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Original Article

Atmospheric Water Generator Using Smart Automation Systems

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Abstract *- This paper aims to solve an ongoing issue. Coastal areas show high relative humidity, typically 70-80%. Therefore, propose the use of ventilation from these sources as a sustainable solution to meet water demand through the installation of dehumidifier units. Furthermore, it is noteworthy that sun insulation remains exceedingly increased in these particular regions at some point in the year. This tool serves the crucial function of providing requisite strength to the dehumidifier unit. As such, potable water will be procured via ambient air by leveraging sun power. This state-of-the-art piece of device is identified as an Atmospheric Water Generator in English terminology. Also enhance the sustainability of the paper, we can integrate this with green technology. So it can also leverage renewable energy sources, which include the use of solar panels, optimizing energy efficiency, and incorporating recycled and biodegradable materials. So need to take care of Implementing water-saving features and can also promote local production and further mitigation of environmental impact when conducting Life Cycle Assessment (LCA). It ensures continuous improvement. By adopting the above principles, AWGs can provide a sustainable solution to water scarcity while maintaining and minimizing ecological harm.*

Keywords *- Dehumidifier, Desalination, Relative humidity, Water harvesting, IoT-enabled water generation.*

1. Introduction

Water scarcity in the modern world poses an urgent challenge. Despite covering more than about 70%, the percentage of safe water supply for use and daily work is as low as 2.5%. Consequently, it is forced these countries have their water needs met through seawater desalination- a process distinguished by its high cost.

The potential failure of desalination plants could threaten water supplies on a large scale, as recently demonstrated in the Maldives. It is therefore, important for countries like the Maldives that are totally dependent on these sources to meet their water needs. Alternatives to drinking water production should be urgently explored and adopted to ensure complete water availability. India should redouble its efforts to address the legitimate issue of water scarcity, contrary to what would be expected given its extensive coastline. Currently, no solution to convert seawater into drinking water for public consumption has been developed within India. This issue deserves immediate attention and action [12].

The atmospheric water generator paper focuses on creating a sustainable and innovative solution to tackle. By harnessing the power of Peltier (TEC) modules, this technology aims to extract moisture from the surroundings into drinkable water. The building block of this paper is the thermoelectric phenomenon, which in turn enables the use of Peltier modules to establish that on one side out of the element, the catalytic exchange occurs, and on the other side, the element outflows heat. As the cooled surface in the dew formation process faces contact with the atmosphere, the water molecules present in such air condenses so that it removes water in the atmosphere [2, 15].

Among the numerous papers of such kind, this specific paper stands out because it aims to offer a dependable and eco-friendly source of water for drinking as well as regions with a water shortage (arid and coastal regions) that are not able to get access to groundwater, which is the traditional source of water [12, 18].

Some previous innovations in AWG haven't found any IOT-based smart automation system. The paper focuses on the new way of Condensation process through the Peltier module, which is efficient in terms of power consumption and water production. Unlike the previous research papers, as created this machine is small and easy to carry and can be operated using Household electricity. The atmospheric humidity harvesters evolve this acquiring water technology by introducing a compelling alternative to the energy-intensive desalination plants or water transportation across long distances, thus reducing the negative impacts produced on the environment.

2. Literature Survey

Literature, including research papers, journal articles, conference proceedings, and books, to gain insights into the technology of atmospheric water generators (AWGs). The AWGs have emerged as an innovative solution to address water scarcity issues. They extract moisture from humid air and convert it into potable water, as highlighted [1, 2].

Several studies have explored various designs and working principles of AWGs, according to Zhang et al. The most widely used technique in AWGs is cooling condensation, where cooled air condenses is the due point of water vapour [7, 20]. In addition to this, sorption dehumidification and membrane separation methods have also been utilized. Experimental and theoretical evaluations of these systems have determined key performance parameters [5, 11].

Shourideh et al. AWG is based on Peltier cooling. The purpose was to demonstrate its feasibility and analyze various factors such as ambient temperature, humidity levels, air flow rate, and velocity that affect water generation [8, 19]. In their study, Ma et al. conducted experiments on an AWG with Peltier modules to determine the optimal configurations for maximizing efficiency. The results of their studies indicate that higher relative humidity and lower ambient temperatures enhance productivity [4, 16].

In addition, several researchers have focused on energy efficiency and integrating renewable sources to enhance the sustainability of AWGs. In their study, Othman et al. developed sun solar powered by AWG, aligning the system's electricity demand with the output of solar panels. Additionally, researchers have proposed integrating AWGs with other renewable energy sources, such as wind energy and waste heat recovery [4, 15].

