Article

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

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Abstract: The problem of water drinking supply is very important in the world, especially for developing countries, in particular Algeria. In this work we propose to study a distillation system based on solar energy process using an artificial intelligence approach in order to enhance the performance and the daily production. For this purpose, a conventional solar still and capillary film solar still was used. The operating parameters of the two distilleries are 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 operating parameters of the solar still for two cases have 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

1. Introduction

The introduction Algeria has significant solar radiation seen owing to the surface of the country sunny throughout the year. Thus, the Saharan climate is very hot in summer and moderate in winter [1-2]. All these climatic factors have enabled Algeria to become a promising candidate in the future and can be compete with the major countries in the field of renewable energy exploitation, particularly solar thermal energy in the field of drinking water production [3-6]. Recently, Algeria has several investments in water desalination, in particular reverse osmosis, but this is not satisfactory because to the great 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 tried to enhance the freshwater productivity by using diverse still condensers and geometry [15]. 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. [16-17]. A review study of different types of solar still intended for water desalination was presented by Das et al. [18]. A six stage of solar distiller was tested and studied under laboratory conditions by Huang et al. in order to reduce the salinity of the water from 36000 to 24.56 mg/l after 2 hours [19]. The innovative methods of water desalination were carried out by introducing nanofluids in the form of metal nanoparticles in order to enhancing the heat transfer and the amount of distillate produced about 30% [20]. Sharshir et al. proposed to use the phase change material (PCM) for water desalination in order to enhancement of freshwater productivity. The maximum productivity enhancement obtained is about 65% compared with conventional methods of solar still [21]. A different applications, technical characteristic and designs of solar still

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are presented by Katekar et al., Patel et al., Srithar et al., Arunkumar et al. and Omara et al. [22-26].

A few research in literature dedicated to study 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 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 [27-28]. Later, Zerrouki et al. and Belhadj et al. are proposed, a simplified and detailed numerical model 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 article is to propose the use of artificial neural networks for the optimization of the distillation system through certain parameters of the operation of a conventional solar still and capillary film solar still. The obtained results including solar radiations, the ambient temperature and the daily production of water are analyzed and discussed.

2. Materials and Methods

2.1 Experimental apparatus

The system presented in Figure 1, consists essentially 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 radiations, transmitted by the glass cover, the water heats up and part of it evaporates. The steam produced condenses on the inside of the glass and the condensate is collected by a receiver. Adding water compensates for the distillate flow.

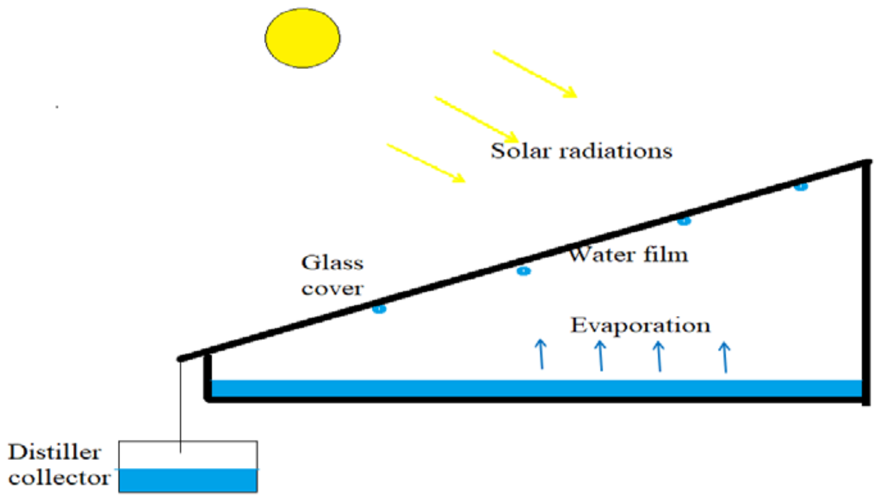

Figure 1. Schematic diagram of a conventional solar still

In a 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 that 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.

