An Intelligent Artificial Approach Applied for Water Solar Distillation in the Algerian Sahara Area

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Received: 07-01-2023 **Accepted:** 14-07-2023 **Published:** 21-07-2023

Abstract: The problem of the water drinking supply is significant in the world, especially in developing countries, particularly in Algeria. In this work, we propose to study a distillation system based on the solar energy process using an artificial intelligence approach to enhance performance and daily production. For this purpose, a conventional solar still and capillary film solar still are in operation. The operating parameters of the two distilleries were analyzed, and the neural network approach was used to predict the performance through the amount of distillate, solar radiation, and ambient temperature. The sensitivity between the solar operating parameters for two cases has been studied through the artificial neuron network model. The obtained results are promising, analyzed, and discussed.
Keywords: Solar distillation; Intelligent artificial approach; Thermal analysis; Water treatment.

Tob Regul Sci. ™ 2023;9(1): 3630-3640
DOI: doi.org/10.18001/TRS.9.1.254

1. Introduction

Algeria has significant solar radiation due to the country's surface being sunny throughout the year. Thus, the Saharan climate is scorching in summer and moderate in winter [1-2]. All these climatic factors have enabled Algeria to become a promising candidate in the future. They can compete with the major countries in renewable energy exploitation, particularly solar thermal energy in drinking water production [3-6]. Recently, Algeria has made several investments in water desalination, particularly reverse osmosis, but this is not satisfactory because of the significant growth and demand for drinking water and industrial, thanks to the lack of a clear and well-oriented policy [7-10]. Despite this significant potential of solar energy, Algeria remains an undeveloped country in this area because of the management of these non-polluting and renewable sources of natural resources [11-14].

More works are presented in the literature that tried to enhance freshwater productivity by using diverse still condensers and geometry [15]. Idrees Khan et al [16] developed an efficient technology, Photodegradation, for removing methylene blue from wastewater. Muhammed Wahab et al [17] studied an Adsorption-Membrane Hybrid Approach for the Removal of Azithromycin from Water to Minimize Drug Resistance Problem. A detailed numerical model and experimental study for analysis of single slope conventional simple solar still presented by Dumka et al. and Sellami et al. [18-19]. A review study of different types of solar still intended for water desalination was presented by Das et al. [20]. A six-stage solar distiller was tested and studied under laboratory conditions by Huang et al. to reduce the water's salinity from 36000 to 24.56 mg/l after 2 hours [21]. The innovative methods of water desalination were carried out by introducing nanofluids in the form of metal nanoparticles to enhance the heat transfer and the amount of distillate produced by about 30% [22]. Sharshir et al. proposed using the phase change material (PCM) for water desalination to enhance freshwater productivity. The maximum productivity enhancement obtained is about 65% compared with conventional methods of solar still [23]. Different applications, technical characteristics, and designs of solar still are presented by Katekar et al., Patel et al., Srithar et al., Arunkumar et al., and Omara et al. [24-28].

A few research in literature dedicated to studying the capillary film solar still is published by Bouchekima et al. [11] and Zerrouki et al. [4]. Bouchekima et al. studied in detail one and two-stage of a distiller with a film in capillary called DIFICAP in Sahara regions; the maximum distillate production is estimated between 0.38 and 0.65 (l/hm)2 for one and two-stage, respectively [29-30]. Later, Zerrouki et al. and Belhadj et al. proposed a simplified and detailed numerical model that characterizes thermophysical phenomena related to the capillary film solar still [3-4].

In this research work, we present the problem of water production through solar distillation due to the importance of this research theme. The purpose of this paper is to propose using artificial neural networks to optimize the distillation system through specific parameters of the operation of a conventional solar still and capillary film solar still. The obtained results, including solar radiation, ambient temperature, and daily water production, are analyzed and discussed.

2. Materials and Methods

2.1 Experimental apparatus

The system presented in Figure 1 consists of a sealed capacity surmounted by a glass. The lower part is covered with a body of water (saline water). Under the action of solar radiation transmitted by the glass cover, the water heats up, and part of it evaporates. The steam produced condenses inside the glass, and a receiver collects the condensate. Adding water compensates for the distillate flow.