Compared to previous innovations, AWG offers better efficiency in highly humid environments compared to alternatives like solar-based AWG, whose efficiency depends upon the amount of sunlight environment factors. The paper offers low-cost solutions which use minimal electricity to produce water. This project has better sustainability in terms of cooling system and it is more Adaptable because of reliable water production in various conditions. The operational cost of AWG is cheaper compared to the traditional AWG, which uses high energy-consuming condensers for the condensation process. In addition to technical evaluations, studies have also examined the life cycle costs, environmental impacts, scalability, and commercialization potential of AWGs through modelling and simulations. The literature provides realistic perspectives on deploying AWGs by considering relevant parameters beyond just water generation capacity.

3. Background

Atmospheric Water Generators (AWGs) are innovative devices designed to absorb moisture present in the air and change it into usable, potable water. They offer sustainable solutions to address water scarcity issues in regions with limited access to traditional water sources. Water scarcity is a global issue affecting numerous regions due to factors like population growth, climate change, and contamination of existing water sources.

Access yet many people lack this basic necessity. AWGs utilize the principles of condensation and dehumidification to extract water vapor from the atmosphere. The basic components of an AWG include a compressor, a condenser, a filtration system, and a storage tank. Air is drawn into the system cooled, and the moisture in the air condenses into liquid water. It is then filtered and stored for consumption. AWGs can be powered by a variety of energy sources, including electricity, solar panels, wind turbines, and even waste heat from industrial processes.

The choice of energy source can impact the sustainability and affordability of an AWG system. It's crucial to highlight that the water generated by AWGs is typically of high quality. The air filtration and purification processes ensure that the water meets or exceeds drinking water standards. This makes AWGs a reliable source of clean water. Compared to other water sources, AWGs generally have a lower environmental impact. They reduce the need for extensive water transportation, which can be energy-intensive and environmentally harmful. However, the energy source used to power the AWG can affect its environmental footprint. AWGs have a range of applications, including providing drinking water to homes and communities and supporting disasters in arid regions.

Over the years, there have been significant technological advancements in AWG systems, improving their efficiency, scalability, and integration with other technologies. These advancements have made them more practical and accessible. AWGs contribute to sustainability by reducing the need for traditional water sources and decreasing the carbon footprint associated with water transportation. They can also be integrated with renewable energy sources for a more sustainable water supply. There are several challenges associated with AWGs, including energy consumption, maintenance requirements, initial setup costs, and climate-specific considerations.

Additionally, in very arid climates, the water extraction rate may be limited. The cost of AWG systems varies depending on their size and capacity. At the same time, initial costs on water bills and reduced reliance on water infrastructure can make AWGs cost-effective in the right contexts. The use of AWGs may be subject to regulations and standards that vary by region. It's important to comply with local laws and quality standards when deploying AWG systems. AWGs can have a profound impact on communities with limited access to clean water. They provide a reliable and sustainable source of potable water, improving public health and overall quality of life.

The objective of this paper is to devise a portable apparatus capable of fulfilling the water needs of an average household. This device operates by condensing atmospheric water vapour and subsequently purifying it to meet potable standards. The atmospheric water generator was conceptualized with three fundamental criteria: it must yield sufficient water for household consumption, be user-friendly for individuals lacking technical expertise or chemical knowledge and remain economically viable.

3.1. Objective

- Ease of Use: The design must be operable by individuals with minimal to no technical experience.
- Safety: The design must ensure the safety of users throughout its regular operation, posing no hazards.
- In pursuit of these objectives, we also have established specific goals:
- Power Source Flexibility: The design should accommodate various power sources, including solar and wind energy, in addition to the conventional power grid.
- Maximization of Efficiency: Our aim is to optimize water production relative to energy consumption, maximizing efficiency.
- Cost Minimization: The design should minimize both capital and operating costs per unit of water production.

4. System Implementation

Design aspects: The AWG consist of 3 main parts, which are the Cooling system, Condenser, IOT control system, and Power management unit.

Circuitary: The control unit of the project is the IOT section which controls the state of the AWG and power management unit. The power management unit consists of a 12V AC-DC converter for the Peltier and a 5V AC-DC converter for the fans. It is connected to the heat observer, takes heat from the hot Peltier and releases it to the environment. One water pump is connected to the power supply, which helps to flow the coolant from the container to the copper pipe.

Software Strategy: The IOT part is implemented using Node MCU ESP8266. The software is implemented using Arduino IDE with the help of Blynk Software. The Node MCU is connected to the internet via an inbuilt Wi-Fi module; it sends the current state of the AWG to the Blynk server like Water level, Mode, and On/Off state.

5. Methodology

After analyzing numerous papers on the criteria of being eco-friendly, clean to function, and price-effective, we have determined to explore the opportunity of making an atmospheric water generator. The technique includes utilizing a vapor compression refrigeration machine, which is extensively identified as the most applied approach by air-conditioners in the trendy world. This serves because it is the medium to absorb and also get rid of heat from the area that desires needs to be cooled up. It then releases this warmth to the ecosystem.

