The thermal system for solar desalination working with photovoltaic system panels and flat plate collectors

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Abstract: Membrane distillation is a thermal process, which water vapor is transported through a hydrophobic porous membrane to obtain distilled water. This confirms that the thermal system has a very important role in this process. For therefore, has been validated a model for forced circulation solar water heating systems with flat plate collectors. The total volume of daily consumption is 600 L/day. Therefore, the energy needed has calculated for this thermal system, the amount of solar panels required to provide the energy required was added and calculated in the thermal system. Accordingly, have been made a complete system combining the solar power system using energy storage battery and thermal system. The power of the battery is estimated at 1.2 KW. The purpose of this study is the use of solar panels in Photovoltaic system and flat plate collector to produce the necessary energy for the use it of thermal system of membrane in the state Ain-Temouchent, Algeria. Will be this study using the program TRNSYS and PVGIS.

Keywords: Membrane distillation, Solar water heater, Flat plate collector, Photovoltaic system, TRNSYS.

1. Introduction

Several techniques of drinking water production are put in place to meet the needs of the growing population. Vacuum membrane distillation appears as an attractive solution with a free energy source [1]. Several types of membrane distillations exist. These include Direct Contact Membrane Distillation (DMCD), Vacuum Membrane Distillation (DMV), Air Gap Membrane Distillation (AGMD) [2], and Permeate-gap Membrane Distillation (PGMD)[3]. In this study, the performance of the thermal system plays a major role in the desalination of water resulting from membrane distillation. This is why have manufactured a water-heating model for the distillation membrane using solar energy that reduces the cost of this thermal system. The use of solar energy considerably reduces the operating costs; however, its intermittent nature requires a non-stationary optimal operation that can be achieved by means of advanced control strategies. In this study, we hope to conceive a control system that will be used for this thermal system for distillation membrane throughout the year in the weather of the state Ain Temouchent, Algeria. This was done with the help of TRNSYS and PVGIS programs [4],[5].

2. Description of the thermal system

The studied system contains the thermal energy loop, as shown in figure 1. The system incorporating a flat plate collector (FPC) with an area of 20 m2 providing heat via a freshwater heat transfer fluid to a storage tank containing 300L with heat exchanger internal and auxiliary heaters, a pump and a controller in differential temperature. Figure 2 shows the total volume of daily consumption 600 L/day and the volume of consumption in each hour of the day. This model is studied in the weather of the state Ain-Temouchent (latitude 35°3′0″ N, longitude 1°1′0″ E in Algeria).

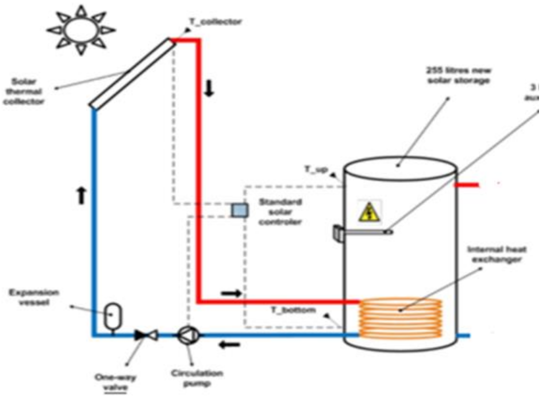


Fig. 1 solar hot water system.

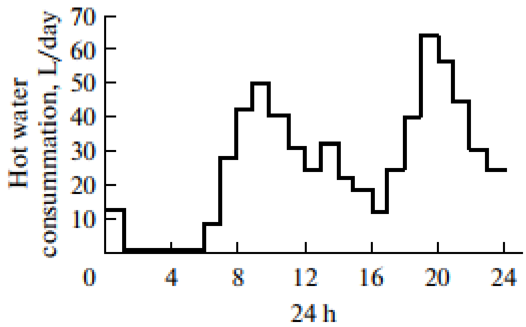


Fig. 2 Daily hot water consumption profile (600 L/day) in Ain Temouchent [1].