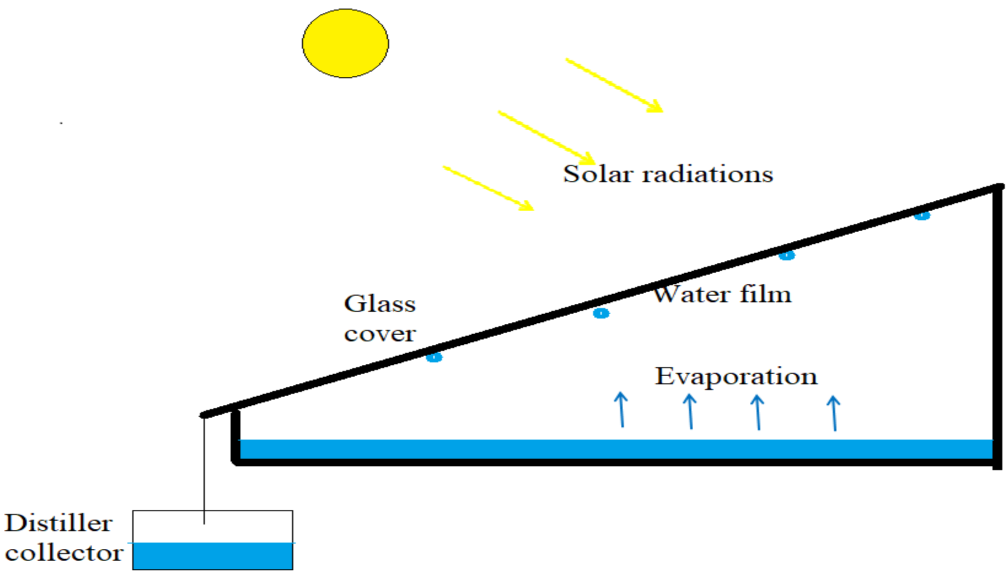

Figure 1. Schematic diagram of a conventional solar still.

In capillary film solar still presented in figure 2, the feed water flows slowly through a porous packing, absorbing radiation (wick). Two advantages are claimed over pond distillers. First, the wick can be tilted, so the feed water has a better angle to the sun (reducing reflection and having a large effective area). Second, less feed water is in the distiller at any time, so the water is heated faster and to a higher temperature.

