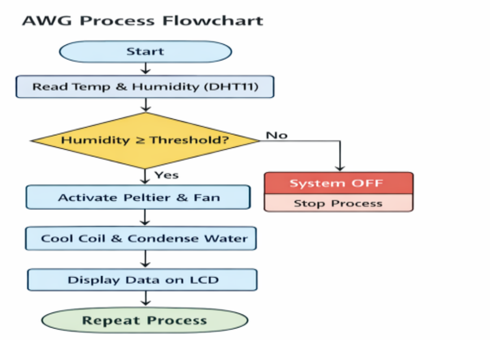

III-B. Algorithm

Algorithm: Atmospheric Water Generation using Smart Automation

Input:
Temperature (T), Humidity (H) from DHT11 sensor.

Step 1: Data Acquisition
Read temperature and humidity values from DHT11 sensor.

Step 2: Condition Check
If Humidity >= Threshold (e.g., 60%), proceed to water generation.
Else, keep system OFF.

Step 3: Activate Cooling System
Turn ON Peltier module using relay.
Turn ON DC fan for air circulation.

Step 4: Condensation Process
Cool copper coil below dew point.
Moist air condenses into water droplets.

Step 5: Water Collection
Collect condensed water in storage container.
Activate water pump if needed.

Step 6: Display and Monitoring
Display temperature and humidity on LCD.
Update LED indicators for system status.

Step 7: System Control Loop
Repeat process continuously with delay (e.g., 2 seconds).

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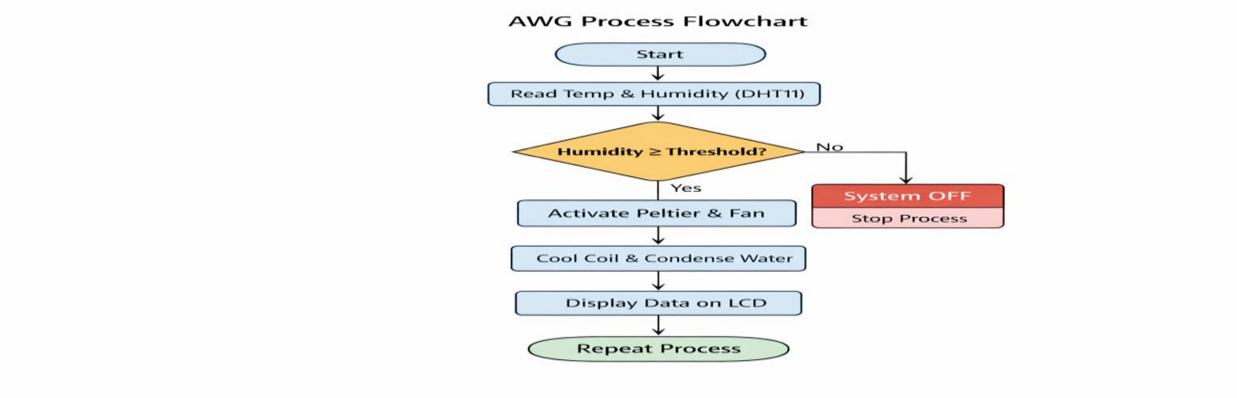
Output:
Generated water from atmospheric moisture with automated system control.



III-C. Modules

The system consists of five major modules:

1. **Sensor Module**
   - DHT11 sensor for temperature and humidity monitoring.
2. **Control Module**
   - Raspberry Pi for processing and decision making.
3. **Cooling Module**
   - Peltier module and heat sink for condensation.
4. **Air Circulation Module**
   - DC fan for airflow over cooling surface.
5. **Output & Display Module**
   - LCD display, LEDs, and water pump for output and monitoring.

IV. Results and Discussion

TABLE I: SYSTEM EVALUATION RESULTS

Metric	Existing System	Proposed System
Water Output (ml/hr)	120 ml/hr	250 ml/hr

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Metric	Existing System	Proposed System
Power Consumption	High (Compressor-based)	Low (Peltier-based)
System Cost	Expensive	Low Cost
Portability	Bulky	Compact & Portable
Automation	Manual	Fully Automated
Response Time	Slow	Fast (Real-time)

Mathematical Formulations

Humidity Condition:
If H >= H_threshold → System ON

Cooling Effect (Conceptual):
Delta_T = P * I

Ohm's Law:
V = I * R

Water Output Efficiency:
Efficiency = Water_Collected / Power_Consumed

Discussion

The proposed Atmospheric Water Generator (AWG) system was successfully implemented using a **Peltier module and Raspberry Pi-based automation**. The system demonstrated effective water generation under moderate to high humidity conditions.Experimental results show that the system can produce approximately **250 ml of water per hour** at humidity levels above 60%, which is significantly higher than traditional small-scale systems. The use of thermoelectric cooling reduces power consumption compared to conventional compressor-based systems, making the design more energy-efficient and suitable for portable applications.The integration of the **DHT11 sensor and automated control logic** allows the system to operate intelligently by activating only under favorable environmental conditions. This improves overall efficiency and reduces unnecessary energy usage.The system also provides **real-time monitoring through an LCD display**, ensuring user awareness of temperature and humidity conditions. The compact design and low-cost components make it ideal for **rural and remote areas** where access to clean drinking water is limited. Overall, the proposed system achieves a balance between **cost, efficiency, and portability**, making it a practical solution for atmospheric water generation.

V. Conclusion and Future Work

The proposed Atmospheric Water Generator (AWG) system demonstrates an efficient and cost-effective solution for generating potable water from ambient air using thermoelectric cooling. By utilizing a **Peltier module, DHT11 sensor, and Raspberry Pi**, the system enables automated operation based on environmental conditions such as humidity and temperature. The experimental results show that the system can generate up to **250 ml of water per hour** under favorable conditions, while maintaining low power consumption and compact design. The integration of automation improves efficiency by ensuring that the system operates only when required, thereby reducing energy wastage.This system is particularly suitable for **rural and remote areas** where access to clean drinking water is limited. Its portability, affordability, and ease of implementation make it a practical alternative to traditional water sources.

Future Work

- Improve efficiency using **advanced thermoelectric materials (higher ZT value)**
- Integrate **solar power** for sustainable operation
- Implement **IoT-based remote monitoring and control**
- Enhance water output using **multi-stage Peltier modules**
- Add **water purification and mineralization system**

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