3. Modelling

3. 1. TRNSYS Model

The model of solar water heating system was developed using transient simulation software TRNSYS, as shown in Figure 3. The following solar system components will be used:

- Reading and processing of meteorological data (TYPE109-TM2)
- Single speed pump (Type 3b)
- Flat plate collector (Type 1b)
- Storage tank with optional internal auxiliary heaters and optional internal heat exchangers with 1 input and 1 output (Type 60d)
- Distribution Water Supply Profile (Type 14e)
- Differential temperature controller (Type 2b)
- Online plotters with files (Type 65c)

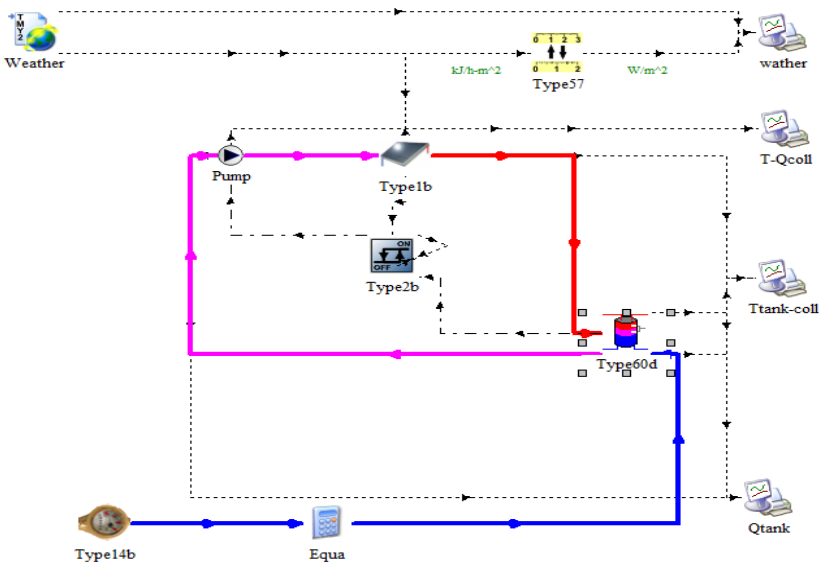


Fig.3 Assembly diagram of the solar system in the TRNSYS simulation.

The parameters of the solar system components of this model appear in the tables below :

Table 1 :

Hot water cylinder		
Parameters	Value	Unit
Tank volume	300	l
Tank height	1.42	m
Height of flow inlet 1	0.215	m
Height of flow outlet 1	1.415	m
Fluid specific heat	4.19	$kj.kg^{-1}k^{-1}$
Heat exchanger inside diameter	0.01	m
Heat exchanger outside diameter	0.012	m
Heat exchanger fin diameter	0.012	m
Total surface area of heat exchanger	1.4	m^2
Heat exchanger length	32	m
Heat exchanger wall conductivity	1.8	$kJ.hr^{-1}\ m^{-1}\ K^{-1}$
Heat exchanger material conductivity	1.8	$kJ.hr^{-1}\ m^{-1}\ K^{-1}$
Height of heat exchanger inlet	0.905	m
Height of heat exchanger outlet	0.215	m

Table 2 :

Solar collector parameters		
Parameters	Value	Unit
Number in series	1	-
Collector absorber area	20	m^2
Fluid specific heat	4.19	$kj.kg^{-1}k^{-1}$
Collector slope	45	Degrees

Table 3 :

Pump parameters		
Parameters	Value	Unit
Rated flow rate	200	$kg.hr^{-1}$
Fluid specific heat capacity	4.19	$kj.kg^{-1}k^{-1}$