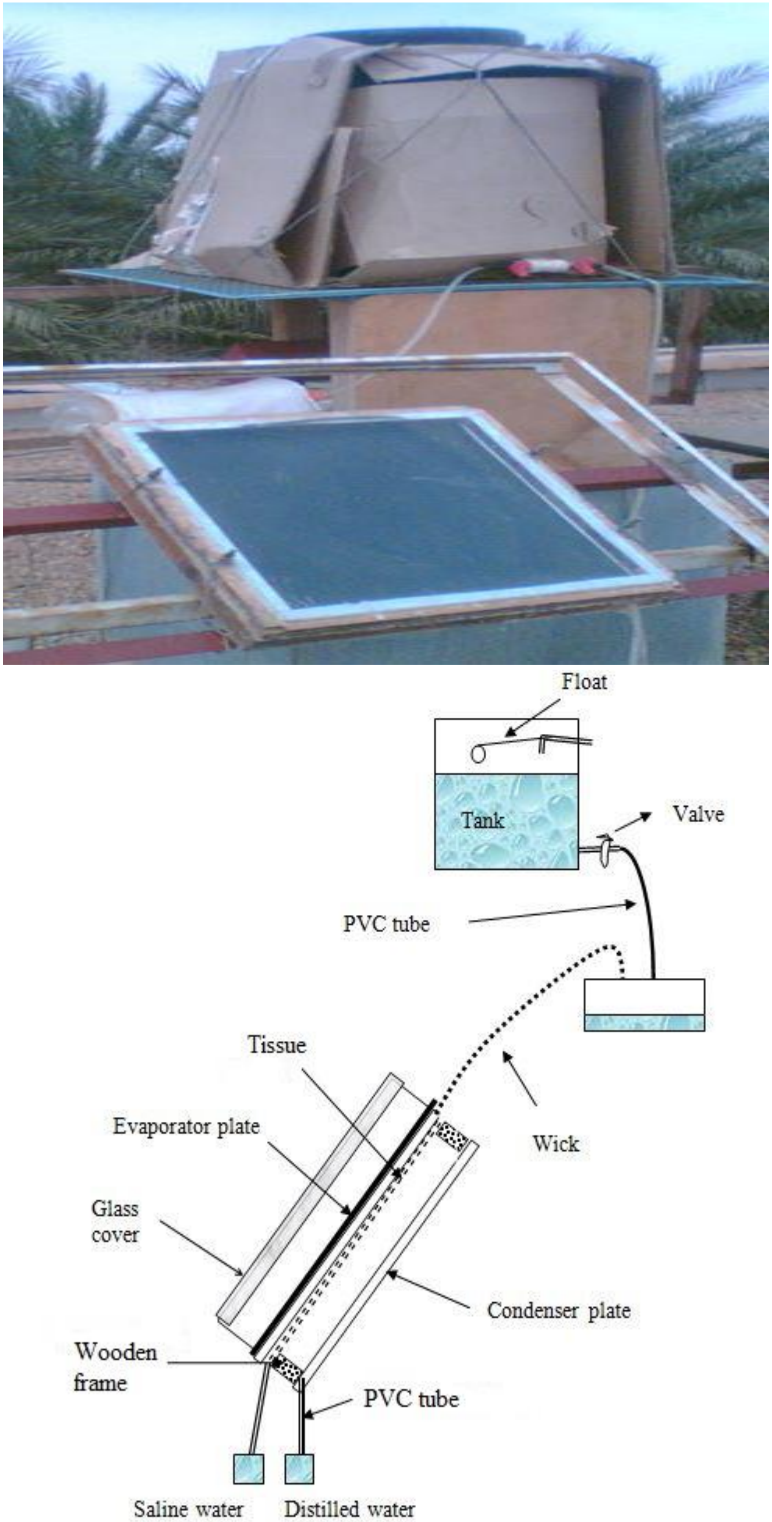

Figure 2. Experimental apparatus and Schematic diagram of capillary film solar still.

The experimental measurements have been carried out under the following assumptions and considerations:

-The brackish water is characterized by a salinity that exceeds 1.5 g/l. According to OMS standards, the salinity must be lower or equal to 0.5 g/l

-The fabric used is hydrophilic gauze (100 %kinds of cotton)

-The flow rate of feed water is 0.6 l/h

-The area of DIFICAP is 0.5x0.5 m^2

-The thermal conductivity of tissue is 0.028 $W.m^{-1}. K^{-1}$

Table 1 shows the dimensions and thermophysical properties of the capillary film solar still (DIFICAP) used in this work for experimental measurements.

T**able 1.** Dimensions and thermophysical properties of the capillary film solar still

Parameters	**Evaporator**	**Condenser**	**Glass**
Conductivity (W/mK)	20	20	0.78
Density (kg/m3)	7864	7864	2700
Heat capacity (J/kg K)	460	460	840
Thickness (m)	0.001	0.0006	0.003
Surface (m2)	1	1	1
Emissivity (-)	0.2	0.2	0.9
Absorptivity (-)	0.95	0.95	0.1
Distance (m) (Glass-evaporator)	0.05		
Distance (m) (Glass-condenser)	0.04		

2.2 Artificial neural networks approach

Artificial Intelligence is a branch of fundamental computing developed to simulate the behavior of the human brain. In 1943 Mc Culloch and Pitts proposed the first notions of the formal neuron [31]. This concept was then networked with Rosenblatt's entry and exit layer in 1959 to simulate retinal functioning and try to recognize shapes [32]. This is the origin of the perceptron. A biological neuron is a cell that is characterized by:

- synapses, the connection points with other neurons, nerves, or muscle fibers.
- Dendrites or inputs of the neurons.
- The axons, or outputs of the neuron to other neurons or muscle fibers.
- The nucleus activates the outputs according to the input stimulations.

Figure 3 showing in detail that the principle of an artificial neural network is based on the following steps [14]:

- The input variables and the output variable.
- The architecture of the network: the number of hidden layers corresponding to an ability to deal with the problem of neurons per hidden layer. These two choices directly condition the number of

parameters to be estimated and, therefore, the complexity of the model. They participate in the search for a good compromise bias/variance, i.e., the balance between quality of learning and forecast quality.

· Other parameters are involved in this compromise: the maximum number of iterations and the maximum error tolerated.