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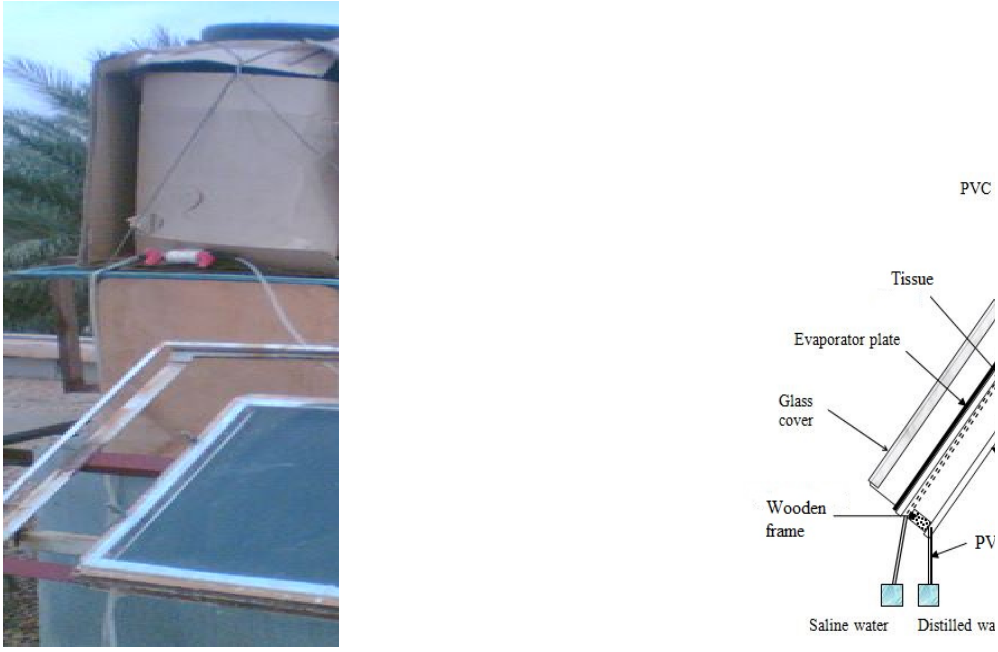

Figure 2. Experimental apparatus and Schematic diagram of capillary film solar still

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

-The brackish water is characterized by a salinity which 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٪ cotton)

-The flow rate of feed water is 0,6 l/h

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

-The thermal conductivity of tissue is 0,028 $W.m^{-1}. K^{-1}$

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

Table 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, a branch of fundamental computing developed with the objective of simulating the behavior of the human brain. In 1943 Mc Culloch and Pitts proposed the first notions of formal neuron [29]. This concept was then networked with an entry and exit layer by Rosenblatt in 1959 to simulate retinal functioning and to try to recognize shapes [30]. This is the origin of the perceptron. A biological neuron is a cell that is characterized by:

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

The fig.3 showing in detail 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 which corresponds 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 also involved in this compromise: the maximum number of iterations, the maximum error tolerated.

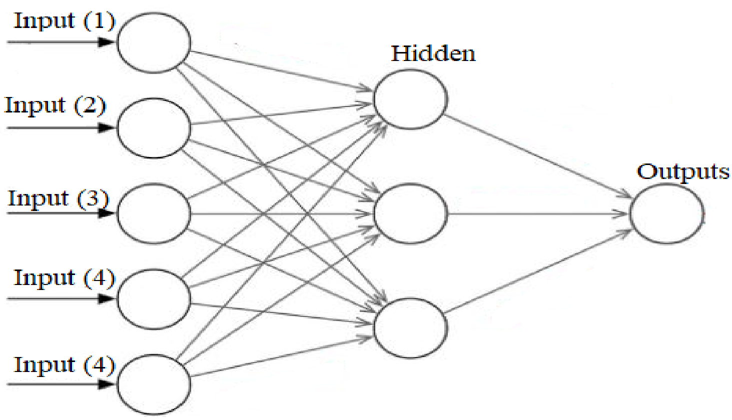

Figure 3. Schematic diagram of an artificial neural networks approach

3. Results and discussions

This The figure 4 shows the measurements of solar radiation for a typical day of June and July for Ouargla city located in southeastern of Algeria, which presents a Saharan climate. The solar radiation has a bell-like shape and symmetric with a progressive evolution over time then reaches its maximum almost at 13h00 for the two typical days of the month.

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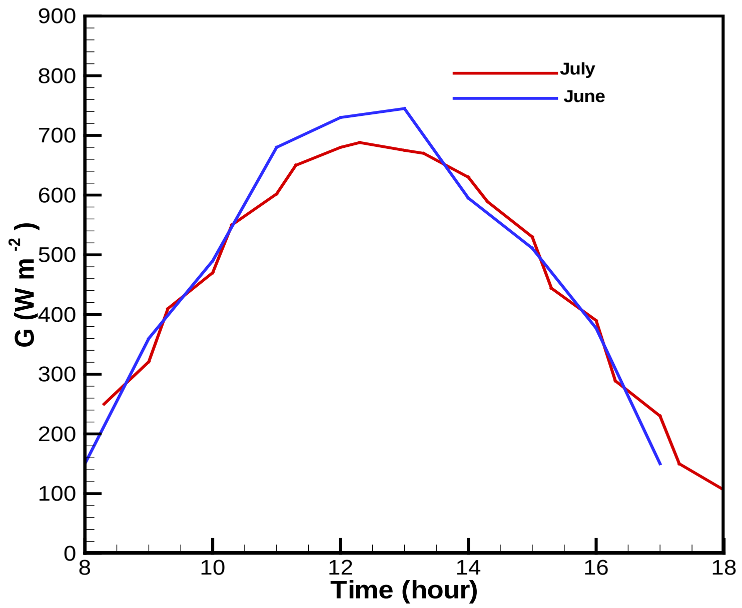