The discern illustrates a single-stage vapor-compression system. This machine includes the four most important additives: a compressor, condenser, thermal enlargement valve, and an evaporator. Refrigerant circulates through the machine, getting into the compressor as a saturated vapour, after which it is compressed. This compression will increase each the stress and temperature then emerge as superheated vapour, attaining a temperature and strain appropriate for condensation with the process of cooled water or cooled air. This warm vapour is then directed via a condenser in which it gets cooled and condensed.

The liquid refrigerant, referred to as a saturated liquid, is then flowed via the expansion valve, causing an unexpected pressure drop. This will result in the liquid refrigerant. The technique, known as refrigeration, entails decreasing the temperature vapour refrigerant mixture, making it less warm than the enclosed area of the favored temperature. This bloodless aggregate is then circulated via the copper coil inside an evaporator. The fan circulates heated air throughout the enclosed space while the refrigerant rejects warmness from the machine. The coils convey condensed, bloodless refrigerant liquid and vapor aggregate.

The warm air is reasoning to liquid a part of bloodless refrigerant to evaporate, concurrently cooling the circulating air and lowering the temperature from the enclosed space to the favored level. Circulating refrigerant will absorb warmness through the evaporator (covered from a cylindrical plate) and get rid of it.

This warmness is then transferred to the condenser and rejected, both through water or air used within the condenser. To complete the refrigeration cycle, the saturated vapor refrigerant exiting the evaporator is again back to the compressor. In the atmospheric cooling of the air water generator, the compressor is circulated by the refrigerant through a condenser and the coil of the evaporator. In this manner, cooling of the air surrounding the coil decreases its temperature to the dew factor and, inflicting water to condense. The fan with managed velocity files filtered air all over the coil. The resulting water is further handed to the preserving tank, ready with which it is carried for purification along with a filtration gadget. This system allows for maintaining the purity of the water. It reduces the chance of viruses and bacteria that could be collected through ambient air to the coil of the evaporator, which is circulated through the condensation method. The rate through which the water flows could be produced primarily relies upon the relative humidity, temperature, ambient air and compressor scale. The water available at atmospheric state further mills, which turns out to be greater powerful with respect to relative humidity and growth of the temperature in the air. A popular rule that might not perform at an optimal level while located in at air-conditioned place.

The cost-effectiveness of an AWG is reliable on numerous factors, together with the gadget's capability, while measuring the local humidity, temperature conditions and value of the powering unit individually. In coastal tropical regions, wherein the ambient air is humid and hot, water gets frequently condensed from the air by means of air conditioners. This water will be conveniently used for drinking purposes. The below diagram is the Peltier module setup for colling coolant, which will pass through the copper pipe and cause condensation.