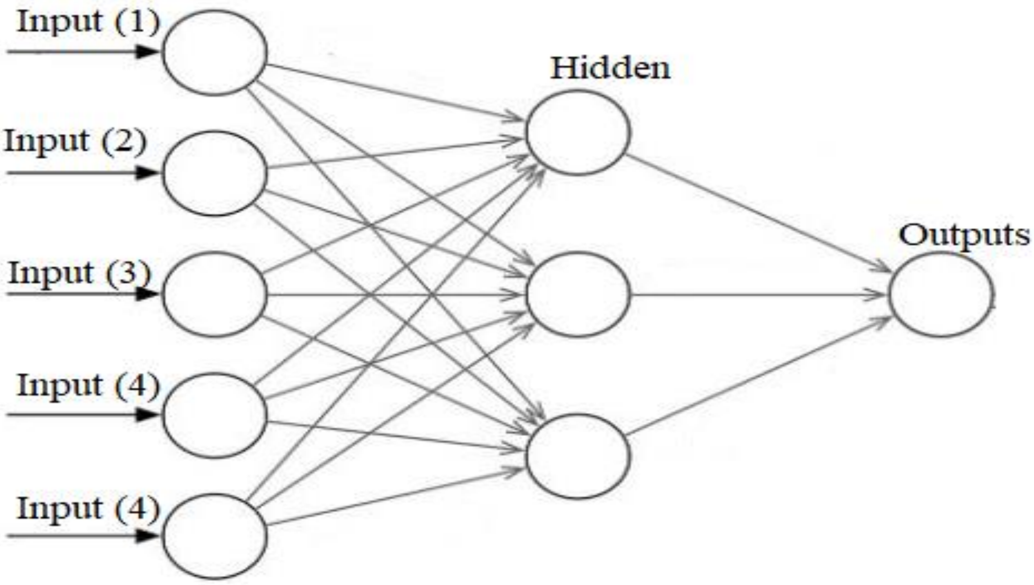

Figure 3. Schematic diagram of an artificial neural networks approach.

3. Results and discussions

Figure 4 shows the solar radiation measurements for a typical day in June and July for Ouargla city, located in southeastern Algeria, which presents a Saharan climate. The solar radiation has a bell-like shape and is symmetric with a progressive evolution over time, then reaches its maximum almost at 01 PM for the two typical days of the month.

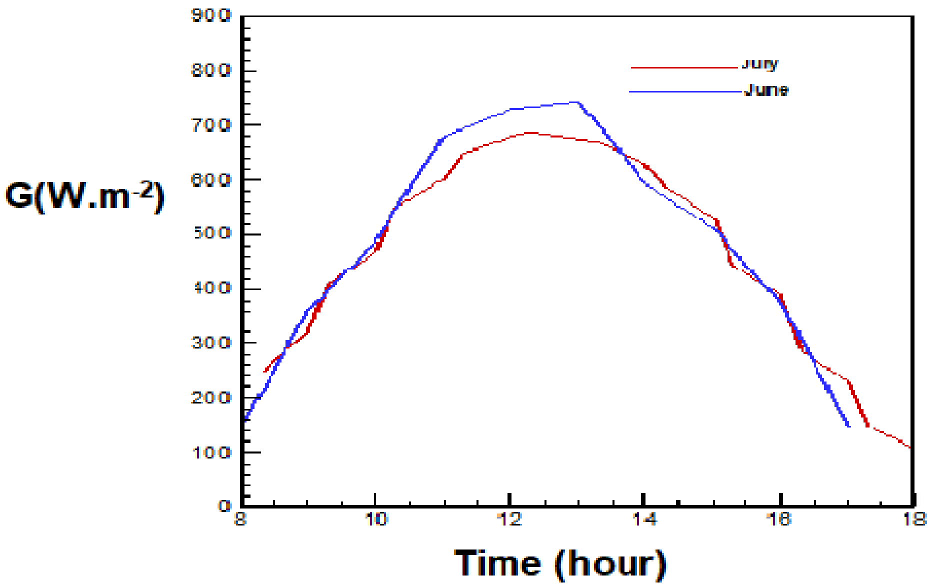

Figure 4. Measurement of solar radiations as function of time in Ouargla city for typical days in July and June

Figure 5 illustrates the ambient temperature measurement and the daily water distilled as a function of time in Ouargla city for a typical day in June. The ambient temperature curve fluctuates during the day and reaches the maximum value at 02 PM. The temperature fluctuations may be due to cloudy weather. Thus, in the exact figure with a different scale, we have represented the evolution of the volume of distilled water during the day. A gradual increase was noted and reached its maximum of about 370 ml at 06 PM.