Figure 4. Measurement of solar radiations as function of time in Ouargla city for typical days in July and June

The figure 5 illustrates the ambient temperature measurement and the daily water distilled as function of time in Ouargla city for typical day in June. The ambient temperature curve fluctuates during the day and reaches the maximum value at 14h00. The temperature fluctuations may be due to cloudy weather. Thus, in the same 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 about 370 ml at 18h00.

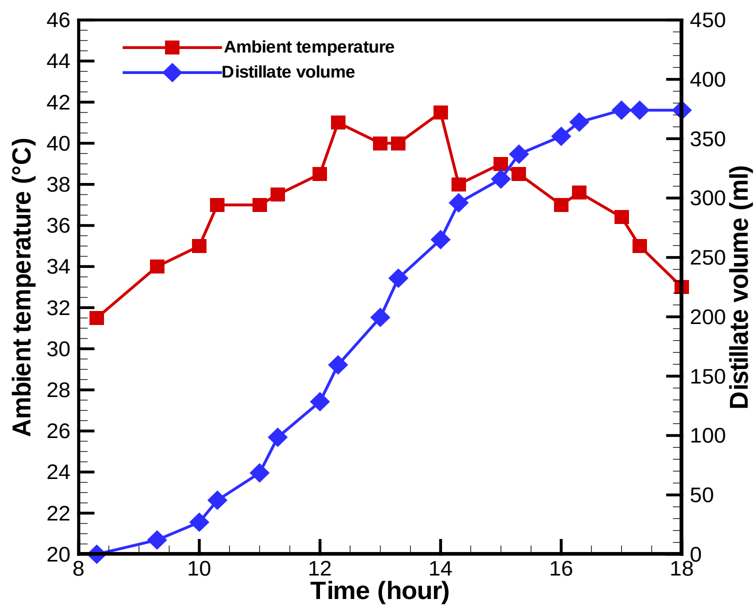

Figure 5. Ambient temperature measurement and the daily water distilled as function of time in Ouargla city for typical day in June.

The investigation of performance of a conventional solar still and capillary film solar still has been caried out by using an artificial neural networks method.

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

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

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

The typical results obtained from numerical simulation of solar still has been carried out by using artificial neural networks between predicted values and experiment 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 of R = 0.99992 shown in Figure 6 for different inputs values of the model of the artificial neural network presented in figure 7 which 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 found about 0.97%. The value of this error is very low and indicates that the capacity of the proposed model is very good for the production /day prediction for various operating parameters of the simple solar distiller.

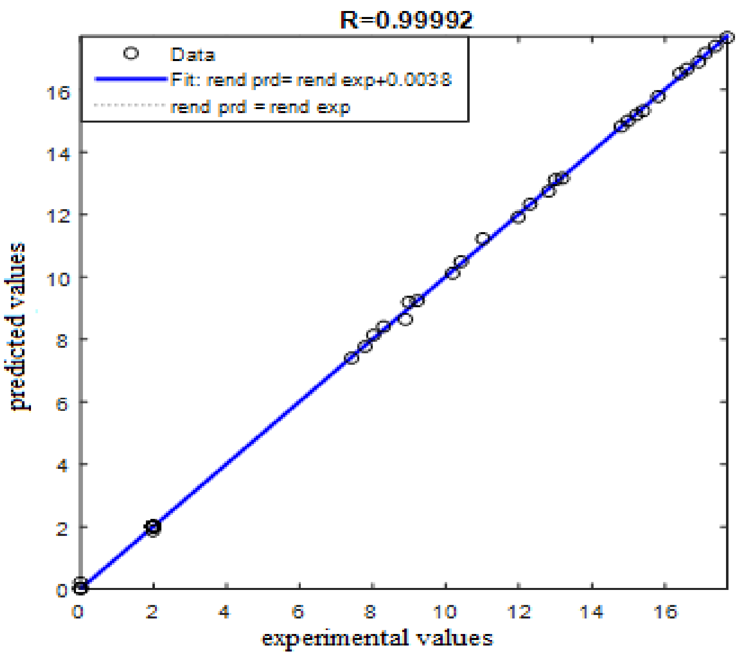

Figure 6. Correlation between experimental data and daily production predictions of the simple distiller (Case of conventional solar still).