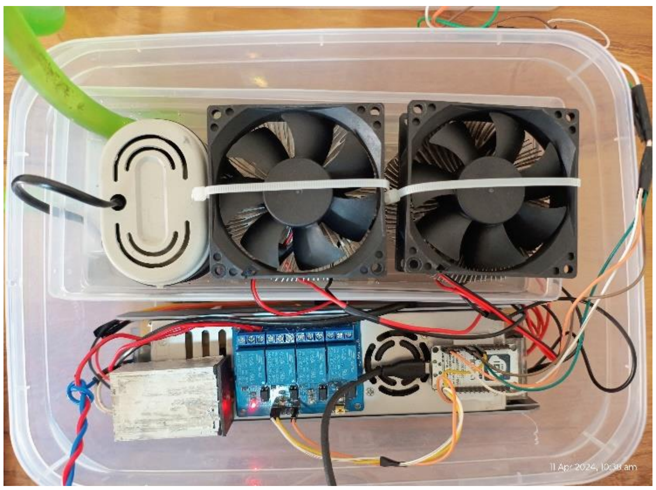

Fig. 1 Cooling system

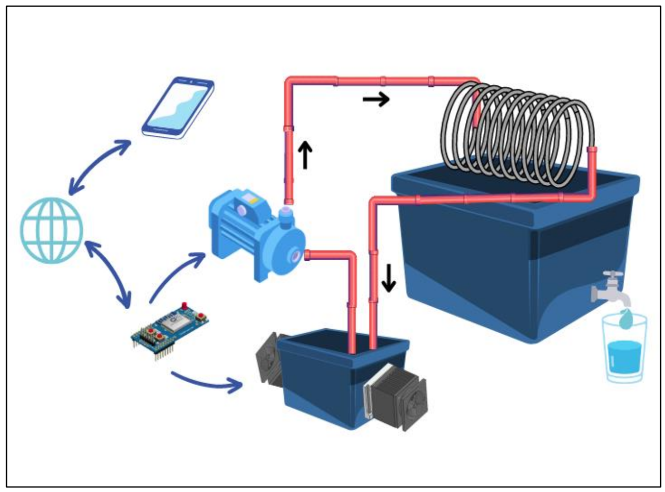

Fig. 2 Block diagram

6. Components

Table 1. Component list details

Component	Description
Heat Sink with Cooling Fan	Dissipates heat generated by Peltier chips
Condenser	Condenses coolant vapor back into liquid form
Water Tank with Attached Tap	Stores coolant liquid
Circulation Pump	Circulates coolant through the system
Temperature/Moisture Sensors	Measures temperature and humidity levels
Coolant Liquid	Cools the system and transfers heat away from Peltier chips
Spiral Copper Pipe	Conducts heat away from the source
12V 20A Power Supply Unit	Provides power to the components in the system
Water Level Sensors	Monitors the level of coolant liquid in the tank
Cool Box for Coolant Liquid	Insulated container to keep the coolant cool
Peltier Chips	When an electric current is applied, the Thermoelectric modules difference in temperature
Water Basic Filter	Filters impurities from the coolant liquid
Arduino ESP 8266	Microcontroller for data processing and control
16x2 LCD Display	Displays information and feedback to the user
Suction Fan	Enhances airflow and cooling within the system7.

7. Comparative Analysis

Atmospheric Water Generators (AWGs) have garnered attention as sustainable solutions for addressing water scarcity. This comparative analysis aims to explore the strengths and weaknesses of two distinct AWG designs: Paper A and Paper B.

Paper A: Condensation-based Atmospheric Water Generator Paper A utilizes a condensation-based mechanism that employs a cooling system to extract moisture from the air. It relies on advanced condensation technology and efficient heat exchange. Strengths: High efficiency in humid environments. Well-established technology with proven effectiveness. Reliable water production in various atmospheric conditions. Weaknesses: Limited efficiency in low-humidity environments. Energy-intensive cooling systems may not be environmentally friendly. Relatively higher initial cost for advanced condensation units.

Paper B: Solar-powered Atmospheric Water Generator Paper B focuses on a solar-powered approach, utilizing solar energy to drive the condensation process. Its main objective is to promote sustainability by reducing reliance on external power sources. Strengths: Environmentally friendly with reduced energy consumption. Suitable for remote areas with ample sunlight. Lower operational costs once implemented.

Weaknesses: Dependent on sunlight, may not be efficient in cloudy or nighttime conditions. The initial setup cost for solar panels may be relatively high. Requires careful design for optimal energy utilization.

Conclusion: Both Paper A and Paper B present viable solutions for atmospheric water generation, each with its own strengths and weaknesses. Paper A offers reliability in varied conditions, while Paper B emphasizes sustainability.

The choice between them depends on specific environmental, economic, and operational considerations. However, a hybrid approach that combines the strengths of both papers could potentially offer a more robust solution for addressing water scarcity challenges.

8. Experiment Working

Table 2. Temperature vs Applied voltage

DT(ºC)	I = 1.51A	I = 3.02A	I= 4.53A	I= 6.05A	I= 7.56A
10	2.8	5.4	8	10.6	13
20	3.2	6	8.6	11.2	13.6
30	3.6	6.4	9.2	11.8	14.2
40	4	6.8	9.8	12.2	14.8
50	-	7.2	10.2	12.8	15.2
60	-	7.8	10.8	13.4	15.6