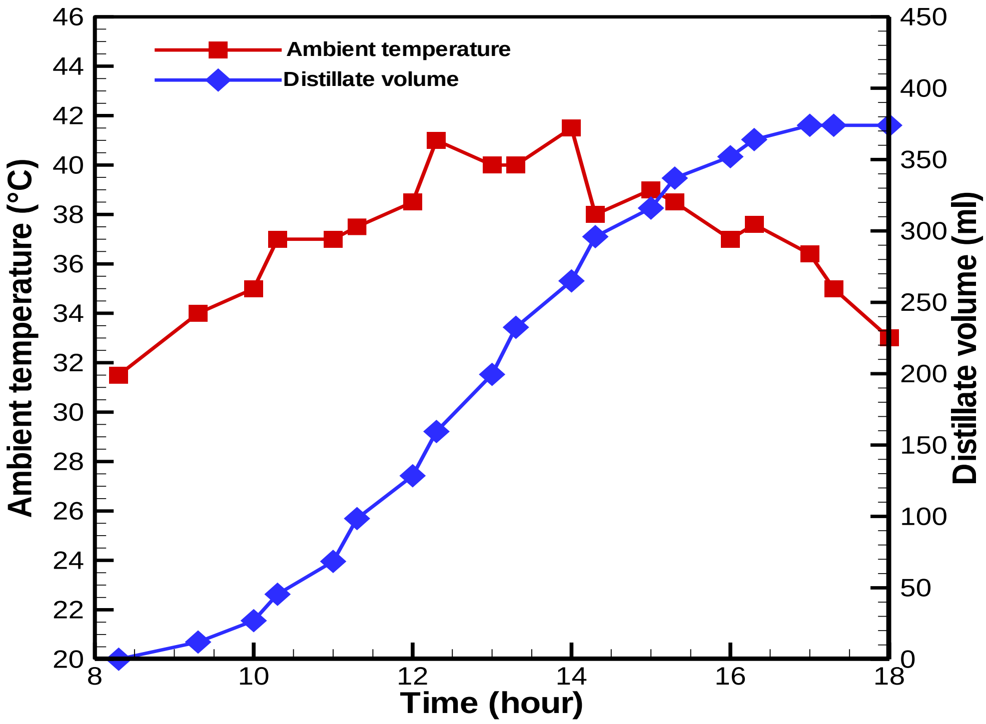

Figure 5. Ambient temperature measurement and the daily water distilled as function of time in Ouargla city for typical day in June.

The performance of a conventional solar still and capillary film solar still has been investigated using an artificial neural network method.

For the obtained results, the mean square (MSE) and the error between experimental measurement and predicted values can be calculated respectively by using equations (1) and (2).

$$MSE = \sum_{i=1}^{m} \frac{\left(d_{\exp i} - d_{prid\, i}\right)^2}{m} \qquad (1)$$

$$E_r = \left| \frac{d_{exp} - d_{prid}}{d_{exp}} \right| \times 100 \qquad (2)$$

The typical results obtained from numerical solar simulation still have been carried out using artificial neural networks between predicted and experimental values.

Figure 6 shows the correlation between experimental data and daily production predictions of the simple distiller (Case of conventional solar still).

A correlation coefficient R = 0.99992 is shown in Figure 6 for different inputs values of the model of the artificial neural network presented in Figure 7, which is obtained between the predicted and experimental values according to the data presented in Table 2, which acts to study the effect of ambient temperature, insulating temperature, basin temperature and water temperature on daily production stabilized over time. The total mean error value obtained between the experimental and predicted results is about 0.97%. The value of this error is deficient and indicates that the capacity of the proposed model is perfect for the production /day prediction for various operating parameters of the simple solar distiller.