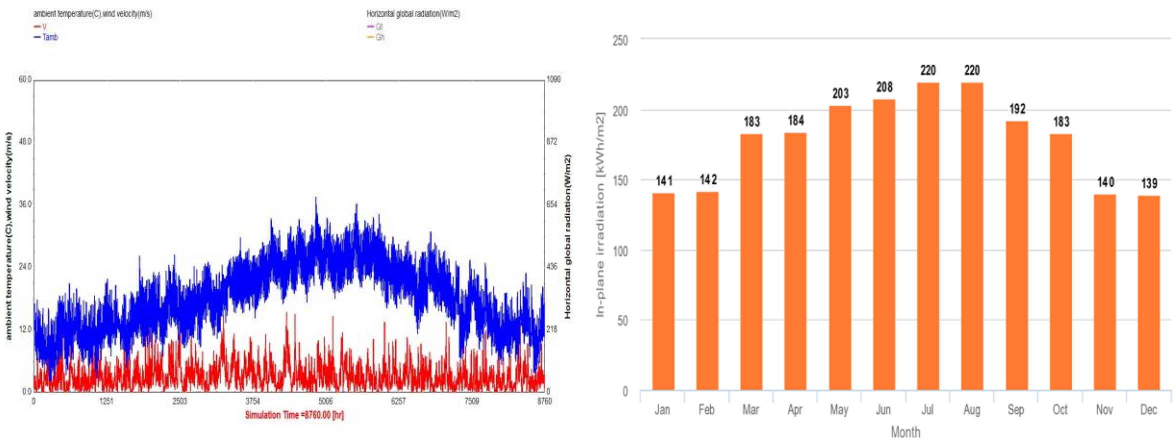
3. 2. Weather data

This model is installed in Ain-Temouchent weather (latitude 35 ° 3'0 "N, longitude 1 ° 1'0" E in Algeria). Figure 4 shows changing climate conditions throughout the year

The weather of the state Ain-Temouchent is pleasant, warm and moderate in general. At an average temperature of 25.7 degrees Celsius, August is the hottest month of the year. At 10.8°C on average, January is the coldest month of the year. And Therefore, in this figure 4a, we notice a change in temperature throughout the year, which reaches up to 40 degrees Celsius in the month of August, and we note that the wind is fairly moderate and does not exceed the speed of the this one 15 m/s. For the irradiation, it changes during the months of the year and reaches up to 220 KWh/m² in the month of August and July, as shown in figure 4b, because the temperature be high in this period of the year.