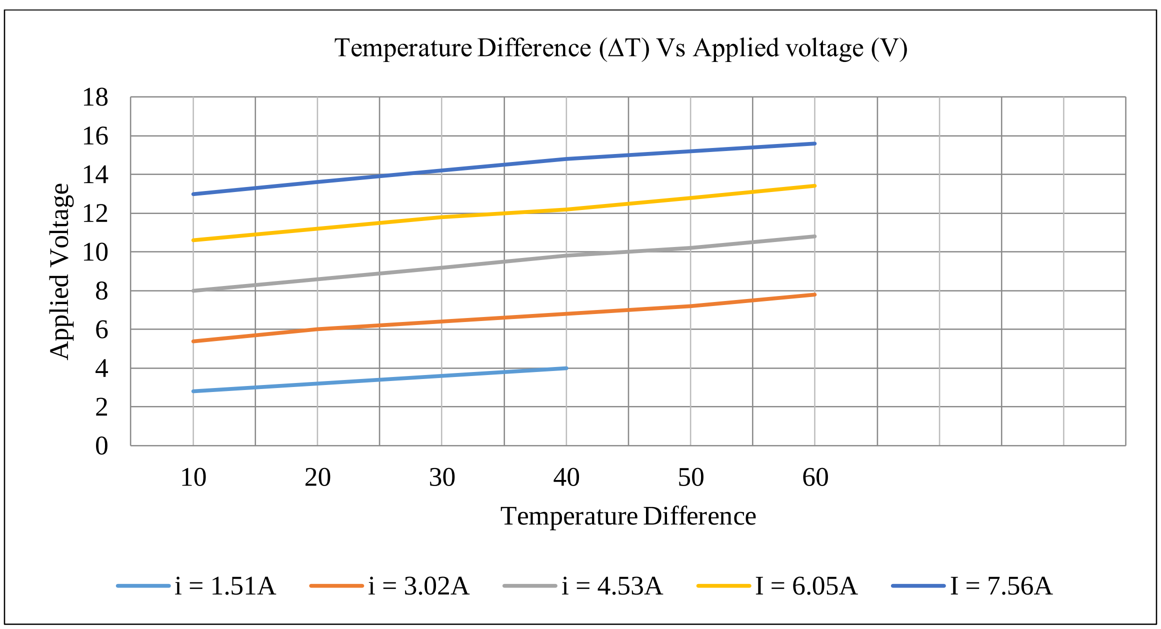

Fig. 3 Temperature vs applied voltage

The relationship between temperature difference (ΔT) and applied voltage (V) in a Peltier element can be represented by a linear equation, which is commonly referred to as the Peltier effect equation:

$$\Delta T = P * I$$

Where:

- ΔT is the temperature difference (in degrees Celsius or Kelvin) of the Peltier element.
- P is the Peltier coefficient (in volts per ampere or V/A), which represents the ability of the material to absorb or emit heat at the junctions.
- I is the electric current (in amperes) passing through the Peltier element.
- The relationship between voltage (V) and current (I) in an electrical circuit is given by Ohm's law:

$$V = I \cdot R$$

Where:

- V- Voltage across the Peltier element (in volts).
- I- Current passing through Peltier element (in amperes).
- R- Resistance of the Peltier element (in ohms).
- Substituting Ohm's law into the Peltier effect equation, so get:

$$\Delta T = P \cdot (RV)$$

In this equation, the relationship between temperature difference (ΔΔT) and applied voltage (V) depends on the Peltier coefficient (P) and the electrical resistance (R) of the Peltier element. The Peltier coefficient is a material property and remains constant for a specific material. The electrical resistance can vary based on the design and configuration of the Peltier element and the materials used.

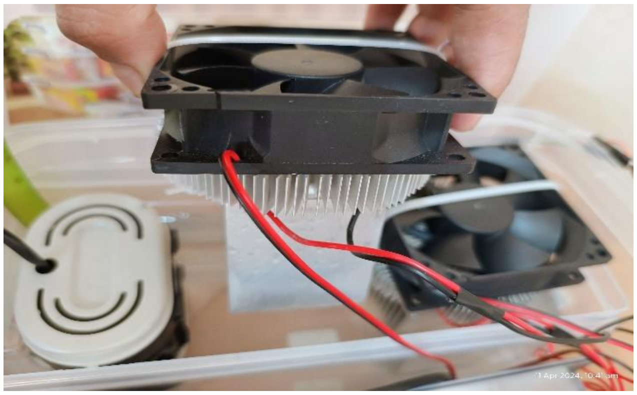

Fig. 4 Measuring temperature difference on applied voltage

Table 3. Output readings of cooling power and temperature

DT(ºC)	I=1A	I=2A	I=3A	I=4A	I=5A	Imax=6A
0	14	29	37	49	55	61
5	11	24	34	47	52	58
10	9	21	31	44	48	55
15	6	18	28	42	46	52
20	3	15	25	38	42	48
25	0	12	22	34	39	42
30		9	17.5	30	35	38
35		6	14	26.6	30	33
40		3	11.5	22.2	24	28
45		0	7	17.8	20	21
50			3.5	13.4	15.6	16
55			0	9	11.7	12
60				4.5	7.8	8
65				0	4	4
70					0	0