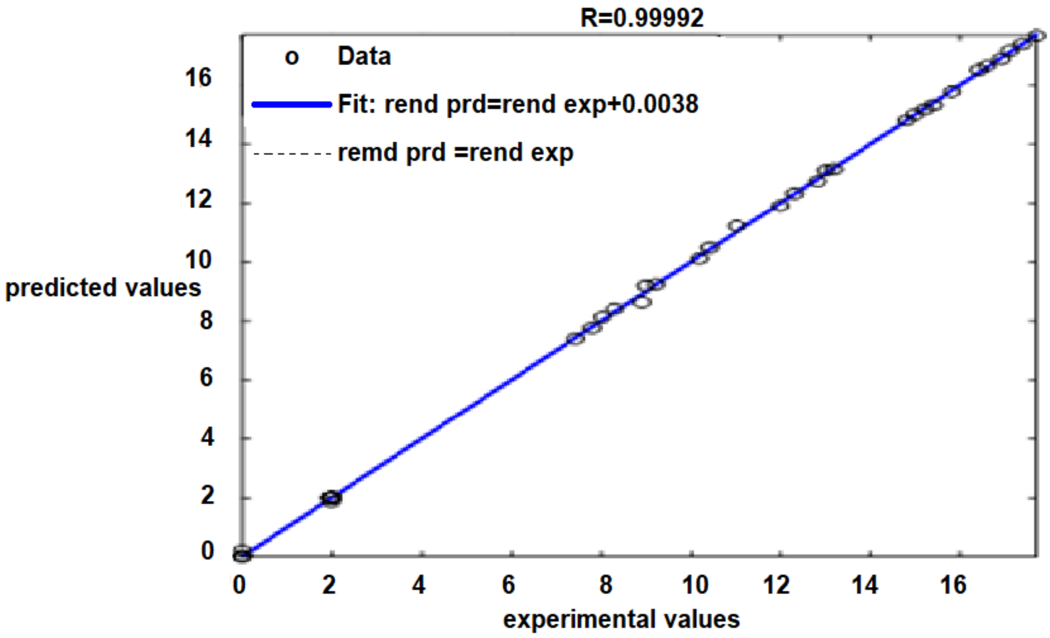

Figure 6. Correlation between experimental data and daily production predictions of the simple distiller (Case of conventional solar still).

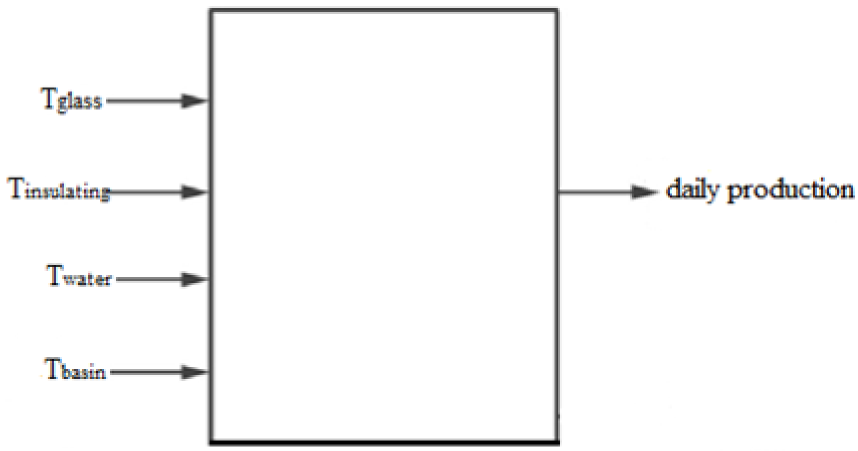

Figure 7. Neural networks architecture used for a solar distiller simple.

Also, figure 8 illustrates the Correlation between experimental data and daily production predictions of the simple distiller (Case of capillary film solar still) with a correlation coefficient of R = 0.99952. it is clear that the difference between the two correlations in the conventional case and the capillary film solar still can be neglected; the error is almost zero.