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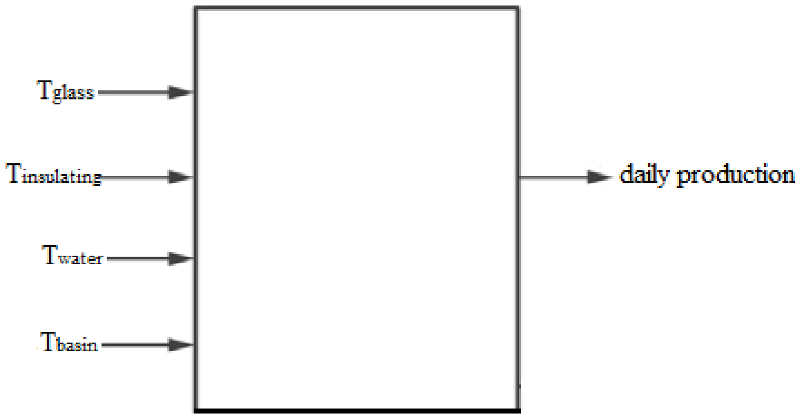

Figure 7. Neural networks architecture used for a solar distiller simple

Also, the 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.

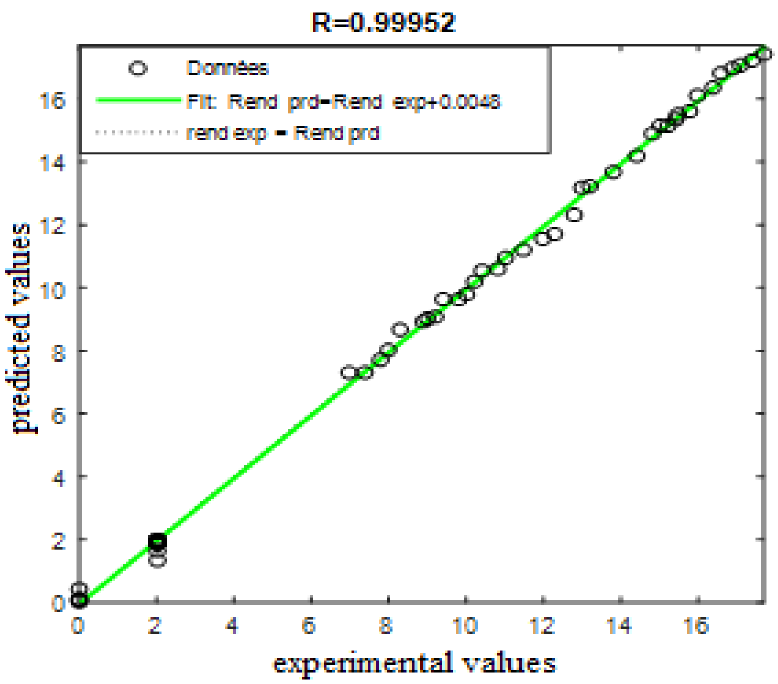

Figure 8. Correlation between experimental data and daily production predictions of the simple distiller (Case of capillary film solar still).

The figure 9 presents a schematic diagram for different inputs values used injected in model of the artificial neural network for conventional solar still and capillary film solar still.

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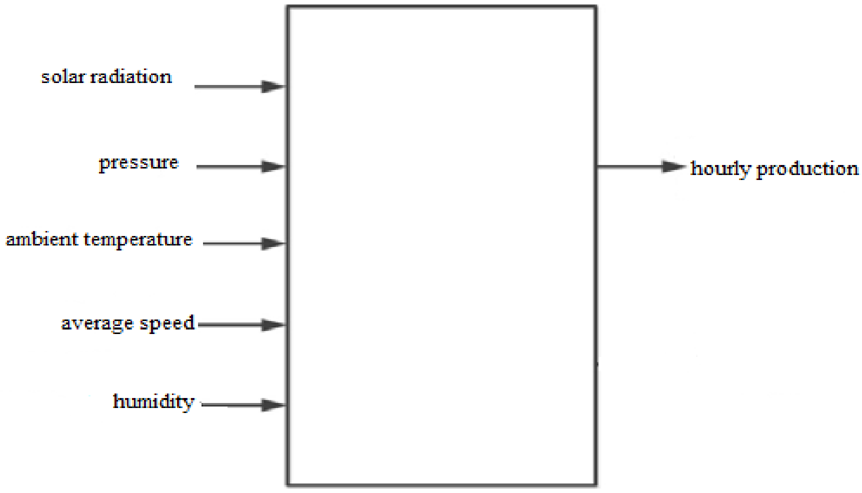