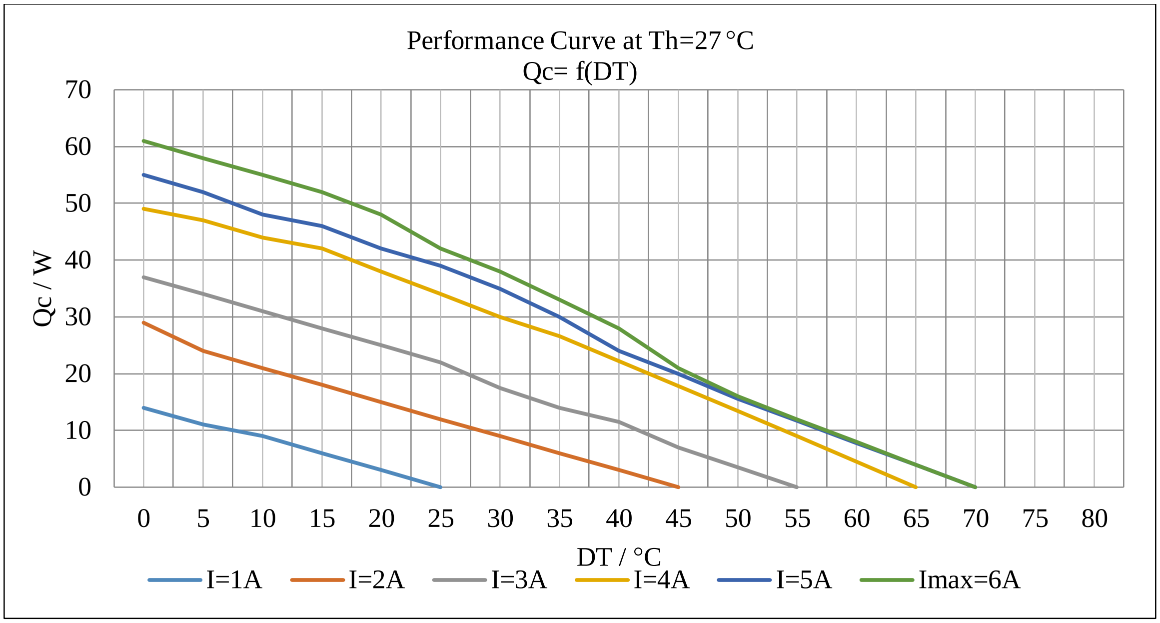

Fig. 5 The graph between Qc(watts) (cooling capacity module) and DT(ºC) (temperature difference at the cold side) shows decreasing

Table 4. Output readings of temperature difference and voltage

DT(ºC)	I = 1A	I = 2A	I = 3A	I = 4A	I = 5A	Imax = 6A
0	2	4	6	8	10.2	12.2
10	2.5	4.5	6.6	8.5	10.8	12.7
20	3	5.2	7	9.1	11.3	13.5
30		5.8	7.3	9.8	11.8	13.9
40		6.3	7.7	10.4	12.2	14.4
50			7.9	11	12.9	15
60				11.4	13.5	15.6

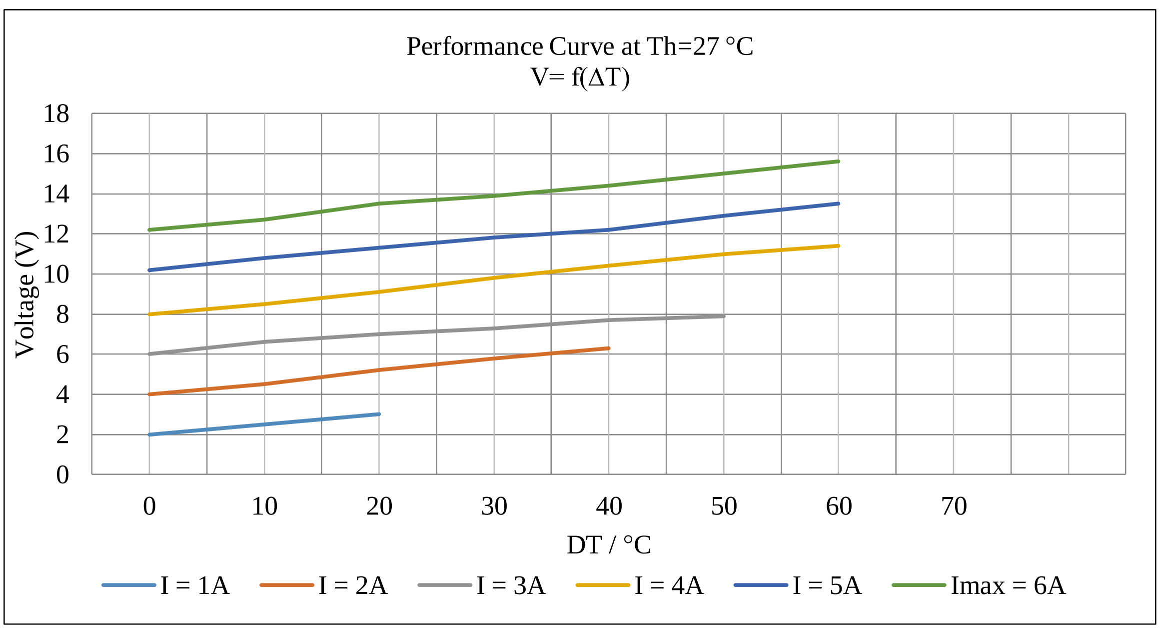

Fig. 6 The graph between Th (temperature difference) and voltage (V) shows a linear increasing relation

Table 5. Output readings of voltage and cooling capacity

V (volt)	DT = 0°C	DT = 10°C	DT = 20°C	DT = 30°C	DT = 40°C	DT = 50°C	DT = 60°C
0	0	0	0	0	0	0	0
1	8	0	0	0	0	0	0
2	15	5	0	0	0	0	0
3	20	11	0	0	0	0	0
4	26	17	8	0	0	0	0
5	31	23	14	6	0	0	0
6	36	28	20	11	0	0	0
7	41	33	24	16	6	0	0
8	45	37	28	20	10	0	0
9	49	40	32	24	15	6	0
10	52	44	35	27	18	9	0
11	55	46	37	29	21	11	3
12	57	48	39	31	23	14	5
13	58	50	40	33	24	15	7
14	60	51	41	34	25	17	8
15	60.5	52	42	35	25	18	9
16	62	53	43	35	25	18	9