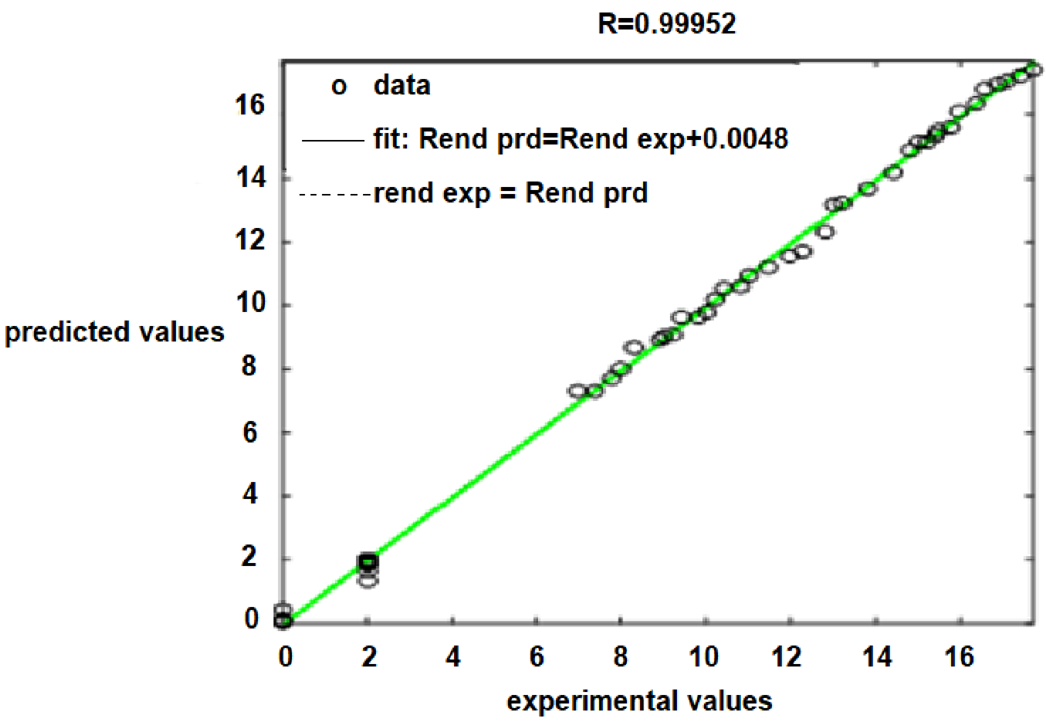

Figure 8. Correlation between experimental data and daily production predictions of the simple distiller (Case of capillary film solar still).

Figure 9 presents a schematic diagram for different input values injected in the artificial neural network model for conventional solar still and capillary film solar still.

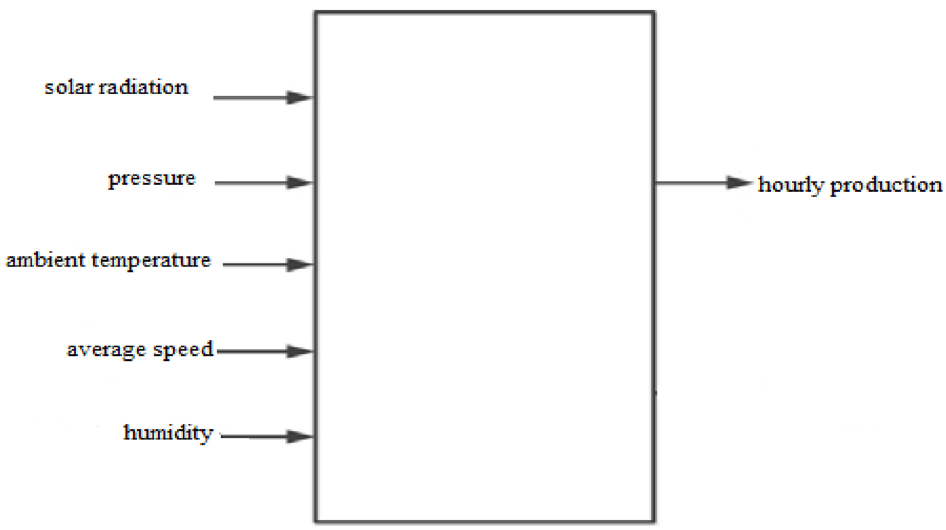

Figure 9. Relationship between the input and output data in the neuron network.