Figure 9. Relationship between the input and output data used in the neuron network

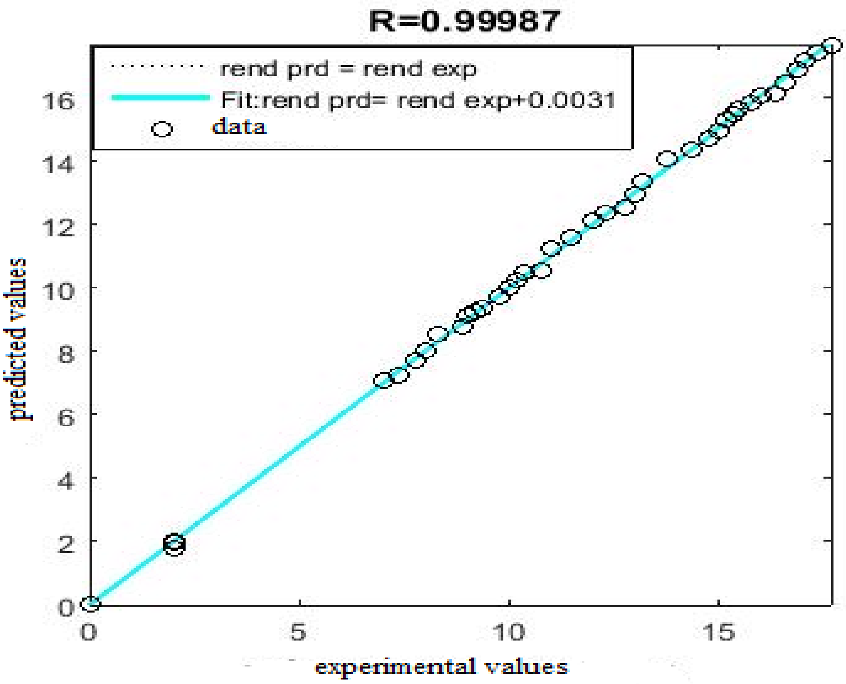

Figure 10. Correlation between experimental data and daily production predictions of the simple distiller (Case of conventional solar still).

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

Also, the 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 the order of 0.99751 was noted for capillary film solar still.

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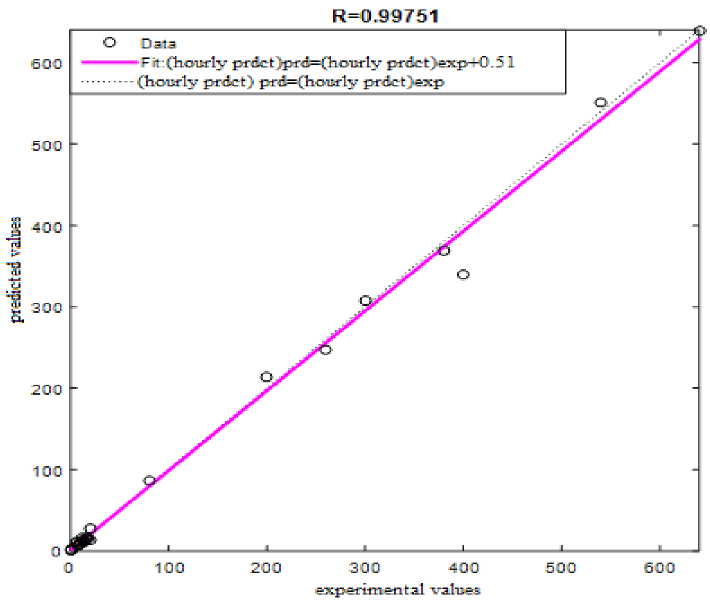

Figure 11. Correlation between experimental data and daily production predictions of the simple distiller (Case of capillary film solar still).

Table 2. Values of the training parameters used 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

3.1. Subsection

3.1.1. Subsubsection

5. Conclusions

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

The investigation of thermal parameters of conventional solar still and capillary film solar still is affected by using artificial neural networks approach. This study was conducted to develop models of an artificial neural networks used to predict the daily production of a solar distiller. The following conclusion can be noted the good 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 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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