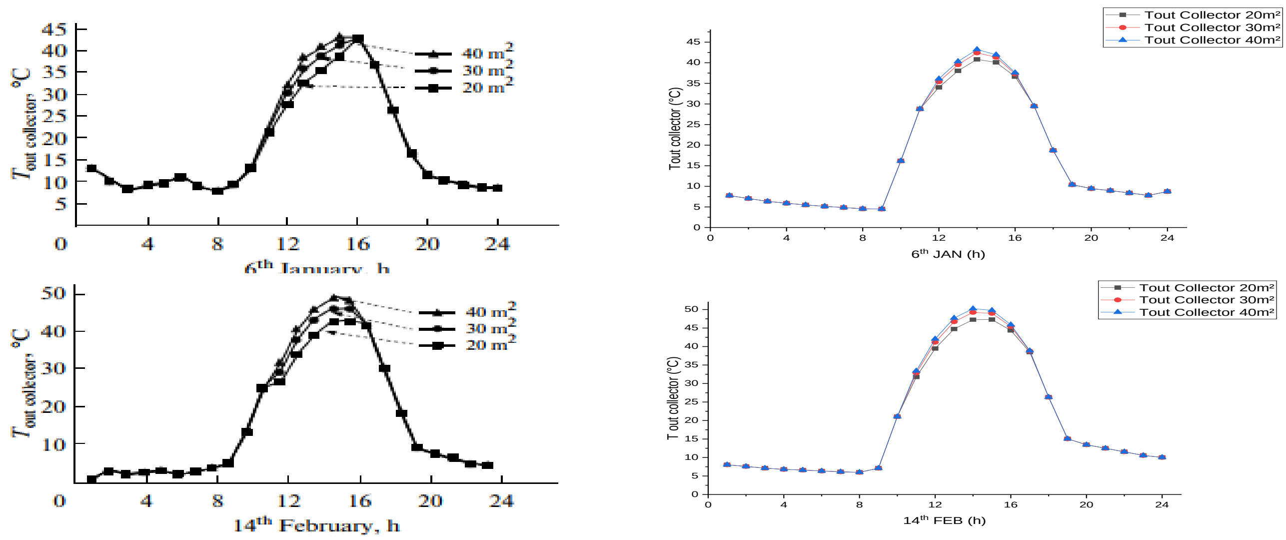
4. Model validation

This part aims to check the validity of the input data and some output results of a solar domestic hot water system in Oujda (Morocco) with those in Ain-Temouchent (Algeria) .This model has been validated to obtain correct and reliable results [1] as shown in Figure 5. Therefore, the same conditions used in Oujda was keeped, like a total volume of daily consumption 600 L/day and the volume of consumption in each hour of the day.



(a) **(b)**

Fig.4 (a) Ambient temperature, wind speed and (b) irradiation in the weather of Ain-Temouchent.



(a) Results of T.Essabani et al. [9] **(b) Model validation**

Fig.5 Variation of collector outlet temperature as function of collector area.

Figure 5 shows how the thermal system was validated for distillation membrane. This project of the article was studied is to simulate the solar based domestic hot water system considered as a field trial installation in Oujda, Morocco (latitude 34°4′0″ N, longitude 2°1′0″ E and UTM position WC96) [1]. Com putations using TRNSYS software have been performed for a plan solar collector with an area of 20 m^2 and a storage tank containing 300 L of water using electric auxiliary heater.

5. Photovoltaic system

The use of solar energy considerably reduces the operating costs, however, its intermittent nature requires a non-stationary optimal operation that can be achieved by means of advanced control strategies. In this study, the control system and model of thermal system of the membrane was make with the use of Photovoltaic panels system for cost savings.

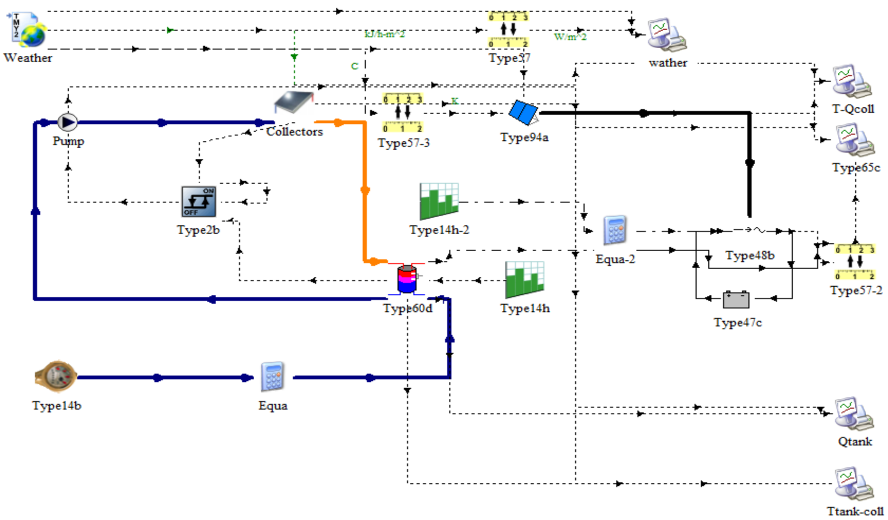


Fig.6 The model that combines the thermal system for the distillation membrane and the photovoltaic system.