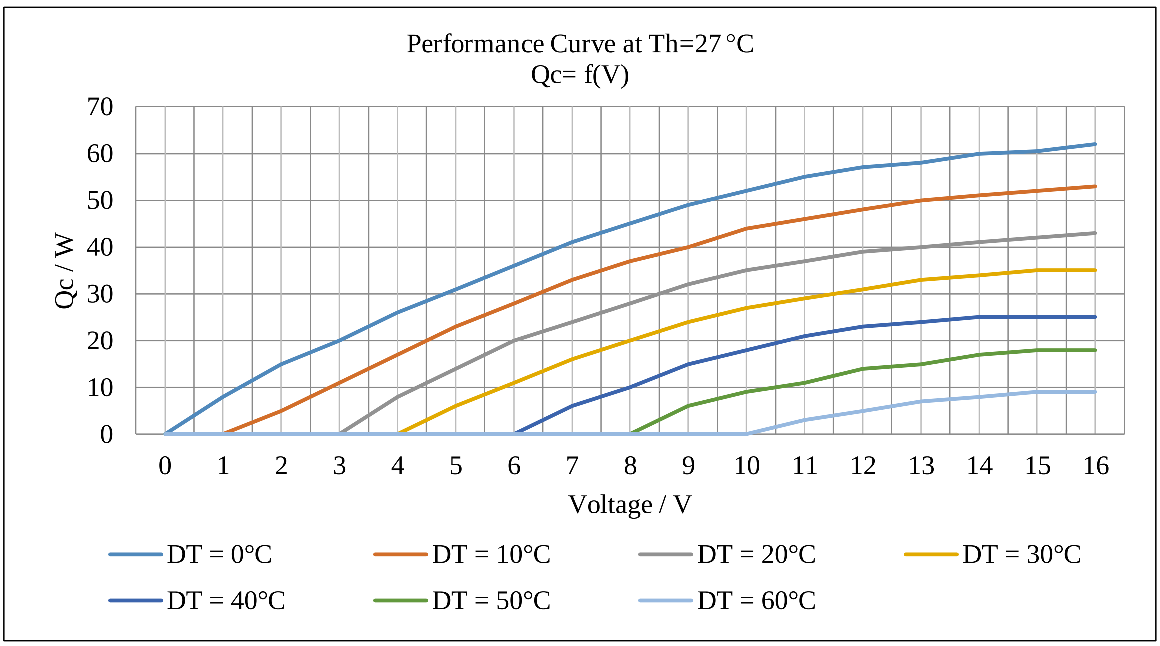

Fig. 7 The graph between voltage (V) and Qc (watts) (Cooling capacity of the module)

Copper is not commonly used as a material for humidity sensors due to its limited sensitivity to humidity changes. However, copper can be used in temperature sensors and has some temperature-sensing properties. One of the notable properties of copper is its high thermal conductivity, which means it can quickly respond to changes in temperature. Here are a few points regarding the temperature-sensing properties of copper:

1. Thermal Conductivity: Copper has excellent thermal conductivity, which means it can efficiently conduct heat. This property allows copper temperature sensors to respond rapidly to temperature changes.
2. Temperature Coefficient of Resistance: Like many metals, copper's electrical resistance changes with temperature. Copper has a positive temperature coefficient of resistance, meaning its resistance increases

with rising temperature. This property can be utilized in resistance temperature detectors (RTDs), where the electrical resistance of the copper wire changes predictably with temperature.

3. Inearity: Copper temperature sensors, especially RTDs, can exhibit good linearity over a wide temperature range. This linearity simplifies the calibration process and enhances the accuracy of temperature measurements.
4. Stability: Copper is stable over a wide temperature range, making it suitable for various temperature-sensing applications.

9. Result

The AWG offer several benefits and has seen significant advancements over the years. These innovations make them a promising solution for addressing water scarcity and providing clean drinking water.

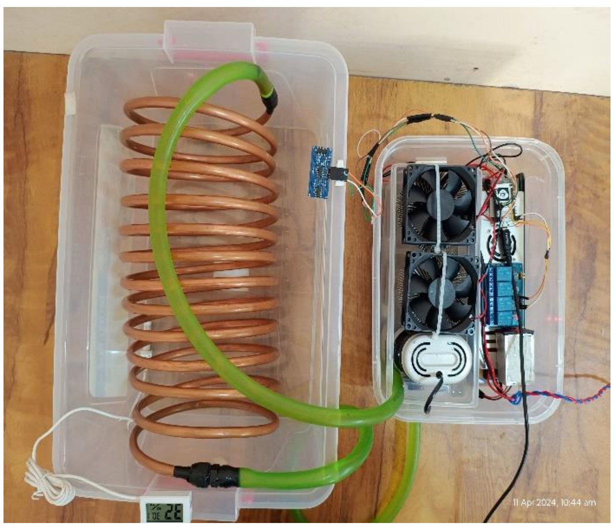

Fig. 8 Paper setup

Here are the benefits and recent advancements in AWG technology:

Clean and Safe Drinking Water: AWGs produce high-quality, potable water. The air filtration and purification processes remove contaminants and impurities, ensuring the water meets or exceeds drinking water standards. Water Security: AWGs provide a consistent source of water, reducing dependency on traditional water sources, which can be vulnerable to pollution, drought, or infrastructure issues. This enhances water security, especially in arid or disaster-prone regions.

