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Effect of Temperature and Humidity Factors on Water Production Using Solar Energy with Smart Controlling

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HIGHLIGHTS

- High temperatures lead to the increase in evaporation and then to an increase in the percentage of water in the air
- The humidity factor is better in the range between (25 to 65) %
- The water harvesting device was designed as a solution to reduce moisture considering it a source of drinking water using solar energy, with a low cost, a work efficiency of up to 60%, and most importantly smart controlling.

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ABSTRACT

The aim of the current work is to study the effect of temperature and humidity factors on the production of water from humid air using clean energy, as we have noticed that both factors have an effective impact on the atmospheric air and on the amount of water that was obtained, which is useful in areas that do not have electric power sources or fresh water, and solar energy is used as the main source of energy in open areas. The motivation is to evaluate the performance of the system in light of different air flow rates and in different locations in Iraq depending on the experimental data obtained and the parameters related to the proposed system. We have noticed that high temperatures lead to the increase in evaporation and then to an increase in the percentage of water in the air, and the humidity factor is better in the range between (25 to 65) %, and when the relative humidity reaches 100%, the water vapor begins to condense to form dew, and the temperature is called the dew point when this occurs. Therefore, the water harvesting device was designed as a solution to reduce moisture considering it a source of drinking water, keeping in mind the main contribution which is to use solar energy, with a low cost, a work efficiency of up to 60%, and most importantly smart controlling.

1. Introduction

Throughout the 20th and 21st centuries, it has been observed that the number of the world's population has increased by nearly three times than what it was, and the consumption of drinking water has increased by six times than what it was previously. The usable water has become scarce and scarce, and the change in climatic conditions and the entry of environmental pollutants and human-made pollutants lead to an increase in the withdrawal of existing water. The groundwater has constituted a strong pressure on pure water resources, and the variation in the distribution of potable water in the world has played a major role in the increase and decrease in fresh water resources. One of the used indicators that determines the volume of water resources is the (FSI) indicator, where it is classified in countries within gradual stages in the quantities of decreasing water depending on the share of each individual of the water (PWR). In most cases, the process of diverting water from one area to another is very expensive, and water purification depends on the presence of various water sources, which is a rare case in dry desert places. The atmosphere is the largest reservoir of water [1]. The surface of the earth is also clean, except for some areas where the air is polluted. It has been noted that the amount of water in the air is estimated at about 14,000 cubic kilometers, while the amount of water in rivers and lakes is approximately 1200 cubic kilometers. The process of obtaining water from the atmosphere has many advantages when compared to other methods, and there are several ways to extract water from the air, but the most used of these methods is the method of cooling moist air. Within a temperature that is less than the point of air condensation, the process of extracting water from moist air is carried out using liquid and solid desiccant materials. Water recovery is through the process of heating the dryer, which in turn works to intensify evaporation. Despite that, the first method in the water transfer process is expensive, while the other method based on desalination depending on the presence of water sources is scarce in desert areas [2]. There is a third method that depends on the water stored in the

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atmosphere, which carries about 3100 cubic miles of water, divided into 98% that takes the form of vapor and 2% that takes the form of clouds. There is information confirming that 280 cubic mile of water travels from the atmosphere daily, in addition to an estimated amount per cubic mile that contains more than a trillion gallons of water. In our first method, we relied on cooling the air to a temperature lower than the second by absorbing steam from the air, and we used dryers that heat and then condense the evaporated water. Niles AG et al. presented a thermal method for the purpose of cooling and removing moisture from the atmospheric air by using a helical coil from which water is obtained [3]. We have mentioned that the desert areas have a high temperature and we have learned that the lower layers of soil are colder as the pumping device moves the air that surrounds the moisture. Below the ground, it passes through the pipes, and then the moisture begins to condense on the walls of the internal pipes, and then drops of water come out directly from the pipes to the crops in the fields. It can also be used for drinking, and this method is designed for areas with high to medium humidity, and they are called atmospheric water generators (AWG). The device works to convert water vapor into liquid and was manufactured for agricultural and irrigation works in areas where there is water scarcity. The (AWG) concepts were developed by their first team using a palter and a second heat exchanger. The concept of heat exchanger works while passing the coolant that is cooled to a few temperatures and then creating both applications (AWG). The result of using sustainable engineering was considered. There are foundations to reduce energy consumption and also reduce cost (especially when we compare it with (AWGS) available in the market now). Note that the designs have produced sufficient quantities of water to plant two fruit trees per day (1 gallon per week), 60% humidity, 31 degrees Celsius temperature, and since Iraq has suffered greatly from water shortage, which prompted our scientific departments to find alternative sources of water. This research paper includes several basic topics in the work of the device, including:

1.1 Experimental work

It includes performance evaluation equations responsible for evaluating the performance of the device, device's parts, where the main and secondary parts of the device are mentioned in detail, and the practical work. The principle of work for the device and water is explained. In this part of the research, water purification processes and the most important modern and traditional methods in this field are discussed in addition to discussing the principle of the work for the intelligent control system and ways to control it.

1.2 Results and discussions

The results obtained through practical work are mainly discussed, in addition to the discussion of the principle of the control system's work and its importance.

1.3 Conclusion

It includes the most important conclusions resulting from practical experiments, which are based on theoretical calculations, and the consistency of the results.

2. Experimental work

Mechanism of the work of the water harvesting device that uses solar power as a source of electricity and the effect of humidity and temperature factors are presented in this section.

2.1 Performance evaluation equations:

The governing equations are Carnot cop which are the main performance equations for the coefficient of performance of the device [4]:

$$carnot\ COP = \frac{Area41ab}{Area1234} = \frac{T_1\,(S_a - S_b)}{(T_2 - T_1)(S_a - S_b)} \tag{1}$$

$$= \frac{T_1}{T_2 - T_1} \text{ or } \frac{T_4}{T_3 - T_4} \tag{2}$$

$$carnot\ COP = \frac{Eva[pratpr\ te,[eratire(absolute)}{Condenser\ temperature - Evaporator\ temperature} \tag{3}$$

2.2 Device parts

The device consists of solar panel, battery, inverter and transformer, moist air collecting tank , compressor, fan speed control device, device temperature controller and the most important device is the smart control system of arduous and its sensors of humidity and temperature.

2.3 Practical work

Water vapor in the air is condensed by cooling the air below its dew point, exposing the air to desiccants, or pressurizing the air. The primary technique in use is cooling by capturing water vapor from the air and channels it towards a condensation system controlled by a smart system as shown in Figure 1. The smart system (main controller) is responsible for the cut of the circuit of the invertor when the humidity or the temperature becomes lower than the values that have been inserted to the arduous application. Signals are sent to the arduous and then the arduous sends a signal to the invertor to cut the circuit or turn it on again by sending another signal when the humidity and temperature get back to the inserted values.

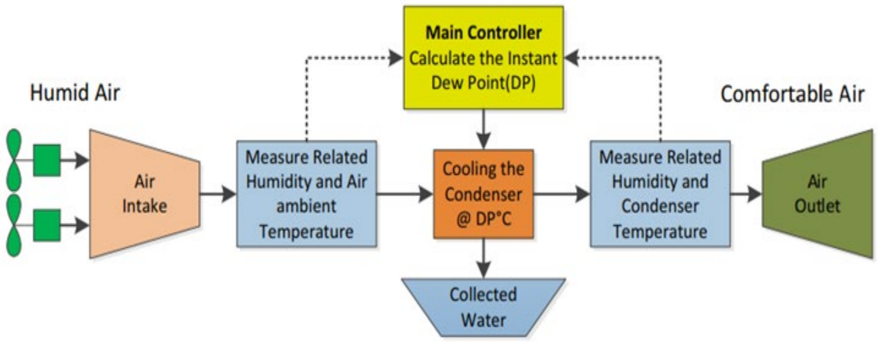


Figure 1: Device main parts

2.4 Water Purification and Controlling Systems

Areas of high humidity often contain vital contaminants such as bacteria, viruses, etc., as well as possible pollutants from factories or generators smoke if they are near, so harvested water must be filtered. For water filtration, there are several ways. Some are old but still effective and low in price and others are new and more efficient but also quite expensive:

2.4.1 Classic filtration system

This system starts with a slow bio-sand filter after that there is a layer of bio-char (charcoal) filter, then a gravel roughing filter, and finally to a collecting barrel as shown in Figure 2 and Figure 3. This ancient system can be used by people in poor areas [5].

2.4.1 Advanced water filtration system

This section discusses the solar powered water purification system. This system allows us to extract potable water with minimal effort, but the problem lies in its high price and the consumption of a large amount of electrical energy [6][7].

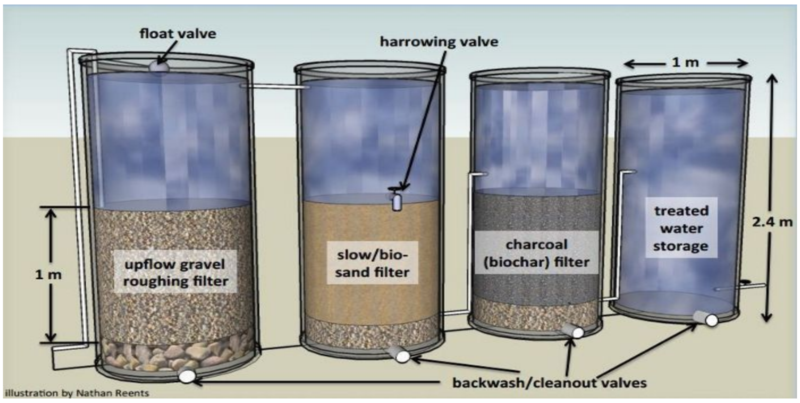


Figure 2: Classic filtration system for raw water

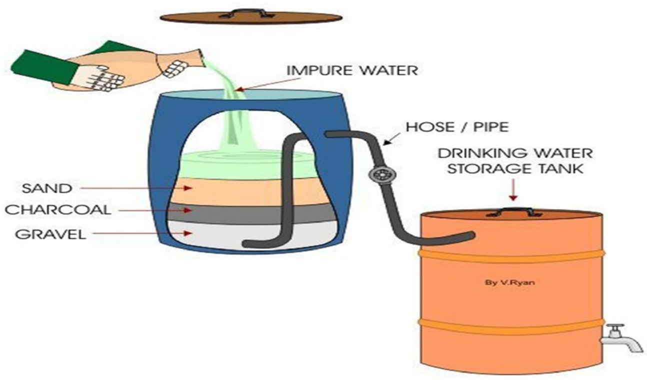


Figure 3: Simple mini system

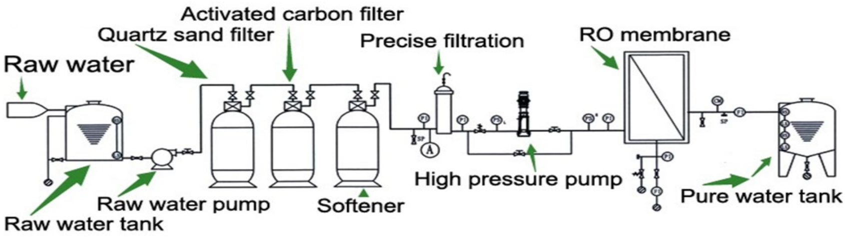


Figure 4: Advanced water filtration system

Water purification in this process will remove undesirable chemicals, biological contaminants, suspended solids, and gases from water. Water purification may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae and fungi as well as reduce the concentration of a range of dissolved and particulate matter [8].