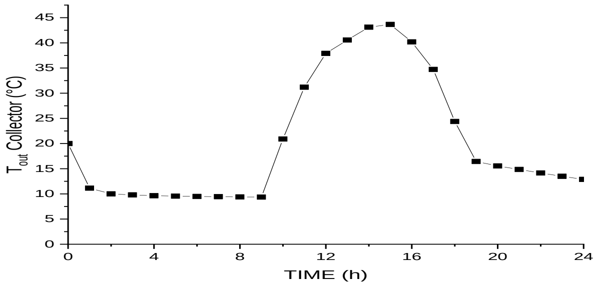
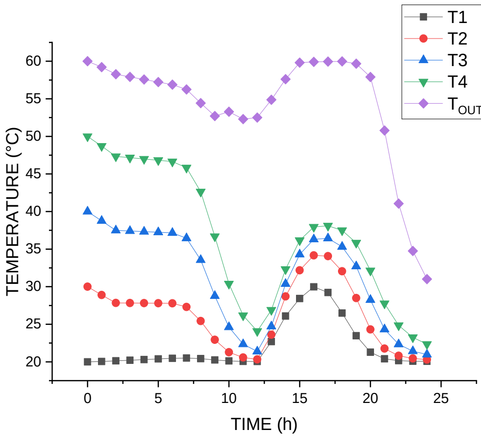


Fig.7 Collector Outlet Temperature



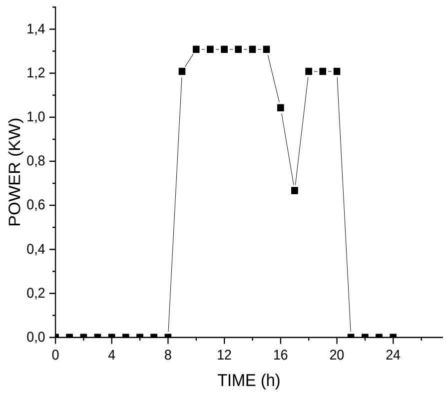


Fig.8 Outlet Temperature of Storage Tank. **Fig.9 Power load of the photovoltaic system**

Figure 6 shows the photovoltaic system that replace by the electrical energy of the auxiliary heater. Therefore, the number of photovoltaic panels that estimated at 14 panels and also the power of the battery that estimated at 1208 W was calculated. It was with the help using PVGIS software.

6. Results and discussion

6.1 Collector Outlet Temperature

At the weather of the state Ain-Temouchent, January is the coldest month of the year. Therefore, the first day of that month is given the lowest temperature of the year, and therefore is considered like a reference to this numerical study of the thermal system of membrane distillation. Figure7 shows changes in the external temperature of flat panel collectors on the first day of January, which reaches up to 44 degrees Celsius maximum.

6.2 Outlet Temperature of Storage Tank and power load of the photovoltaic system

Figure 8 shows the temperature at the outlet of the storage tank at 60 ° C. For temperatures 1, 2,3 and 4 resulting from the heat exchanger, it reaches a maximum of 37 degrees Celsius on this first day of the cold month of January. For this reason, the auxiliary heater has been added to reach a temperature of 60 degrees Celsius when the weather temperature is low. Therefore, to reduce the operating cost, the photovoltaic system was used with a storage battery that replaces the power load of the auxiliary heater, which appear in Figure 9.

7. Conclusions

The Solar Membrane Distillation is recently an under-investigation desalination process suitable for developing self-sufficient small-scale applications. The use of solar energy considerably reduces the operating costs, however, its intermittent nature requires a non-stationary optimal operation that can be achieved by means of advanced control strategies. Thermal system is very important in this process as mentioned earlier. Therefore, in this paper, a TRNSYS model was developed solar water heating systems with flat plate collector, heat exchanger and auxiliary heater of the storage tank that was used with the photoelectric system. The model was validated using data for system installed in Oujda, Morocco. We considered the following output parameters that are the outlet temperature of a solar collector and auxiliary power supplied to the storage tank. The control system and model of thermal system of distillation membrane also was make with the use of Photovoltaic panels system for cost savings. Results obtained showed that The validated TRNSYS model can be used to predict long-term performance of the solar water heating systems in different locations for distillation membrane, and It can also be used to study simulate system performances under different weather and operating conditions.

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