Sustainability: AWGs water sources reduce the need for energy-intensive water transportation and can be powered by renewable energy sources, promoting sustainability. Reduction of Water Stress: AWGs can help alleviate water stress in water-scarce regions, making it a valuable technology for communities facing water shortages

Versatility: These systems are versatile and can be deployed in various environments, from remote villages and disaster-stricken areas to urban settings and industrial applications. Reduction in Water Bills: For residential and commercial users, AWGs can lead to cost savings over time as they reduce reliance on municipal water supplies with associated costs.

Health Benefits: Access to clean water through AWGs can significantly improve public health by reducing the risk of waterborne diseases and the need for water treatment. Emergency Response: AWGs can be deployed rapidly in disaster-stricken areas, providing a quick and reliable source of clean water for affected populations.

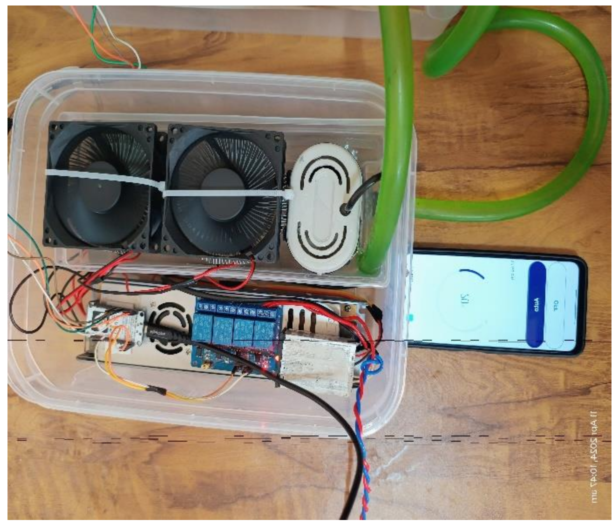

Fig. 9 Working model

10. Conclusion

In conclusion, Atmospheric Water Generators (AWGs) represent a promising and innovative solution to the critical global issue of water scarcity. These devices harness the natural moisture in the air to provide clean and safe drinking water, offering a range of benefits and recent advancements that make them a compelling technology. AWGs are capable of producing high-quality drinking water, enhancing water security, promoting sustainability, and reducing water stress in regions facing shortages. Their versatility allows them to be deployed in diverse environments, from remote communities to disaster-stricken areas and urban settings, benefiting public health and reducing water-related costs.

Recent advancements in AWG technology have improved energy efficiency, scalability, and integration with renewable energy sources. They have become smarter, with IoT capabilities for remote monitoring and control, and have seen innovations in water filtration, maintenance reduction, and material durability. These advancements have enhanced the reliability and accessibility of AWGs. As the world continues to grapple with water scarcity challenges, AWGs offer a beacon of hope, providing a consistent, clean, and sustainable source of drinking water. Further improvements, make AWGs an increasingly attractive solution for addressing water scarcity and ensuring access to clean water for communities in need.

10.1. Future scope

Improved Energy Efficiency: Recent advancements have focused on increasing the energy efficiency of AWGs, making them more sustainable. This includes the development of more efficient cooling systems and improved heat exchange processes. Scalability: AWG systems now come in various sizes and capacities, making them adaptable to different applications, from small residential units to larger commercial and industrial systems.

Smart and IoT Integration: Some AWG systems are incorporating smart technology and IoT (Internet of Things) capabilities. This allows for remote monitoring, control, and maintenance of the systems, optimizing their performance. Water Filtration Innovations: Advances in water filtration technology have improved the quality of water produced by AWGs, ensuring that it is safe and pure. Reduced Maintenance Requirements: Newer AWG systems have been designed with reduced maintenance needs, making them more user-friendly and reliable. Material and Component Innovations: The use of advanced materials and components has increased the durability and longevity of AWG systems, reducing the frequency of replacements or repairs.

Energy Recovery: Some AWGs incorporate energy recovery mechanisms, which recycle heat or energy from the condensation process, further enhancing energy efficiency. Water Quality Monitoring: Many modern AWGs have built-in sensors and monitoring systems to ensure consistent water quality and alert users to any potential issues. Research and Development: Ongoing research and development efforts continue to push the boundaries of AWG technology, with a focus on improving efficiency, water production rates, and affordability.

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