2.4.2 Control system

The Adriano system transmits information wirelessly with the computer, then the computer sends commands wirelessly to a wireless circuit breaker that is responsible for turning the device on and off as shown in Figure 5 that illustrates the device's smart controller working mechanism.

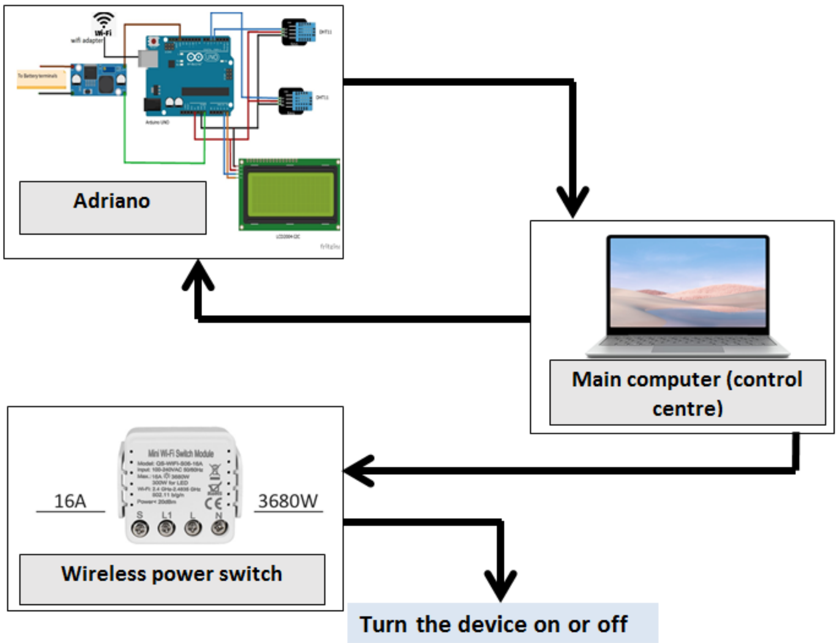


Figure 5: Wireless smart controller working mechanism

3. Results and Discussion

3.1 Effect of humidity and temperature factors

The main factors affecting the work of the water harvesting device, which were addressed as the main topic in this research paper, are the factors of temperature and humidity, as the main factors affecting the amount of water obtained [9]. Through the practical measurement of the device’s work during the period between (February to June) and by taking an average of temperature and humidity during this period of (120) days and for a working period of the device of up to (8) hours during the day, the average quantities of water were reached in the results of Table (1) below:

Table 1: Average quantities of water reached in (120) days of work

TEMPRETURE (C˚)	HUMIDITY (%)	GENERATED WATER (ml)
29	28	300
32	30	400
37	35	500
39	45	600
43	60	570
45	75	550

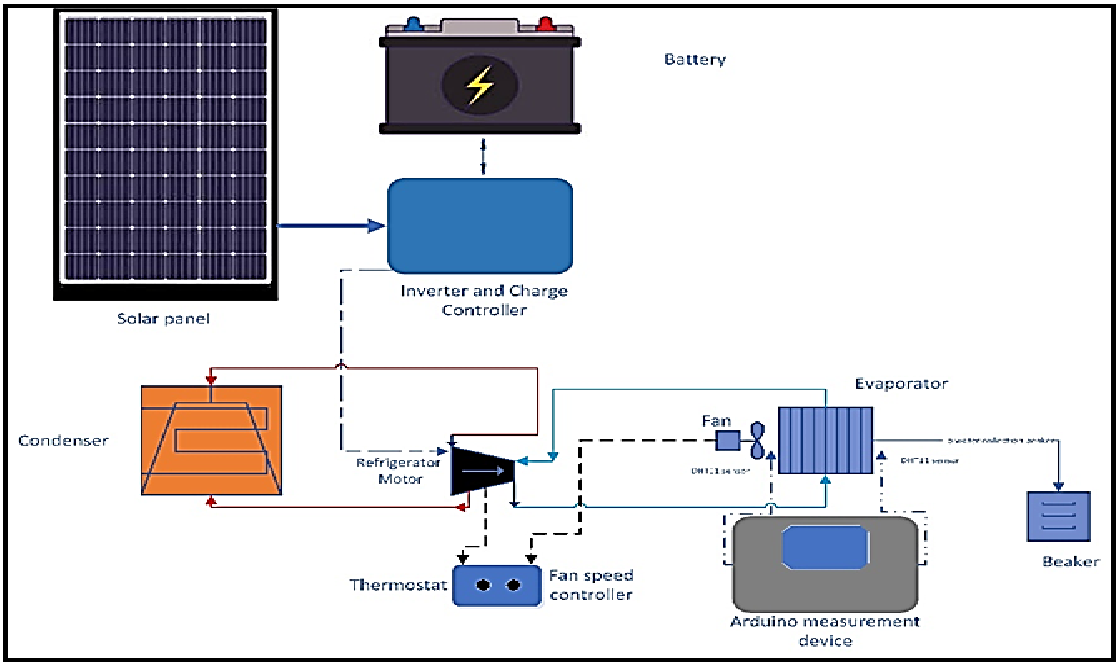


Figure 5: (1) Schematic diagram of the experimental rig

Figure 5: (2) Experimental setup

Where it was observed that with the increase in temperature to a certain extent, the humidity of the air increases, and at a temperature between (39-43) C° and humidity between (45-60)%, the device reaches the most efficient water collection capacity. It was also noted that when the temperature and humidity rise to a degree higher than the ideal values, the amount of water obtained will begin to gradually decrease again as a result of the decrease in the efficiency of the device's work at certain temperatures and humidity [10][11], which are shown in Figure 6.

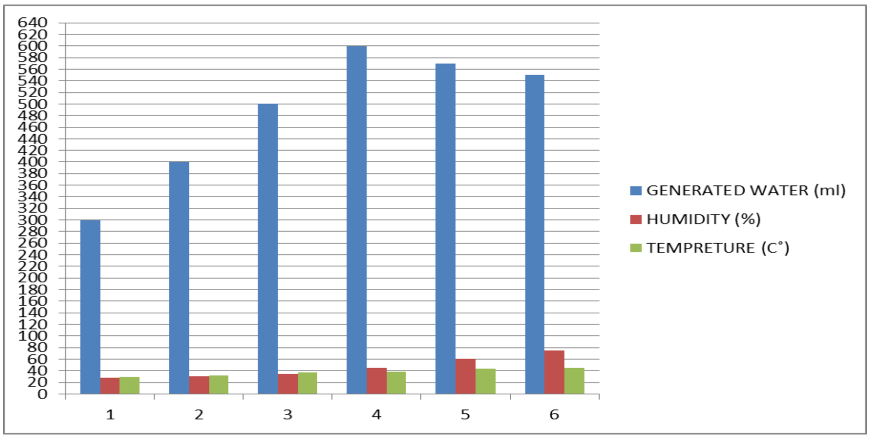


Figure 6: The relationship between effective factors and obtained water

From the curve that represents the relationship between temperature and the amount of water obtained, it was observed that the increase in temperature, up to a specific value, leads to an increase in the amount of water generated. This is because the rise in temperature leads to an increase in the evaporation of water from its natural sources, thereby, increasing the moisture of the air and increasing the amount of water generated as shown in the figure below:

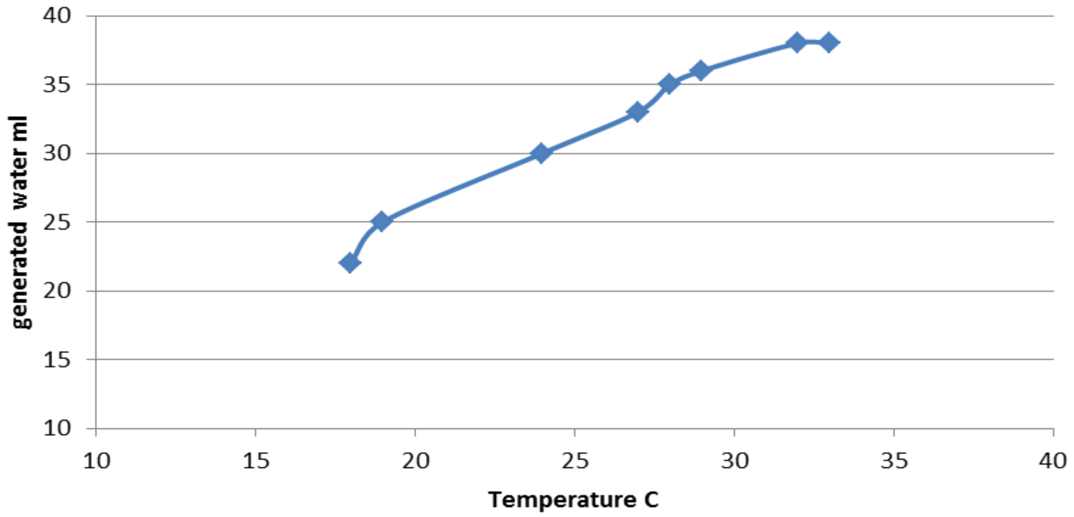


Figure 7: The relationship between temperature and the amount of generated water

It was observed that high levels of atmospheric humidity, even to a certain value, lead to an increase in the amount of condensed water on the pipes of the device and this leads to an increase in the amount of water generated [12], as shown below:

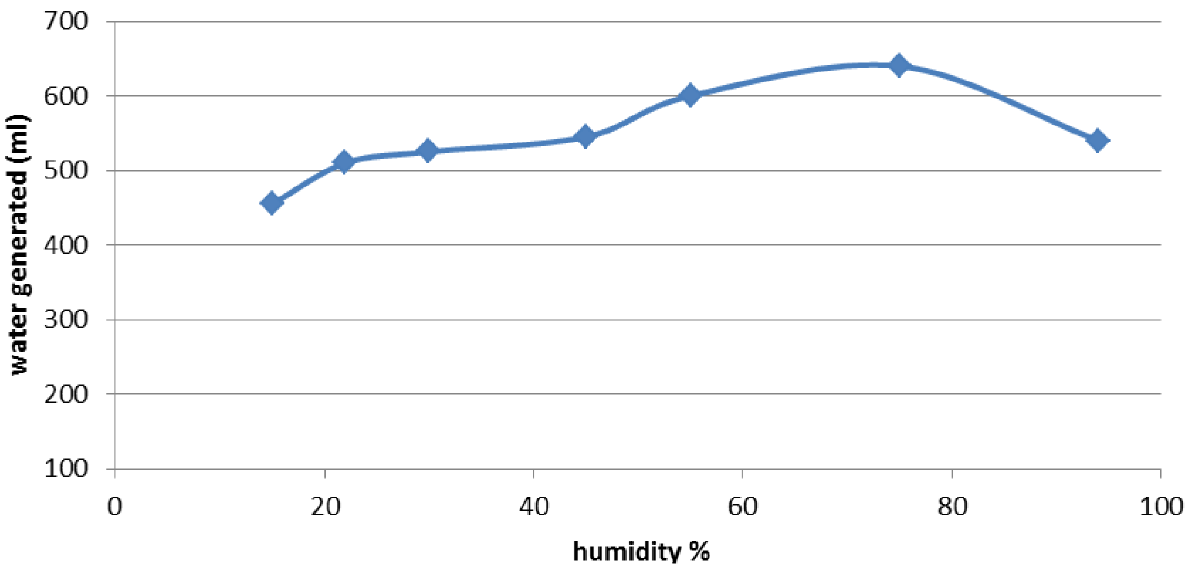


Figure 8: The relationship between humidity and the amount of water obtained

It was noted that when using an intelligent control system that controls the period of operation of the device, this will lead to obtaining quantities of water that approach to what was obtained when the device continues to operate without stopping. However, by reducing the work of the device and keeping the parts from depreciation, it was noted that during a continuous eight-hour working period, the device harvested an amount of water of about (600) ml, while during a period of intermittent work during eight hours of operation with a working period of up to six and a half hours, the device harvested an amount of water equals to (576) ml. It is considered an ideal percentage compared to the working time, as the work effort was reduced by an hour and a half and with an efficiency of 96% for water harvested amount as shown in the figures below:

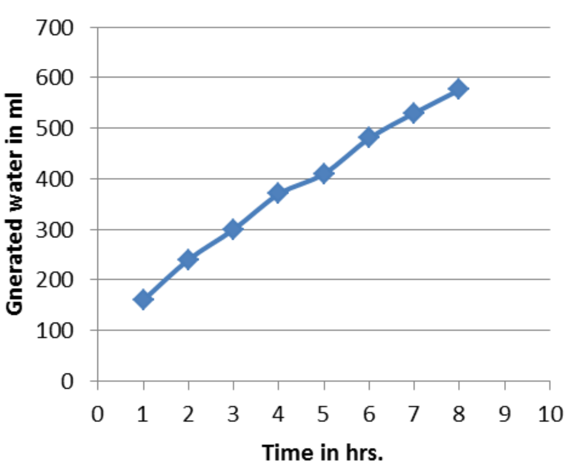
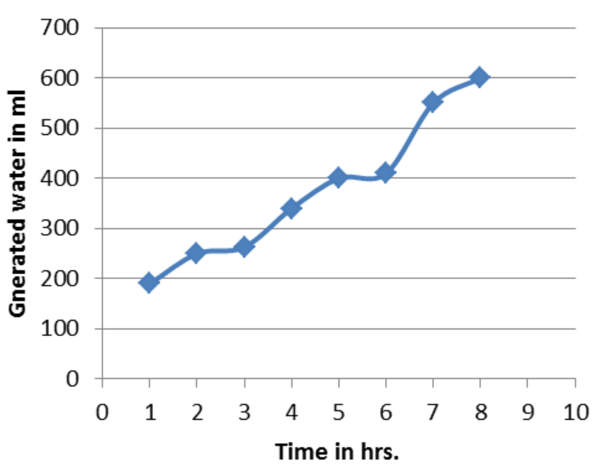


Figure 9: Device working curve with the smart control system



gure 10: Device working curve without the smart controller for controlling on/off time

3.2 Device smart controller

As the water harvesting device project uses clean solar energy, it was necessary to conserve this energy through the design of an intelligent control system that contains sensors to measure humidity and temperature factors, and thus the process of operating and extinguishing the device can be controlled depending on the efficiency of weather conditions in order to save energy [13]. The process of controlling the device is carried out through the Adriano by measuring the temperature and humidity entering and leaving the device by sensors located at the entrance and exit of the air, which gives a clearer picture of the efficiency of the device's work by measuring the difference between the temperature and humidity entering and exiting [14]. When the temperature and humidity values drop or rise below the minimum and maximum for the device's work, the Adriano system translates this information in order to turn off the device or restart it when the appropriate conditions return. The Adriano system remains effective even when the device is turned off, thereby obtaining the most efficient working capacity of the device as much as possible to save electrical energy and the longest possible life for the parts of the device used [15].

The most important reasons that prompted the use of the Adriano system as a simulation system include:

1) Easy to program and simple in working environment
2) It is highly efficient in giving results
3) Fast in translating data into practical results
4) Low cost compared to other more complex programs

4. Conclusions

The following conditions are drawn:

1) The increase in temperature led to an increase in the amount of water obtained.
2) The high relative humidity makes the air unable to carry more water vapor than it was carrying, and therefore, leading to stabilization in water intake.
3) The use of solar cells led to savings in electricity and access to clean energy.
4) The presence of the smart control saves the parts of the device from consumption and saves the energy used.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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