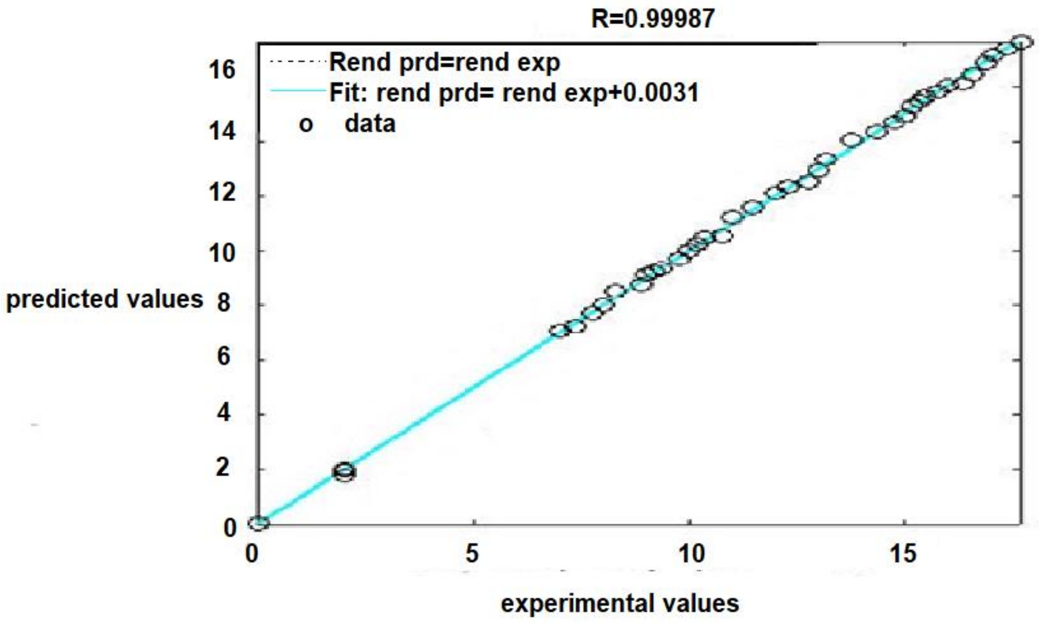

Figure 10. Correlation between experimental data and daily production predictions of the simple distiller (Case of conventional solar still).

Figure 10 illustrates a good agreement between the predicted and experimental values with a regression coefficient of 0.99987 for the conventional solar still.

Also, figure 11 shows the variations of the experimental values as a function of the predicted values for the architecture presented in figure 9. In this case, a regression coefficient of 0.99751 was noted for capillary film solar still.

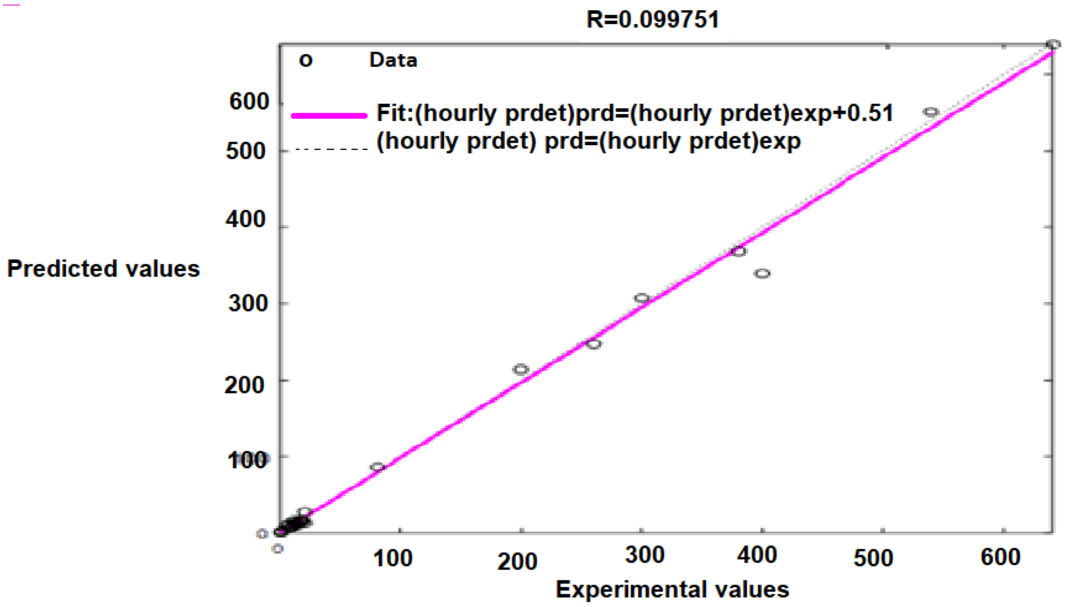

Figure 11. Correlation between experimental data and daily production predictions of the simple distiller (Case of capillary film solar still).

Table 2. Values of the training parameters worked with in the Neural network model of daily production

Neural networks parameters	Number of input layer	Number of output layer	Train Function	Transfer function	Performance function	Error after learning	Train epochs
Values and nomination in MATLAB	05	01	TRAINLM	TANSIG	MSE	0.001	1000

5. Conclusions

The city of Ouargla has a large solar field, and solar radiation measurements have verified this during the year's hottest months. Similarly, concerning the ambient temperature. A parametric study based on an artificial neural networks model was carried out for two types of still in order to show the reliability of solar distillation.

Using an artificial neural network approach, the investigation of thermal parameters of conventional solar still and capillary film solar still is affected. This study was conducted to develop models of artificial neural networks used to predict the daily production of a solar distiller. The following conclusion can be noted the excellent performance of a conventional solar still and capillary film solar still using artificial neural networks for the prediction of daily production with a correlation coefficient of about 0.99987 and 0.99751, respectively, corresponding to experimental regression values for the first case presented in figure 7 and about 0.99992 and 0.99952 for the second case presented in figure 9.

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